# Construction of Azepino[2,3-*b*]indole Core *via* Sulfur Ylide Mediated Annulations

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## Supporting Information

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## 1. General Information

**General Procedures.** All reactions were performed in oven-dried reaction vessels. The flasks were fitted with Teflon screw caps and reactions were conducted directly (without the need of an argon atmosphere). Gas-tight syringes with stainless steel needles were used to transfer liquid chemicals. Flash column chromatography was performed using silica gel (40–63 μm, 230–400 mesh).

Analytical thin layer chromatography (TLC) was performed on silica gel 60 $F_{254}$ aluminum plates (Merck) containing a 254 nm fluorescent indicator. TLC plates were visualized by exposure to short wave ultraviolet light (254 nm) and to a solution of $KMnO_4$ (1 g of $KMnO_4$, 6 g of $K_2CO_3$ and 0.1 g of KOH in 100 mL of $H_2O$) or vanillin (2 g of vanillin and 4 mL of concentrated $H_2SO_4$ in 100 mL of EtOH) followed by heating.

Organic solutions were concentrated at 30-50 ℃ on rotary evaporators at ~10 torr followed by drying on vacuum pump at ~1 torr. Reaction temperatures are reported as the temperature of the bath surrounding the vessel unless otherwise stated.

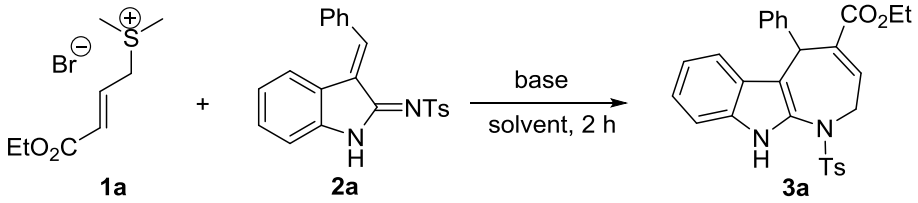
**Materials.** Commercial reagents and solvents were were obtained from Adamas-beta, Aldrich Chemical Co., Alfa Aesar, Macklin and Energy Chemical and used as received with the following exceptions: THF, 1,4-dioxane and toluene were purified by refluxing over Na-benzophenone under positive argon pressure followed by distillation. [1] The aza-diene substrates were prepared according to literature procedure. [2]

**Instrumentation.**

- Proton nuclear magnetic resonance ($^1$H NMR) spectra were recorded with *J*EOL 600MHz spectrometers. Proton chemical shifts are reported in parts per million (δ scale), and are referenced using residual protium in the NMR solvent ($CDCl_3$: δ 7.26 ($CHCl_3$) or DMSO-$d^6$: δ 2.54 (DMSO)). Data are reported as follows: chemical shift [multiplicity (s = singlet, d = doublet, t = triplet, q = quartet, m = multiplet, br s = broad singlet), coupling constant(s) (Hz), integration].
- Carbon-13 nuclear magnetic resonance ($^{13}$C NMR) spectra were recorded with *J*EOL 600MHz spectrometers. Carbon chemical shifts are reported in parts per million (δ scale), and are referenced using the carbon resonances of the solvent (δ 77.16 ($CHCl_3$) or δ 39.52 (DMSO)). Data are reported as follows: chemical shift [multiplicity (if not singlet), assignment ($C_q$ = fully substituted carbon)].
- High resolution mass spectra (HRMS) were recorded on a Waters SYNAPT G2 using an electrospray (ESI) ionization source.

## 2. Further Optimization Studies

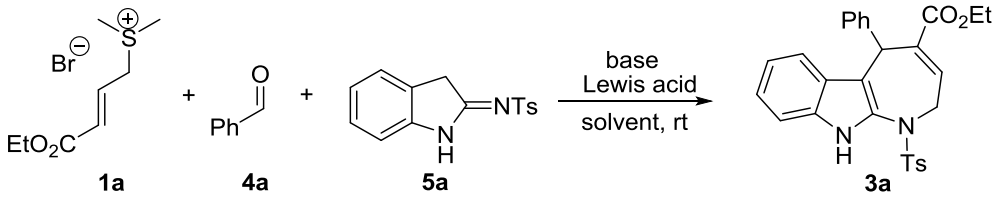
**Table S1. the Reaction of Iminoindole 1a and Sulfonium Salt 2a**[a]




| Entry | Solvent | Base | Yield (%)[c] |
|---|---|---|---|
| 1 | MeCN | $K_2CO_3$ | 90 |
| 2 | MeCN | $NaHCO_3$ | 47 |
| 3 | MeCN | DBU[b] | 30 |
| 4 | MeCN | TABF[b] | N.R.[d] |
| 5 | MeCN | TBAB[b] | N.R.[d] |
| **6** | **MeCN** | **$Cs_2CO_3$** | **96** |
| 7 | MeCN | TEA[b] | 92 |
| 8 | MeCN | $NaH_2PO_4$ | N.R.[d] |
| 9 | MeCN | - | N.R.[d] |
| 10 | Tol | $Cs_2CO_3$ | 79 |
| 11 | $CHCl_3$ | $Cs_2CO_3$ | 82 |
| 12 | 1,4-dioxane | $Cs_2CO_3$ | 26 |
| 13 | DCM | $Cs_2CO_3$ | 85 |
| 14 | $CCl_4$ | $Cs_2CO_3$ | 40 |
| 15 | THF | $Cs_2CO_3$ | 87 |
| 16 | EtOH | $Cs_2CO_3$ | 42 |

[a] Reactions were performed with 0.12 mmol of **1a**, 0.10 mmol of **2a**, and 0.12 mmol of the base in 1.0 mL of solvent for 2 hours. [b] DBU: 1,8-diazabicyclo[5.4.0]-7-Undecene; TEA: triethylamine; TBAF: tetrabutylammoniumfluoride; TBAB: tetrabutylammonium bromide; [c] Isolated yield. [d] N.R.: no reaction.

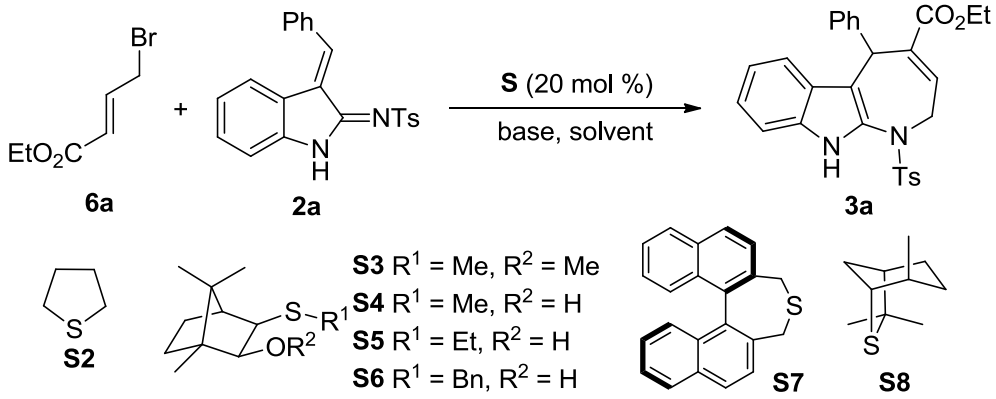
**Table S2. Optimization of [3+1+3] Cascade**[a]




| Entry | Base | Lewis acid | Solvent | Yield (%)[b] |
|---|---|---|---|---|
| 1 | $Cs_2CO_3$ | $BF_3{\cdot}OEt_2$ | MeCN | 93 |
| 2[c] | $Cs_2CO_3$ | $BF_3{\cdot}OEt_2$ | MeCN | 91 |
| 3[d] | $Cs_2CO_3$ | $BF_3{\cdot}OEt_2$ | MeCN | 57 |
| 4 | TEA | $BF_3{\cdot}OEt_2$ | MeCN | 84 |
| 5 | $Cs_2CO_3$ | $Sc(OTf)_3$ | MeCN | 32 |
| 6 | $Cs_2CO_3$ | $BF_3{\cdot}OEt_2$ | toluene | 46 |
| 7 | $Cs_2CO_3$ | $BF_3{\cdot}OEt_2$ | DCM | 89 |
| 8 | $Cs_2CO_3$ | $BF_3{\cdot}OEt_2$ | THF | 29 |

[a] Reactions were performed with sulfonium salt **1a** (0.12 mmol), aldehyde **4a** (0.15 mmol), iminoindoline **5a** (0.1 mmol), Lewis acid (0.1 mmol) and base (0.12 mmol) in 1.0 mL of MeCN at room temperature for 4 h. [b] Isolated yield of **3a**. [c] $BF_3{\cdot}OEt_2$ (0.3 mmol) was used. [d] $BF_3{\cdot}OEt_2$ (0.02 mmol) was used.

**Table S3. the Sulfide Catalyzed Cyclization of 2a and 6a**[a]

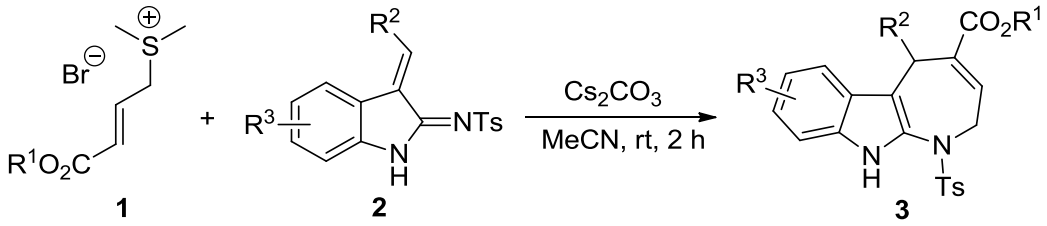



| Entry | Sulfide **S** | Base | Solvent | Yield (%)[c] | e.r.[d] |
|---|---|---|---|---|---|
| 1 | **S2** | $K_2CO_3$ | MeCN | 86 | - |
| 2 | **S2** | $NaHCO_3$ | MeCN | 60 | - |
| 3 | **S2** | DBU[b] | MeCN | - | - |
| 4 | **S2** | TBAF[b] | MeCN | - | - |
| 5 | **S2** | TBAB[b] | MeCN | - | - |
| 6 | **S2** | TEA[b] | MeCN | 70 | - |
| 7 | **S2** | $NaH_2PO_4$ | MeCN | - | - |
| 8 | **S2** | $Cs_2CO_3$ | $CHCl_3$ | 47 | - |
| 9 | **S2** | $Cs_2CO_3$ | 1,4-dioxane | 49 | - |
| 10 | **S2** | $Cs_2CO_3$ | $CCl_4$ | 68 | - |
| 11 | **S3** | $Cs_2CO_3$ | MeCN | 71 | 82:18 |
| 12 | **S4** | $Cs_2CO_3$ | MeCN | 57 | 77:23 |
| 13 | **S5** | $Cs_2CO_3$ | MeCN | 41 | 50:50 |
| 14 | **S6** | $Cs_2CO_3$ | MeCN | - | - |
| 15 | **S7** | $Cs_2CO_3$ | MeCN | 46 | 76:24 |
| 16 | **S8** | $Cs_2CO_3$ | MeCN | 37 | 20:80 |
| 17 | **S3** | $Cs_2CO_3$ | toluene | - | - |
| 18 | **S3** | $Cs_2CO_3$ | $CHCl_3$ | 47 | 76:24 |
| 19 | **S3** | $Cs_2CO_3$ | 1,4-dioxane | 49 | 76:24 |
| 20 | **S3** | $Cs_2CO_3$ | DCM | 71 | 77:33 |
| 21 | **S3** | $Cs_2CO_3$ | THF | - | - |

[a] Unless otherwise noted, reactions were performed with 0.10 mmol of **2a**, 0.15 mmol of **6a**, 0.02 mmol of sulfide **S** and 0.12 mmol of the base in 0.05 mL of the solvent for 1 hour. [b] DBU: 1,8-diazabicyclo[5.4.0]-7-Undecene; TEA: triethylamine; TBAF: tetrabutylammoniumfluoride; TBAB: tetrabutylammonium bromide. [c] Isolated yield. [d] Determined by HPLC using a chiral stationary phase.

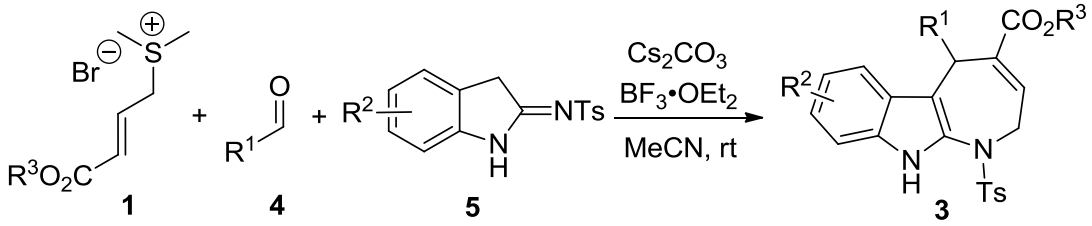
## 3. General Procedure for the Synthesis of Product 3

*Proceduer A: the direct annulation of **1** and **2***



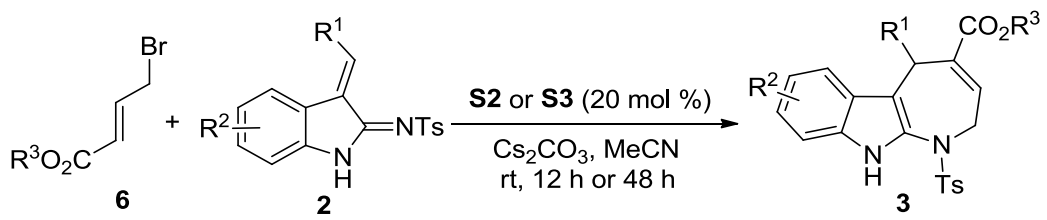

A glass reaction tube (as the reaction vessel) was charged with sulfonium salt **1** (0.12 mmol), aza-diene **2** (0.10 mmol), $Cs_2CO_3$ (0.12 mmol) in 1 mL MeCN. The mixture was stirred at room temperature for 2 hours. Then the mixture was concentrated, and purified by column chromatography on silica gel eluting with petroleum ether/ethyl acetate from 10:1 to 4:1 to afford the corresponding product **3**.

*Proceduer B: the three-component reaction of **1**, **4** and **5***




A glass reaction tube (as the reaction vessel) was charged with sulfonium salt **1** (0.12 mmol), aldehyde **4** (0.12 mmol), iminoindoline **5** (0.10 mmol), $BF_3$•$OEt_2$ (0.1 mmol) and $Cs_2CO_3$ (0.12 mmol) in 1 mL MeCN. The mixture was stirred at room temperature for 4 hours. Then the mixture was concentrated, and purified by column chromatography on silica gel eluting with petroleum ether/ethyl acetate from 10:1 to 4:1to afford the corresponding product **3**.

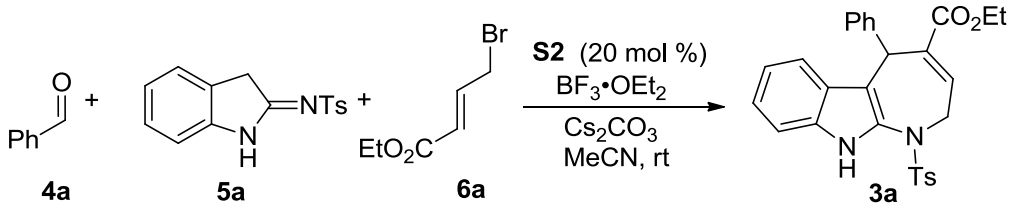
*Proceduer C: the sulfide catalyzed cyclization of **6** and **2***




A glass reaction tube (as the reaction vessel) was charged with crotonate bromide **6** (0.15 mmol), aza-diene **2** (0.10 mmol), tetrahydrothiophene **S2** or chiral sulfide **S3** (0.02 mmol), $Cs_2CO_3$ (0.12 mmol) in 0.05 mL MeCN (2M). The mixture was stirred at room temperature

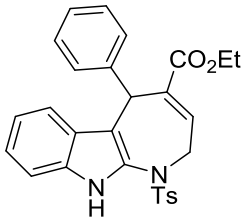
for 12 hours (for **S2**) or 48 hours (for **S3**). Then the mixture was concentrated, and purified by column chromatography on silica gel eluting with petroleum ether/ethyl acetate 10:1 to afford the corresponding product **3**.

*Proceduer D: the sulfide catalyzed three-component reaction of **4**, **5** and **6***




A glass reaction tube (as the reaction vessel) was charged with crotonate bromide **6a** (0.15 mmol), aldehyde **4a** (0.10 mmol), iminoindole **5a**, tetrahydrothiophene **S2** (0.02 mmol), $BF_3$•$OEt_2$ (0.1 mmol) and $Cs_2CO_3$ (0.12 mmol) in 1 mL MeCN. The mixture was stirred at room temperature for 24 hours. Then the mixture was concentrated, and purified by column chromatography on silica gel eluting with petroleum ether/ethyl acetate 10:1 to afford the product **3a**.

***ethyl 5-phenyl-1-tosyl-1,2,5,10-tetrahydroazepino[2,3-b]indole-4-carboxylate 3a***




White solid; Procedure A: 23.3 mg, 96% yield; Proceduce B: 22.6 mg, 93% yield; Procedure C (with **S2**): 22.4 mg, 92% yield; Procedure D: 10.5 mg, 43% yield; according to Procedure C by using chiral sulfide **S3** as the catalyst, **3a** was obtained in 71% yield, and the enantiomeric ratio was determined to be 82:18 by chiral HPLC analysis on Chiralpak AD column (20% 2-propanol/*n*-hexane, 1 mL/min), UV 220 nm, $t_{minor}$ = 29.19 min, $t_{major}$ = 25.76 min; m.p. = 107–109 ℃.

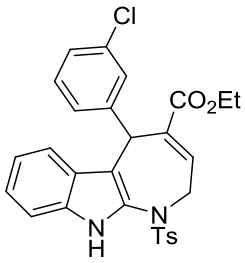
*NMR and HRMS data for the product* **3a**:

**$^1$H NMR (600 MHz, $CDCl_3$)** δ (ppm): 9.08 (s, 1H), 7.40 – 7.39 (m, 3H), 7.24 – 7.20 (m, 2H), 7.17 – 7.11 (m, 5H), 7.07 – 7.02 (m, 3H), 6.65 (t, *J* = 7.8 Hz, 1H), 5.60 (s, 1H), 4.52 (dd, *J* = 15.6, 7.8 Hz, 1H), 4.28 (dd, *J* = 15.0, 7.2 Hz, 1H), 4.14 – 4.08 (m, 2H), 2.34 (s, 3H), 1.26 (t, *J* = 6.6 Hz, 3H).

**$^{13}$C NMR (150 MHz, $CDCl_3$)** δ (ppm): 166.1, 144.3, 142.9, 140.1, 135.0, 133.1, 132.8, 132.6, 132.3, 129.7, 128.4, 127.4, 127.2, 126.4, 122.5, 120.0, 118.7, 110.6, 101.9, 61.2, 45.2, 38.3, 21.5, 14.2.

**HRMS (ESI)** m/z calculated for $C_{28}H_{26}N_2O_4S+Na^+$: 509.1505, found: 509.1512.

***ethyl 5-(3-chlorophenyl)-1-tosyl-1,2,5,10-tetrahydroazepino[2,3-b]indole-4-carboxylate 3b***




Prepared according to the Procedure A to afford **3b** 24.2 mg in 93% yield as white solid; m.p. = 131–135 ℃.

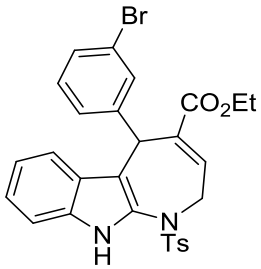
*NMR and HRMS data for the product* **3b**:

**$^1$H NMR (600 MHz, $CDCl_3$)** δ (ppm): 9.11 (s, 1H), 7.40 – 7.38 (m, 3H), 7.24 – 7.21 (m, 2H), 7.14 (d, *J* = 7.8 Hz, 2H), 7.11 – 7.05 (m, 4H), 6.94 (d, *J* = 7.8 Hz, 1H), 6.68 (t, *J* = 7.8 Hz, 1H), 5.56 (s, 1H), 4.54 (dd, *J* = 15.6, 7.8 Hz, 1H), 4.23 (dd, *J* = 15.6, 7.8 Hz, 1H), 4.15 – 4.09 (m, 2H), 2.34 (s, 3H), 1.26 (t, *J* = 6.6 Hz, 3H).

**$^{13}$C NMR (150 MHz, $CDCl_3$)** δ (ppm): 165.9, 144.9, 144.3, 139.4, 134.9, 134.3, 133.6, 132.6, 132.2, 129.7, 129.6, 127.3, 127.3, 127.1, 126.7, 125.5, 122.6, 120.1, 118.5, 110.7, 101.2, 61.3, 45.2, 38.0, 21.5, 14.2.

**HRMS (ESI)** m/z calculated for $C_{28}H_{25}ClN_2O_4S+Na^+$: 543.1116($^{35}$Cl), 545.1086($^{37}$Cl), found: 543.1119, 545.1101.

***ethyl 5-(3-bromophenyl)-1-tosyl-1,2,5,10-tetrahydroazepino[2,3-b]indole-4-carboxylate 3c***




White solid; Procedure A: 25.9 mg, 92% yield; Procedure B: 22.3 mg, 79% yield; Procedure C (with **S2**): 26.2 mg, 93% yield; m.p. = 117–120 ℃.

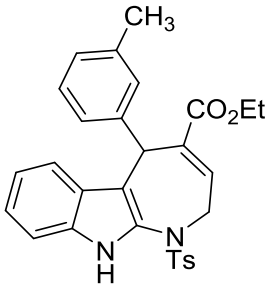
*NMR and HRMS data for the product* **3c**:

**$^1$H NMR (600 MHz, $CDCl_3$)** δ (ppm): 9.12 (s, 1H), 7.40 – 7.38 (m, 3H), 7.25 – 7.21 (m, 4H), 7.14 (d, *J* = 7.8 Hz, 2H), 7.07 – 7.05 (m, 1H), 7.02 – 6.97 (m, 2H), 6.68 (t, *J* = 7.8 Hz, 1H), 5.56 (s, 1H), 4.55 (dd, *J* = 15.6, 7.8 Hz, 1H), 4.23 (dd, *J* = 15.6, 7.8 Hz, 1H), 4.15 – 4.09 (m, 2H), 2.34 (s, 3H), 1.26 (t, *J* = 7.2 Hz, 3H).

**$^{13}$C NMR (150 MHz, $CDCl_3$)** δ (ppm): 165.9, 145.2, 144.3, 139.3, 134.9, 133.6, 132.6, 132.2, 130.2, 129.9, 129.7, 129.7, 127.3, 127.1, 125.9, 122.7, 122.6, 120.1, 118.5, 110.7, 101.2, 61.3, 45.2, 38.0, 21.5, 14.2.

**HRMS (ESI)** m/z calculated for $C_{28}H_{25}BrN_2O_4S+Na^+$: 587.0611($^{79}$Br), 589.0590($^{81}$Br); found: 587.0610, 589.0596.

***ethyl 5-(m-tolyl)-1-tosyl-1,2,5,10-tetrahydroazepino[2,3-b]indole-4-carboxylate 3d***




White solid; Procedure A: 23.8 mg, 95% yield; Procedure B: 20.5 mg, 82% yield, Procedure C (with **S2**): 22.0 mg, 88% yield; m.p. = 225–228 ℃.

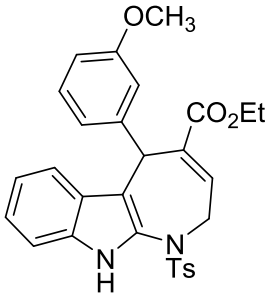
*NMR and HRMS data for the product* **3d**:

**$^1$H NMR (600 MHz, $CDCl_3$)** δ (ppm): 9.09 (s, 1H), 7.40 – 7.39 (m, 3H), 7.24 – 7.20 (m, 2H), 7.14 (d, *J* = 7.8 Hz, 2H), 7.05 – 7.02 (m, 2H), 6.94 (d, *J* = 7.2 Hz, 1H), 6.90 (s, 1H), 6.85 (d, *J* = 8.4 Hz, 1H), 6.63 (t, *J* = 7.8 Hz, 1H), 5.57 (s, 1H), 4.53 (dd, *J* = 15.6, 7.8 Hz, 1H), 4.32 (dd, *J* = 15.6, 7.8 Hz, 1H), 4.15 – 4.08 (m, 2H), 2.34 (s, 3H), 2.20 (s, 3H),1.26 (t, *J* = 7.2 Hz, 3H).

**$^{13}$C NMR (150 MHz, $CDCl_3$)** δ (ppm): 166.1, 144.2, 142.8, 140.1, 138.0, 135.0, 133.0, 132.5, 132.3, 129.7, 128.2, 127.9, 127.4, 127.3, 127.3, 124.3, 122.4, 119.9, 118.7, 110.6, 101.9, 61.1, 45.2, 38.2, 21.5, 21.5, 14.2.

**HRMS (ESI)** m/z calculated for $C_{29}H_{28}N_2O_4S+Na^+$: 523.1662, found: 523.1665.

***ethyl 5-(3-methoxyphenyl)-1-tosyl-1,2,5,10-tetrahydroazepino[2,3-b]indole-4-carboxylate 3e***




Prepared according to the Procedure A to afford **3e** 25.0 mg in 97% yield as white solid; m.p. = 161–163 ℃.

*NMR and HRMS data for the product* **3e**:

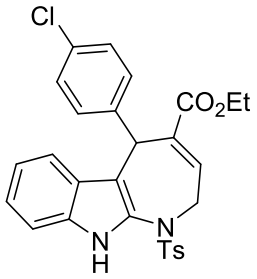
**$^1$H NMR (600 MHz, $CDCl_3$)** δ (ppm): 9.06 (s, 1H), 7.39 – 7.37 (m, 3H), 7.26 – 7.20 (m, 2H), 7.13 (d, *J* = 7.8 Hz, 2H), 7.08 – 7.03 (m, 2H), 6.67 – 6.63 (m, 4H), 5.57 (s, 1H), 4.52 (dd, *J* = 15.6, 7.8 Hz, 1H), 4.32 (dd, *J* = 15.6, 7.8 Hz, 1H), 4.13 – 4.08 (m, 2H), 3.67 (s, 3H), 2.34 (s, 3H),1.25 (t, *J* = 7.2 Hz, 3H).

**$^{13}$C NMR (150 MHz, $CDCl_3$)** δ (ppm): 166.1, 159.5, 144.5, 144.2, 139.8, 135.0, 133.2, 132.5, 132.2, 129.6, 129.3, 127.3, 122.4, 119.9, 119.7, 118.7, 113.7, 111.1, 110.6, 101.8, 61.1,

55.0, 45.2, 38.2, 21.5, 14.2.

**HRMS (ESI)** m/z calculated for $C_{29}H_{28}N_2O_5S+Na^+$: 539.1611, found: 539.1616.

***ethyl 5-(4-chlorophenyl)-1-tosyl-1,2,5,10-tetrahydroazepino[2,3-b]indole-4-carboxylate 3f***




White solid; Procedure A: 24.4 mg, 94% yield; Procedure B: 22.9 mg, 88% yield; Procedure C (with **S2**): 23.1 mg, 89% yield; m.p. = 125–128 ℃.

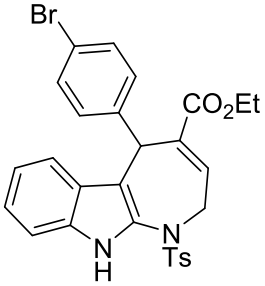
*NMR and HRMS data for the product* **3f**:

**$^1$H NMR (600 MHz, $CDCl_3$)** δ (ppm): 9.08 (s, 1H), 7.40 – 7.38 (m, 3H), 7.24 – 7.20 (m, 2H), 7.12 (dd, *J* = 21.6, 7.8 Hz, 4H), 7.06 – 7.04 (m, 1H), 7.00 – 6.99 (m, 2H), 6.67 (t, *J* = 7.8 Hz, 1H), 5.54 (s, 1H), 4.54 (dd, *J* = 15.6, 7.8 Hz, 1H), 4.22 (dd, *J* = 15.6, 7.8 Hz, 1H), 4.13 – 4.08 (m, 2H), 2.35 (s, 3H), 1.26 (t, *J* = 6.6 Hz, 3H).

**$^{13}$C NMR (150 MHz, $CDCl_3$)** δ (ppm): 166.0, 144.4, 141.4, 139.5, 134.9, 133.5, 132.5, 132.3, 132.2, 129.7, 128.6, 128.5, 127.3, 127.1, 122.6, 120.1, 118.5, 110.7, 101.7, 61.3, 45.3, 37.8, 21.5, 14.2.

**HRMS (ESI)** m/z calculated for $C_{28}H_{25}ClN_2O_4S+Na^+$: 543.1116($^{35}$Cl), 545.1086($^{37}$Cl), found: 543.1119, 545.1110

***ethyl 5-(4-bromophenyl)-1-tosyl-1,2,5,10-tetrahydroazepino[2,3-b]indole-4-carboxylate 3g***




Prepared according to the Procedure A to afford **3g** in 26.2 mg 93% yield as white solid; m.p. = 125–127 ℃.

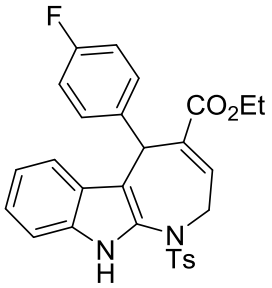
*NMR and HRMS data for the product* **3g**:

**$^1$H NMR (600 MHz, $CDCl_3$)** δ (ppm): 9.10 (s, 1H), 7.40 – 7.38 (m, 3H), 7.26 – 7.24 (m, 2H), 7.21 (t, *J* = 7.8 Hz, 2H), 7.14 (t, *J* = 8.4 Hz, 2H), 7.05 (t, *J* = 7.8 Hz, 1H), 6.94 (d, *J* = 7.8 Hz, 2H), 6.68 (t, *J* = 7.8 Hz, 1H), 5.52 (s, 1H), 4.53 (dd, *J* = 15.6, 7.8 Hz, 1H), 4.22 (dd, *J* = 15.6, 7.8 Hz, 1H), 4.15 – 4.06 (m, 2H), 2.35 (s, 3H), 1.25 (t, *J* = 6.6 Hz, 3H).

**$^{13}$C NMR (150 MHz, $CDCl_3$)** δ (ppm): 166.0, 144.4, 141.9, 139.4, 134.9, 133.5, 132.5, 132.3, 131.4, 129.7, 129.0, 127.3, 127.1, 122.6, 120.3, 120.1, 118.5, 110.7, 101.6, 61.3, 45.3, 37.9, 21.5, 14.2.

**HRMS (ESI)** m/z calculated for $C_{28}H_{25}BrN_2O_4S+Na^+$: 587.0611($^{79}Br$), 589.0590($^{81}Br$); found: 587.0614, 589.0600.

***ethyl 5-(4-fluorophenyl)-1-tosyl-1,2,5,10-tetrahydroazepino[2,3-b]indole-4-carboxylate 3h***




White solid; Procedure A: 23.9 mg, 95% yield; Procedure B: 23.4 mg, 93% yield; m.p. = 104–106 ℃.

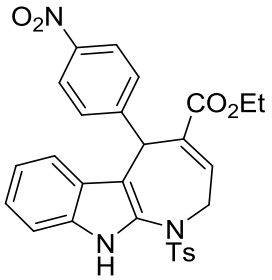
*NMR and HRMS data for the product* **3h**:

**$^1$H NMR (600 MHz, $CDCl_3$)** δ (ppm): 9.08 (s, 1H), 7.39 (d, *J* = 8.4 Hz, 3H), 7.24 – 7.20 (m, 2H), 7.14 (d, *J* = 7.8 Hz, 2H), 7.06 – 7.02 (m, 3H), 6.83 (t, *J* = 9.0 Hz, 2H), 6.67 (t, *J* = 7.8 Hz, 1H), 5.55 (s, 1H), 4.54 (dd, *J* = 15.6, 7.8 Hz, 1H), 4.24 (dd, *J* = 15.6, 7.8 Hz, 1H), 4.14 – 4.08 (m, 2H), 2.35 (s, 3H), 1.25 (t, *J* = 7.2 Hz, 3H).

**$^{13}$C NMR (150 MHz, $CDCl_3$)** δ (ppm): 166.0, 144.3, 139.8, 138.6, 135.0, 133.3, 132.5, 132.3, 129.7, 128.8, 128.7, 127.4, 127.2, 122.6, 120.1, 118.5, 115.2, 115.1, 110.7, 102.1, 61.2, 45.3, 37.8, 21.5, 14.2.

**HRMS (ESI)** m/z calculated for $C_{28}H_{25}FN_2O_4S+Na^+$: 527.1411, found: 527.1420.

***ethyl 5-(4-nitrophenyl)-1-tosyl-1,2,5,10-tetrahydroazepino[2,3-b]indole-4-carboxylate 3i***




White solid; Procedure A: 24.2 mg, 91% yield; Proceduce B: 19.4 mg, 73% yield; m.p. = 97–101 ℃.

*NMR and HRMS data for the product* **3i**:

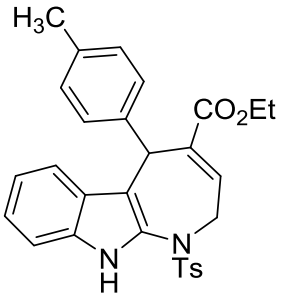
**$^1$H NMR (600 MHz, $CDCl_3$)** δ (ppm): 9.17 (s, 1H), 7.98 (d, *J* = 9.0 Hz, 2H), 7.42 – 7.39 (m, 3H), 7.25 – 7.23 (m, 3H), 7.19 (d, *J* = 7.8 Hz, 1H), 7.15 (d, *J* = 8.4 Hz, 2H), 7.07 (t, *J* = 8.4 Hz, 1H), 6.76 (t, *J* = 7.8 Hz, 1H), 5.66 (s, 1H), 4.56 (dd, *J* = 15.6, 7.8 Hz, 1H), 4.20 – 4.09 (m, 3H), 2.36 (s, 3H), 1.27 (t, *J* = 7.2 Hz, 3H).

**$^{13}$C NMR (150 MHz, $CDCl_3$)** δ (ppm): 165.9, 150.3, 146.5, 144.6, 138.5, 134.9, 134.3, 132.6, 132.3, 129.8, 128.1, 127.3, 126.8, 123.6, 122.9, 120.3, 118.1, 110.9, 101.0, 61.5, 45.3,

38.3, 21.5, 14.2.

**HRMS (ESI)** m/z calculated for $C_{28}H_{25}N_3O_6S+Na^+$: 554.1356, found: 554.1362.

***ethyl 5-(p-tolyl)-1-tosyl-1,2,5,10-tetrahydroazepino[2,3-b]indole-4-carboxylate 3j***




White solid; Procedure A: 23.3 mg, 93% yield; Proceduce B: 23.0 mg, 92% yield; Procedure C(with **S2**): 22.3 mg, 89% yield; m.p. = 113–117 ℃.

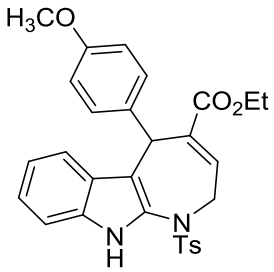
*NMR and HRMS data for the product* **3j**:

**$^1$H NMR (600 MHz, $CDCl_3$)** δ (ppm): 9.07 (s, 1H), 7.40 – 7.38 (m, 3H), 7.23 – 7.20 (m, 2H), 7.14 (d, *J* = 7.8 Hz, 2H), 7.03 (t, *J* = 7.2 Hz, 1H), 6.96 – 6.94 (m, 4H), 6.63 (t, *J* = 7.8 Hz, 1H), 5.56 (s, 1H), 4.52 (dd, *J* = 15.6, 7.8 Hz, 1H), 4.30 (dd, *J* = 15.6, 7.8 Hz, 1H), 4.15 – 4.06 (m, 2H), 2.34 (s, 3H), 2.24 (s, 3H), 1.25 (t, *J* = 7.2 Hz, 3H).

**$^{13}$C NMR (150 MHz, $CDCl_3$)** δ (ppm): 166.1, 144.2, 140.1, 139.9, 136.0, 135.0, 133.0, 132.5, 132.3, 129.6, 129.1, 127.4, 127.3, 127.1, 122.4, 119.9, 118.7, 110.6, 102.1, 61.1, 45.3, 38.0, 21.5, 20.9, 14.2.

**HRMS (ESI)** m/z calculated for $C_{29}H_{28}N_2O_4S+Na^+$: 523.1662, found: 523.1667.

***ethyl 5-(4-methoxyphenyl)-1-tosyl-1,2,5,10-tetrahydroazepino[2,3-b]indole-4-carboxylate 3k***




White solid; Procedure A: 24.8 mg, 96% yield; Proceduce B: 21.2 mg, 82% yield; Procedure C(with **S2**): 22.5 mg, 87% yield; m.p. = 89–91 ℃.

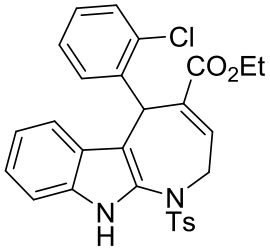
*NMR and HRMS data for the product* ***3k***:

**$^1$H NMR (600 MHz, $CDCl_3$)** δ (ppm): 9.05 (s, 1H), 7.40 – 7.38 (m, 3H), 7.23 – 7.20 (m, 2H), 7.14 (d, *J* = 7.8 Hz, 2H), 7.03 (t, *J* = 7.2 Hz, 1H), 6.99 (d, *J* = 9.0 Hz, 2H), 6.68 (d, *J* = 8.4 Hz, 2H), 6.63 (t, *J* = 7.8 Hz, 1H), 5.53 (s, 1H), 4.53 (dd, *J* = 15.6, 7.8 Hz, 1H), 4.29 (dd, *J* = 15.6, 7.8 Hz, 1H), 4.14 – 4.06 (m, 2H), 3.71 (s, 3H), 2.34 (s, 3H), 1.25 (t, *J* = 7.2 Hz, 3H).

**$^{13}$C NMR (150 MHz, $CDCl_3$)** δ (ppm): 166.2, 158.0, 144.2, 140.1, 135.0, 132.9, 132.4, 132.3, 129.6, 128.2, 127.4, 127.3, 127.1, 122.5, 119.9, 118.8, 113.7, 110.6, 102.3, 61.1, 55.1, 45.3, 37.6, 21.5, 14.2.

**HRMS (ESI)** m/z calculated for $C_{29}H_{26}N_2O_5S+Na^+$: 539.1611, found: 539.1617.

***ethyl 5-(2-chlorophenyl)-1-tosyl-1,2,5,10-tetrahydroazepino[2,3-b]indole-4-carboxylate 3l***




White solid; Procedure A: 23.9 mg, 92% yield; Proceduce B: 23.9 mg, 92% yield; m.p. = 135–137 ℃.

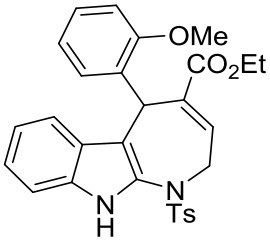
*NMR and HRMS data for the product* **3l**:

**$^1$H NMR (600 MHz, $CDCl_3$)** δ (ppm): 9.15 (s, 1H), 7.42 – 7.38 (m, 3H), 7.30 (d, *J* = 7.8 Hz, 1H), 7.26 – 7.20 (m, 2H), 7.16 (d, *J* = 7.8 Hz, 2H), 7.08 (t, *J* = 7.8 Hz, 1H), 7.04 (t, *J* = 7.8 .Hz, 1H), 6.95 (t, *J* = 7.2 Hz, 1H), 6.88 (d, *J* = 7.8 Hz, 1H), 6.44 (t, *J* = 7.2 Hz, 1H), 5.65 (s, 1H), 4.52 (dd, *J* = 15.6, 7.8 Hz, 1H), 4.40 (dd, *J* = 15.6, 7.8 Hz, 1H), 4.12 (q, *J* = 16.8, 7.2 Hz, 2H), 2.36 (s, 3H), 1.26 (t, *J* = 7.2 Hz, 3H),

**$^{13}$C NMR (150 MHz, $CDCl_3$)** δ (ppm): 166.3, 144.4, 140.0, 139.2, 135.3, 133.2, 132.6, 132.3, 132.1, 130.2, 130.1, 129.8, 128.1, 127.3, 126.7, 126.6, 122.6, 120.0, 118.7, 110.7, 101.8, 60.9, 44.9, 37.5, 21.5, 14.1.

**HRMS (ESI)** m/z calculated for $C_{28}H_{25}ClN_2O_4S+Na^+$: 543.1116($^{35}$Cl), 545.1086($^{37}$Cl), found: 543.1120, 545.1110.

***ethyl 5-(2-methoxyphenyl)-1-tosyl-1,2,5,10-tetrahydroazepino[2,3-b]indole-4-carboxylate 3m***




White solid; Procedure A: 23.5 mg, 91% yield; Proceduce B: 18.3 mg, 71% yield; m.p. = 135–137 ℃.

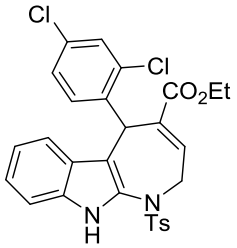
*NMR and HRMS data for the product* **3m**:

**$^1$H NMR (600 MHz, $CDCl_3$)** δ (ppm): 9.17 (s, 1H), 7.41 – 7.38 (m, 3H), 7.25 – 7.21 (m, 2H), 7.15 – 7.11 (m, 3H), 7.04 (t, *J* = 7.2 Hz, 1H), 6.79 (d, *J* = 7.8 Hz, 1H), 6.69 – 6.64 (m, 2H), 6.23 (t, *J* = 7.2 Hz, 1H), 5.56 (s, 1H), 4.41 (dd, *J* = 15.6, 7.8 Hz, 1H), 4.31 (dd, *J* = 15.6, 7.8 Hz, 1H), 4.09 – 4.05 (m, 2H), 3.69 (s, 3H), 2.35 (s, 3H), 1.24 (t, *J* = 7.2 Hz, 3H).

**$^{13}$C NMR (150 MHz, $CDCl_3$)** δ (ppm): 166.6, 156.3, 144.2, 141.5, 135.3, 133.1, 132.1, 130.7, 130.1, 129.7, 128.7, 127.9, 127.3, 122.3, 120.1, 119.8, 118.6, 110.6, 110.5, 100.9, 60.5, 54.8, 44.5, 34.9, 21.5, 14.4.

**HRMS (ESI)** m/z calculated for $C_{29}H_{28}N_2O_5S+Na^+$: 539.1611, found: 539.1617.

***ethyl 5-(2,4-dichlorophenyl)-1-tosyl-1,2,5,10-tetrahydroazepino[2,3-b]indole-4-carboxylate 3n***




Prepared according to the Procedure A to afford **3n** 26.0 mg in 94% yield as white solid; m.p. = 130–131 ℃.

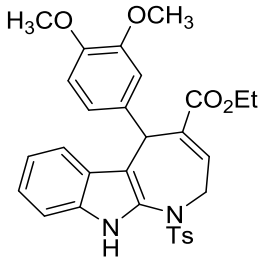
*NMR and HRMS data for the product* **3n**:

**$^1$H NMR (600 MHz, $CDCl_3$)** δ (ppm): 9.14 (s, 1H), 7.42 – 7.39 (m, 3H), 7.31 (d, *J* = 1.8 Hz, 1H), 7.27 – 7.25 (m, 1H), 7.24 – 7.22 (m, 1H), 7.16 (d, *J* = 7.8 Hz, 2H), 7.07 (t, *J* = 7.2 Hz, 1H), 6.89 (dd, *J* = 8.4, 1.8 Hz, 1H), 6.80 (d, *J* = 8.4 Hz, 1H), 6.50 (t, *J* = 7.2 Hz, 1H), 5.61 (s, 1H), 4.52 (dd, *J* = 15.6, 7.8 Hz, 1H), 4.38 (dd, *J* = 15.6, 7.8 Hz, 1H), 4.07 – 4.00 (m, 2H), 2.37 (s, 3H), 1.21 (t, *J* = 7.2 Hz, 3H).

**$^{13}$C NMR (150 MHz, $CDCl_3$)** δ (ppm): 166.1, 144.5, 138.8, 138.3, 135.2, 133.8, 133.2, 132.7, 132.5, 132.3, 131.0, 129.8, 127.2, 126.8, 126.4, 122.7, 120.2, 118.6, 110.8, 101.8, 61.1, 45.1, 37.1, 21.6, 14.1.

**HRMS (ESI)** m/z calculated for $C_{28}H_{24}Cl_2N_2O_4+Na^+$: 577.0726($^{35}$Cl), 579.0697($^{37}$Cl), found: 577.0727, 579.0705.

***ethyl 5-(3,4-dimethoxyphenyl)-1-tosyl-1,2,5,10-tetrahydroazepino[2,3-b]indole-4-carboxylate 3o***




Prepared according to the Procedure A to afford **3o** 22.9 mg in 84% yield as white solid; m.p. = 171–174 ℃.

*NMR and HRMS data for the product* **3o**:

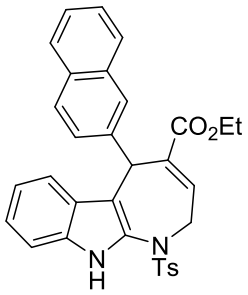
**$^1$H NMR (600 MHz, $CDCl_3$)** δ (ppm): 9.05 (s, 1H), 7.40 – 7.38 (m, 3H), 7.24 – 7.20 (m, 2H), 7.14 (d, *J* = 7.8 Hz, 2H), 7.03 (t, *J* = 7.8 Hz, 1H), 6.75 (s, 1H), 6.64 (t, *J* = 7.2 Hz, 1H), 6.60 (d, *J* = 8.4 Hz, 1H), 6.53 – 6.51 (m, 1H), 5.52 (s, 1H), 4.54 (dd, *J* = 15.6, 7.8 Hz, 1H), 4.35 (dd, *J* = 15.6, 7.8 Hz, 1H), 4.14 – 4.07 (m, 2H), 3.77 (s, 3H), 3.71 (s, 3H), 2.34 (s, 3H), 1.25 (t, *J* = 7.2 Hz, 3H).

**$^{13}$C NMR (150 MHz, $CDCl_3$)** δ (ppm): 166.3, 148.7, 147.5, 144.2, 139.9, 135.4, 135.0,

133.0, 132.5, 132.3, 129.6, 127.4, 127.3, 122.5, 119.9, 119.2, 118.7, 110.7, 110.7, 110.6, 102.2, 61.1, 55.7, 45.2, 38.1, 21.5, 14.2.

**HRMS (ESI)** m/z calculated for $C_{30}H_{30}N_2O_6S+Na^+$: 569.1717, found: 569.1722.

***ethyl 5-(naphthalen-2-yl)-1-tosyl-1,2,5,10-tetrahydroazepino[2,3-b]indole-4-carboxylate 3p***




White solid; Procedure A: 23.9 mg, 89% yield; Proceduce B: 22.8 mg, 85% yield; m.p. = 198–200 ℃.

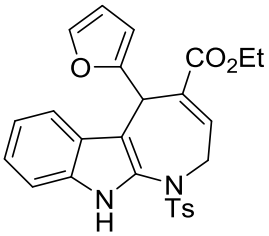
*NMR and HRMS data for the product* **3p**:

**$^1$H NMR (600 MHz, $CDCl_3$)** δ (ppm): 9.14 (s, 1H), 7.74 – 7.73 (m, 1H), 7.65 (d, *J* = 8.4 Hz, 1H), 7.61 – 7.59 (m, 1H), 7.43 – 7.38 (m, 6H), 7.29 – 7.20 (m, 3H), 7.12 (d, *J* = 8.4 Hz, 2H), 7.02 (t, *J* = 7.2 Hz, 1H), 6.68 (t, *J* = 7.2 Hz, 1H), 5.75 (s, 1H), 4.52 (dd, *J* = 15.6, 7.8 Hz, 1H), 4.38 (dd, *J* = 15.6, 7.8 Hz, 1H), 4.17 – 4.11 (m, 2H), 2.34 (s, 3H), 1.27 (t, *J* = 7.2 Hz, 3H).

**$^{13}$C NMR (150 MHz, $CDCl_3$)** δ (ppm): 166.2, 144.3, 140.3, 139.7, 135.0, 133.5, 133.1, 132.6, 132.3, 132.1, 129.7, 128.2, 127.9, 127.4, 127.3, 126.0, 125.8, 125.6, 125.6, 122.5, 120.0, 118.7, 110.6, 101.9, 61.2, 45.2, 38.5, 21.5, 14.2.

**HRMS (ESI)** m/z calculated for $C_{32}H_{28}N_2O_4S+Na^+$: 559.1662, found: 559.1667.

***ethyl 5-(furan-2-yl)-1-tosyl-1,2,5,10-tetrahydroazepino[2,3-b]indole-4-carboxylate 3q***




White solid; Procedure A: 21.7 mg, 91% yield; Proceduce B: 21.0 mg, 88% yield; Procedure C(with **S2**): 19.3 mg, 81% yield; m.p. = 89–91 ℃.

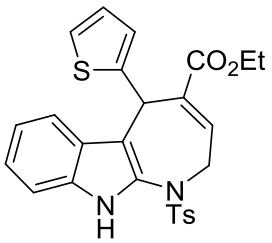
*NMR and HRMS data for the product* **3q**:

**$^1$H NMR (600 MHz, $CDCl_3$)** δ (ppm): 8.96 (s, 1H), 7.45 (d, *J* = 7.8 Hz, 1H), 7.37 – 7.35 (m, 3H), 7.24 – 7.20 (m, 2H), 7.13 – 7.09 (m, 3H), 6.78 (t, *J* = 7.8 Hz, 1H), 6.15 (dd, *J* = 3.0, 1.8 Hz, 1H), 5.91 – 5.90 (m, 1H), 5.58 (s, 1H), 4.62 (dd, *J* = 7.2, 1.2 Hz, 2H), 4.10 – 4.06 (m, 2H), 2.32 (s, 3H), 1.24 (t, *J* = 7.2 Hz, 3H).

**$^{13}$C NMR (150 MHz, $CDCl_3$)** δ (ppm): 165.2, 154.2, 144.2, 141.8, 136.4, 134.9, 134.8, 132.2, 132.1, 129.6, 127.4, 126.9, 122.5, 119.9, 118.6, 110.6, 110.0, 106.4, 100.6, 61.1, 45.5, 33.6, 21.5, 14.2.

**HRMS (ESI)** m/z calculated for $C_{26}H_{24}N_2O_5S+Na^+$: 499.1298, found: 499.1304.

***ethyl 5-(thiophen-2-yl)-1-tosyl-1,2,5,10-tetrahydroazepino[2,3-b]indole-4-carboxylate 3r***




White solid; Procedure A: 22.6 mg, 92% yield; Proceduce B: 20.2 mg, 82% yield; m.p. = 92–93 ℃.

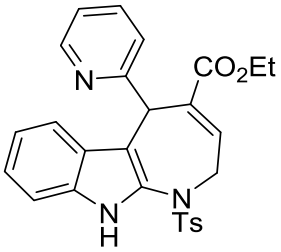
*NMR and HRMS data for the product* **3r**:

**$^1$H NMR (600 MHz, $CDCl_3$)** δ (ppm): 9.00 (s, 1H), 7.39 – 7.34 (m, 4H), 7.24 – 7.21 (m, 1H), 7.13 (d, *J* = 7.8 Hz, 2H), 7.09 – 7.07 (m, 1H), 7.05 (dd, *J* = 4.8, 1.8 Hz, 1H), 6.78 (q, *J* = 5.4, 3.0 Hz, 1H), 6.72 – 6.69 (m, 1H), 6.66 – 6.65 (m, 1H), 5.73 (s, 1H), 4.60 (dd, *J* = 15.6, 7.2 Hz, 1H), 4.46 (dd, *J* = 15.6, 7.8 Hz, 1H), 4.14 – 4.10 (m, 2H), 2.33 (s, 3H), 1.27 (t, *J* = 7.2 Hz, 3H).

**$^{13}$C NMR (150 MHz, $CDCl_3$)** δ (ppm): 165.4, 146.7, 144.3, 139.0, 134.9, 133.9, 132.2, 132.1, 129.7, 127.4, 127.0, 126.4, 124.7, 124.0, 122.6, 120.0, 118.6, 110.7, 102.6, 61.2, 45.3, 34.8, 21.5, 14.2.

**HRMS (ESI)** m/z calculated for $C_{26}H_{24}N_2O_4S_2+Na^+$: 515.1070, found: 515.1075.

***ethyl 5-(pyridin-2-yl)-1-tosyl-1,2,5,10-tetrahydroazepino[2,3-b]indole-4-carboxylate 3s***




Prepared according to the Procedure A to afford **3s** in 20.9 mg 86% yield yield as white solid; m.p. = 146–150 ℃.

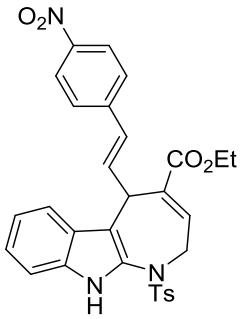
*NMR and HRMS data for the product* **3s**:

**$^1$H NMR (600 MHz, $CDCl_3$)** δ (ppm): 9.02 (s, 1H), 8.41 – 8.40 (m, 1H), 7.51 – 7.48 (m, 1H), 7.38 (d, *J* = 8.4 Hz, 2H), 7.33 – 7.29 (m, 2H), 7.23 (d, *J* = 7.2 Hz, 1H), 7.19 – 7.16 (m, 1H), 7.12 (d, *J* = 8.4 Hz, 2H), 7.04 – 7.01 (m, 2H), 6.76 (t, *J* = 7.8 Hz, 1H), 5.62 (s, 1H), 5.06 (dd, *J* = 15.6, 7.2 Hz, 1H), 4.55 (dd, *J* = 15.6, 7.8 Hz, 1H), 4.07 (q, *J* = 14.4, 7.8 Hz, 2H), 2.33 (s, 3H), 1.23 (t, *J* = 7.2 Hz, 3H).

**$^{13}$C NMR (150 MHz, $CDCl_3$)** δ (ppm): 165.8, 162.0, 149.8, 144.1, 138.3, 136.4, 135.1, 134.6, 132.6, 132.3, 129.6, 127.4, 127.1, 122.4, 122.3, 121.6, 119.8, 118.3, 110.7, 102.3, 61.0, 45.9, 42.1, 21.5, 14.2.

**HRMS (ESI)** m/z calculated for $C_{27}H_{25}N_3O_4S+Na^+$: 510.1458, found: 510.1464.

***ethyl (E)-5-(4-nitrostyryl)-1-tosyl-1,2,5,10-tetrahydroazepino[2,3-b]indole-4-carboxylate 3t***




White solid; Procedure A: 25.6 mg, 92% yield; Proceduce B: 25.9 mg, 93% yield; m.p. = 97–101 ℃.

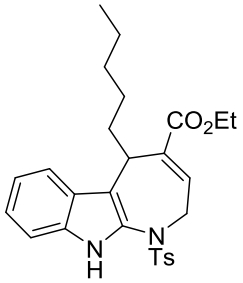
*NMR and HRMS data for the product* **3t**:

**$^1$H NMR (600 MHz, $CDCl_3$)** δ (ppm): 9.01 (s, 1H), 8.08 (d, *J* = 9.0 Hz, 2H), 7.45 – 7.44 (m, 1H), 7.41 – 7.38 (m, 3H), 7.34 – 7.32 (m, 2H), 7.27 – 7.26 (m, 1H), 7.15 – 7.12 (m, 3H), 6.80 (t, *J* = 7.2 Hz, 1H), 6.40 – 6.36 (m, 1H), 6.29 – 6.26 (m, 1H), 5.09 – 5.08 (m, 1H), 4.64 (dd, *J* = 15.6, 7.8 Hz, 1H), 4.38 (dd, *J* = 15.0, 7.2 Hz, 1H), 4.13 – 4.10 (m, 2H), 2.32 (s, 3H), 1.27 (t, *J* = 7.2 Hz, 3H),

**$^{13}$C NMR (150 MHz, $CDCl_3$)** δ (ppm): 165.4, 146.7, 144.4, 143.3, 136.8, 135.0, 134.8, 134.1, 132.4, 132.3, 129.7, 127.9, 127.4, 126.9, 123.8, 122.7, 120.2, 118.3, 110.8, 101.0, 61.3, 45.7, 37.4, 29.7, 21.5, 14.2.

**HRMS (ESI)** m/z calculated for $C_{30}H_{27}N_3O_6S+Na^+$: 580.1513, found: 580.1519.

***ethyl 5-pentyl-1-tosyl-1,2,5,10-tetrahydroazepino[2,3-b]indole-4-carboxylate 3u***




Colorless semisolid; Procedure A: 21.8 mg, 91% yield; Proceduce B: 21.6 mg, 90% yield.

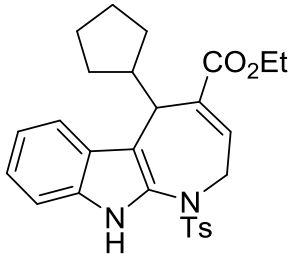
*NMR and HRMS data for the product* **3u**:

**$^1$H NMR (600 MHz, $CDCl_3$)** δ (ppm): 8.81 (s, 1H), 7.49 (d, *J* = 8.4 Hz, 1H), 7.36 – 7.35 (m, 3H), 7.24 – 7.21 (m, 1H), 7.15 – 7.10 (m, 3H), 6.70 (t, *J* = 7.2 Hz, 1H), 4.60 – 4.53 (m, 3H), 4.21 (dd, *J* = 8.4, 5.4 Hz, 1H), 4.09 – 4.05 (m, 2H), 2.31 (s, 3H), 1.58 – 1.46 (m, 3H), 1.24 (t, *J* = 7.2 Hz, 3H), 1.20 – 1.10 (m, 5H), 0.80 (t, *J* = 7.2 Hz, 3H).

**$^{13}$C NMR (150 MHz, $CDCl_3$)** δ (ppm): 166.4, 144.1, 139.0, 135.2, 133.3, 132.4, 130.7, 129.5, 127.3, 126.9, 122.3, 119.6, 118.5, 110.7, 106.6, 60.9, 46.2, 37.9, 34.0, 31.8, 27.5, 22.5, 21.5, 14.2, 14.0.

**HRMS (ESI)** m/z calculated for $C_{27}H_{32}N_2O_4S+Na^+$: 503.1975, found: 503.1977.

***ethyl 5-cyclopentyl-1-tosyl-1,2,5,10-tetrahydroazepino[2,3-b]indole-4-carboxylate 3v***




Prepared according to the Procedure A to afford **3v** 20.8 mg in 87% yield as white solid; m.p. = 98–100 ℃.

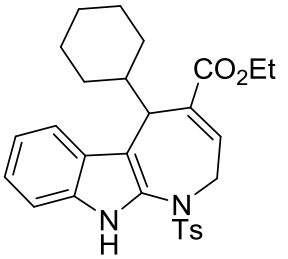
*NMR and HRMS data for the product* **3v**:

**$^1$H NMR (600 MHz, $CDCl_3$)** δ (ppm): 8.93 (s, 1H), 7.54 (d, *J* = 7.8 Hz, 1H), 7.40 – 7.38 (m, 2H), 7.35 – 7.33 (m, 1H), 7.22 – 7.19 (m, 1H), 7.13 – 7.10 (m, 3H), 6.64 (t, *J* = 6.0 Hz, 1H), 4.74 (dd, *J* = 17.4, 6.6 Hz, 1H), 4.54 (dd, *J* = 16.8, 6.0 Hz, 1H), 4.12 – 4.06 (m, 3H), 2.32 (s, 3H), 1.53 – 1.37 (m, 3H), 1.24 (t, *J* = 7.2 Hz, 3H), 1.22 – 1.11 (m, 6H).

**$^{13}$C NMR (150 MHz, $CDCl_3$)** δ (ppm): 166.9, 144.1, 138.5, 135.4, 132.8, 132.1, 130.1, 129.6, 127.2, 122.1, 119.5, 119.0, 110.6, 107.9, 61.0, 49.4, 46.4, 37.6, 32.4, 30.7, 24.1, 23.8, 21.5, 14.2.

**HRMS (ESI)** m/z calculated for $C_{27}H_{30}N_2O_4S+Na^+$: 501.1818, found: 501.1823.

***ethyl 5-cyclohexyl-1-tosyl-1,2,5,10-tetrahydroazepino[2,3-b]indole-4-carboxylate 3w***




White solid; Procedure A: 20.2 mg, 82% yield; Proceduce B: 20.4 mg, 83% yield; Procedure C(with **S2**): 20.2 mg, 82% yield; m.p. = 155–159 ℃.

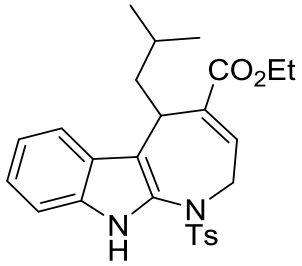
*NMR and HRMS data for the product* **3w**:

**$^1$H NMR (600 MHz, $CDCl_3$)** δ (ppm): 9.00 (s, 1H), 7.52 (d, *J* = 7.2 Hz, 1H), 7.37 – 7.34 (m, 3H), 7.22 – 7.19 (m, 1H), 7.13 – 7.11 (m, 3H), 6.65 (t, *J* = 7.2 Hz, 1H), 4.64 – 4.55 (m, 2H), 4.09 – 4.04 (m, 3H), 2.31 (s, 3H), 1.53 – 1.42 (m, 6H), 1.23 (t, *J* = 7.2 Hz, 3H), 1.03 – 0.83 (m, 5H).

**$^{13}$C NMR (150 MHz, $CDCl_3$)** δ (ppm): 166.8, 144.2, 139.2, 135.1, 132.5, 131.9, 130.8, 129.7, 127.9, 127.2, 122.0, 119.5, 119.2, 110.5, 105.4, 60.9, 46.3, 45.9, 39.3, 32.2, 31.0, 26.4, 26.3, 26.1, 21.5, 14.1.

**HRMS (ESI)** m/z calculated for $C_{28}H_{32}N_2O_4S+Na^+$: 515.1975, found: 515.1979.

***ethyl 5-isobutyl-1-tosyl-1,2,5,10-tetrahydroazepino[2,3-b]indole-4-carboxylate 3x***




Colorless semisolid. Procedure A: 22.3 mg, 93% yield; Proceduce B: 18.2 mg, 76% yield; Procedure C(with **S2**): 20.4 mg, 85% yield.

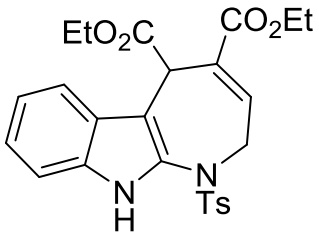
*NMR and HRMS data for the product* **3x**:

**$^1$H NMR (600 MHz, $CDCl_3$)** δ (ppm): 8.82 (s, 1H), 7.47 (d, *J* = 7.8 Hz, 1H), 7.36 (t, *J* = 8.4 Hz, 3H), 7.24 – 7.21 (m, 1H), 7.15 – 7.11 (m, 3H), 6.69 (t, *J* = 7.2 Hz, 1H), 4.62 – 4.53 (m, 2H), 4.31 (dd, *J* = 9.6, 4.8 Hz, 1H), 4.06 (q, *J* = 13.8, 7.2 Hz, 2H), 2.31 (s, 3H), 1.53 – 1.41 (m, 2H), 1.38 – 1.28 (m, 1H), 1.25 (t, *J* = 7.2 Hz, 3H), 0.95 (d, *J* = 6.0 Hz, 3H), 0.83 (d, *J* = 6.6 Hz, 3H).

**$^{13}$C NMR (150 MHz, $CDCl_3$)** δ (ppm): 166.4, 144.1, 139.5, 135.2, 133.5, 132.3, 130.8, 129.6, 127.3, 126.7, 122.3, 119.6, 118.2, 110.7, 106.7, 60.9, 48.0, 46.1, 31.6, 26.1, 23.6, 22.0, 21.5, 14.1.

**HRMS (ESI)** m/z calculated for $C_{27}H_{32}N_2O_4S+Na^+$: 489.1818, found: 489.1819.

***diethyl 1-tosyl-1,2,5,10-tetrahydroazepino[2,3-b]indole-4,5-dicarboxylate 3y***




Prepared according to the Procedure A to afford **3y** 22.2 mg in 92% yield as colorless semisolid.

*NMR and HRMS data for the product* **3y**:

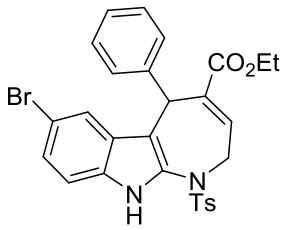
**$^1$H NMR (600 MHz, $CDCl_3$)** δ (ppm): 8.99 (s, 1H), 7.65 (d, *J* = 7.8 Hz, 1H), 7.35 (d, *J* =8.4 Hz, 3H), 7.25 – 7.23 (m, 1H), 7.17 – 7.15 (m, 1H), 7.11 (d, *J* = 7.8 Hz, 2H), 6.89 (t, *J* = 6.6 Hz, 1H), 5.16 (s, 1H), 4.74 (dd, *J* = 14.4, 7.2 Hz, 1H), 4.64 (dd, *J* = 15.6, 7.8 Hz, 1H), 4.08 – 4.02 (m, 4H), 2.31 (s, 3H), 1.24 (t, *J* = 7.2 Hz, 3H), 1.16 (t, *J* = 7.2 Hz, 3H).

**$^{13}$C NMR (150 MHz, $CDCl_3$)** δ (ppm): 170.9, 165.1, 144.3, 137.0, 135.0, 133.9, 132.6, 132.0, 129.7, 127.3, 126.9, 122.6, 120.0, 119.0, 110.6, 98.4, 61.7, 61.2, 45.9, 40.7, 21.5, 14.1,

14.0.

**HRMS (ESI)** m/z calculated for $C_{25}H_{26}N_2O_6S+Na^+$: 505.1404, found: 505.1410.

***ethyl 7-bromo-5-phenyl-1-tosyl-1,2,5,10-tetrahydroazepino[2,3-b]indole-4-carboxylate 3z***




White solid; Procedure A: 25.1 mg, 89% yield; Proceduce B: 19.7 mg, 70% yield; Procedure C(with **S2**): 21.2 mg, 75% yield; m.p. = 198–199 ℃.

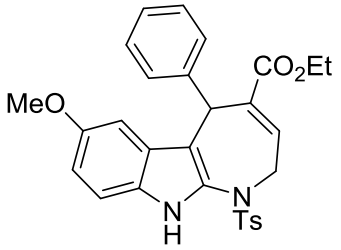
*NMR and HRMS data for the product* **3z**:

**$^1$H NMR (600 MHz, $CDCl_3$)** δ (ppm): 9.15 (s, 1H), 7.38 – 7.35 (m, 3H), 7.31 – 7.28 (m, 1H), 7.27 – 7.25 (m, 1H), 7.18 – 7.14 (m, 5H), 7.03 (d, *J* = 7.2 Hz, 2H), 6.65 (t, *J* = 7.8 Hz, 1H), 5.51 (s, 1H), 4.50 (dd, *J* = 15.0, 7.8 Hz, 1H), 4.24 (dd, *J* = 15.0, 7.8 Hz, 1H), 4.15 – 4.09 (m, 2H), 2.35 (s, 3H), 1.27 (t, *J* = 7.2 Hz, 3H).

**$^{13}$C NMR (150 MHz, $CDCl_3$)** δ (ppm): 166.0, 144.5, 142.4, 140.2, 134.8, 133.6, 133.1, 130.8, 129.8, 129.1, 128.5, 127.3, 127.1, 126.6, 125.4, 121.1, 113.3, 112.1, 101.4, 61.3, 45.0, 37.9, 21.6, 14.2.

**HRMS (ESI)** m/z calculated for $C_{28}H_{25}BrN_2O_4S+Na^+$: 587.0611($^{79}$Br), 589.0590($^{81}$Br); found: 587.0613, 589.0594.

***ethyl 7-methoxy-5-phenyl-1-tosyl-1,2,5,10-tetrahydroazepino[2,3-b]indole-4-carboxylate 3aa***




White solid; Procedure A: 21.4 mg, 83% yield; Proceduce B: 19.9 mg, 77% yield; Procedure C(with **S2**): 20.4 mg, 79% yield; m.p. = 105–110 ℃.

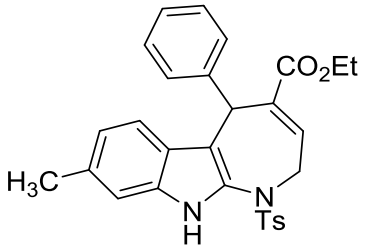
*NMR and HRMS data for the product* **3aa**:

**$^1$H NMR (600 MHz, $CDCl_3$)** δ (ppm): 8.98 (s, 1H), 7.38 (d, *J* = 8.4 Hz, 2H), 7.28 (d, *J* = 8.4Hz, 1H), 7.18 – 7.05 (m, 8H), 6.86 (dd, *J* = 8.4 Hz, 2.4 Hz, 1H), 6.67 – 6.64 (m, 1H), 5.52 (s, 1H), 4.51 (dd, *J* = 15.6, 7.8 Hz, 1H), 4.24 (dd, *J* = 15.6, 7.8 Hz, 1H), 4.14 – 4.08 (m, 2H), 3.71 (s, 3H), 2.35 (s, 3H), 1.26 (t, *J* = 6.6 Hz, 3H).

**$^{13}$C NMR (150 MHz, $CDCl_3$)** δ (ppm):δ 166.2, 154.3, 144.2, 142.8, 140.2, 135.0, 133.2, 132.9, 129.7, 128.4, 127.9, 127.3, 127.2, 127.2, 126.4, 112.1, 111.4, 101.9, 100.8, 61.2, 55.8, 45.2, 38.3, 21.5, 14.2.

**HRMS (ESI)** m/z calculated for $C_{29}H_{28}N_2O_5S+Na^+$: 539.1611, found: 539.1611.

***ethyl 8-methyl-5-phenyl-1-tosyl-1,2,5,10-tetrahydroazepino[2,3-b]indole-4-carboxylate 3ab***




Prepared according to the Procedure A to afford **3ab** 23.5 mg in 94% yield as white solid; m.p. = 105–110 ℃.

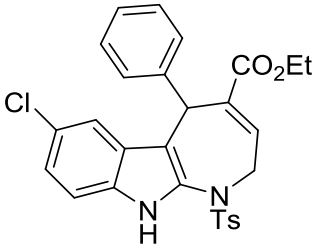
*NMR and HRMS data for the product* **3ab**:

**$^1$H NMR (600 MHz, $CDCl_3$)** δ (ppm): 8.93 (s, 1H), 7.37 (d, *J* = 8.4 Hz, 2H), 7.19 – 7.06 (m, 9H), 6.86 (d, *J* = 8.4 Hz, 1H), 6.63 (t, *J* = 7.2 Hz, 1H), 5.56 (s, 1H), 4.51 (dd, *J* = 15.6, 7.8 Hz, 1H), 4.26 (dd, *J* = 15.6, 7.8 Hz, 1H), 4.13 – 4.07 (m, 2H), 2.46 (s, 3H), 2.34 (s, 3H), 1.25 (t, *J* = 6.6 Hz, 3H).

**$^{13}$C NMR (150 MHz, $CDCl_3$)** δ (ppm): 166.2, 144.2, 142.9, 139.9, 135.0, 133.1, 132.7, 132.4, 131.9, 129.6, 128.4, 127.4, 127.2, 126.4, 125.1, 121.6, 118.5, 110.6, 102.0, 61.1, 45.3, 38.4, 21.7, 21.5, 14.2.

**HRMS (ESI)** m/z calculated for $C_{29}H_{28}N_2O_4S+Na^+$: 523.1662, found: 523.1667.

***ethyl 8-methyl-5-phenyl-1-tosyl-1,2,5,10-tetrahydroazepino[2,3-b]indole-4-carboxylate 3ac***




White solid; Procedure A: 23.4 mg, 90% yield; Proceduce B: 19.0 mg, 73% yield; Procedure C(with **S2**): 18.2 mg, 70% yield; m.p. = 105–110 ℃.

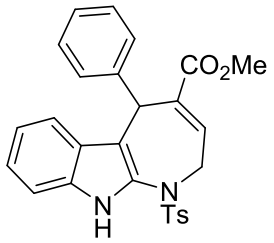
*NMR and HRMS data for the product* **3ac**:

**$^1$H NMR (600 MHz, $CDCl_3$)** δ (ppm): 9.08 (s, 1H), 7.40 – 7.36 (m, 3H), 7.17 – 7.11 (m, 6H), 7.04 – 7.03 (m, 2H), 7.00 – 6.98 (m, 1H), 6.66 (t, *J* = 7.8 Hz, 1H), 5.54 (s, 1H), 4.52 (dd, *J* = 15.0, 7.8 Hz, 1H), 4.25 (dd, *J* = 15.0, 7.8 Hz, 1H), 4.14 – 4.08 (m, 2H), 2.35 (s, 3H), 1.26 (t, *J* = 6.6 Hz, 3H).

**$^{13}$C NMR (150 MHz, $CDCl_3$)** δ (ppm): 166.1, 144.4, 142.5, 139.8, 134.8, 133.1, 133.0, 132.6, 129.7, 128.5, 128.3, 127.3, 127.2, 126.6, 125.9, 120.7, 119.6, 110.6, 102.1, 61.2, 45.2, 38.2, 21.5, 14.2.

**HRMS (ESI)** m/z calculated for $C_{28}H_{25}ClN_2O_4S+Na^+$: 543.1116($^{35}Cl$), 545.1086($^{37}Cl$), found: 543.1112, 545.1088.

***methyl 5-phenyl-1-tosyl-1,2,5,10-tetrahydroazepino[2,3-b]indole-4-carboxylate 3ad***




White solid; Procedure A: 22.9 mg, 97% yield; Proceduce B: 21.5 mg, 91% yield; Procedure C(with **S2**): 22.0 mg, 93% yield; m.p. = 102–105 ℃.

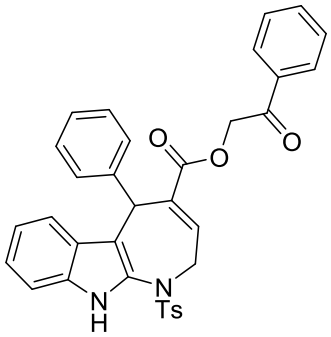
*NMR and HRMS data for the product* **3ad**:

**$^1$H NMR (600 MHz, $CDCl_3$)** δ (ppm): 9.05 (s, 1H), 7.40 – 7.37 (m, 3H), 7.24 – 7.20 (m, 2H), 7.16 – 7.12 (m, 5H), 7.06 – 7.02 (m, 3H), 6.63 (t, *J* = 7.2 Hz, 1H), 5.58 (s, 1H), 4.51 (dd, *J* = 15.6, 7.8 Hz, 1H), 4.26 (dd, *J* = 15.6, 7.8 Hz, 1H), 3.66 (s, 3H), 2.36 (s, 3H).

**$^{13}$C NMR (150 MHz, $CDCl_3$)** δ (ppm):166.6, 144.3, 142.8, 139.6, 134.9, 133.6, 132.5, 132.3, 129.6, 128.4, 127.4, 127.3, 127.2, 126.4, 122.5, 120.0, 118.7, 110.6, 102.0, 52.2, 45.3, 38.4, 21.5.

**HRMS (ESI)** m/z calculated for $C_{27}H_{24}N_2O_4S+Na^+$: 495.1349, found: 495.1353.

***2-oxo-2-phenylethyl 5-phenyl-1-tosyl-1,2,5,10-tetrahydroazepino[2,3-b]indole-4-carboxylate 3ae***




Prepared according to the Procedure A to afford **3ae** in 26.5 mg 92% yield as white solid; m.p. = 178–181 ℃.

*NMR and HRMS data for the product* **3ae**:

**$^1$H NMR (600 MHz, $CDCl_3$)** δ (ppm): 9.13 (s, 1H), 7.93 – 7.92 (m, 2H), 7.65 – 7.63 (m, 1H), 7.53 – 7.50 (m, 2H), 7.44 (d, *J* = 8.4 Hz, 2H), 7.39 (d, *J* = 8.4 Hz, 1H), 7.25 – 7.11 (m, 9H), 7.05 – 7.02 (m, 1H), 6.85 (t, *J* = 7.2 Hz, 1H), 5.62 (s, 1H), 5.31 (q, *J* = 29.4, 16.2 Hz, 2H), 4.56 (dd, *J* = 15.6, 7.8 Hz, 1H), 4.30 (dd, *J* = 15.0, 7.2 Hz, 1H), 2.34 (s, 3H).

**$^{13}$C NMR (150 MHz, $CDCl_3$)** δ (ppm): 191.3, 165.7, 144.5, 142.6, 139.6, 134.8, 134.6, 134.2, 134.0, 132.5, 132.3, 129.9, 129.0, 128.4, 127.7, 127.4, 127.3, 127.3, 126.5, 122.4,

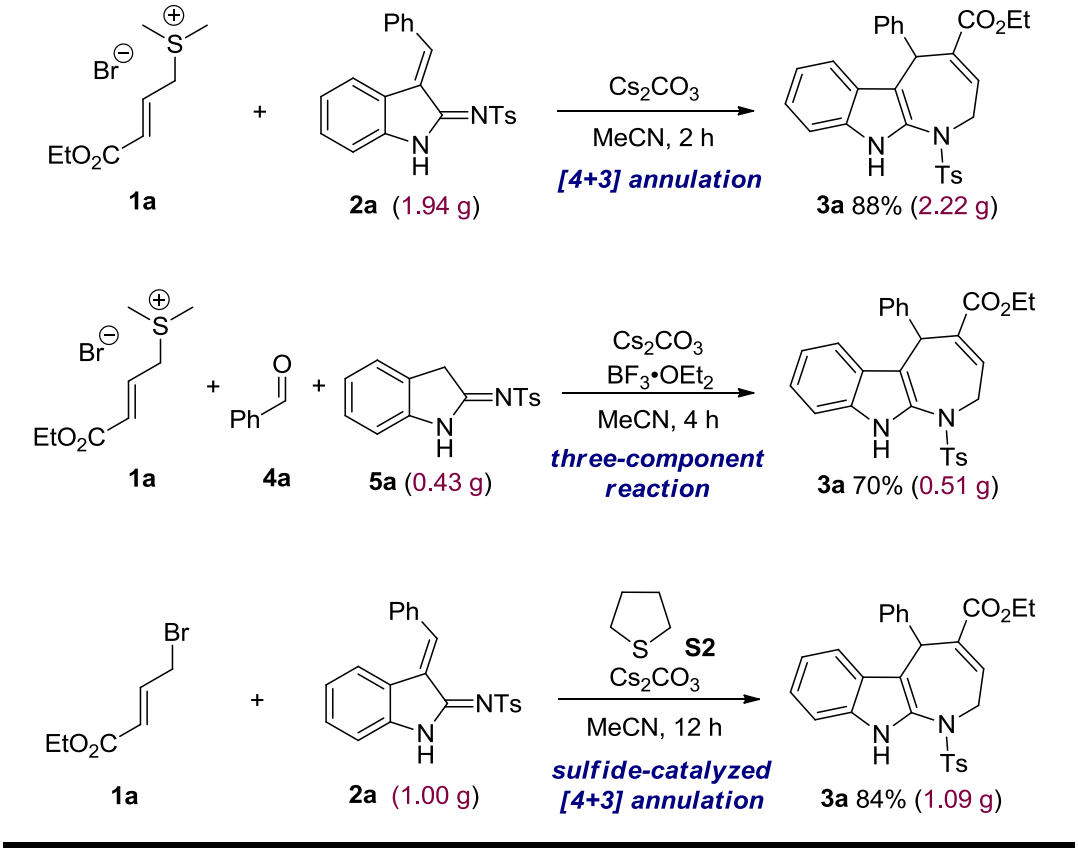
120.0, 118.6, 110.6, 101.8, 66.5, 45.2, 38.4, 21.6.

**HRMS (ESI)** m/z calculated for $C_{34}H_{28}N_2O_5S+Na^+$: 599.1611, found: 599.1608.

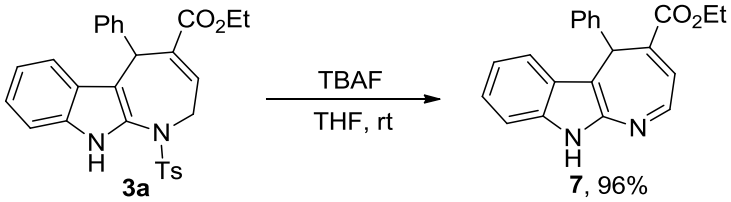
- **Large-Scale Reaction:**

The large-scale experiments were also conducted according to the relative genneral procedure A, B or C. As shown in the following scheme, all the three reactions proceeded well, affording reasonable yields.

***Large-scale experiments***



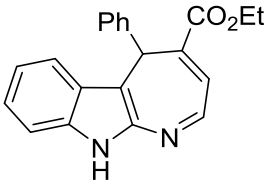

## 4. Synthetic Transformations of the Product 3a




To a solution of **3a** (0.1 mmol) in 1 mL of THF was added tetrabutylammonium fluoride (TBAF, 0.5 mmol), and the reaction was stirred at 60 ℃ for 12 hour. Then $H_2O$ (5 mL) was added to quench the reaction and the resulting mixture was extracted with ethyl acetate (5 mL

× 2). The combined organic layer was dried over $Na_2SO_4$, filtered and concentrated to dryness under reduced pressure. The residue was purified through column chromatograghy on silica gel (petroleum ether/ethyl acetate = 6:1) to afford the desired product **7** as a red solid.

***ethyl 1-benzoyl-6,6-dimethyl-4,8-dioxospiro[2.5]octane-1-carboxylate 7***



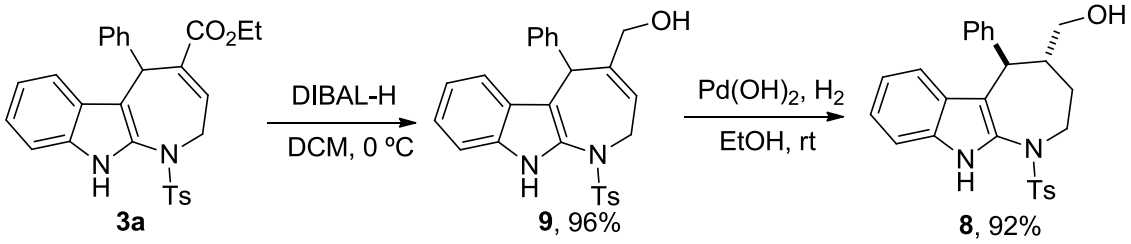

Purification of the crude product *via* column chromatography delivered **7** 15.8 mg in 96% yield as red solid; m.p. = 194–196 ℃.

*NMR and HRMS data for the product* **7**:

**$^1$H NMR (600 MHz, $CDCl_3$)** δ (ppm): 9.31 (s, 1H), 7.98 (d, *J* = 4.2 Hz, 1H), 7.77 (d, *J* = 8.4 Hz, 1H), 7.39 (d, *J* = 7.8 Hz, 1H), 7.31 – 7.28 (m, 1H), 7.22 – 7.21 (m, 1H), 7.18 – 7.15 (m, 3H), 7.13 – 7.10 (m, 1H), 7.08 – 7.06 (m, 2H), 6.08 (s, 1H), 4.38 – 4.32 (m, 2H), 1.38 (t, *J* = 7.2 Hz, 3H).

**$^{13}$C NMR (150 MHz, $CDCl_3$)** δ (ppm): 166.5, 151.7, 142.1, 141.7, 138.3, 137.3, 128.3, 127.5, 126.8, 126.7, 126.0, 124.4, 120.3, 119.5, 111.1, 106.2, 62.0, 38.0, 14.2.

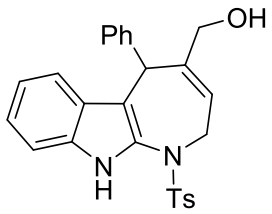
**HRMS (ESI)** m/z calculated for $C_{21}H_{18}N_2O_2$+$Na^+$: 353.1260, found: 353.1263.




A solution of **3a** (0.1 mmol) in 1 mL of DCM was cooled to 0 ℃. then slowly added diisobutyl aluminium hydride (DIBAL-H, 0.25 mmol). The reaction was stirred at 0 ℃ for 30 minutes. Then $H_2O$ (5 mL) was added to quench the reaction and the resulting mixture was extracted with DCM (5 mL × 2). The combined organic layer was dried over $Na_2SO_4$, filtered and concentrated to dryness under reduced pressure. The residue was purified through column chromatograghy on silica gel (petroleum ether/ethyl acetate =4:1) to afford the product **9** 21.3 mg as a white solid. The second reaction was conducted with **9** (21.3 mg, 0.096 mmol), $Pd(OH)_2$ (4 mg) in EtOH (1 mL) under $H_2$ atmosphere (1 atm). The mixture was stirred at room temperature for 24 hours. When the reaction was completed, the mixture was concentrated, and purified by column chromatography on silica gel eluting with petroleum

ether/ethyl acetate from 6:1 to 4:1 to afford the product **6**, which was dried under vacuum and further analyzed by $^{1}$H NMR, $^{13}$C HMR, HRMS, *etc*.

***(5-phenyl-1-tosyl-1,2,5,10-tetrahydroazepino[2,3-b]indol-4-yl)methanol 9***




Purification of the crude product *via* column chromatography delivered **9** 21.3 mg in 96% yield as white solid; m.p. = 198–199 ℃.

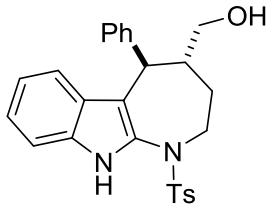
*NMR and HRMS data for the product* **9**:

**$^{1}$H NMR (600 MHz, $CDCl_3$)** δ (ppm): 9.03 (s, 1H), 7.44 – 7.42 (m, 2H), 7.39 – 7.37 (m, 1H), 7.21 – 7.12 (m, 9H), 7.02 – 6.99 (m, 1H), 5.51 (t, *J* = 7.2 Hz, 1H), 4.73 (s, 1H), 4.45 (dd, *J* = 15.6, 7.8 Hz, 1H), 4.28 (dd, *J* = 15.6, 7.2 Hz, 1H), 3.84 – 3.78 (m, 2H), 2.40 (s, 3H).

**$^{13}$C NMR (150 MHz, $CDCl_3$)** δ (ppm): 148.6, 144.3, 143.1, 136.0, 132.6, 132.4, 129.4, 128.5, 127.8, 127.4, 127.2, 126.6, 122.4, 119.8, 119.4, 118.7, 110.6, 103.2, 66.8, 46.2, 41.5, 21.5.

**HRMS (ESI)** m/z calculated for $C_{26}H_{24}N_2O_3$+$Na^+$: 467.1400, found: 467.1402.

***(5-phenyl-1-tosyl-1,2,3,4,5,10-hexahydroazepino[2,3-b]indol-4-yl)methanol 8***




Purification of the crude product *via* column chromatography delivered **8** 20.5 mg in 92% yield as white solid. The diastereomeric ratio was determined to be >19:1 by crude $^{1}$H NMR analysis.

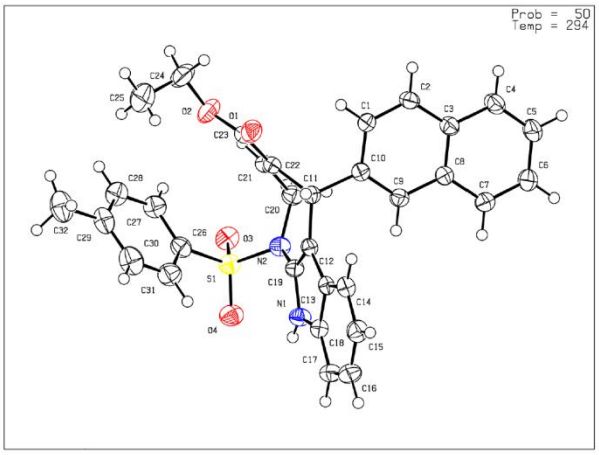
*NMR and HRMS data for the product* **8**:

**$^{1}$H NMR (600 MHz, $CDCl_3$)** δ (ppm): 8.94 (s, 1H), 7.67 (d, *J* = 8.4 Hz, 2H), 7.31 – 7.29 (m, 1H), 7.27 – 7.25 (m, 2H), 7.14 – 7.11 (m, 1H), 7.07 – 7.01 (m, 2H), 6.99 – 6.96 (m, 2H), 6.92 – 6.89 (m, 1H), 6.61 (d, *J* = 7.2 Hz, 2H), 4.28 – 4.23 (m, 1H), 4.07 (d, *J* = 9.0 Hz, 1H), 3.87 – 3.82 (m, 1H), 3.48 (dd, *J* = 10.8, 4.8 Hz, 1H), 3.32 (dd, *J* = 10.8, 6.6 Hz, 1H), 2.44 (s, 3H), 2.06 – 2.01 (m, 1H), 1.95 – 1.90 (m, 1H), 1.80 – 1.73 (m, 1H).

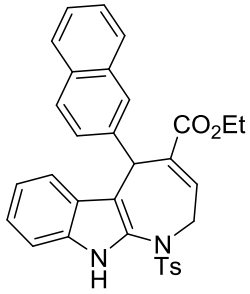
**$^{13}$C NMR (150 MHz, $CDCl_3$)** δ (ppm): 144.2, 143.3, 136.2, 133.4, 130.0, 129.1, 128.1, 128.0, 125.4, 127.4, 126.0, 122.2, 119.6, 119.0, 110.6, 107.6, 64.7, 49.6, 44.0, 43.1, 27.9, 21.6.

**HRMS (ESI)** m/z calculated for $C_{26}H_{26}N_2O_3S$+$Na^+$: 469.1556, found: 469.1554.

## 5. Crystal Data and Structure Refinement for Representative Product 3p



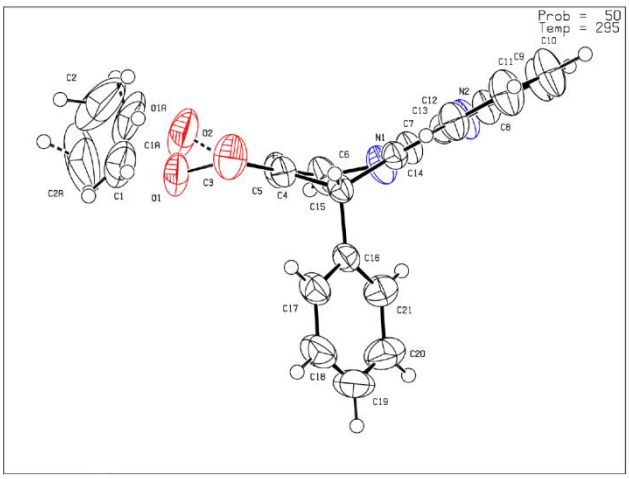

≡

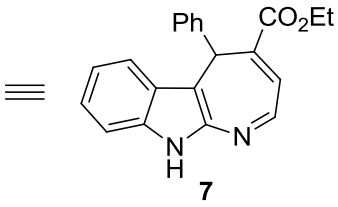



**3p**

| | |
|---|---|
| Identification code | **3p** |
| Empirical formula | $C_{32}H_{28}N_2O_4S$ |
| Formula weight | 536.62 |
| Temperature/K | 180 |
| Crystal system | triclinic |
| Space group | P-1 |
| a/Å | 10.0453(6) |
| b/Å | 10.6051(8) |
| c/Å | 15.2624(9) |
| α/° | 85.076(5) |
| β/° | 76.712(5) |
| γ/° | 73.509(6) |
| Volume/Å$^3$ | 1516.93(17) |
| Z | 2 |
| $\rho_{calc}$g/cm$^3$ | 1.175 |
| μ/mm$^{-1}$ | 1.243 |
| F(000) | 564.0 |
| Crystal size/mm$^3$ | 0.6 × 0.3 × 0.1 |
| Radiation | CuKα (λ = 1.54184) |
| 2Θ range for data collection/° | 8.698 to 145.826 |
| Index ranges | -11 ≤ h ≤ 12, -13 ≤ k ≤ 12, -18 ≤ l ≤ 18 |
| Reflections collected | 16717 |
| Independent reflections | 5907 [$R_{int}$ = 0.0531, $R_{sigma}$ = 0.0512] |
| Data/restraints/parameters | 5907/0/354 |
| Goodness-of-fit on F$^2$ | 1.448 |
| Final R indexes [I>=2σ (I)] | $R_1$ = 0.1122, $wR_2$ = 0.3352 |
| Final R indexes [all data] | $R_1$ = 0.1253, $wR_2$ = 0.3596 |
| Largest diff. peak/hole / e Å$^{-3}$ | 3.23/-0.58 |

## 6. Crystal Data and Structure Refinement for 7




**7**

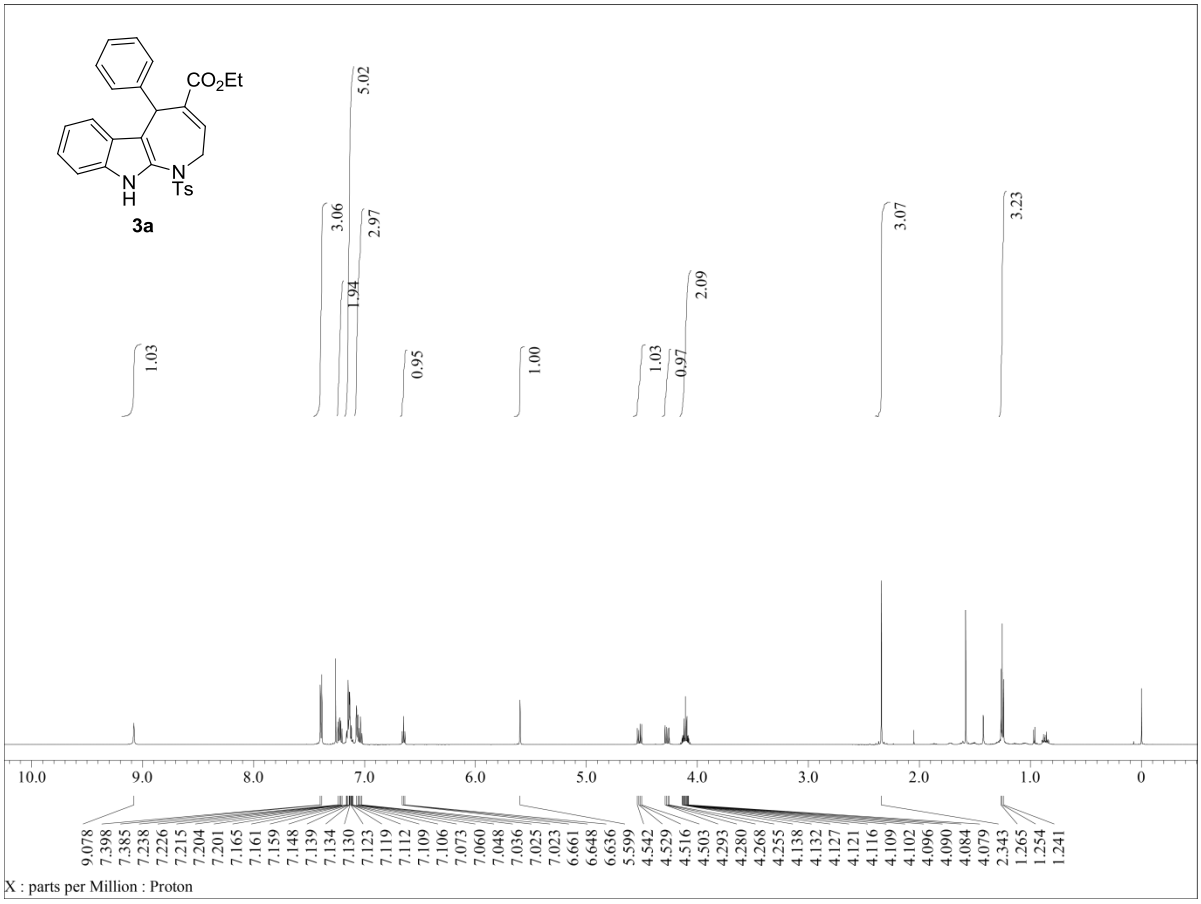
| | |
|---|---|
| Identification code | **7** |
| Empirical formula | $C_{21}H_{18}N_2O_2$ |
| Formula weight | 330.37 |
| Temperature/K | 295.39(10) |
| Crystal system | monoclinic |
| Space group | $P2_1/c$ |
| a/Å | 10.3152(3) |
| b/Å | 21.8940(6) |
| c/Å | 8.1031(2) |
| α/° | 90 |
| β/° | 110.046(3) |
| γ/° | 90 |
| Volume/Å$^3$ | 1719.15(9) |
| Z | 4 |
| $\rho_{calc}$g/cm$^3$ | 1.276 |
| μ/mm$^{-1}$ | 0.664 |
| F(000) | 696.0 |
| Crystal size/mm$^3$ | 0.6 × 0.4 × 0.3 |
| Radiation | CuKα (λ = 1.54184) |
| 2Θ range for data collection/° | 8.076 to 145.432 |
| Index ranges | $-12 \le h \le 8$, $-27 \le k \le 23$, $-9 \le l \le 9$ |
| Reflections collected | 9566 |
| Independent reflections | 3354 [$R_{int}$ = 0.0251, $R_{sigma}$ = 0.0218] |
| Data/restraints/parameters | 3354/0/258 |
| Goodness-of-fit on $F^2$ | 1.031 |
| Final R indexes [I>=2σ (I)] | $R_1$ = 0.0570, $wR_2$ = 0.1545 |
| Final R indexes [all data] | $R_1$ = 0.0638, $wR_2$ = 0.1638 |
| Largest diff. peak/hole / e Å$^{-3}$ | 0.20/-0.36 |

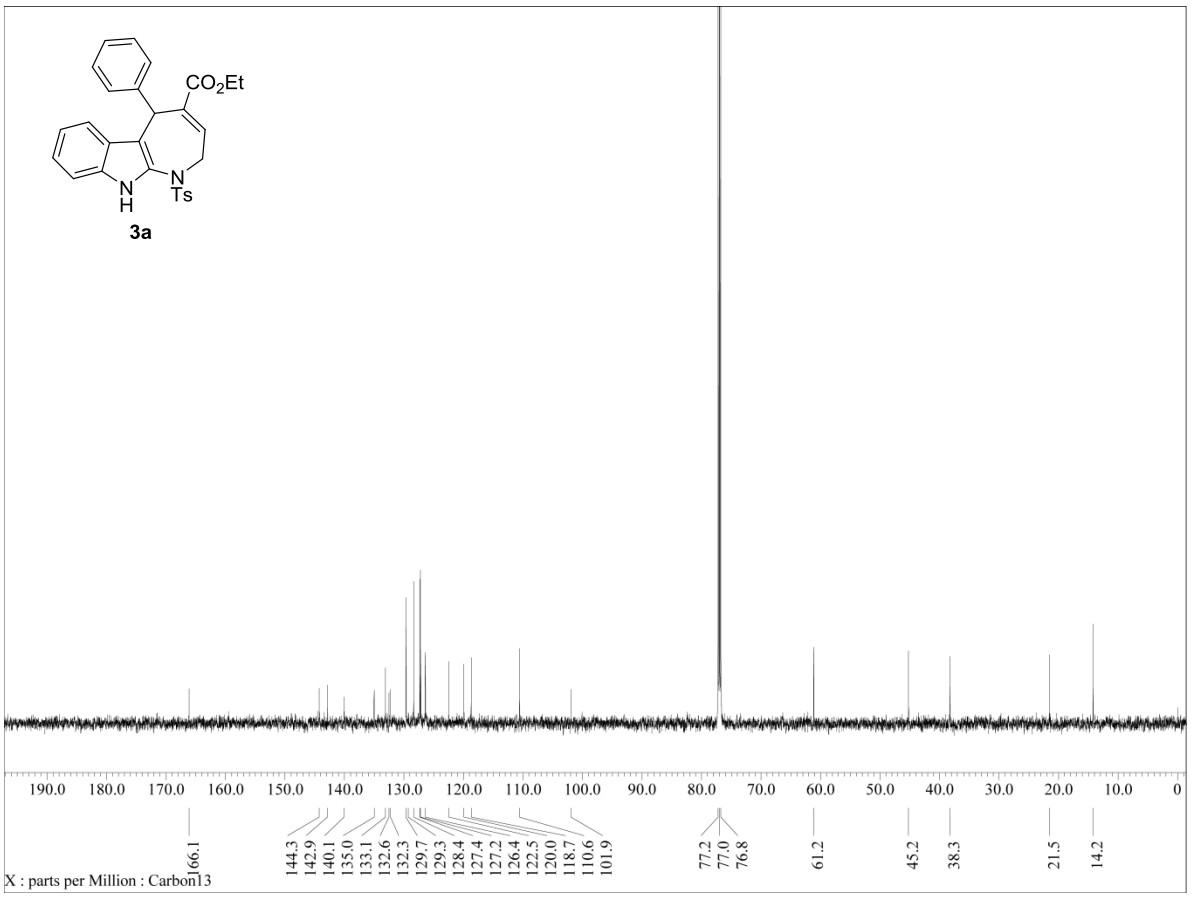
## 7. References and Notes

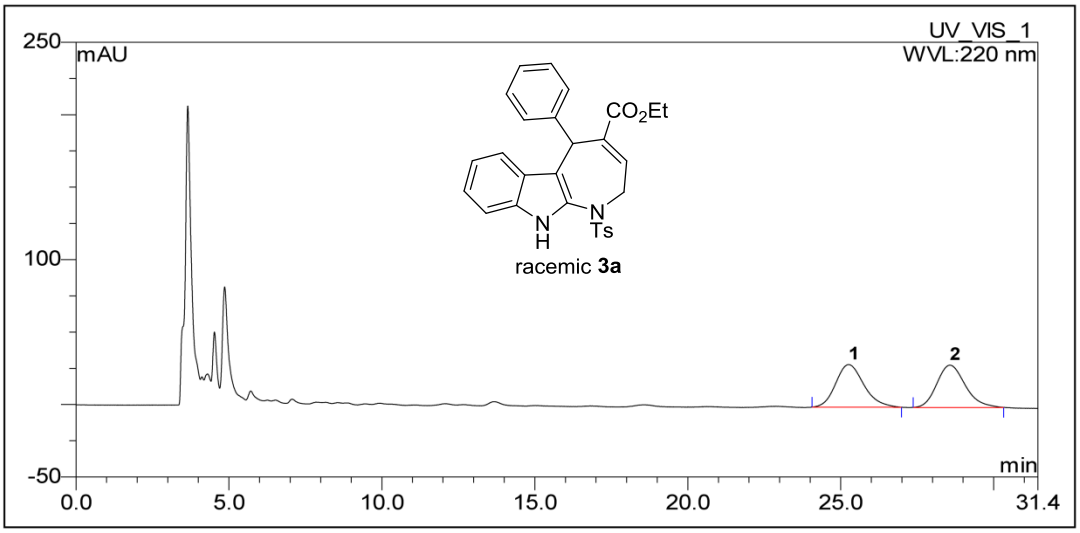
[1] (a) Krell, E. *Handbook of Laboratory Distillation*, Elseriver Publishing Company,Amsterdam-London-New York, **1963**. (b) Rosengart, M. *J. The Technique of Distillation and Rectification in the Laboratory*, VEB Verlag Technik, Berlin, 1954. (c) Stage, F. *Angew. Chem.* **1947**, *19*, 175–183.

[2] Moriyama, K.; Ishida, K.; Togo, H. *Chem. Commun*. **2015**, *51*, 2273–2276.

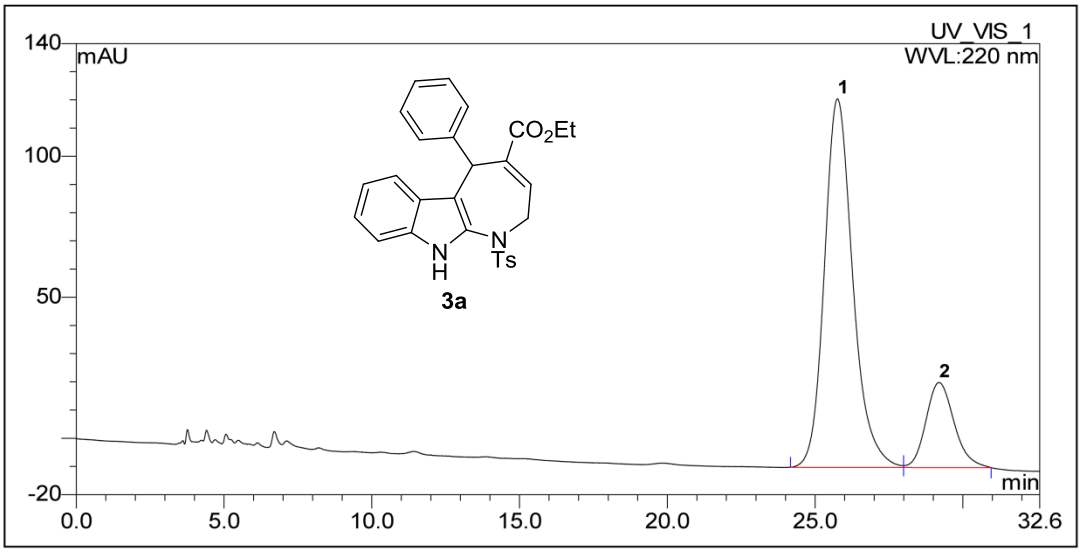
## 8. NMR and HPLC Spectra of the Products



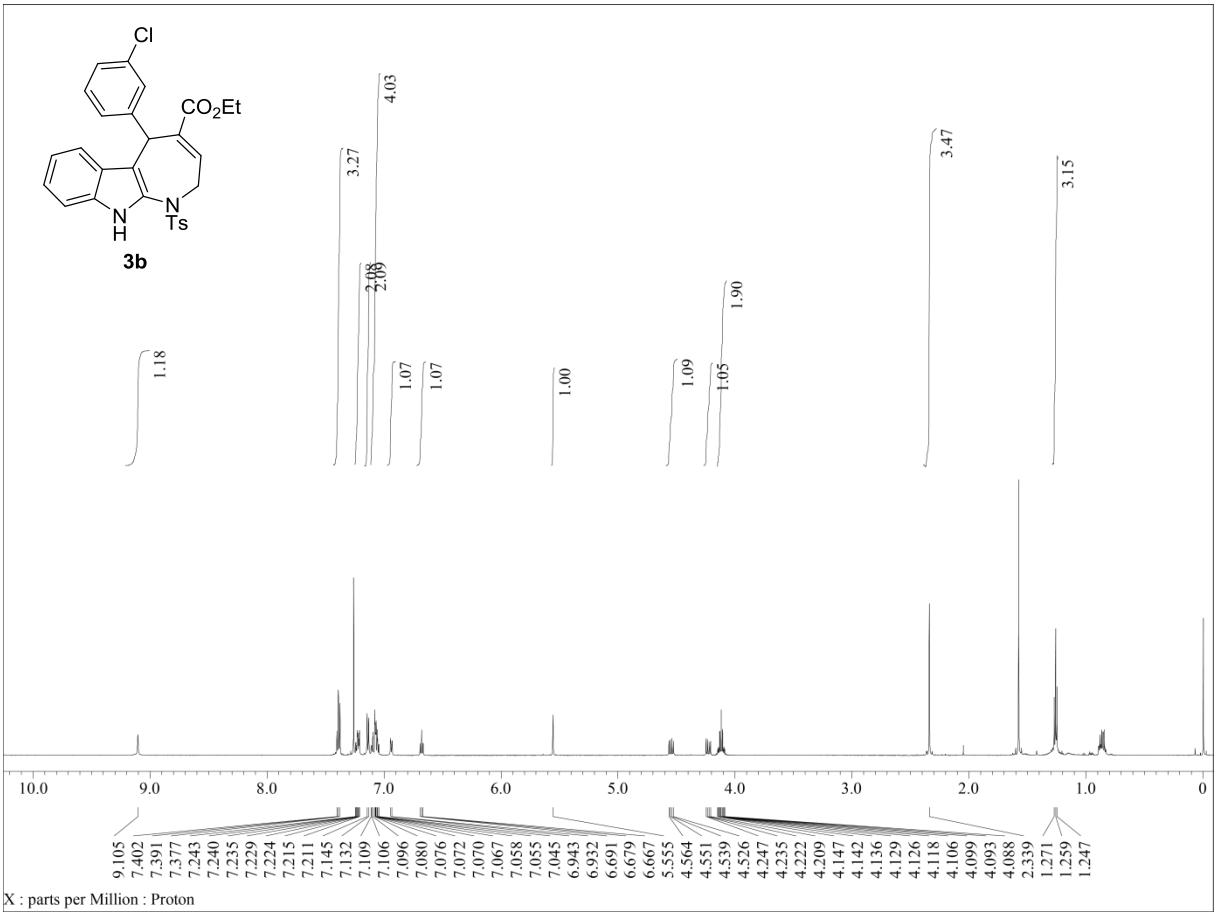



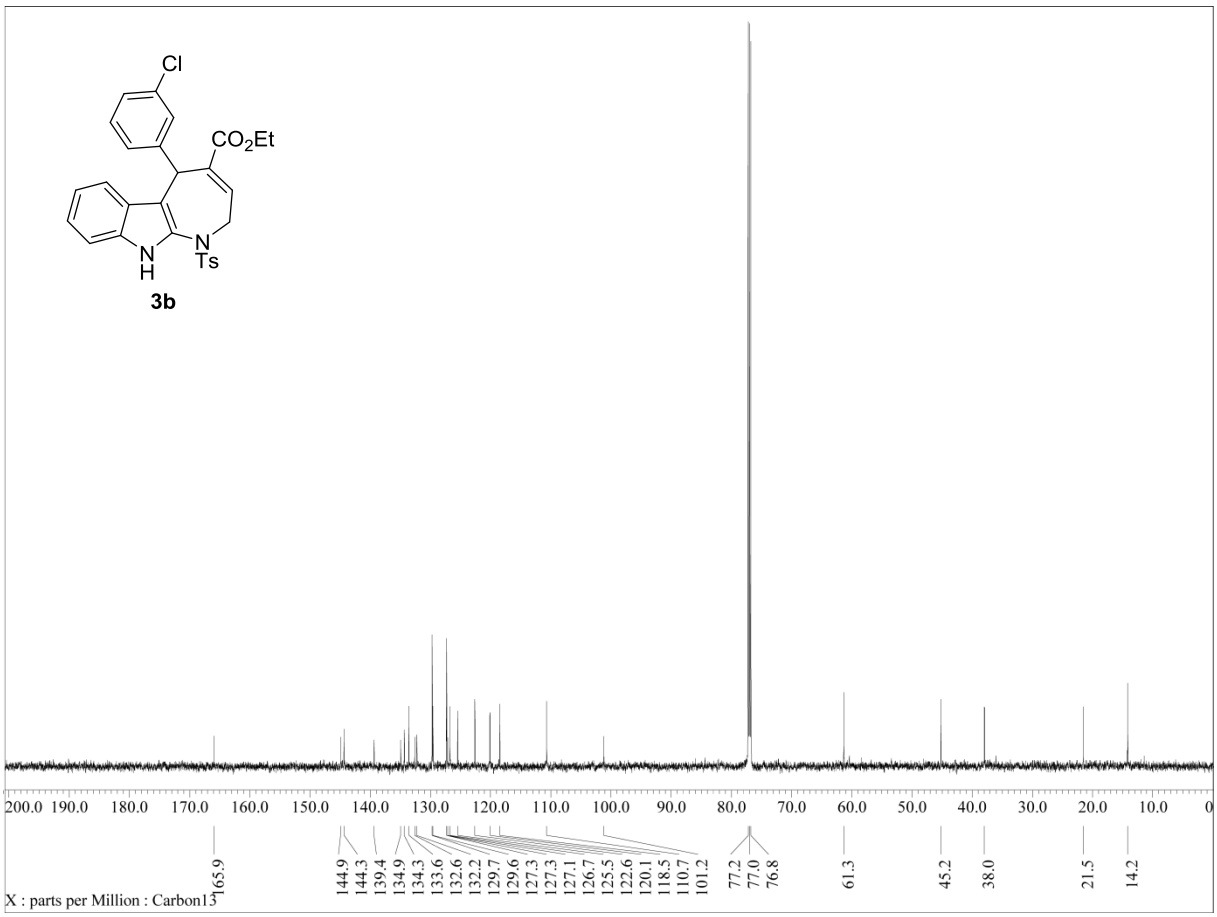


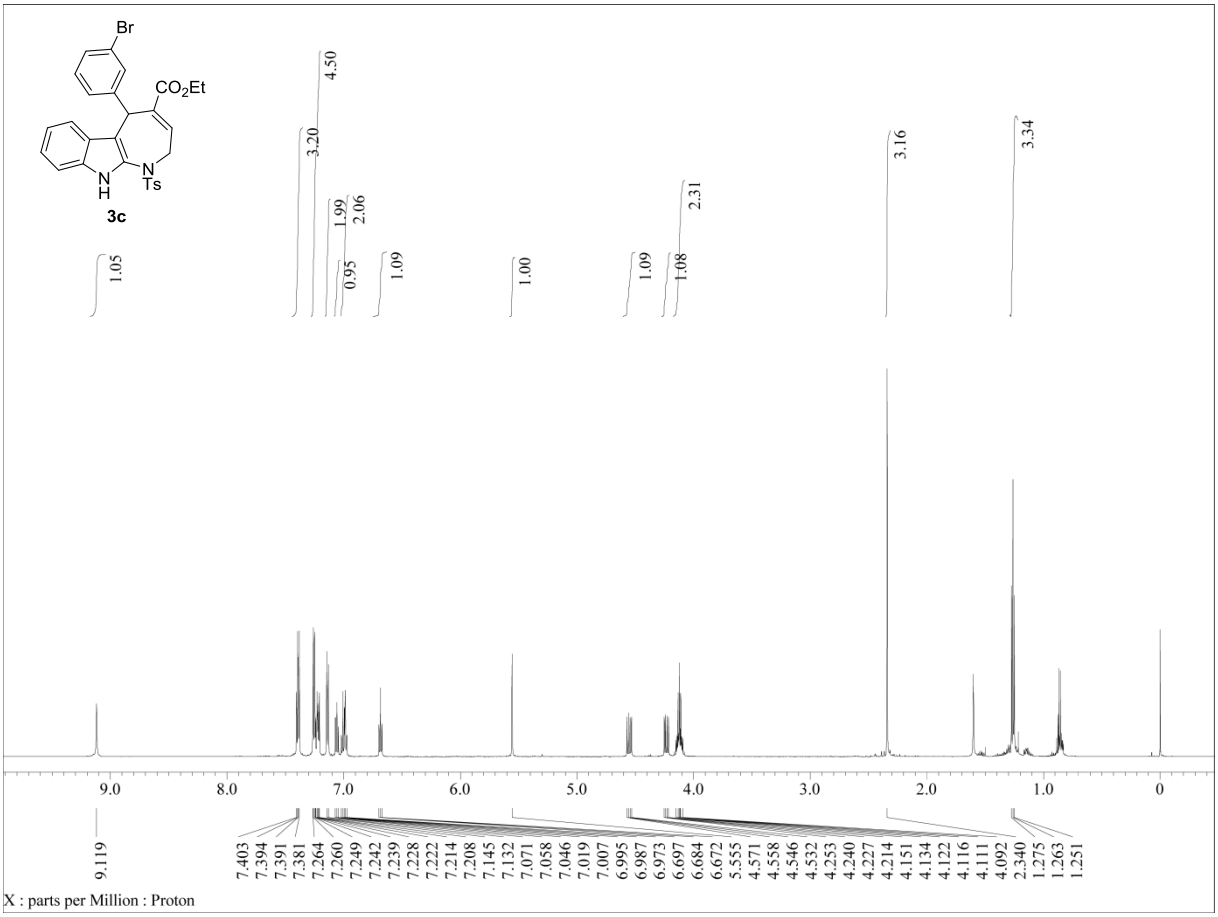

| No. | Ret.Time min | Height mAU | Area mAU*min | Rel.Area % |
|---|---|---|---|---|
| 1 | 25.25 | 29.409 | 31.514 | 50.04 |
| 2 | 28.56 | 29.196 | 31.464 | 49.96 |
| **Total:** | | 58.604 | 62.978 | 100.00 |

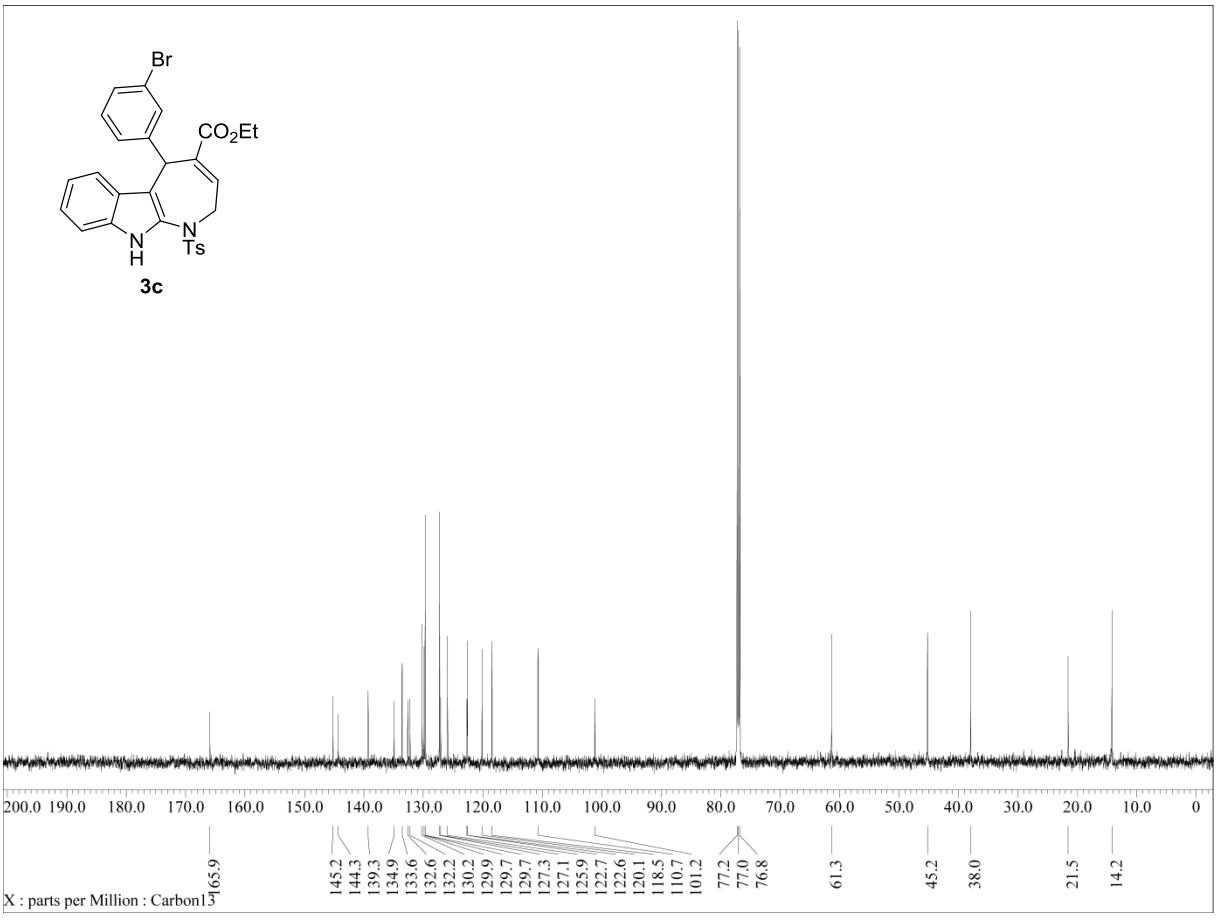


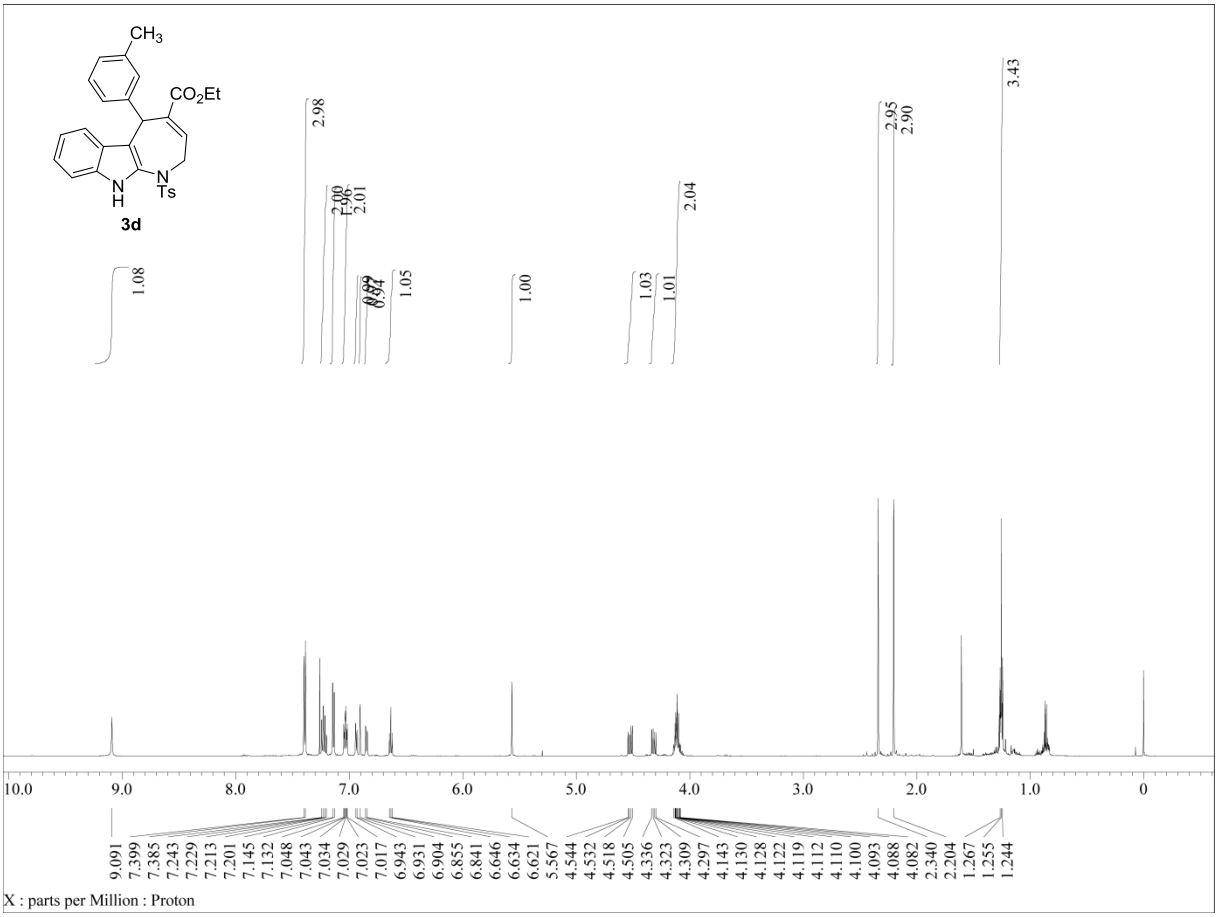

| No. | Ret.Time min | Height mAU | Area mAU*min | Rel.Area % |
|---|---|---|---|---|
| 1 | 25.76 | 130.765 | 145.805 | 82.34 |
| 2 | 29.19 | 30.200 | 33.444 | 17.66 |
| **Total:** | | 160.965 | 179.249 | 100.00 |

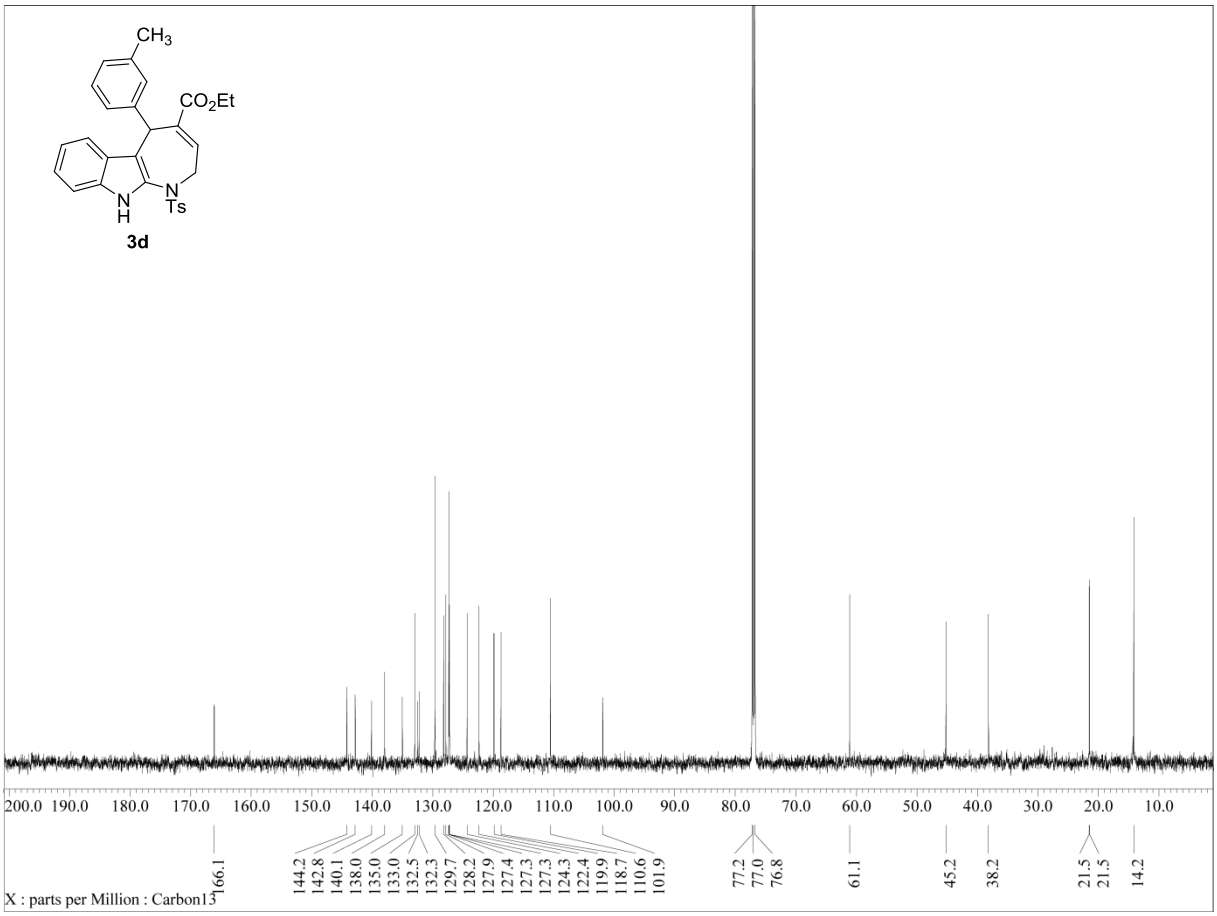

Cl
CO2Et
N
H
N
Ts
3b
1.18
3.27
4.03
2.08
2.05
1.07
1.07
1.00
1.09
1.05
1.90
3.47
3.15
10.0
9.0
8.0
7.0
6.0
5.0
4.0
3.0
2.0
1.0
0
9.105
7.402
7.391
7.377
7.243
7.240
7.235
7.229
7.224
7.215
7.211
7.145
7.132
7.109
7.106
7.096
7.080
7.076
7.072
7.070
7.067
7.058
7.055
7.045
6.943
6.932
6.691
6.679
6.667
5.555
4.564
4.551
4.539
4.526
4.247
4.235
4.222
4.209
4.147
4.142
4.136
4.129
4.126
4.118
4.106
4.099
4.093
4.088
2.339
1.271
1.259
1.247
X : parts per Million : Proton

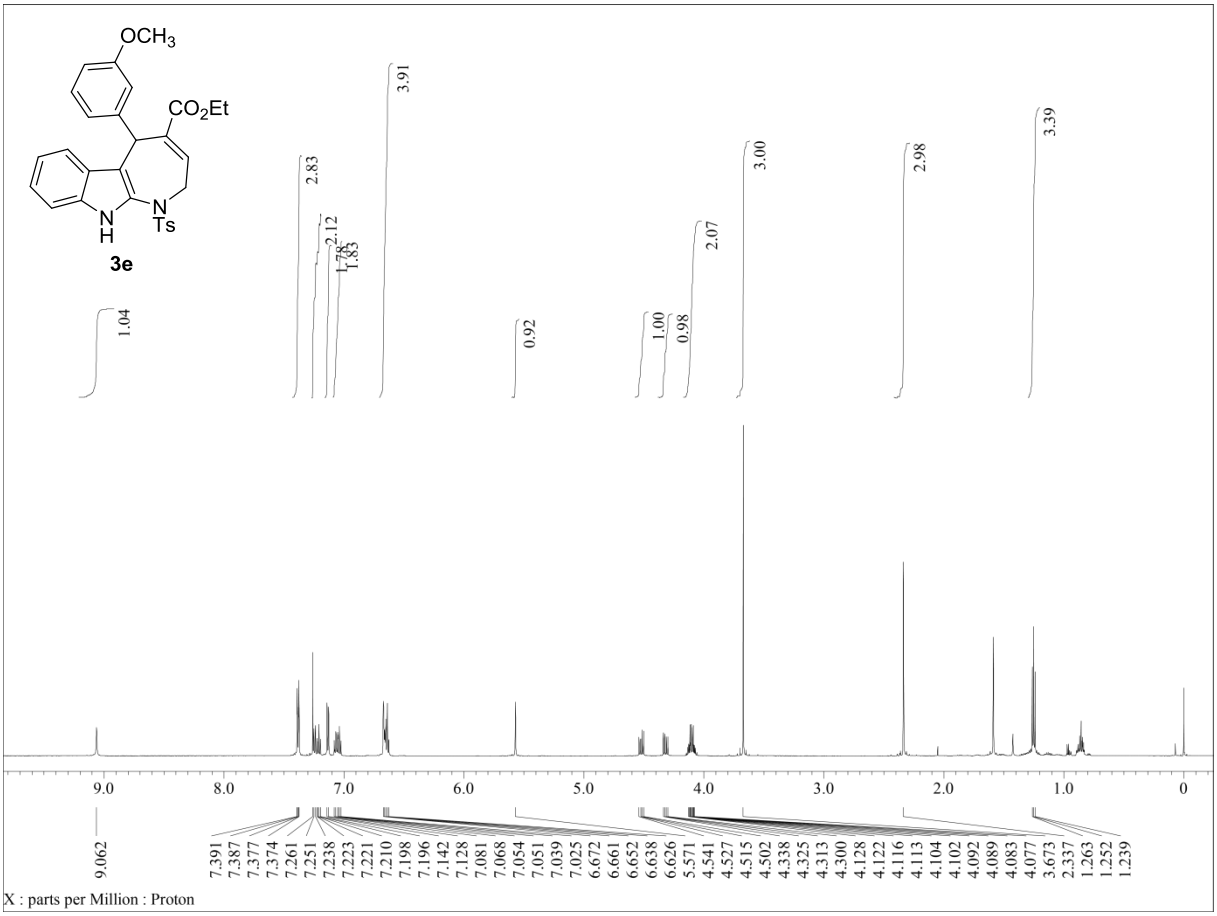

Cl
CO2Et
N
H
N
Ts
3b
200.0
190.0
180.0
170.0
160.0
150.0
140.0
130.0
120.0
110.0
100.0
90.0
80.0
70.0
60.0
50.0
40.0
30.0
20.0
10.0
0
165.9
144.9
144.3
139.4
134.9
134.3
133.6
132.6
132.2
129.7
129.6
127.3
127.3
127.1
126.7
125.5
122.6
120.1
118.5
110.7
101.2
77.2
77.0
76.8
61.3
45.2
38.0
21.5
14.2
X : parts per Million : Carbon13

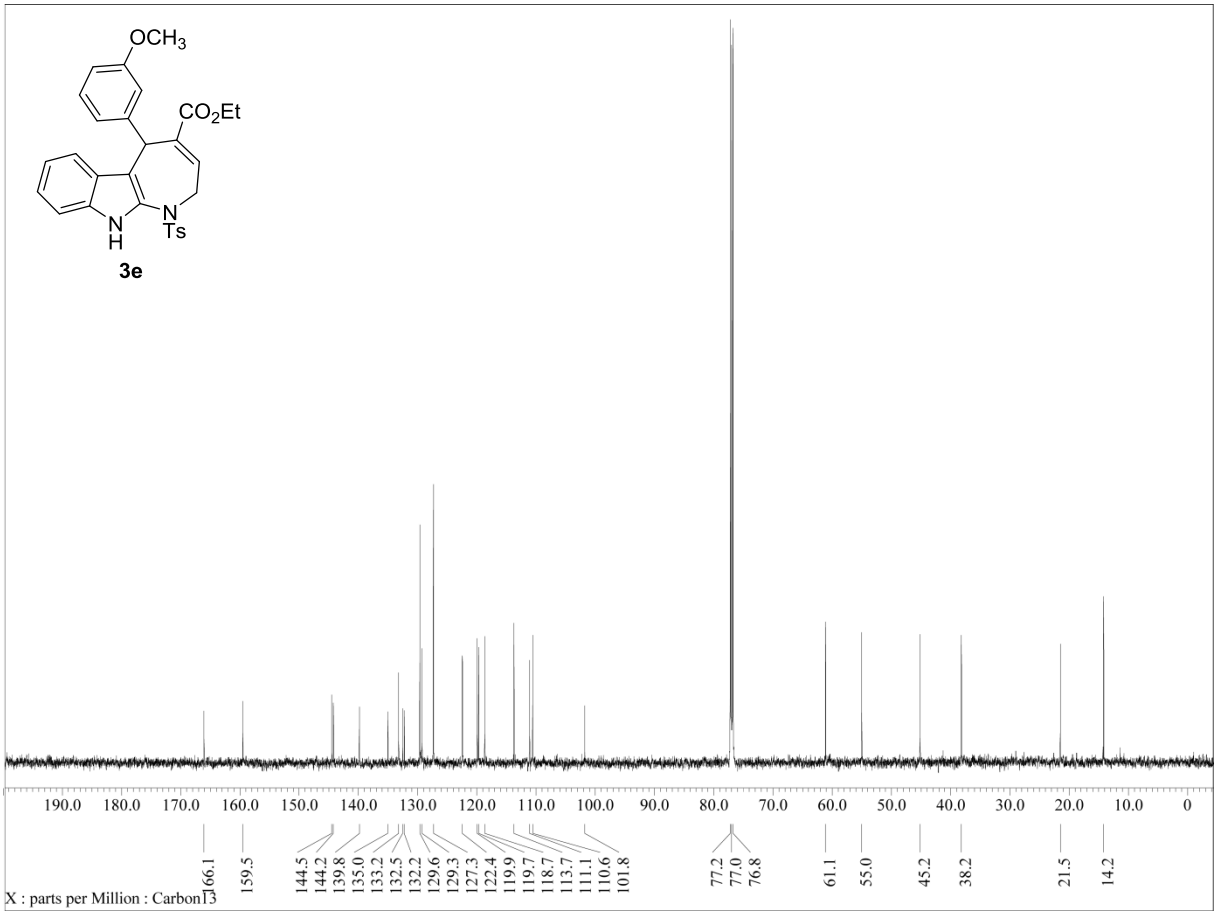

Br
CO2Et
N
H
N
Ts
3c
4.50
3.20
1.99
2.06
0.95
1.09
1.05
1.00
1.09
1.08
2.31
3.16
3.34
9.0
8.0
7.0
6.0
5.0
4.0
3.0
2.0
1.0
0
9.119
7.403
7.394
7.391
7.381
7.264
7.260
7.249
7.242
7.239
7.228
7.222
7.214
7.208
7.145
7.132
7.071
7.058
7.046
7.019
7.007
6.995
6.987
6.973
6.697
6.684
6.672
5.555
4.571
4.558
4.546
4.532
4.253
4.240
4.227
4.214
4.151
4.134
4.122
4.116
4.111
4.092
2.340
1.275
1.263
1.251
X : parts per Million : Proton

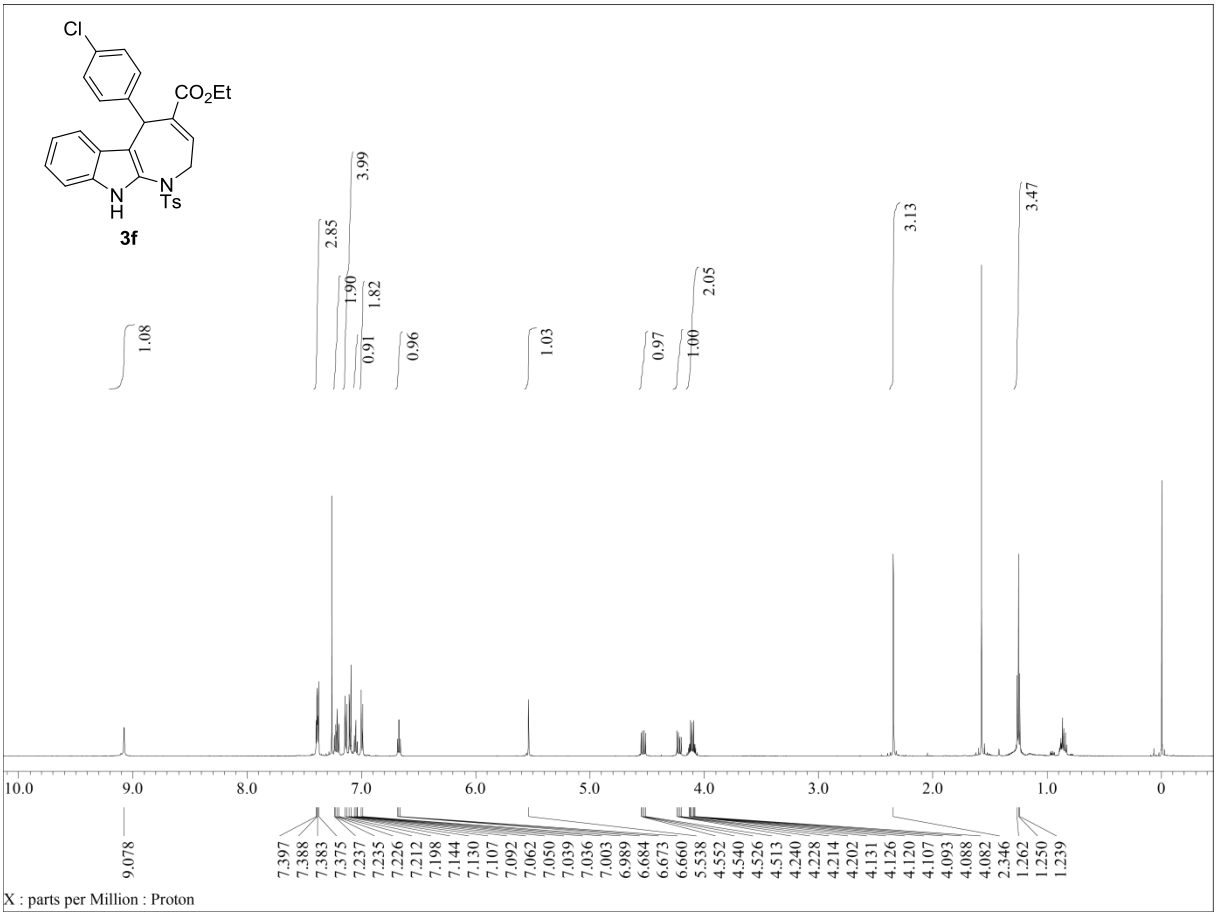

Br
CO2Et
N
H
N
Ts
3c
200.0
190.0
180.0
170.0
160.0
150.0
140.0
130.0
120.0
110.0
100.0
90.0
80.0
70.0
60.0
50.0
40.0
30.0
20.0
10.0
0
165.9
145.2
144.3
139.3
134.9
133.6
132.6
132.2
130.2
129.9
129.7
129.7
127.3
127.1
125.9
122.7
122.6
120.1
118.5
110.7
101.2
77.2
77.0
76.8
61.3
45.2
38.0
21.5
14.2
X : parts per Million : Carbon13

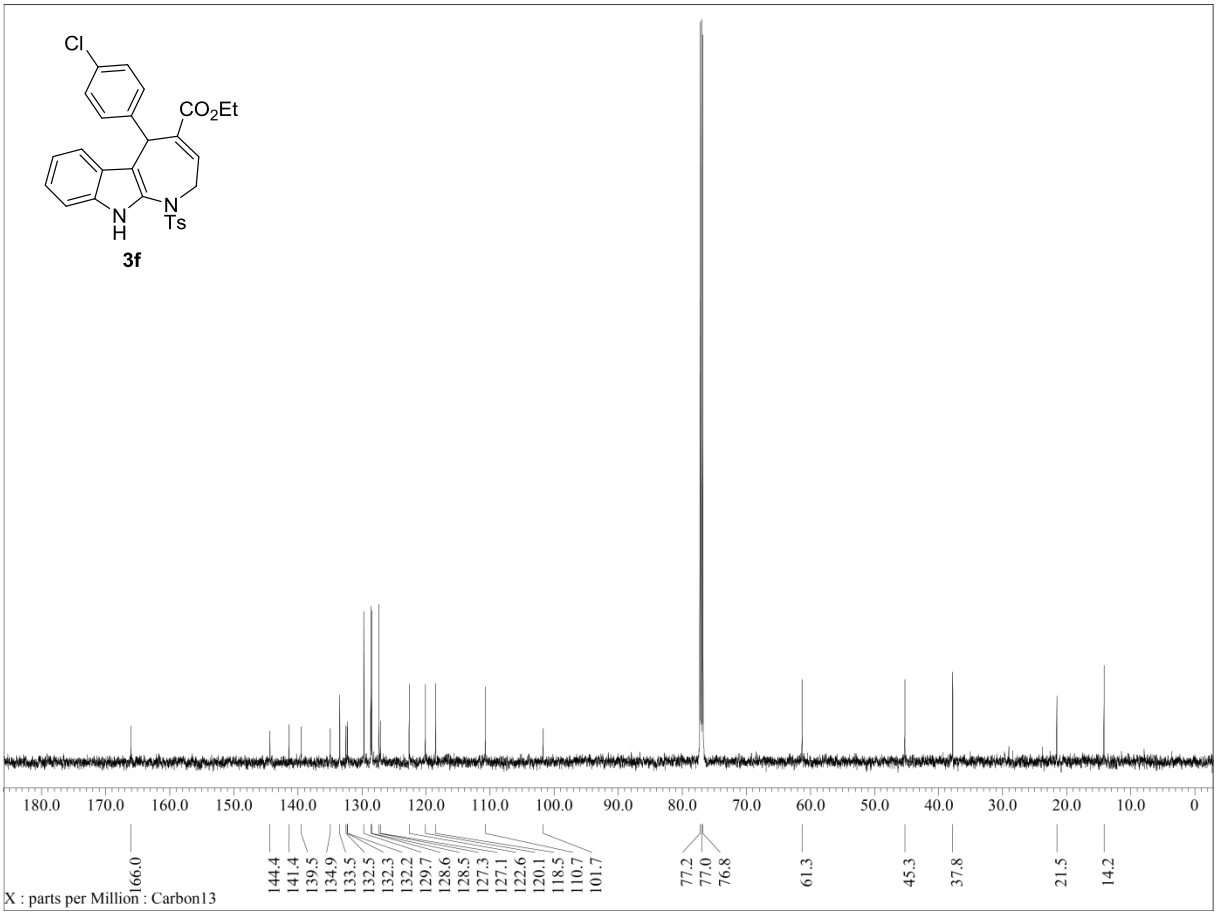

CH3
CO2Et
N
H
N
Ts
3d
2.98
2.00
2.06
2.01
1.08
1.05
1.00
1.03
1.01
2.04
2.95
2.90
3.43
10.0
9.0
8.0
7.0
6.0
5.0
4.0
3.0
2.0
1.0
0
9.091
7.399
7.385
7.243
7.229
7.213
7.201
7.145
7.132
7.048
7.043
7.034
7.029
7.023
7.017
6.943
6.931
6.904
6.855
6.841
6.646
6.634
6.621
5.567
4.544
4.532
4.518
4.505
4.336
4.323
4.309
4.297
4.143
4.130
4.128
4.122
4.119
4.112
4.110
4.100
4.093
4.088
4.082
2.340
2.204
1.267
1.255
1.244
X : parts per Million : Proton

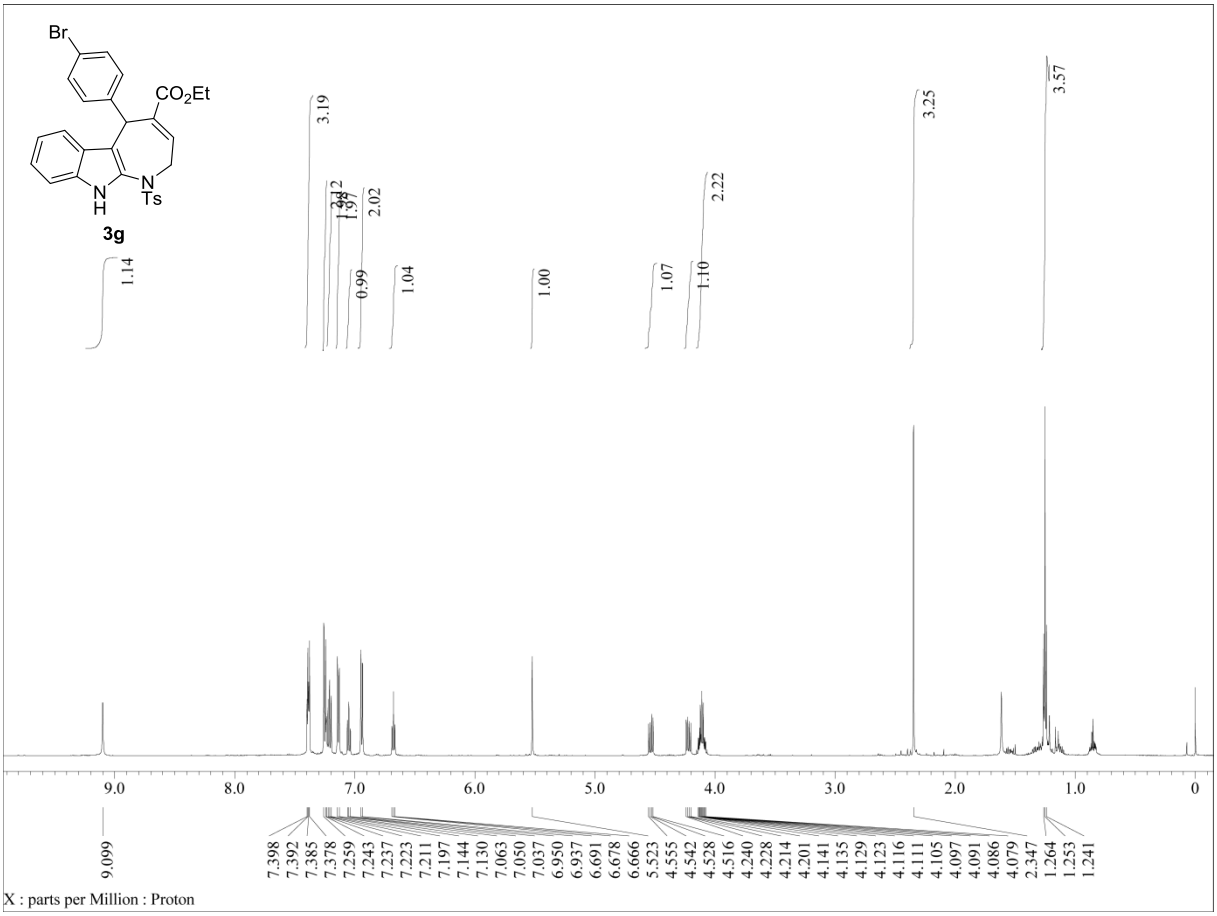

CH3
CO2Et
N
H
N
Ts
3d
200.0
190.0
180.0
170.0
160.0
150.0
140.0
130.0
120.0
110.0
100.0
90.0
80.0
70.0
60.0
50.0
40.0
30.0
20.0
10.0
166.1
144.2
142.8
140.1
138.0
135.0
133.0
132.5
132.3
129.7
128.2
127.9
127.4
127.3
127.3
124.3
122.4
119.9
118.7
110.6
101.9
77.2
77.0
76.8
61.1
45.2
38.2
21.5
21.5
14.2
X : parts per Million : Carbon13

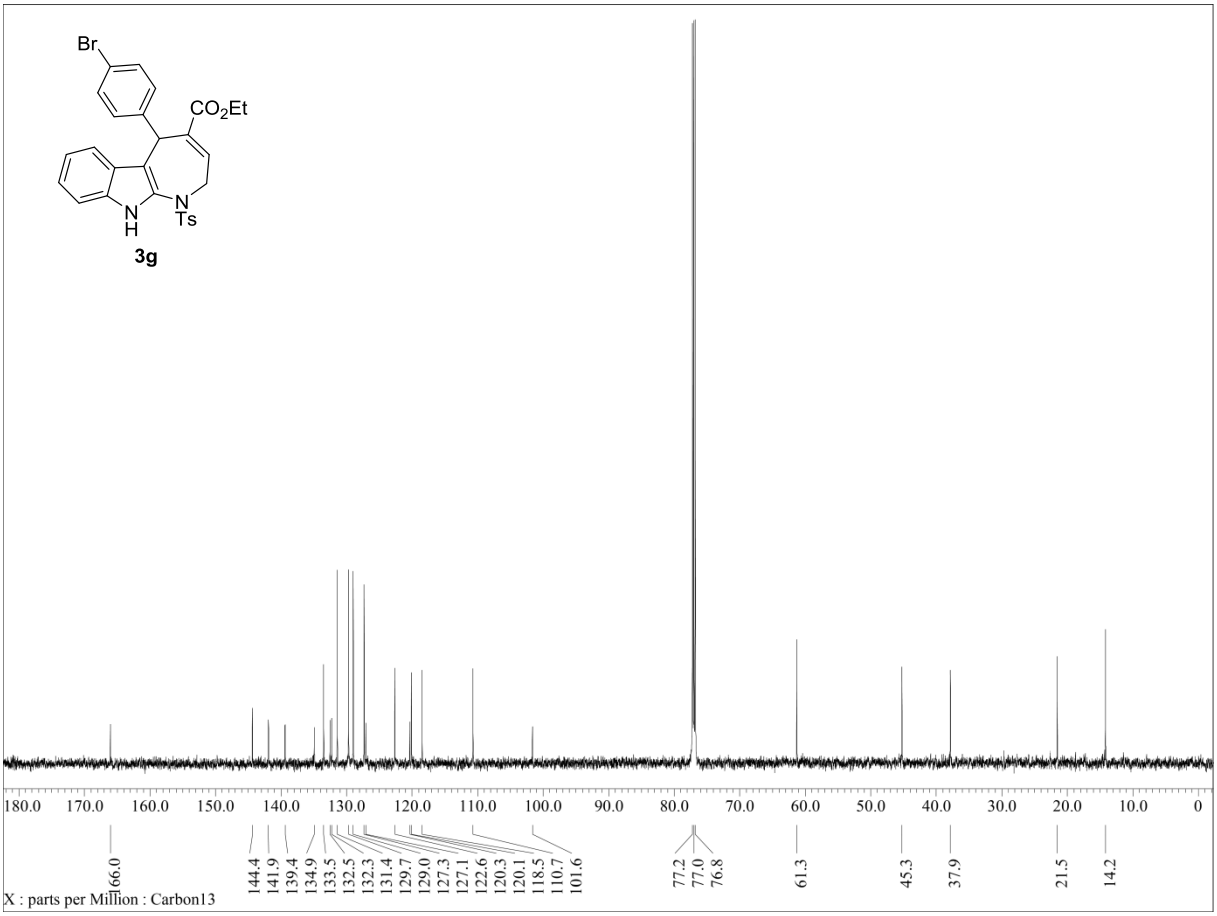

OCH3
CO2Et
N
H
N
Ts
3e
1.04
2.83
2.12
1.78
1.83
3.91
0.92
1.00
0.98
2.07
3.00
2.98
3.39
9.062
7.391
7.387
7.377
7.374
7.261
7.251
7.238
7.223
7.221
7.210
7.198
7.196
7.142
7.128
7.081
7.068
7.054
7.051
7.039
7.025
6.672
6.661
6.652
6.638
6.626
5.571
4.541
4.527
4.515
4.502
4.338
4.325
4.313
4.300
4.128
4.122
4.116
4.113
4.104
4.102
4.092
4.089
4.083
4.077
3.673
2.337
1.263
1.252
1.239
X : parts per Million : Proton

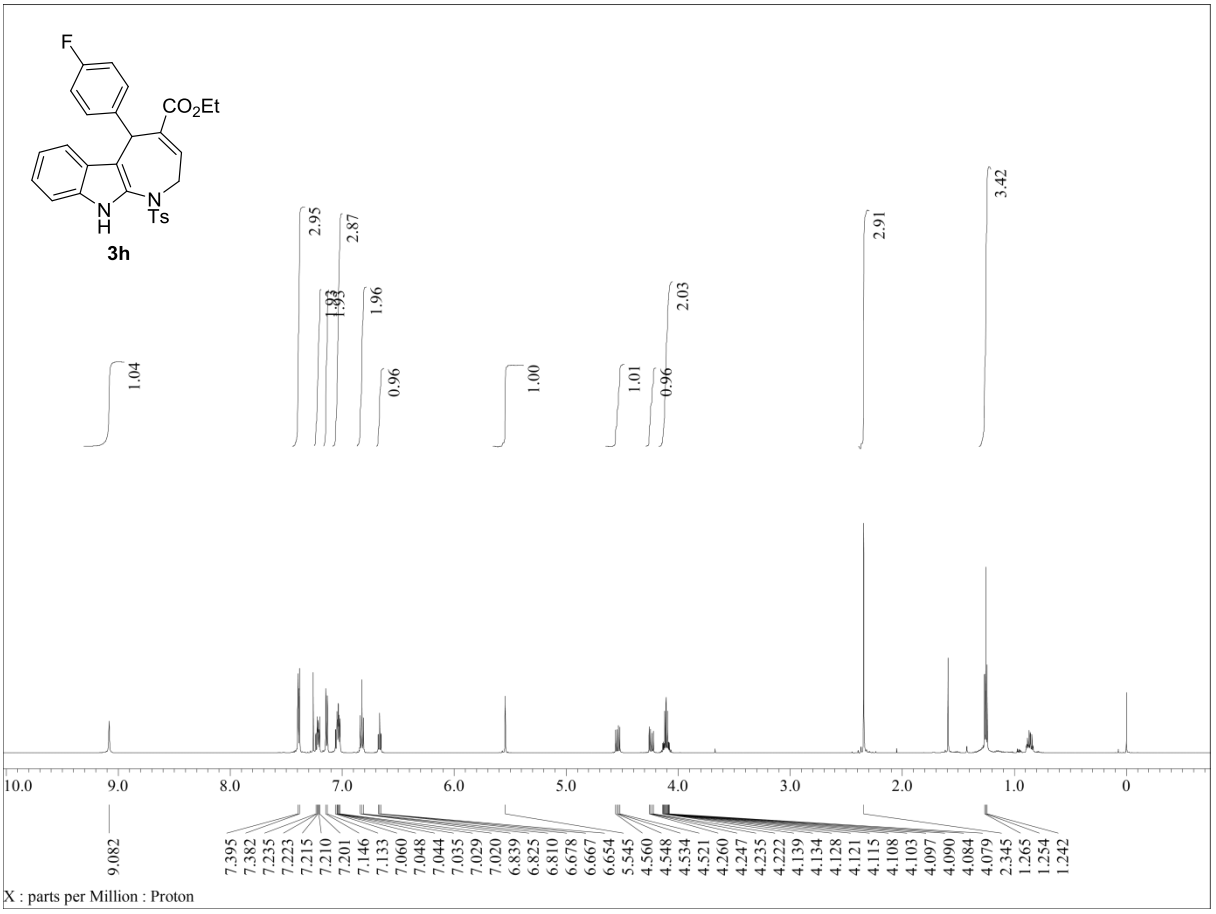

OCH3
CO2Et
N
H
N
Ts
3e
166.1
159.5
144.5
144.2
139.8
135.0
133.2
132.5
132.2
129.6
129.3
127.3
122.4
119.9
119.7
118.7
113.7
111.1
110.6
101.8
77.2
77.0
76.8
61.1
55.0
45.2
38.2
21.5
14.2
X : parts per Million : Carbon13

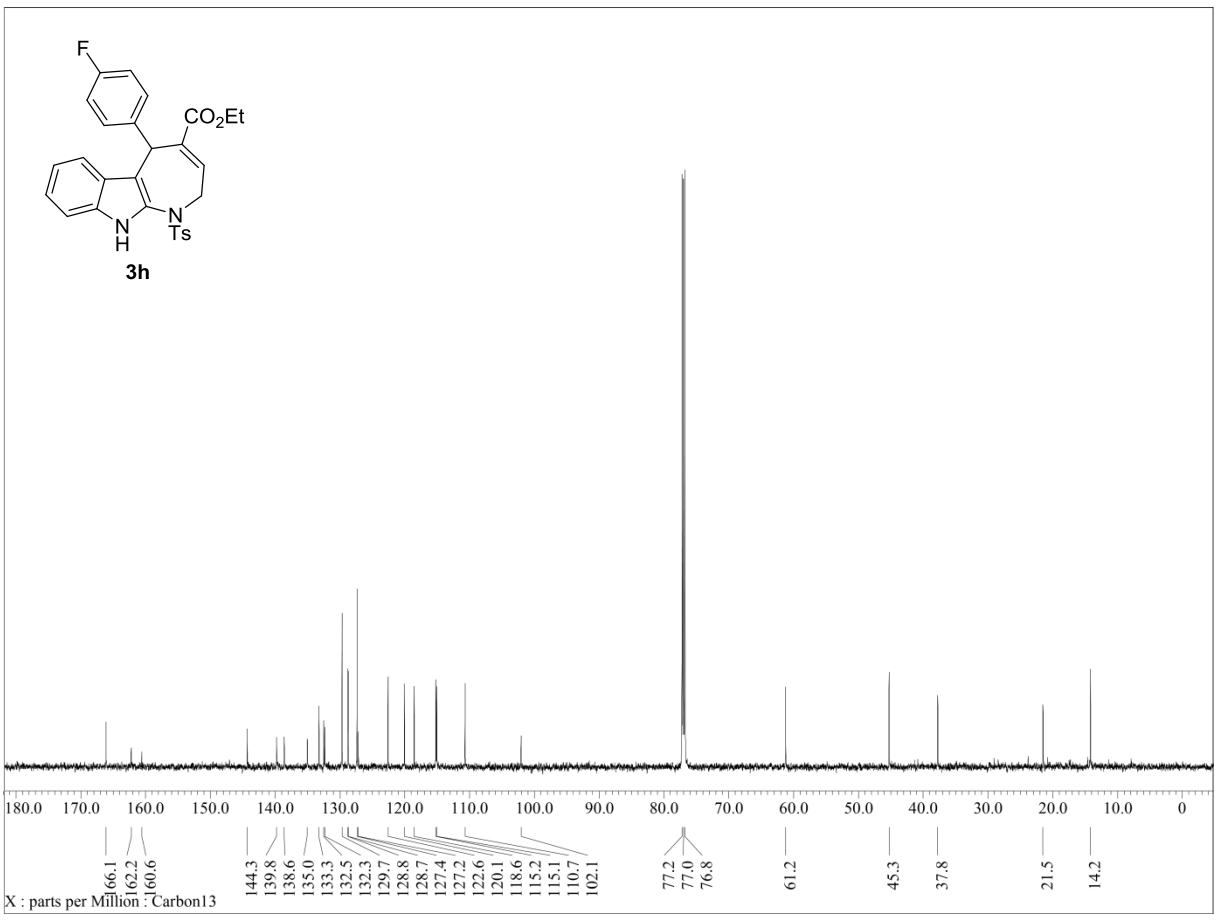

Cl
CO2Et
N
Ts
H
3f
1.08
2.85
3.99
1.90
1.82
0.91
0.96
1.03
0.97
1.00
2.05
3.13
3.47
10.0
9.0
8.0
7.0
6.0
5.0
4.0
3.0
2.0
1.0
0
9.078
7.397
7.388
7.383
7.375
7.237
7.235
7.226
7.212
7.198
7.144
7.130
7.107
7.092
7.062
7.050
7.039
7.036
7.003
6.989
6.684
6.673
6.660
5.538
4.552
4.540
4.526
4.513
4.240
4.228
4.214
4.202
4.131
4.126
4.120
4.107
4.093
4.088
4.082
2.346
1.262
1.250
1.239
X : parts per Million : Proton

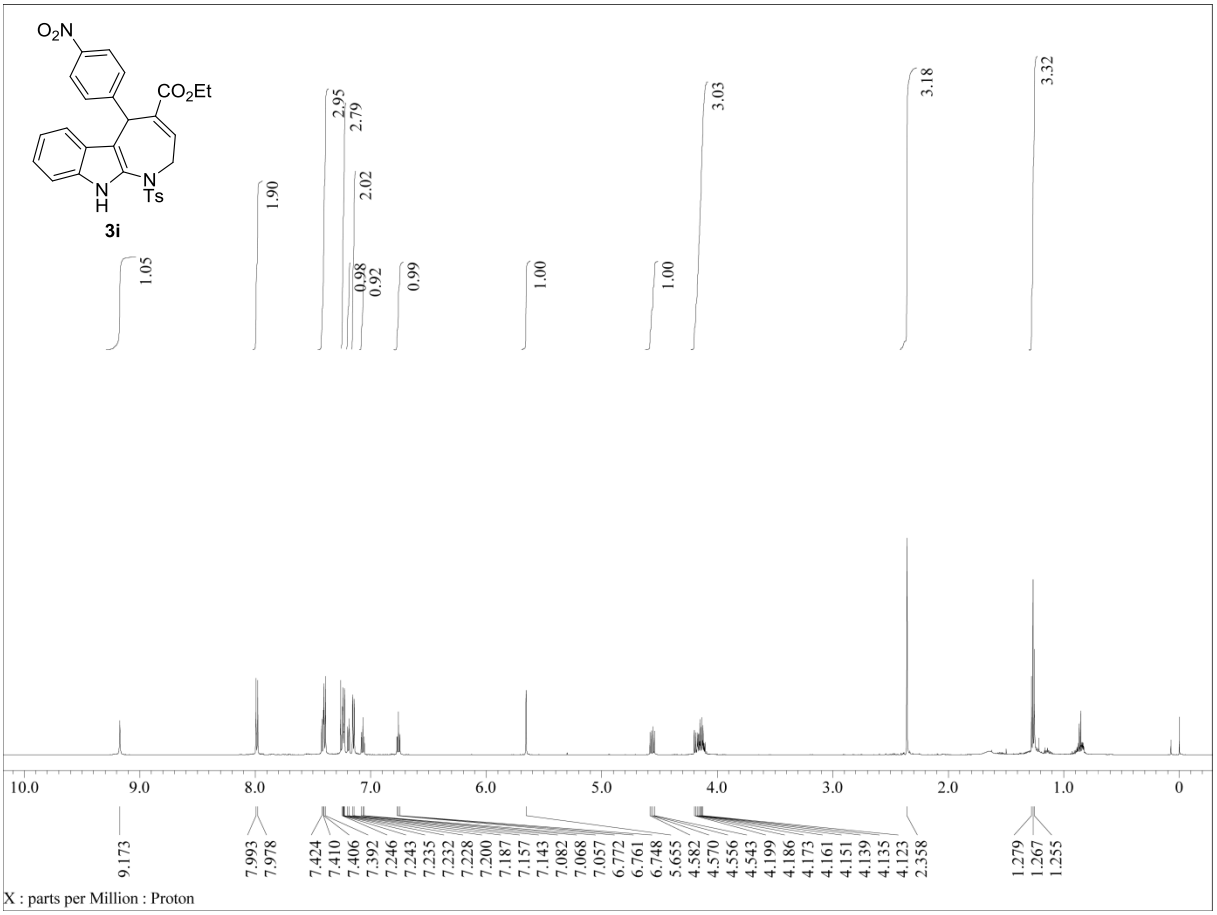

Cl
CO2Et
N
Ts
H
3f
180.0
170.0
160.0
150.0
140.0
130.0
120.0
110.0
100.0
90.0
80.0
70.0
60.0
50.0
40.0
30.0
20.0
10.0
0
166.0
144.4
141.4
139.5
134.9
133.5
132.5
132.3
132.2
129.7
128.6
128.5
127.3
127.1
122.6
120.1
118.5
110.7
101.7
77.2
77.0
76.8
61.3
45.3
37.8
21.5
14.2
X : parts per Million : Carbon13

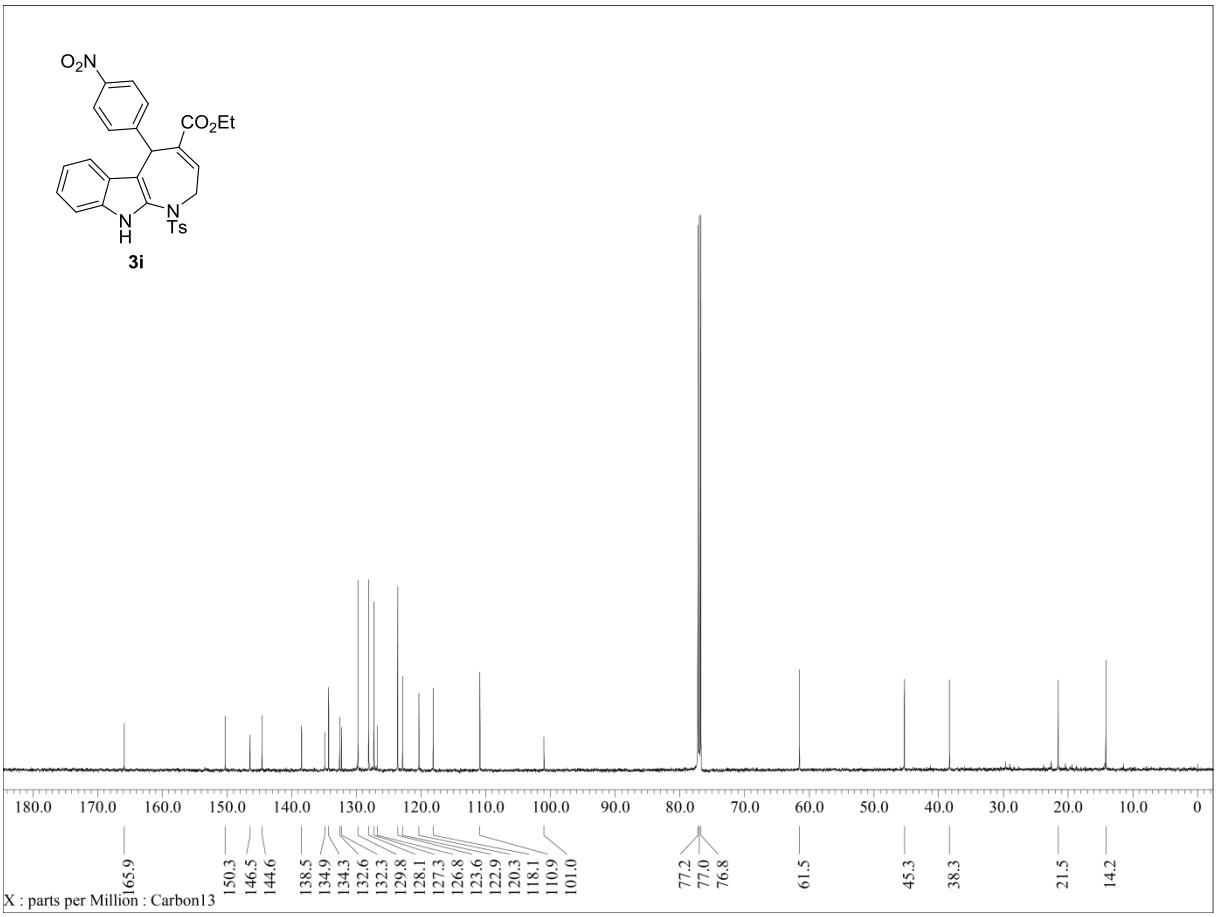

Br
CO2Et
N
H
N
Ts
3g
3.19
2.02
2.22
3.25
3.57
1.14
0.99
1.04
1.00
1.07
1.10
9.099
7.398
7.392
7.385
7.378
7.259
7.243
7.237
7.223
7.211
7.197
7.144
7.130
7.063
7.050
7.037
6.950
6.937
6.691
6.678
6.666
5.523
4.555
4.542
4.528
4.516
4.240
4.228
4.214
4.201
4.141
4.135
4.129
4.123
4.116
4.111
4.105
4.097
4.091
4.086
4.079
2.347
1.264
1.253
1.241
X : parts per Million : Proton

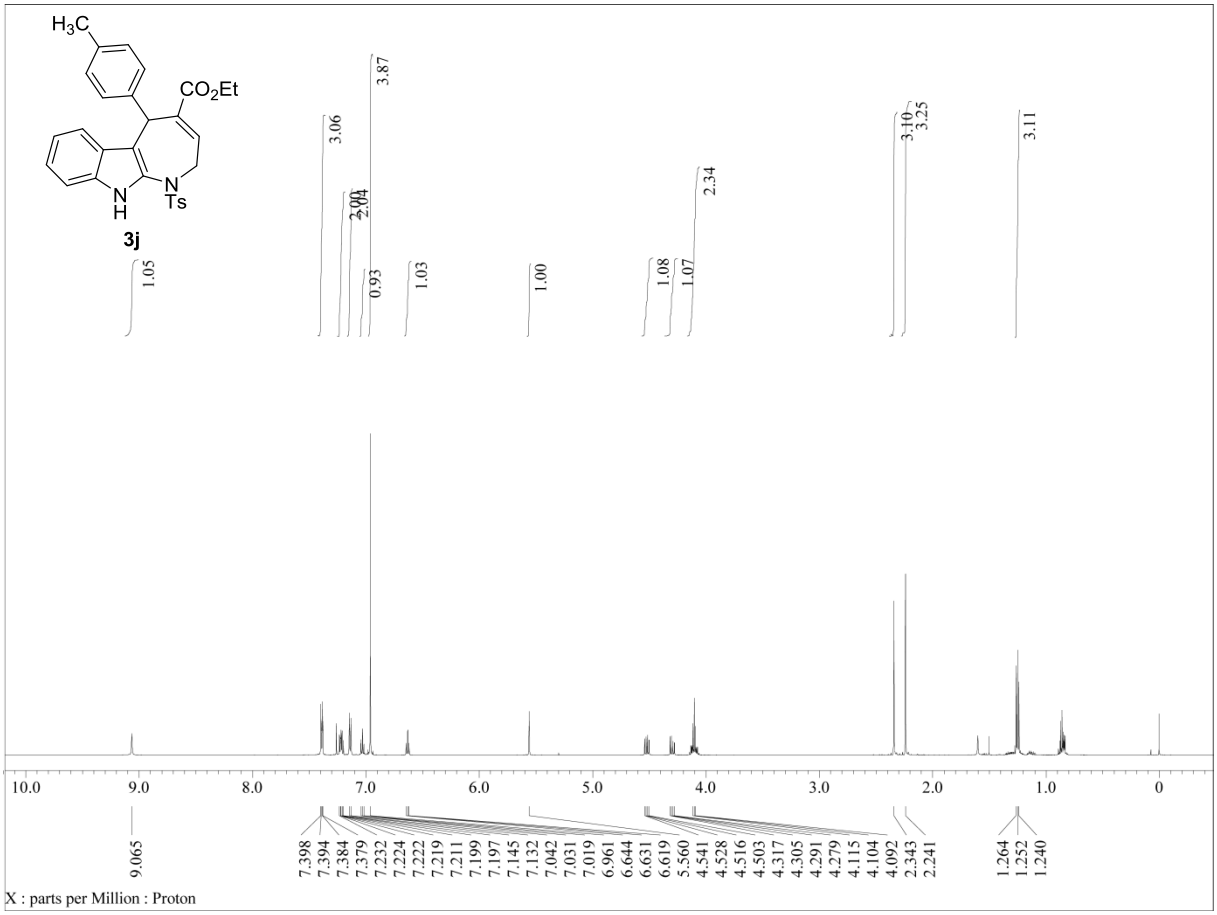

Br
CO2Et
N
H
N
Ts
3g
166.0
144.4
141.9
139.4
134.9
133.5
132.5
132.3
131.4
129.7
129.0
127.3
127.1
122.6
120.3
120.1
118.5
110.7
101.6
77.2
77.0
76.8
61.3
45.3
37.9
21.5
14.2
X : parts per Million : Carbon13

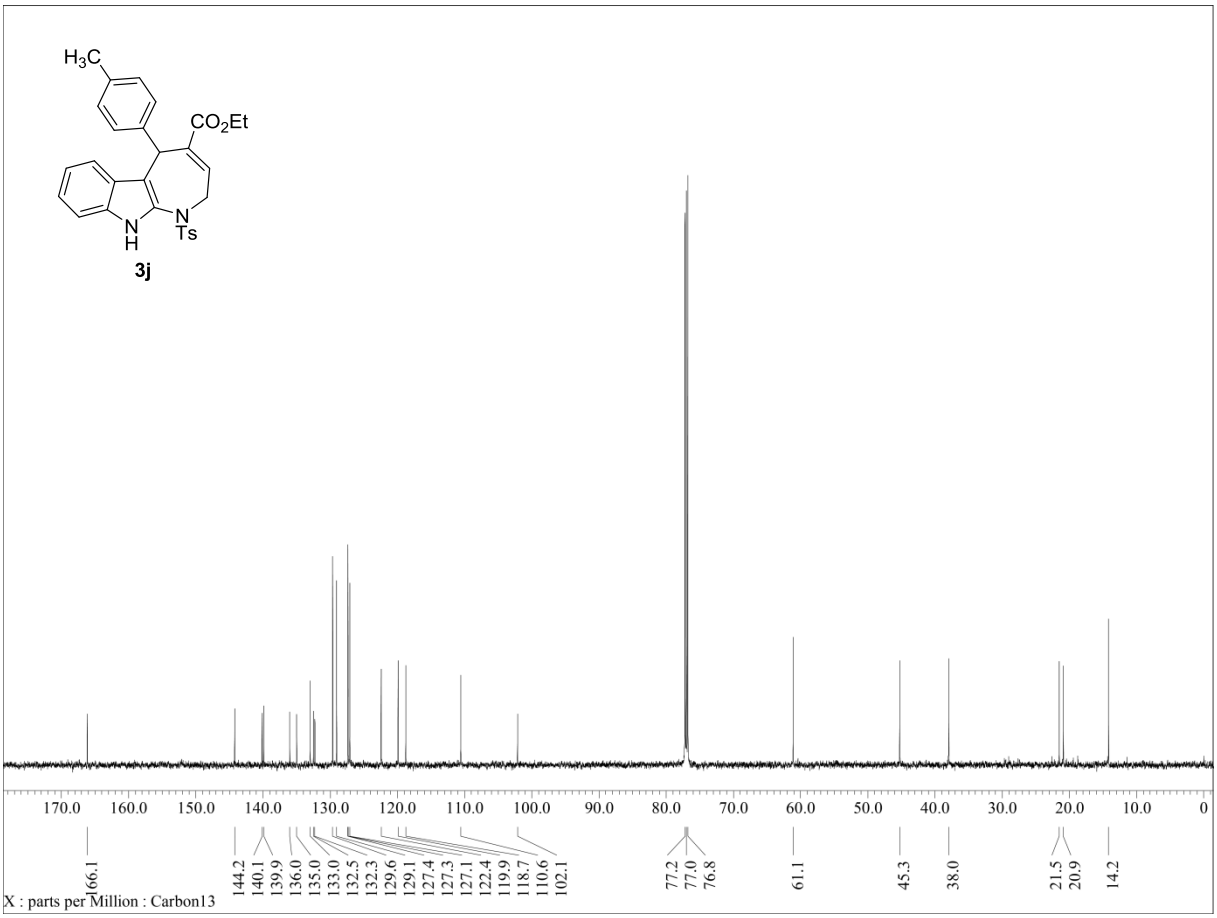

F
CO2Et
N
H
N
Ts
3h
2.95
2.87
1.93
1.93
1.96
0.96
1.04
1.00
1.01
0.96
2.03
2.91
3.42
10.0
9.0
8.0
7.0
6.0
5.0
4.0
3.0
2.0
1.0
0
9.082
7.395
7.382
7.235
7.223
7.215
7.210
7.201
7.146
7.133
7.060
7.048
7.044
7.035
7.029
7.020
6.839
6.825
6.810
6.678
6.667
6.654
5.545
4.560
4.548
4.534
4.521
4.260
4.247
4.235
4.222
4.139
4.134
4.128
4.121
4.115
4.108
4.103
4.097
4.090
4.084
4.079
2.345
1.265
1.254
1.242
X : parts per Million : Proton

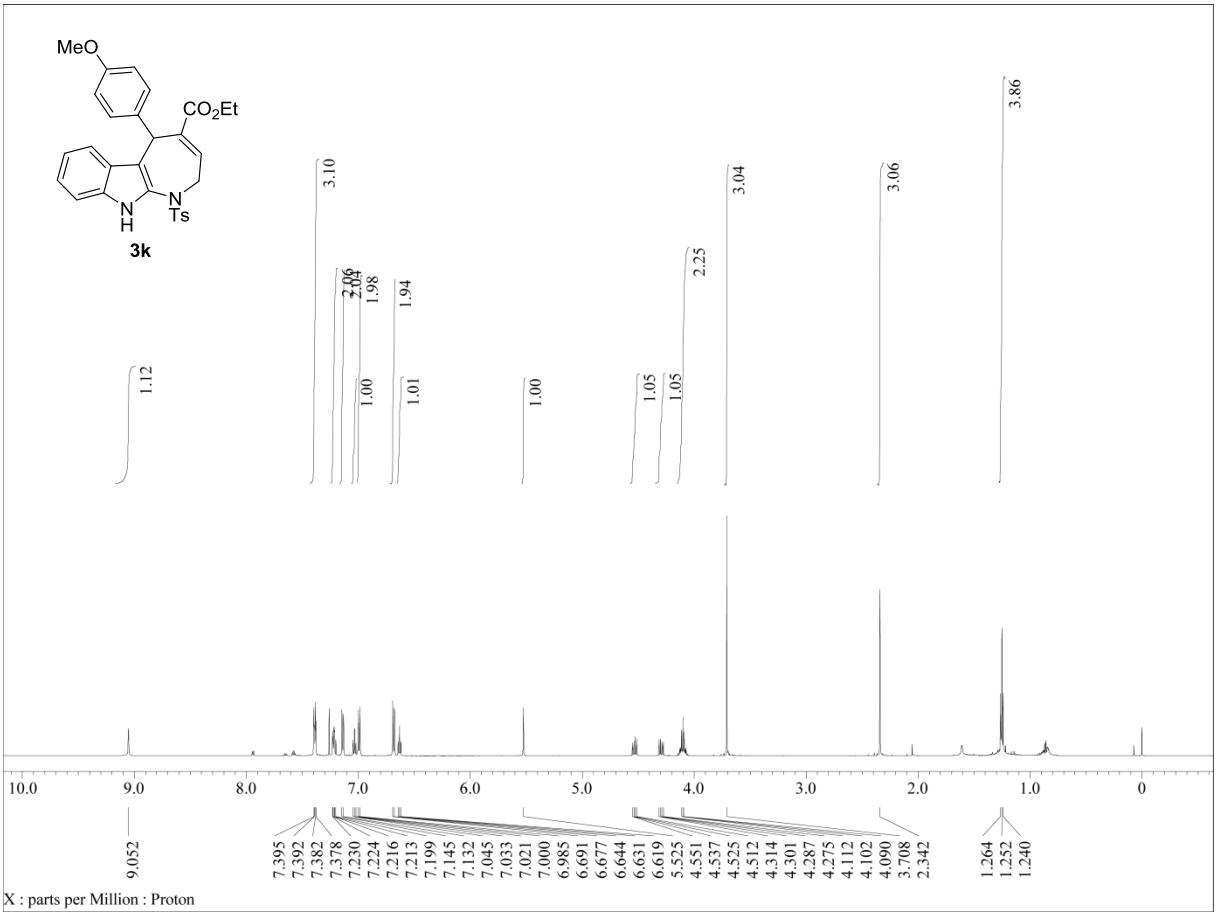

F
CO2Et
N
H
N
Ts
3h
180.0
170.0
160.0
150.0
140.0
130.0
120.0
110.0
100.0
90.0
80.0
70.0
60.0
50.0
40.0
30.0
20.0
10.0
0
166.1
162.2
160.6
144.3
139.8
138.6
135.0
133.3
132.5
132.3
129.7
128.8
128.7
127.4
127.2
122.6
120.1
118.6
115.2
115.1
110.7
102.1
77.2
77.0
76.8
61.2
45.3
37.8
21.5
14.2
X : parts per Million : Carbon13

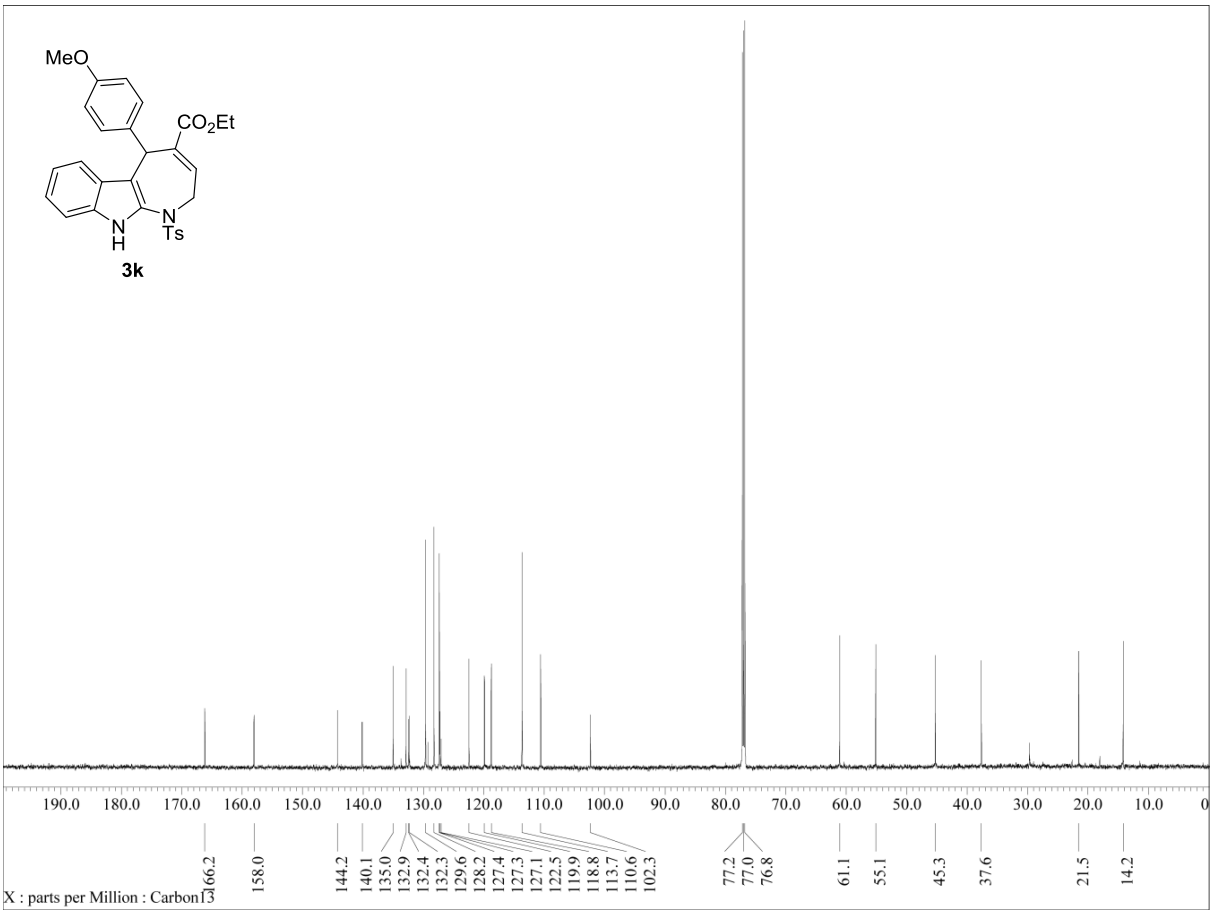

O2N
CO2Et
N
H
N
Ts
3i
1.05
1.90
2.95
2.79
2.02
0.98
0.92
0.99
1.00
1.00
3.03
3.18
3.32
10.0
9.0
8.0
7.0
6.0
5.0
4.0
3.0
2.0
1.0
0
9.173
7.993
7.978
7.424
7.410
7.406
7.392
7.246
7.243
7.235
7.232
7.228
7.200
7.187
7.157
7.143
7.082
7.068
7.057
6.772
6.761
6.748
5.655
4.582
4.570
4.556
4.543
4.199
4.186
4.173
4.161
4.151
4.139
4.135
4.123
2.358
1.279
1.267
1.255
X : parts per Million : Proton

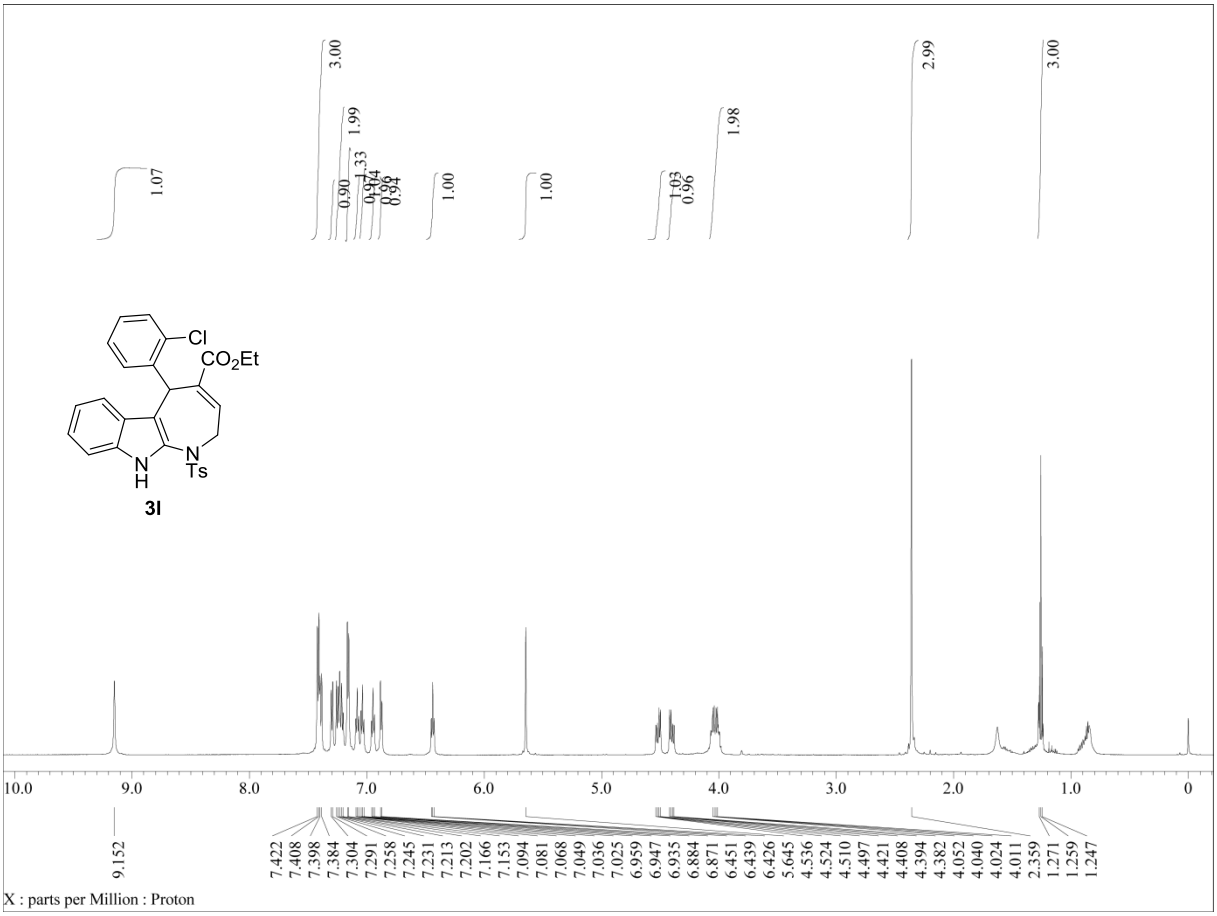

O2N
CO2Et
N
H
N
Ts
3i
180.0
170.0
160.0
150.0
140.0
130.0
120.0
110.0
100.0
90.0
80.0
70.0
60.0
50.0
40.0
30.0
20.0
10.0
0
165.9
150.3
146.5
144.6
138.5
134.9
134.3
132.6
132.3
129.8
128.1
127.3
126.8
123.6
122.9
120.3
118.1
110.9
101.0
77.2
77.0
76.8
61.5
45.3
38.3
21.5
14.2
X : parts per Million : Carbon13

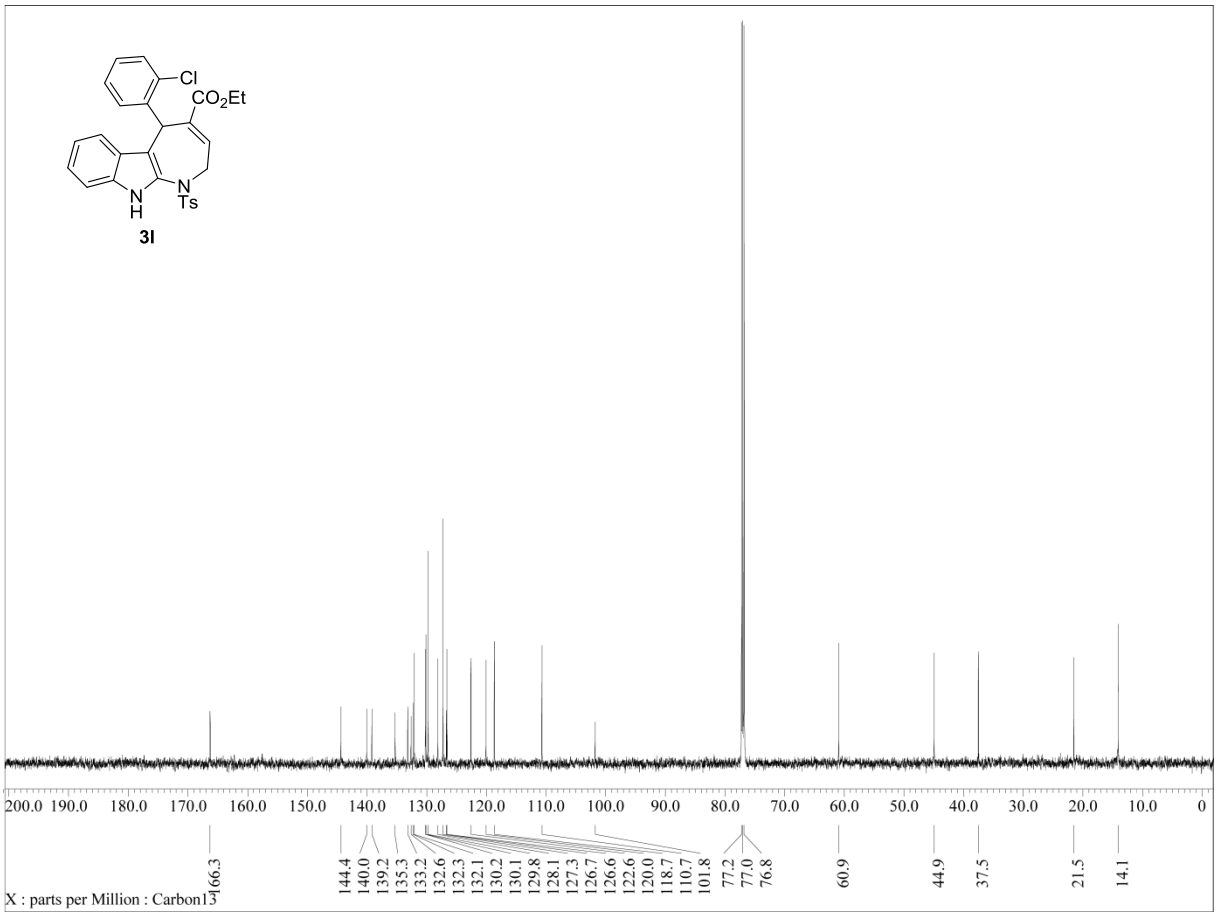

H3C
CO2Et
N
H
N
Ts
3j
3.87
3.06
2.34
3.10
3.25
3.11
1.05
0.93
1.03
1.00
1.08
1.07
10.0
9.0
8.0
7.0
6.0
5.0
4.0
3.0
2.0
1.0
0
9.065
7.398
7.394
7.384
7.379
7.232
7.224
7.222
7.219
7.211
7.199
7.197
7.145
7.132
7.042
7.031
7.019
6.961
6.644
6.631
6.619
5.560
4.541
4.528
4.516
4.503
4.317
4.305
4.291
4.279
4.115
4.104
4.092
2.343
2.241
1.264
1.252
1.240
X : parts per Million : Proton

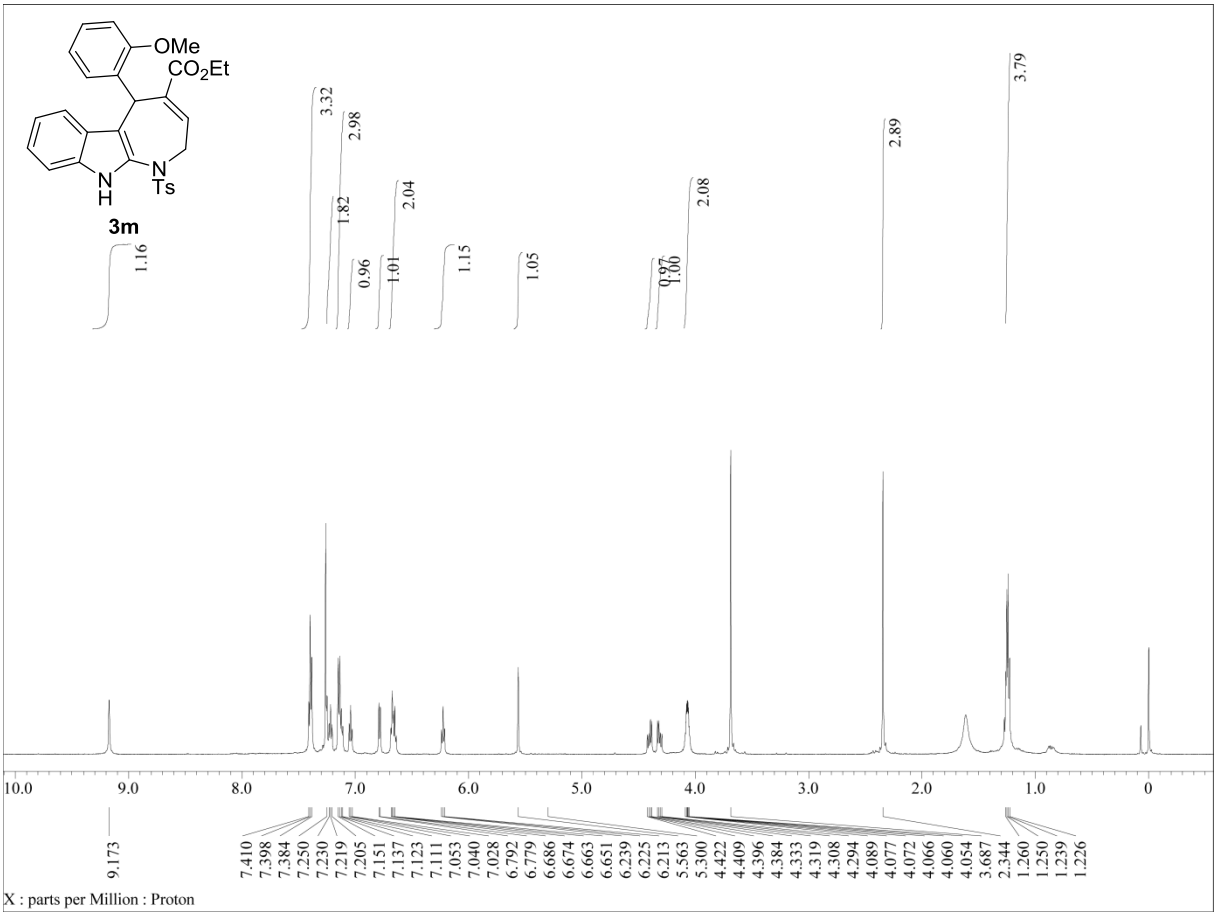

H3C
CO2Et
N
H
N
Ts
3j
170.0
160.0
150.0
140.0
130.0
120.0
110.0
100.0
90.0
80.0
70.0
60.0
50.0
40.0
30.0
20.0
10.0
0
166.1
144.2
140.1
139.9
136.0
135.0
133.0
132.5
132.3
129.6
129.1
127.4
127.3
127.1
122.4
119.9
118.7
110.6
102.1
77.2
77.0
76.8
61.1
45.3
38.0
21.5
20.9
14.2
X : parts per Million : Carbon13

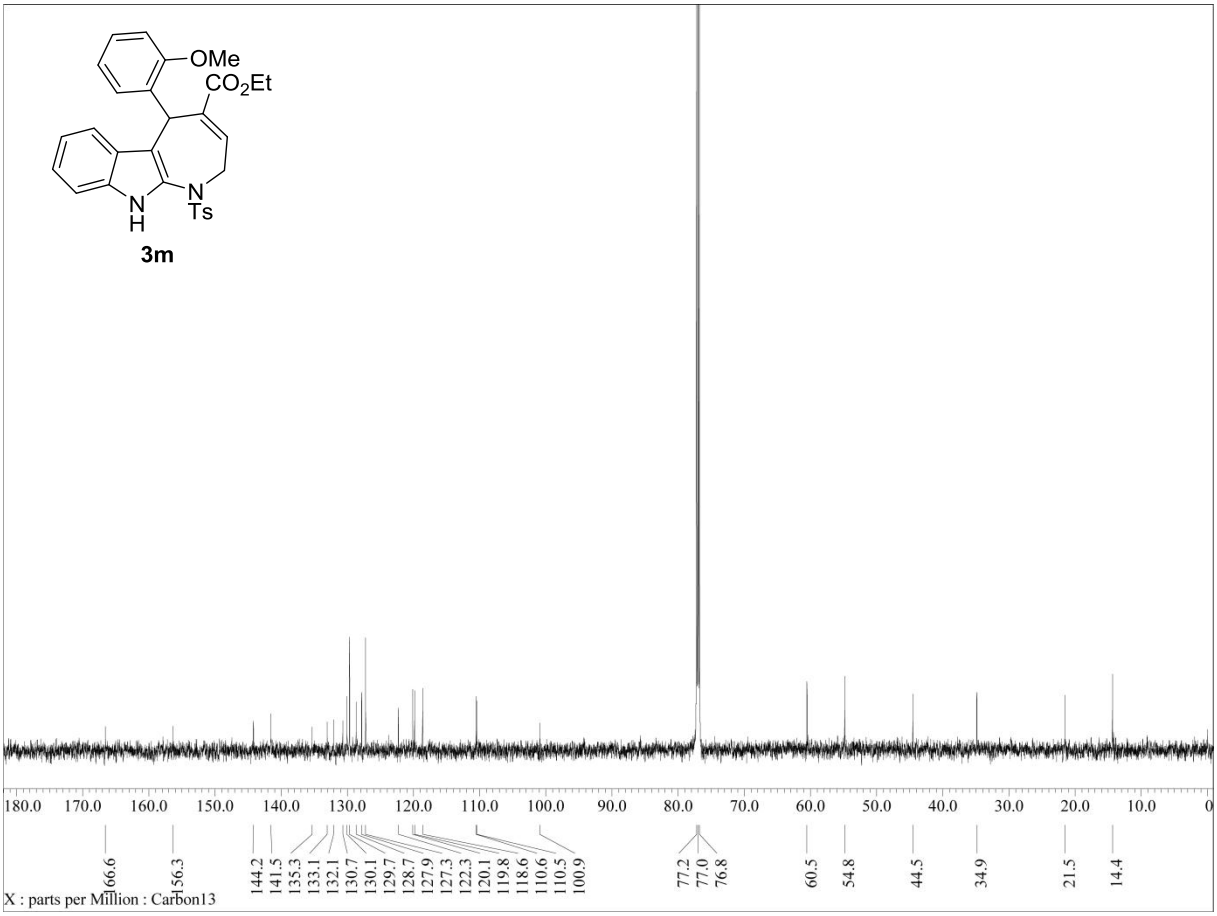

MeO
CO2Et
N
H
N
Ts
3k
3.10
2.06
2.04
1.98
1.94
1.12
1.00
1.01
1.00
1.05
1.05
2.25
3.04
3.06
3.86
10.0
9.0
8.0
7.0
6.0
5.0
4.0
3.0
2.0
1.0
0
9.052
7.395
7.392
7.382
7.378
7.230
7.224
7.216
7.213
7.199
7.145
7.132
7.045
7.033
7.021
7.000
6.985
6.691
6.677
6.644
6.631
6.619
5.525
4.551
4.537
4.525
4.512
4.314
4.301
4.287
4.275
4.112
4.102
4.090
3.708
2.342
1.264
1.252
1.240
X : parts per Million : Proton

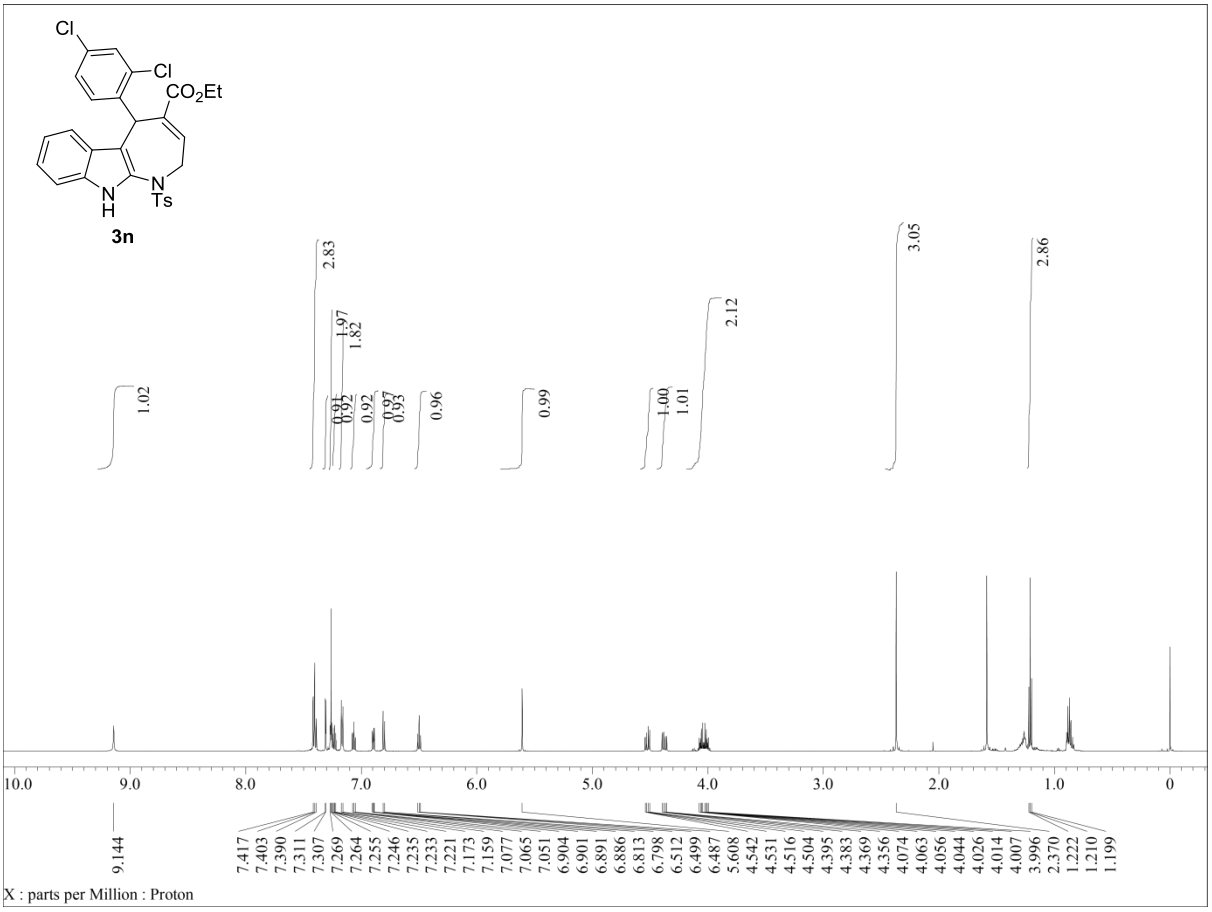

MeO
CO2Et
N
H
N
Ts
3k
190.0
180.0
170.0
160.0
150.0
140.0
130.0
120.0
110.0
100.0
90.0
80.0
70.0
60.0
50.0
40.0
30.0
20.0
10.0
0
166.2
158.0
144.2
140.1
135.0
132.9
132.4
132.3
129.6
128.2
127.4
127.3
127.1
122.5
119.9
118.8
113.7
110.6
102.3
77.2
77.0
76.8
61.1
55.1
45.3
37.6
21.5
14.2
X : parts per Million : Carbon13

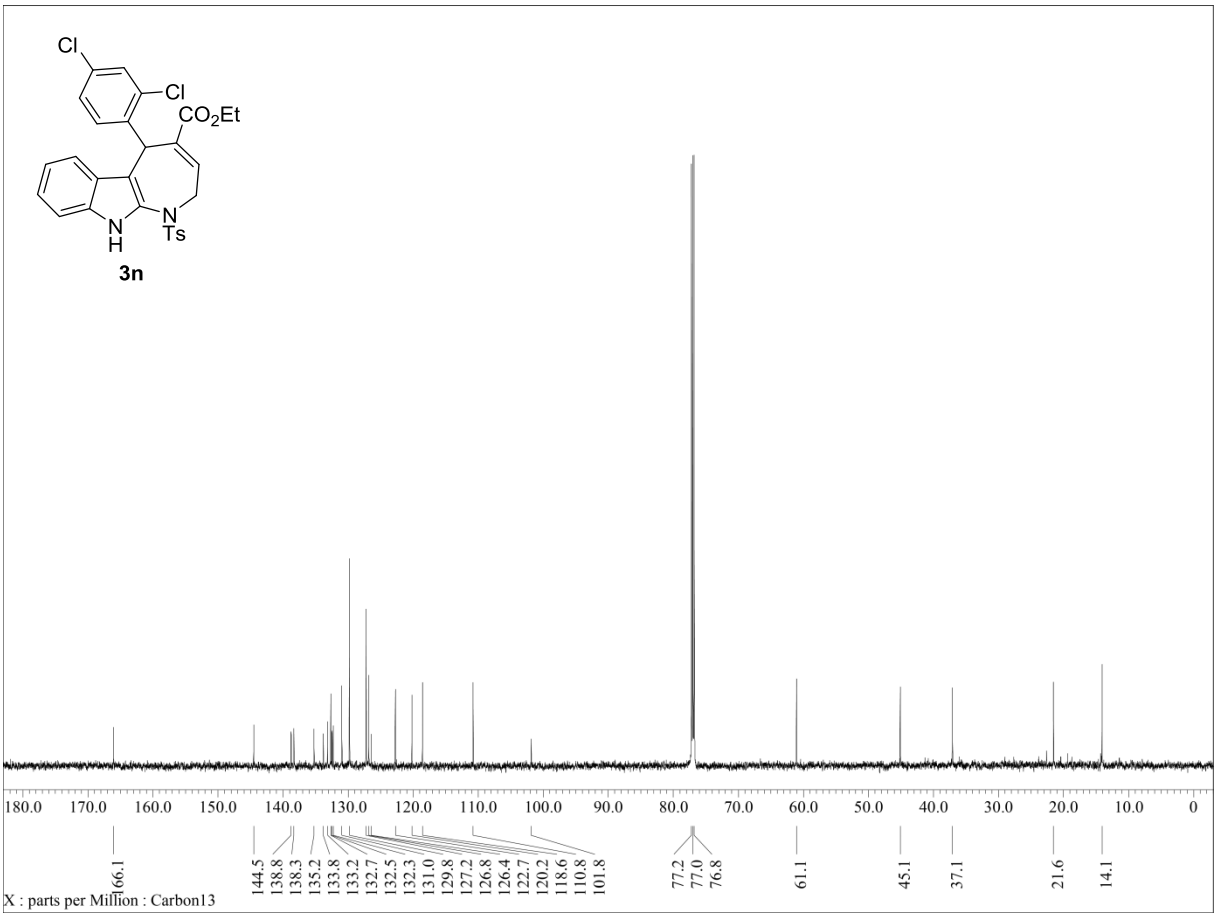

3.00
1.99
1.33
0.90
0.97
0.94
0.96
0.94
1.00
1.00
1.07
1.03
0.96
1.98
2.99
3.00
Cl
CO2Et
N
H
N
Ts
3l
10.0
9.0
8.0
7.0
6.0
5.0
4.0
3.0
2.0
1.0
0
9.152
7.422
7.408
7.398
7.384
7.304
7.291
7.258
7.245
7.231
7.213
7.202
7.166
7.153
7.094
7.081
7.068
7.049
7.036
7.025
6.959
6.947
6.935
6.884
6.871
6.451
6.439
6.426
5.645
4.536
4.524
4.510
4.497
4.421
4.408
4.394
4.382
4.052
4.040
4.024
4.011
2.359
1.271
1.259
1.247
X : parts per Million : Proton

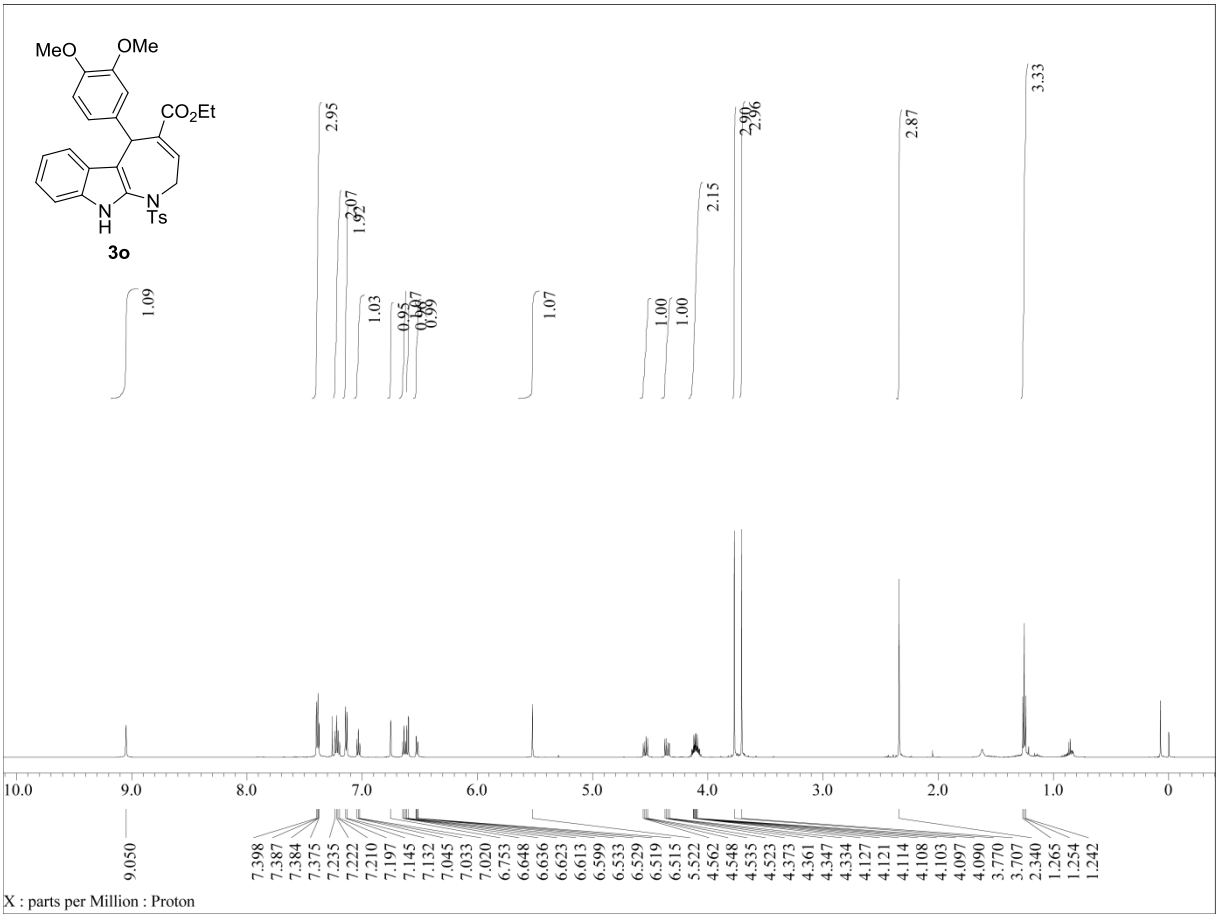

Cl
CO2Et
N
H
N
Ts
3l
200.0
190.0
180.0
170.0
160.0
150.0
140.0
130.0
120.0
110.0
100.0
90.0
80.0
70.0
60.0
50.0
40.0
30.0
20.0
10.0
0
166.3
144.4
140.0
139.2
135.3
133.2
132.6
132.3
132.1
130.2
130.1
129.8
128.1
127.3
126.7
126.6
122.6
120.0
118.7
110.7
101.8
77.2
77.0
76.8
60.9
44.9
37.5
21.5
14.1
X : parts per Million : Carbon13

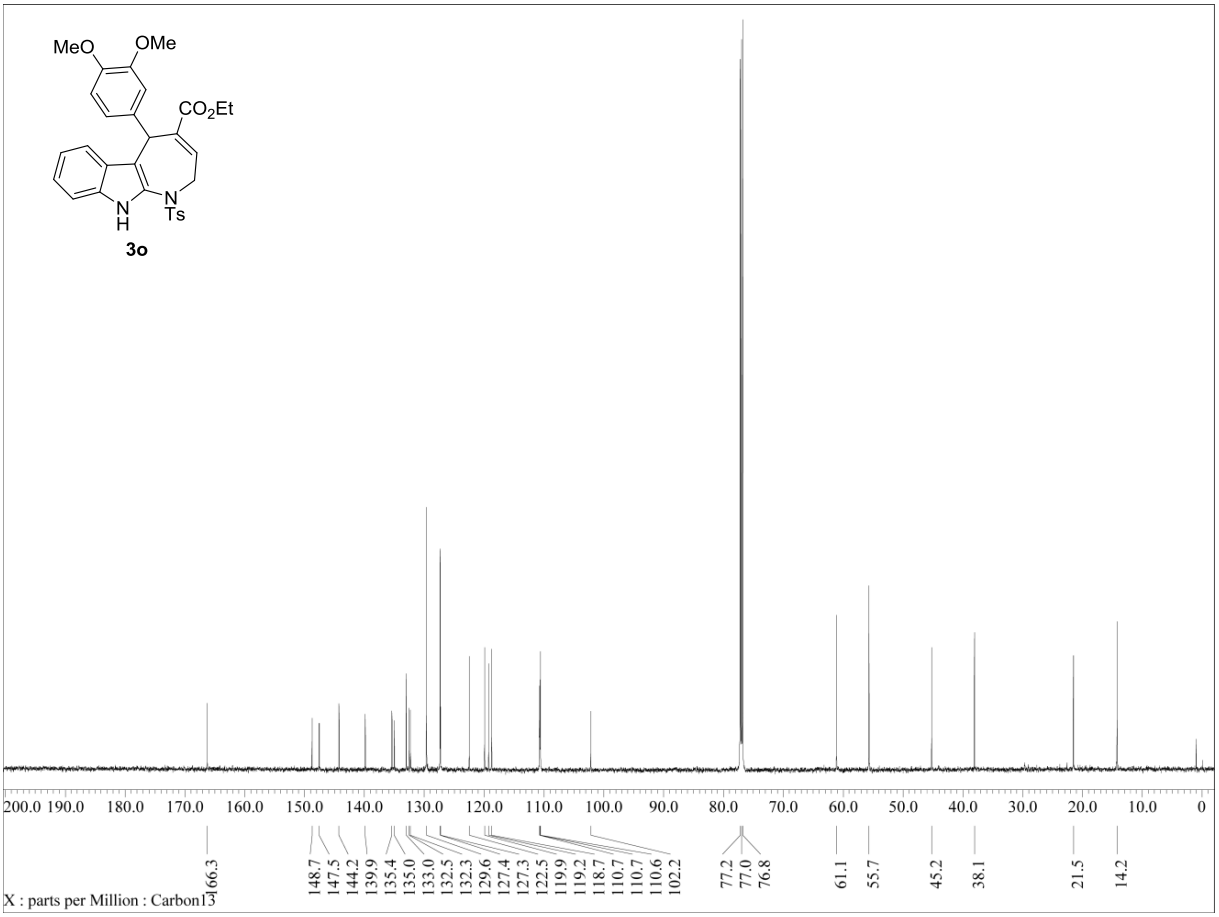

OMe
CO2Et
N
H
N
Ts
3m
3.32
2.98
1.82
2.04
2.89
3.79
2.08
1.16
0.96
1.01
1.15
1.05
0.97
1.00
9.173
7.410
7.398
7.384
7.250
7.230
7.219
7.205
7.151
7.137
7.123
7.111
7.053
7.040
7.028
6.792
6.779
6.686
6.674
6.663
6.651
6.239
6.225
6.213
5.563
5.300
4.422
4.409
4.396
4.384
4.333
4.319
4.308
4.294
4.089
4.077
4.072
4.066
4.060
4.054
3.687
2.344
1.260
1.250
1.239
1.226
X : parts per Million : Proton

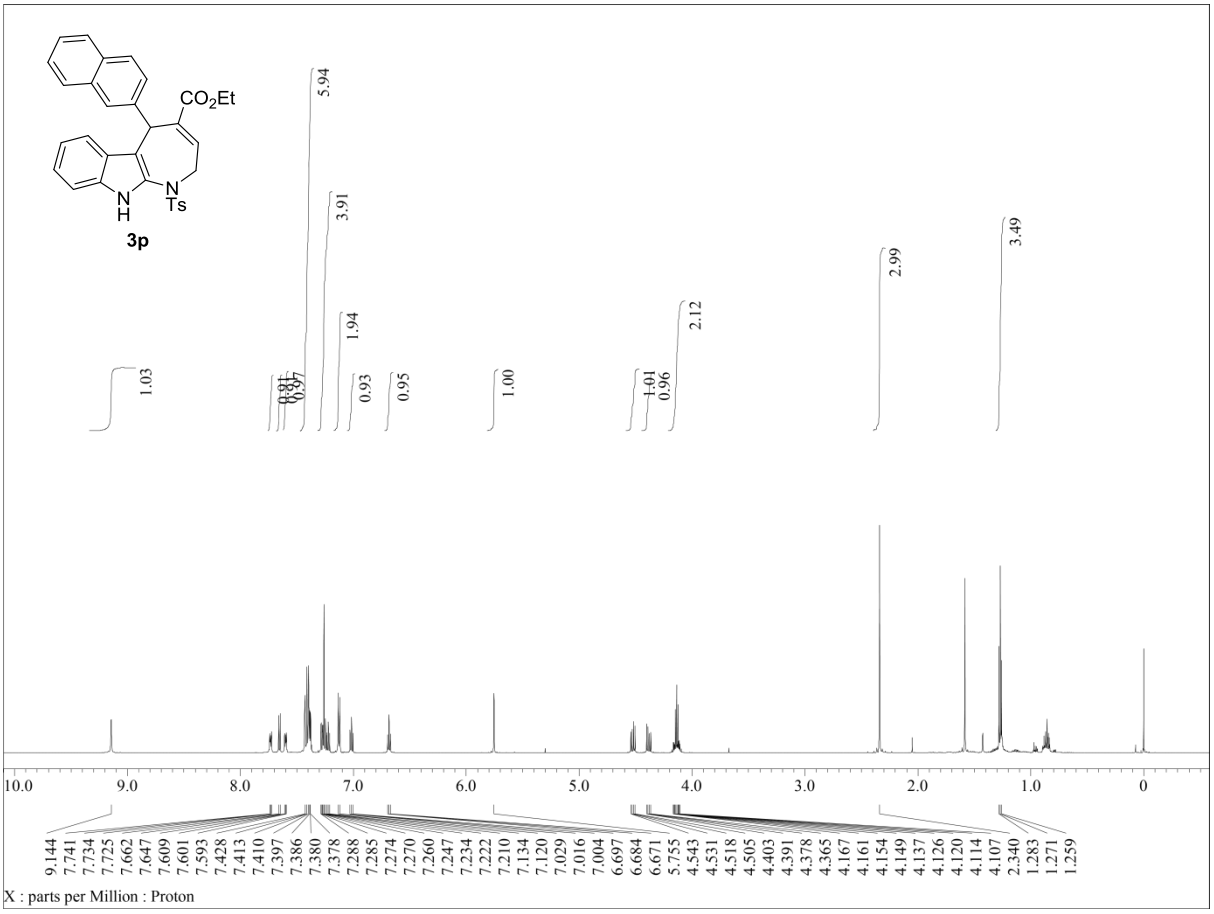

OMe
CO2Et
N
H
N
Ts
3m
166.6
156.3
144.2
141.5
135.3
133.1
132.1
130.7
130.1
129.7
128.7
127.9
127.3
122.3
120.1
119.8
118.6
110.6
110.5
100.9
77.2
77.0
76.8
60.5
54.8
44.5
34.9
21.5
14.4
X : parts per Million : Carbon13

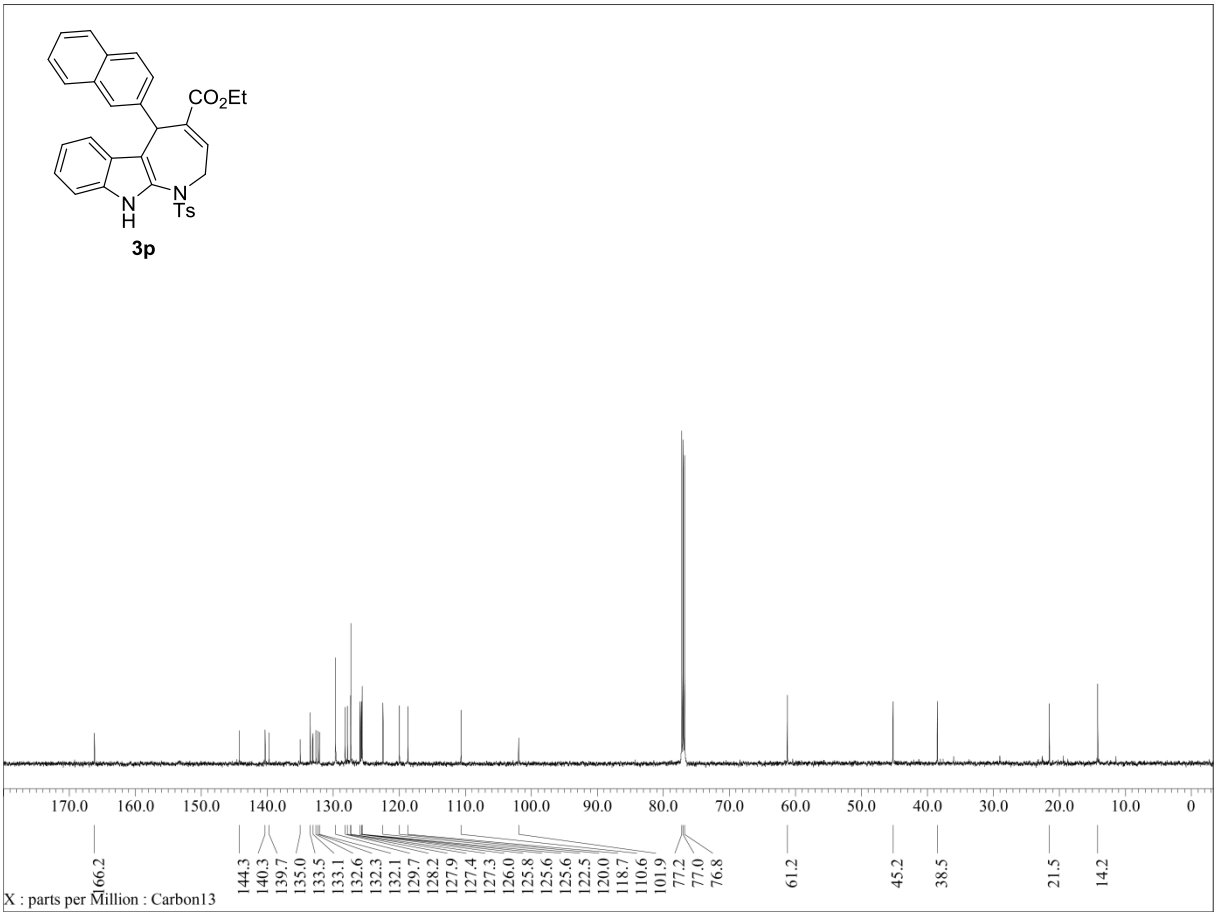

Cl
Cl
CO2Et
N
H
N
Ts
3n
2.83
1.97
1.82
1.02
0.92
0.96
0.99
2.12
3.05
2.86
10.0
9.0
8.0
7.0
6.0
5.0
4.0
3.0
2.0
1.0
0
9.144
X : parts per Million : Proton

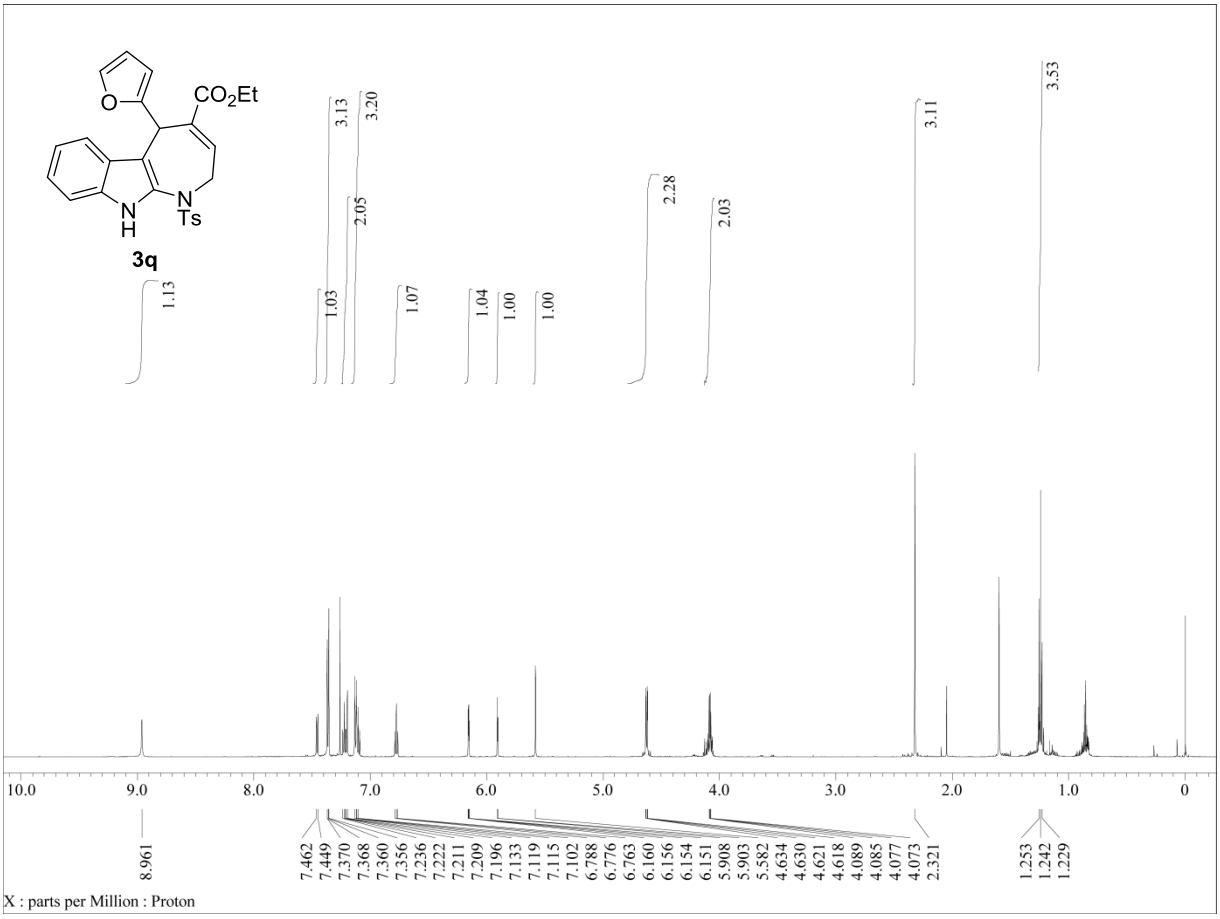

Cl
Cl
CO2Et
N
H
N
Ts
3n
180.0
170.0
160.0
150.0
140.0
130.0
120.0
110.0
100.0
90.0
80.0
70.0
60.0
50.0
40.0
30.0
20.0
10.0
0
166.1
144.5
138.8
138.3
135.2
133.8
133.2
132.7
132.5
132.3
131.0
129.8
127.2
126.8
126.4
122.7
120.2
118.6
110.8
101.8
77.2
77.0
76.8
61.1
45.1
37.1
21.6
14.1
X : parts per Million : Carbon13

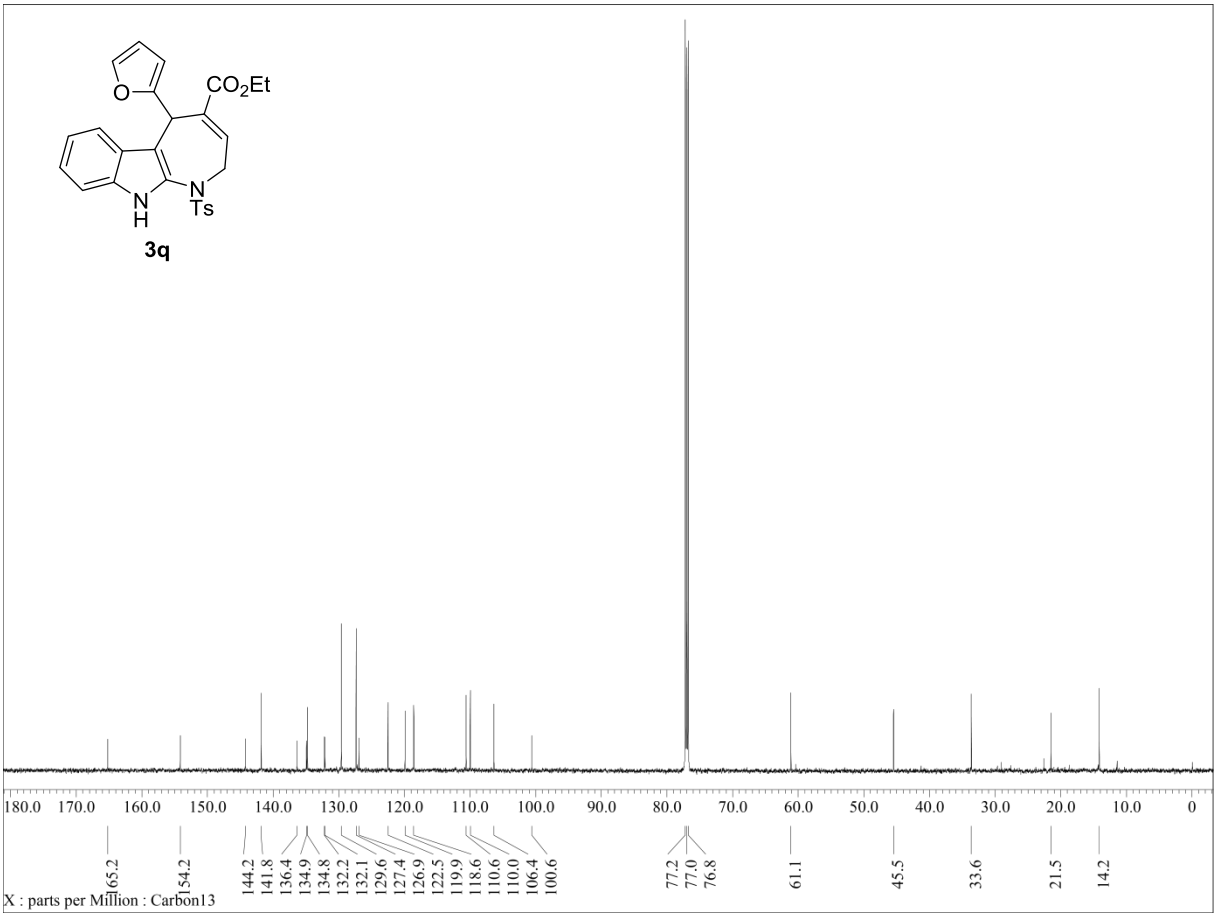

MeO
OMe
CO2Et
N
H
N
Ts
3o
2.95
2.07
1.92
1.03
1.09
1.07
1.00
1.00
2.15
2.90
2.96
2.87
3.33
9.050
7.398
7.387
7.384
7.375
7.235
7.222
7.210
7.197
7.145
7.132
7.045
7.033
7.020
6.753
6.648
6.636
6.623
6.613
6.599
6.533
6.529
6.519
6.515
5.522
4.562
4.548
4.535
4.523
4.373
4.361
4.347
4.334
4.127
4.121
4.114
4.108
4.103
4.097
4.090
3.770
3.707
2.340
1.265
1.254
1.242
X : parts per Million : Proton

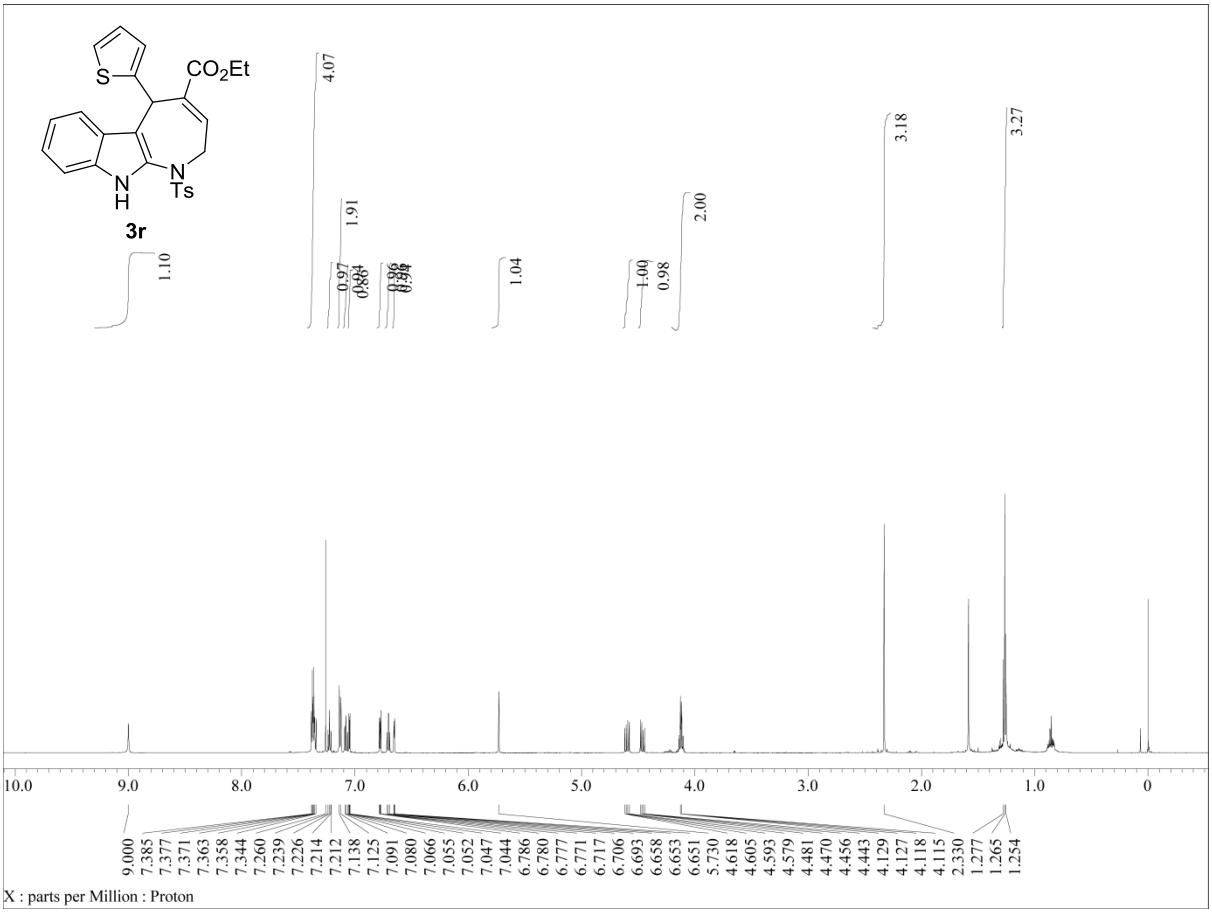

MeO
OMe
CO2Et
N
H
N
Ts
3o
166.3
148.7
147.5
144.2
139.9
135.4
135.0
133.0
132.5
132.3
129.6
127.4
127.3
122.5
119.9
119.2
118.7
110.7
110.7
110.6
102.2
77.2
77.0
76.8
61.1
55.7
45.2
38.1
21.5
14.2
X : parts per Million : Carbon13

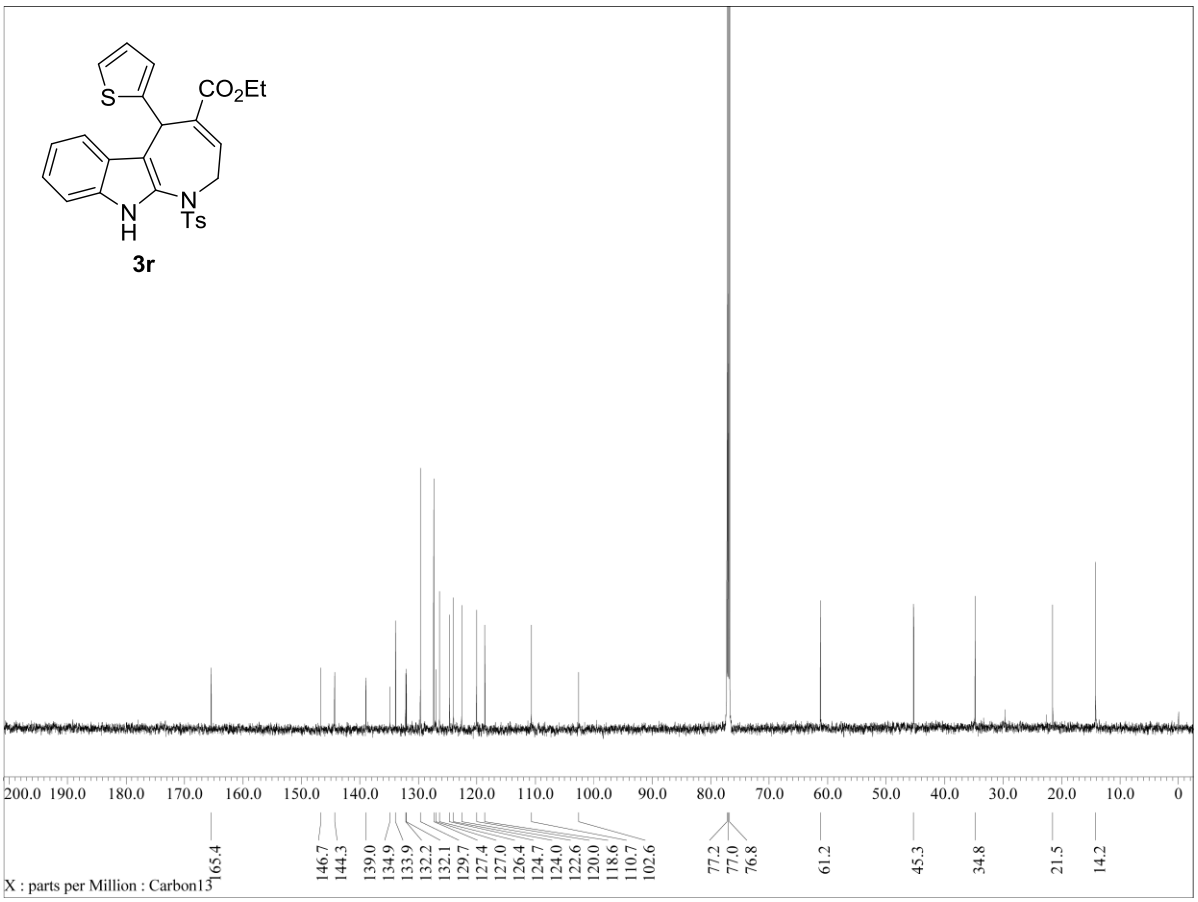

CO2Et
N
H
N
Ts
3p
5.94
3.91
1.94
0.93
0.95
1.00
1.03
2.12
2.99
3.49
10.0
9.0
8.0
7.0
6.0
5.0
4.0
3.0
2.0
1.0
0
X : parts per Million : Proton

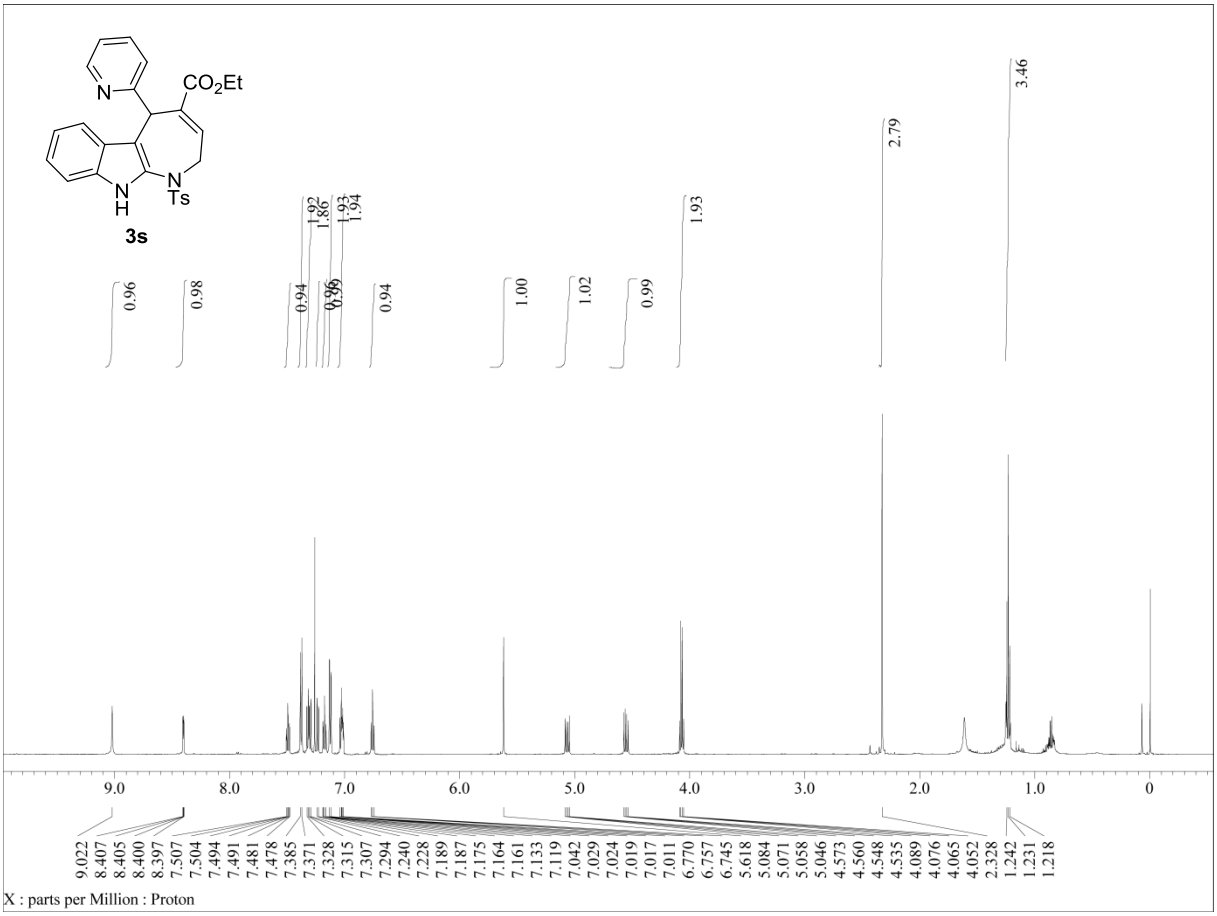

CO2Et
N
H
N
Ts
3p
170.0
160.0
150.0
140.0
130.0
120.0
110.0
100.0
90.0
80.0
70.0
60.0
50.0
40.0
30.0
20.0
10.0
0
X : parts per Million : Carbon13

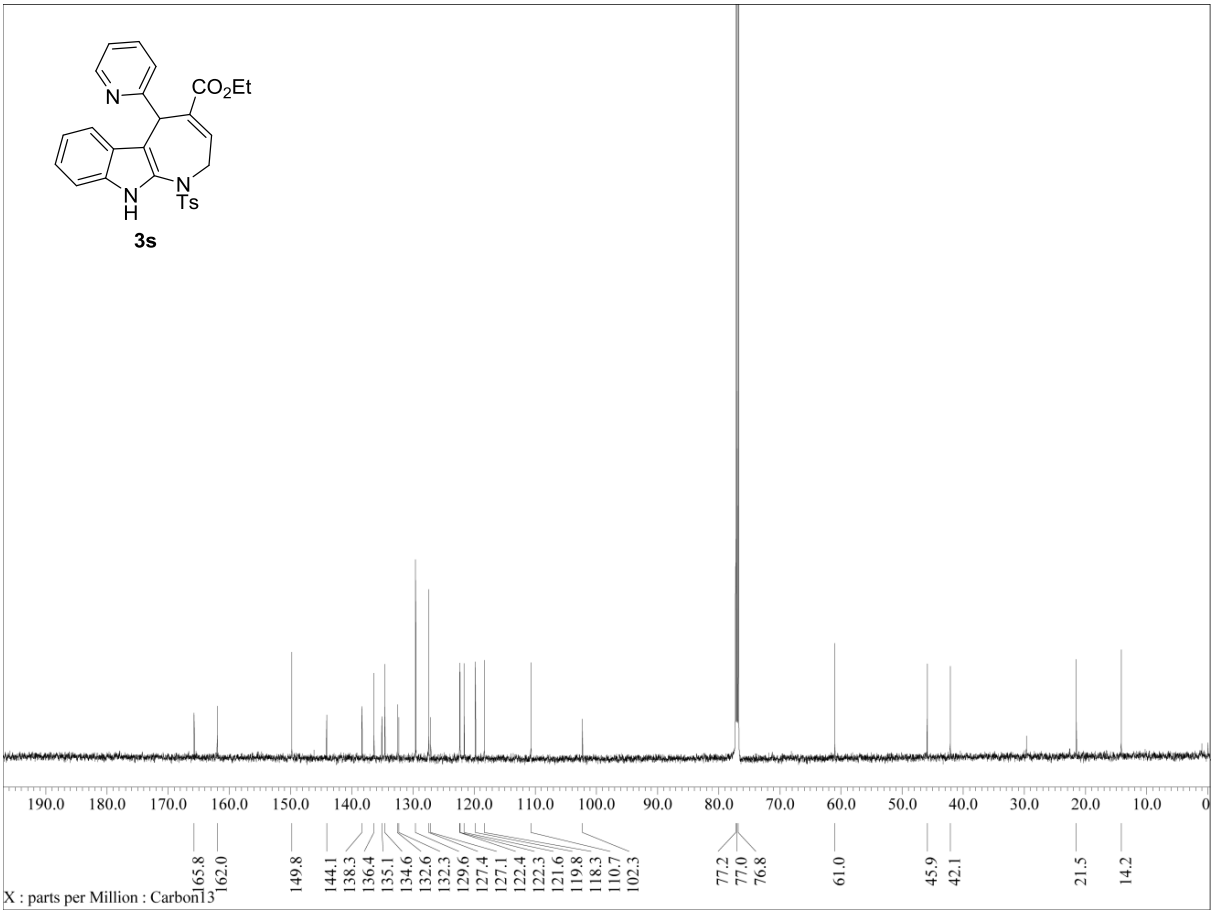

CO2Et
O
N
H
N
Ts
3q
1.13
1.03
3.13
3.20
2.05
1.07
1.04
1.00
1.00
2.28
2.03
3.11
3.53
10.0
9.0
8.0
7.0
6.0
5.0
4.0
3.0
2.0
1.0
0
8.961
7.462
7.449
7.370
7.368
7.360
7.356
7.236
7.222
7.211
7.209
7.196
7.133
7.119
7.115
7.102
6.788
6.776
6.763
6.160
6.156
6.154
6.151
5.908
5.903
5.582
4.634
4.630
4.621
4.618
4.089
4.085
4.077
4.073
2.321
1.253
1.242
1.229
X : parts per Million : Proton

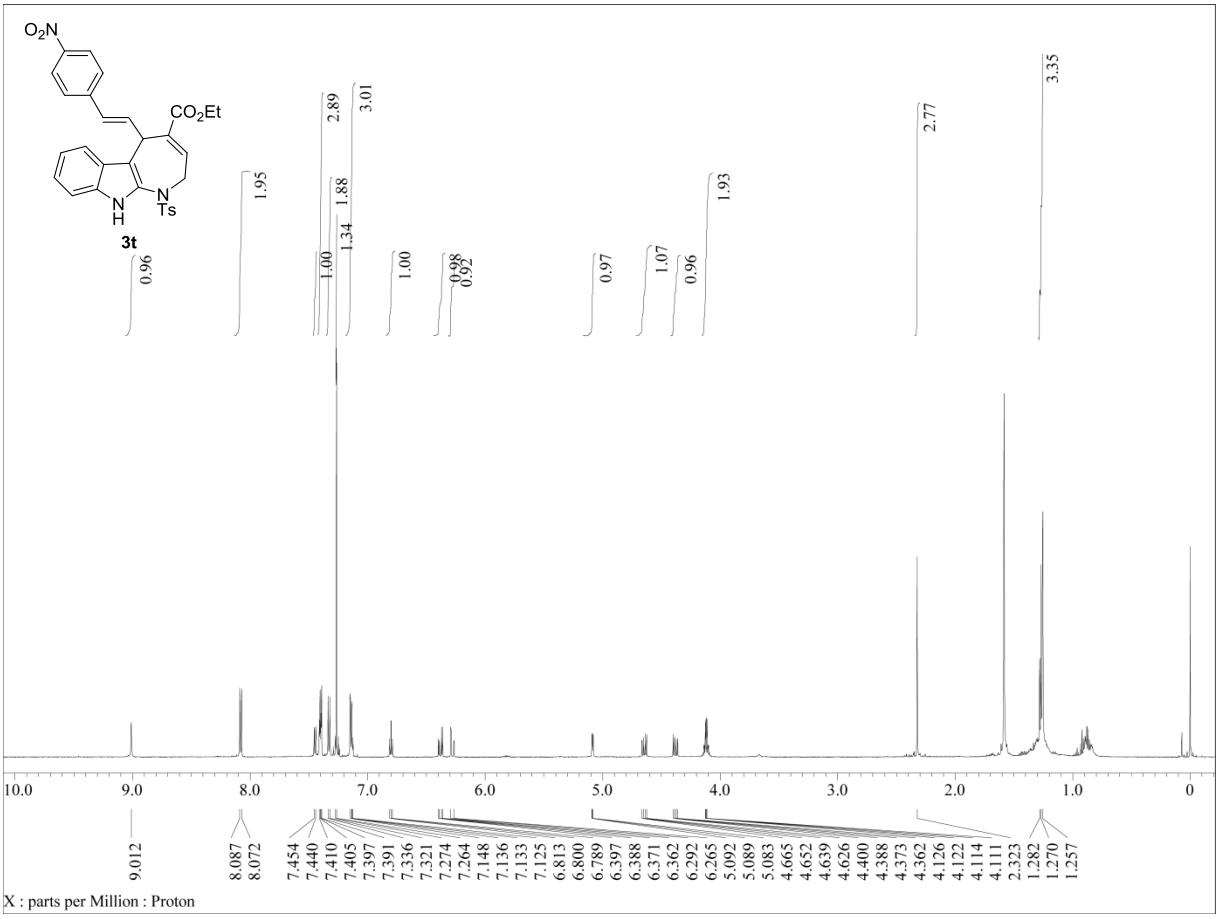

CO2Et
O
N
H
N
Ts
3q
180.0
170.0
160.0
150.0
140.0
130.0
120.0
110.0
100.0
90.0
80.0
70.0
60.0
50.0
40.0
30.0
20.0
10.0
0
165.2
154.2
144.2
141.8
136.4
134.9
134.8
132.2
132.1
129.6
127.4
126.9
122.5
119.9
118.6
110.6
110.0
106.4
100.6
77.2
77.0
76.8
61.1
45.5
33.6
21.5
14.2
X : parts per Million : Carbon13

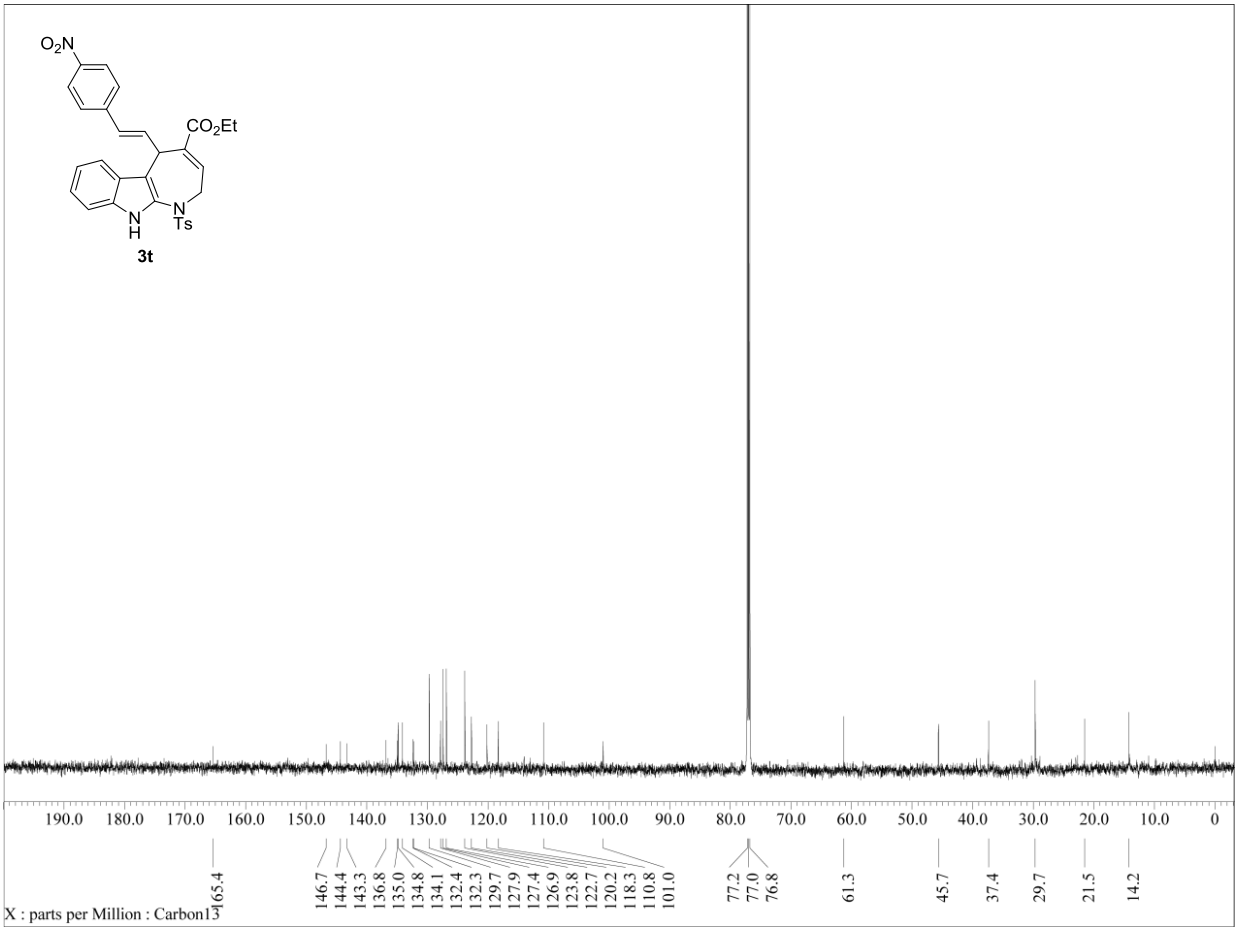

CO2Et
S
N
H
N
Ts
3r
4.07
1.91
1.10
1.04
1.00
0.98
2.00
3.18
3.27
10.0
9.0
8.0
7.0
6.0
5.0
4.0
3.0
2.0
1.0
0
9.000
7.385
7.377
7.371
7.363
7.358
7.344
7.260
7.239
7.226
7.214
7.212
7.138
7.125
7.091
7.080
7.066
7.055
7.052
7.047
7.044
6.786
6.780
6.777
6.771
6.717
6.706
6.693
6.658
6.653
6.651
5.730
4.618
4.605
4.593
4.579
4.481
4.470
4.456
4.443
4.129
4.127
4.118
4.115
2.330
1.277
1.265
1.254
X : parts per Million : Proton

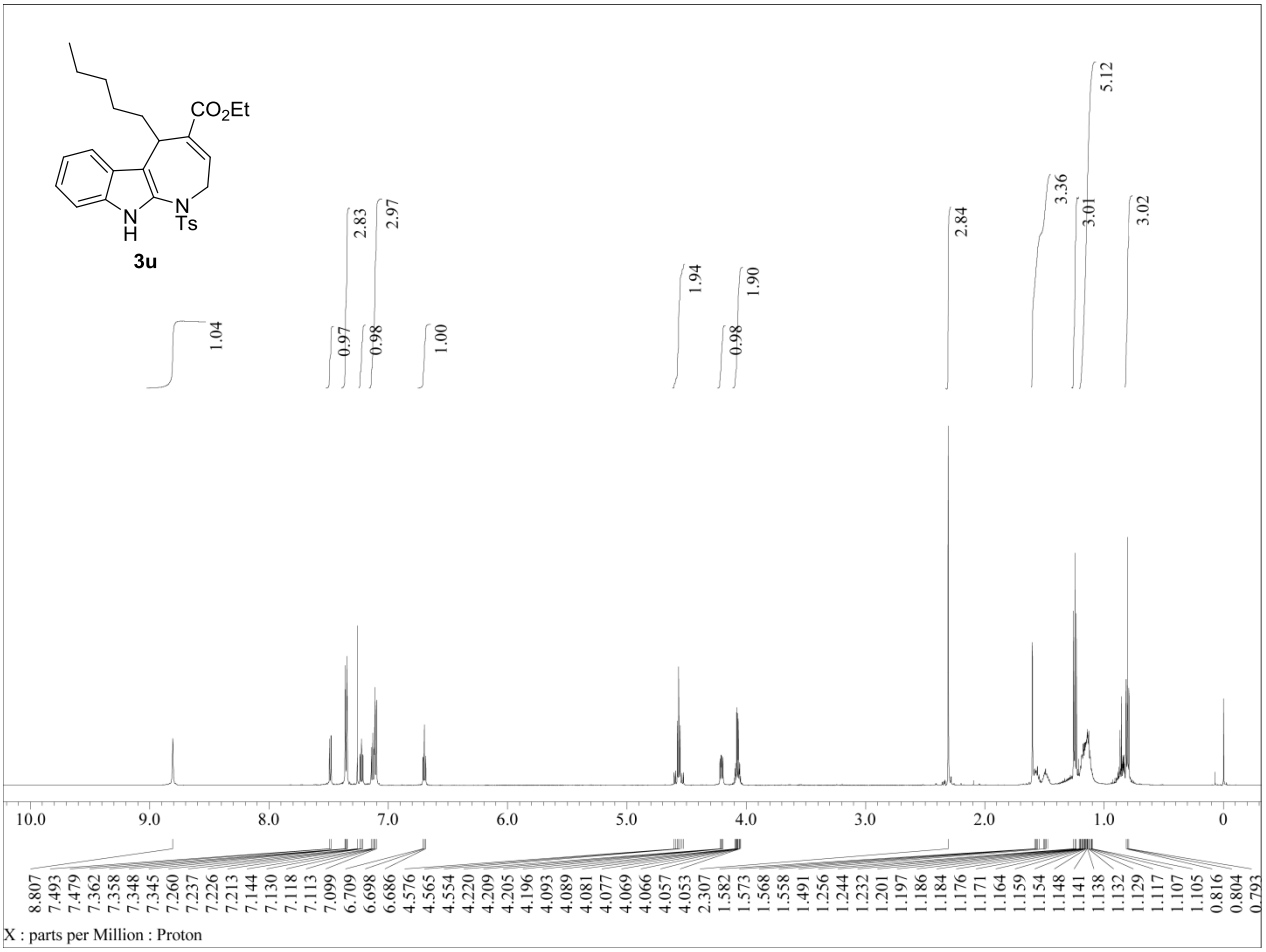

CO2Et
S
N
H
N
Ts
3r
200.0
190.0
180.0
170.0
160.0
150.0
140.0
130.0
120.0
110.0
100.0
90.0
80.0
70.0
60.0
50.0
40.0
30.0
20.0
10.0
0
165.4
146.7
144.3
139.0
134.9
133.9
132.2
132.1
129.7
127.4
127.0
126.4
124.7
124.0
122.6
120.0
118.6
110.7
102.6
77.2
77.0
76.8
61.2
45.3
34.8
21.5
14.2
X : parts per Million : Carbon13

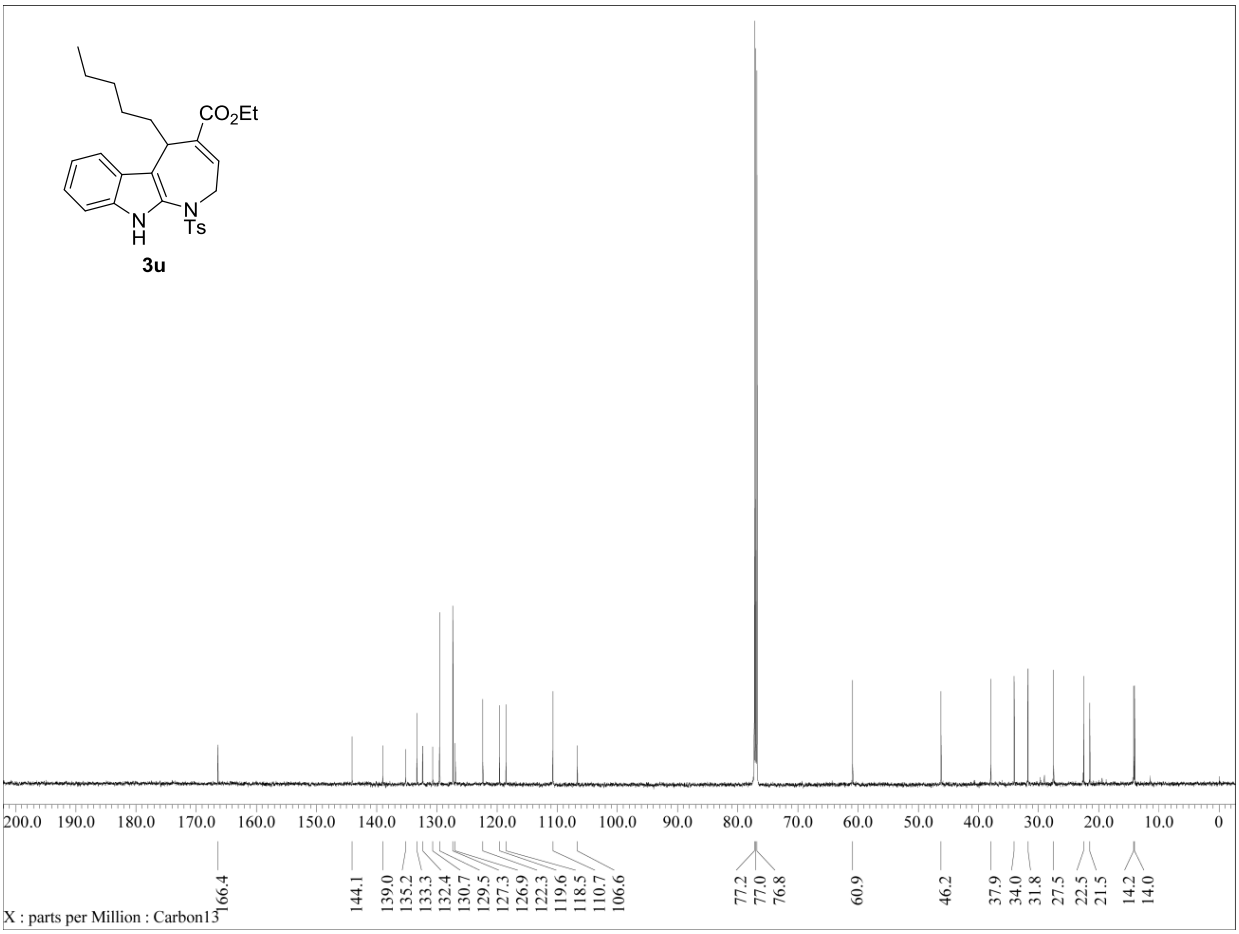

CO2Et
N
N
H
N
Ts
3s
0.96
0.98
0.94
1.92
1.86
1.93
1.94
0.94
1.00
1.02
0.99
1.93
2.79
3.46
9.0
8.0
7.0
6.0
5.0
4.0
3.0
2.0
1.0
0
9.022
8.407
8.405
8.400
8.397
7.507
7.504
7.494
7.491
7.481
7.478
7.385
7.371
7.328
7.315
7.307
7.294
7.240
7.228
7.189
7.187
7.175
7.164
7.161
7.133
7.119
7.042
7.029
7.024
7.019
7.017
7.011
6.770
6.757
6.745
5.618
5.084
5.071
5.058
5.046
4.573
4.560
4.548
4.535
4.089
4.076
4.065
4.052
2.328
1.242
1.231
1.218
X : parts per Million : Proton

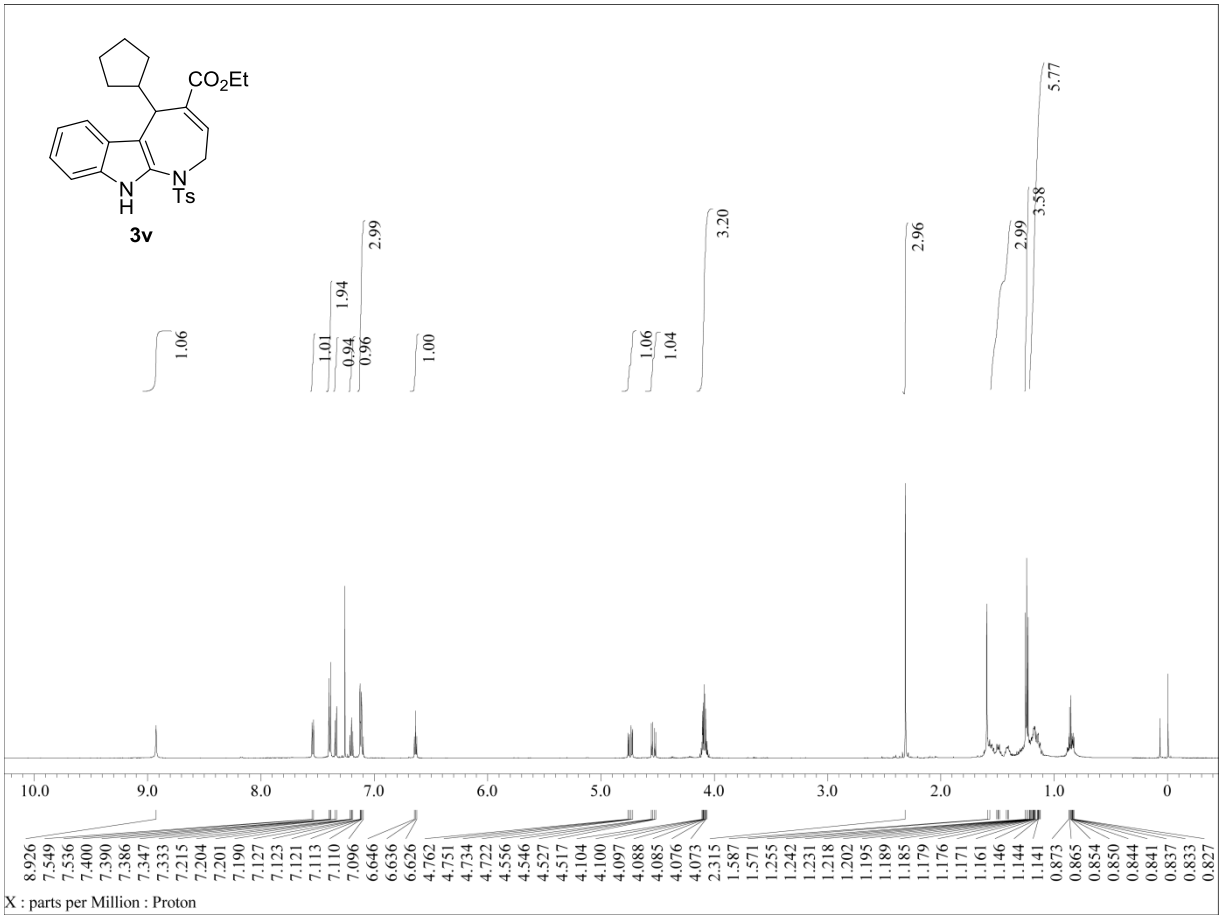

CO2Et
N
N
H
N
Ts
3s
190.0
180.0
170.0
160.0
150.0
140.0
130.0
120.0
110.0
100.0
90.0
80.0
70.0
60.0
50.0
40.0
30.0
20.0
10.0
0
165.8
162.0
149.8
144.1
138.3
136.4
135.1
134.6
132.6
132.3
129.6
127.4
127.1
122.4
122.3
121.6
119.8
118.3
110.7
102.3
77.2
77.0
76.8
61.0
45.9
42.1
21.5
14.2
X : parts per Million : Carbon13

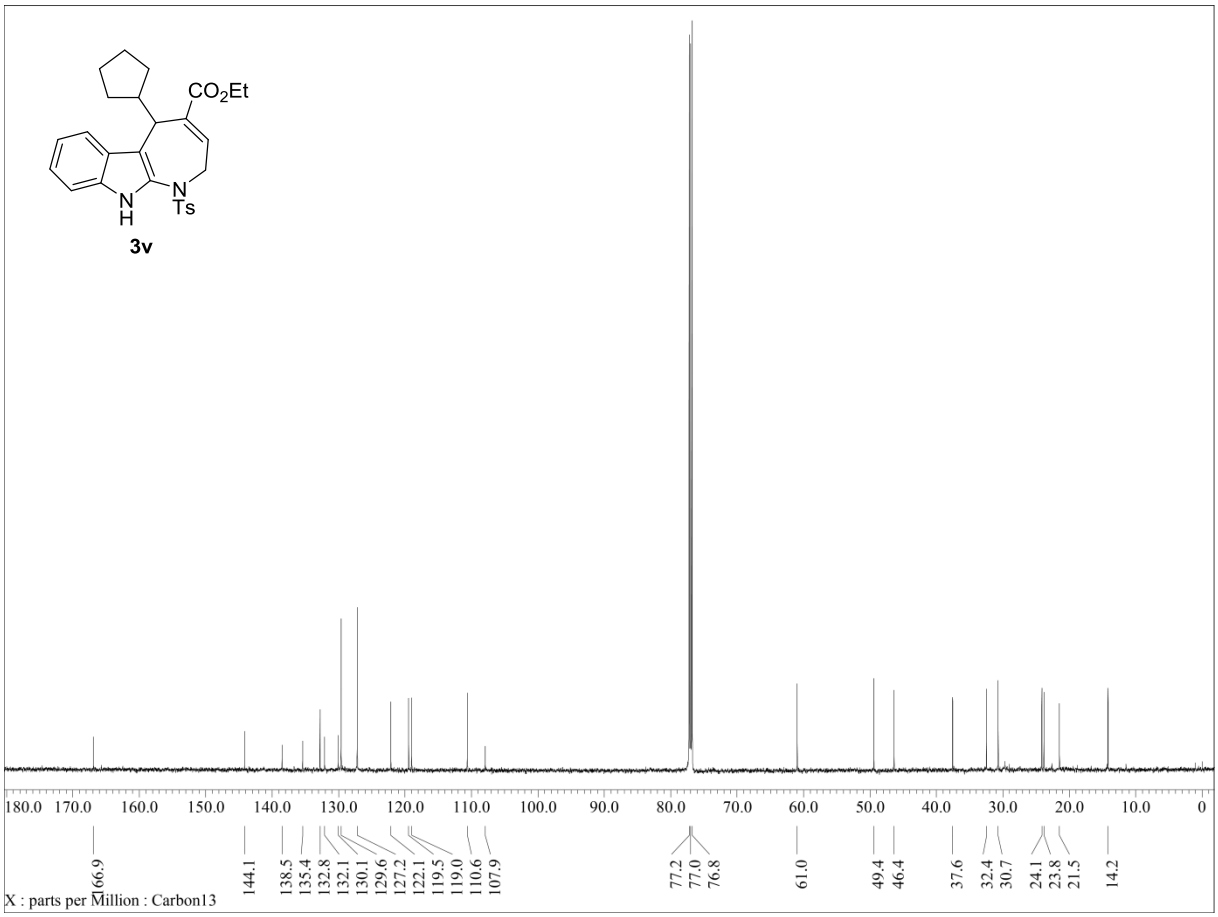

O2N
CO2Et
N
H
N
Ts
3t
0.96
1.95
1.00
1.00
1.88
1.34
2.89
3.01
1.00
0.98
0.92
0.97
1.07
0.96
1.93
2.77
3.35
10.0
9.0
8.0
7.0
6.0
5.0
4.0
3.0
2.0
1.0
0
9.012
8.087
8.072
7.454
7.440
7.410
7.405
7.397
7.391
7.336
7.321
7.274
7.264
7.148
7.136
7.133
7.125
6.813
6.800
6.789
6.397
6.388
6.371
6.362
6.292
6.265
5.092
5.089
5.083
4.665
4.652
4.639
4.626
4.400
4.388
4.373
4.362
4.126
4.122
4.114
4.111
2.323
1.282
1.270
1.257
X : parts per Million : Proton

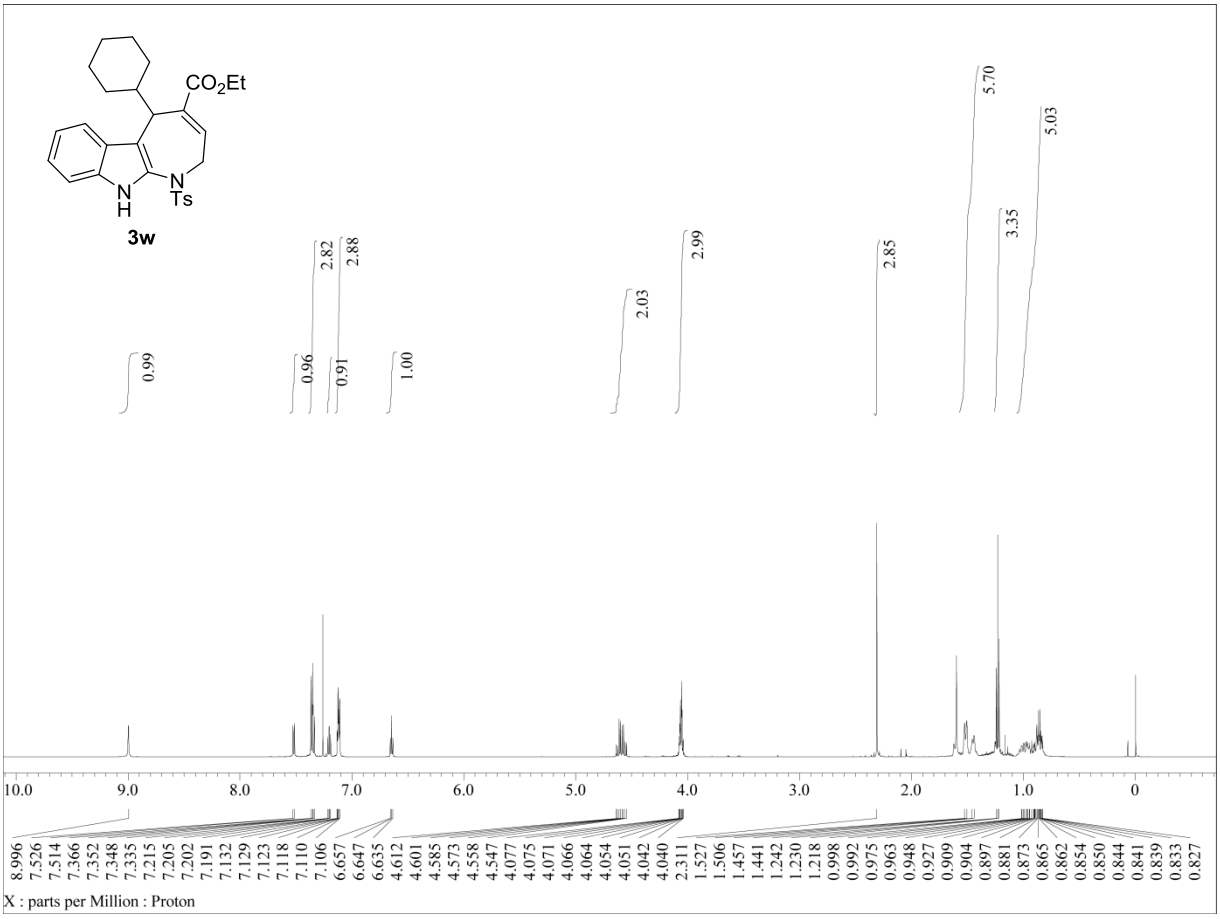

O2N
CO2Et
N
H
N
Ts
3t
190.0
180.0
170.0
160.0
150.0
140.0
130.0
120.0
110.0
100.0
90.0
80.0
70.0
60.0
50.0
40.0
30.0
20.0
10.0
0
165.4
146.7
144.4
143.3
136.8
135.0
134.8
134.1
132.4
132.3
129.7
127.9
127.4
126.9
123.8
122.7
120.2
118.3
110.8
101.0
77.2
77.0
76.8
61.3
45.7
37.4
29.7
21.5
14.2
X : parts per Million : Carbon13

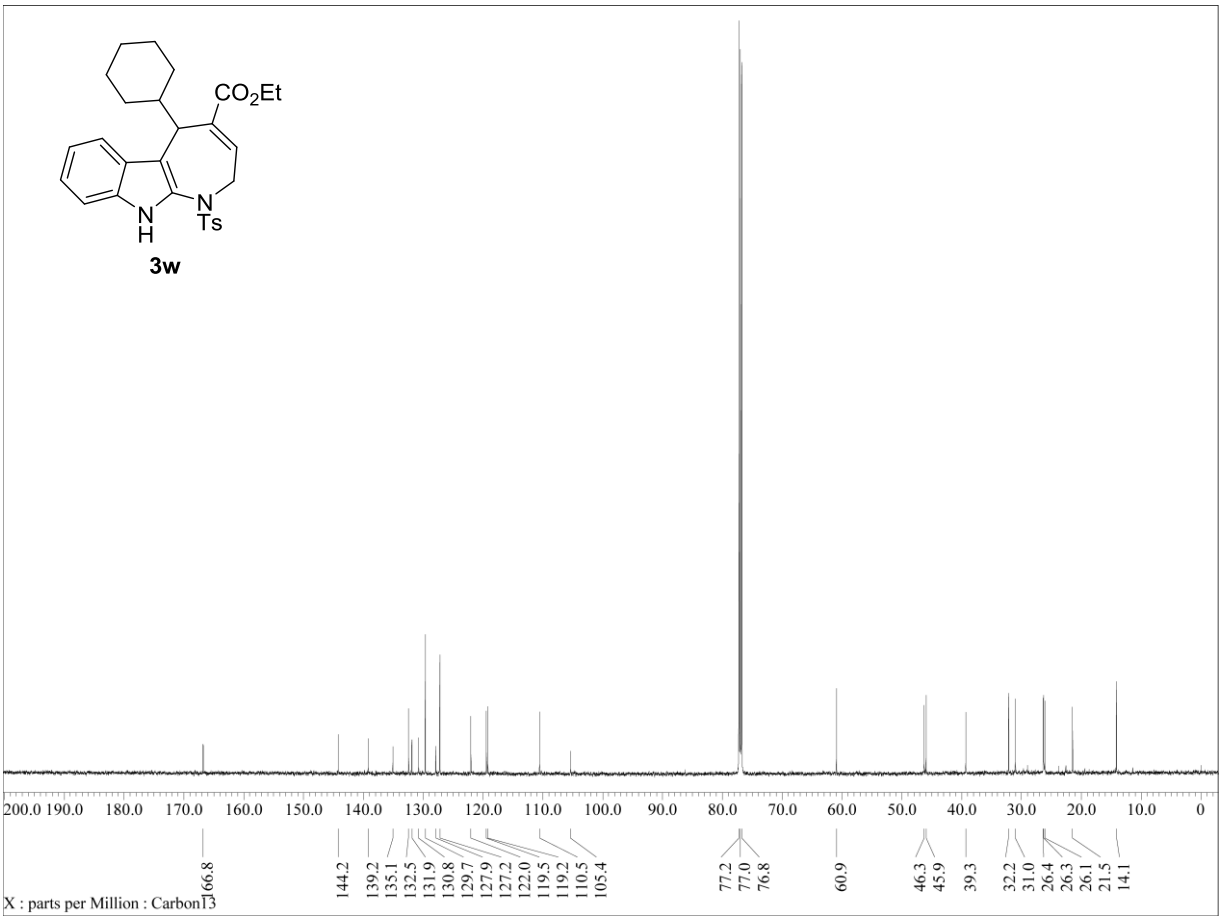

CO2Et
N
H
N
Ts
3u
1.04
0.97
2.83
0.98
2.97
1.00
1.94
0.98
1.90
2.84
3.36
3.01
5.12
3.02
10.0
9.0
8.0
7.0
6.0
5.0
4.0
3.0
2.0
1.0
0
8.807
7.493
7.479
7.362
7.358
7.348
7.345
7.260
7.237
7.226
7.213
7.144
7.130
7.118
7.113
7.099
7.709
6.698
6.686
4.576
4.565
4.554
4.220
4.209
4.205
4.196
4.093
4.089
4.081
4.077
4.069
4.066
4.057
4.053
2.307
1.582
1.573
1.568
1.558
1.491
1.256
1.244
1.232
1.201
1.197
1.186
1.184
1.176
1.171
1.164
1.159
1.154
1.148
1.141
1.138
1.132
1.129
1.117
1.107
1.105
0.816
0.804
0.793
X : parts per Million : Proton

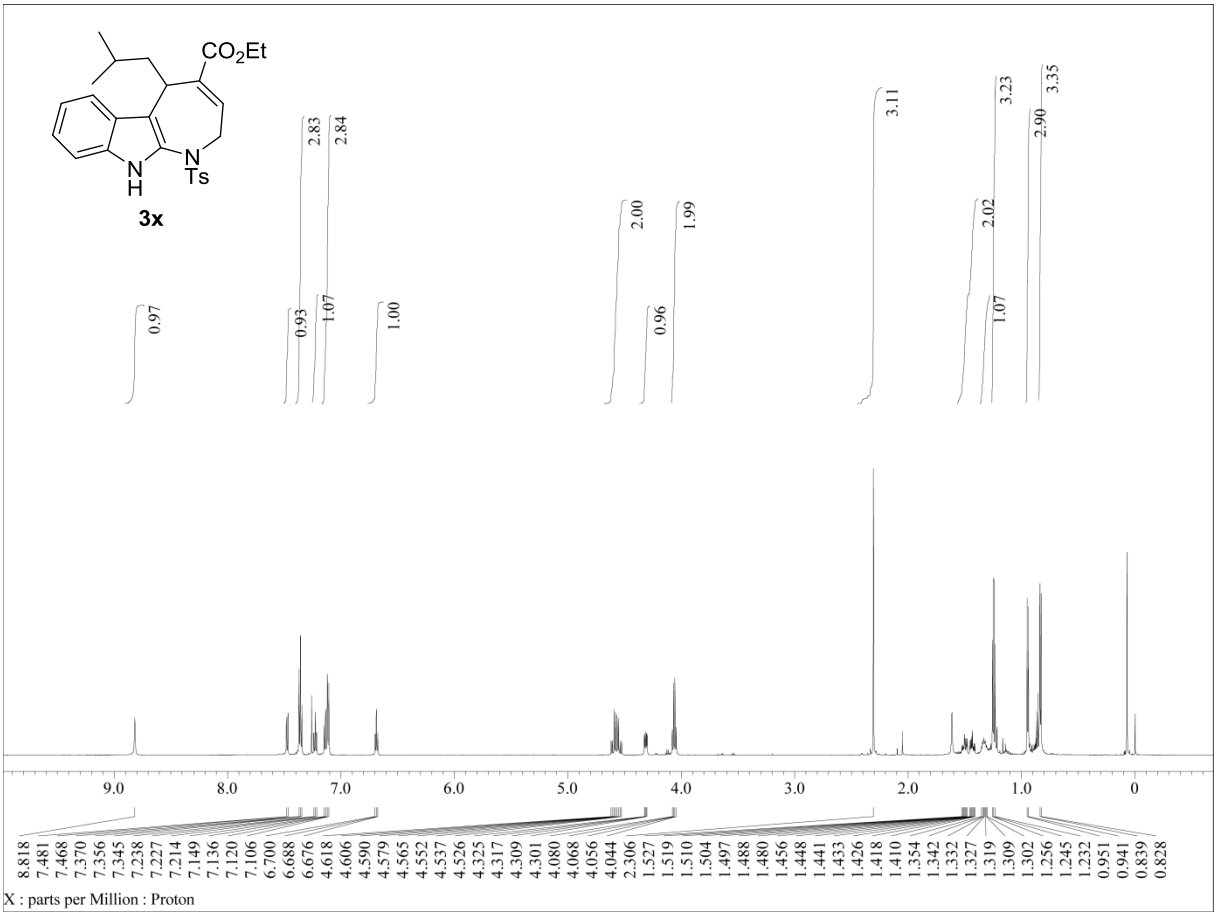

CO2Et
N
H
N
Ts
3u
200.0
190.0
180.0
170.0
160.0
150.0
140.0
130.0
120.0
110.0
100.0
90.0
80.0
70.0
60.0
50.0
40.0
30.0
20.0
10.0
0
166.4
144.1
139.0
135.2
133.3
132.4
130.7
129.5
127.3
126.9
122.3
119.6
118.5
110.7
106.6
77.2
77.0
76.8
60.9
46.2
37.9
34.0
31.8
27.5
22.5
21.5
14.2
14.0
X : parts per Million : Carbon13

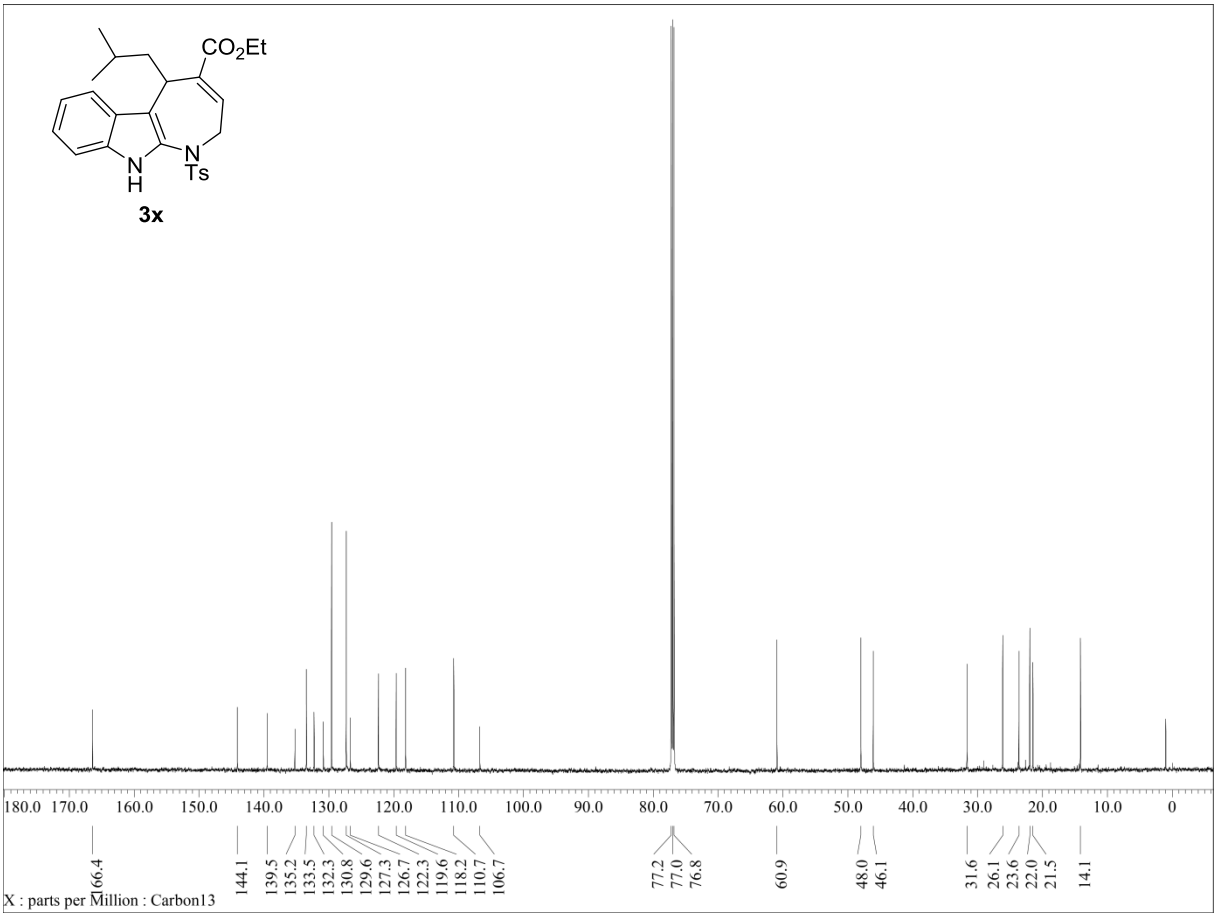

CO2Et
N
H
N
Ts
3v
1.06
1.01
1.94
0.94
0.96
2.99
1.00
1.06
1.04
3.20
2.96
2.99
3.58
5.77
10.0
9.0
8.0
7.0
6.0
5.0
4.0
3.0
2.0
1.0
0
8.926
7.549
7.536
7.400
7.390
7.386
7.347
7.333
7.215
7.204
7.201
7.190
7.127
7.123
7.121
7.113
7.110
7.096
6.646
6.636
6.626
4.762
4.751
4.734
4.722
4.556
4.546
4.527
4.517
4.104
4.100
4.097
4.088
4.085
4.076
4.073
2.315
1.587
1.571
1.255
1.242
1.231
1.218
1.202
1.195
1.189
1.185
1.179
1.176
1.171
1.161
1.146
1.144
1.141
0.873
0.865
0.854
0.850
0.844
0.841
0.837
0.833
0.827
X : parts per Million : Proton

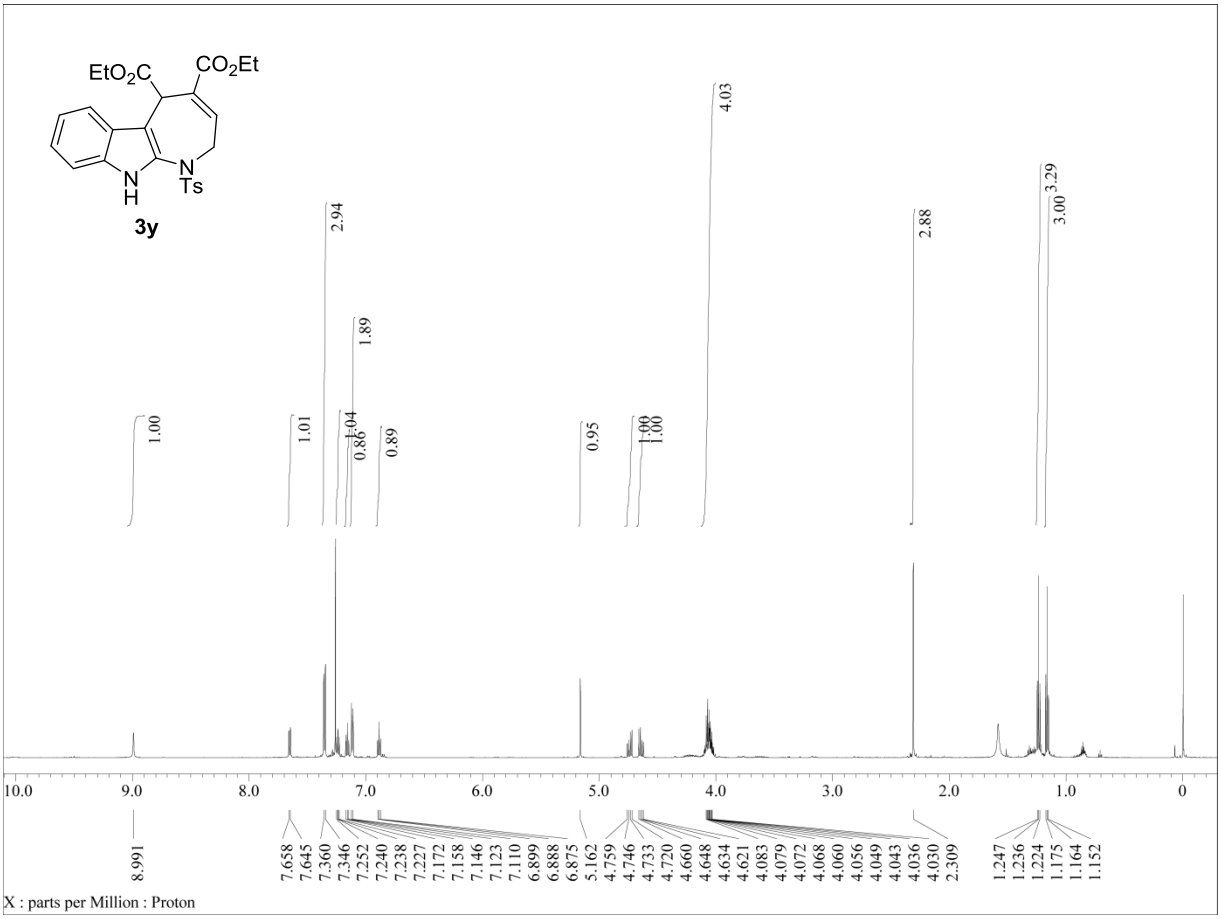

CO2Et
N
H
N
Ts
3v
180.0
170.0
160.0
150.0
140.0
130.0
120.0
110.0
100.0
90.0
80.0
70.0
60.0
50.0
40.0
30.0
20.0
10.0
0
166.9
144.1
138.5
135.4
132.8
132.1
130.1
129.6
127.2
122.1
119.5
119.0
110.6
107.9
77.2
77.0
76.8
61.0
49.4
46.4
37.6
32.4
30.7
24.1
23.8
21.5
14.2
X : parts per Million : Carbon13

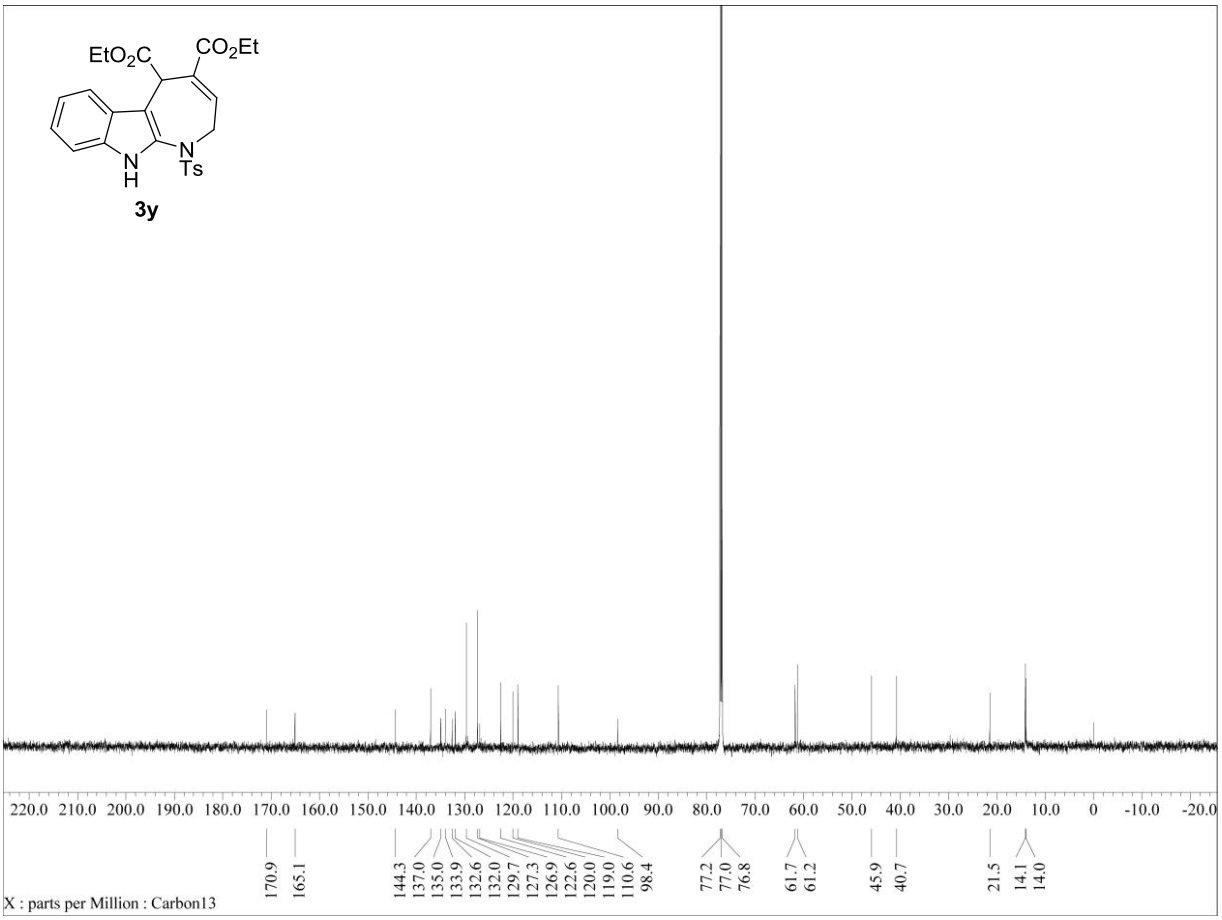

CO2Et
N
H
N
Ts
3w
0.99
0.96
2.82
0.91
2.88
1.00
2.03
2.99
2.85
5.70
3.35
5.03
10.0
9.0
8.0
7.0
6.0
5.0
4.0
3.0
2.0
1.0
0
8.996
7.526
7.514
7.366
7.352
7.348
7.335
7.215
7.205
7.202
7.191
7.132
7.129
7.123
7.118
7.110
7.106
6.657
6.647
6.635
4.612
4.601
4.585
4.573
4.558
4.547
4.077
4.075
4.071
4.066
4.064
4.054
4.051
4.042
4.040
2.311
1.527
1.506
1.457
1.441
1.242
1.230
1.218
0.998
0.992
0.975
0.963
0.948
0.927
0.909
0.904
0.897
0.881
0.873
0.865
0.862
0.854
0.850
0.844
0.841
0.839
0.833
0.827
X : parts per Million : Proton

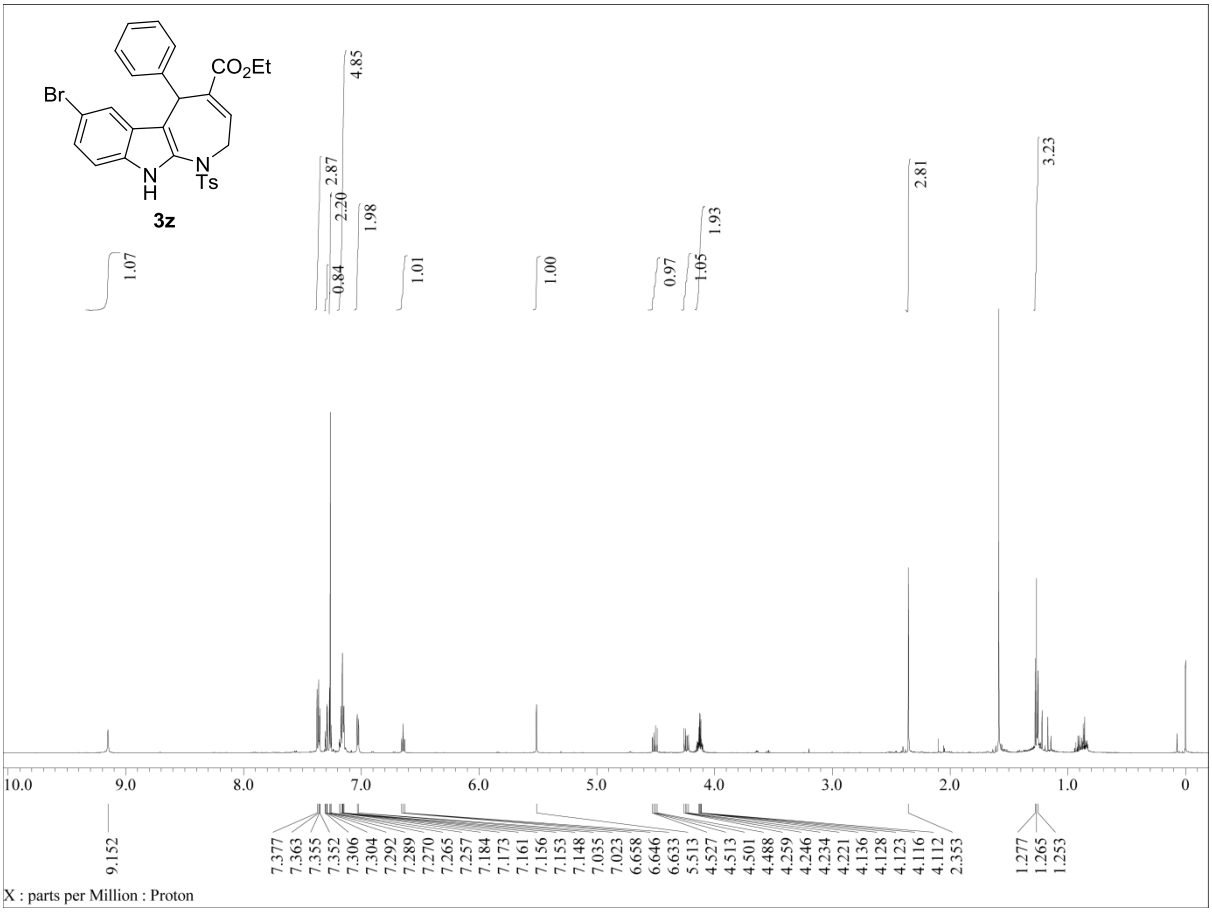

CO2Et
N
H
N
Ts
3w
200.0
190.0
180.0
170.0
160.0
150.0
140.0
130.0
120.0
110.0
100.0
90.0
80.0
70.0
60.0
50.0
40.0
30.0
20.0
10.0
0
166.8
144.2
139.2
135.1
132.5
131.9
130.8
129.7
127.9
127.2
122.0
119.5
119.2
110.5
105.4
77.2
77.0
76.8
60.9
46.3
45.9
39.3
32.2
31.0
26.4
26.3
26.1
21.5
14.1
X : parts per Million : Carbon13

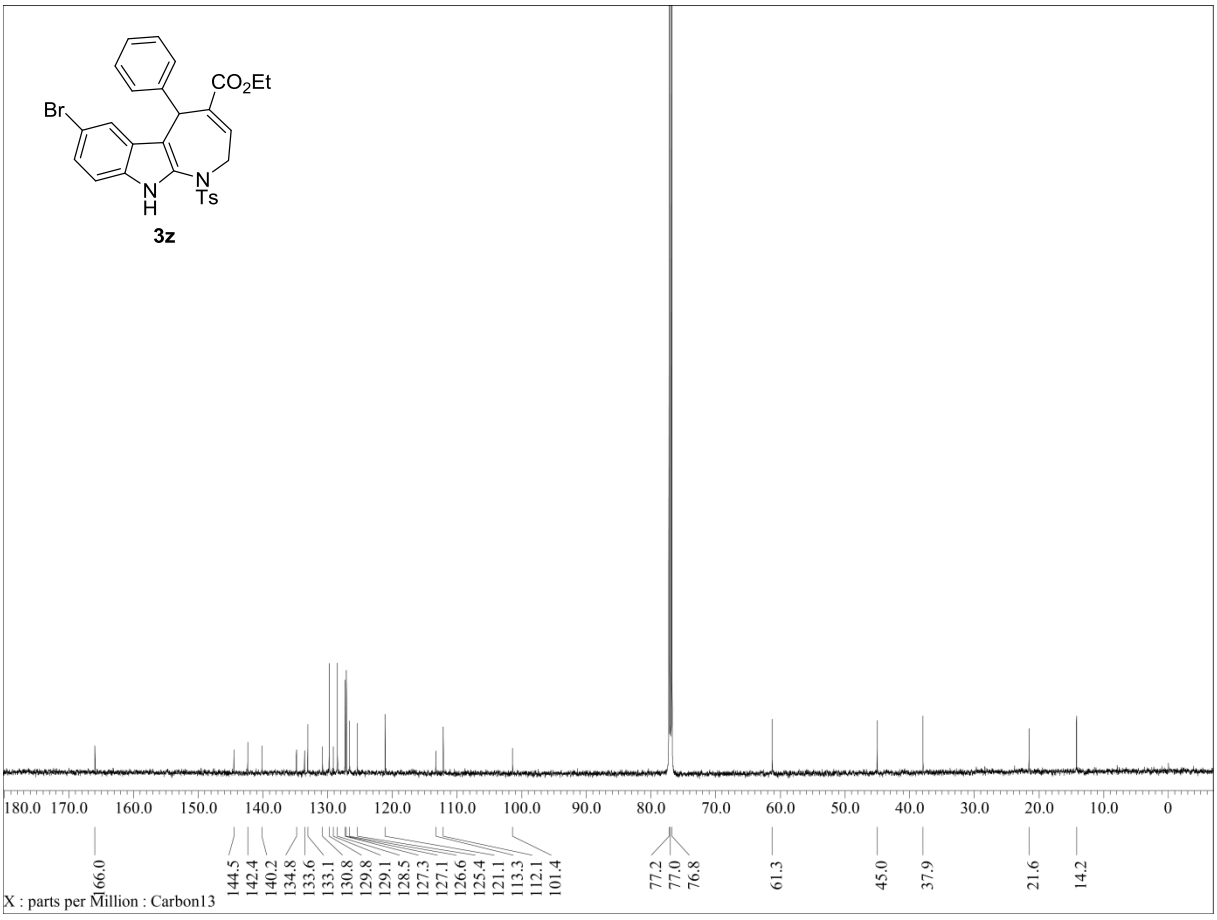

CO2Et
N
H
N
Ts
3x
0.97
0.93
1.07
1.00
2.83
2.84
2.00
0.96
1.99
3.11
2.02
1.07
3.23
2.90
3.35
9.0
8.0
7.0
6.0
5.0
4.0
3.0
2.0
1.0
0
8.818
7.481
7.468
7.370
7.356
7.345
7.238
7.227
7.214
7.149
7.136
7.120
7.106
6.700
6.688
6.676
4.618
4.606
4.590
4.579
4.565
4.552
4.537
4.526
4.325
4.317
4.309
4.301
4.080
4.068
4.056
4.044
2.306
1.527
1.519
1.510
1.504
1.497
1.488
1.480
1.456
1.448
1.441
1.433
1.426
1.418
1.410
1.354
1.342
1.332
1.327
1.319
1.309
1.302
1.256
1.245
1.232
0.951
0.941
0.839
0.828
X : parts per Million : Proton

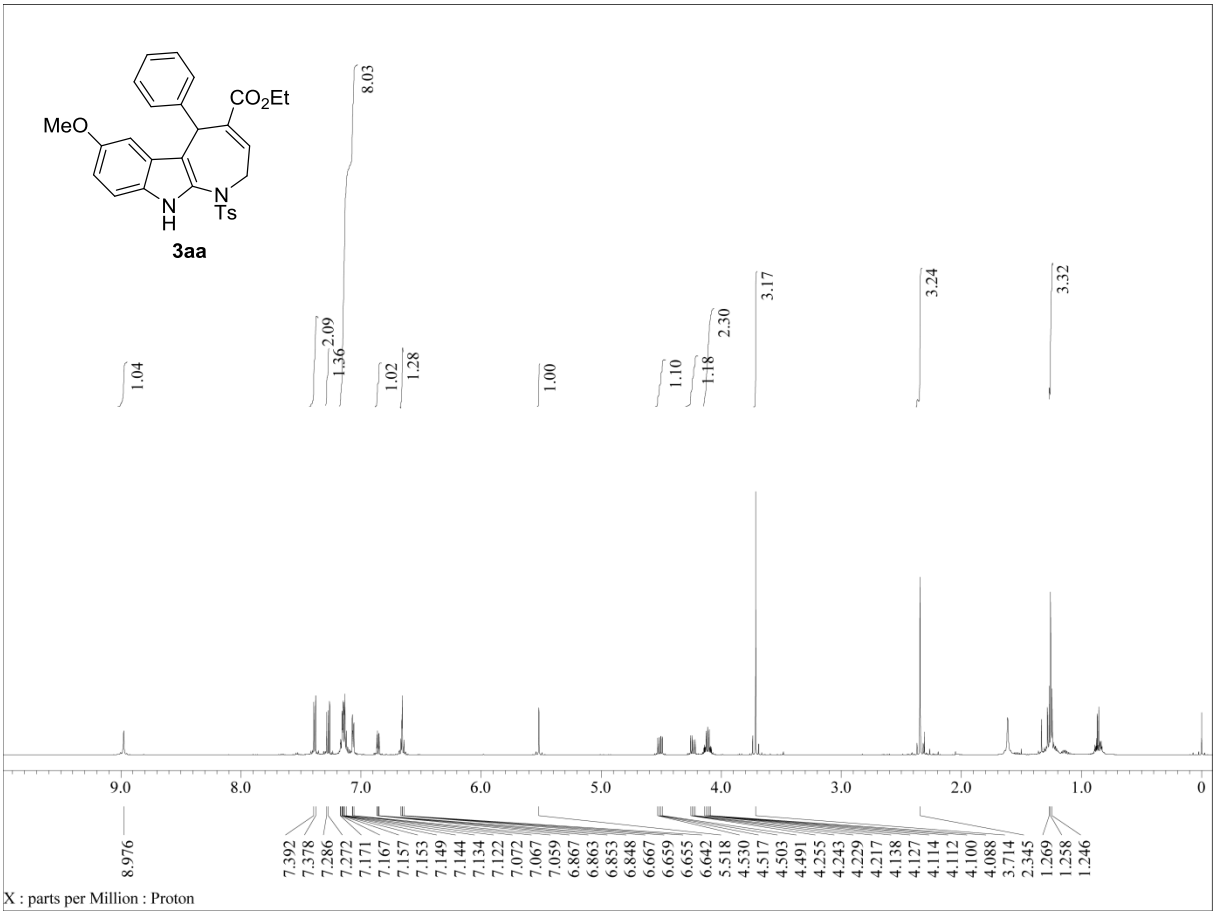

CO2Et
N
H
N
Ts
3x
180.0
170.0
160.0
150.0
140.0
130.0
120.0
110.0
100.0
90.0
80.0
70.0
60.0
50.0
40.0
30.0
20.0
10.0
0
166.4
144.1
139.5
135.2
133.5
132.3
130.8
129.6
127.3
126.7
122.3
119.6
118.2
110.7
106.7
77.2
77.0
76.8
60.9
48.0
46.1
31.6
26.1
23.6
22.0
21.5
14.1
X : parts per Million : Carbon13

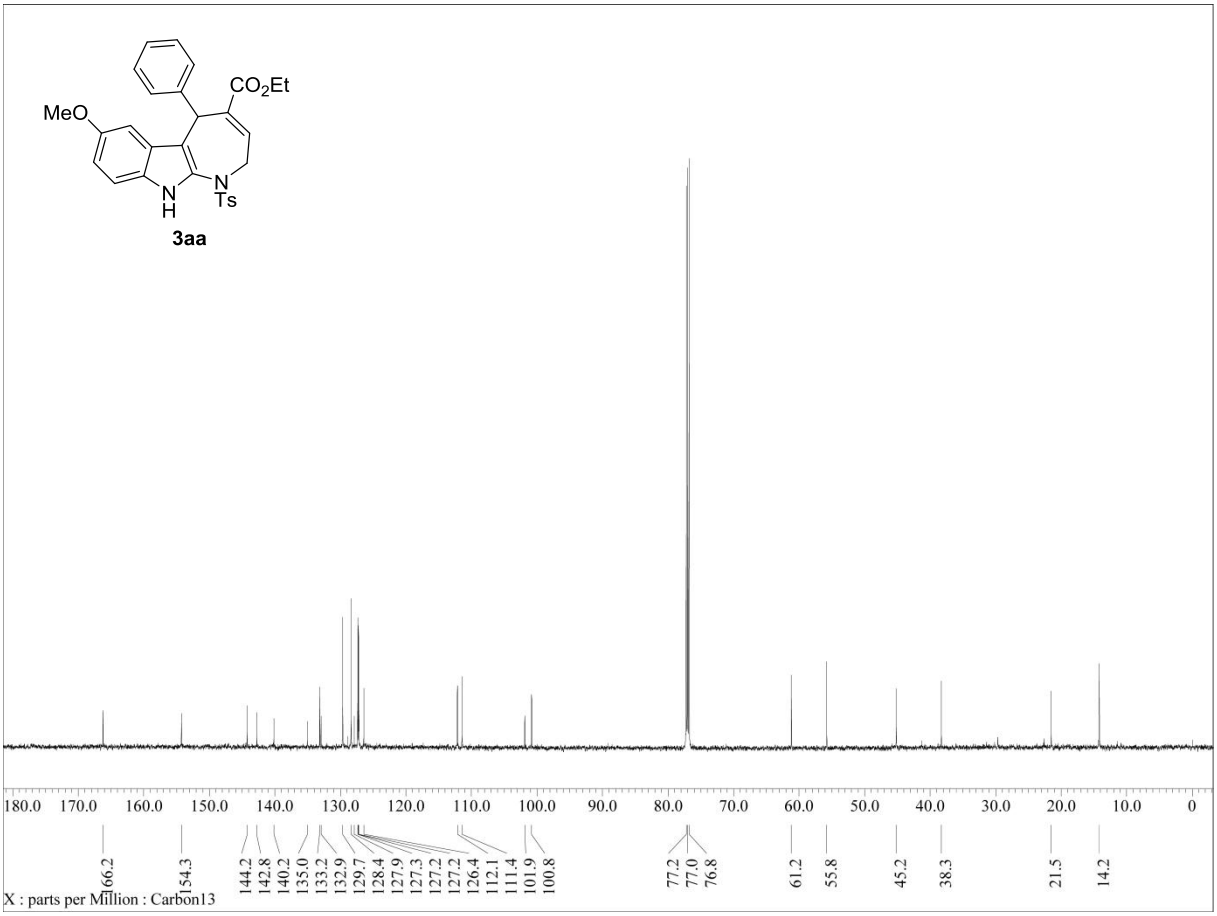

EtO2C
CO2Et
N
H
N
Ts
3y
4.03
2.94
3.29
3.00
2.88
1.89
1.00
1.01
1.04
0.86
0.89
0.95
1.00
1.00
10.0
9.0
8.0
7.0
6.0
5.0
4.0
3.0
2.0
1.0
0
8.991
7.658
7.645
7.360
7.346
7.252
7.240
7.238
7.227
7.172
7.158
7.146
7.123
7.110
6.899
6.888
6.875
5.162
4.759
4.746
4.733
4.720
4.660
4.648
4.634
4.621
4.083
4.079
4.072
4.068
4.060
4.056
4.049
4.043
4.036
4.030
2.309
1.247
1.236
1.224
1.175
1.164
1.152
X : parts per Million : Proton

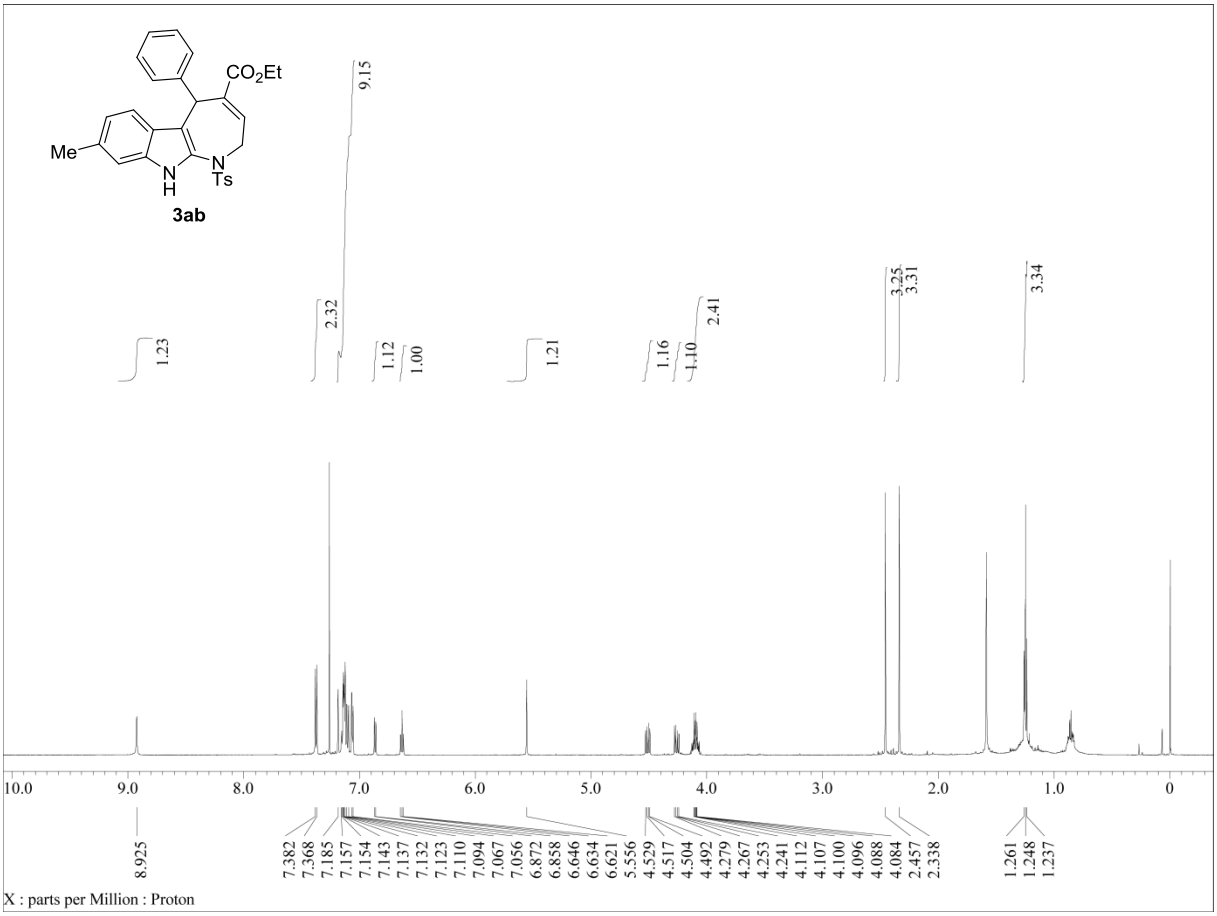

EtO2C
CO2Et
N
H
N
Ts
3y
220.0
210.0
200.0
190.0
180.0
170.0
160.0
150.0
140.0
130.0
120.0
110.0
100.0
90.0
80.0
70.0
60.0
50.0
40.0
30.0
20.0
10.0
0
-10.0
-20.0
170.9
165.1
144.3
137.0
135.0
133.9
132.6
132.0
129.7
127.3
126.9
122.6
120.0
119.0
110.6
98.4
77.2
77.0
76.8
61.7
61.2
45.9
40.7
21.5
14.1
14.0
X : parts per Million : Carbon13

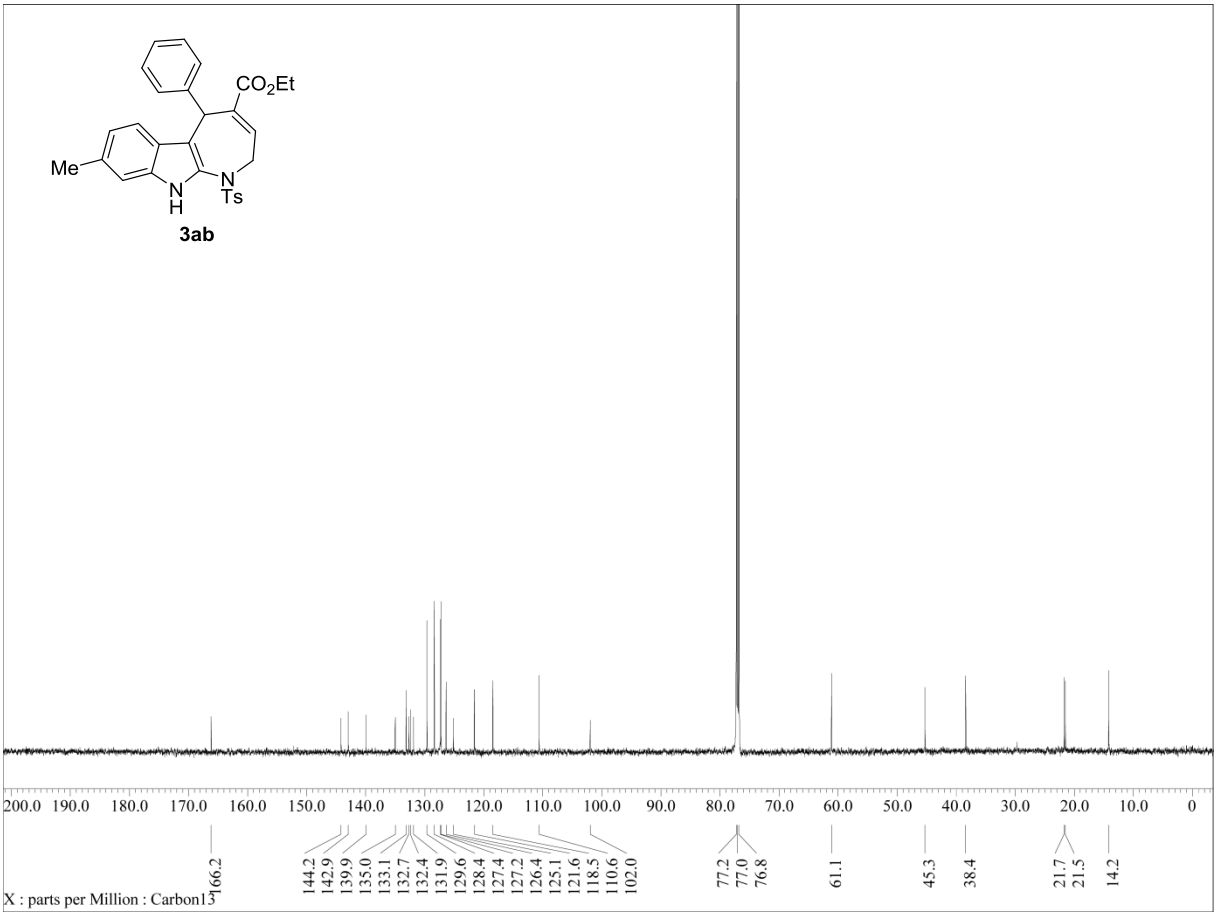

CO2Et
Br
N
H
N
Ts
3z
4.85
2.87
2.20
1.98
1.93
3.23
2.81
1.07
0.84
1.01
1.00
0.97
1.05
10.0
9.0
8.0
7.0
6.0
5.0
4.0
3.0
2.0
1.0
0
9.152
7.377
7.363
7.355
7.352
7.306
7.304
7.292
7.289
7.270
7.265
7.257
7.184
7.173
7.161
7.156
7.153
7.148
7.035
7.023
6.658
6.646
6.633
5.513
4.527
4.513
4.501
4.488
4.259
4.246
4.234
4.221
4.136
4.128
4.123
4.116
4.112
2.353
1.277
1.265
1.253
X : parts per Million : Proton

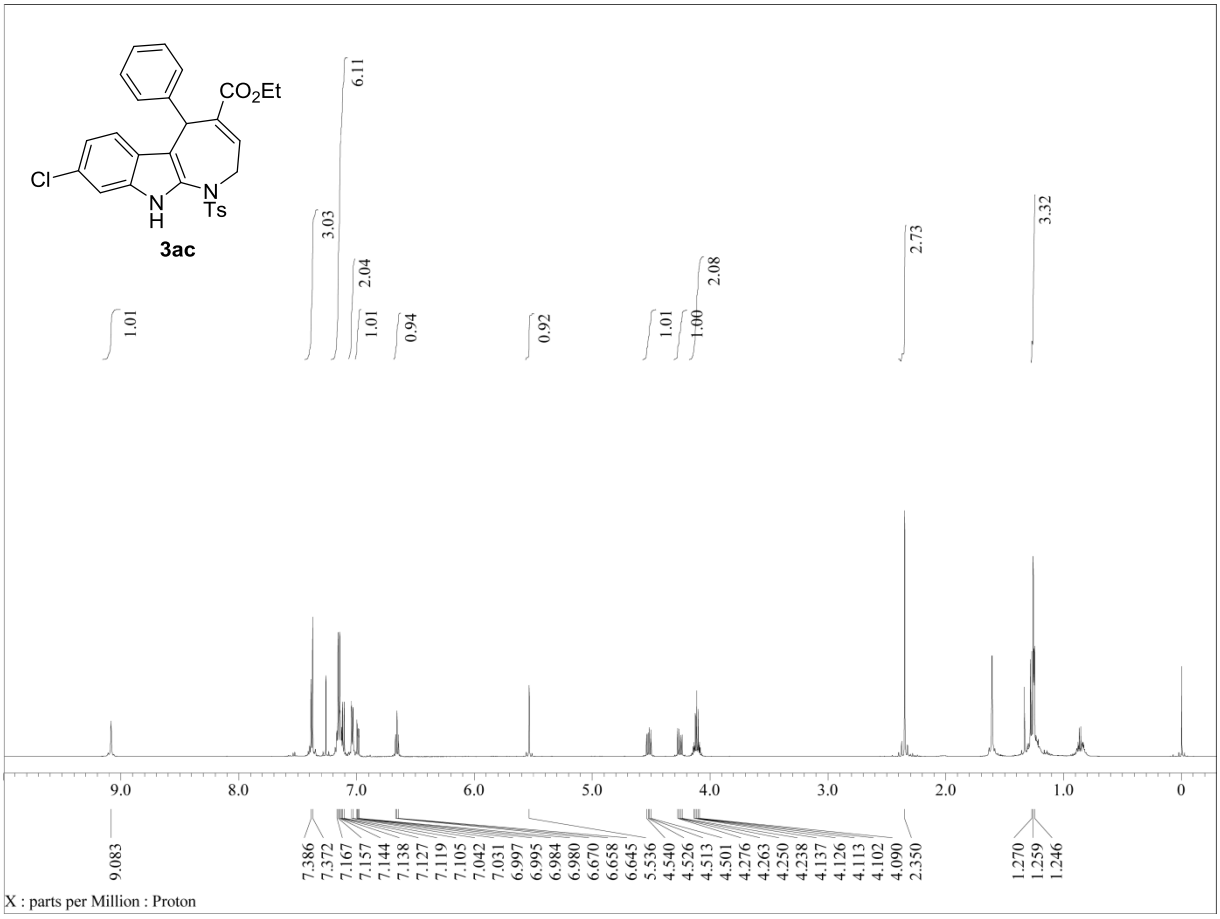

CO2Et
Br
N
H
N
Ts
3z
180.0
170.0
160.0
150.0
140.0
130.0
120.0
110.0
100.0
90.0
80.0
70.0
60.0
50.0
40.0
30.0
20.0
10.0
0
166.0
144.5
142.4
140.2
134.8
133.6
133.1
130.8
129.8
129.1
128.5
127.3
127.1
126.6
125.4
121.1
113.3
112.1
101.4
77.2
77.0
76.8
61.3
45.0
37.9
21.6
14.2
X : parts per Million : Carbon13

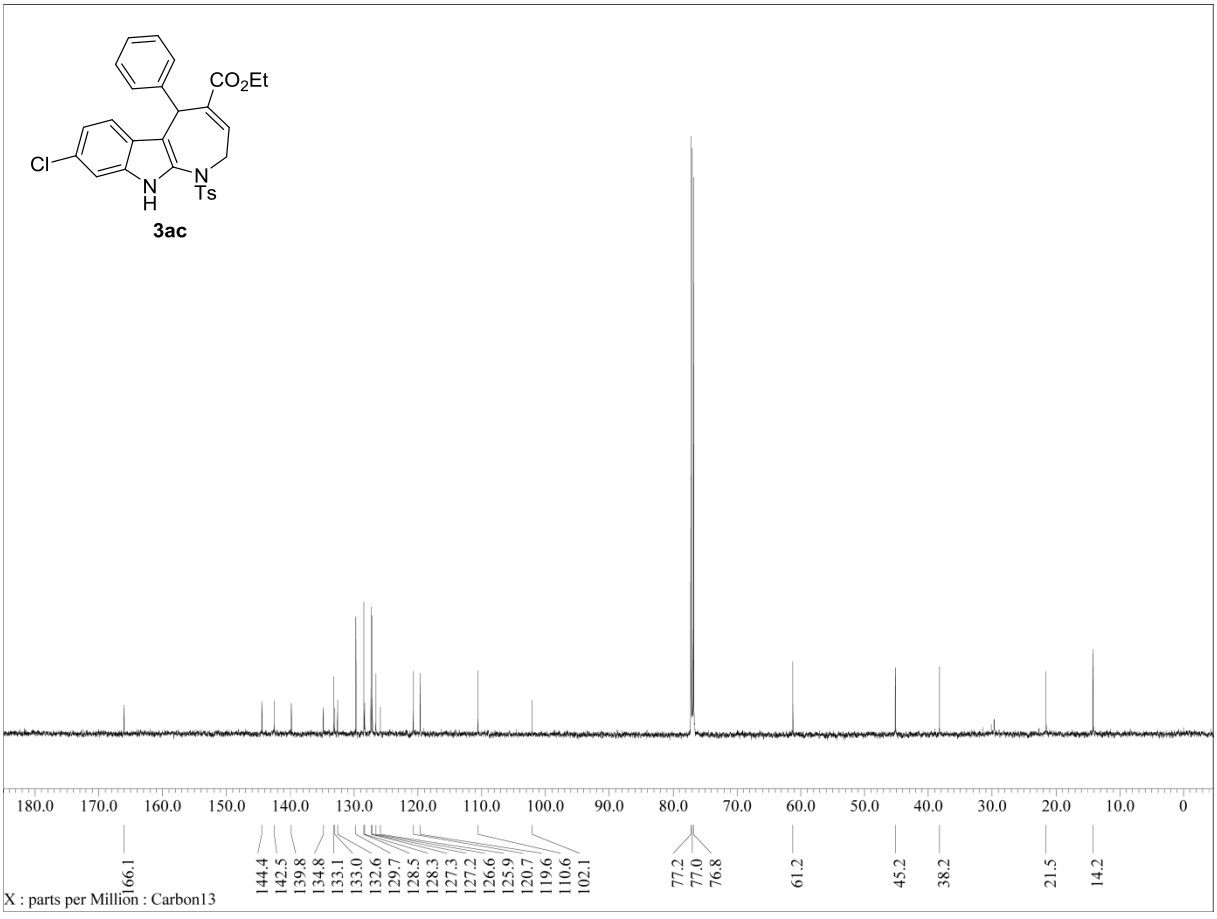

MeO
CO2Et
N
H
N
Ts
3aa
8.03
2.09
1.36
1.02
1.28
1.00
1.10
1.18
2.30
3.17
3.24
3.32
1.04
9.0
8.0
7.0
6.0
5.0
4.0
3.0
2.0
1.0
0
8.976
7.392
7.378
7.286
7.272
7.171
7.167
7.157
7.153
7.149
7.144
7.134
7.122
7.072
7.067
7.059
6.867
6.863
6.853
6.848
6.667
6.659
6.655
6.642
5.518
4.530
4.517
4.503
4.491
4.255
4.243
4.229
4.217
4.138
4.127
4.114
4.112
4.100
4.088
3.714
2.345
1.269
1.258
1.246
X : parts per Million : Proton

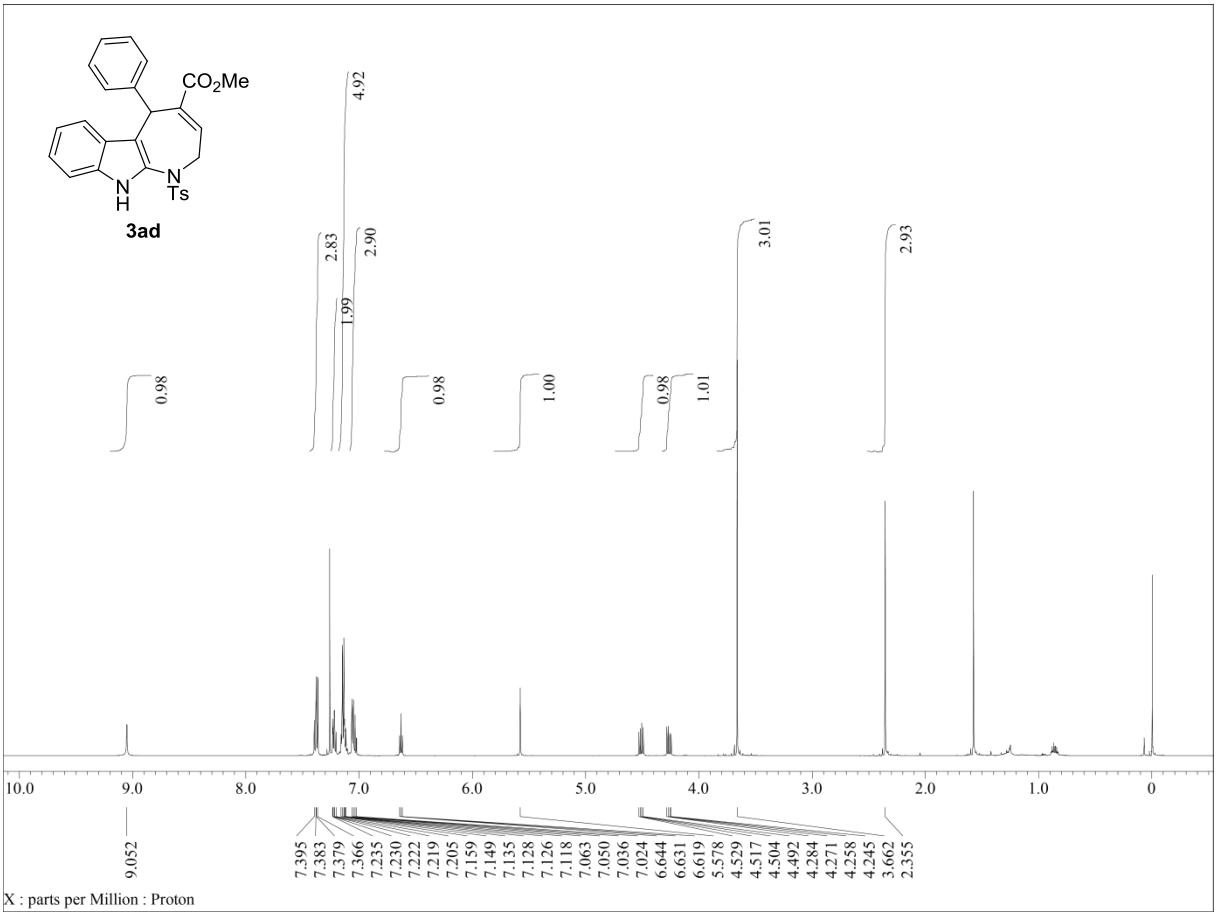

MeO
CO2Et
N
H
N
Ts
3aa
180.0
170.0
160.0
150.0
140.0
130.0
120.0
110.0
100.0
90.0
80.0
70.0
60.0
50.0
40.0
30.0
20.0
10.0
0
166.2
154.3
144.2
142.8
140.2
135.0
133.2
132.9
129.7
128.4
127.9
127.3
127.2
127.2
126.4
112.1
111.4
101.9
100.8
77.2
77.0
76.8
61.2
55.8
45.2
38.3
21.5
14.2
X : parts per Million : Carbon13

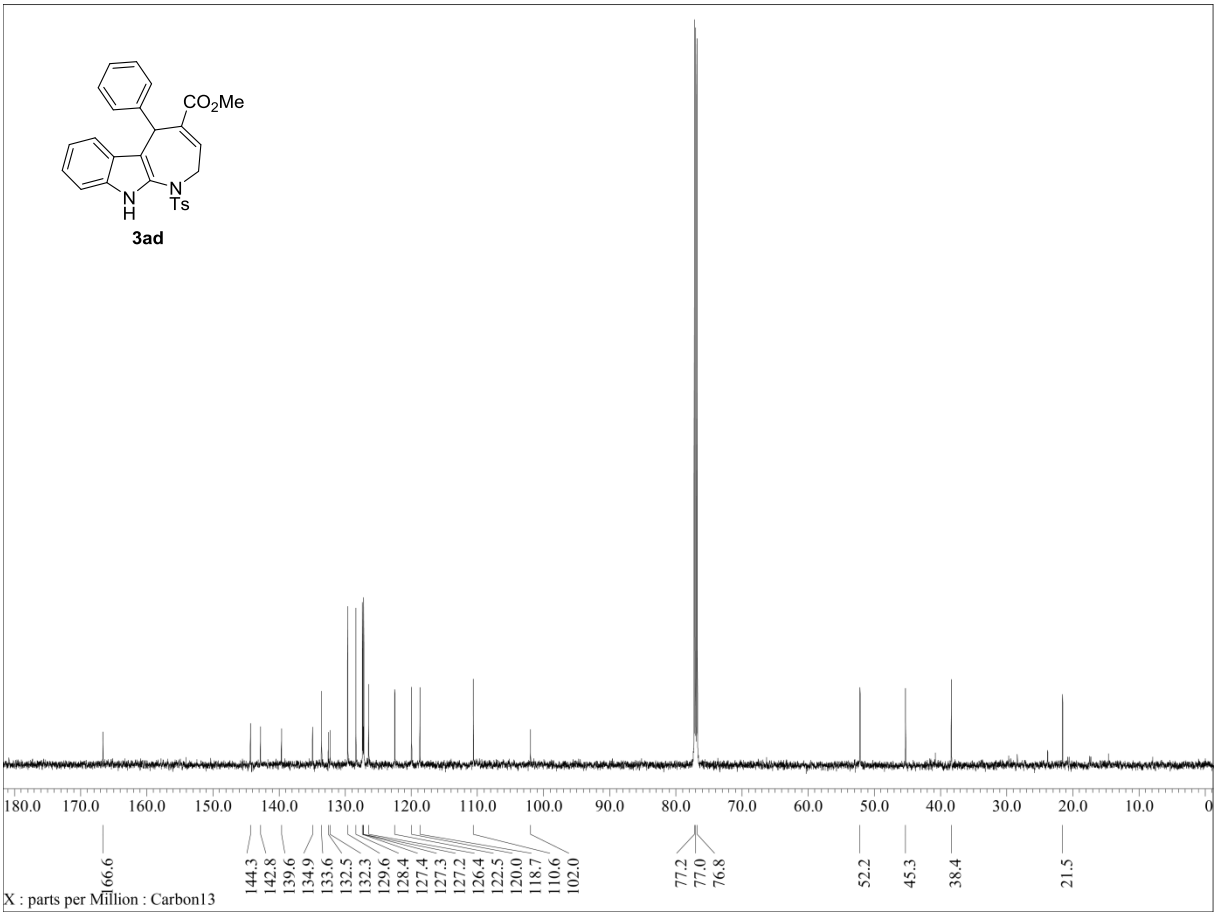

CO2Et
Me
N
H
N
Ts
3ab
9.15
2.32
1.23
1.12
1.00
1.21
1.16
1.10
2.41
3.25
3.31
3.34
10.0
9.0
8.0
7.0
6.0
5.0
4.0
3.0
2.0
1.0
0
8.925
7.382
7.368
7.185
7.157
7.154
7.143
7.137
7.132
7.123
7.110
7.094
7.067
7.056
6.872
6.858
6.646
6.634
6.621
5.556
4.529
4.517
4.504
4.492
4.279
4.267
4.253
4.241
4.112
4.107
4.100
4.096
4.088
4.084
2.457
2.338
1.261
1.248
1.237
X : parts per Million : Proton

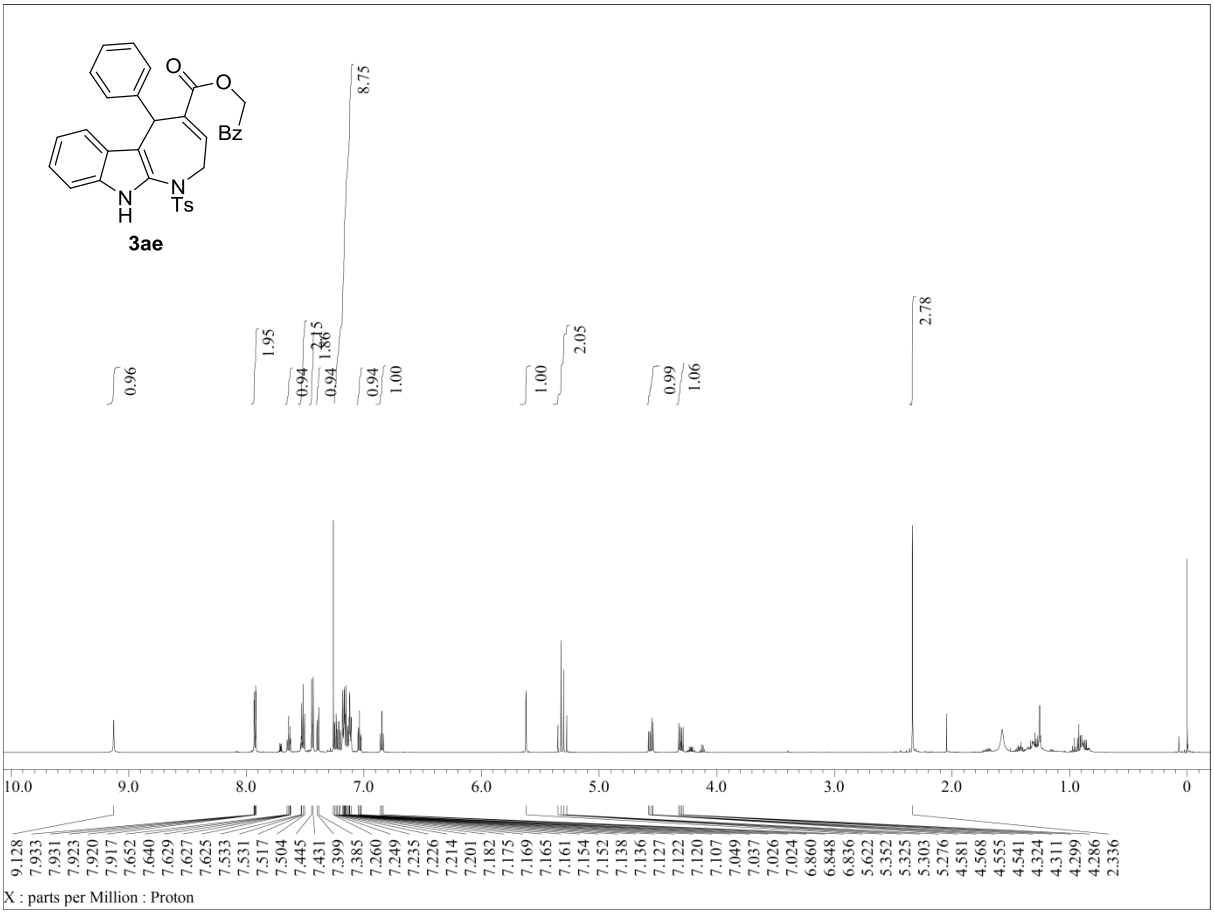

CO2Et
Me
N
H
N
Ts
3ab
200.0
190.0
180.0
170.0
160.0
150.0
140.0
130.0
120.0
110.0
100.0
90.0
80.0
70.0
60.0
50.0
40.0
30.0
20.0
10.0
0
166.2
144.2
142.9
139.9
135.0
133.1
132.7
132.4
131.9
129.6
128.4
127.4
127.2
126.4
125.1
121.6
118.5
110.6
102.0
77.2
77.0
76.8
61.1
45.3
38.4
21.7
21.5
14.2
X : parts per Million : Carbon13

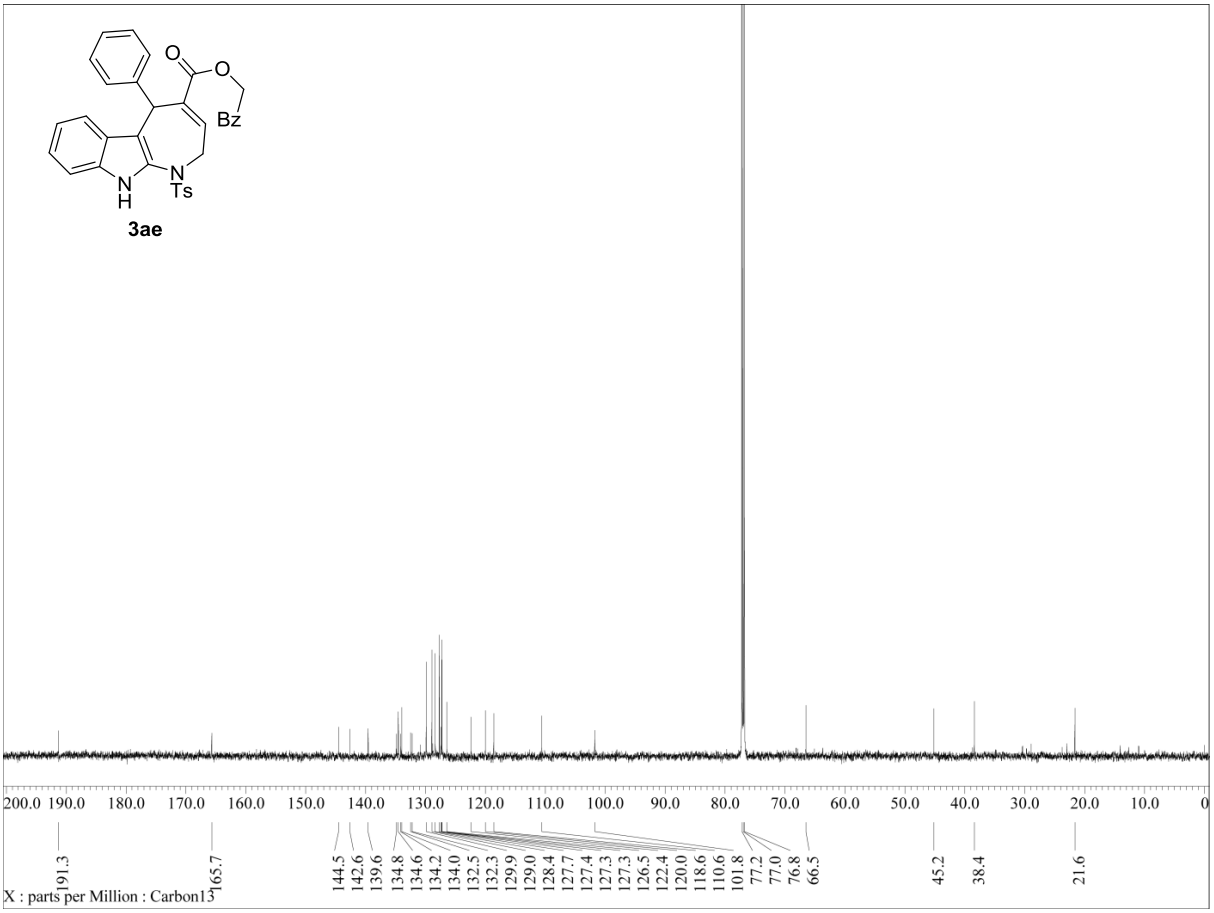

CO2Et
Cl
N
H
N
Ts
3ac
6.11
3.03
2.04
1.01
0.94
0.92
1.01
1.00
2.08
2.73
3.32
1.01
9.0
8.0
7.0
6.0
5.0
4.0
3.0
2.0
1.0
0
9.083
7.386
7.372
7.167
7.157
7.144
7.138
7.127
7.119
7.105
7.042
7.031
6.997
6.995
6.984
6.980
6.670
6.658
6.645
5.536
4.540
4.526
4.513
4.501
4.276
4.263
4.250
4.238
4.137
4.126
4.113
4.102
4.090
2.350
1.270
1.259
1.246
X : parts per Million : Proton

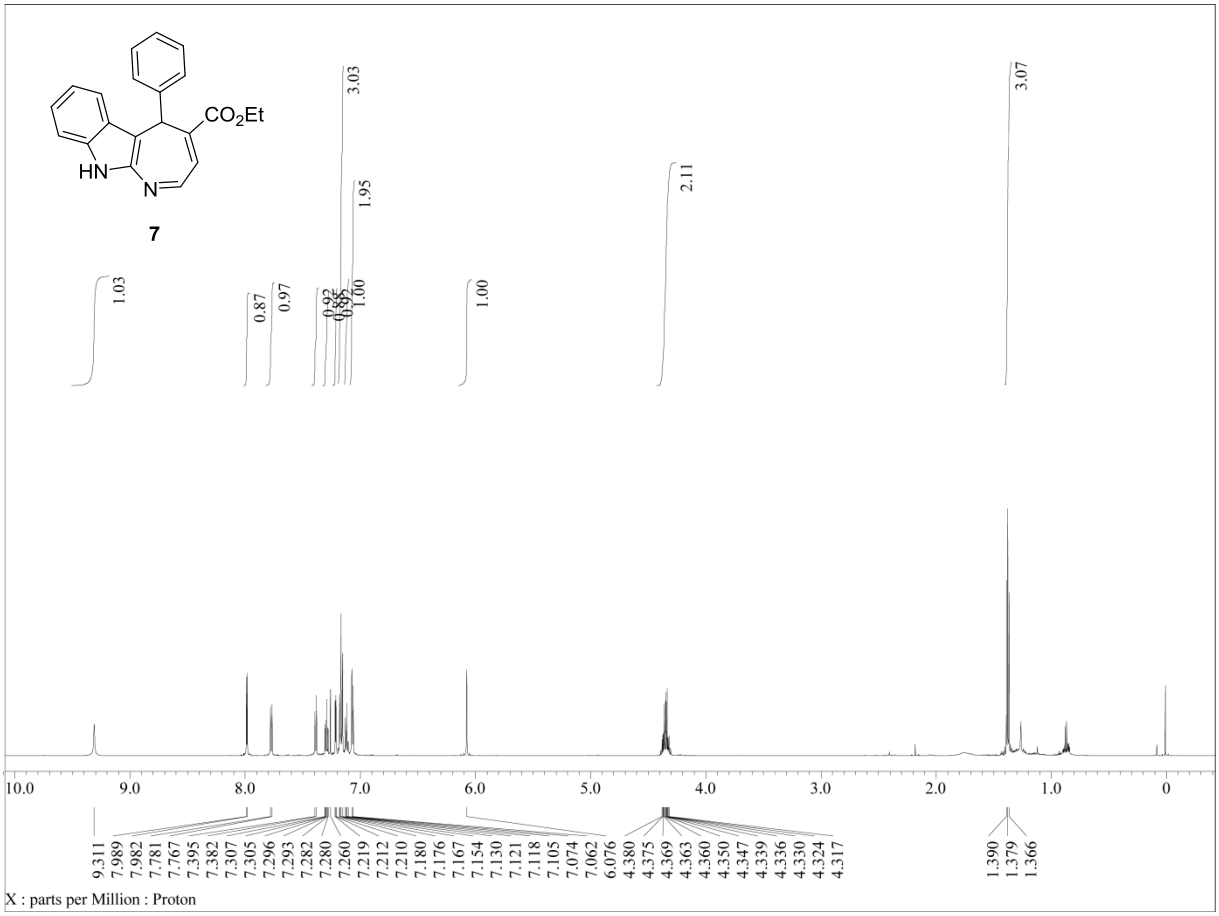

CO2Et
Cl
N
H
N
Ts
3ac
180.0
170.0
160.0
150.0
140.0
130.0
120.0
110.0
100.0
90.0
80.0
70.0
60.0
50.0
40.0
30.0
20.0
10.0
0
166.1
144.4
142.5
139.8
134.8
133.1
133.0
132.6
129.7
128.5
128.3
127.3
127.2
126.6
125.9
120.7
119.6
110.6
102.1
77.2
77.0
76.8
61.2
45.2
38.2
21.5
14.2
X : parts per Million : Carbon13

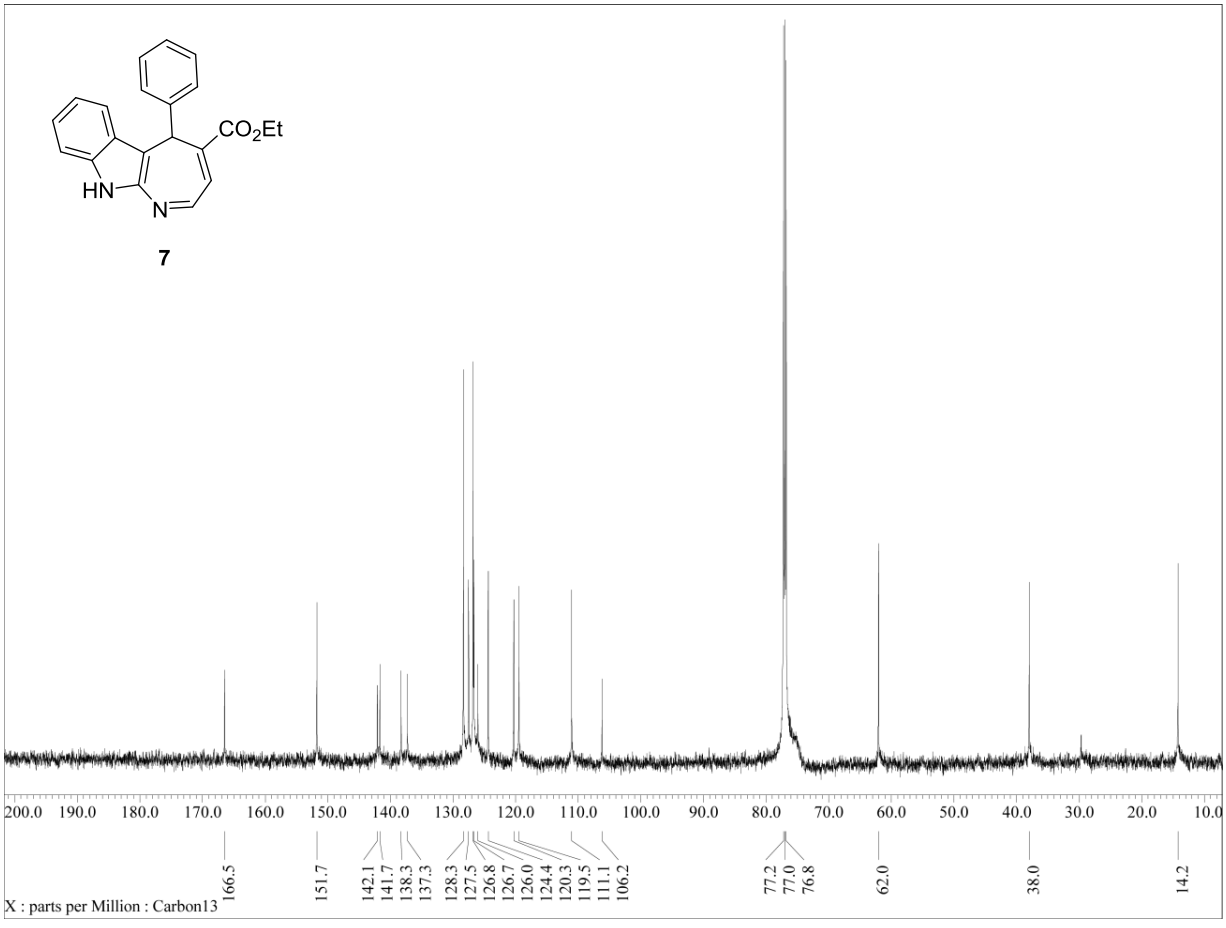

CO2Me
N
H
N
Ts
3ad
4.92
2.83
2.90
1.99
3.01
2.93
0.98
0.98
1.00
0.98
1.01
10.0
9.0
8.0
7.0
6.0
5.0
4.0
3.0
2.0
1.0
0
9.052
7.395
7.383
7.379
7.366
7.235
7.230
7.222
7.219
7.205
7.159
7.149
7.135
7.128
7.126
7.118
7.063
7.050
7.036
7.024
6.644
6.631
6.619
5.578
4.529
4.517
4.504
4.492
4.284
4.271
4.258
4.245
3.662
2.355
X : parts per Million : Proton

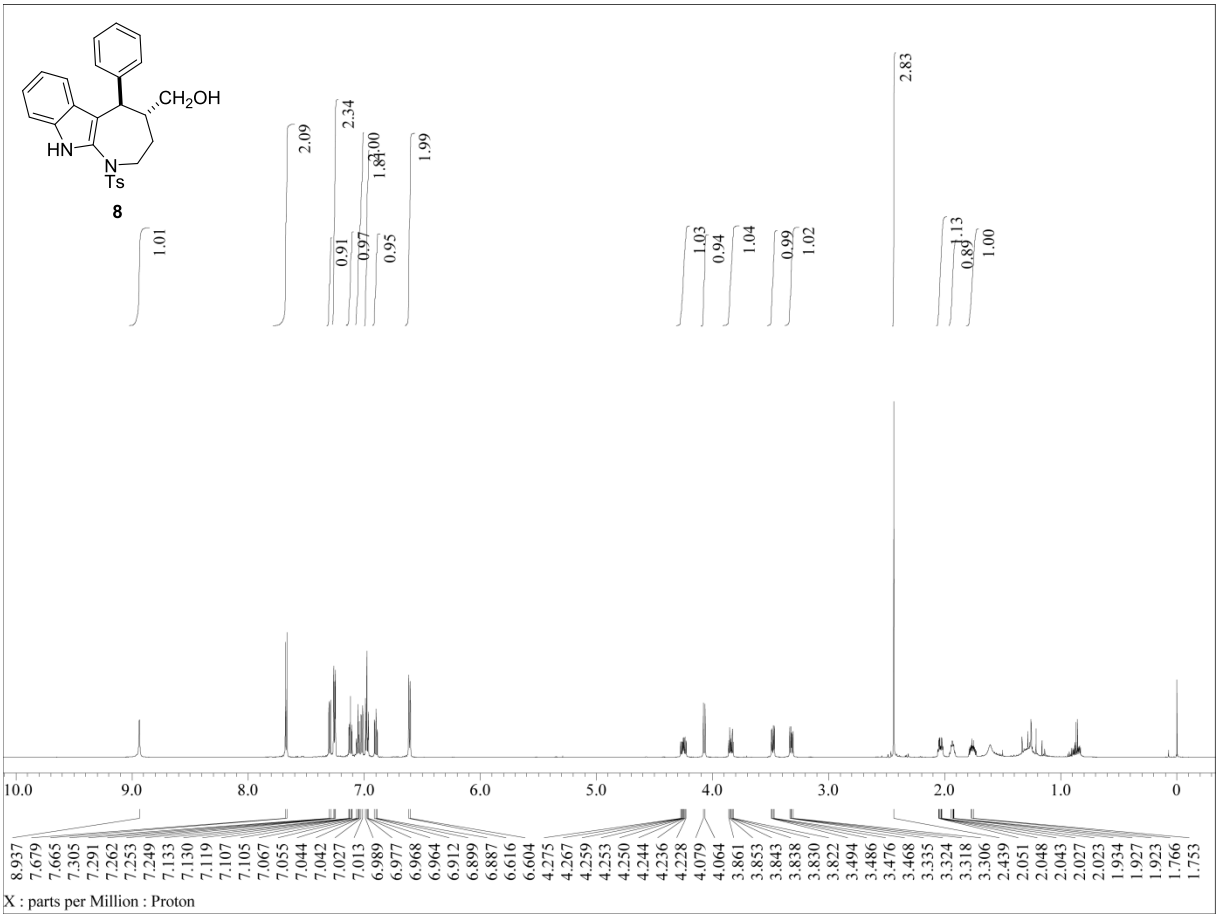

CO2Me
N
H
N
Ts
3ad
180.0
170.0
160.0
150.0
140.0
130.0
120.0
110.0
100.0
90.0
80.0
70.0
60.0
50.0
40.0
30.0
20.0
10.0
0
166.6
144.3
142.8
139.6
134.9
133.6
132.5
132.3
129.6
128.4
127.4
127.3
127.2
126.4
122.5
120.0
118.7
110.6
102.0
77.2
77.0
76.8
52.2
45.3
38.4
21.5
X : parts per Million : Carbon13

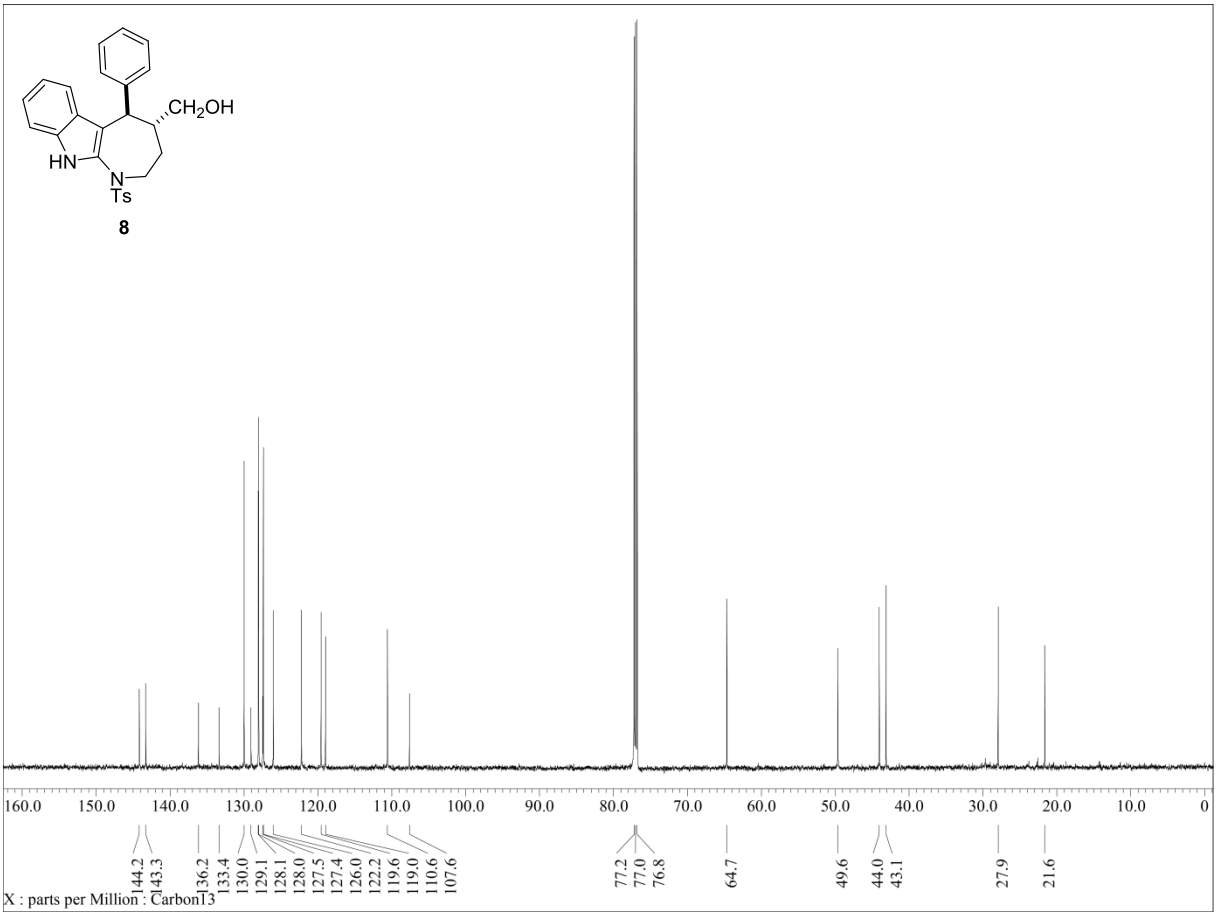

3ae
0.96
1.95
0.94
2.15
1.88
0.94
8.75
0.94
1.00
1.00
2.05
0.99
1.06
2.78
10.0
9.0
8.0
7.0
6.0
5.0
4.0
3.0
2.0
1.0
0
9.128
7.933
7.931
7.923
7.920
7.917
7.652
7.640
7.629
7.627
7.625
7.533
7.531
7.517
7.504
7.445
7.431
7.399
7.385
7.260
7.249
7.235
7.226
7.214
7.201
7.182
7.175
7.169
7.165
7.161
7.154
7.152
7.138
7.136
7.127
7.122
7.120
7.107
7.049
7.037
7.026
7.024
6.860
6.848
6.836
5.622
5.352
5.325
5.303
5.276
4.581
4.568
4.555
4.541
4.324
4.311
4.299
4.286
2.336
X : parts per Million : Proton

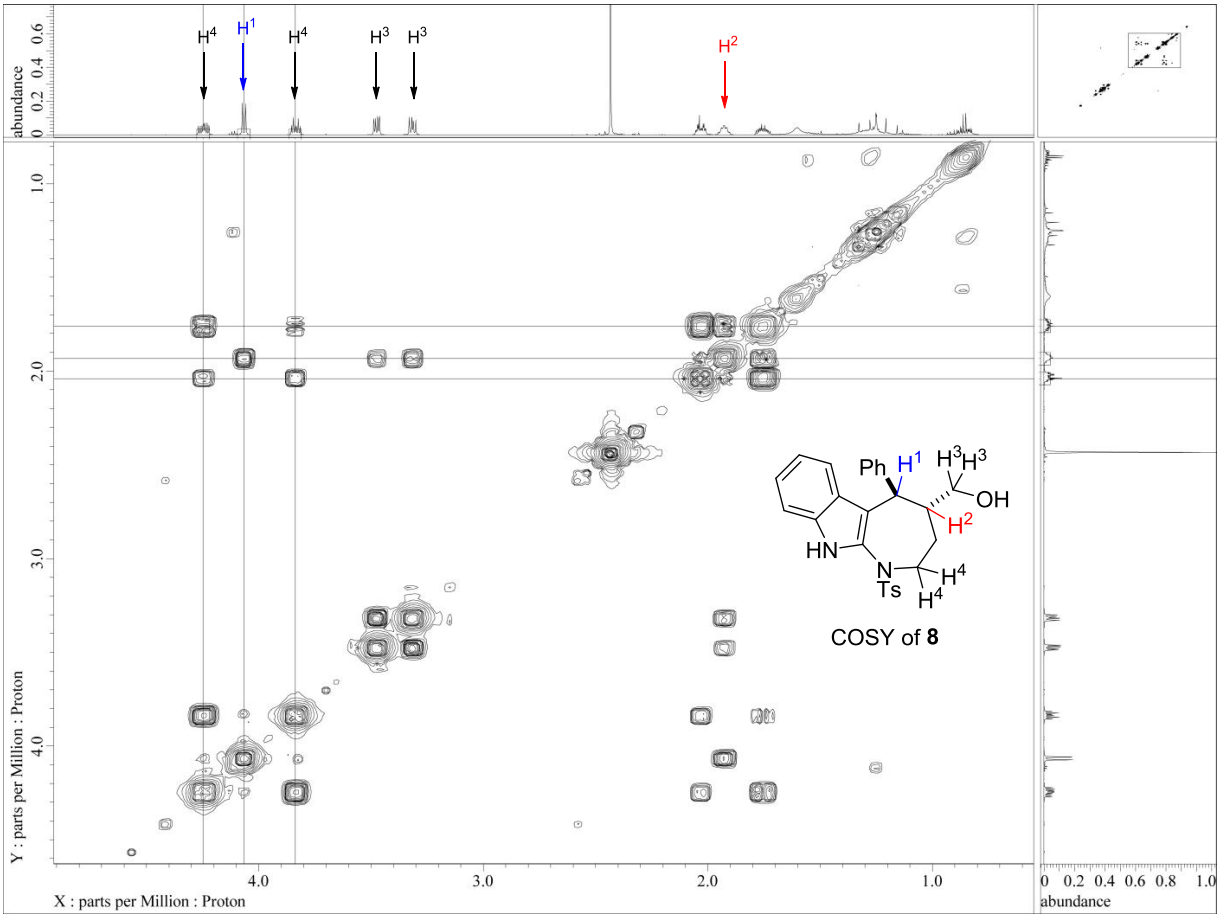

3ae
200.0
190.0
180.0
170.0
160.0
150.0
140.0
130.0
120.0
110.0
100.0
90.0
80.0
70.0
60.0
50.0
40.0
30.0
20.0
10.0
0
191.3
165.7
144.5
142.6
139.6
134.8
134.6
134.2
134.0
132.5
132.3
129.9
129.0
128.4
127.7
127.4
127.3
127.3
126.5
122.4
120.0
118.6
110.6
101.8
77.2
77.0
76.8
66.5
45.2
38.4
21.6
X : parts per Million : Carbon13


CO2Et
HN
N
7
3.03
1.95
2.11
3.07
1.03
0.87
0.97
1.00
1.00
10.0
9.0
8.0
7.0
6.0
5.0
4.0
3.0
2.0
1.0
0
9.311
7.989
7.982
7.781
7.767
7.395
7.382
7.307
7.305
7.296
7.293
7.282
7.280
7.260
7.219
7.212
7.210
7.180
7.176
7.167
7.154
7.130
7.121
7.118
7.105
7.074
7.062
6.076
4.380
4.375
4.369
4.363
4.360
4.350
4.347
4.339
4.336
4.330
4.324
4.317
1.390
1.379
1.366
X : parts per Million : Proton

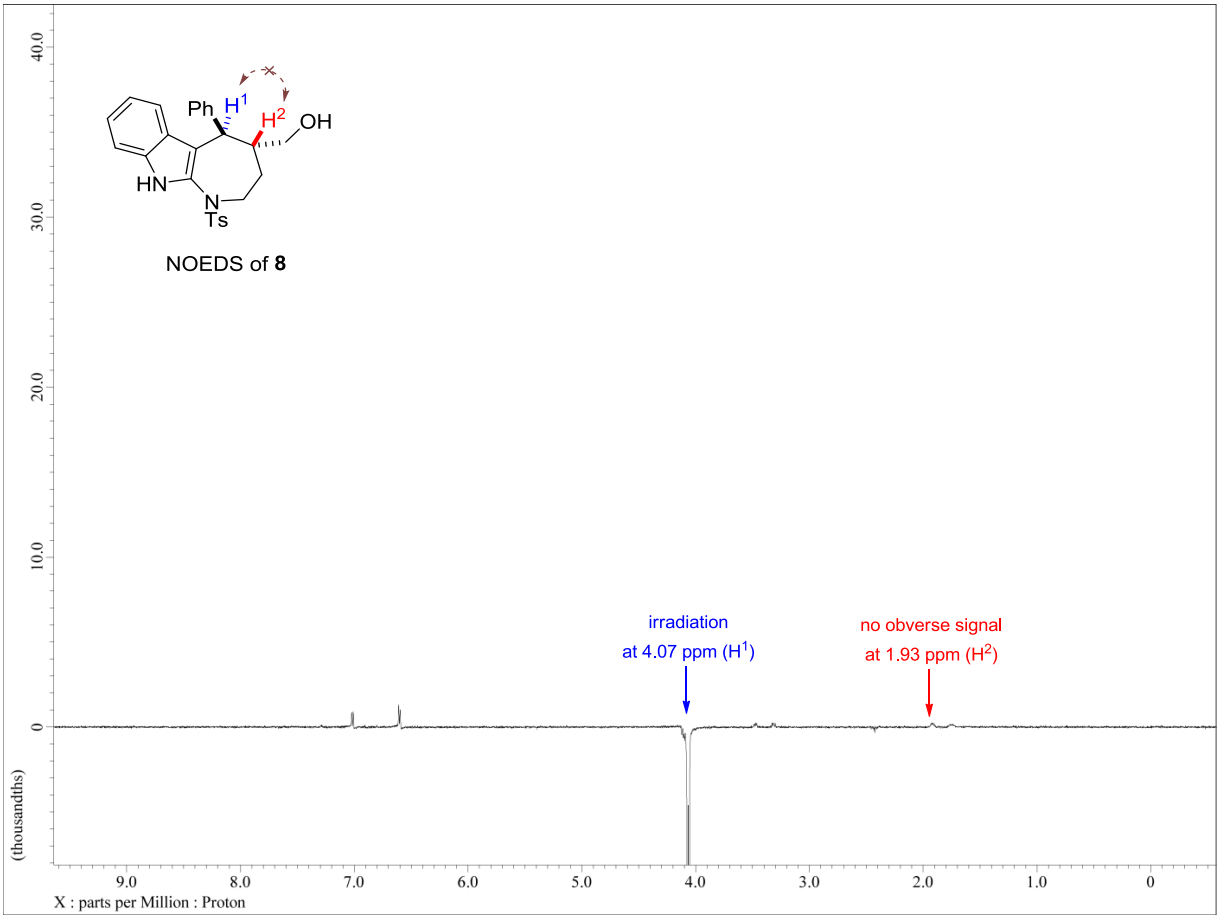

CO2Et
HN
N
7
200.0
190.0
180.0
170.0
160.0
150.0
140.0
130.0
120.0
110.0
100.0
90.0
80.0
70.0
60.0
50.0
40.0
30.0
20.0
10.0
166.5
151.7
142.1
141.7
138.3
137.3
128.3
127.5
126.8
126.7
126.0
124.4
120.3
119.5
111.1
106.2
77.2
77.0
76.8
62.0
38.0
14.2
X : parts per Million : Carbon13


CH2OH
HN
N
Ts
8
2.09
2.34
1.81
1.00
1.99
1.01
0.91
0.97
0.95
1.03
0.94
1.04
0.99
1.02
2.83
1.13
0.89
1.00
10.0
9.0
8.0
7.0
6.0
5.0
4.0
3.0
2.0
1.0
0
8.937
7.679
7.665
7.305
7.291
7.262
7.253
7.249
7.133
7.130
7.119
7.107
7.105
7.067
7.055
7.044
7.042
7.027
7.013
6.989
6.977
6.968
6.964
6.912
6.899
6.887
6.616
6.604
4.275
4.267
4.259
4.253
4.250
4.244
4.236
4.228
4.079
4.064
3.861
3.853
3.843
3.838
3.830
3.822
3.494
3.486
3.476
3.468
3.335
3.324
3.318
3.306
2.439
2.051
2.048
2.043
2.027
2.023
1.934
1.927
1.923
1.766
1.753
X : parts per Million : Proton

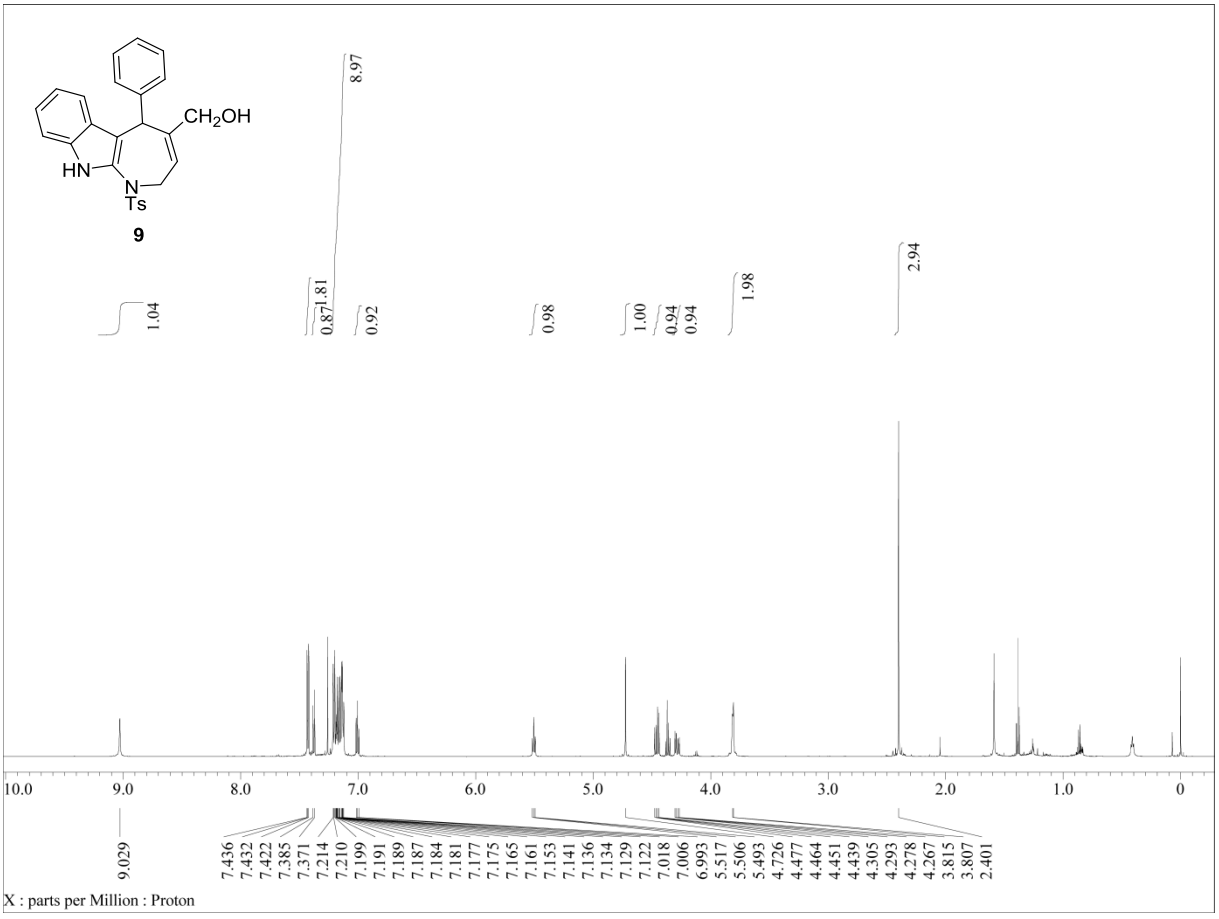

CH2OH
HN
N
Ts
8
160.0
150.0
140.0
130.0
120.0
110.0
100.0
90.0
80.0
70.0
60.0
50.0
40.0
30.0
20.0
10.0
0
144.2
143.3
136.2
133.4
130.0
129.1
128.1
128.0
127.5
127.4
126.0
122.2
119.6
119.0
110.6
107.6
77.2
77.0
76.8
64.7
49.6
44.0
43.1
27.9
21.6
X : parts per Million : Carbon13

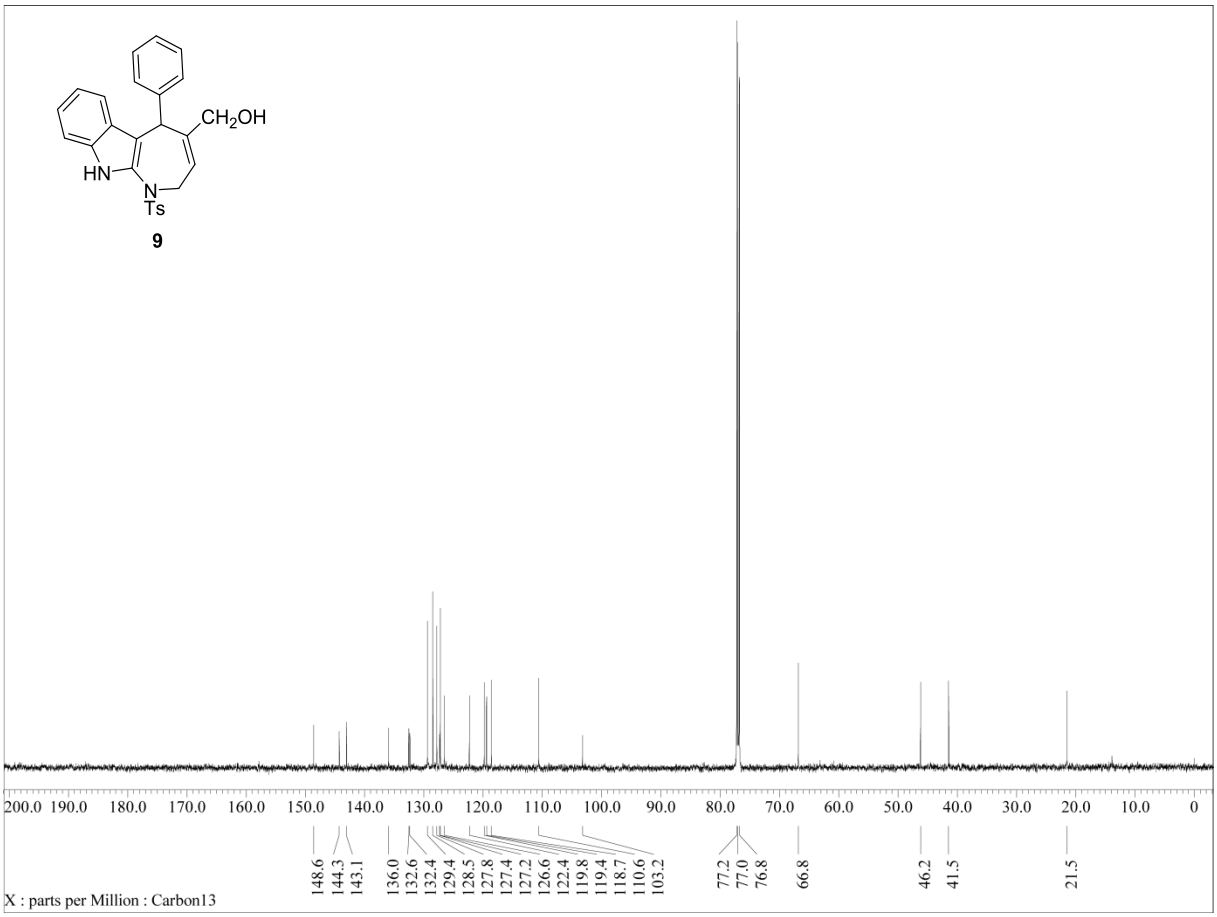



COSY of **8**




NOEDS of **8**


CH2OH
HN
N
Ts
9
8.97
2.94
1.98
1.04
1.81
0.87
0.92
0.98
1.00
0.94
0.94
10.0
9.0
8.0
7.0
6.0
5.0
4.0
3.0
2.0
1.0
0
9.029
7.436
7.432
7.422
7.385
7.371
7.214
7.210
7.199
7.191
7.189
7.187
7.184
7.181
7.177
7.175
7.165
7.161
7.153
7.141
7.136
7.134
7.129
7.122
7.018
7.006
6.993
5.517
5.506
5.493
4.726
4.477
4.464
4.451
4.439
4.305
4.293
4.278
4.267
3.815
3.807
2.401
X : parts per Million : Proton


CH2OH
HN
N
Ts
9
200.0
190.0
180.0
170.0
160.0
150.0
140.0
130.0
120.0
110.0
100.0
90.0
80.0
70.0
60.0
50.0
40.0
30.0
20.0
10.0
0
148.6
144.3
143.1
136.0
132.6
132.4
129.4
128.5
127.8
127.4
127.2
126.6
122.4
119.8
119.4
118.7
110.6
103.2
77.2
77.0
76.8
66.8
46.2
41.5
21.5
X : parts per Million : Carbon13