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# An unusual acetylene–allene rearrangement in iodomethylates of cotarnine acetylene derivatives

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1D and 2D NMR spectra of compounds **2a**, **2b**, **3c** and **3d** were recorded at 20 °C on Bruker AVANCE 600 (600 MHz). Chemical shifts of nuclei $^1$H ($\delta$, ppm) and $^{13}$C were measured relatively the residual signals of deuteron solvent ($\delta$ = 2.49 ppm for protons and 39.5 ppm for carbon nuclei). Mass spectra (EI, 70 eV) were obtained on Finnigan MATINCOS-50 instrument using direct input of sample. IR spectra were recorded on Varian Excalibur 3100 FT-IR spectrometer in nujol.

## Experimental

*4-Methoxy-6,6-dimethyl-5-(3-phenoxyprop-1-yn-1-yl)-5,6,7,8-tetrahydro[1,3]dioxolo-[4,5-g]isoquinolin-6-ium iodide* **2a**. Compound **1a** (0.9 g, 2.5 mmol) was dissolved in ethyl acetate (10 ml), $CH_3I$ (0.5 ml, 8 mmol) was added, and the mixture was slightly warmed until it got turbid and quickly crystallized. The precipitate was filtered off and washed with ethyl acetate and petroleum ether to afford the colorless product with mp 174-175 °C. Yield 1.1 g (87%). IR (Nujol, $\nu$/cm$^{-1}$): 1620s, 1787m, 1499s, 1486vs (arom.). $^1$H NMR (600 MHz, DMSO-$d_6$, $\delta$, *J*/Hz): 3.00 (s, 3H, $N^+CH_3$), 3.07 (m, 2H, $C^8H_2$), 3.28 (s, 3H, $N^+CH_3$), 3.60 (m, 2H, $C^7H_2$), 3.92 (s, 3H, $OCH_3$), 4.93 (d, 2H, $CH_2O$, *J* = 1.6), 5.71 (d, 1H, $C^5H$, *J* = 1.3), 6.03 (m, 2H, O-$CH_2$-O), 6.60 (s, 1H, $C^9H$), 6.98 (m, 3H, $CH_{arom.}$), 7.29 (m, 2H, $CH_{arom.}$). $^1$H NMR (600 MHz, $CDCl_3$, $\delta$, *J*/Hz): 2.96 (m, 1H, $C^8H_2$), 3.22 (m, 1H, $C^8H_2$), 3.48 (s, 3H, $N^+CH_3$), 3.60 (m, 1H, $C^7H_2$), 3.61 (s, 3H, $N^+CH_3$), 4.05 (s, 3H, $CH_3O$), 4.40 (m, 1H, $C^7H_2$), 4.78 (d, 2H, $CH_2OPh$, *J* = 1.7), 5.46 (t, 1H, $C^5H$, *J* = 1.6), 5.95 (dd, 2H, $C^2H_2$, $^2J$ = 10.2, $^5J$ = 1.4), 6.38 (s, 1H, $C^9H$), 6.90 (d, 2H, CHarom., *J* = 7.7), 7.01 (m, 1H, $CH_{arom.}$), 7.28 (m, 2H, $CH_{arom.}$). $^{13}$C NMR (150 MHz, DMSO-$d_6$, $\delta$): 23.09, 46.80, 52.37, 54.37, 55.40, 58.20, 59.54, 78.75 ($C^{1'}$), 87.38 ($C^{2'}$), 101.64, 102.76, 113.28, 115.01, 121.41, 123.05, 129.40, 134.76, 139.14, 149.74, 156.82.

*5-[3-(4-Fluorophenoxy)prop-1-yn-1-yl]-4-methoxy-6,6-dimethyl-5,6,7,8-tetrahydro-[1,3]dioxolo[4,5-g]isoquinolin-6-ium iodide* **2b**. Compound **1b** (0.6 g, 1.6 mmol) was dissolved on heating in *i*-PrOH (30 ml), then $CH_3I$ (0.5 ml, 8 mmol) was added. The mixture grew turbid and a precipitate formed rather quickly. In 1 h, the precipitate was filtered off and washed with ethyl acetate and petroleum ether to afford colorless compound with m.p. 197-198 °C. Yield 0.4 g (48%). IR (Nujol, ν/cm$^{-1}$): 1620s, 1503vs, 1485vs, 1787m, 1463s (arom.). $^1$H NMR (300 MHz, DMSO-$d_6$, δ, *J*/Hz): 3.07 (s, 3H, $N^+CH_3$), 3.10 (m, 2H, $C^8H_2$), 3.35 (s, 3H, $N^+CH_3$), 3.70 (m, 2H, $C^7H_2$), 3.98 (s, 3H, $OCH_3$), 4.85 (d, $CH_2O$, *J* = 1.5), 5.75 (s, 1H, $C^5H$), 6.00 (d. split, 2H, O-$CH_2$-O, *J* = 3.0), 6.51 (s, 1H, $C^9H$), 6.80-7.20 (m, 4H, $CH_{arom.}$). $^{13}$C NMR (150 MHz, $CDCl_3$, δ): 28.66, 42.94, 46.59, 50.72, 57.06, 59.39, 80.12 ($C^{1'}$), 85.10 ($C^{2'}$), 100.78, 102.78, 115.52, 115.67, 116.49, 116.54, 120.54, 127.49, 134.23, 139.74, 148.41, 153.74, 156.81, 158.39. MS (EI, 70 eV), *m*/*z* (%): 369 (7) [M-$CH_3I$], 142 (35) [$CH_3I^+$], 15 (100) [$CH_3^+$].

Electron impact results in decomposition of the iodomethylate to $CH_3I$ and the original acetylenic derivative.

*5-(3-Hydroxyprop-1-en-1-ylidene)-4-methoxy-6,6-dimethyl-5,6,7,8-tetrahydro[1,3]dioxolo-[4,5-g]isoquinolin-6-ium iodide* **3c**. Compound **1c** (0.5 g, 1.8 mmol) was dissolved in a mixture of ethyl acetate (30 ml) and MeOH (2 ml) and slightly warmed (40-50°C), $CH_3I$ (0.6 ml, 9.6 mmol) was added. The mixture was heated to 60-70 °C and kept for 1 h. The precipitate that formed was filtered off and washed with ethyl acetate and petroleum ether. A colorless compound with m.p. 172-174 °C. Yield 0.6 g (76%). IR (Nujol, ν/cm$^{-1}$): 3374s, 3331s (OH), 1624s, 1484s, 1464vs (arom).

*5-(3-Hydroxyprop-1-yn-1-yl)-4-methoxy-6,6-dimethyl-5,6,7,8-tetrahydro[1,3]dioxolo[4,5-g]-isoquinolin-6-ium iodide* (**2c**) is formed on dissolution of allenic derivative **3c** in DMSO-$d_6$.

$^1$H NMR (600 MHz, DMSO-$d_6$, δ, *J*/Hz): 3.03 (s, 3H, $N^+CH_3$), 3.08 (m, 2H, $C^8H_2$), 3.36 (s, 3H, $N^+CH_3$), 3.66 (m, 2H, $C^7H_2$), 3.99 (s, 3H, OCH3), 4.15 (d, 2H, CH2OH, *J* = 3.6), 5.29 (t, 1H, OH, *J* = 5.5), 5.67 (t, 1H, $C^5H$, *J* = 1.92), 6.04 (s, 2H, O-$CH_2$-O), 6.62 (s, 1H, $C^9H$). $^{13}$C NMR (150 MHz, DMSO-$d_6$, δ): 23.15 ($C^8$), 46.72 ($N^+CH_3$), 48.91 (C3’), 52.45 ($N^+CH_3$), 54.20 ($C^7$), 58.36 ($C^5$), 59.69 ($OCH_3$), 75.66 ($C^{1'}$), 91.75 ($C^{2'}$), 101.64 ($C^2$), 102.83 ($C^9$), 113.93 ($C^{4a}$), 122.99 ($C^{8a}$), 134.93 ($C^{3a}$), 139.22 ($C^4$), 149.64 ($C^{9a}$).

*5-(3-Hydroxy-3-methylbut-1-en-1-ylidene)-4-methoxy-6,6-dimethyl-5,6,7,8-tetrahydro-[1,3]dioxolo[4,5-g]isoquinolin-6-ium iodide* **3d**. Compound **1d** (0.7 g, 2.3 mmol) was dissolved in ethyl acetate (15 ml), $CH_3I$ (0.5 ml, 8 mmol) was added, and the mixture was slightly warmed (40-50 °C). Trituration with a glass rod resulted in a precipitate with an oil, which quickly solidified. The mixture was kept for 30 min. at room temperature and cooled with ice. The precipitate was filtered off and washed with ethyl acetate and petroleum ether. A colorless compound with m.p. 178-180 °C. Yield 0.6 g (76%). IR (Nujol, ν/cm$^{-1}$): 3370s (OH), 1624s, 1486s, 1435 (arom.).

*5-(3-Hydroxy-3-methylbut-1-yn-1-yl)-4-methoxy-6,6-dimethyl-5,6,7,8-tetrahydro-[1,3]dioxolo[4,5-g]isoquinolin-6-ium iodide* (**2d**) is formed upon dissolution of compound **3d** in DMSO-$d_6$. $^1$H NMR (600 MHz, DMSO-$d_6$, δ, *J*/Hz): 1.35, 1.37 (both s, 6H, $C(CH_3)_2OH$), 3.03 (s, 3H, $N^+CH_3$), 3.08 (m, 2H, $C^8H_2$), 3.34 (s, 3H, $N^+CH_3$), 3.65 (m, 2H, $C^7H_2$), 3.98 (s, 3H, $CH_3O$), 5.47 (s, 1H, OH), 5.64 (d, 1H, $C^5H$, *J* = 1.3), 6.04 (m, 2H, O-$CH_2$-O), 6.63 (s, 1H, $C^9H$). $^{13}$C NMR (150 MHz, DMSO-$d_6$, δ): 23.16 ($C^8$), 30.84 and 30.89 (distereotopic -CMe(OH)$CH_3$), 46.77 ($N^+CH_3$), 52.41 ($N^+CH_3$), 54.22 ($C^7$), 58.37 ($C^5$), 59.65 ($OCH_3$), 63.27 ($C^{3'}$), 72.71 ($C^{1'}$), 97.26 ($C^{2'}$), 101.69 ($C^2$), 102.94 ($C^9$), 114.14 ($C^{4a}$), 122.94 ($C^{8a}$), 135.10 ($C^{3a}$), 139.28 ($C^4$), 149.59 ($C^{9a}$).

## Dicussion for X-ray

**Table S1** Some bond lengths and bond angles in compounds **2a,b** and **3d**

| **Bond** | **2a/2b** | **3d** | **Bond** | **2a/2b** | **3d** |
|---|---|---|---|---|---|
| C1-C2 | 1.521(3) / 1.518(3) | 1.477(4) | C7-C8 | 1.400(3) / 1.398(3) | 1.402(4) |
| C2-C3 | 1.413(3) / 1.413(3) | 1.415(4) | C8-C9 | 1.507(4) / 1.507(3) | 1.510(4) |
| C3-C4 | 1.368(4) / 1.369(3) | 1.368(4) | C10-N1 | 1.510(3) / 1.508(3) | 1.511(4) |
| C4-O2 | 1.379(3) / 1.381(3) | 1.377(3) | N1-C1 | 1.530(3) / 1.528(3) | 1.492(4) |
| O2-C5 | 1.416(4) / 1.418(4) | 1.423(3) | C1-C14 | 1.470(4) / 1.471(3) | 1.291((4) |
| C5-O1 | 1.427(5) / 1.418(4) | 1.421(5) | C14-C15 | 1.176(4) / 1.180(3) | 1.308(5) |
| O1-C6 | 1.371(3) / 1.370(3) | 1.369(3) | C15-C16 | 1.466(4) / 1.467(3) | 1.522(4) |
| C6-C7 | 1.362(4) / 1.359(4) | 1.356(5) | | | |
| **Angle** | **2a/2b** | **3d** | **Angle** | **2a/2b** | **3d** |
| C1-N1C10 | 108.8(2) / 109.0(2) | 107.5(2) | C1-C14-C15 | 178.9(3) / 178.6(2) | 177.4(4) |
| N1-C1-C2 | 110.8(2) / 110.7(2) | 115.2(2) | C14-C15-C16 | 176.2(3) / 175.9(3) | 126.8(3) |
| N1-C1-C14 | 110.3(2) / 110.4(2) | 117.4(3) | N1-C10-C9 | 111.6(2) / 111.6(2) | 112.0(2) |
| C2-C1-C14 | 111.3(2) / 111.492) | 127.0(3) | C10-C9-C8 | 113.8(2) / 114.5(2) | 114.1(2) |

The geometric parameters of the tricyclic systems in **2a, 2b** and **3d** are the same with high accuracy.

Significant differences correspond to the substituent at the C1 atom of the nitrogen-containing heterocycle. The distribution of bond lengths in the C1-C14≡C15-C16 moiety is 1.470(4)/1.471(3), 1.176(4)/1.180(3), 1.466(4)/1.467(3) Å for molecules **2a-2b**, which is quite consistent with the acetylenic character of the substituent under consideration. This is also confirmed by the bond angles at the C14 and C15 atoms that are 178.9(3)/178(6) and 176.2(3)/175.9(3)º, respectively.

A different picture is observed in the cation of compound **3d**. The distribution of bond lengths in a similar moiety of **3d** is 1.291(4), 1.308(5), 1.522(4) Å, while the angles at the C14 and C15 atoms are 177.4(4) and 126.8(3)º, respectively. This geometry corresponds to a cumulene system.

It was interesting to understand the reasons for the stabilization of such different forms in structurally related compounds. These differences can only be due to some important features of the crystal packing of **2a-2b** and **3d** because, according to NMR data, dissolution of **3d** in DMSO-$d_6$ results in isomerization of the allenic form into acetylenic form **2d**.

The obvious difference in the crystal packings is that compound **3d** contains a hydroxy group and crystallizes in hydrated form.

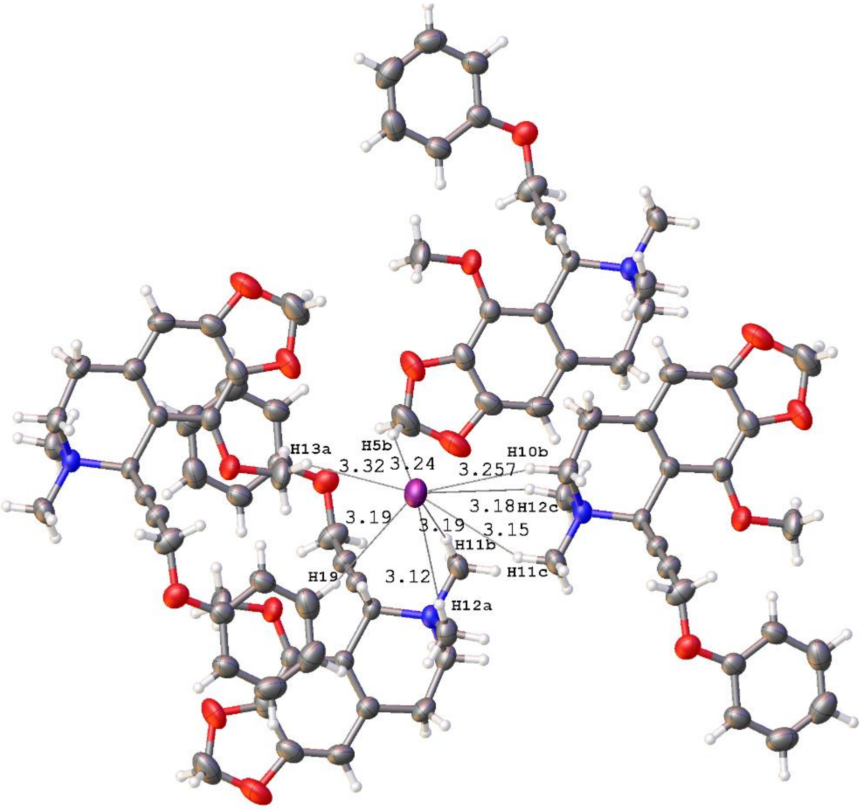

**Figure S1** Environment of an iodide anion in a crystal of **2a**.

## X-Ray diffraction study

Single crystals of compounds **2a-2b** и **3d** were mounted on a CCD area Bruker SMART APEX-II diffractometer (Mo-$K_\alpha$ radiation ($\lambda = 0.71073$)) where crystallographic parameters and diffraction reflections were measured at room temperature. Using Olex2 [S1], the structures were solved with the ShelXT [S2] structure solution program using Intrinsic Phasing and refined with the olex2.refine [S3] refinement package using Gauss-Newton minimisation.

**Crystal Data** for **2a** $C_{22}H_{24}INO_4$ ($M$ = 493.34 g mol$^{-1}$): triclinic, space group P $\bar{1}$ (no. 2), $a$ = 8.5664(2) Å, $b$ = 10.3893(2) Å, $c$ = 13.2519(3) Å, $\alpha$ = 112.9340(10)°, $\beta$ = 94.0460(10)°, $\gamma$ = 96.9030(10)°, $V$ = 1069.38(4) Å$^3$, $Z$ = 2, $T$ = 296 K, μ(Mo Kα) = 1.524 mm$^{-1}$, $D_{calc}$ = 1.5320 g cm$^{-3}$, 18699 reflections measured ($4.28° \leq 2\theta \leq 54.24°$), 4654 unique ($R_{int}$ = 0.0260, $R_\sigma$ = 0.0234) which were used in all calculations. The final $R_1$ was 0.0323 ($I \geq 2\sigma(I)$) and $wR_2$ was 0.0692 (all data). CCDC 2009290.

**Crystal Data** for **2b** $C_{22}H_{23}FINO_4$ ($M$ =511.34 g mol$^{-1}$): triclinic, space group P $\bar{1}$ (no. 2), $a$ = 8.5800(2) Å, $b$ = 10.3125(2) Å, $c$ = 13.2384(3) Å, $\alpha$ = 112.3980(10)°, $\beta$ = 93.3120(10)°, $\gamma$ = 95.1800(10)°, $V$ = 1073.14(4) Å$^3$, $Z$ = 2, $T$ = 296.15 K, μ(Mo Kα) = 1.528 mm$^{-1}$, $D_{calc}$ = 1.5823 g cm$^{-3}$, 18613 reflections measured ($4.3° \leq 2\theta \leq 54.24°$), 4694 unique ($R_{int}$ = 0.0283, $R_\sigma$

= 0.0257) which were used in all calculations. The final $R_1$ was 0.0287 (I ≥ 2σ (I)) and $wR_2$ was 0.0616 (all data). CCDC 2009291.

**Crystal Data** for **3d** $C_{18}H_{25}INO_{4.5}$ ($M$ = 453.28 g mol$^{-1}$): monoclinic, space group C2/c (no. 15), $a$ = 30.958(4) Å, $b$ = 9.5031(12) Å, $c$ = 15.0514(18) Å, $\beta$ = 117.682(4)°, $V$ = 3921.2(8) Å$^3$, $Z$ = 8, $T$ = 296 K, μ(MoKα) = 1.656 mm$^{-1}$, $D_{calc}$ = 1.536 g cm$^{-3}$, 31867 reflections measured (5.92° ≤ 2θ ≤ 54.28°), 4252 unique ($R_{int}$ = 0.0198, $R_\sigma$ = 0.0115) which were used in all calculations. The final $R_1$ was 0.0368 (I ≥2σ(I)) and $wR_2$ was 0.0997 (all data). CCDC 2009292.

## References

[S1] O. V. Dolomanov, L. J. Bourhis, R. J. Gildea, J. A. K. Howard and H. Puschmann, *J. Appl. Crystallogr.*, 2009, **42**, 339.

[S2] G. M. Sheldrick, *Acta Crystallogr.*, 2015, **A71**, 3.

[S3] L. J. Bourhis, O. V. Dolomanov, R. J. Gildea, J. A. K. Howard and H. Puschmann, *Acta Crystallogr.*, 2015, **A71**, 59.

# Spectral data for compounds 2a-d

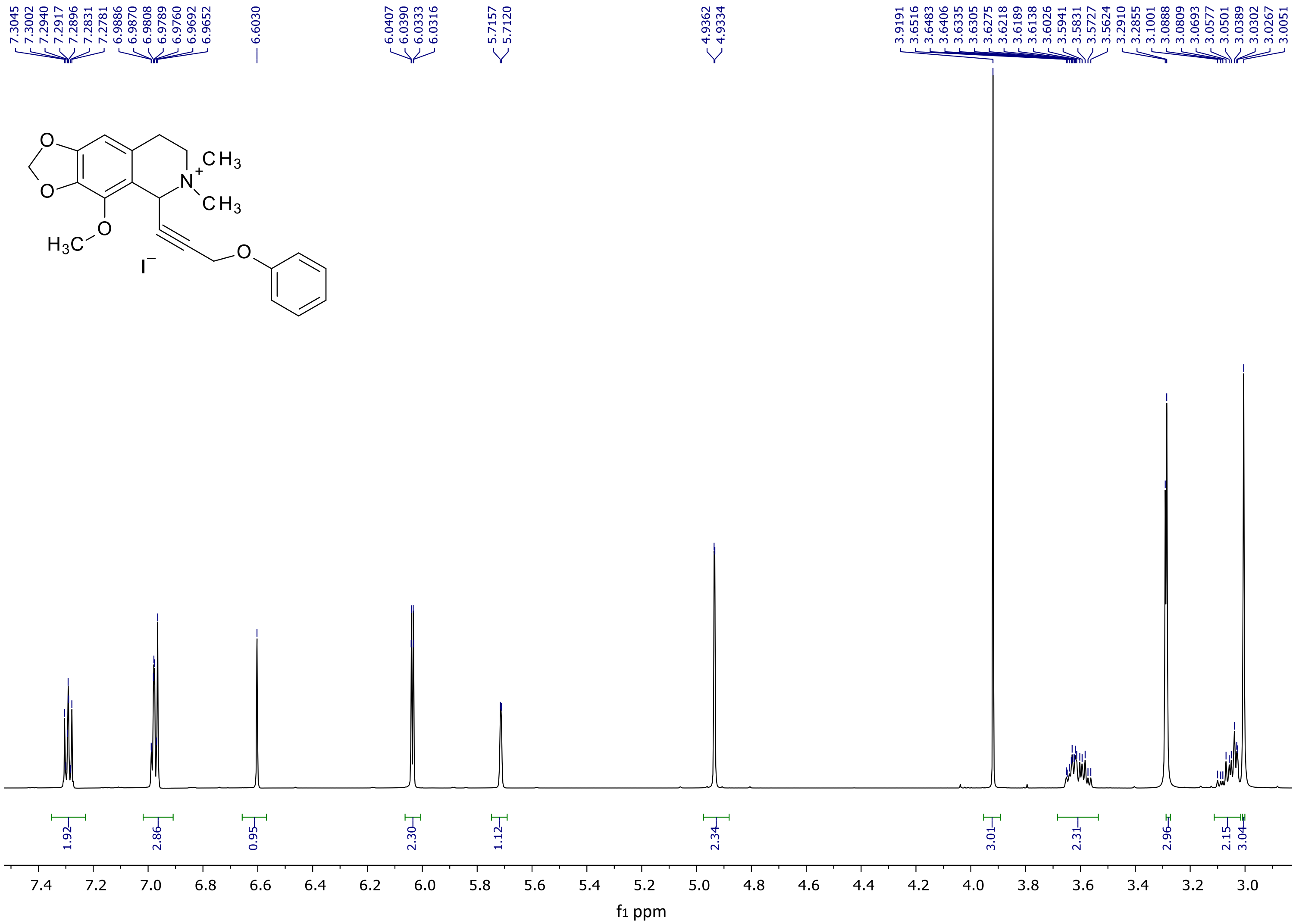

**Figure S2** $^1$H NMR spectrum of compound **2a** recorded at 600 MHz in DMSO-$d_6$

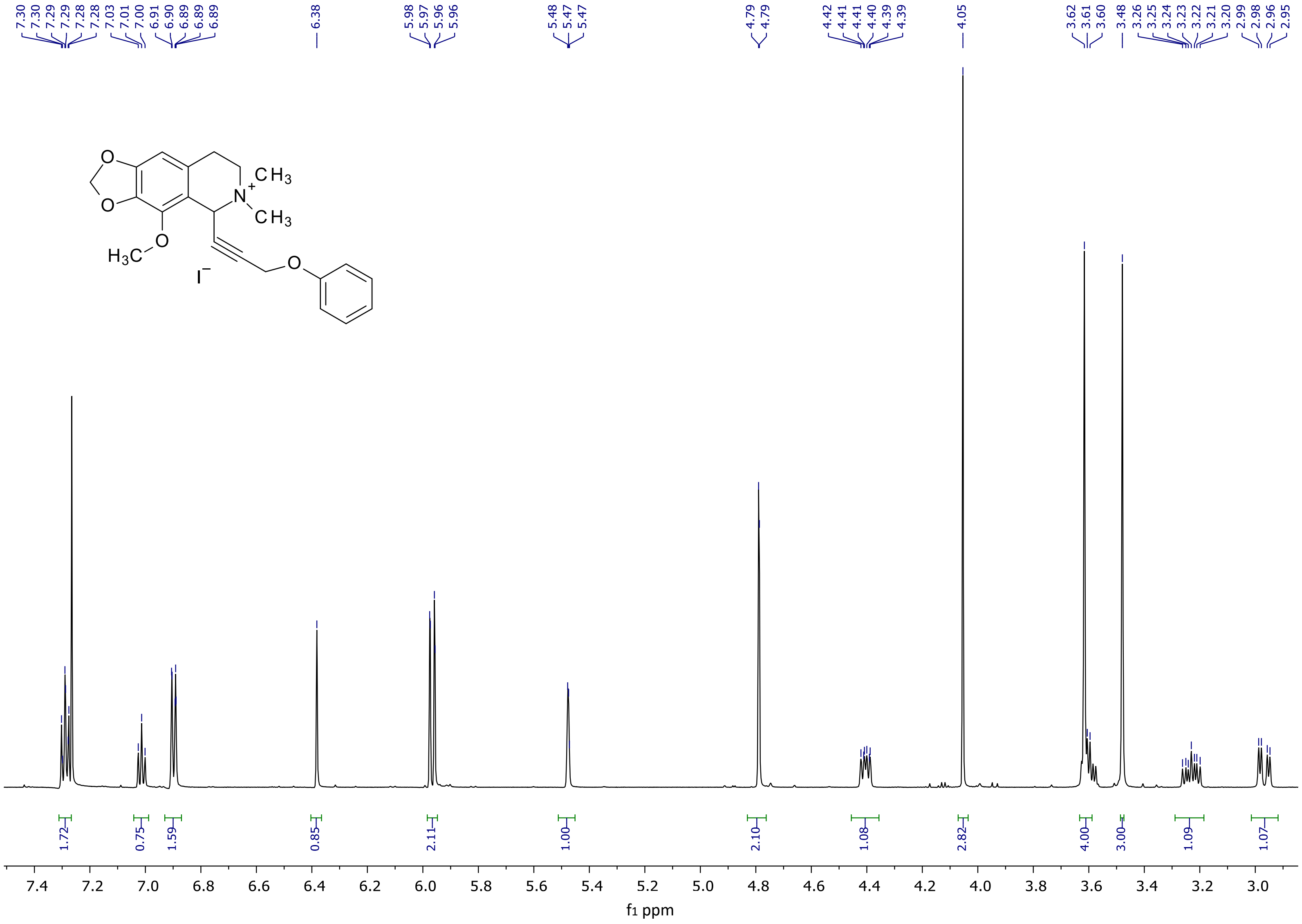

**Figure S3** $^1$H NMR spectrum of compound **2a** recorded at 600 MHz in $CDCl_3$

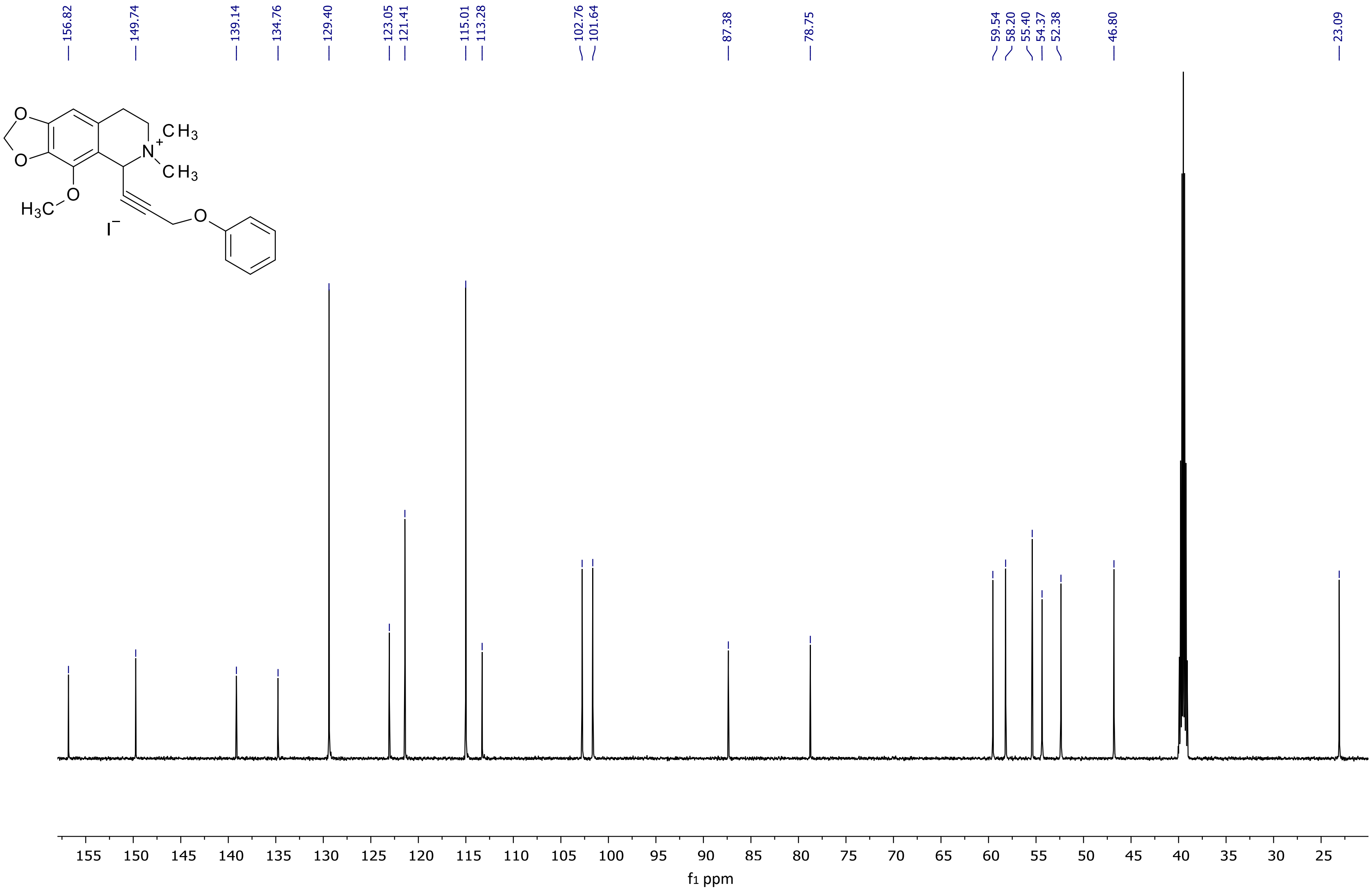

**Figure S4** $^{13}$C NMR spectrum of compound **2a** recorded at 150 MHz in DMSO-$d_6$

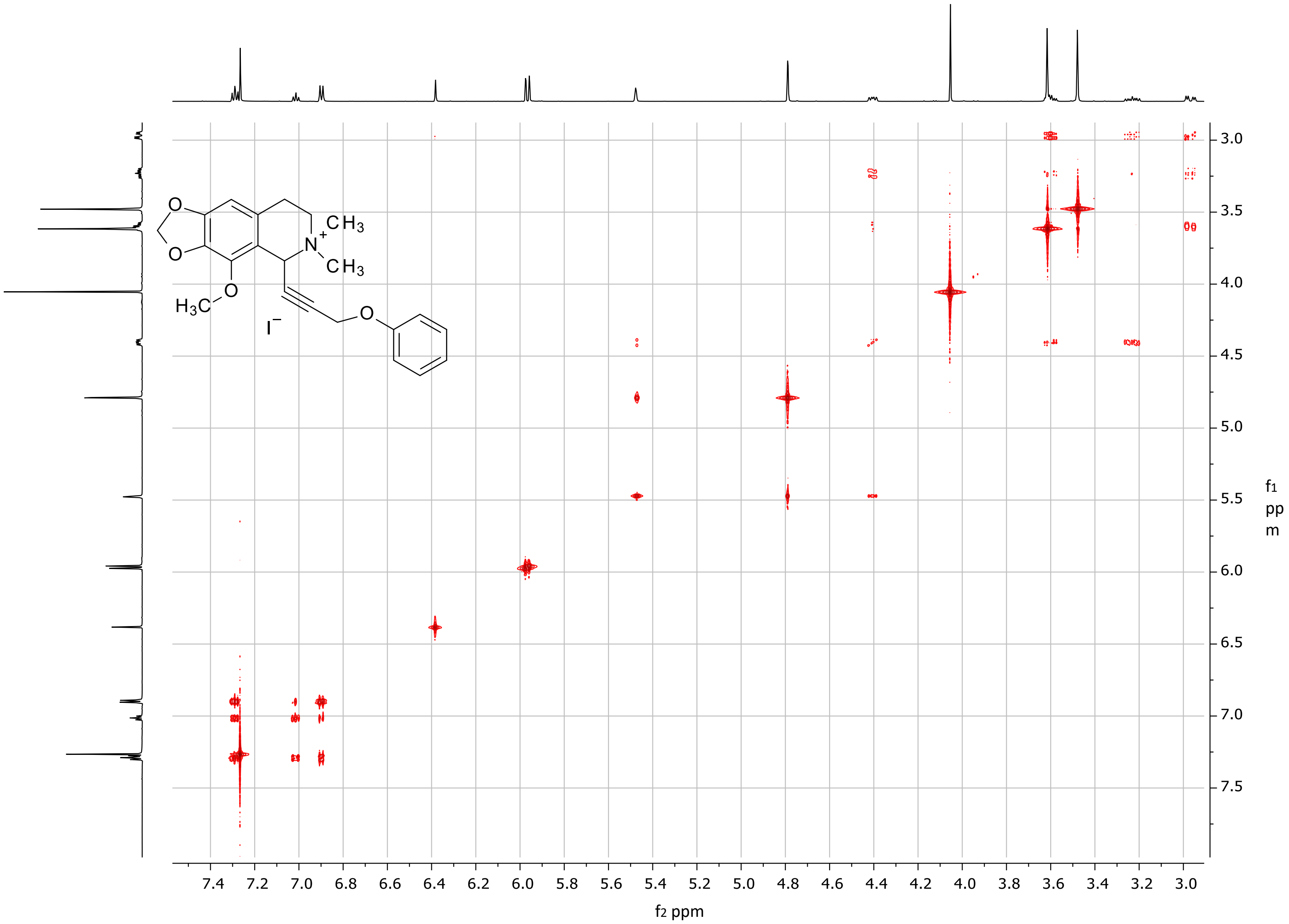

**Figure S5** COSY spectrum of compound **2a** recorded at 600, 600 MHz in $CDCl_3$

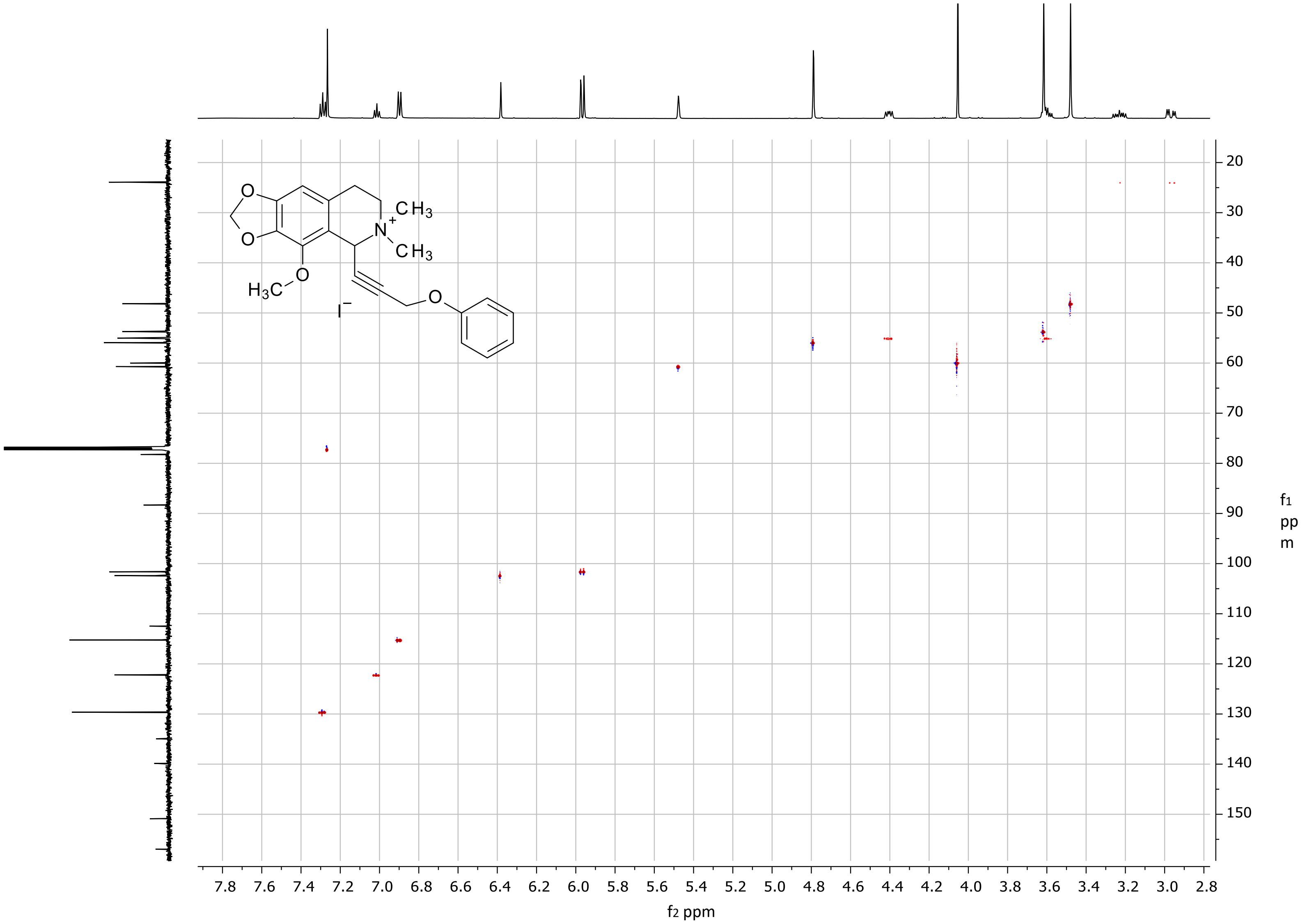

**Figure S6** HSQC spectrum of compound **2a** recorded at 600, 150 MHz in $CDCl_3$

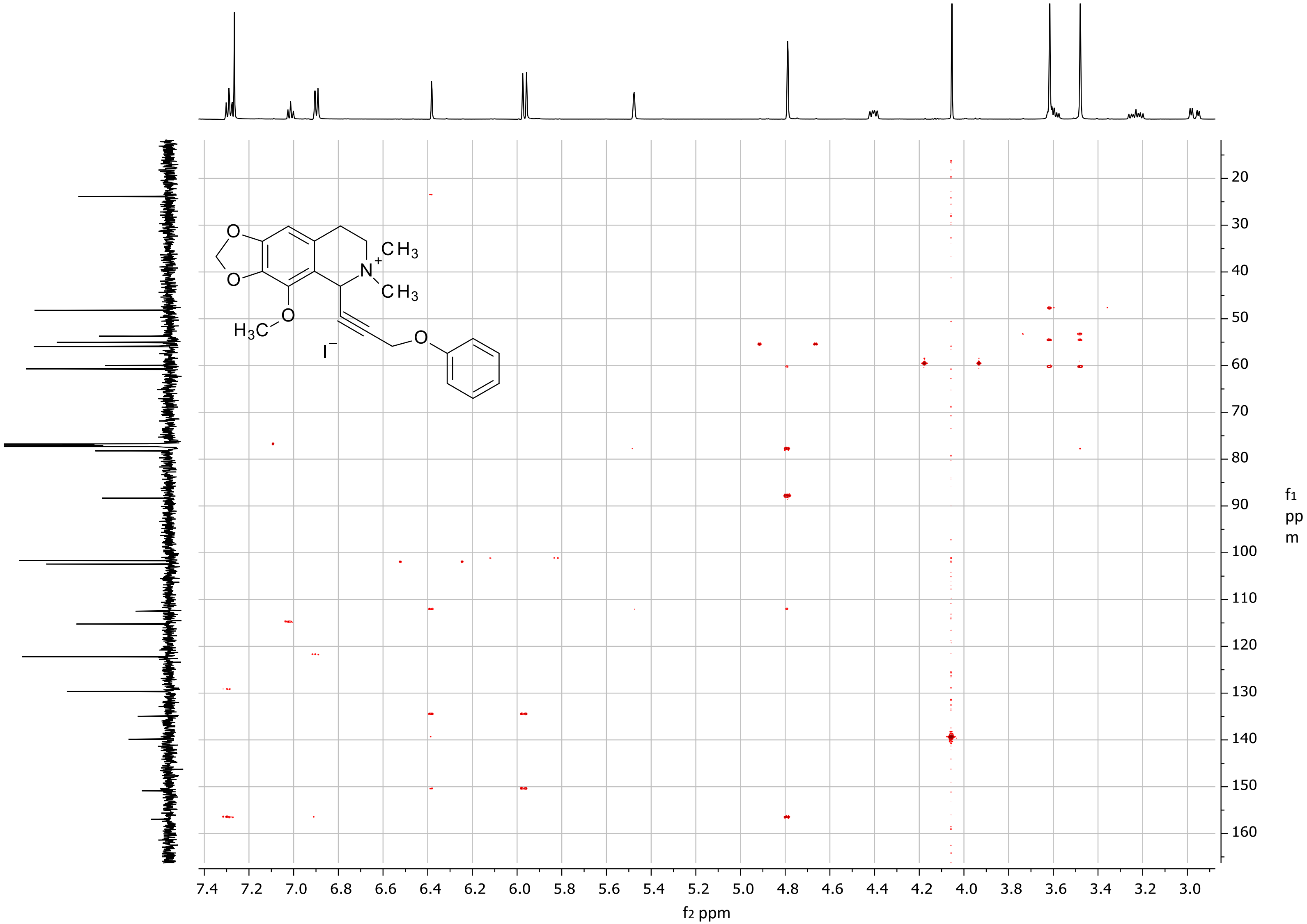

**Figure S7** HMBC spectrum of compound **2a** recorded at 600, 150 MHz in $CDCl_3$

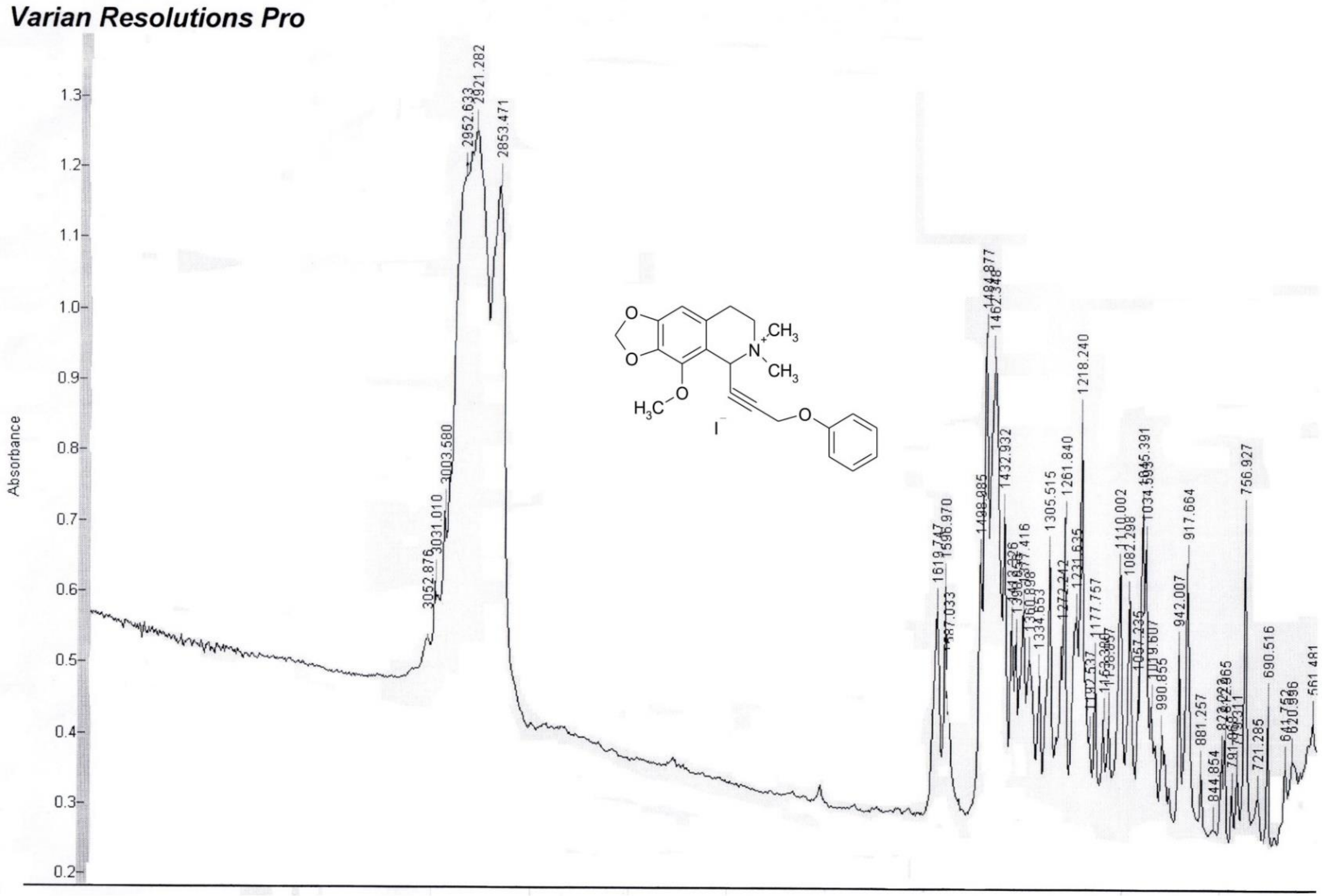

**Figure S8** IR- spectrum of compound **2a** recorded in nujol

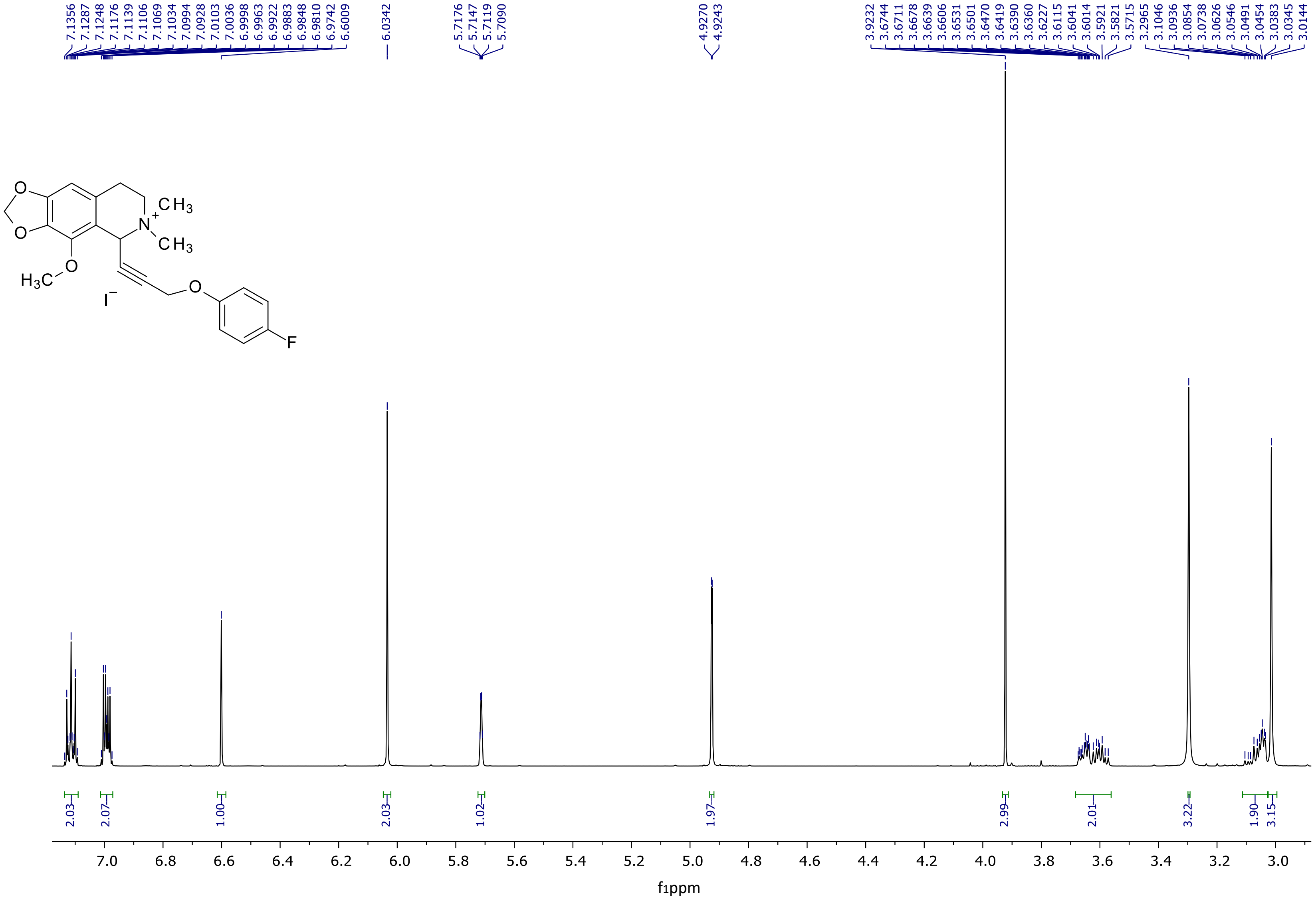

**Figure S9** $^1$H NMR spectrum of compound **2b** recorded at 600 MHz in DMSO-$d_6$

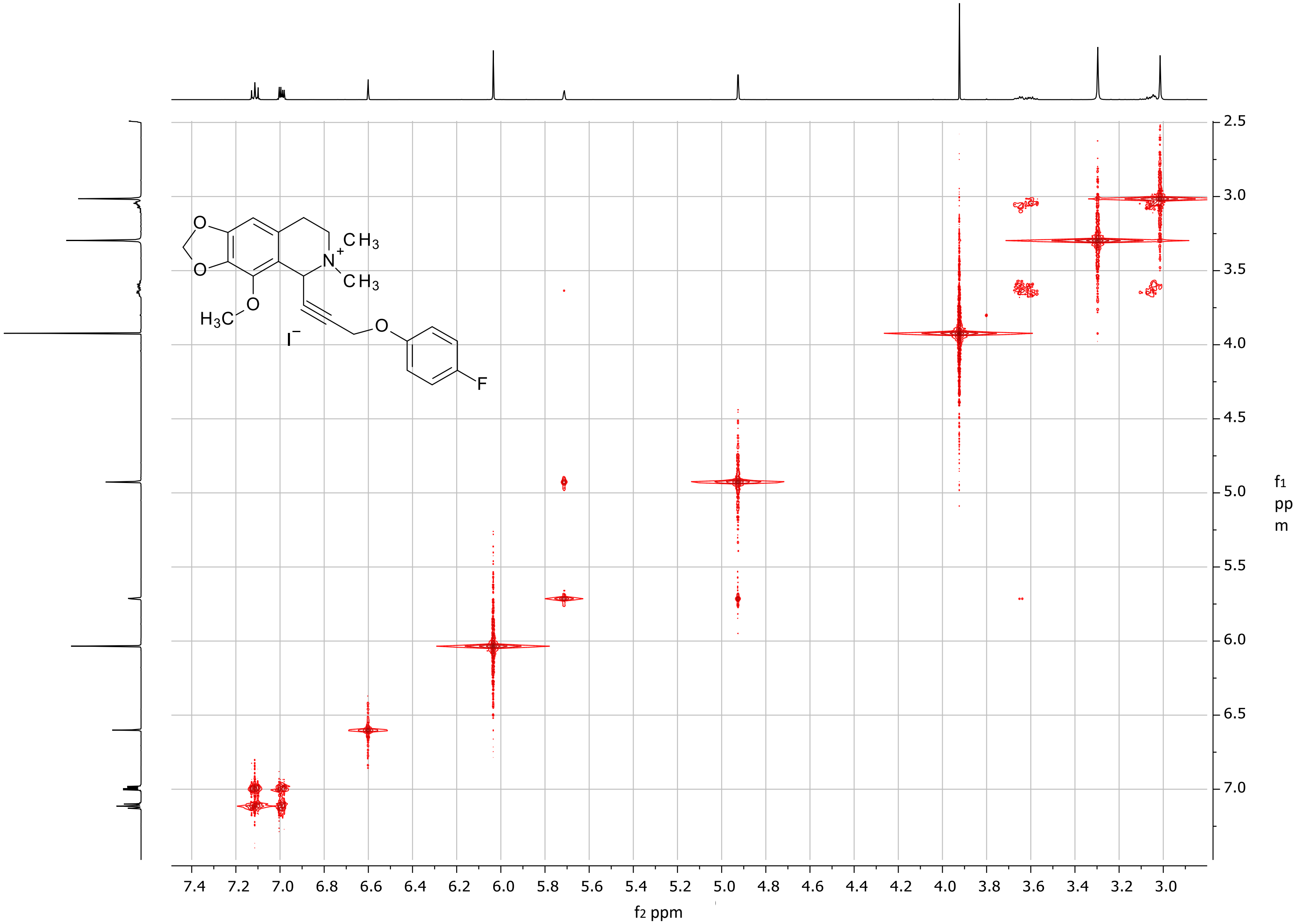

**Figure S10** COSY spectrum of compound **2b** recorded at 600, 600 MHz in DMSO-$d_6$

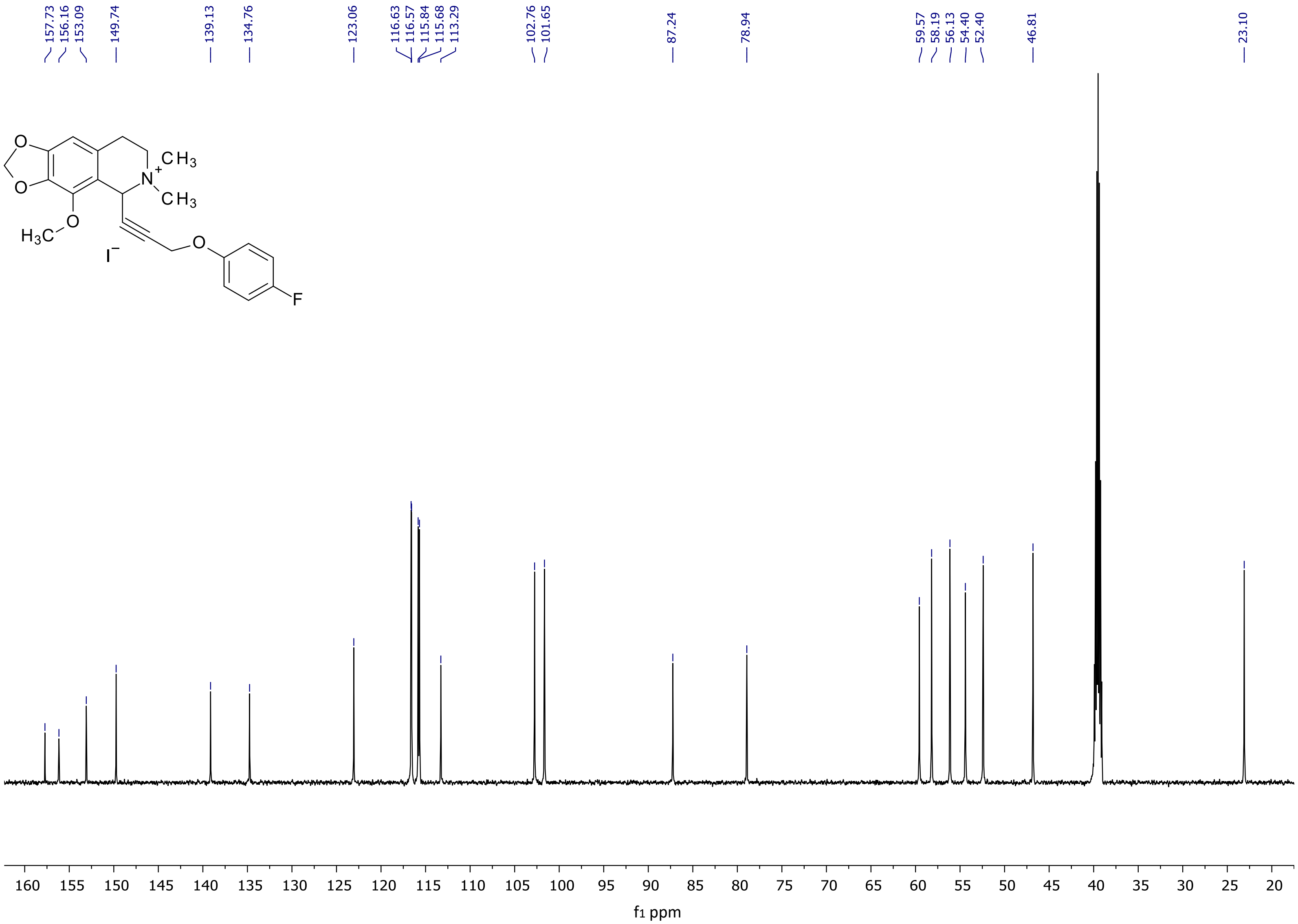

**Figure S11** $^{13}$C NMR spectrum of compound **2b** recorded at 600 MHz in DMSO-$d_6$

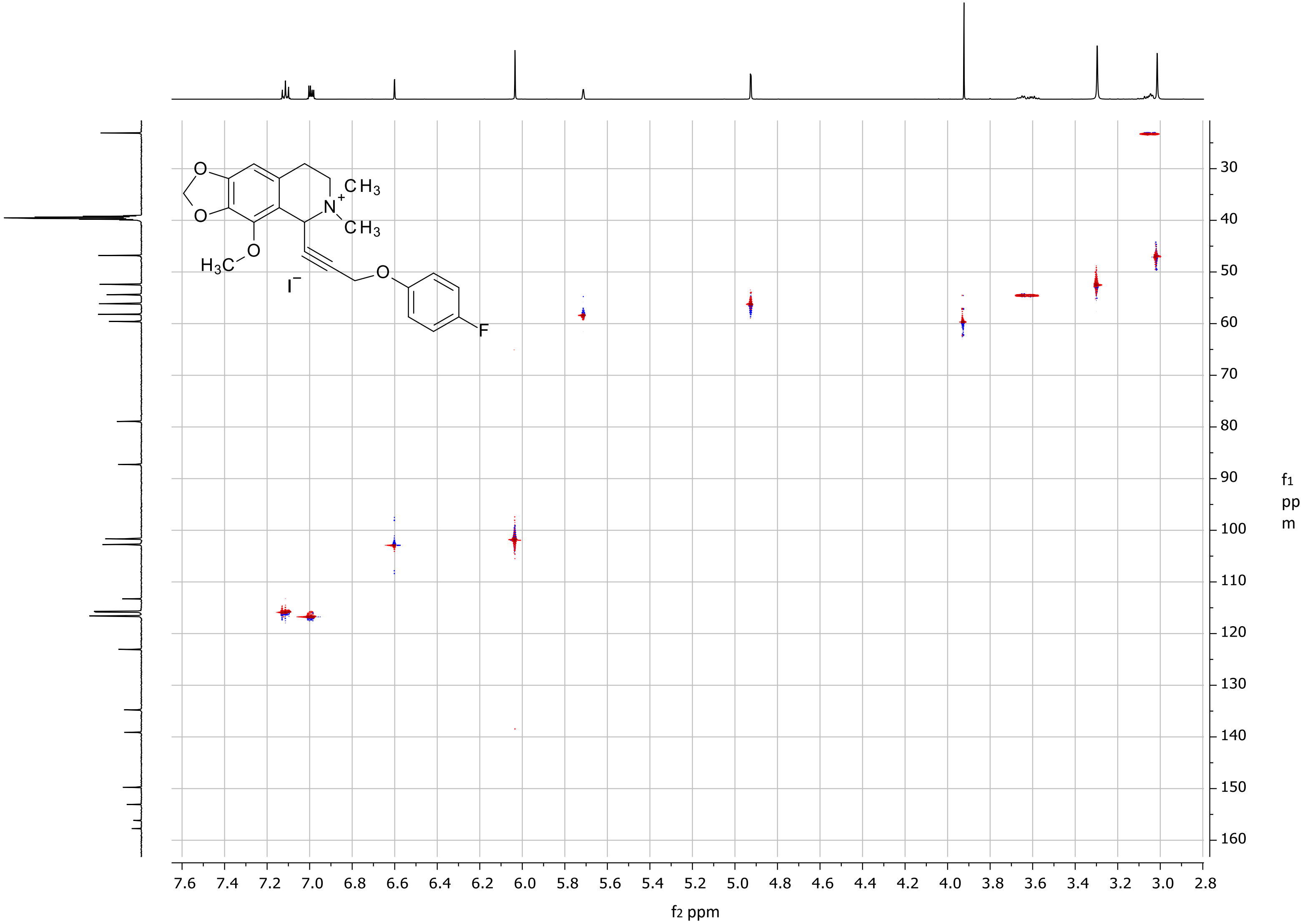

**Figure S12** HSQC spectrum of compound **2b** recorded at 600, 150 MHz in DMSO-$d_6$

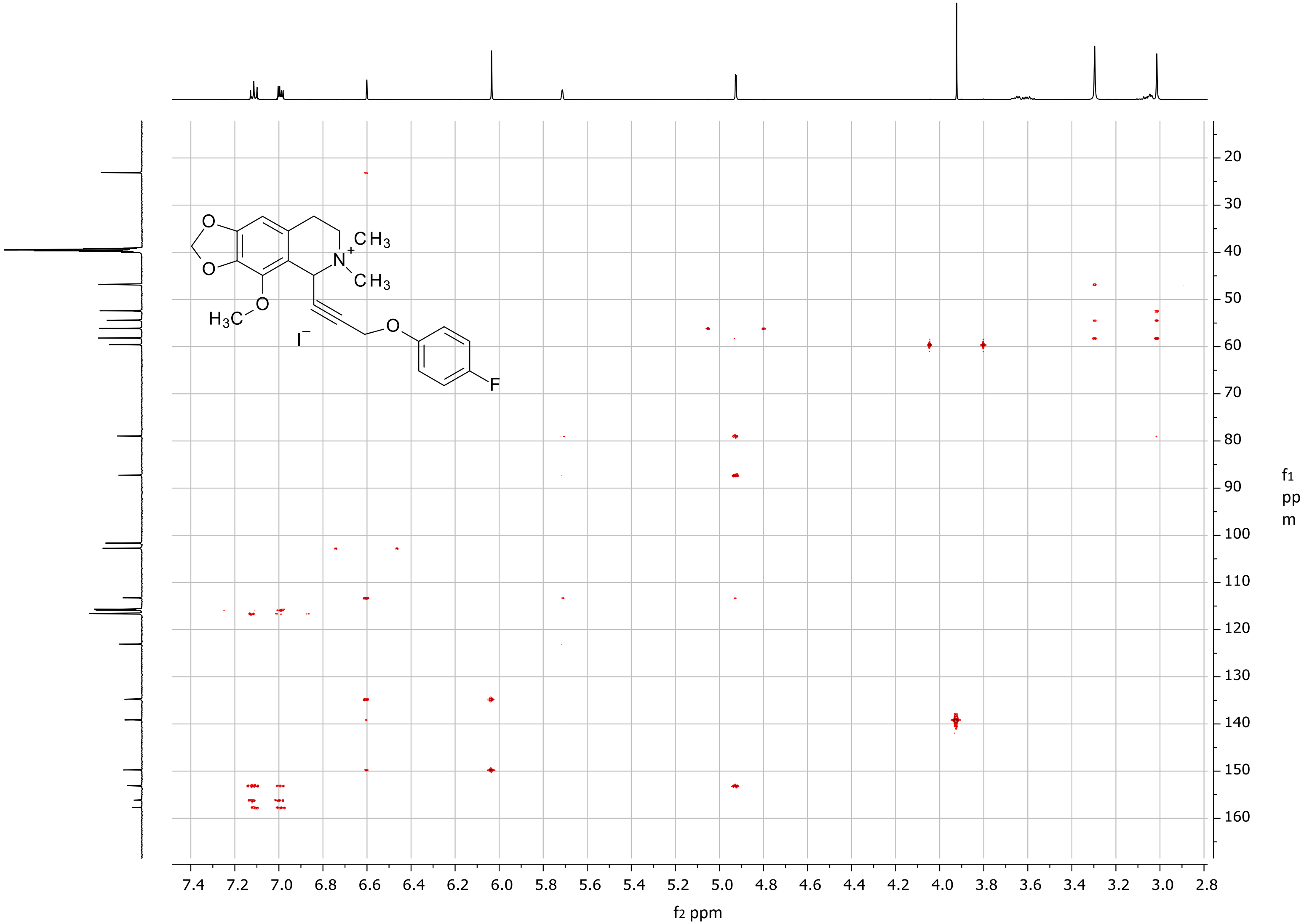

**Figure S13** HMBC spectrum of compound **2b** recorded at 600, 150 MHz in DMSO-$d_6$

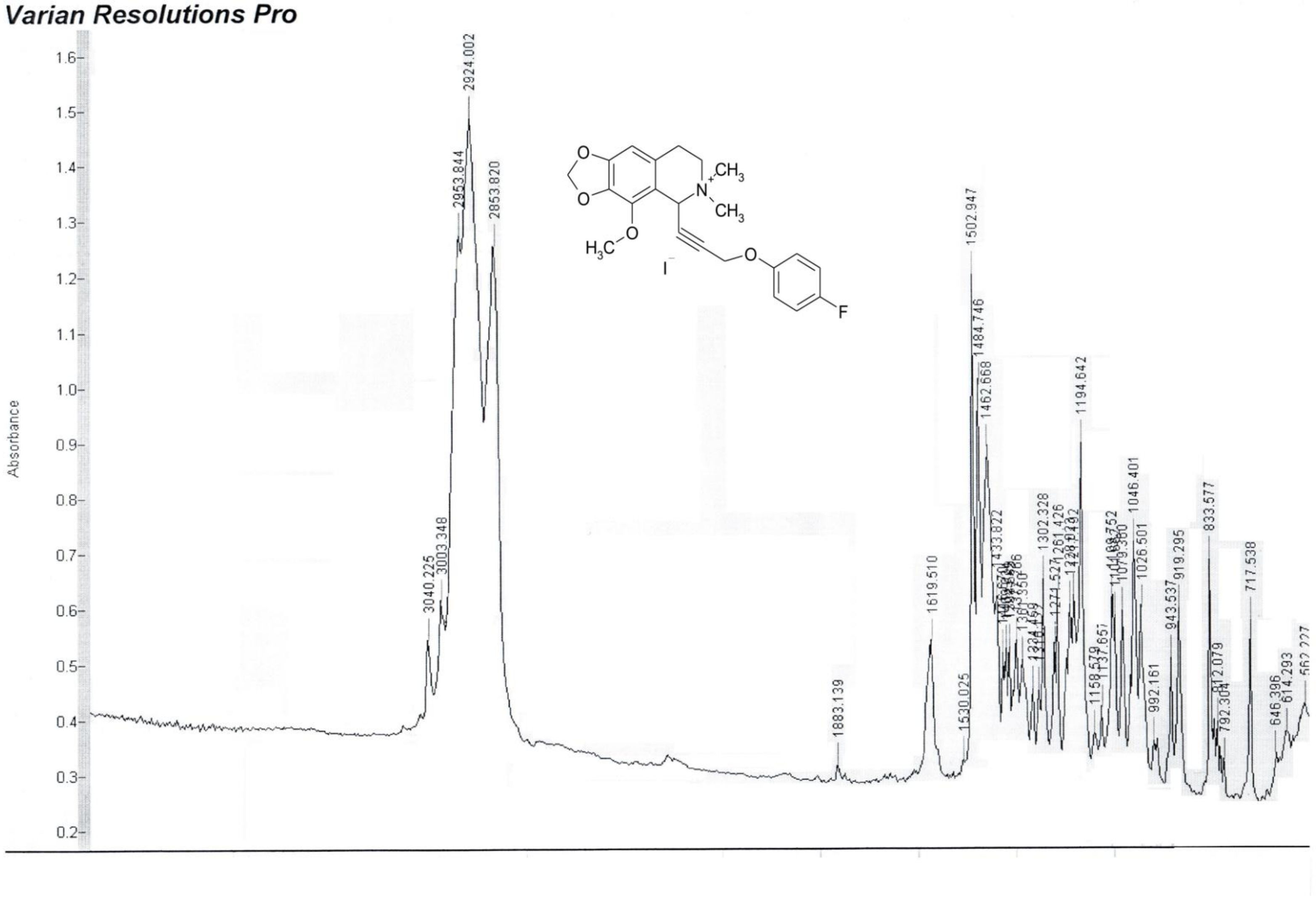

**Figure S14** IR- spectrum of compound **2b** recorded in nujol

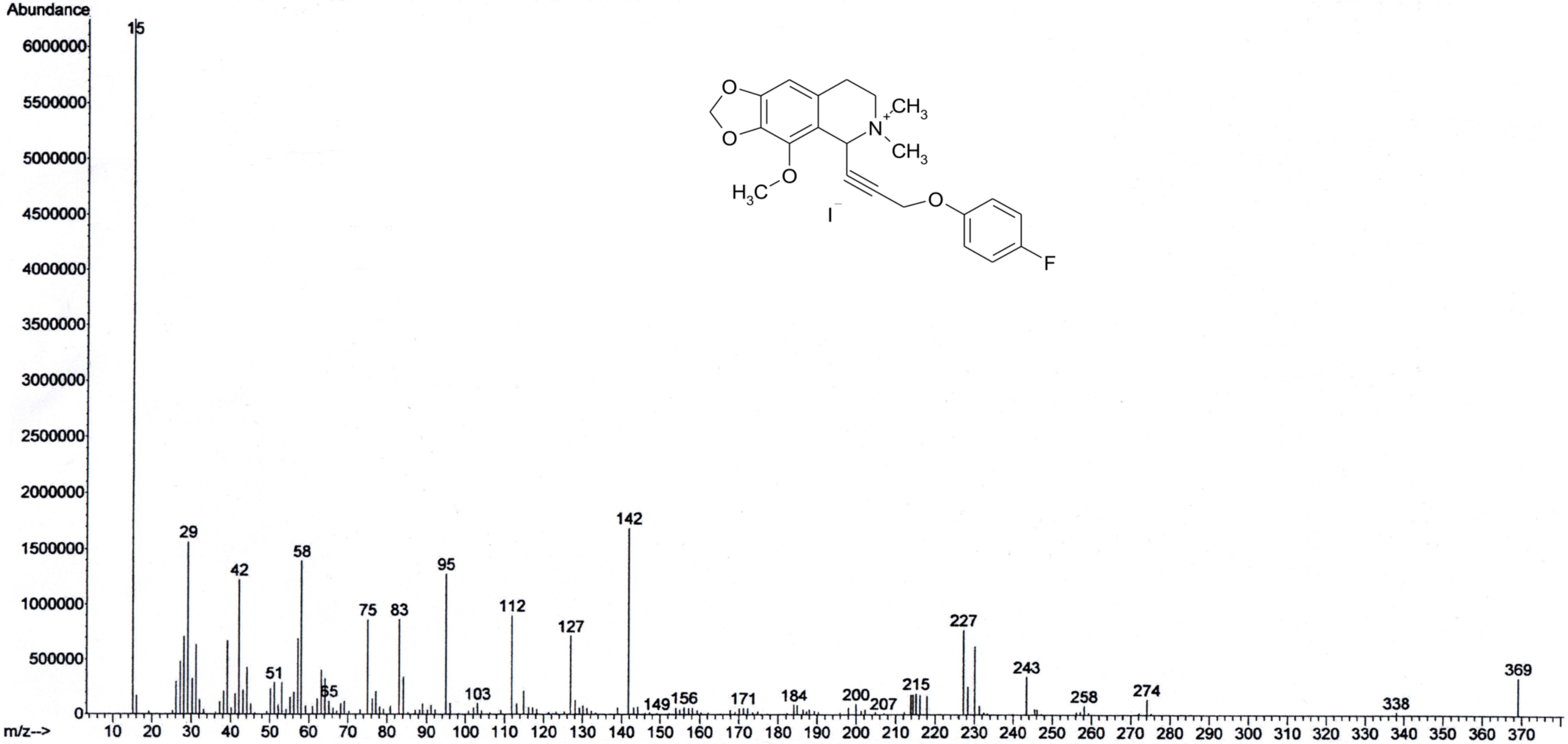

**Figure S15** Mass spectrum of compound **2b**

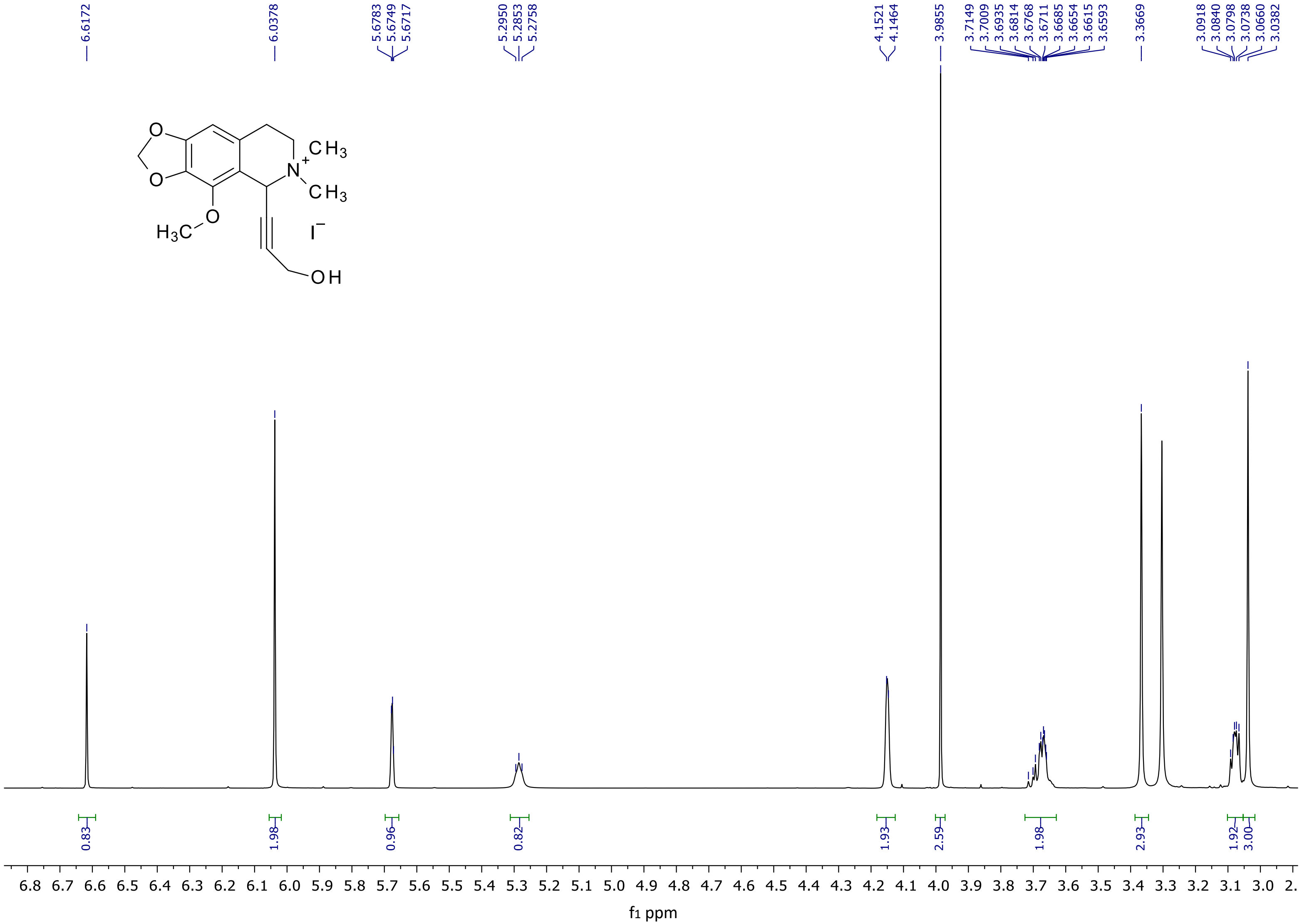

**Figure S16** $^1$H NMR spectrum of compound **3c** (isomerized to compound **2c**) recorded at 600 MHz in DMSO-$d_6$

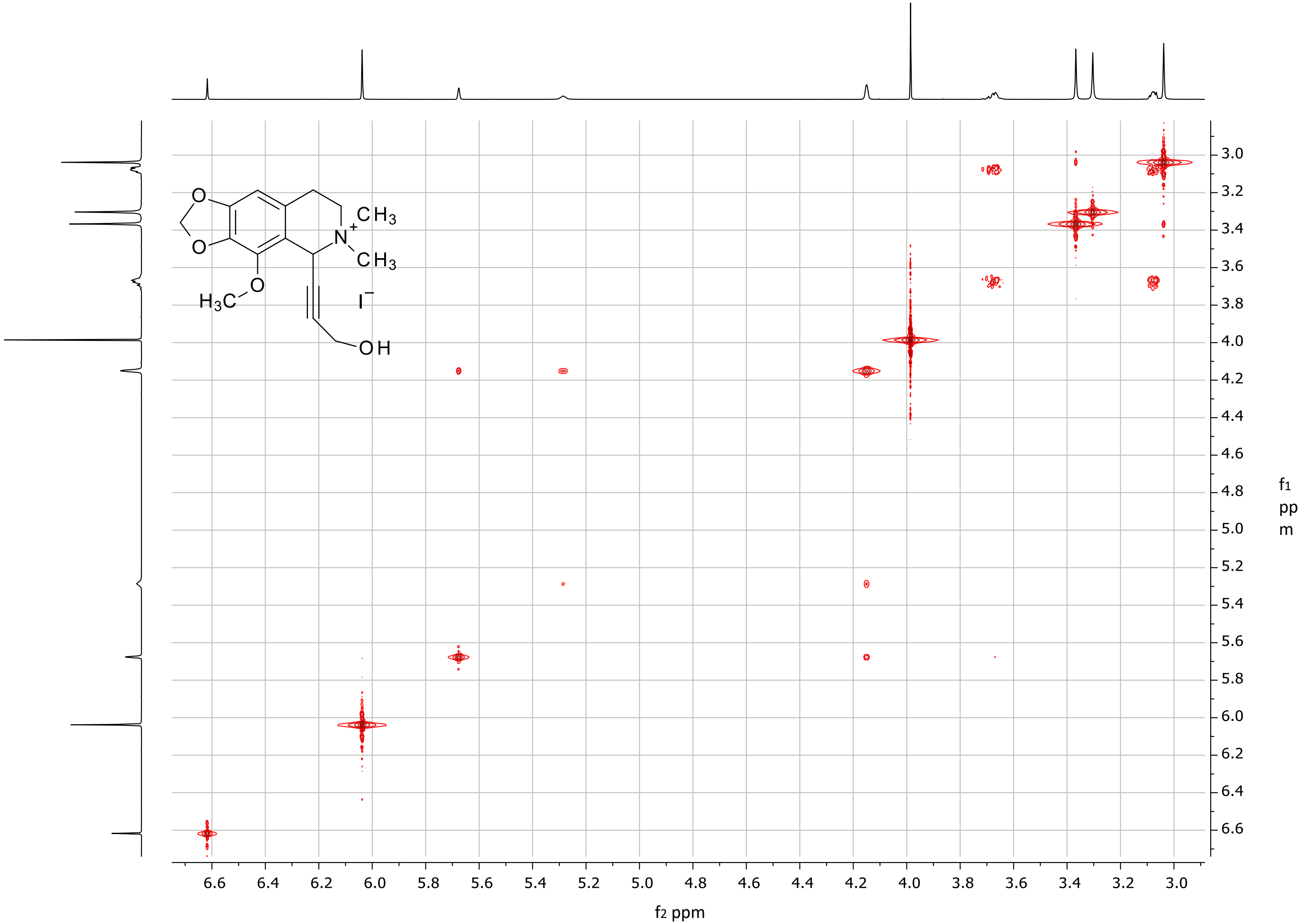

**Figure S17** COSY spectrum of compound **3c** (isomerized to compound **2c**) recorded at 600, 600 MHz in DMSO-$d_6$

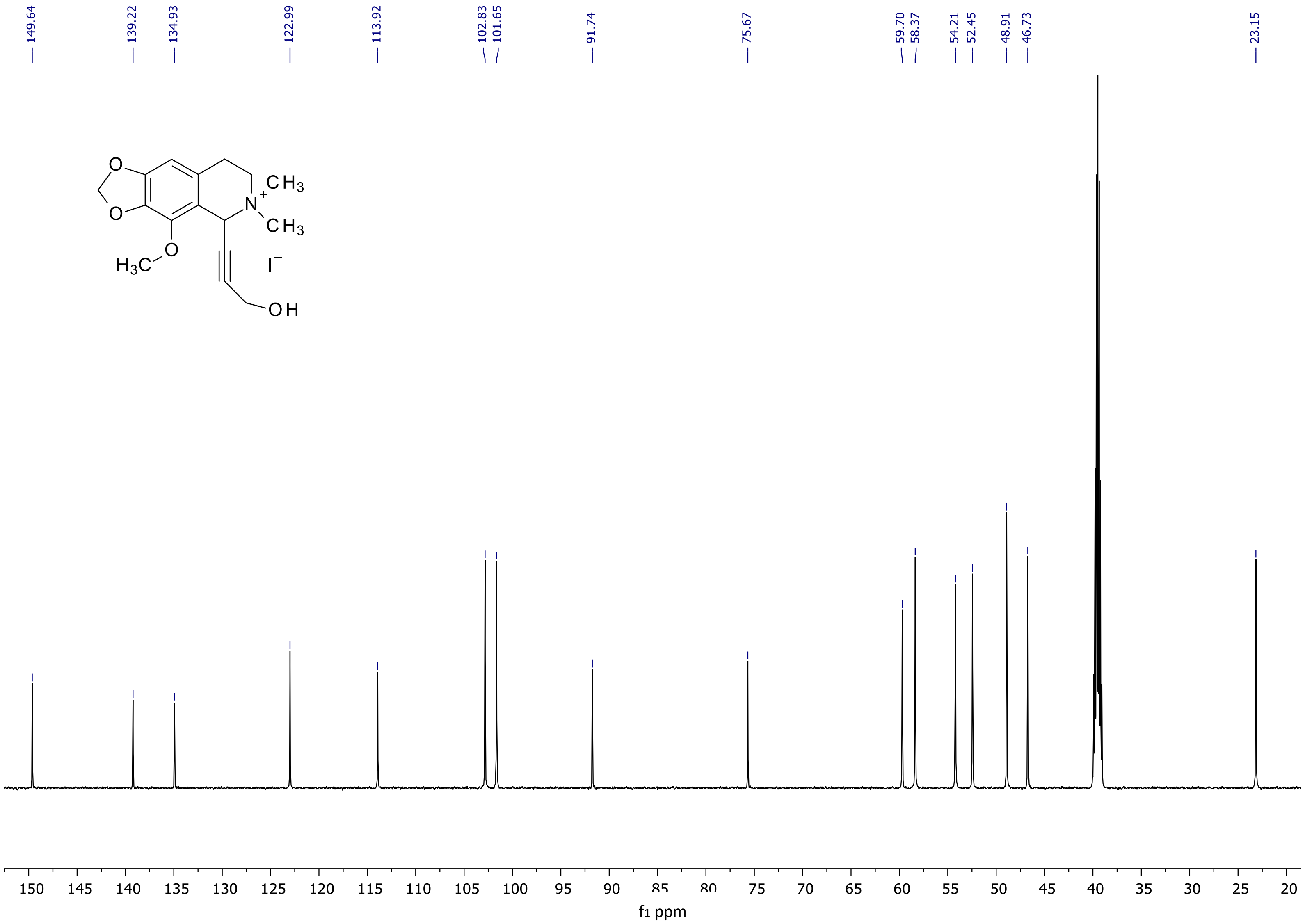

**Figure S18** $^{13}$C spectrum of compound **3c** (isomerized to compound **2c**) recorded at 150 MHz in DMSO-$d_6$

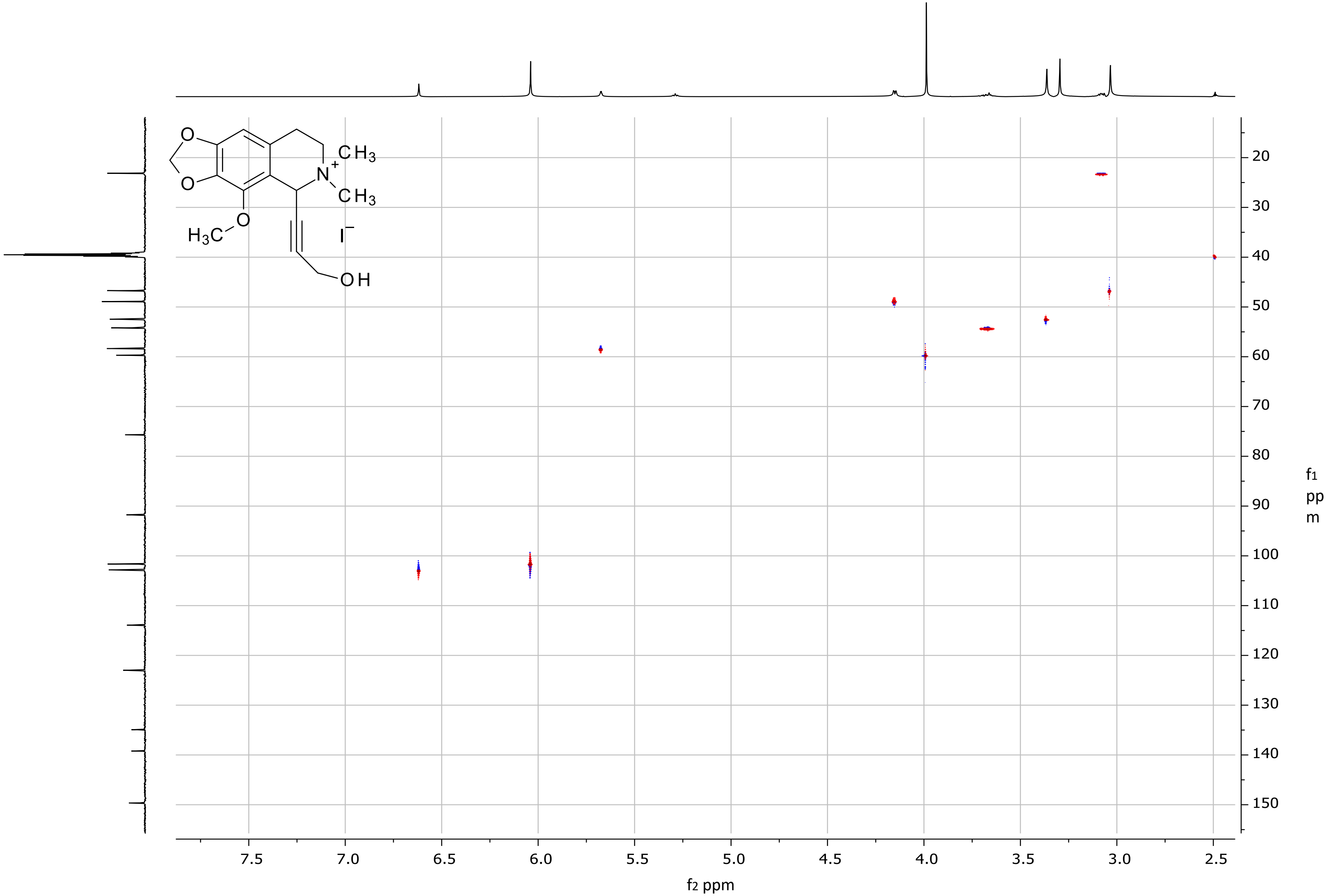

**Figure S19** HSQC spectrum of compound **3c** (isomerized to compound **2c**) recorded at 600, 150 MHz in DMSO-$d_6$

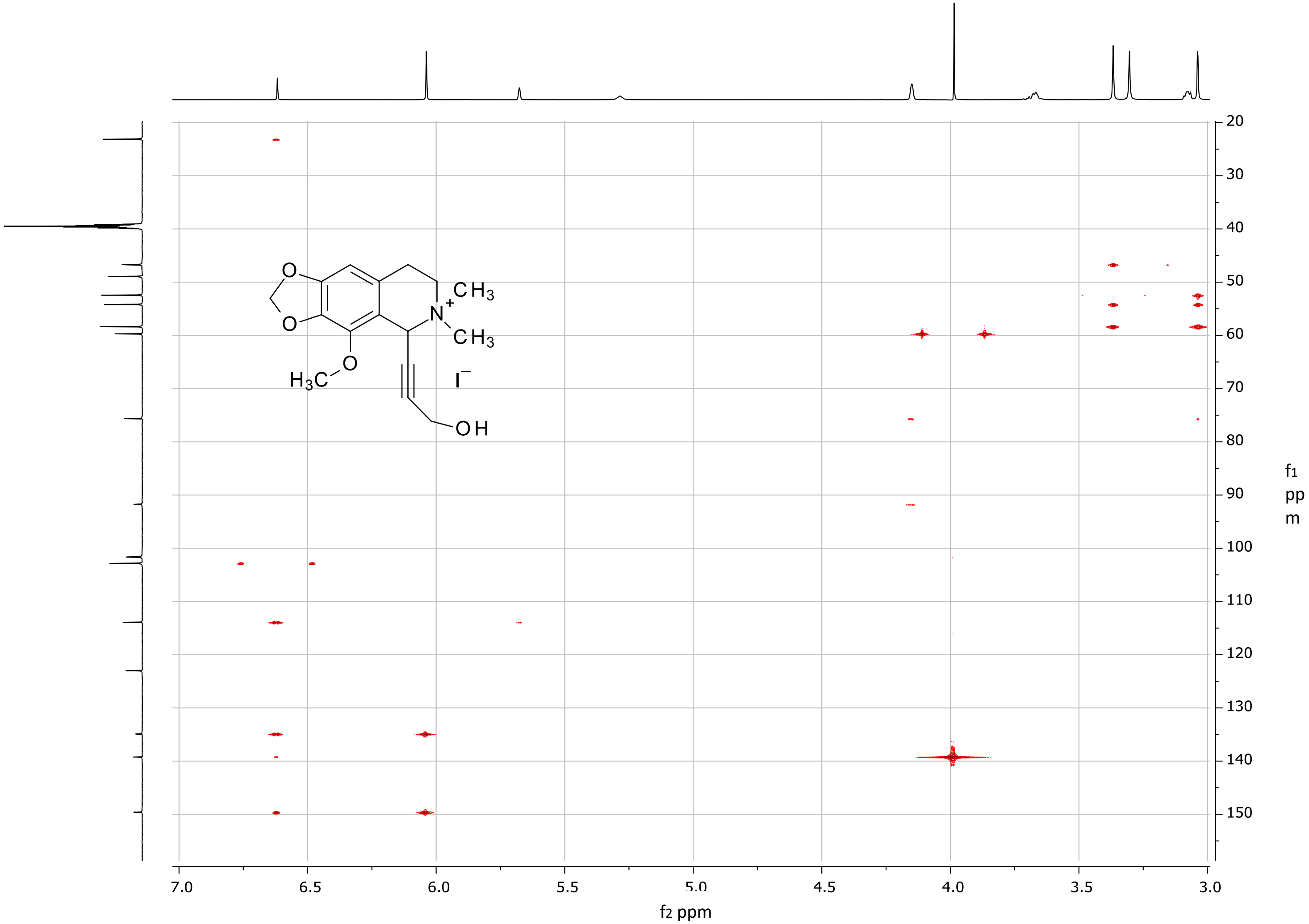

**Figure S20** HMBC spectrum of compound **3c** (isomerized to compound **2c**) recorded at 600, 150 MHz in DMSO-*d*$_6$

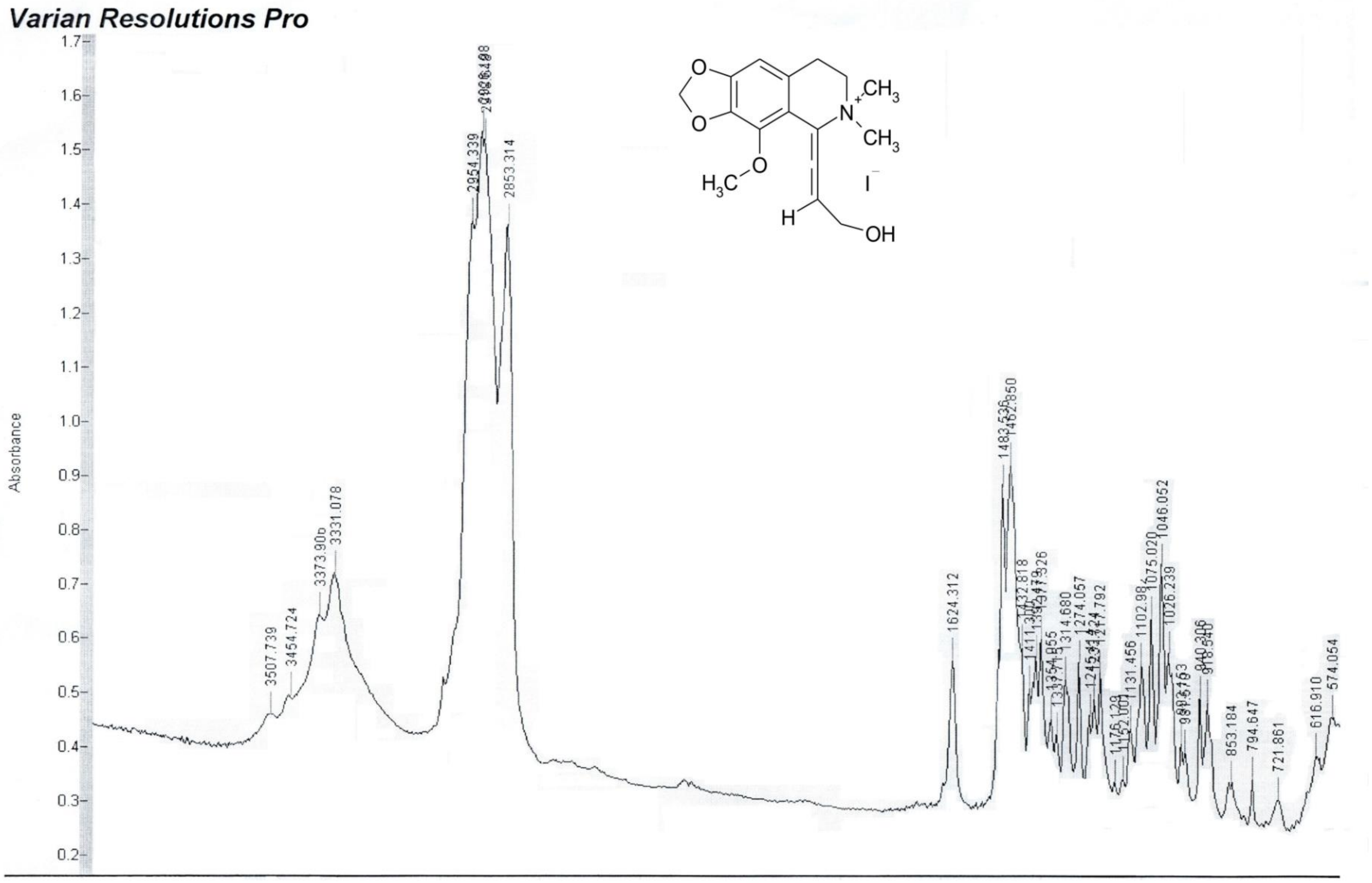

**Figure S21** IR- spectrum of compound **3c** recorded in nujol.

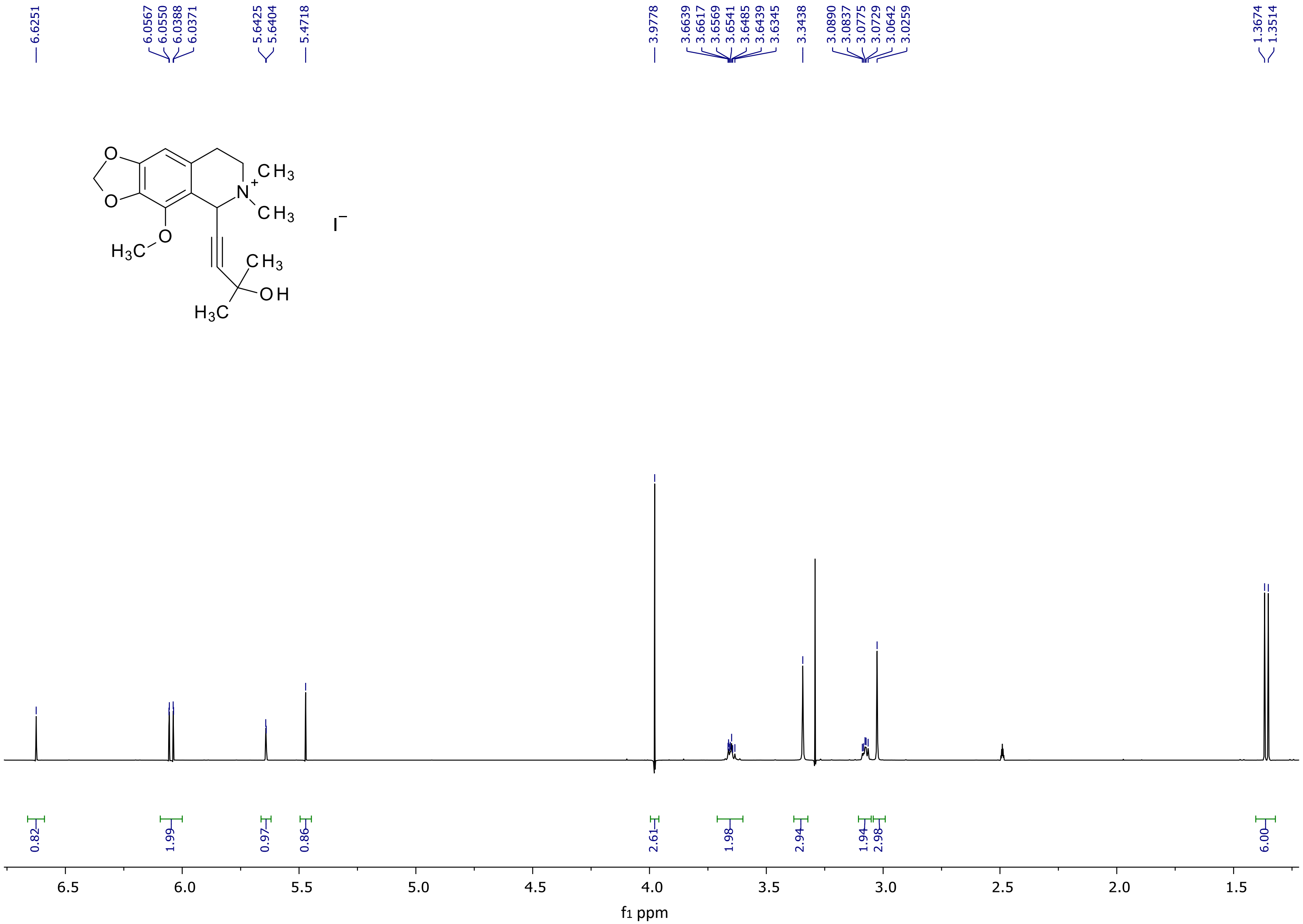

**Figure S22** $^1$H NMR spectrum of compound **3d** (isomerized to compound **2d**) recorded at 600 MHz in DMSO-$d_6$

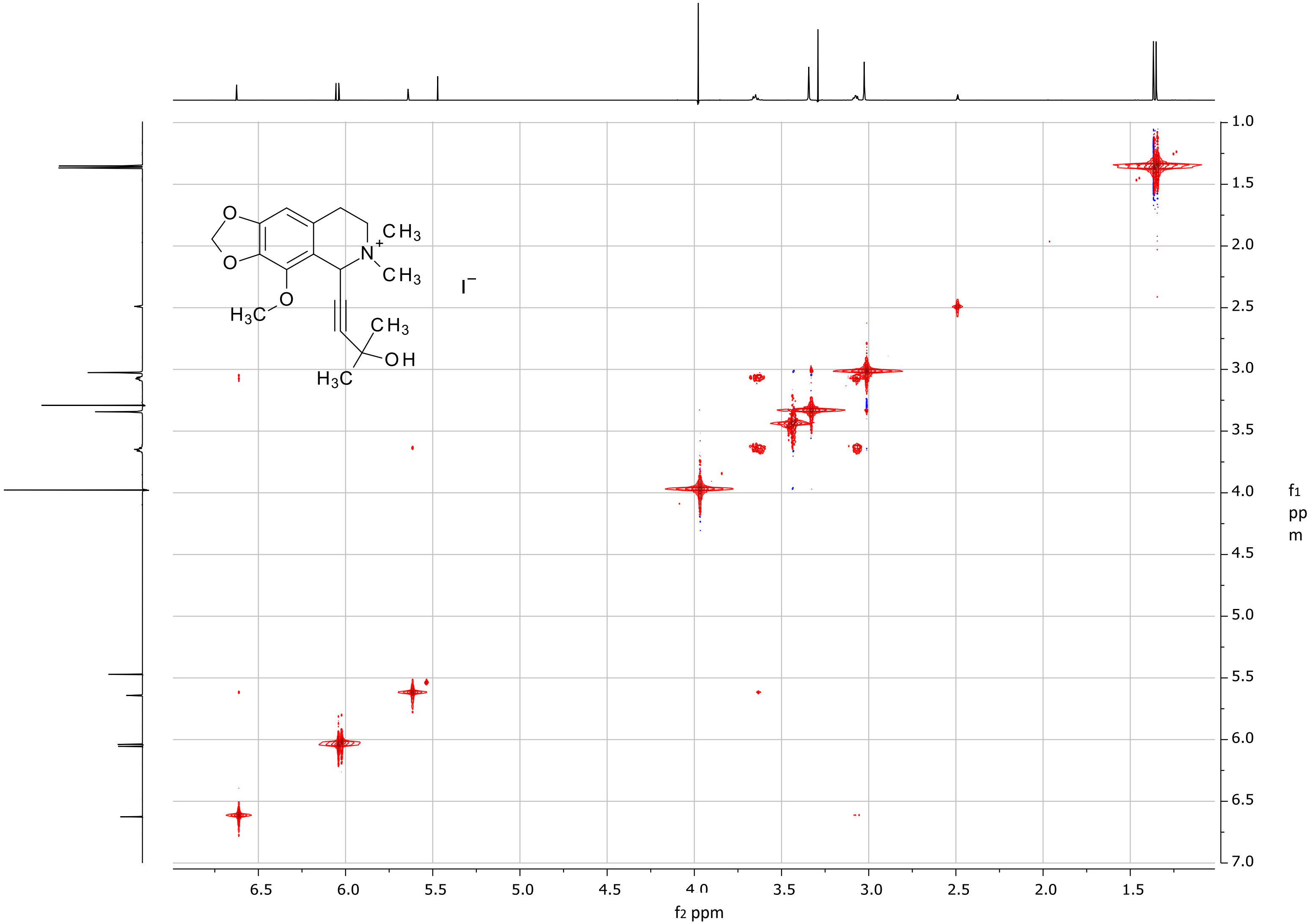

**Figure S23** COSY NMR spectrum of compound **3d** (isomerized to compound **2d**) recorded at 600, 600 MHz in DMSO-*d*$_6$

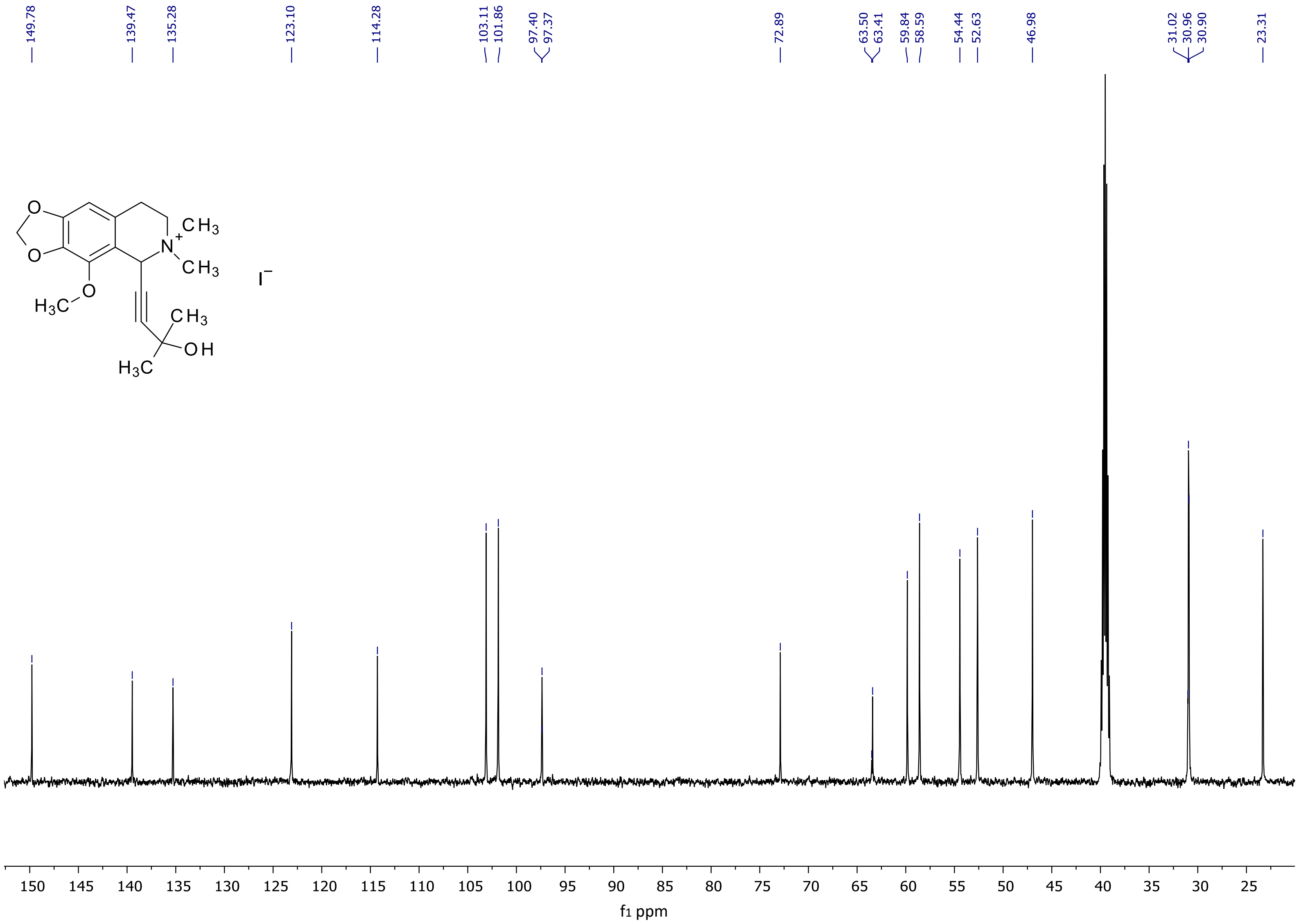

**Figure S24** $^{13}$C NMR spectrum of compound **3d** (isomerized to compound **2d**) recorded at 150 MHz in DMSO-$d_6$

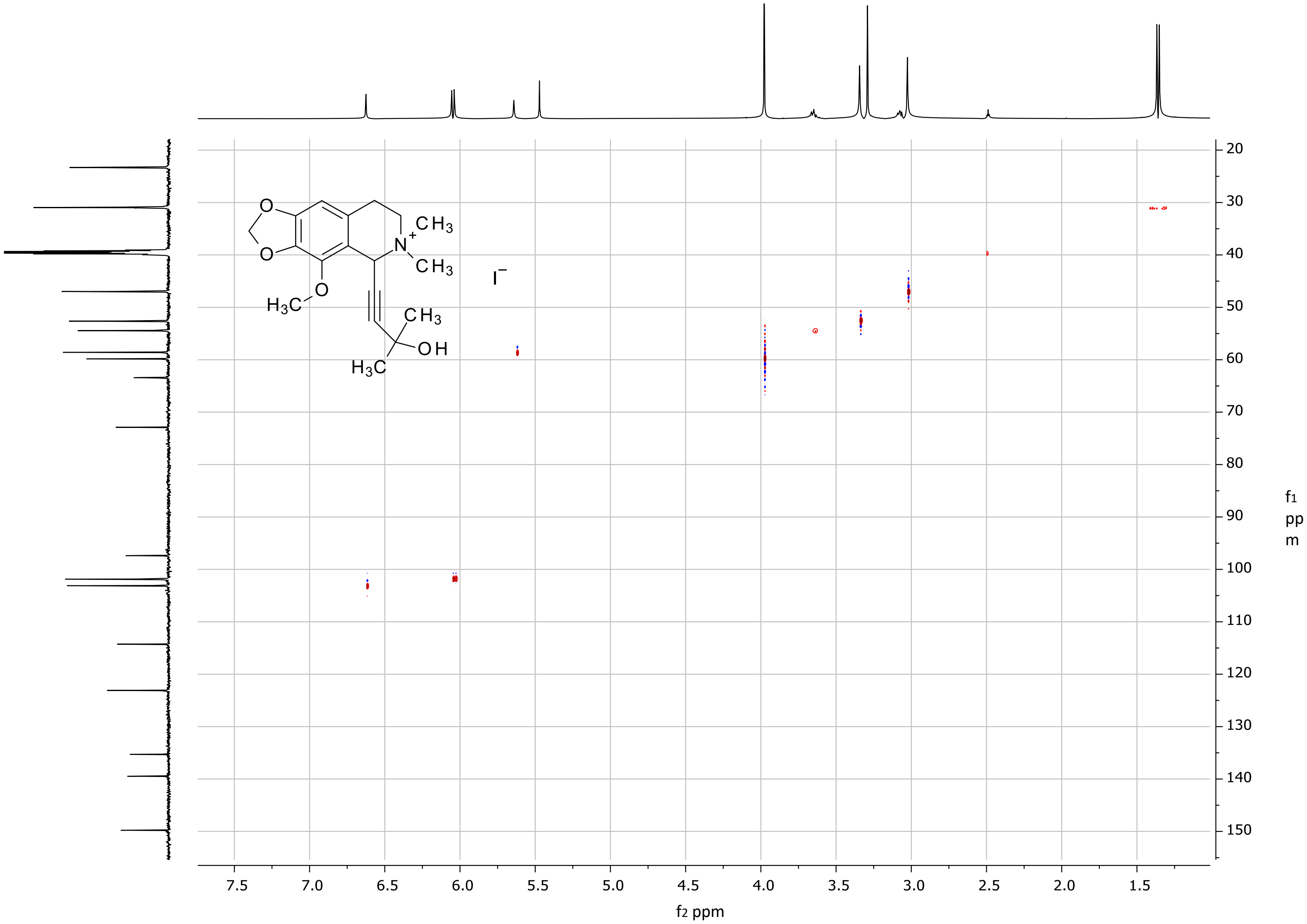

**Figure S25** HSQC spectrum of compound **3d** (isomerized to compound **2d**) recorded at 600, 150 MHz in DMSO-$d_6$

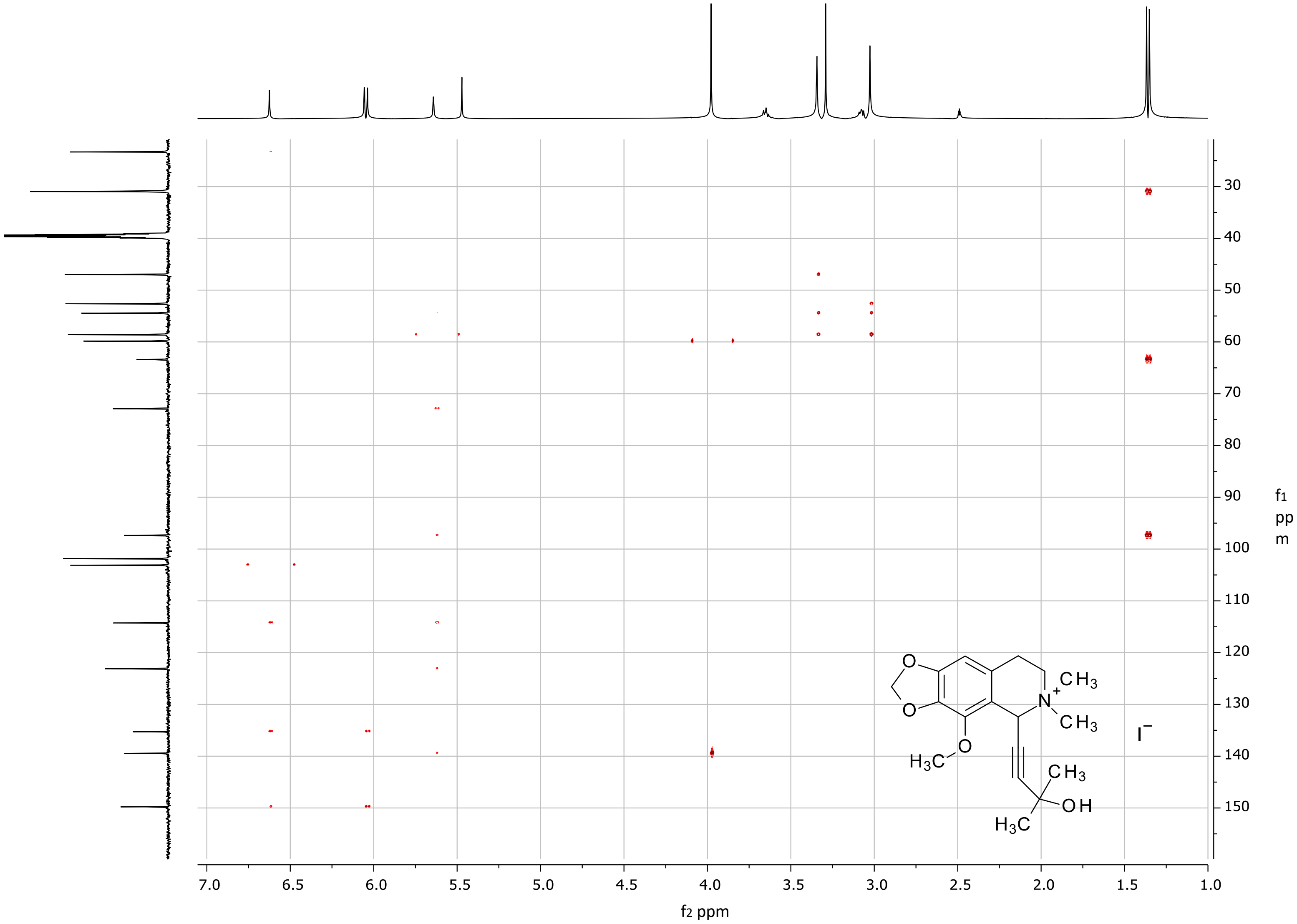

**Figure S26** HMBC spectrum of compound **3d** (isomerized to compound **2d**) recorded at 600, 150 MHz in DMSO-*d*$_6$

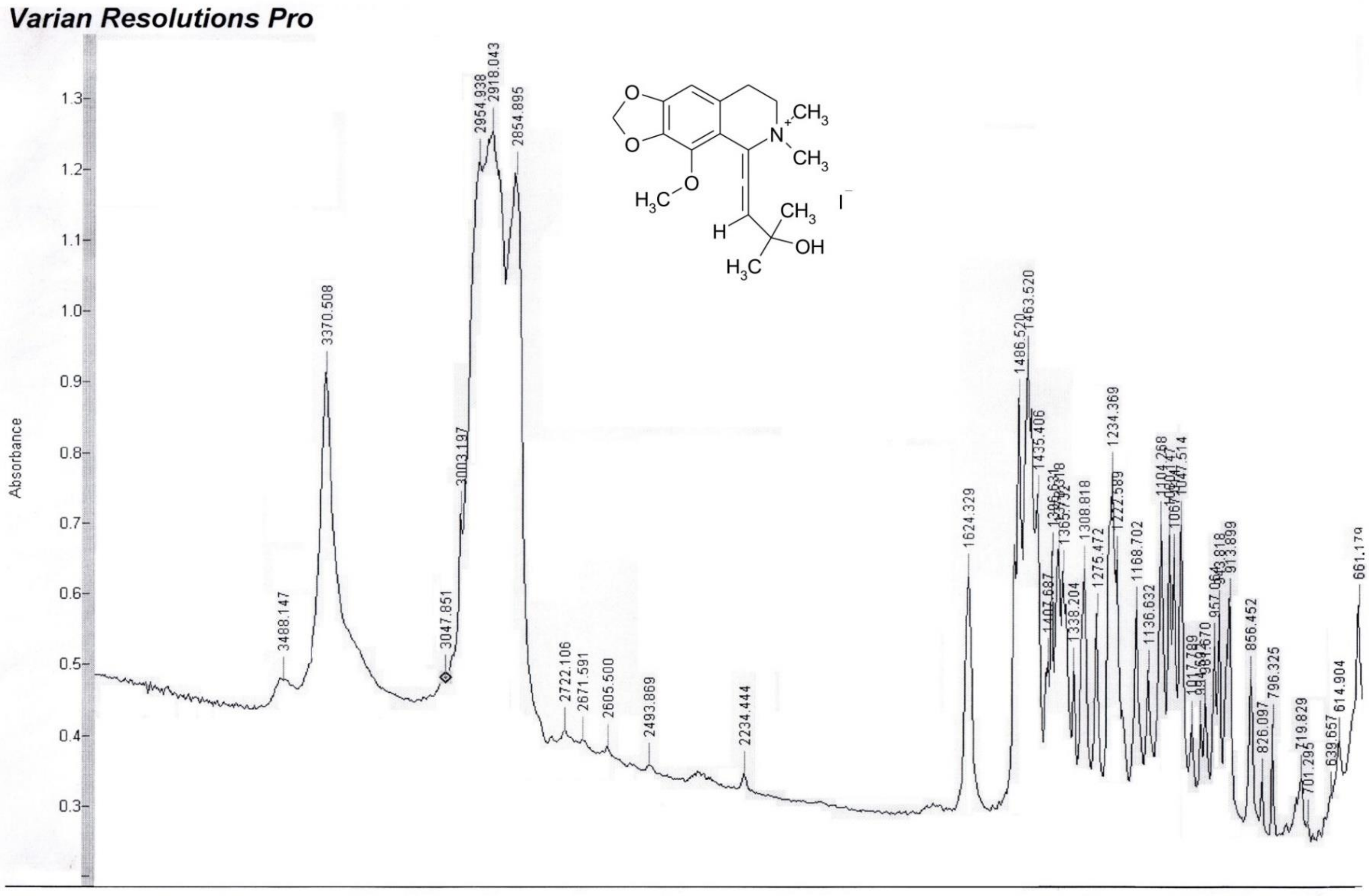

**Figure S27** IR- spectrum of compound **3d** recorded in nujol