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Supporting Information

Synthesis of 1-(3-(1-substituted-1,2,3-triazol-4-yl)-1,2,4-triazol-5-yl)-tetrazoles by Sequential Assembly of Azole Fragments

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Experimental Section

Special precautions were followed when working with sodium azide, organic azides and tetrazoles due to the blasting hazard. NMR spectra were recorded on Bruker Avance III HD instruments operating at 400 and 600 MHz for ^{1}H, and 100 and 126 MHz for ^{13}C. ^{1}H NMR chemical shifts were referenced to residual solvent signal (DMSO-d6: δ = 2.50 ppm) For ^{13}C NMR the following reference value was used: DMSO-d6: δ = 39.52 ppm. ^{1}H-^{15}N HMBC NMR spectra were recorded on a Bruker Avance III spectrometer with a broad-band cryo probe with ATM module operating at 500 MHz for ^{1}H and 125.7 MHz for ^{13}C measured in DMSO-d6 at room temperature. Atom numbering for NMR signals assignment is given in the SI. Mass spectra were acquired on a Varian 1200L GC-MS (EI, 70 eV) and Agilent 1200 HPLC/MS systems. High resolution mass spectrometry was performed on LTQ Orbitrap XL (APCI, ESI) instrument. Melting points were determined on a Koefler table (PTP-M, TU-92, 891.0). Ultrasonic experiments were carried out in an ultrasonic bath (22 kHz) or by an ultrasound probe UZD 22/44 (44 kHz). HPLC experiments were conducted using Shimadzu LC-2030C3D+ chromatograph with a PDA detector (LC-2030/2040 PDA Detector) and a Shim-pack GIST C18 (5μm, 4.6 mm×250 mm) column with a Precolumn C18 (4 mm×10 mm). UV experiments were made on a Perkin Elmer Lambda 40 UV-Vis spectrophotometer. X-Ray crystal diffraction data were collected on an Xcalibur PX system equipped with Onyx CCD detector and a Cu Kα sealed tube (λ = 1.54178 Å) with an enhanced monochromator using combined φ and ω scans at 200 K. CrysAlisProCCD[1] was used for data collection, cell refinement and data reduction. The structure was solved by direct methods with SIR92[2] and refined by full-matrix least-squares on F with CRYSTALS.[3] The positional and anisotropic thermal parameters of all non-hydrogen atoms were refined. All hydrogen atoms were located in a difference map, but those attached to carbon atoms were repositioned geometrically and then refined with riding constraints.

General procedures for the synthesis of azides 12

Benzyl azide (**12a**): Benzyl chloride (1 equiv) was mixed with four-fold volume of water and sodium azide (1.1 equiv) in a round-bottom flask. The emulsion was refluxed for 30 h in an oil bath. A colorless or off-yellow liquid was later separated from water and used further with no

additional purification. 4-Chlorobenzyl azide (**12b**) was obtained similarly. Spectral properties correspond to literature data.[4]

General procedure for the synthesis of phenyl azides (**12c-g**). Aniline (1 equiv) was suspended in a doubled volume of water, the reaction mixture was cooled to 0 °C, and concentrated H_2SO_4 (4 equiv) was added dropwise. For 4-bromophenyl azide **12f** and 4-methoxyphenyl azide **12g** concentrated hydrochloric acid was used instead of H_2SO_4. The reaction medium temperature was kept under 5 °C. After 5 min of stirring a solution of $NaNO_2$ (1.1 equiv) in a minimum amount of water was added dropwise. The mixture was then allowed to stir for 1 h, and then a solution of NaN_3 (1.1 equiv) in a minimum amount of water was added dropwise, not allowing the temperature to raise above 5 °C. After another 10 min of stirring the reaction mixture was gradually warmed to room temperature and stirred for 2 h more. The reaction was monitored by TLC (EtOAc:hexanes 1:4). The final compound was extracted by DCM or EtOAc, organic layer was washed with water and brine and evaporated. (Caution: DCM and NaN_3 can form diazidomethane, which might explode upon scaling up). The resulted azides should be stored in cold and utilized quickly after preparation. The spectra were in accordance with the literature data.[5]

General procedure for the synthesis of 1-substituted-1,2,3-triazole-4-carboxylic acids 13

Organic azide **12** (1 equiv) was dissolved in a 2:1 water-*tert*-BuOH mixture and propiolic acid (1.1 equiv) was added. The mixture was stirred while the catalyst was prepared separately. 5 % mol of $CuSO_4 \cdot 5\ H_2O$ were dissolved in a minimum amount of water, and 20 % mol of sodium ascorbate were added and the suspension was intensively mixed by a spatula until it became ochre in color. This catalyst was then added to the azide-propiolic acid mixture and was allowed to stir 24 h at room temperature. The formed precipitate was filtered and suspended in an 1M aqueous solution of disodium EDTA and then stirred for another 24 h at room temperature. The final triazolecarboxylic acid was filtered, washed with water, dried in the air and used without further purification.

For compounds with an electron-withdrawing substituent (**12e**) the CuAAC reaction was carried out with the help of an ultrasound probe (70% power, 44 kHz) for 3 h in an ice bath.

The spectral data for compounds **13** corresponded to reported in literature.[6,7]

General procedure for the synthesis of 3-substituted-1-amino-1,2,4-triazoles 14

1,2,3-Triazolecarboxylic acid **13** (1 equiv) was mixed with a large excess of $SOCl_2$ in a round-bottom flask. The mixture was refluxed for 1 h, and then was concentrated and dried in vacuo. No further purification was performed. Then, aminoguanidine hydrochloride (1.2 equiv) was added to the acyl chloride and the mixture was thoroughly mixed and heated in an oil bath at 180 °C for 2 h. Four-fold volume of 2.5 M solution of sodium hydroxide was added, again thoroughly stirred with a spatula and refluxed for 2 h. In some cases, some of the precipitate was not dissolved and was filtered off after cooling down, the filtrate was neutralized by glacial acetic acid, and the product was filtered off, dried in the air and used without further purification.

*3-(1-Benzyl-1*H*-1,2,3-triazol-4-yl)-1*H*-1,2,4-triazol-5-amine (**14a**)*

Yield 92%. Mp 252-254 °C. ^{1}H NMR spectrum (400 MHz, DMSO-d6): δ = 5.63 (s, 2H; CH_2 (C5)), 6.00 (br, 2H; NH_2), 7.33-7.40 (m, 5H; CH (C1, C2 and C3)), 8.40 (s, 1H; CH (C6)), 12.19 ppm (br, 1H, NH). ^{13}C NMR spectrum (100 MHz, DMSO-d6): δ = 52.81 (C5), 123.07 (C6), 127.92 (C3), 128.15 (C1), 128.76 (C2), 135.04 (C4), 140.73 (C7), 152.10 and 157.41 ppm (C8 and C9). HRMS (ESI): found 264.09680 $[M+Na]^+$, calculated for $C_{11}H_{11}N_7Na$ 264.09736.

*3-(1-(4-Chlorobenzyl)-1*H*-1,2,3-triazol-4-yl)-1*H*-1,2,4-triazol-5-amine (**14b**)*

Yield 43%. ^{1}H NMR spectrum (400 MHz, DMSO-d6): δ = 5.64 (s, 2H; CH_2 (C5)), 6.15 (br, 2H; NH_2), 7.36-7.45 (m, 4H; CH (C2 and C3)), 8.41 ppm (s, 1H; CH (C6)). ^{13}C NMR spectrum (100 MHz, DMSO-d6): δ = 52.00 (C5), 123.01 (C6), 128.75 (C2), 129.89 (C3), 132.85 (C1), 135.10 (C4), 140.94 ppm (C7), C8 and C9 not detected. MS (ESI) for $C_{11}H_{11}N_7Cl$: 276 $[M+H]^+$.

N-*(3-(1-(4-chlorobenzyl)-1*H*-1,2,3-triazol-4-yl)-1*H*-1,2,4-triazol-5-yl)acetamide (**Ac-14b**)*

Isolated as byproduct in synthesis of aminotriazole **14b**. ^{1}H NMR spectrum (400 MHz, DMSO-d6): δ = 2.12 (s, 3H; CH_3 (C11)), 5.67 (s, 2H; CH_2 (C5)), 7.39 (d, $^3J_{32}$ = 8.3 Hz, 2H; CH (C3)), 7.45 (d, $^3J_{23}$ = 8.3 Hz, 2H; CH (C2)), 8.57 (s, 1H; CH (C6)), 11.68 (br, 1H; NH), 13.45 ppm (br, 1H; NH). ^{13}C NMR spectrum (150 MHz, DMSO-d6): δ = 22.78 (C11), 52.02 (C5), 123.60 (C6), 128.77 (C2), 129.93 (C3), 132.85 (C1), 135.05 (C4), 140.14 (C7), 151.82 (C8 or C9), 169.11 ppm

(C10). ^{15}N-^{1}H HMBC correlations: H11-NH, H5-N2', H6-N1', H5-N1'. MS (ESI) for $C_{13}H_{12}N_7ClO$: 340 $[M+Na]^+$.

*3-(1-Phenyl-1*H*-1,2,3-triazol-4-yl)-1*H*-1,2,4-triazol-5-amine (**14c**)*

Yield 74%. Mp 263-265 °C. ^{1}H NMR spectrum (400 MHz, DMSO-d6): δ = 6.09 (br, 2H; NH_2), 7.48-7.51 (m, 1H; CH (C1)), 7.58-7.62 (m, 2H; CH (C2)), 7.97-7.99 (m, 2H; CH (C3)), 9.03 (s, 1H; CH (C5)), 12.28 ppm (br, 1H, NH). ^{13}C NMR spectrum (100 MHz, DMSO-d6): δ = 120.15 (C3), 120.84 (C5), 128.69 (C1), 129.86 (C2), 136.54 (C4), 141.68 (C6), 152.03 and 157.30 ppm (C7 and C8). HRMS (ESI): found 250.08112 $[M+Na]^+$, calculated for $C_{10}H_9N_7Na$ 250.08171.

*3-(1-(p-Tolyl)-1*H*-1,2,3-triazol-4-yl)-1*H*-1,2,4-triazol-5-amine (**14d**)*

Yield 84%. Mp 258-260 °C. ^{1}H NMR spectrum (400 MHz, DMSO-d6): δ = 2.38 (s, 3H; CH_3 (C1)), 6.06 (br, 2H; NH_2), 7.40 (d, $^{3}J_{34}$ = 8.3 Hz, 2H; CH (C3)), 7.85 (d, $^{3}J_{43}$ = 8.3 Hz, 2H; CH (C4)), 8.96 (s, 1H; CH (C6)), 12.23 ppm (br, 1H, NH). ^{13}C NMR spectrum (100 MHz, DMSO-d6): δ = 20.57 (C1), 120.03 (C4), 120.71 (C6), 130.19 (C3), 134.30 (C5), 138.30 (C2), 141.57 (C7), 152.23 and 157.36 ppm (C8 and C9). HRMS (ESI): found 264.09677 $[M+Na]^+$, calculated for $C_{11}H_{11}N_7Na$ 264.09736.

*3-(1-(4-Bromophenyl)-1*H*-1,2,3-triazol-4-yl)-1*H*-1,2,4-triazol-5-amine (**14f**)*

Yield 99%. Mp >300 °C. ^{1}H NMR spectrum (400 MHz, DMSO-d6): δ = 6.25 (br, 2H; NH_2), 7.80 (d, $^{3}J_{HH}$ = 8.6 Hz, 2H; CH_{Ar}), 7.96 (d, $^{3}J_{HH}$ = 8.6 Hz, 2H; CH_{Ar}), 9.03 ppm (s, 1H; CH (C5)). ^{13}C NMR spectrum (100 MHz, DMSO-d6): δ = 120.87 (C5), 121.33 (C1), 122.09 and 132.73 (C2 and C3), 135.77 (C4), 141.83 (C6), 151.26 and 158.02 ppm (C7 and C8). MS (ESI, neg.): 304/306 $[M-H]^-$, MS (ESI, pos.): 328/330 $[M+Na]^+$.

*3-(1-(4-Methoxyphenyl)-1*H*-1,2,3-triazol-4-yl)-1*H*-1,2,4-triazol-5-amine (**14g**)*

Yield 65%. Mp 272-274 °C. ^{1}H NMR spectrum (400 MHz, DMSO-d6): δ = 3.83 (s, 3H; CH_3 (C1)), 6.13 (br, 2H; NH_2), 7.13 (d, $^{3}J_{34}$ = 8.7 Hz, 2H; CH (C3)), 7.88 (d, $^{3}J_{43}$ = 8.7 Hz, 2H; CH (C4)), 8.92 (s, 1H; CH (C6)), 12.37 ppm (br, 1H, NH). ^{13}C NMR spectrum (100 MHz, DMSO-d6): δ = 55.57 (C1), 114.84 (C3), 120.81 (C6), 121.80 (C4), 129.97 (C5), 141.67 (C7), 152.26 and

157.31 (C8 and C9), 159.28 ppm (C2). HRMS (ESI): found 280.09171 $[M+Na]^+$, calculated for $C_{11}H_{11}ON_7Na$ 280.09228.

General procedure for the preparation of 1-substituted tetrazoles 1

Amine **14** (1 equiv), sodium azide (3 equiv) and freshly distilled trialkyl orthoformate (3 equiv) in a tripled volume of glacial acetic acid were heated for 3 h in a water bath. Reaction mixture was diluted in half by 0.3% HCl(aq.), the precipitate was filtered off, washed with water and dried on air.

*1-(3-(1-Benzyl-1*H*-1,2,3-triazol-4-yl)-1*H*-1,2,4-triazol-5-yl)-1*H*-tetrazole (**1a**)*

Yield 34%. Mp >300 °C. ^{1}H NMR spectrum (600 MHz, DMSO-d6): δ = 5.75 (s, 2H; CH_2 (C5)), 7.39-7.42 (m, 5H; CH (C1, C2 and C3)), 8.94 (s, 1H; CH (C6)), 10.15 (s, 1H; CH (C10)), 15.57 ppm (br, 1H, NH). ^{13}C NMR spectrum (150 MHz, DMSO-d6): δ = 53.28 (C5), 125.16 (C6), 128.13 (C3), 128.40 (C1), 128.89 (C2), 135.51 (C4), 135.62 (C7), 143.09 (C10), 148.81 and 152.67 ppm (C8 and C9). HMBC correlations: H5-C6, H6-C4. ^{15}N-^{1}H HMBC correlations: H10-N9', H10-N10', H6-N1', H5-N2', H5-N1'. HRMS (ESI): found 317.09843 $[M+Na]^+$, calculated for $C_{12}H_{10}N_{10}Na$ 317.09821.

*1-(3-(1-(4-Chlorobenzyl)-1*H*-1,2,3-triazol-4-yl)-1*H*-1,2,4-triazol-5-yl)-1*H*-tetrazole (**1b**)*

Yield 78%. Mp >300 °C. ^{1}H NMR spectrum (600 MHz, DMSO-d6): δ = 5.75 (s, 2H; CH_2 (C5)), 7.39-7.42 (m, 5H; CH (C1, C2 and C3)), 8.94 (s, 1H; CH (C6)), 10.15 (s, 1H; CH (C10)), 15.57 ppm (br, 1H, NH). ^{13}C NMR spectrum (150 MHz, DMSO-d6): δ = 53.28 (C5), 125.16 (C6), 128.13 (C3), 128.40 (C1), 128.89 (C2), 135.51 (C4), 135.62 (C7), 143.09 (C10), 148.81 and 152.67 ppm (C8 and C9). HMBC correlations: H5-C6, H6-C4. ^{15}N-^{1}H HMBC correlations: H10-N9', H10-N10', H6-N1', H5-N2', H5-N1'. HRMS (ESI): found 317.09843 $[M+Na]^+$, calculated for $C_{12}H_{10}N_{10}Na$ 317.09821.

*1-(3-(1-Phenyl-1*H*-1,2,3-triazol-4-yl)-1*H*-1,2,4-triazol-5-yl)-1*H*-tetrazole (**1c**)*

Yield 34%. Mp >300 °C. ^{1}H NMR spectrum (400 MHz, DMSO-d6): δ = 7.54-7.65 (m, 3H; CH (C1 and C2)), 8.03-8.05 (m, 2H; CH (C3)), 9.58 (s, 1H; CH (C5)), 10.16 ppm (s, 1H; CH (C9)). ^{13}C NMR spectrum (100 MHz, DMSO-d6): δ = 120.55 (C3), 123.16 (C5), 129.36 (C1), 129.99 (C2), 136.14 (C4), 136.48 (C6), 143.09 (C9), 148.59 and 152.74 ppm (C7 and C8). HRMS (APCI): found 281.10055 $[M+H]^+$, calculated for $C_{11}H_9N_{10}$ 281.10117. HRMS (ESI, neg.): found 279.08600 $[M-H]^-$, calculated for $C_{11}H_7N_{10}$ 279.08552. MS (ESI, pos.): 253 $[M-CN]^+$.

*1-(3-(1-(p-Tolyl)-1*H*-1,2,3-triazol-4-yl)-1*H*-1,2,4-triazol-5-yl)-1*H*-tetrazole (**1d**)*

Yield 62%. Mp >300 °C. ^{1}H NMR spectrum (400 MHz, DMSO-d6): δ = 2.40 (s, 3H; CH_3 (C1)), 7.42-7.46 (m, 2H; CH (C3)), 7.88-7.92 (m, 2H; CH (C4)), 9.52 (s, 1H; CH (C6)), 10.15 ppm (s, 1H; CH (C10)). ^{13}C NMR spectrum (100 MHz, DMSO-d6): δ = 20.61 (C1), 120.41 (C4), 123.00 (C6), 130.32 (C3), 133.88 (C5), 136.38 (C7), 139.11 (C2), 143.08 (C10), 148.63 and 152.72 ppm (C8 and C9). HRMS (APCI): found 295.11650 $[M+H]^+$, calculated for $C_{12}H_{11}N_{10}$ 295.11682. HRMS (ESI, neg.): found 293.10167 $[M-H]^-$, calculated for $C_{12}H_9N_{10}$ 293.10117.

*1-(3-(1-(4-Bromophenyl)-1*H*-1,2,3-triazol-4-yl)-1*H*-1,2,4-triazol-5-yl)-1*H*-tetrazole (**1f**) (**isolated as inseparable mixture with unreacted aminotriazole 14f**)*

Yield 63% (crude). Mp >300 °C. ^{1}H NMR (400 MHz, DMSO-d6) δ = 7.79-7.82 (m, 2H; CH_{Ar}), 7.96-8.01 (m, 2H; CH_{Ar}), 9.07 (s, 1H; CH (C5)), 9.81 ppm (s, 1H; CH (C9)). ^{13}C NMR spectrum (100 MHz, DMSO-d6): δ = 119.3, 120.9, 121.7, 122.0, 132.6, 132.7, 142.2 ppm (C9). MS (ESI, neg.): 357/359 $[M-H]^-$, MS (ESI, pos.): 332/334 $[M-CN+H]^+$.

*1-(3-(1-(4-Methoxyphenyl)-1*H*-1,2,3-triazol-4-yl)-1*H*-1,2,4-triazol-5-yl)-1*H*-tetrazole (**1g**)*

Yield 64%. Mp >300 °C. ^{1}H NMR spectrum (400 MHz, DMSO-d6): δ = 3.85 (s, 3H; CH_3 (C1)), 7.16-7.19 (m, 2H; CH (C3)), 7.91-7.94 (m, 2H; CH (C4)), 9.48 (s, 1H; CH (C6)), 10.16 ppm (s, 1H; CH (C10)). ^{13}C NMR spectrum (100 MHz, DMSO-d6): δ = 55.64 (C1), 114.97 (C3), 122.20 (C4), 123.03 (C6), 129.48 (C5), 136.29 (C7), 139.11 (C2), 143.08 (C10), 148.67 and 152.72 (C8 and C9), 159.76 ppm (C2). HRMS (APCI): found 311.11113 $[M+H]^+$, calculated for $C_{12}H_{11}ON_{10}$ 311.11173. HRMS (ESI, neg.): found 309.09656 $[M-H]^-$, calculated for $C_{12}H_9ON_{10}$ 309.09608. MS (ESI, pos.): 283 $[M-CN]^+$.

Crystal data for 14b (0.10 × 0.27 × 0.79 mm):

$C_{11}H_{10}Cl_1N_7.H_2O$, monoclinic, space group $P2_1/c$, a = 14.8148(4) Å, b = 9.7016(3) Å, c = 8.9435(3) Å, β = 97.1958(8)°, V = 1275.30(4) Å^3, Z = 4, M = 293.72, 16892 reflections measured, 2255 independent reflections. Final R = 0.033, wR = 0.034, GoF = 1.106 for 2166 reflections with $I > 2\sigma(I)$ and 203 parameters. The asymmetric unit contains one molecule of **14b** and one water molecule which was found to be disordered over two sets of sites with occupancies of 0.666 and 0.334. CCDC deposition number 2083793.

Cited literature:

[1] CrysAlisPro, Oxford Diffraction, **2002**.

[2] A. Altomare, G. Cascarano, C. Giacovazzo, A. Guagliardi, M. C. Burla, G. Polidori, M. Camalli, *J. Appl. Crystallogr.* **1994**, *27*, 435–436.

[3] P. W. Betteridge, J. R. Carruthers, R. I. Cooper, K. Prout, D. J. Watkin, *J. Appl. Crystallogr.* **2003**, *36*, 1487–1487.

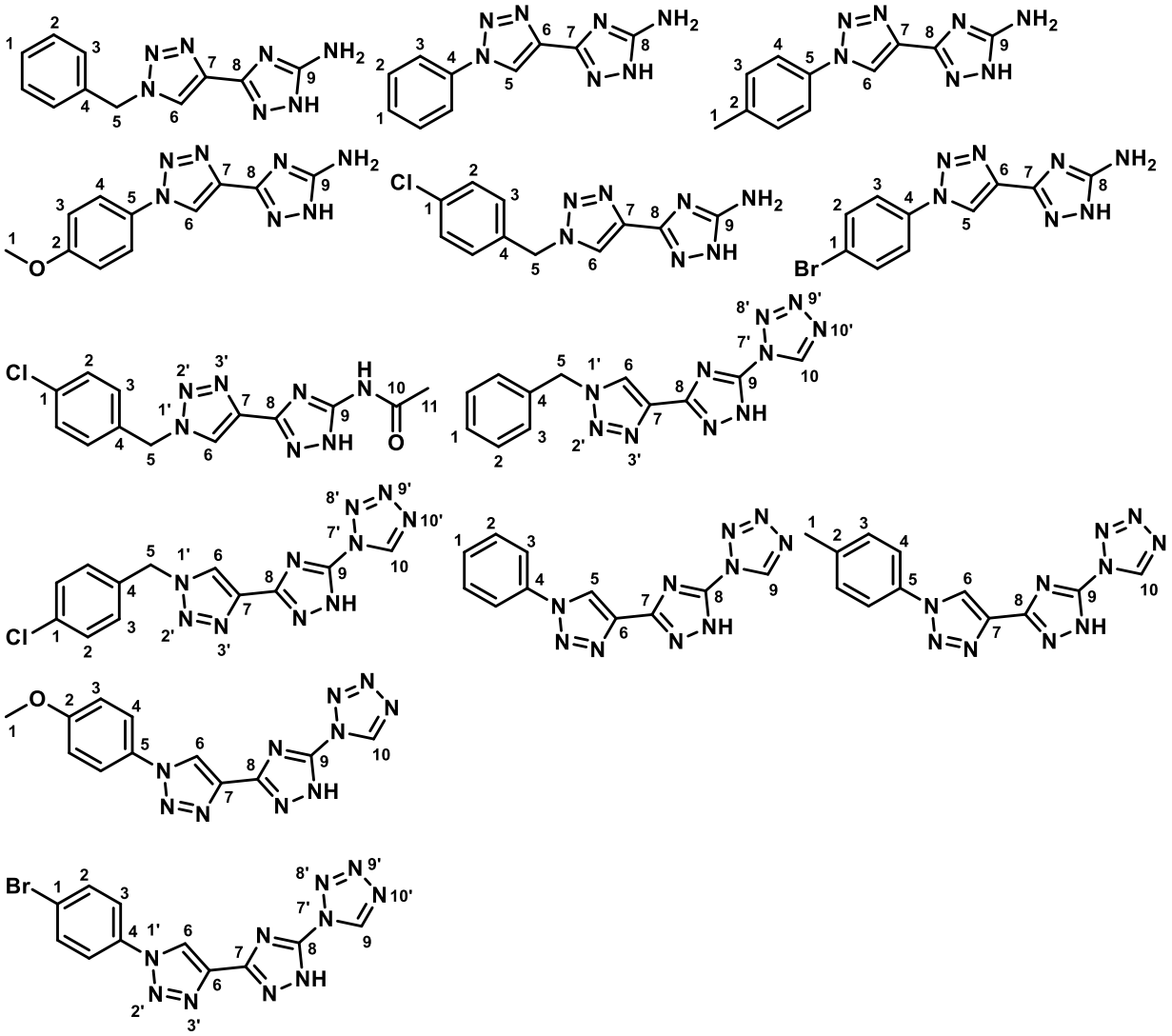
[4] B. Pal, P. Jaisankar, V. S. Giri, *Synth. Commun.* **2004**, *34*, 1317–1323.

[5] M. Hu, J. Li, S. Q. Yao, *Org. Lett.* **2008**, *10*, 5529–5531.

[6] H. Zheng, R. McDonald, D. G. Hall, *Chem. - A Eur. J.* **2010**, *16*, 5454–5460.

[7] M. Liu, Y. Hou, W. Yin, S. Zhou, P. Qian, Z. Guo, L. Xu, Y. Zhao, *Eur. J. Med. Chem.* **2016**, *119*, 96–108.

Scheme SI-1. Atom numbering in isolated compounds.



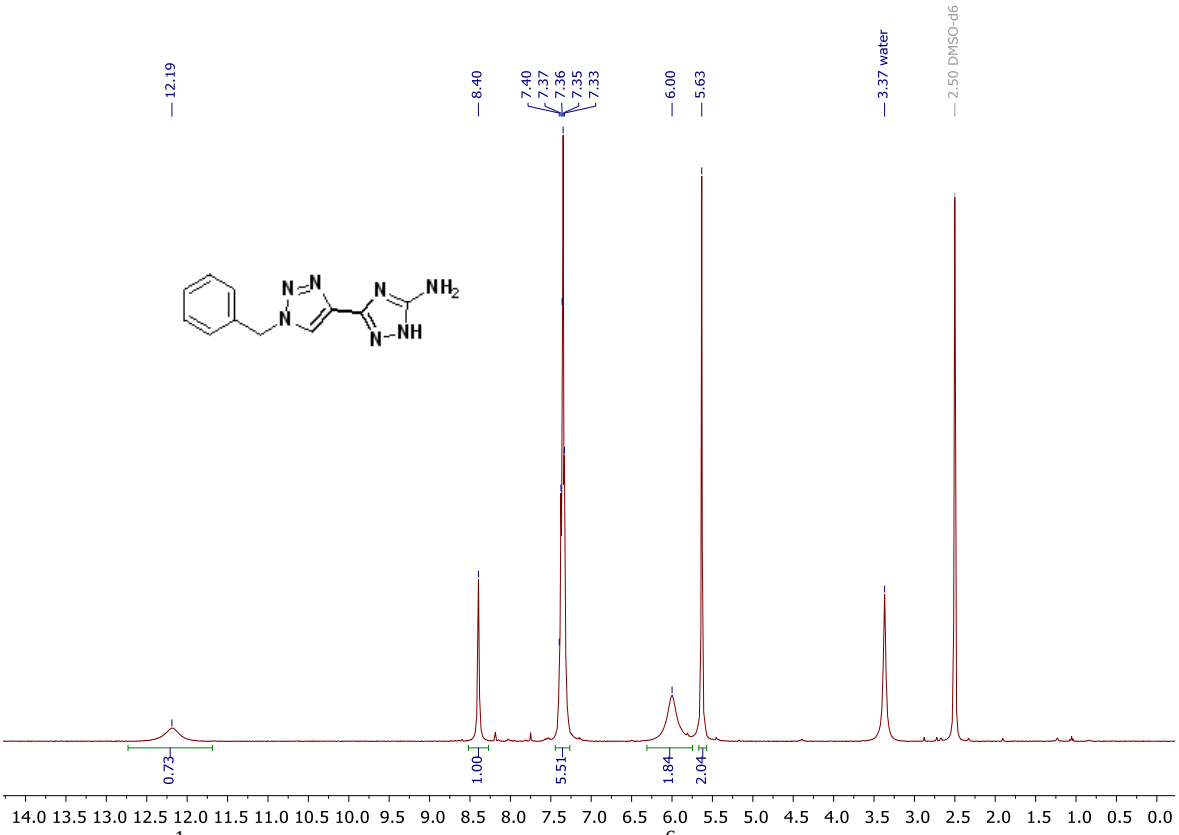


Figure SI-1. ^{1}H NMR spectrum of **14a** in DMSO-d^{6} at 25 °C.

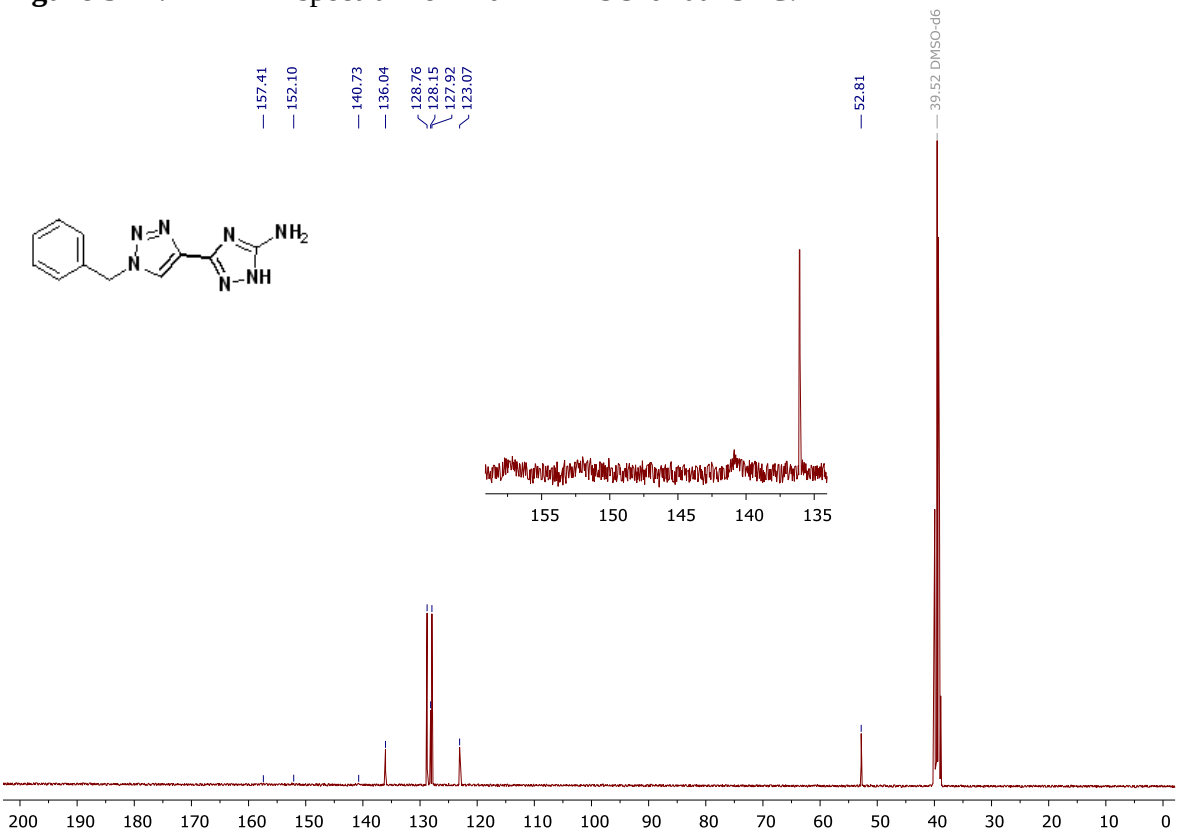


Figure SI-2. ^{13}C NMR spectrum of **14a** in DMSO-d^{6} at 25 °C.

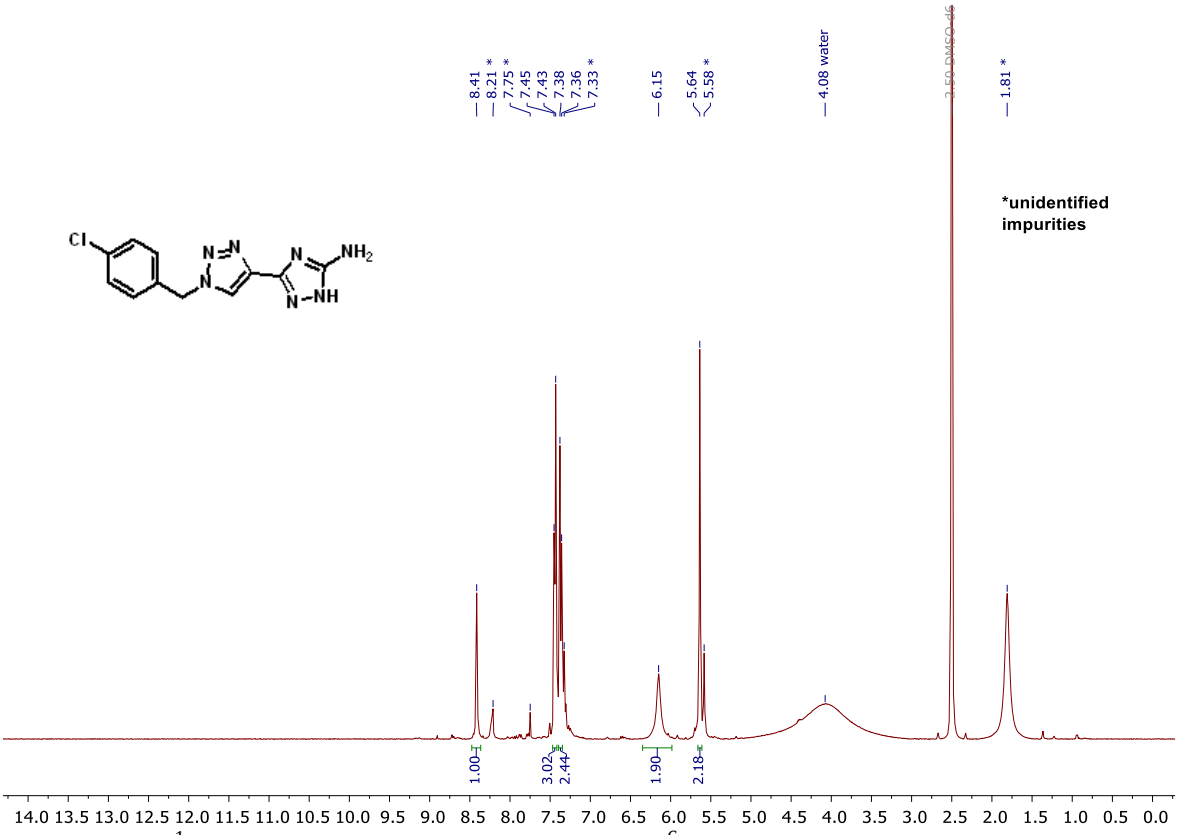


Figure SI-3. ^{1}H NMR spectrum of **14b** in DMSO-d^{6} at 25 °C.

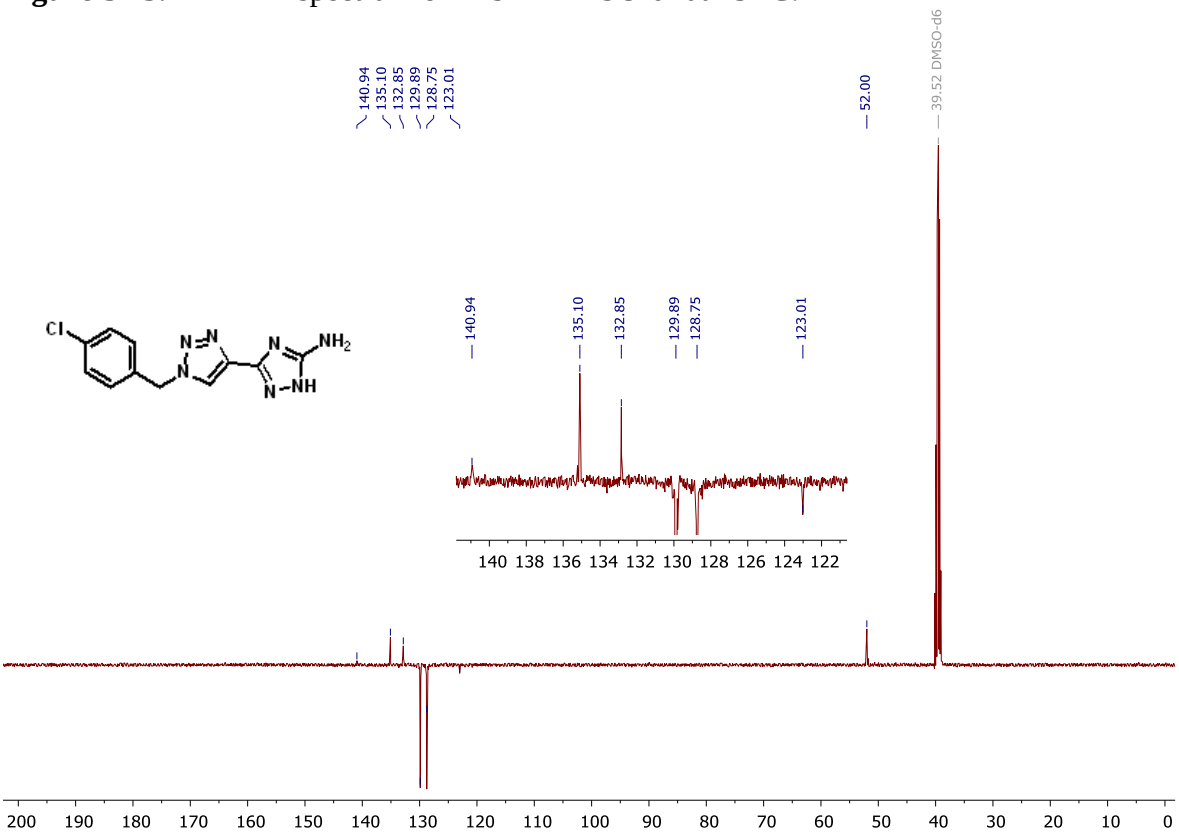


Figure SI-4. ^{13}C APT NMR spectrum of **14b** in DMSO-d^{6} at 25 °C.

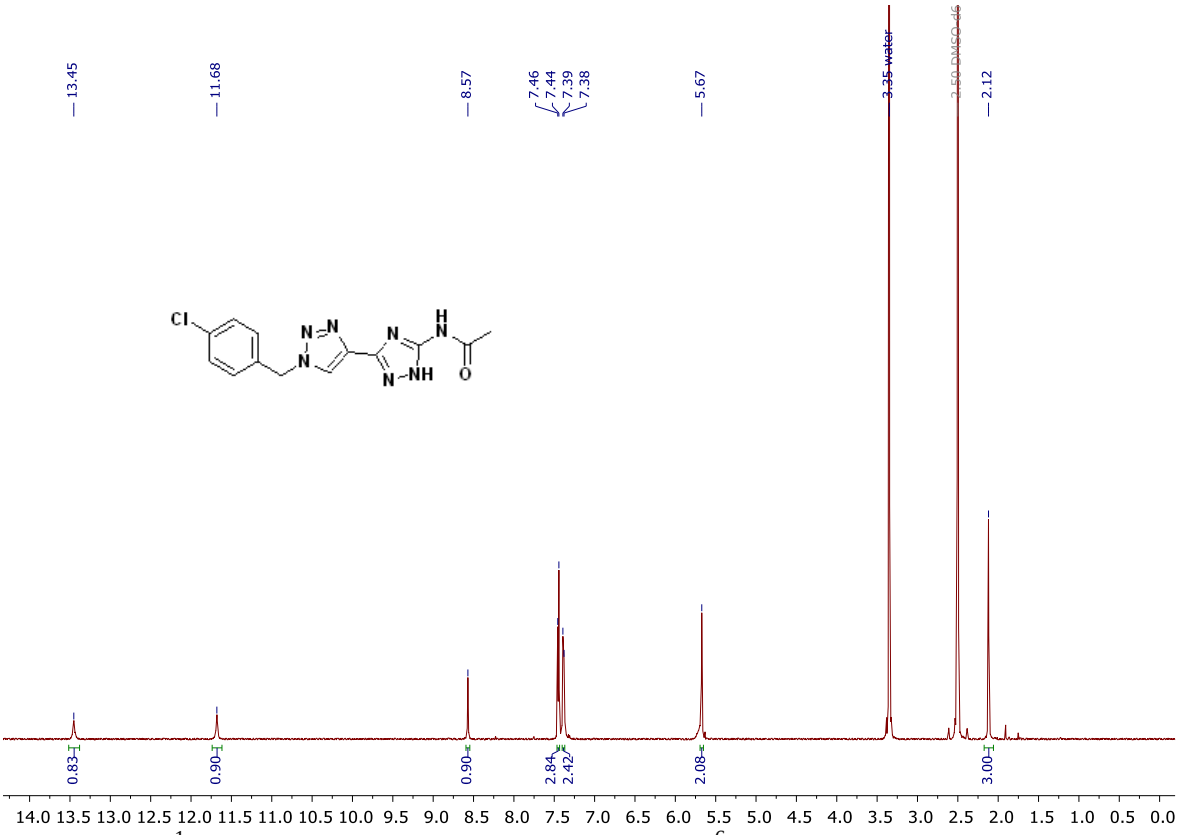


Figure SI-5. ^{1}H NMR spectrum of **Ac-14b** in DMSO-d^{6} at 25 °C.

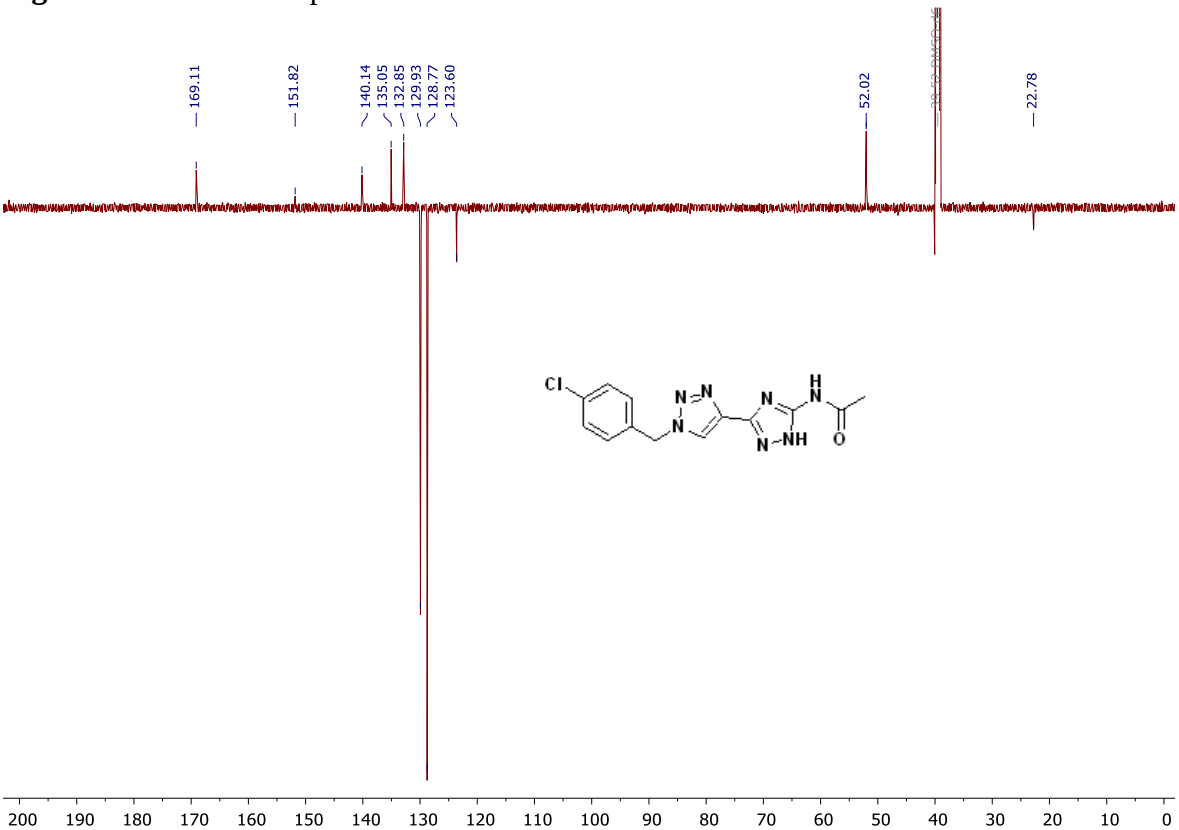


Figure SI-6. ^{13}C APT NMR spectrum of **Ac-14b** in DMSO-d^{6} at 25 °C.

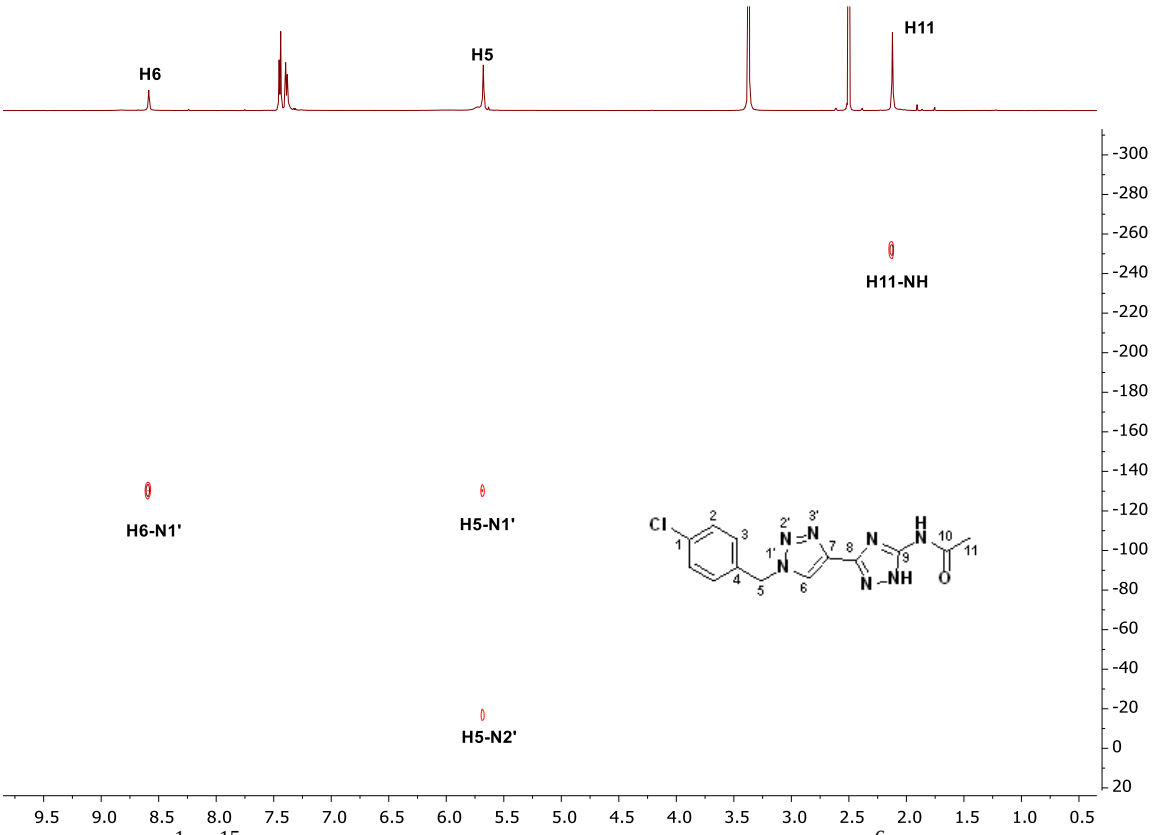


Figure SI-7. ^{1}H-^{15}N-HMBC NMR spectrum of **Ac-14b** in DMSO-d^{6} at 25 °C.

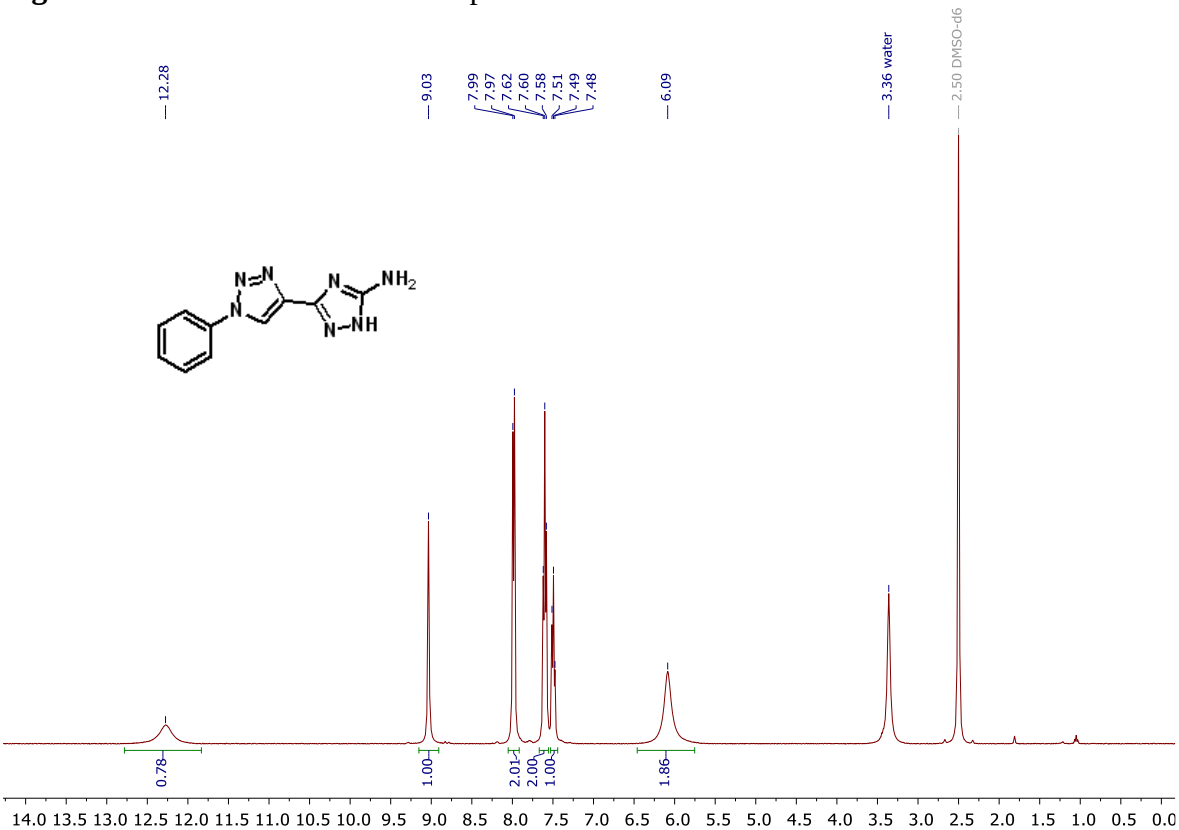


Figure SI-8. ^{1}H NMR spectrum of **14c** in DMSO-d^{6} at 25 °C.

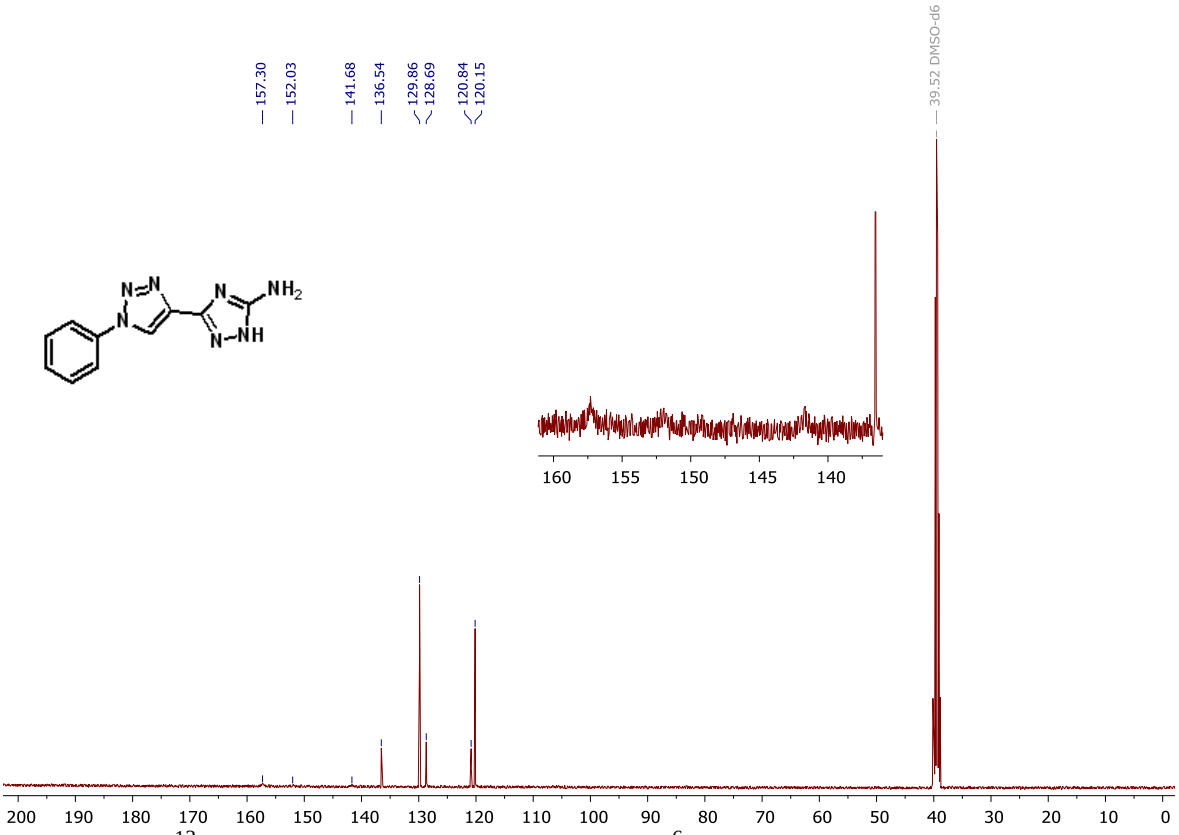


Figure SI-9. ^{13}C NMR spectrum of **14c** in DMSO-d^6 at 25 °C.

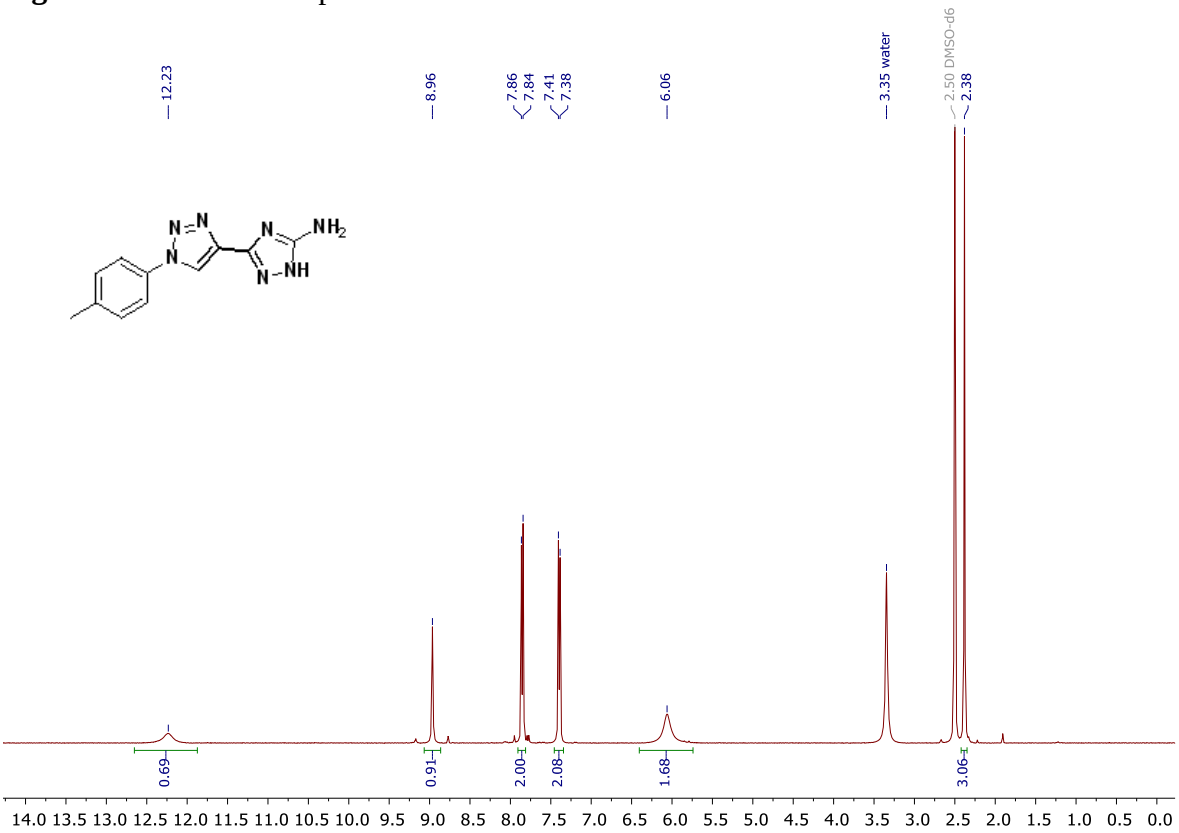


Figure SI-10. ^{1}H NMR spectrum of **14d** in DMSO-d^6 at 25 °C.

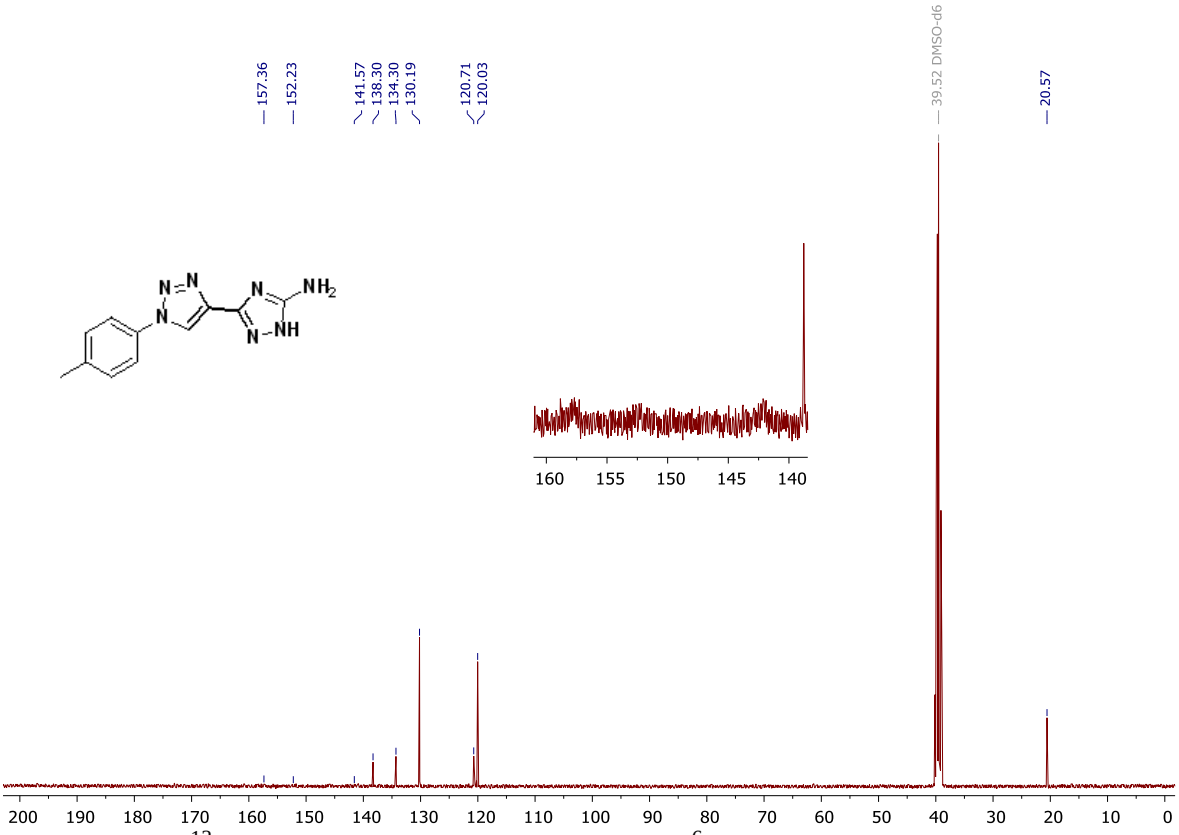


Figure SI-11. ^{13}C NMR spectrum of **14d** in DMSO-d^6 at 25 °C.

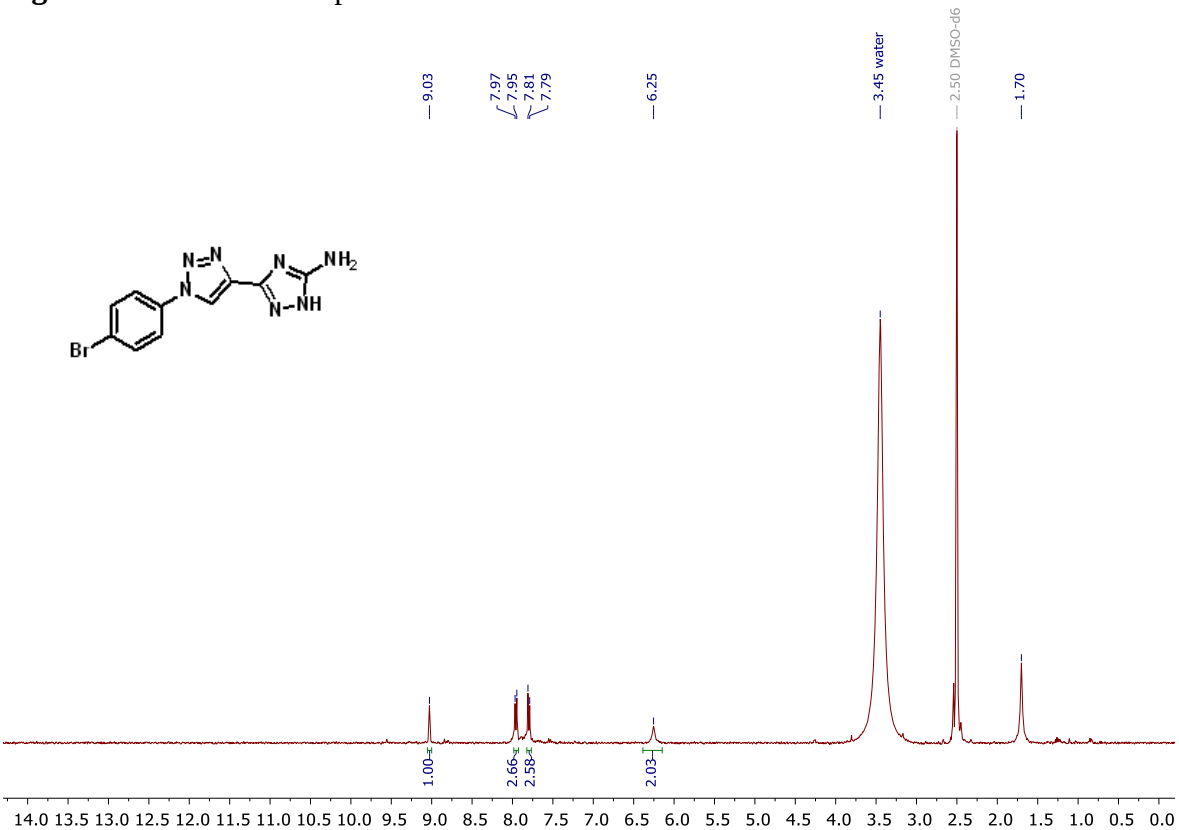


Figure SI-12. ^{1}H NMR spectrum of **14f** in DMSO-d^6 at 25 °C.

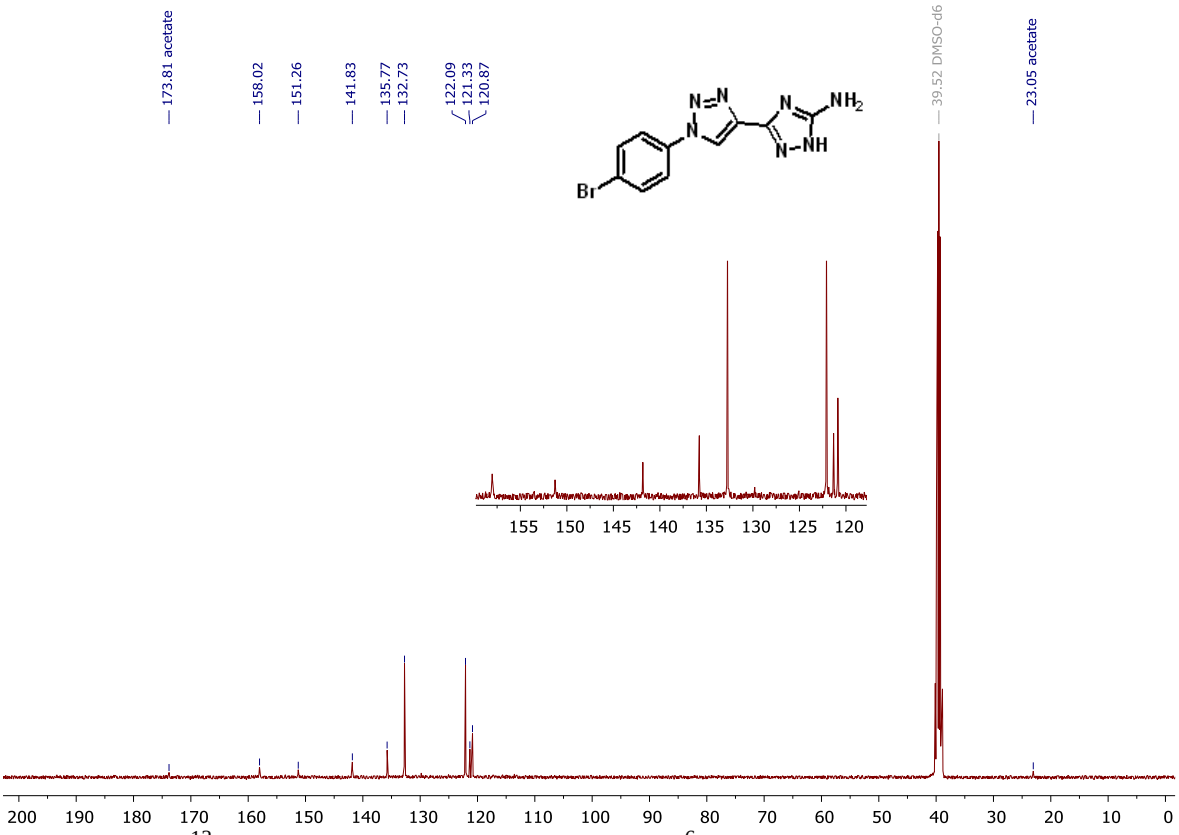


Figure SI-13. ^{13}C NMR spectrum of **14f** in DMSO-d^6 at 25 °C.

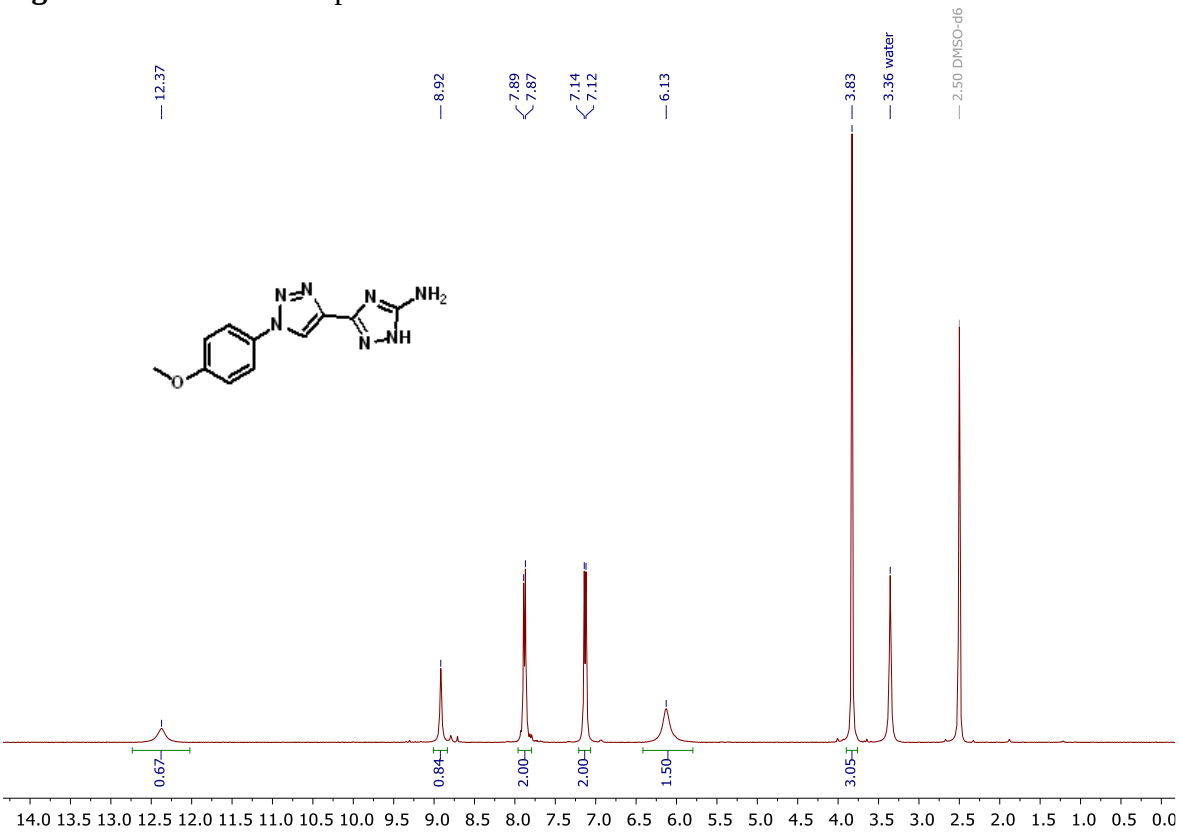


Figure SI-14. ^{1}H NMR spectrum of **14g** in DMSO-d^6 at 25 °C.

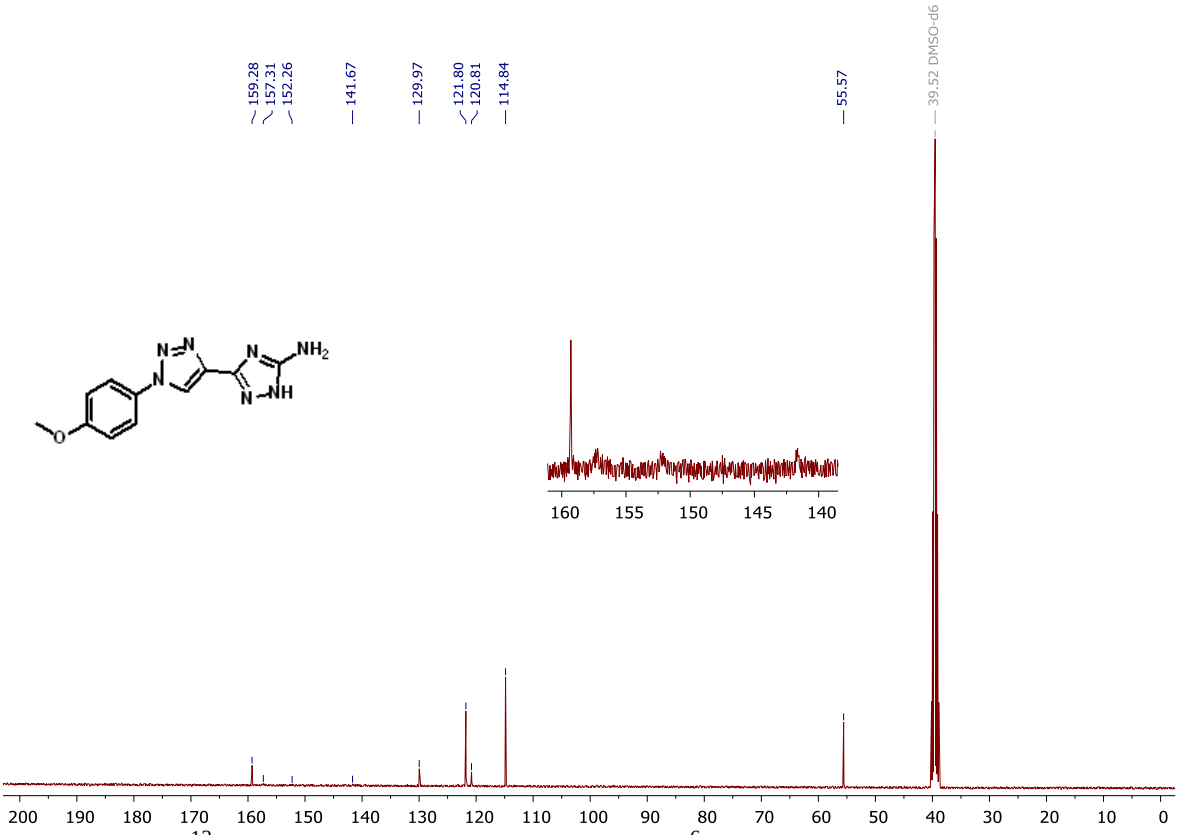


Figure SI-15. ^{13}C NMR spectrum of **14g** in DMSO-d^6 at 25 °C.

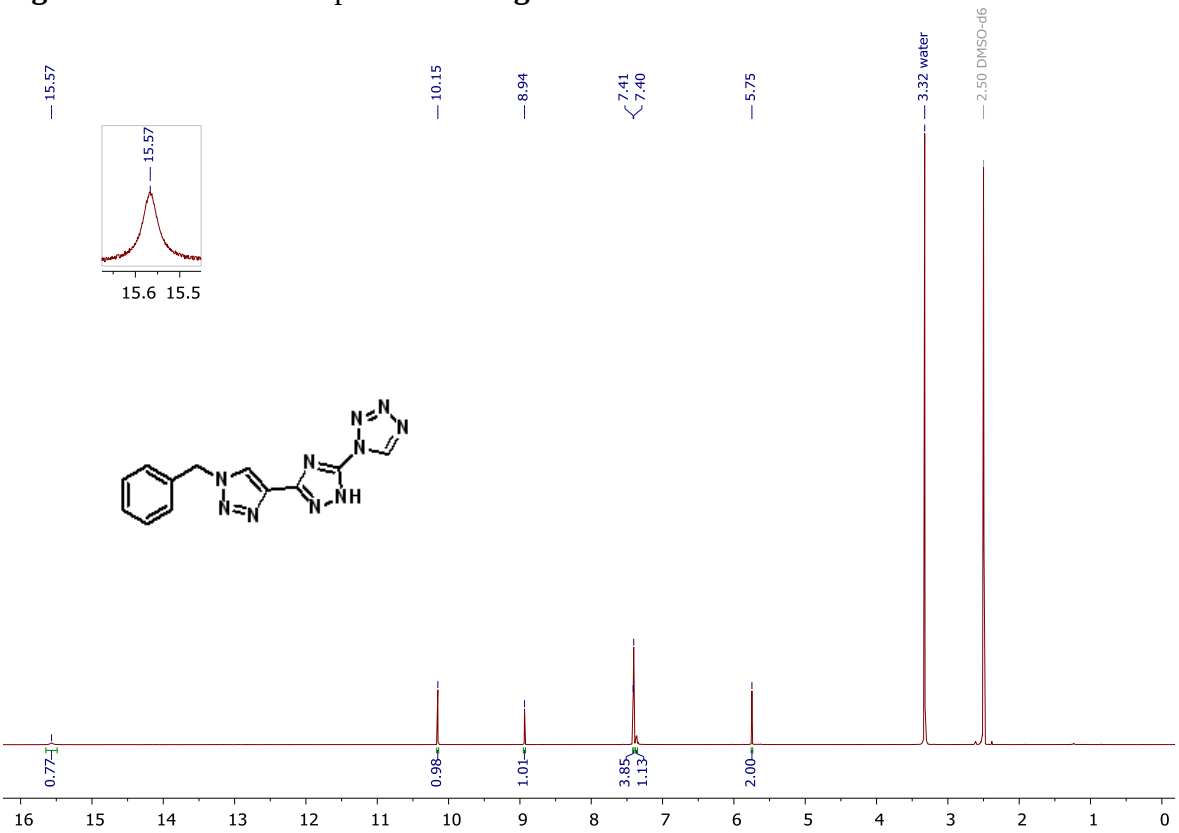


Figure SI-16. ^{1}H NMR spectrum of **1a** in DMSO-d^6 at 25 °C.

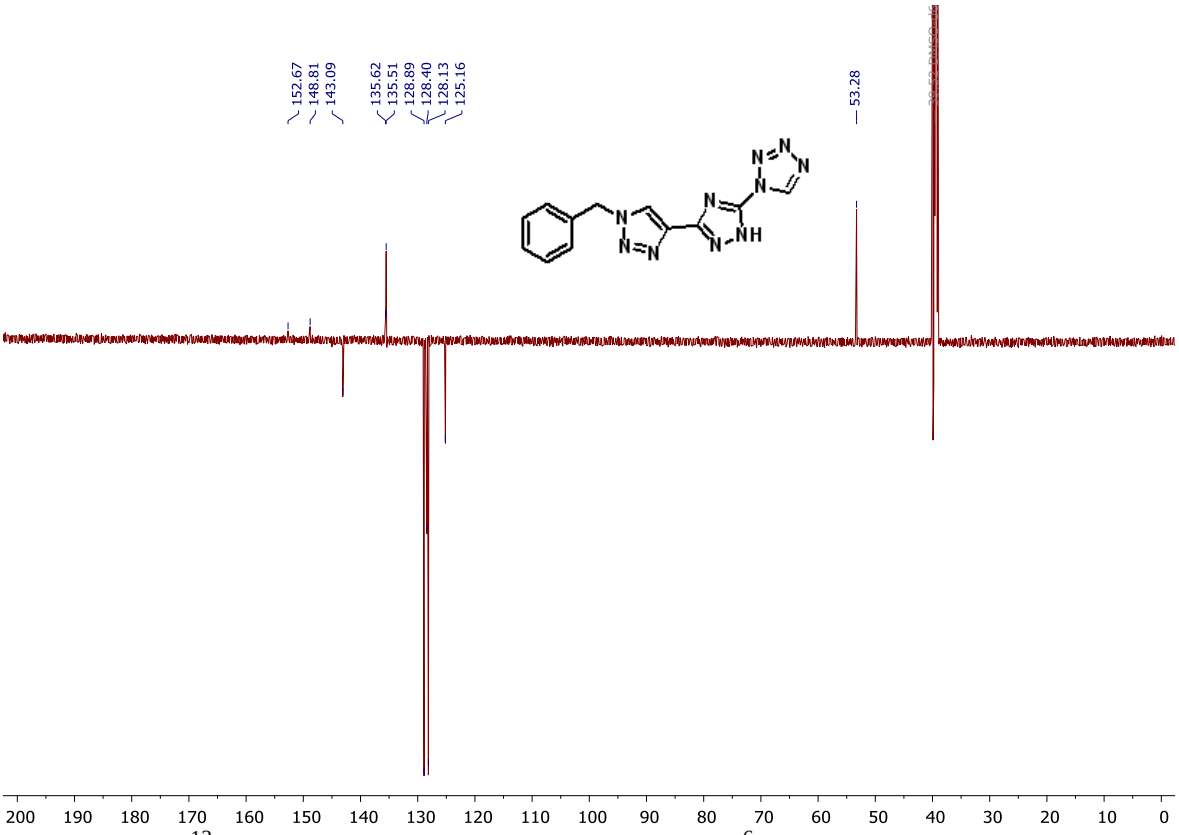


Figure SI-17. ^{13}C APT NMR spectrum of **1a** in DMSO-d^6 at 25 °C.

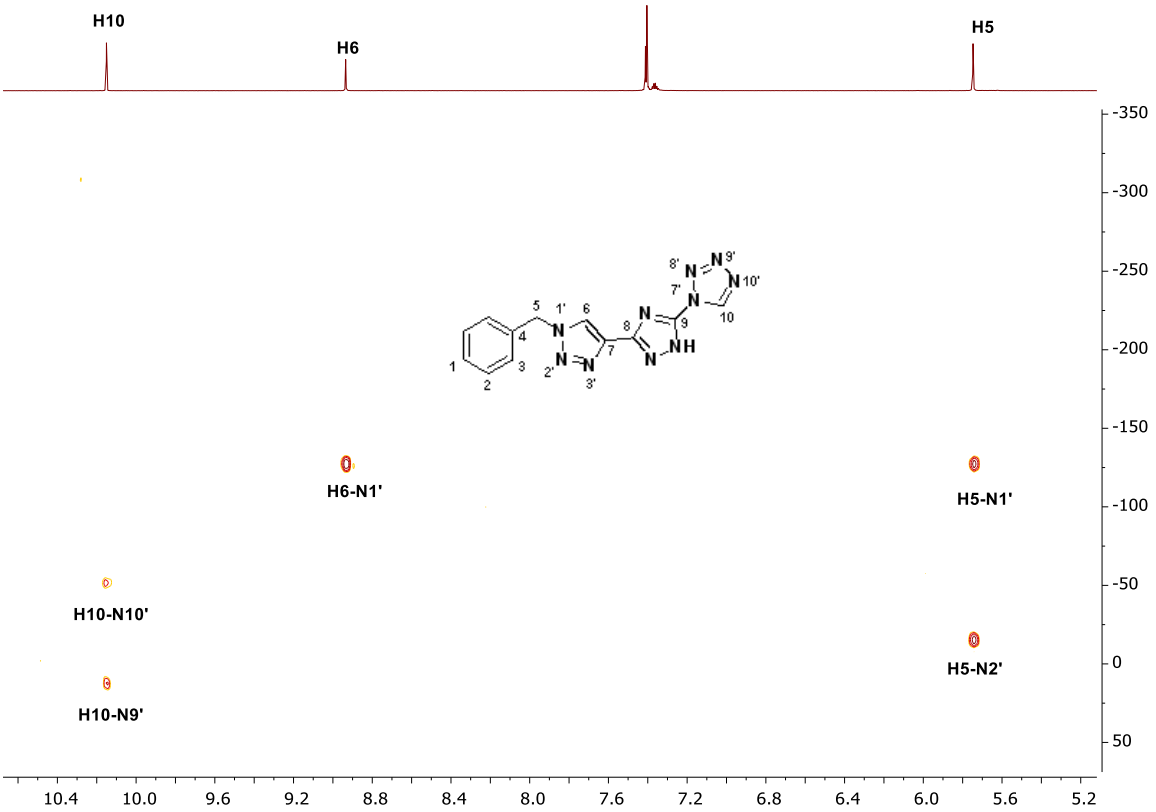


Figure SI-18. ^{1}H-^{15}N-HMBC NMR spectrum of **1a** in DMSO-d^6 at 25 °C.

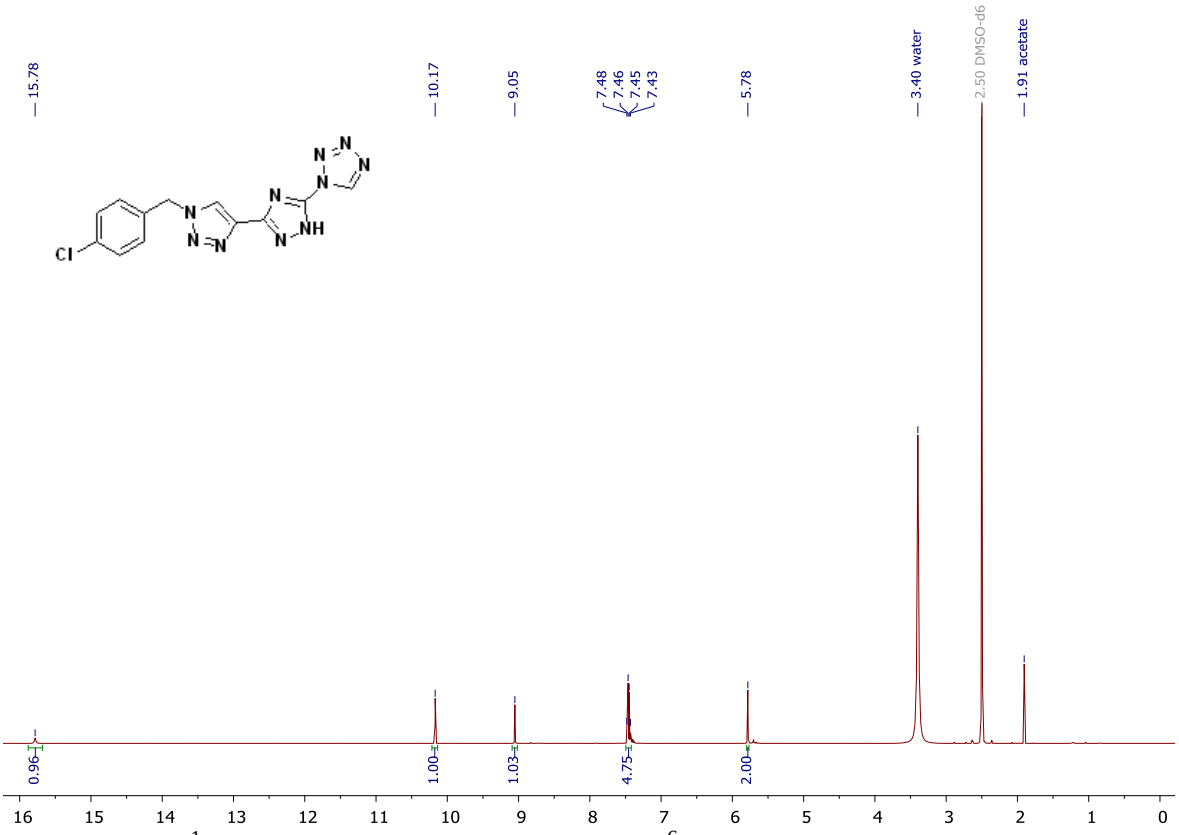


Figure SI-19. ^{1}H NMR spectrum of **1b** in DMSO-d^{6} at 25 °C.

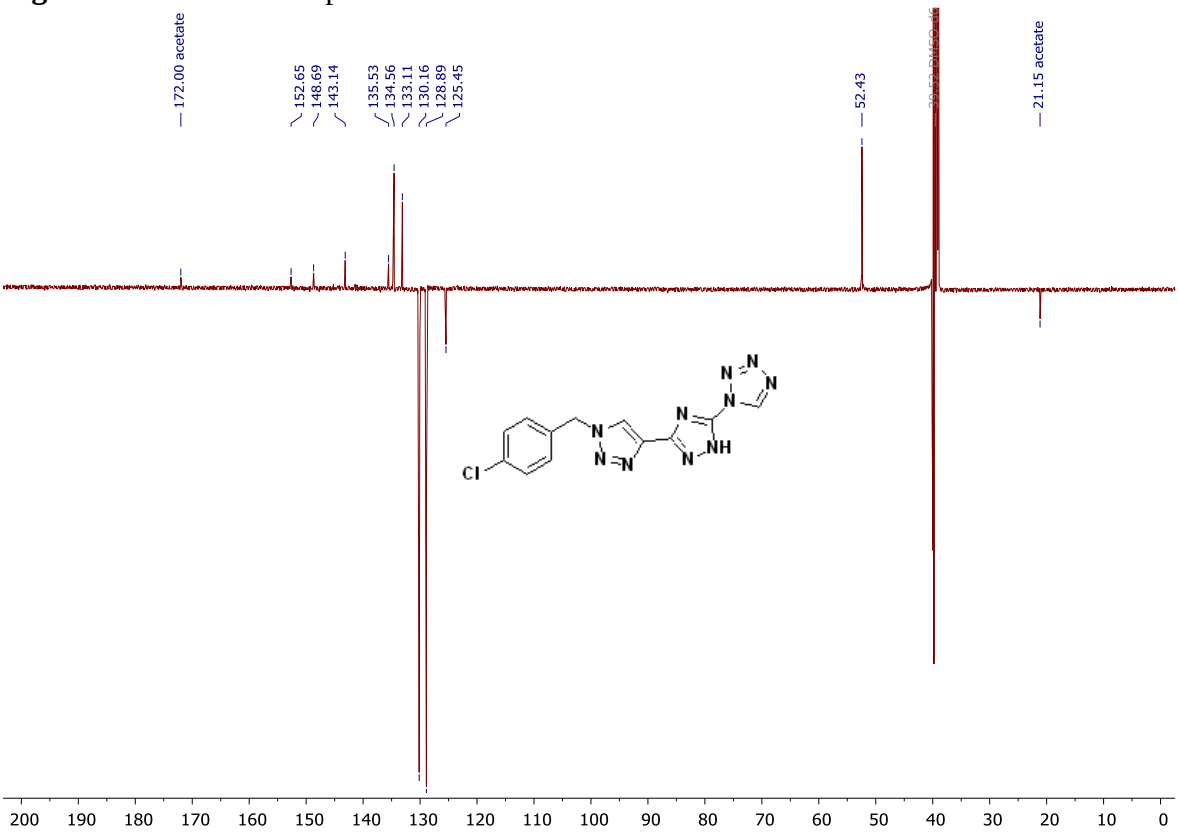


Figure SI-20. ^{13}C APT NMR spectrum of **1b** in DMSO-d^{6} at 25 °C.

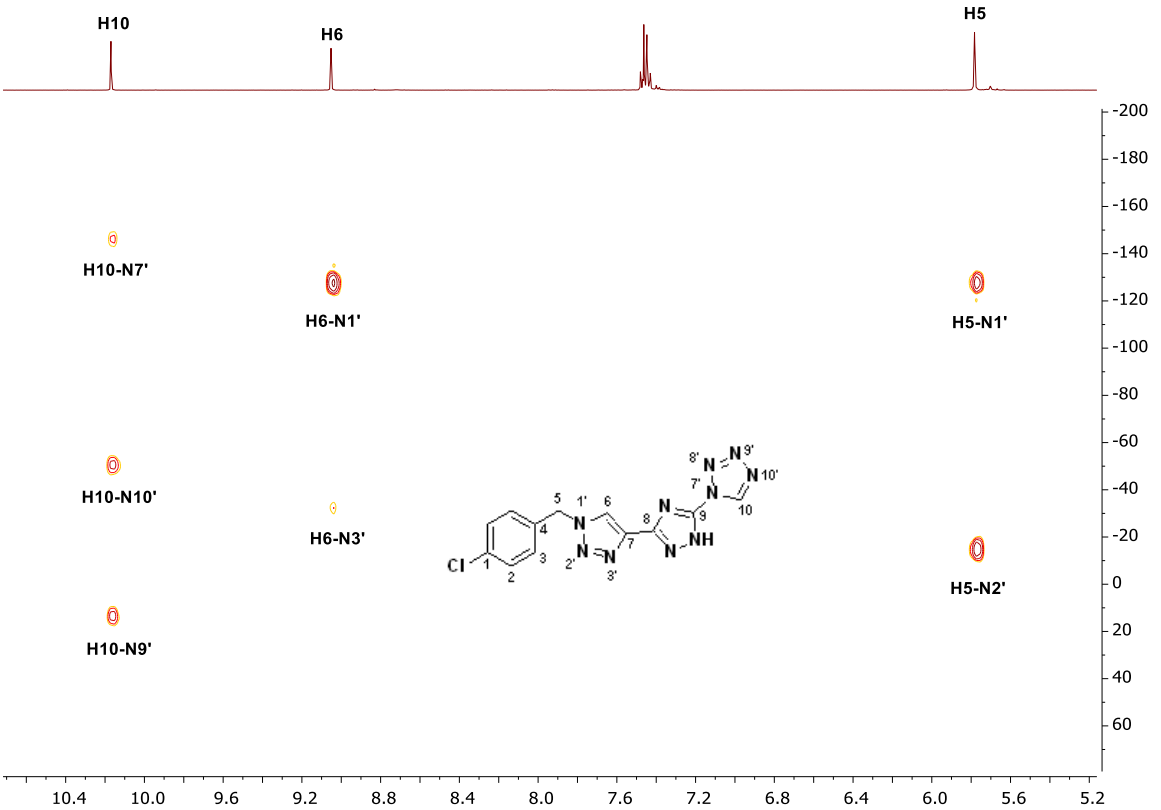


Figure SI-21. ^{1}H-^{15}N-HMBC NMR spectrum of **1b** in DMSO-d^{6} at 25 °C.

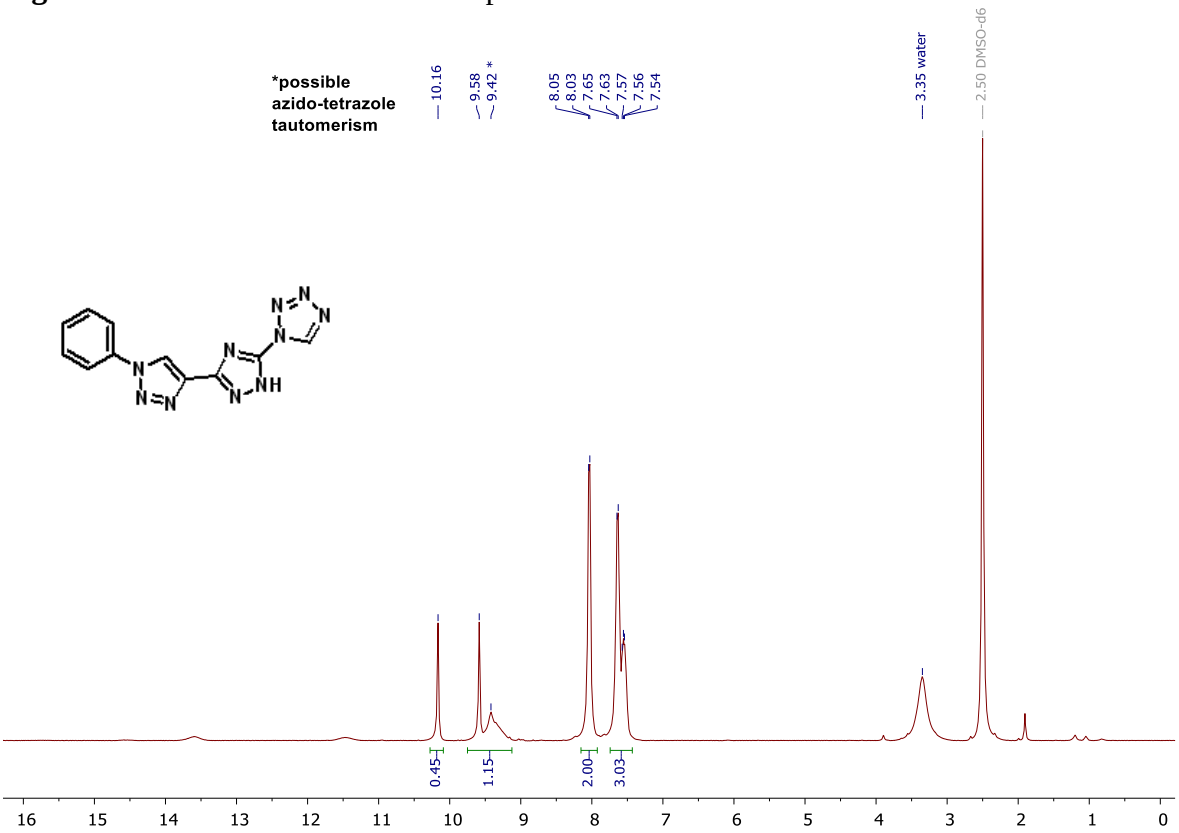


Figure SI-22. ^{1}H NMR spectrum of **1c** in DMSO-d^{6} at 25 °C.

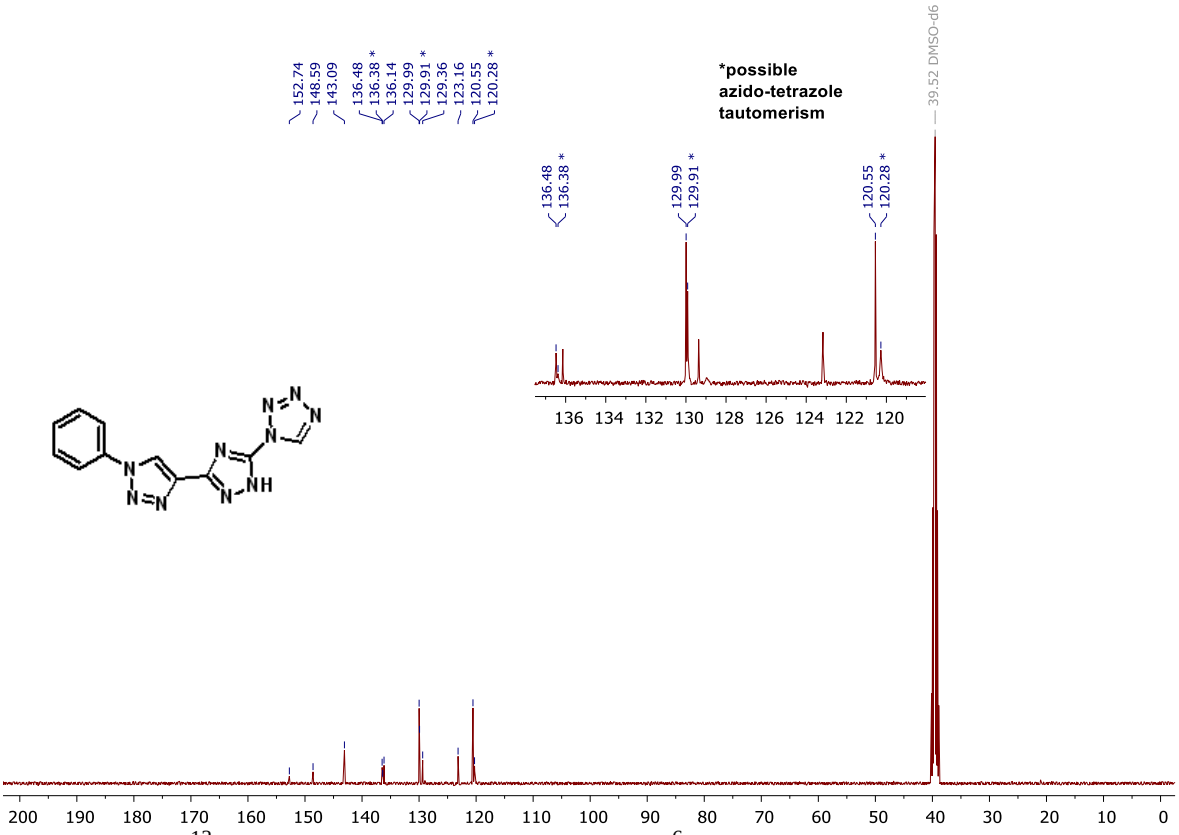


Figure SI-23. ^{13}C NMR spectrum of **1c** in DMSO-d^6 at 25 °C.

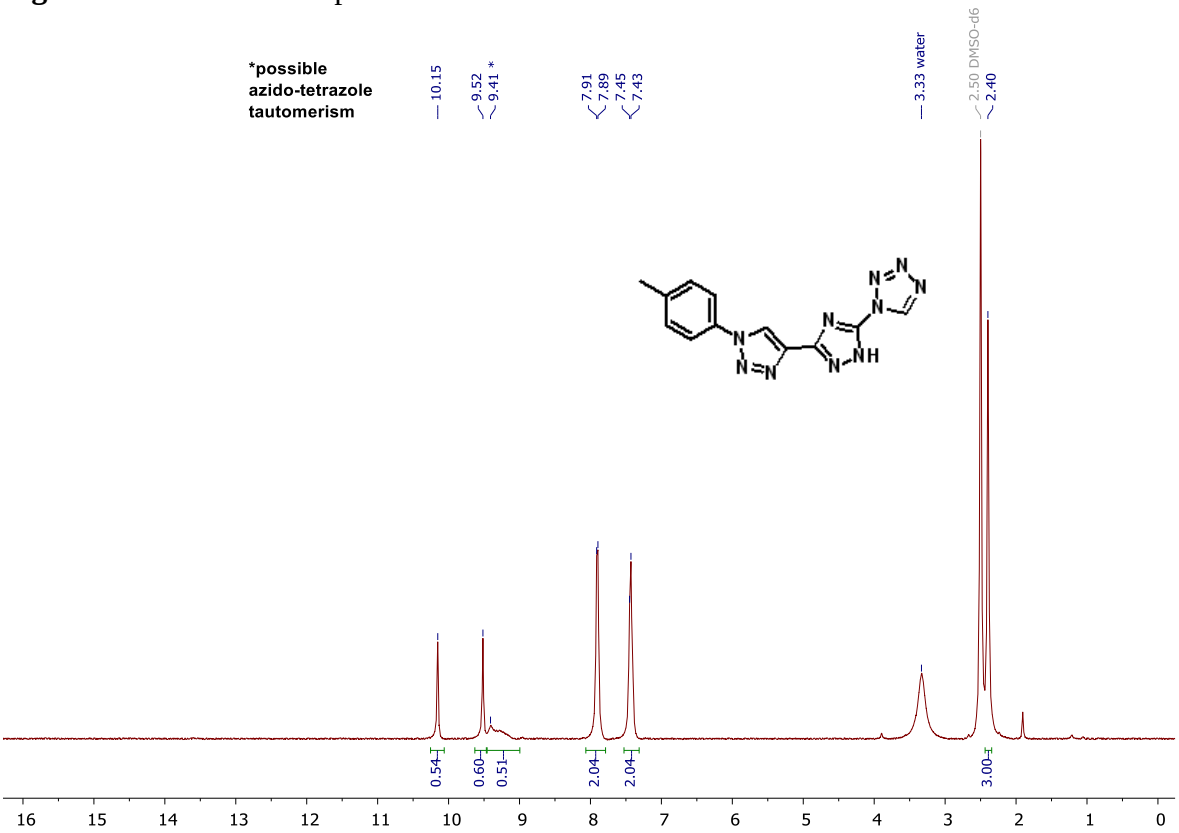


Figure SI-24. ^{1}H NMR spectrum of **1d** in DMSO-d^6 at 25 °C.

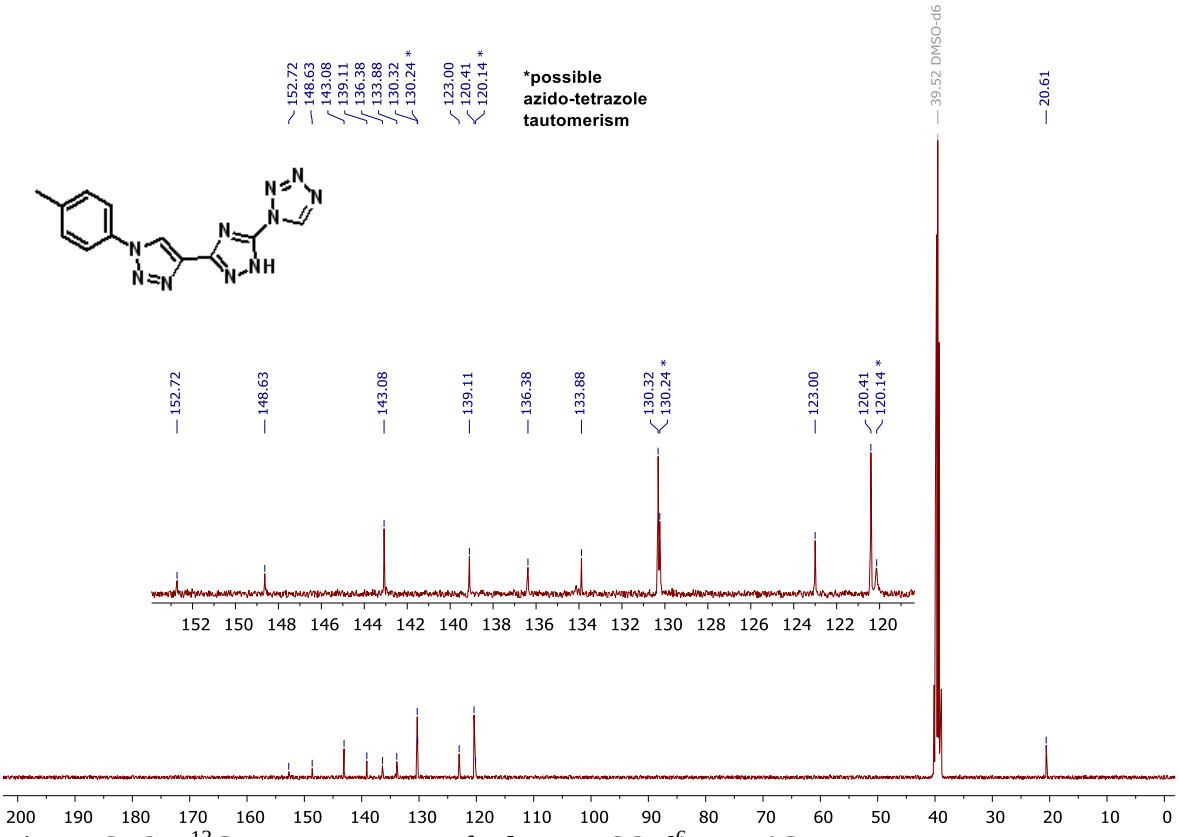


Figure SI-25. ^{13}C NMR spectrum of **1d** in DMSO-d^6 at 25 °C.

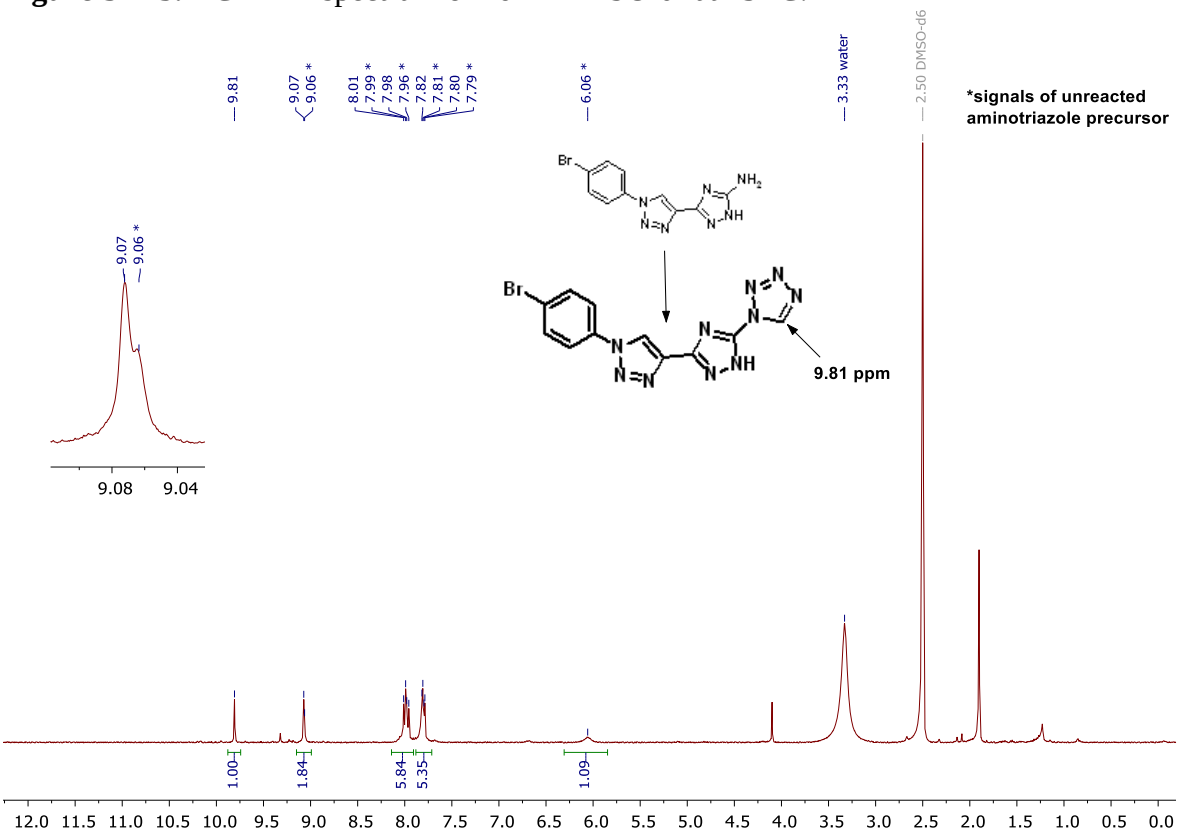


Figure SI-26. ^{1}H NMR spectrum of **crude 1f** in DMSO-d^6 at 25 °C.

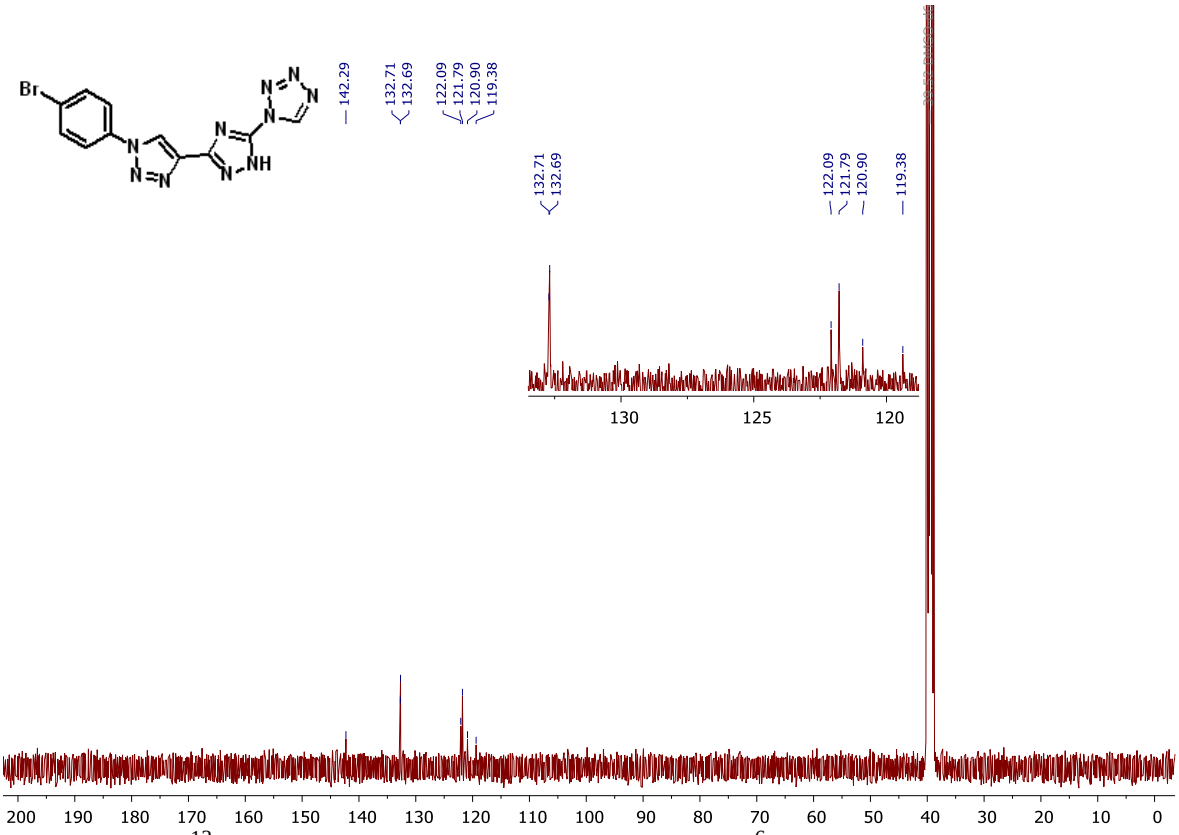


Figure SI-27. ^{13}C NMR spectrum of **crude 1f** in DMSO-d^6 at 25 °C.

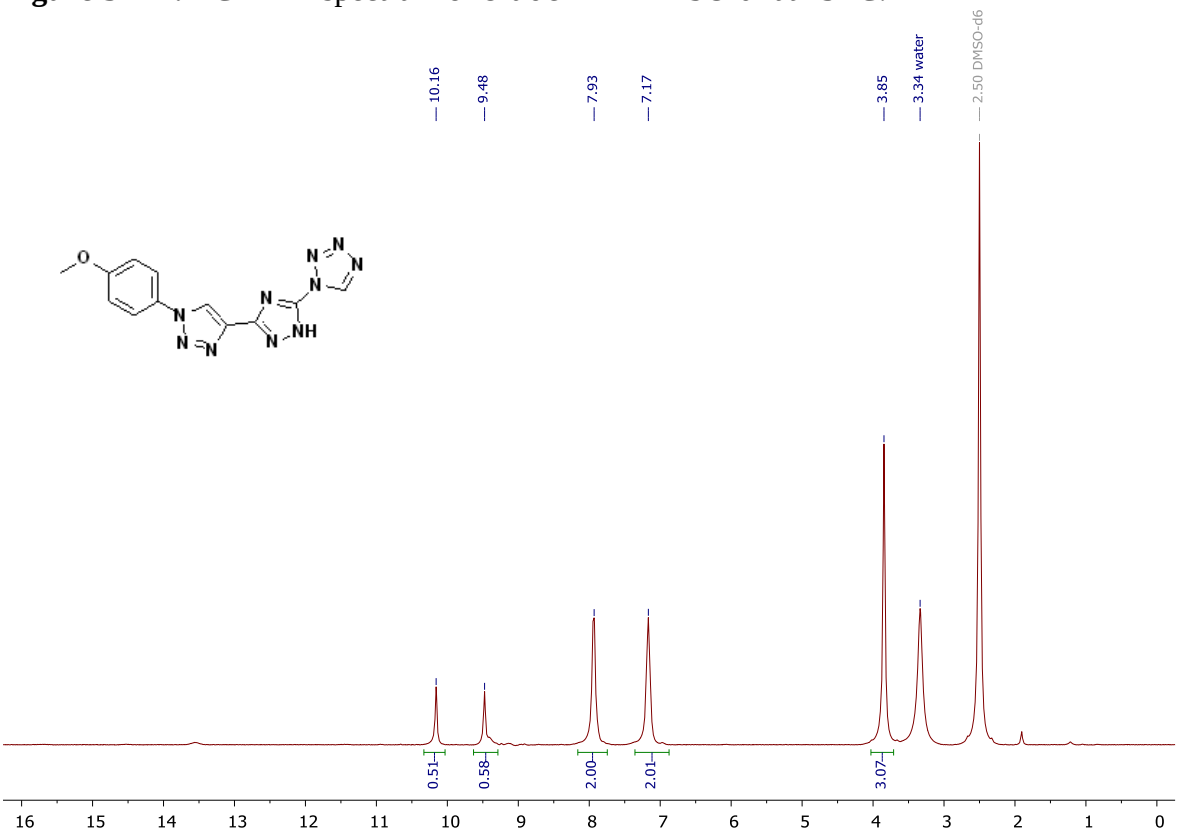


Figure SI-28. ^{1}H NMR spectrum of **1g** in DMSO-d^6 at 25 °C.

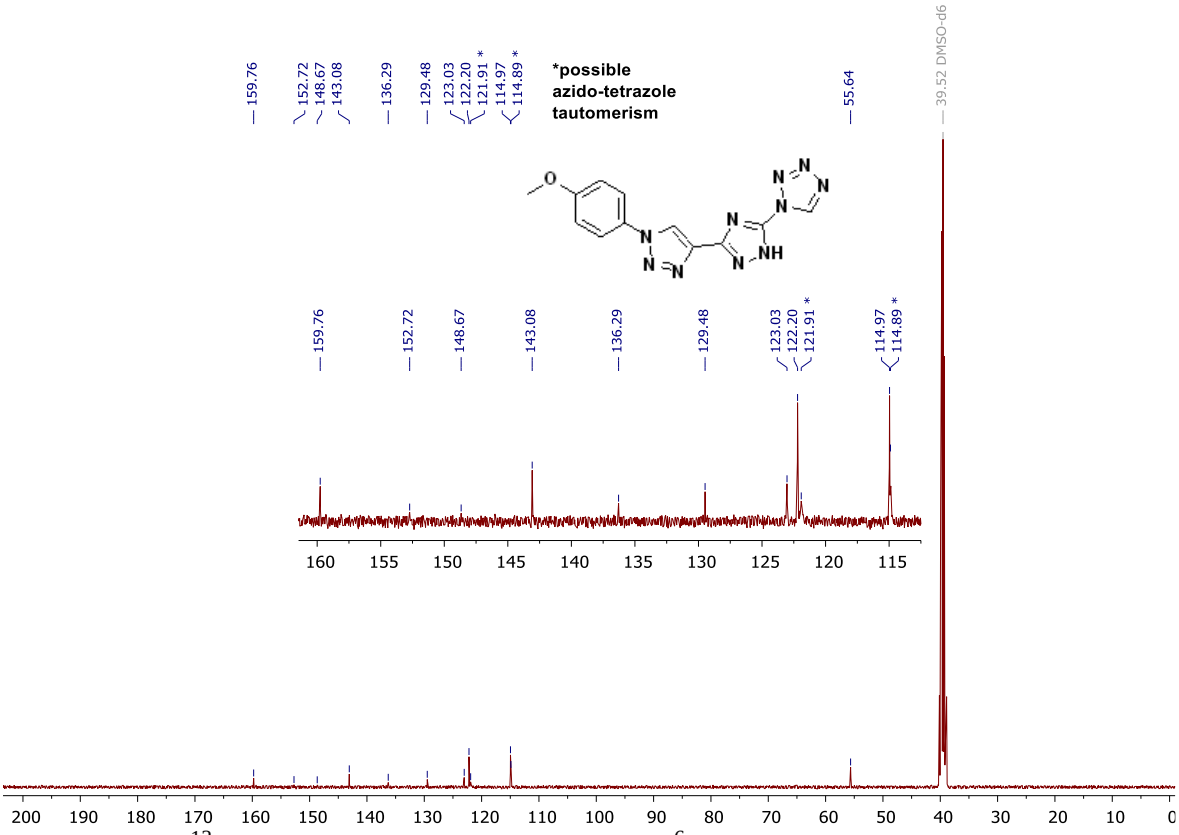


Figure SI-29. ^{13}C NMR spectrum of **1g** in DMSO-d^6 at 25 °C.