

Organic & Biomolecular Chemistry

Electronic supplementary information

A novel approach to bis(1,3-azol-2-yl)acetonitriles and bis(1,3-azol-2-yl)methanes *via* [3+2]-dipolar cycloaddition of imidazole *N*-oxides and 2-heteroaryl-3,3-dimethylacrylonitriles

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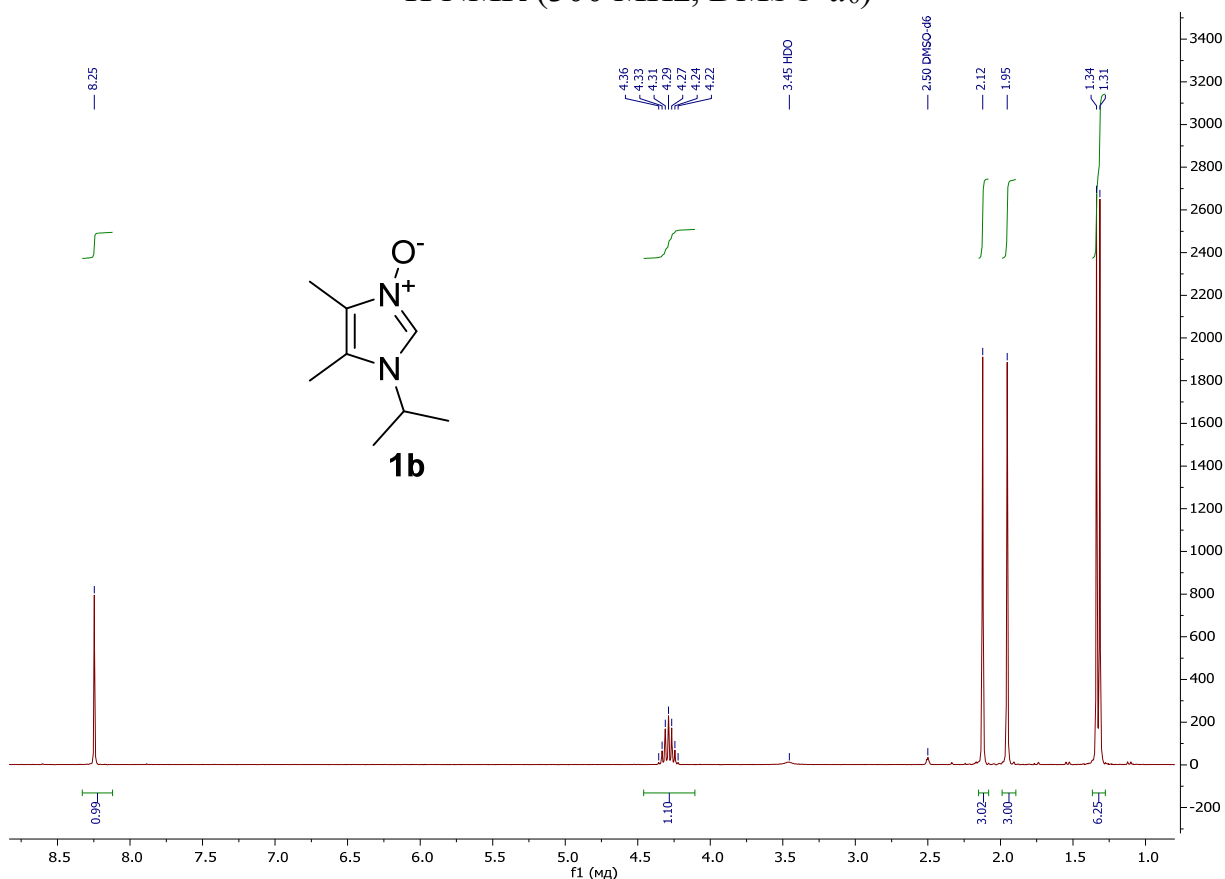
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Academy of Sciences
Vavilova St. 28, Moscow, 119991, Russian Federation
<https://ineos.ac.ru>

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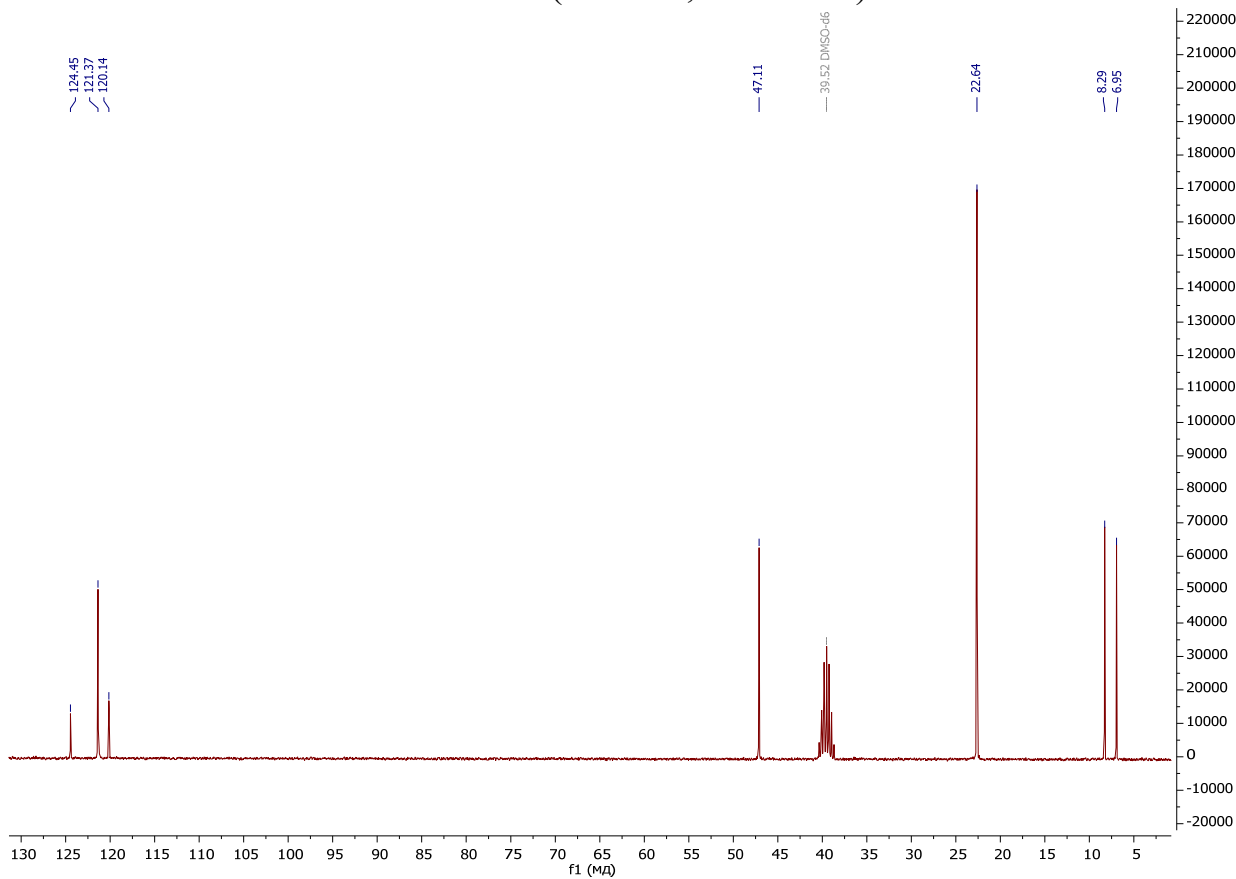
1. Copies of ^1H and ^{13}C NMR spectra.
2. X-ray diffraction data.

1-isopropyl-4,5-dimethyl-1H-imidazole 3-oxide (**1b**)

^1H NMR (300 MHz, $\text{DMSO-}d_6$)

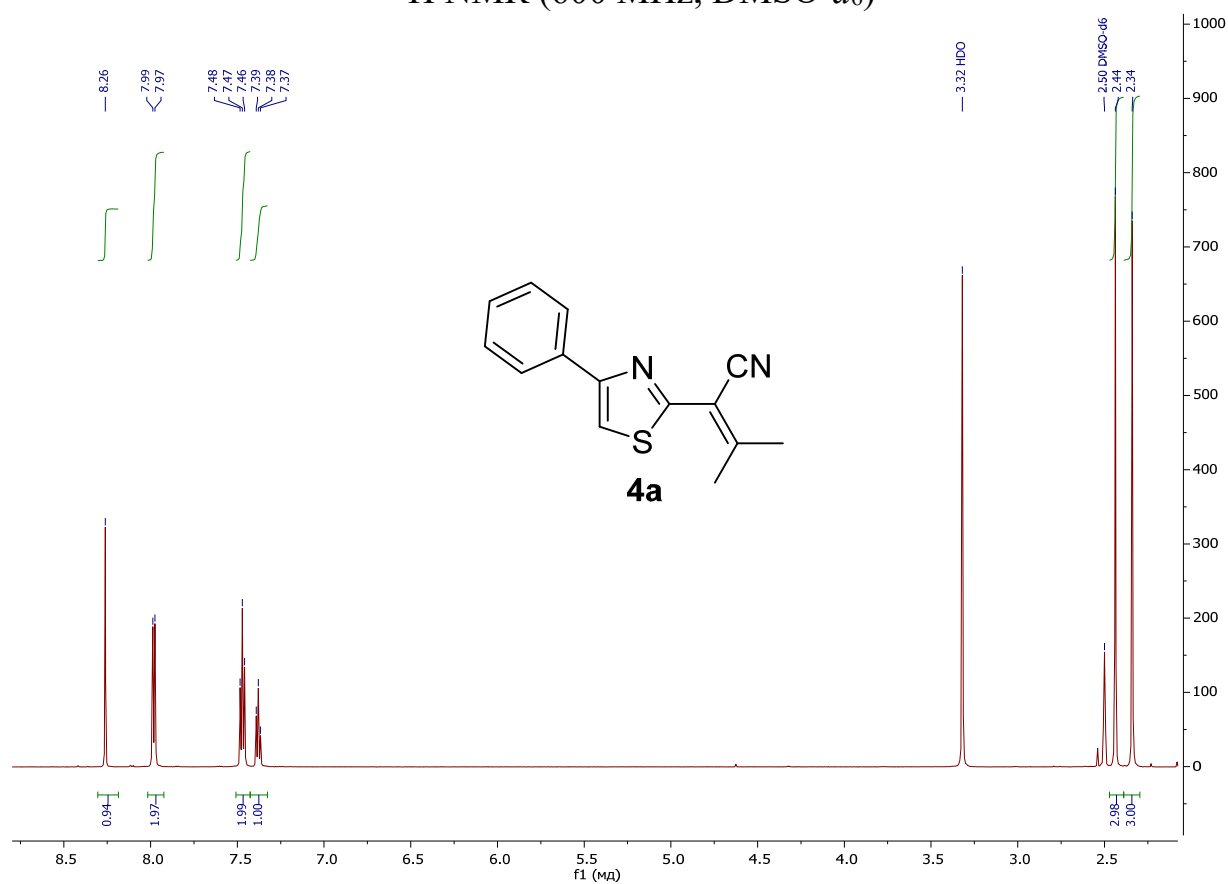


^{13}C NMR (75 MHz, $\text{DMSO-}d_6$)

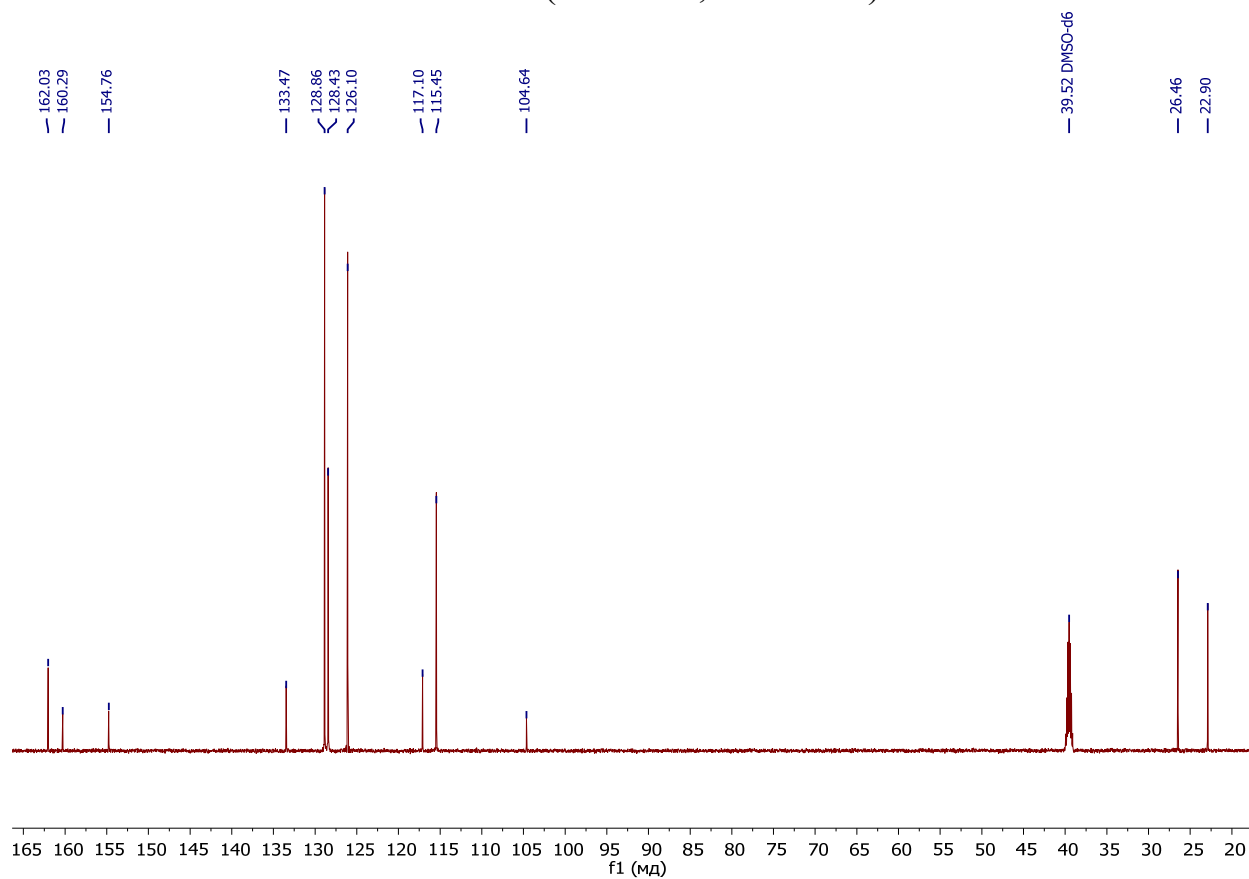


3-Methyl-2-(4-phenylthiazol-2-yl)but-2-enitrile (**4a**)

^1H NMR (600 MHz, $\text{DMSO-}d_6$)

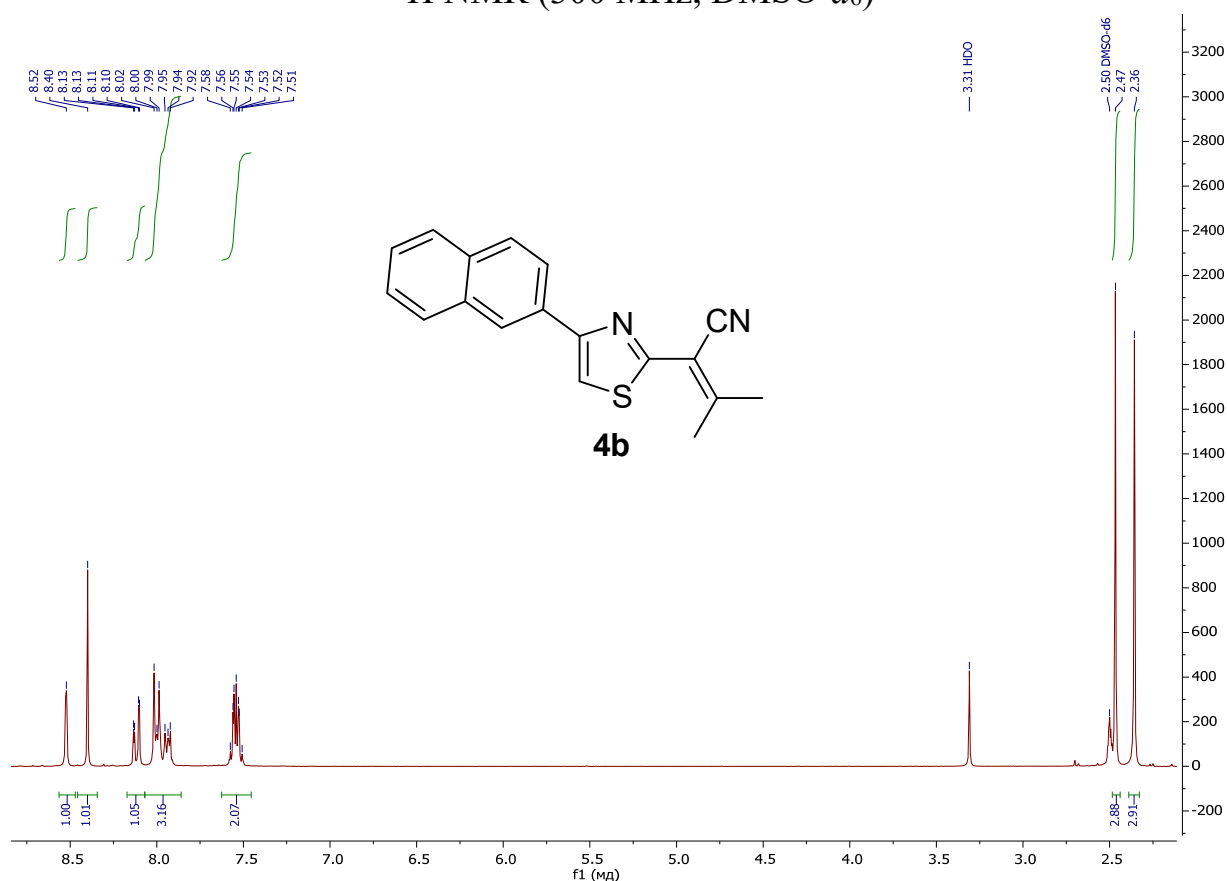


^{13}C NMR (151 MHz, $\text{DMSO-}d_6$)

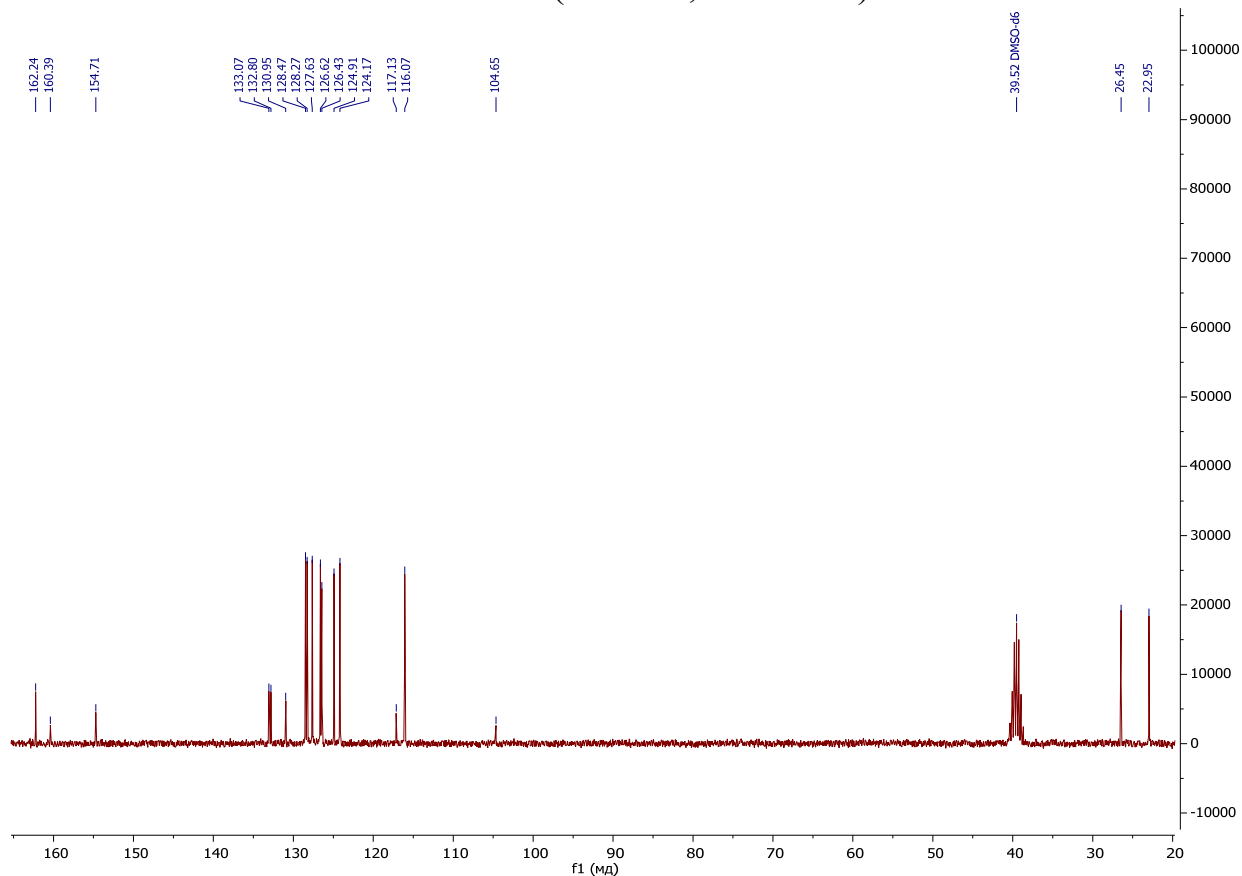


3-Methyl-2-(4-(naphthalen-2-yl)thiazol-2-yl)but-2-enitrile (**4b**)

^1H NMR (300 MHz, $\text{DMSO-}d_6$)

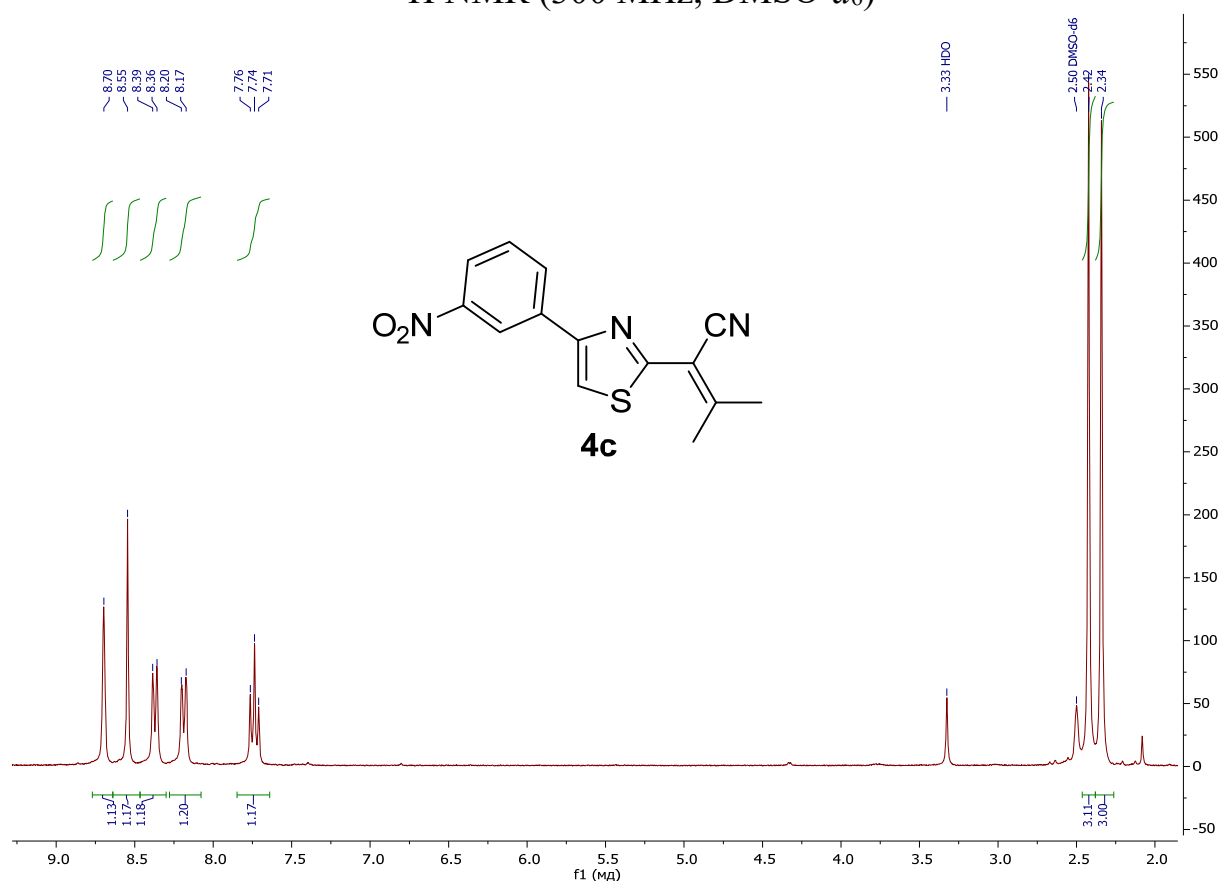


^{13}C NMR (75 MHz, $\text{DMSO-}d_6$)

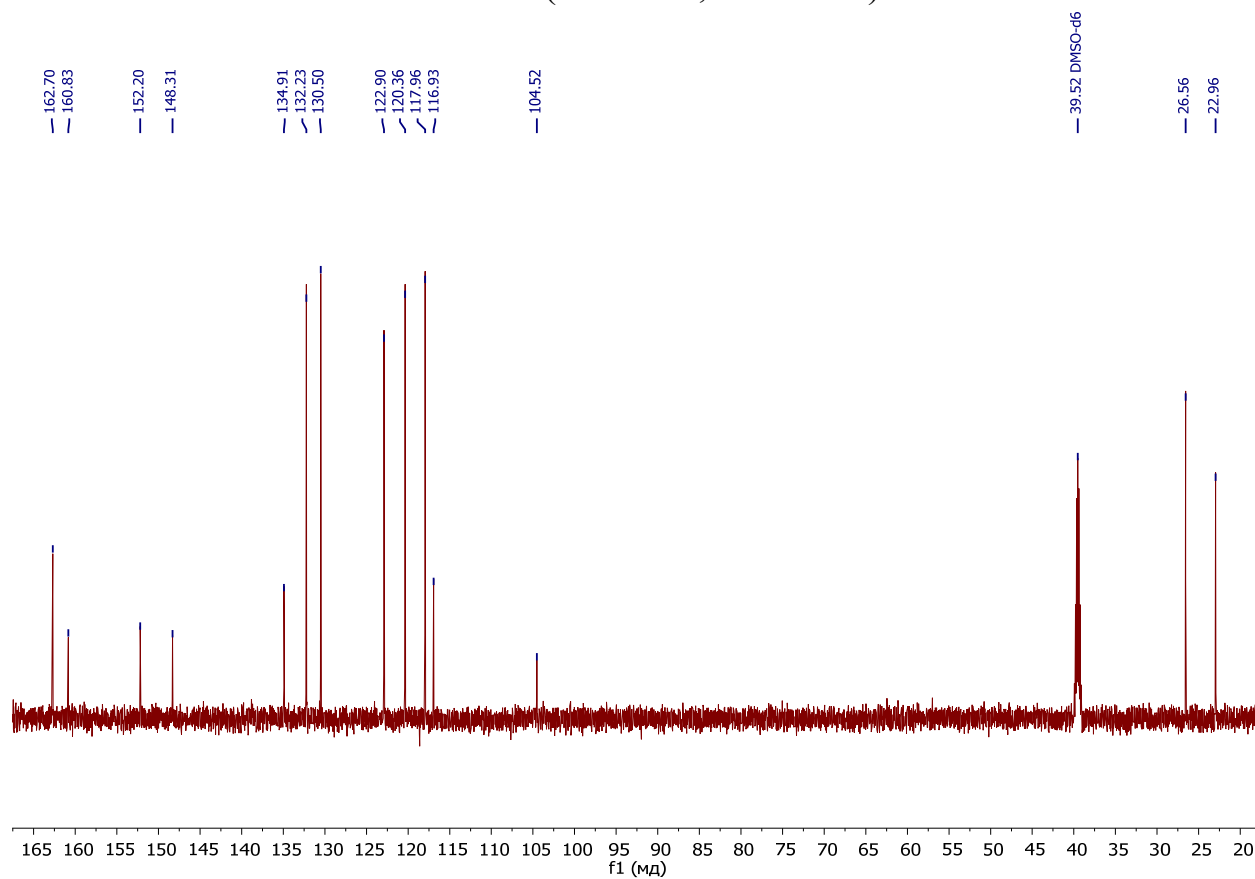


3-Methyl-2-(4-(3-nitrophenyl)thiazol-2-yl)but-2-enitrile (**4c**)

^1H NMR (300 MHz, $\text{DMSO-}d_6$)

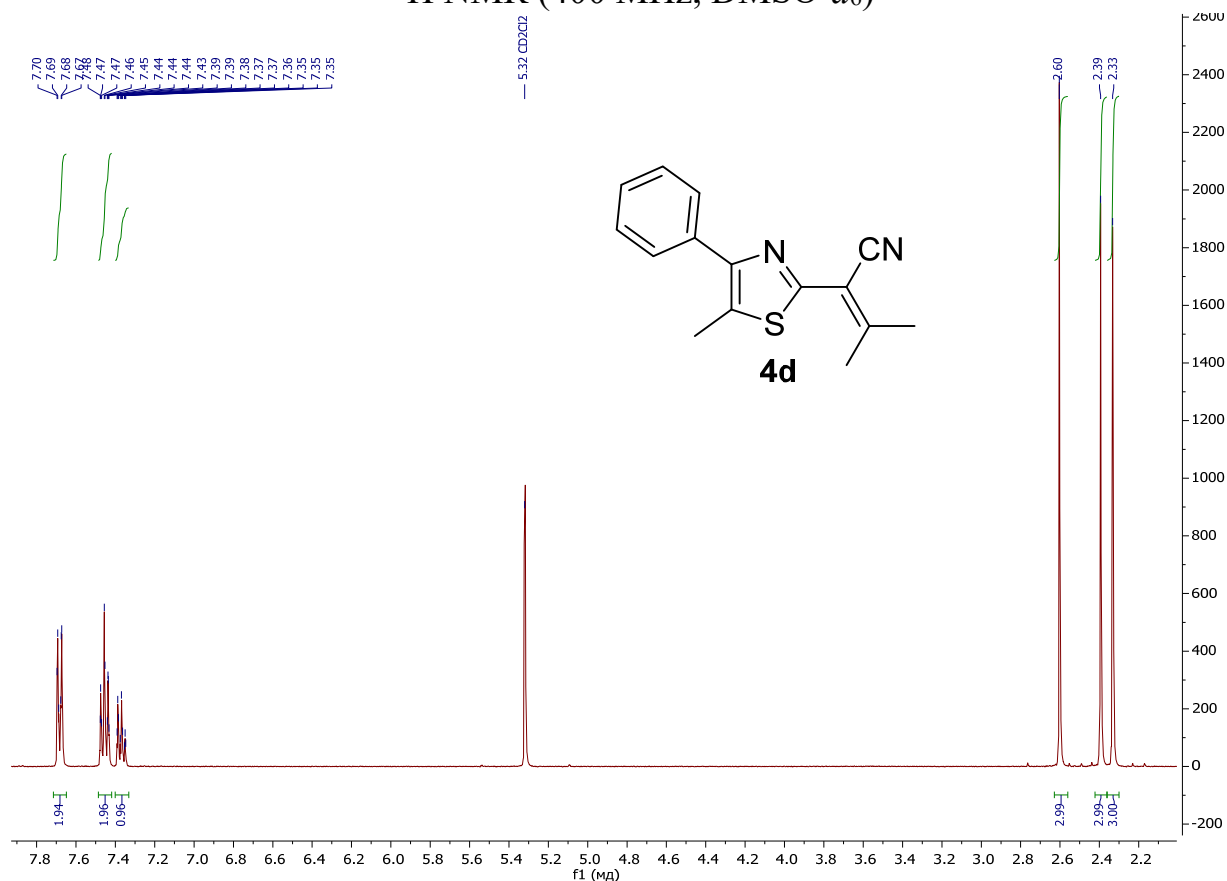


^{13}C NMR (151 MHz, $\text{DMSO-}d_6$)

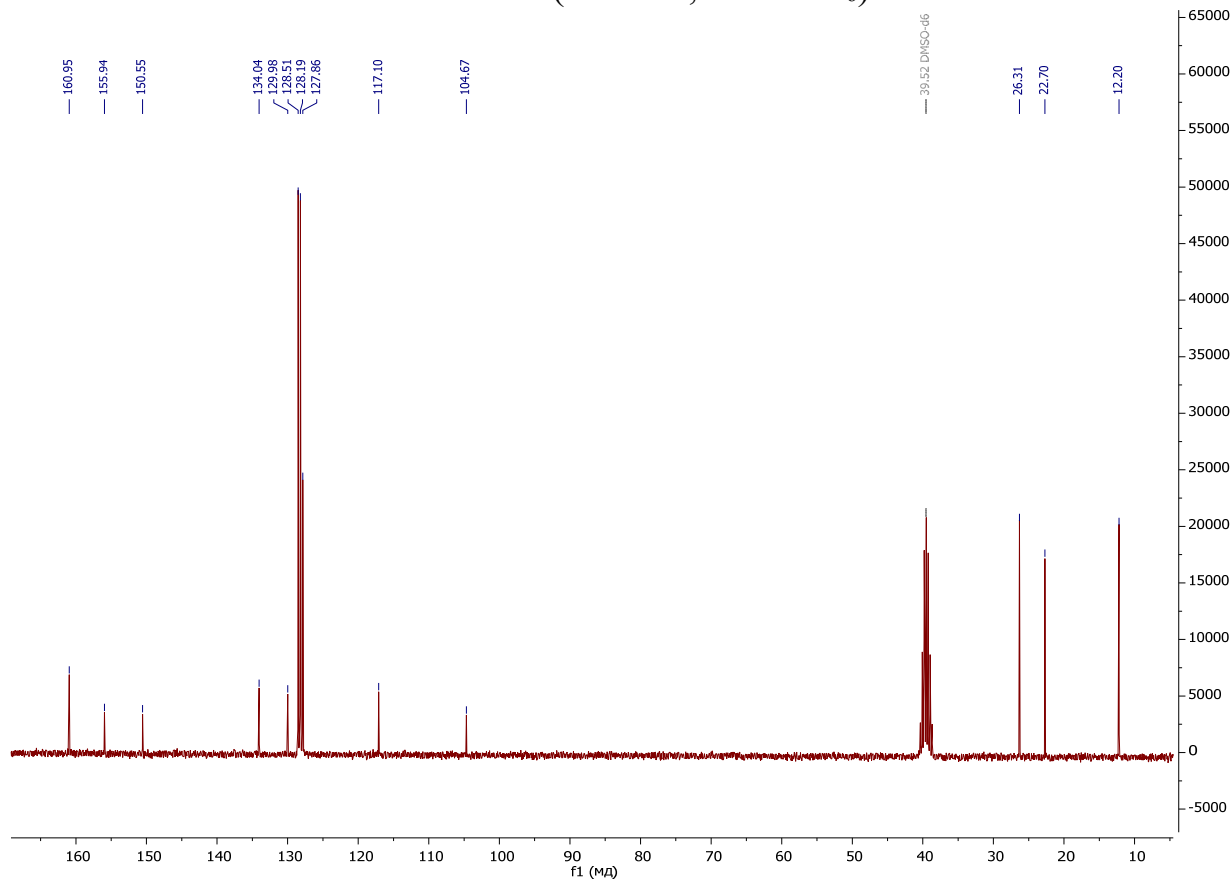


3-Methyl-2-(5-methyl-4-phenylthiazol-2-yl)but-2-enitrile (**4d**)

^1H NMR (400 MHz, $\text{DMSO-}d_6$)

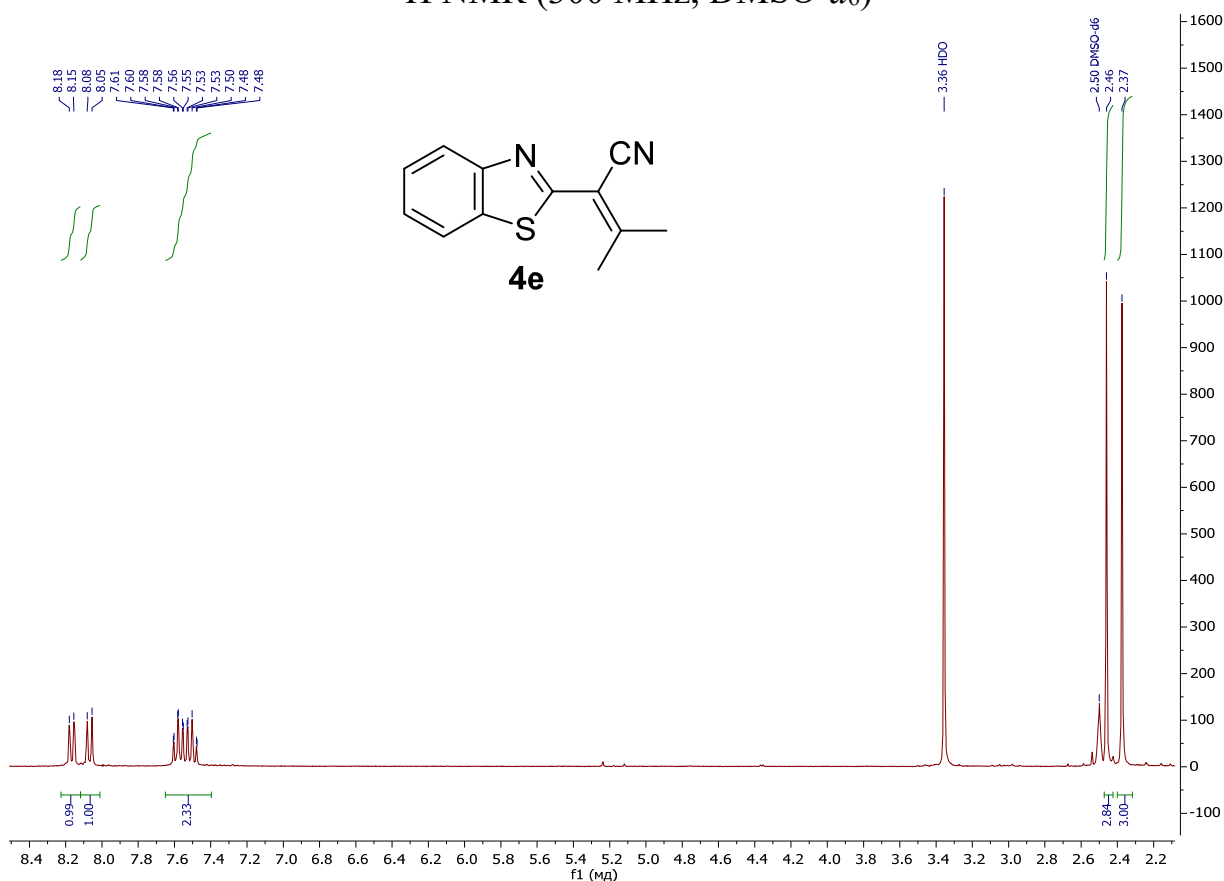


^{13}C NMR (75 MHz, $\text{DMSO-}d_6$)

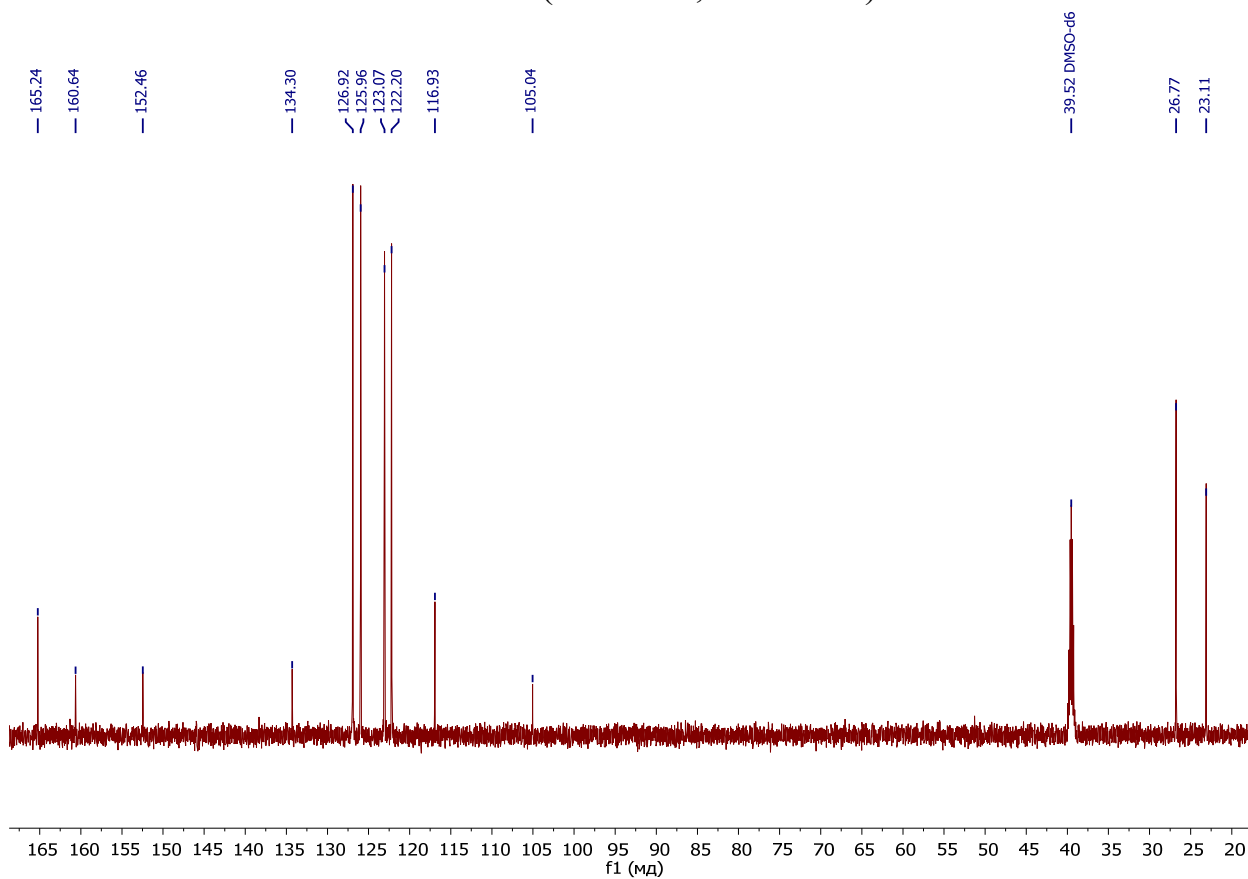


2-(Benzo[d]thiazol-2-yl)-3-methylbut-2-enitrile (**4e**)

¹H NMR (300 MHz, DMSO-*d*₆)

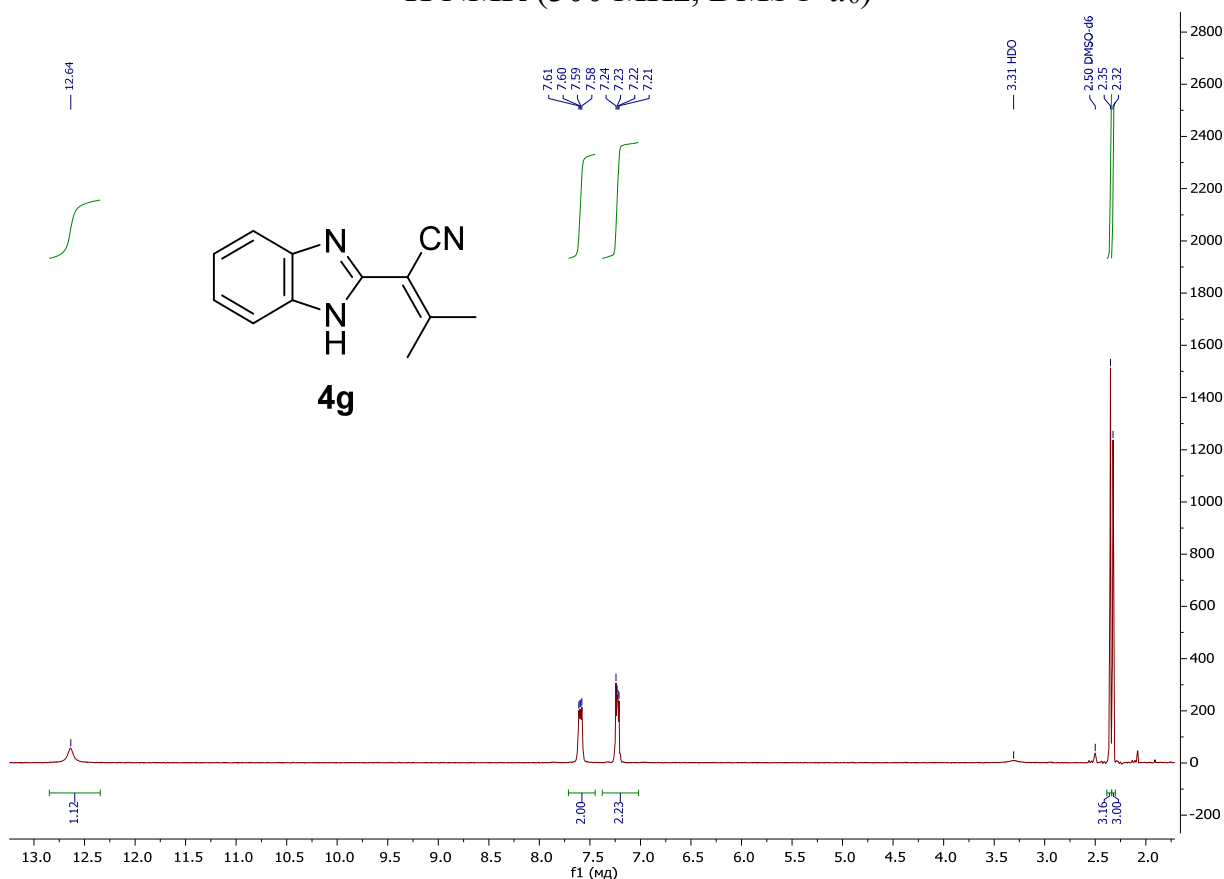


¹³C NMR (151 MHz, DMSO-*d*₆)

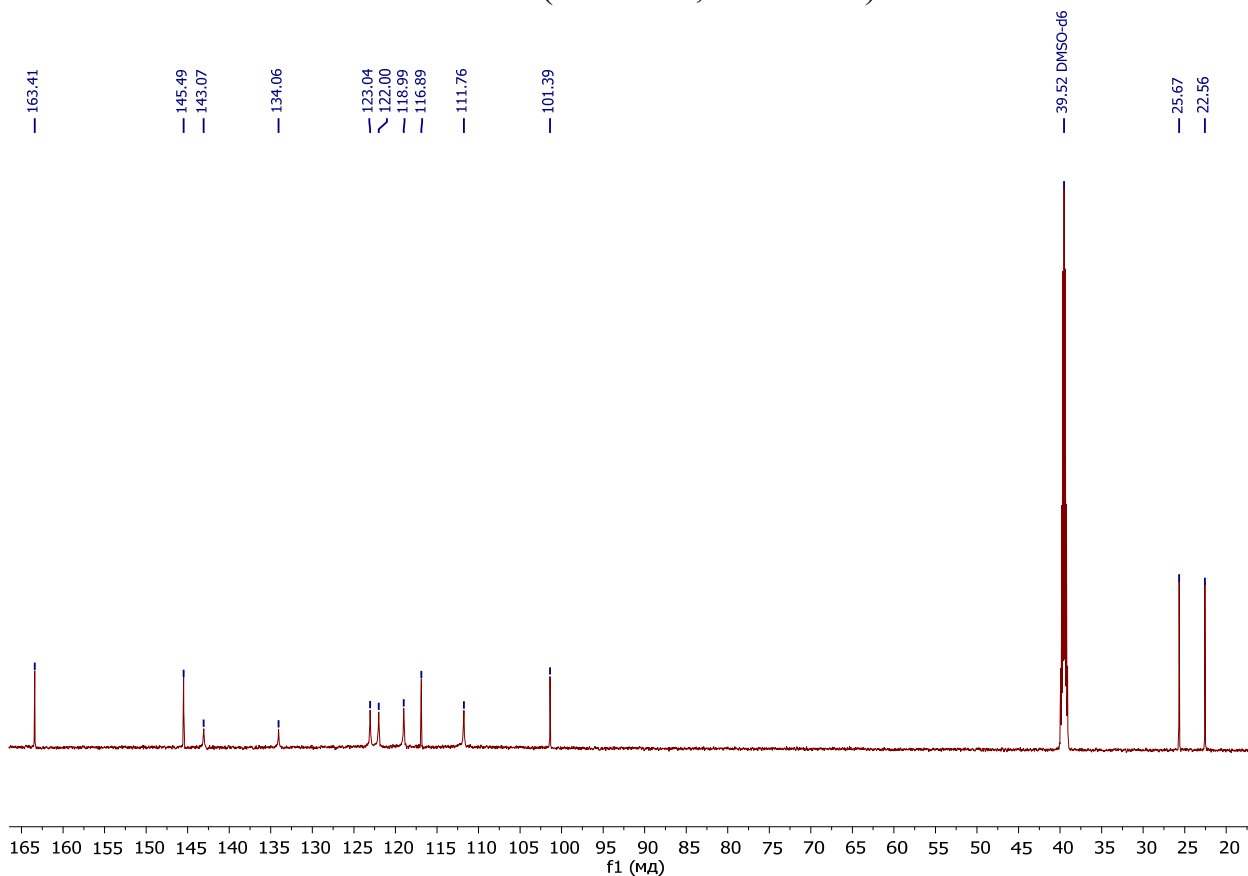


2-(1H-Benzo[d]imidazol-2-yl)-3-methylbut-2-enitrile (**4g**)

¹H NMR (300 MHz, DMSO-*d*₆)

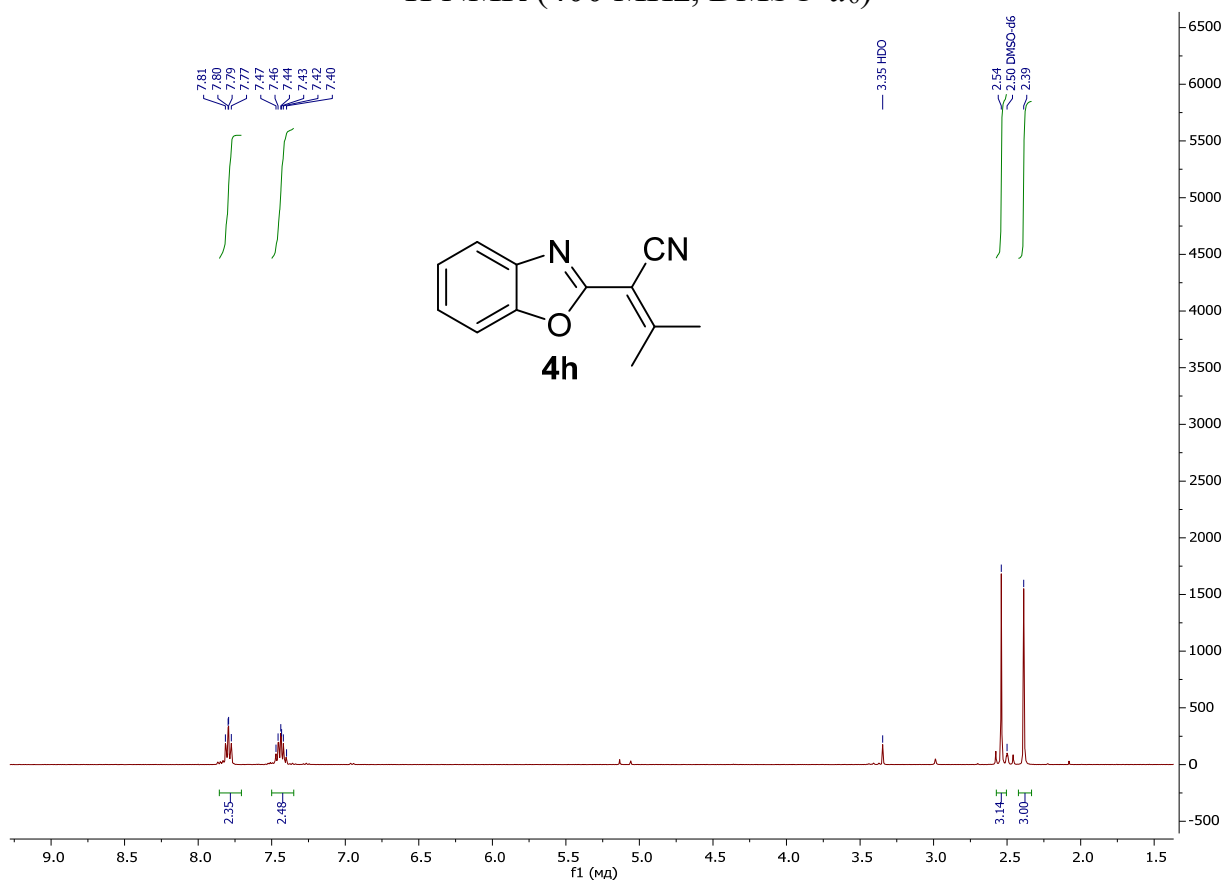


¹³C NMR (151 MHz, DMSO-*d*₆)

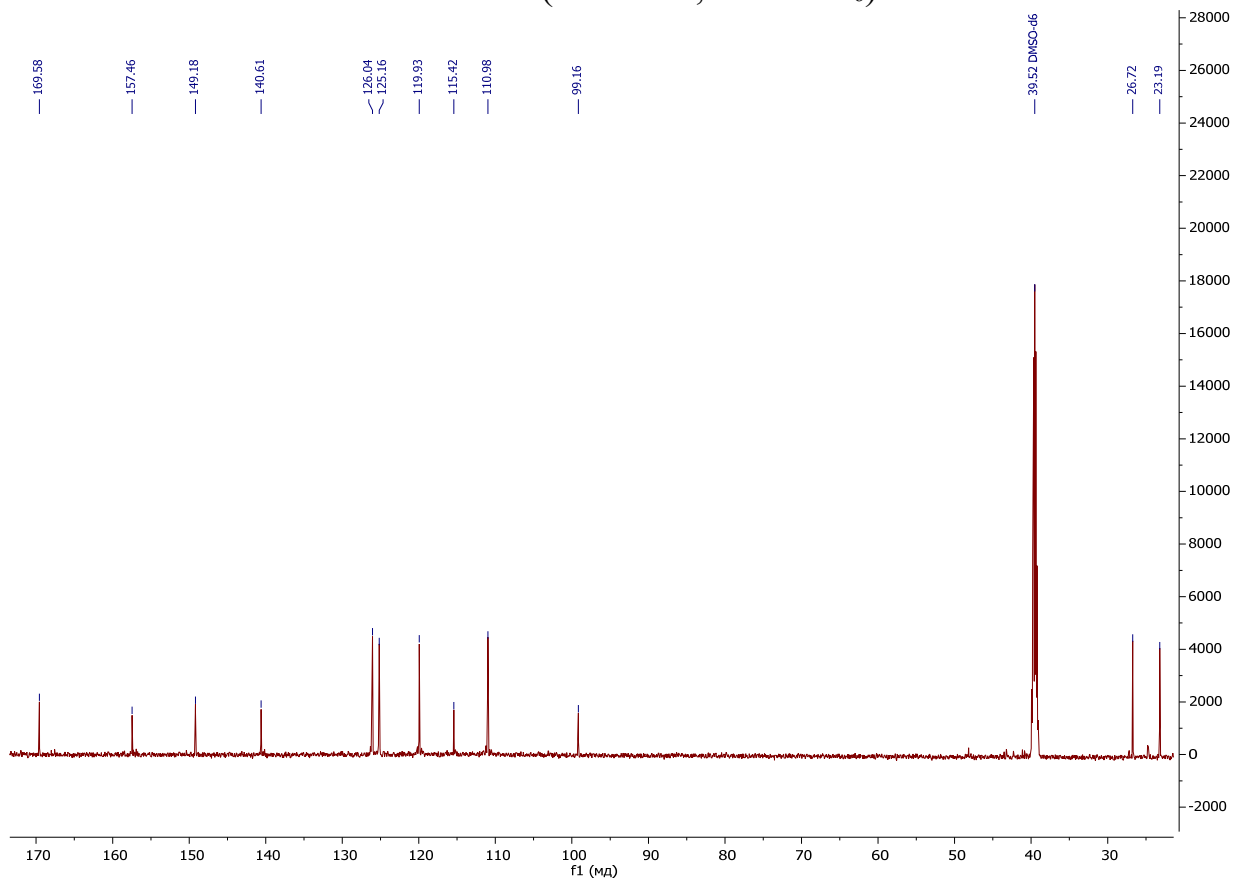


2-(Benzo[d]oxazol-2-yl)-3-methylbut-2-enenitrile (**4h**)

^1H NMR (400 MHz, $\text{DMSO-}d_6$)

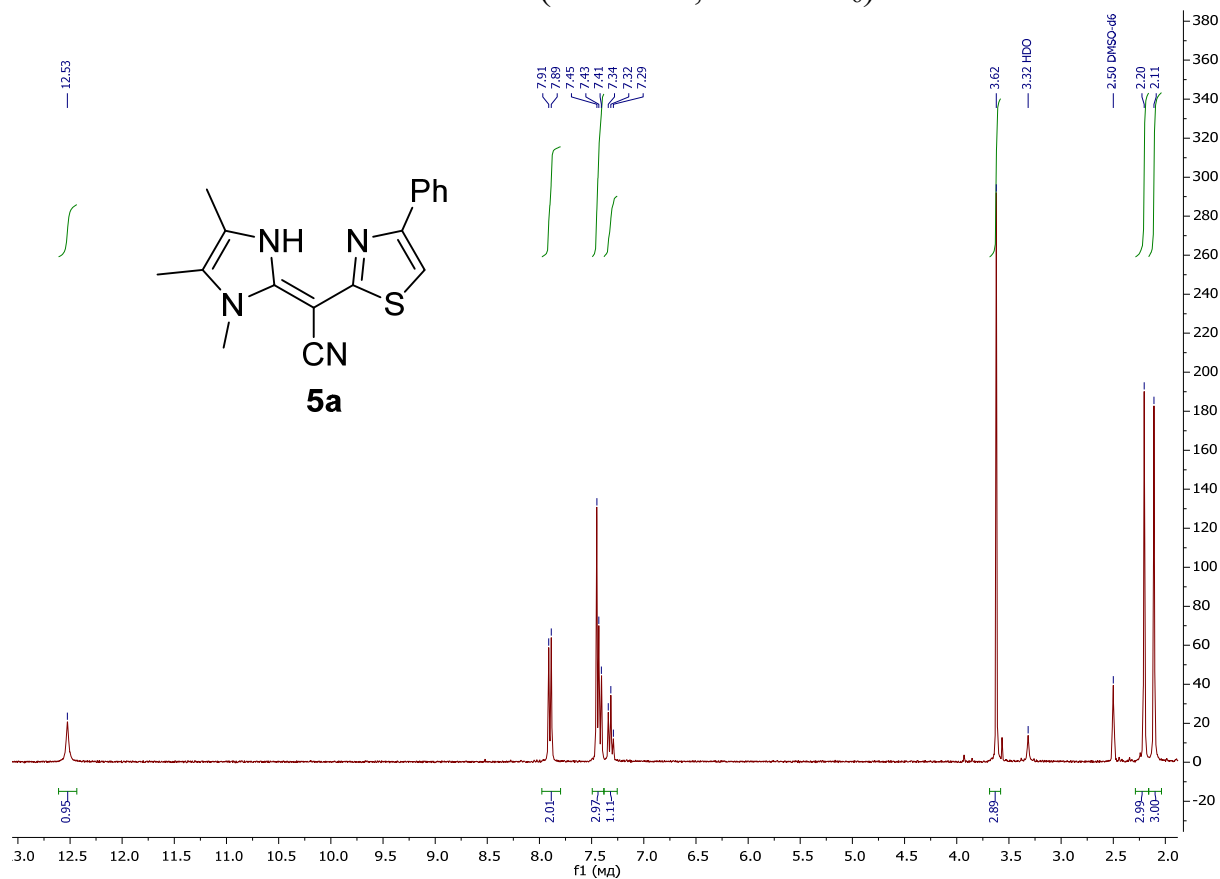


^{13}C NMR (151 MHz, $\text{DMSO-}d_6$)

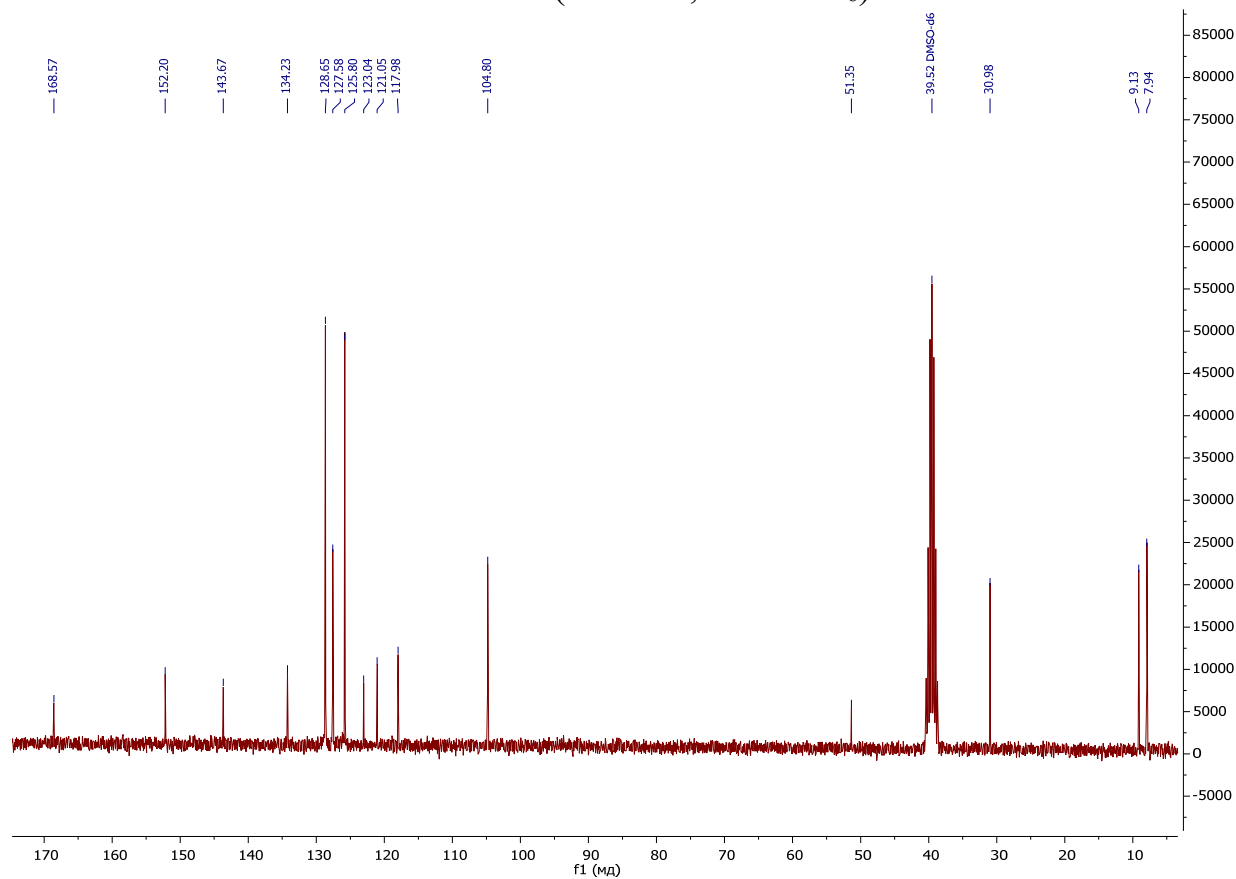


(*E*)-2-(4-phenylthiazol-2-yl)-2-(1,4,5-trimethyl-1,3-dihydro-2H-imidazol-2-ylidene)acetonitrile (**5a**)

^1H NMR (300 MHz, $\text{DMSO-}d_6$)

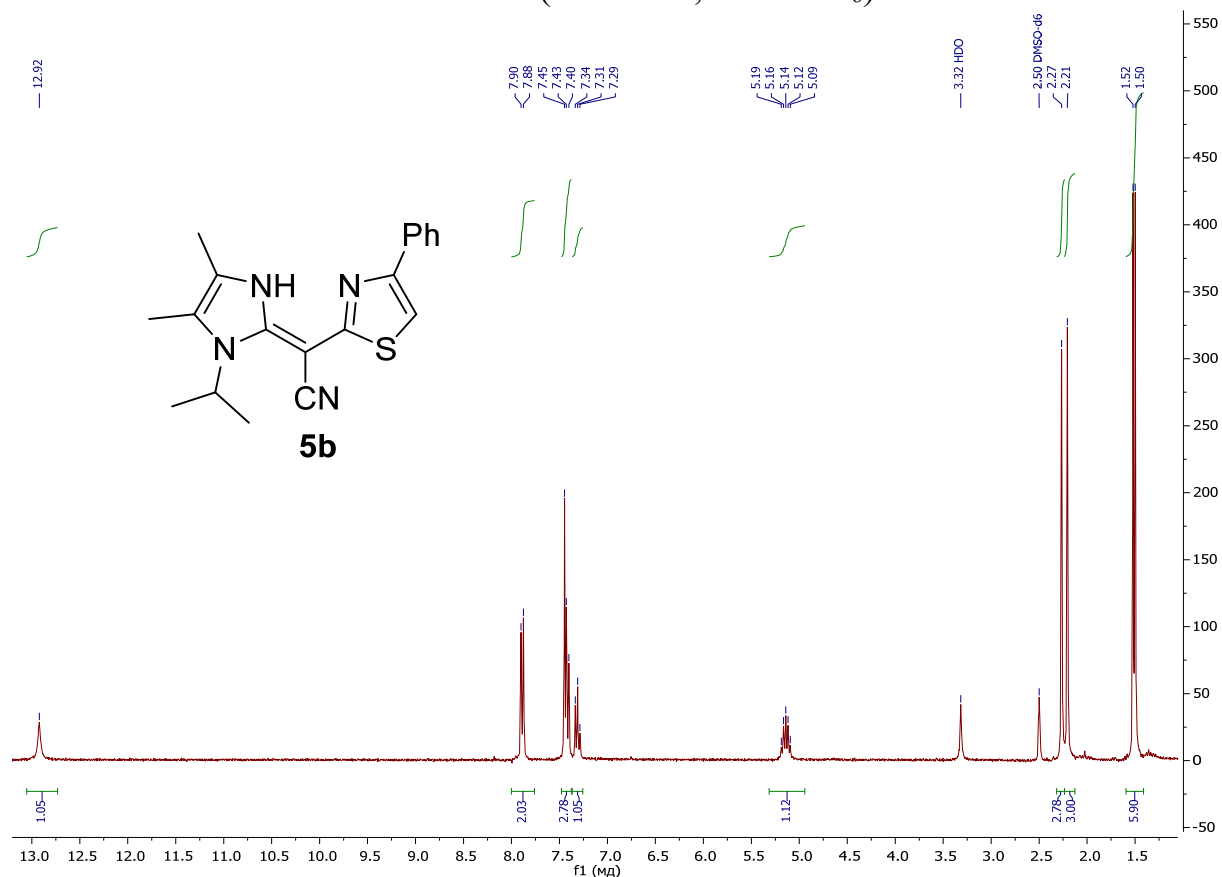


^{13}C NMR (75 MHz, $\text{DMSO-}d_6$)

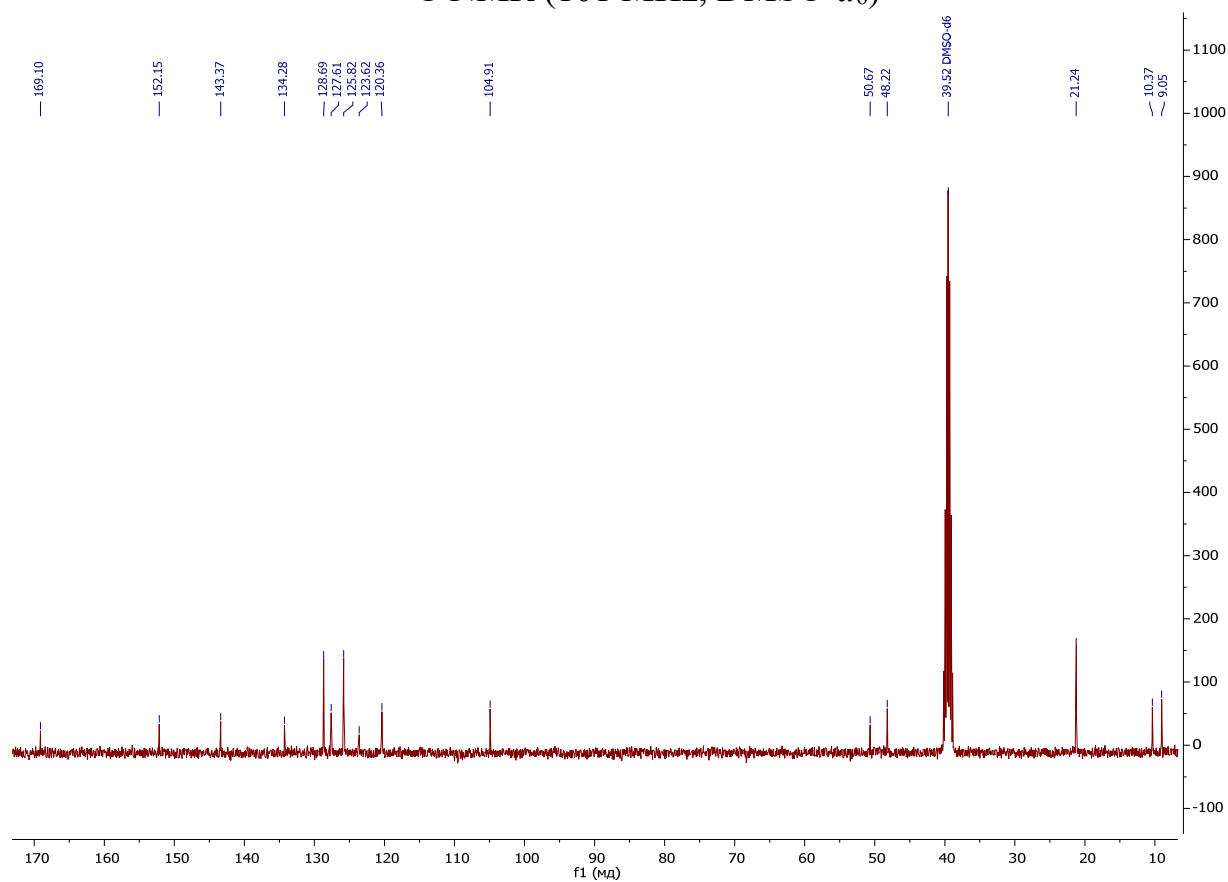


(*E*)-2-(1-isopropyl-4,5-dimethyl-1,3-dihydro-2H-imidazol-2-ylidene)-2-(4-phenylthiazol-2-yl)acetonitrile (**5b**)

^1H NMR (300 MHz, $\text{DMSO-}d_6$)

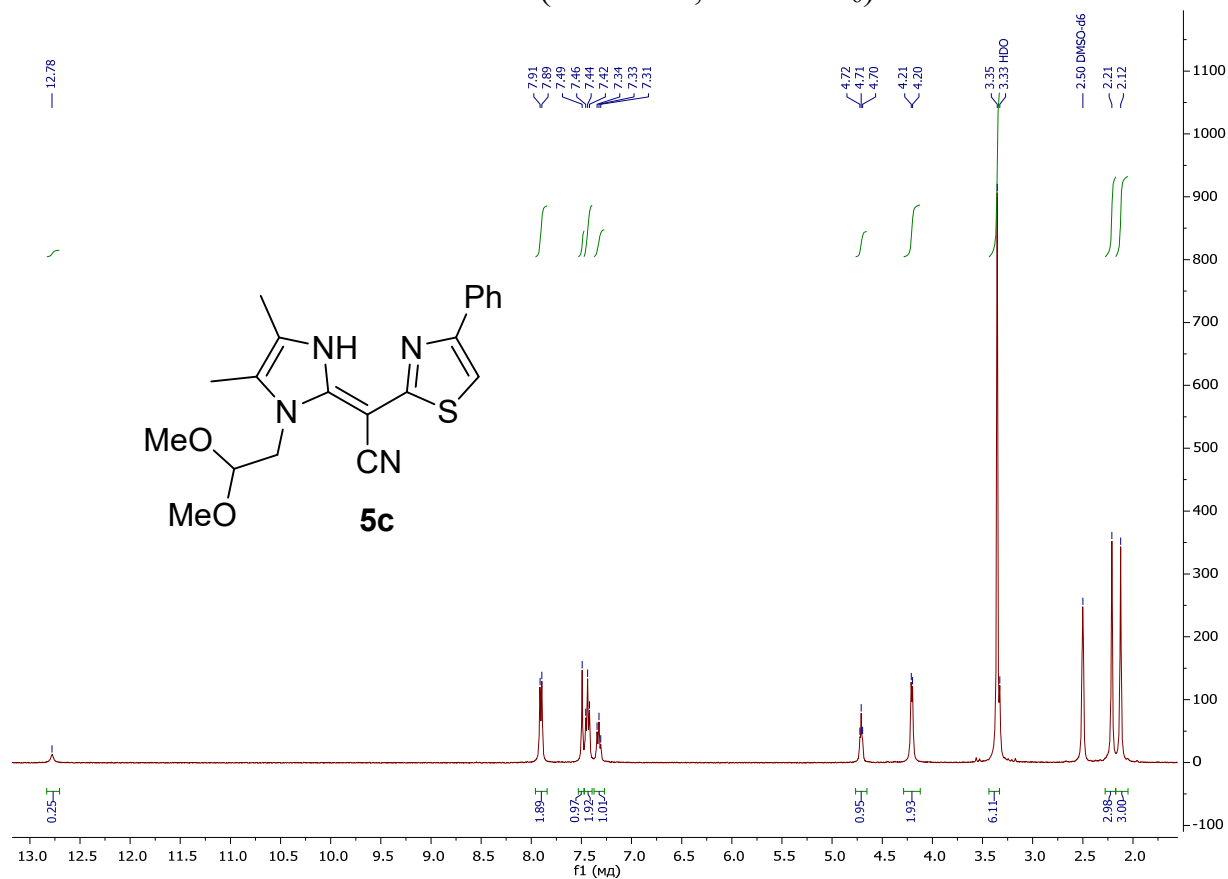


^{13}C NMR (101 MHz, $\text{DMSO-}d_6$)

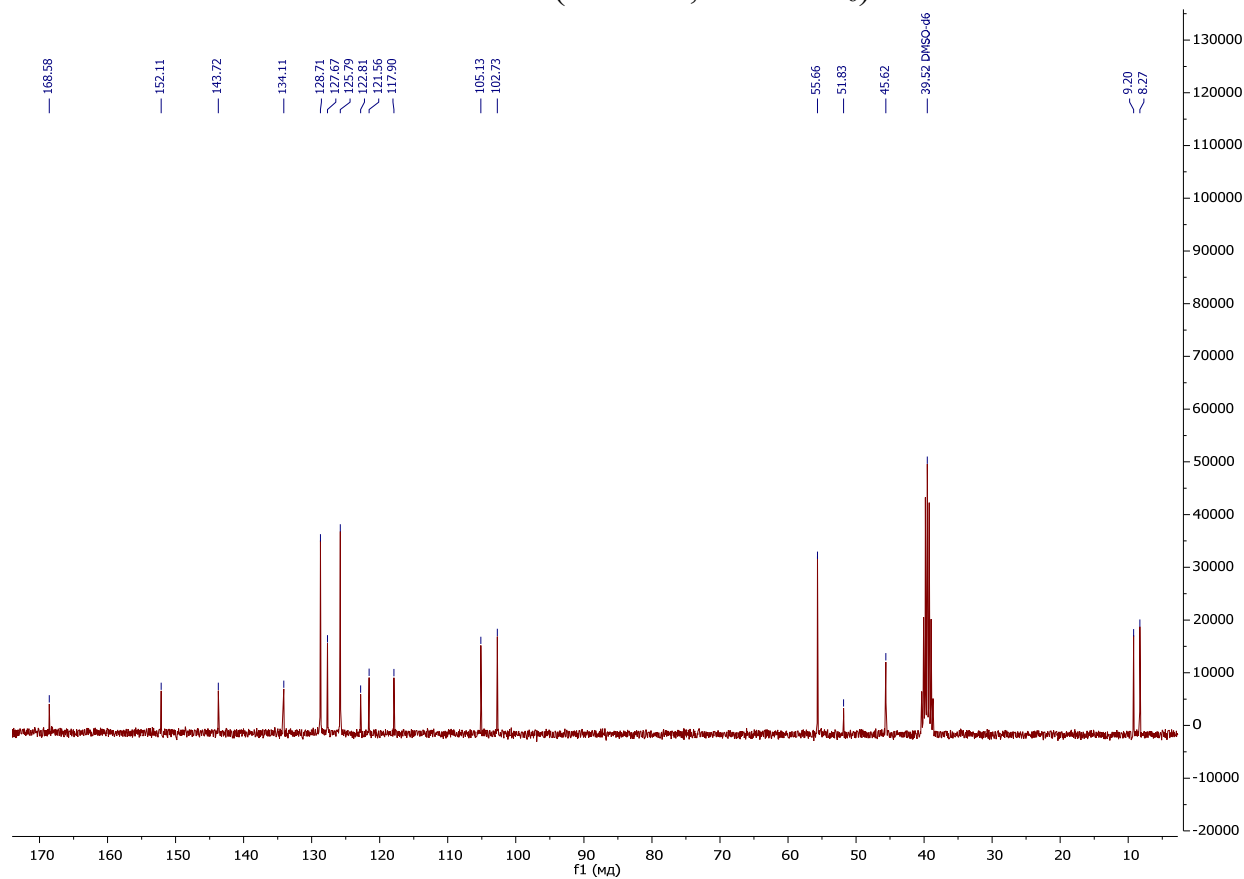


(*E*)-2-(1-(2,2-dimethoxyethyl)-4,5-dimethyl-1,3-dihydro-2H-imidazol-2-ylidene)-2-(4-phenylthiazol-2-yl)acetonitrile (**5c**)

^1H NMR (400 MHz, $\text{DMSO-}d_6$)

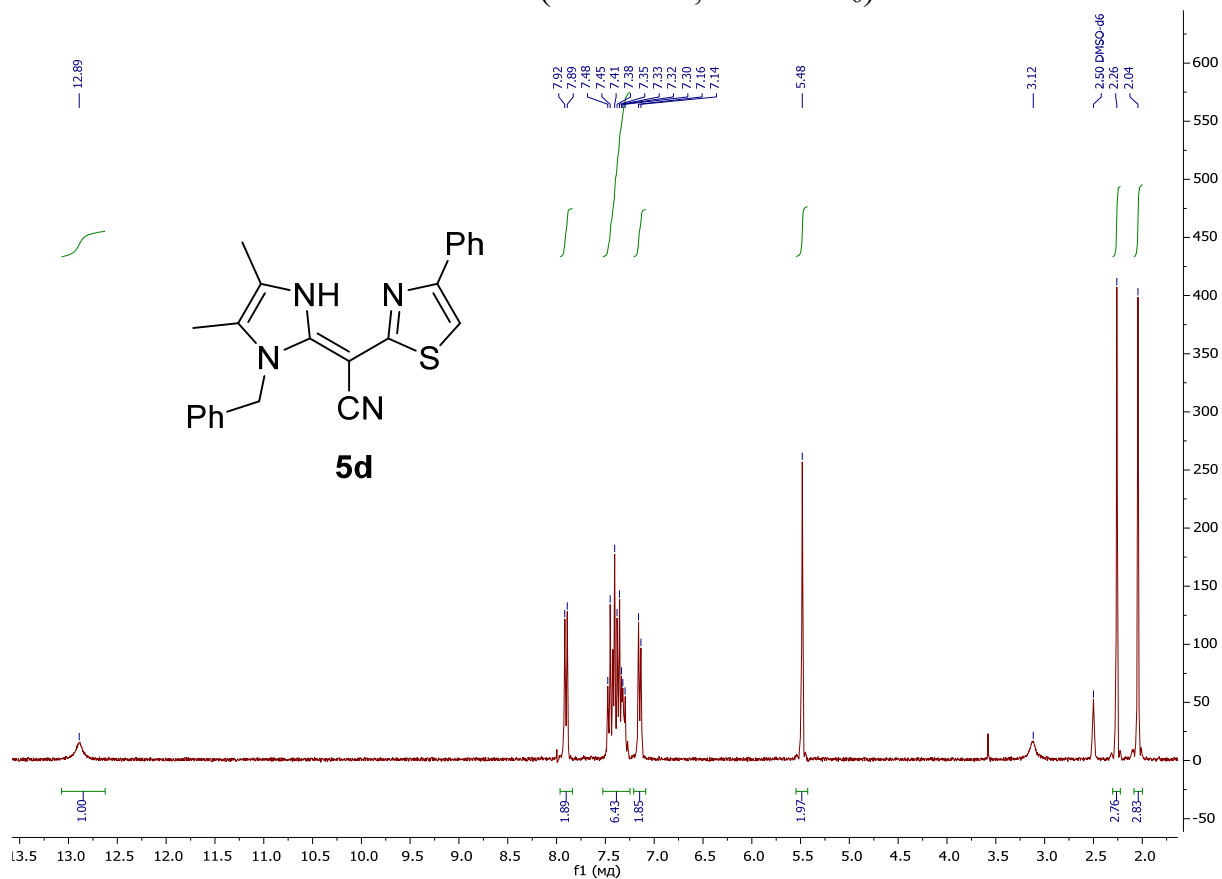


^{13}C NMR (75 MHz, $\text{DMSO-}d_6$)

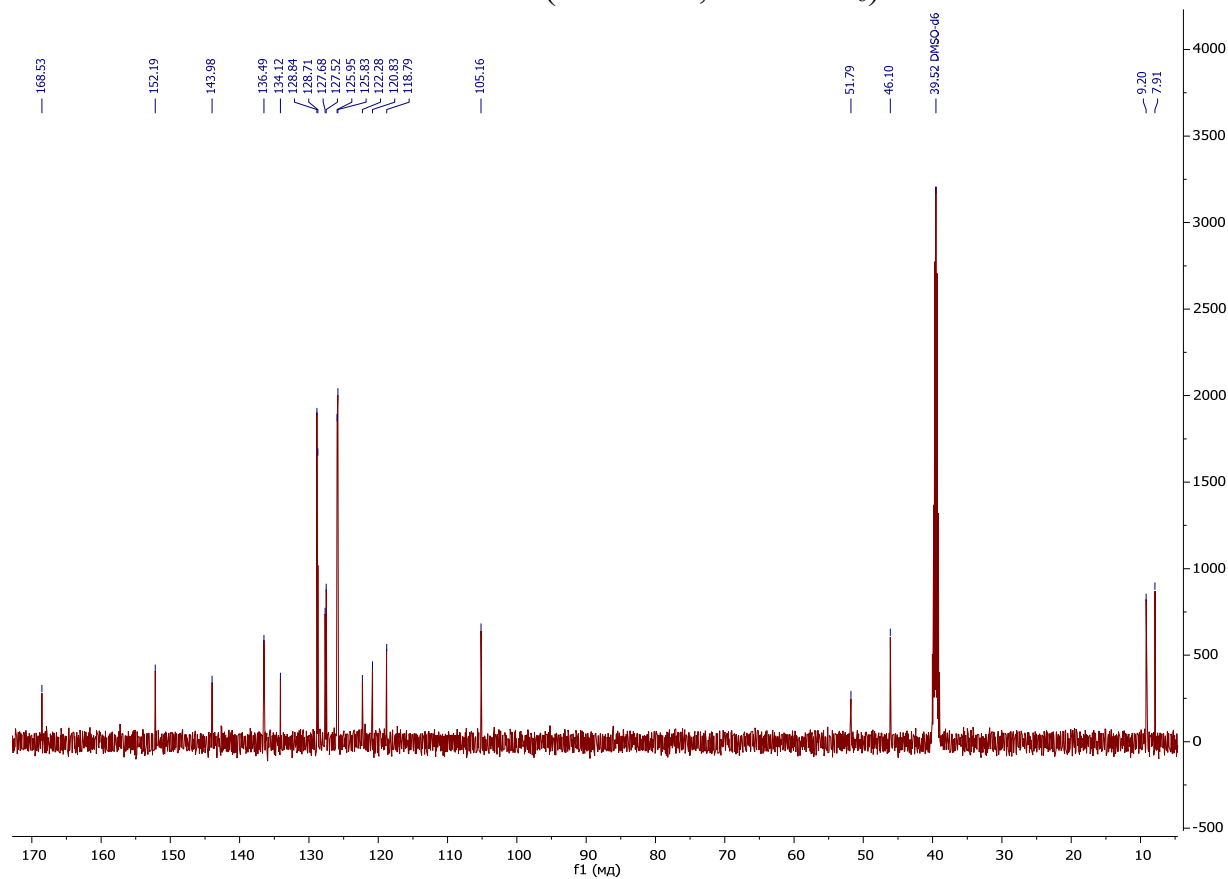


(*E*)-2-(1-benzyl-4,5-dimethyl-1,3-dihydro-2H-imidazol-2-ylidene)-2-(4-phenylthiazol-2-yl)acetonitrile (**5d**)

^1H NMR (300 MHz, $\text{DMSO-}d_6$)

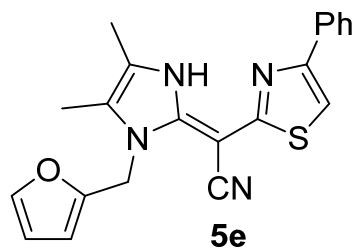
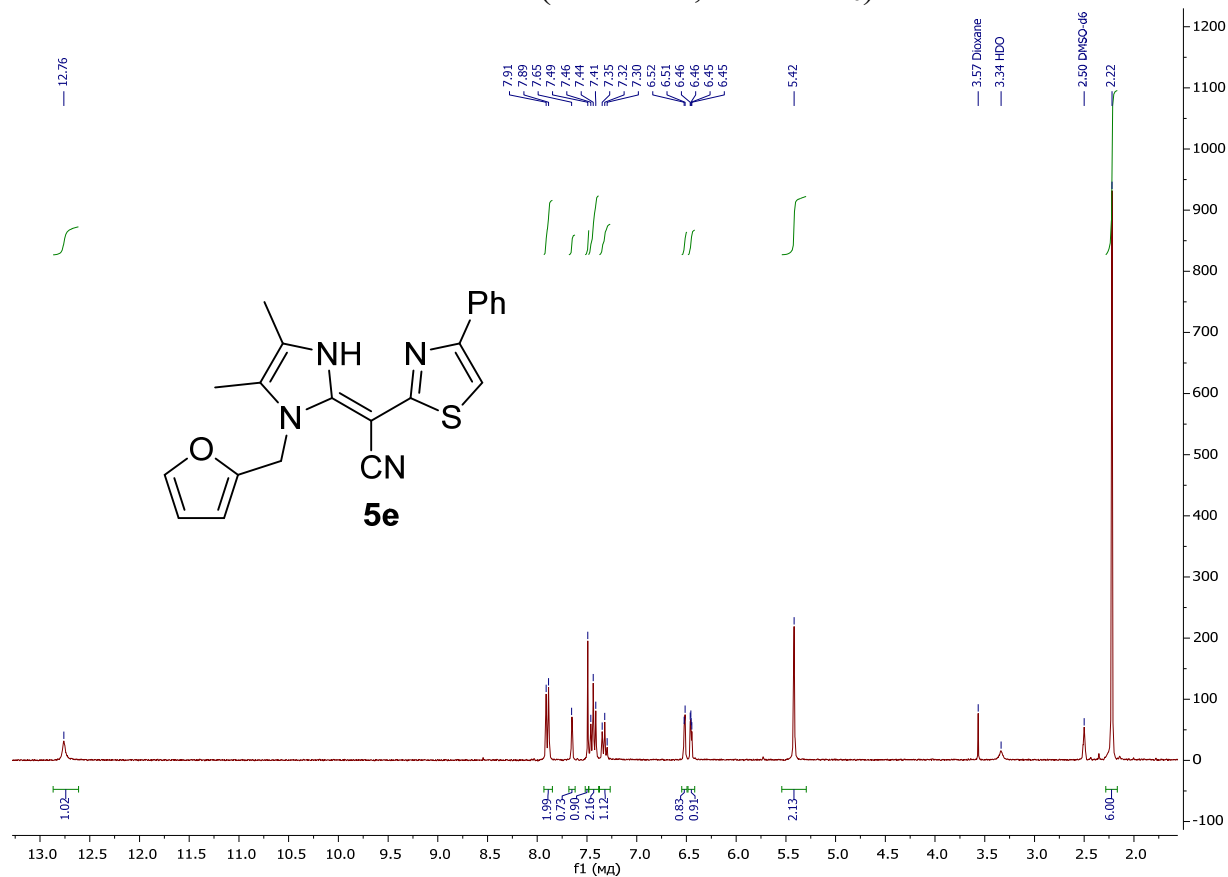


^{13}C NMR (126 MHz, $\text{DMSO-}d_6$)

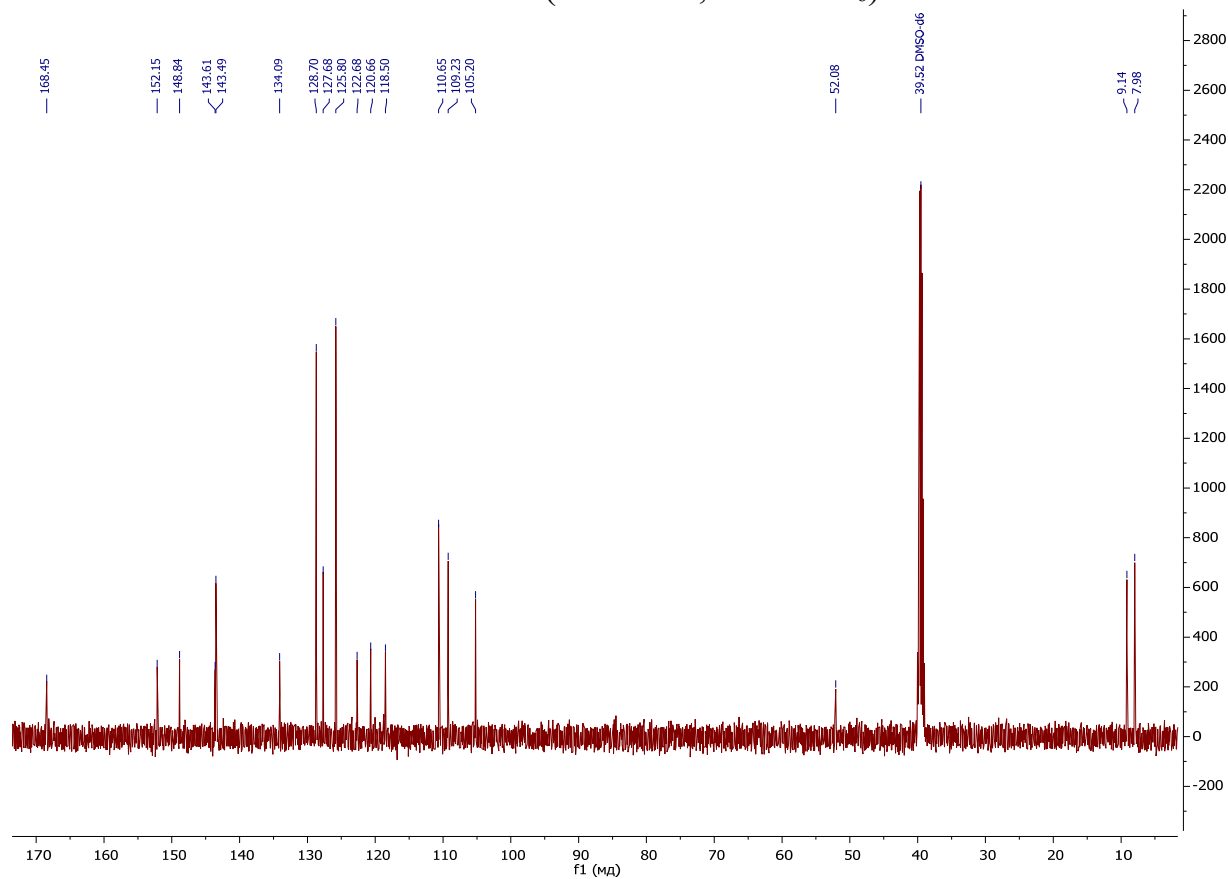


(*E*)-2-(1-(furan-2-ylmethyl)-4,5-dimethyl-1,3-dihydro-2H-imidazol-2-ylidene)-2-(4-phenylthiazol-2-yl)acetonitrile (**5e**)

^1H NMR (300 MHz, $\text{DMSO-}d_6$)

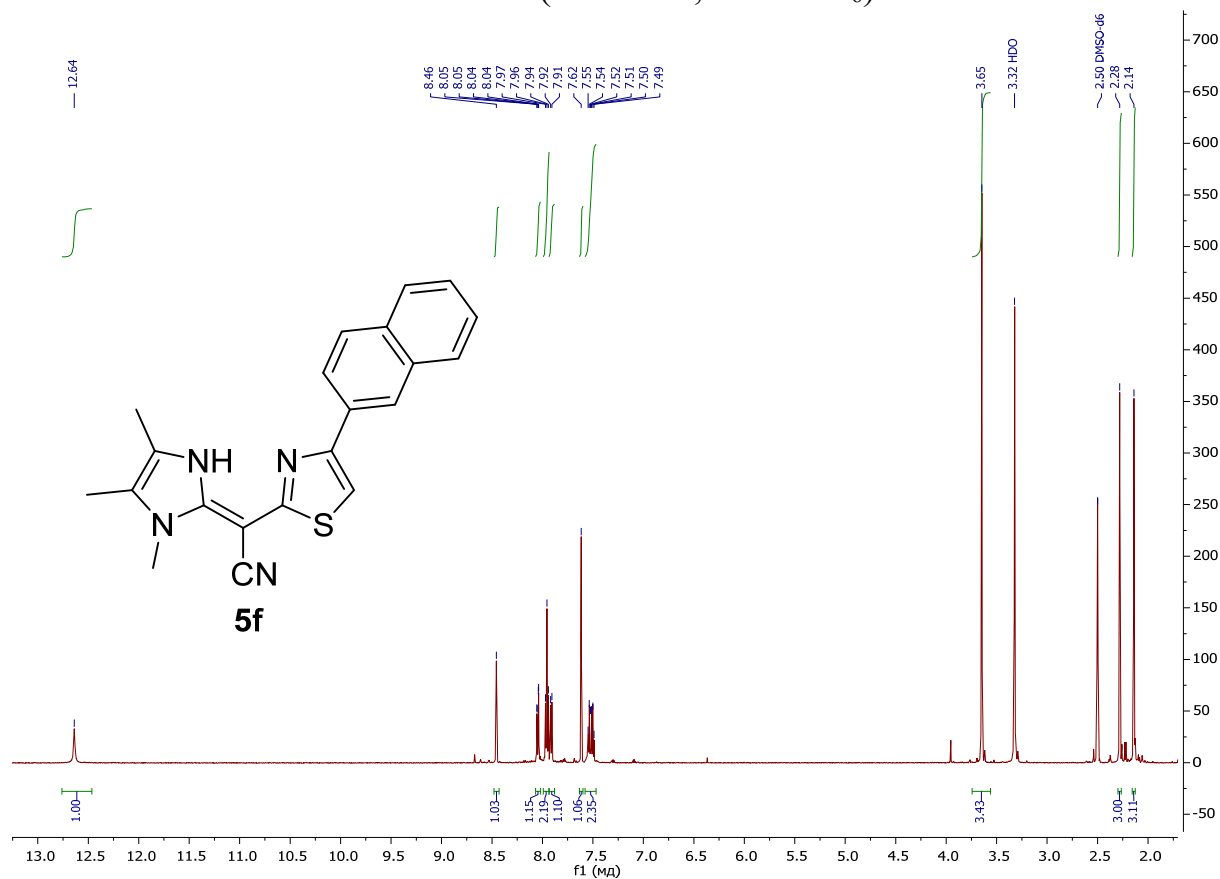


^{13}C NMR (126 MHz, $\text{DMSO-}d_6$)

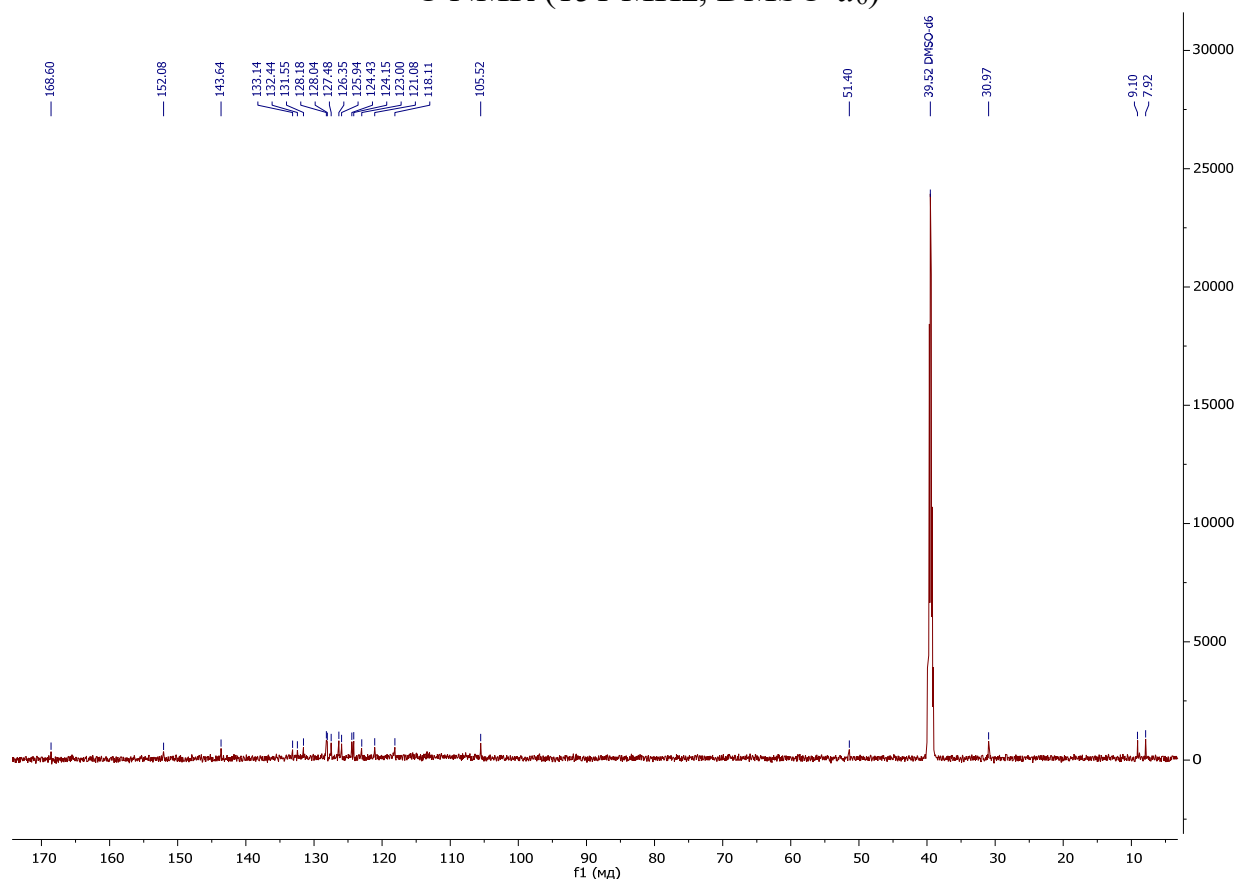


(*E*)-2-(4-(naphthalen-2-yl)thiazol-2-yl)-2-(1,4,5-trimethyl-1,3-dihydro-2H-imidazol-2-ylidene)acetonitrile (**5f**)

^1H NMR (600 MHz, $\text{DMSO-}d_6$)

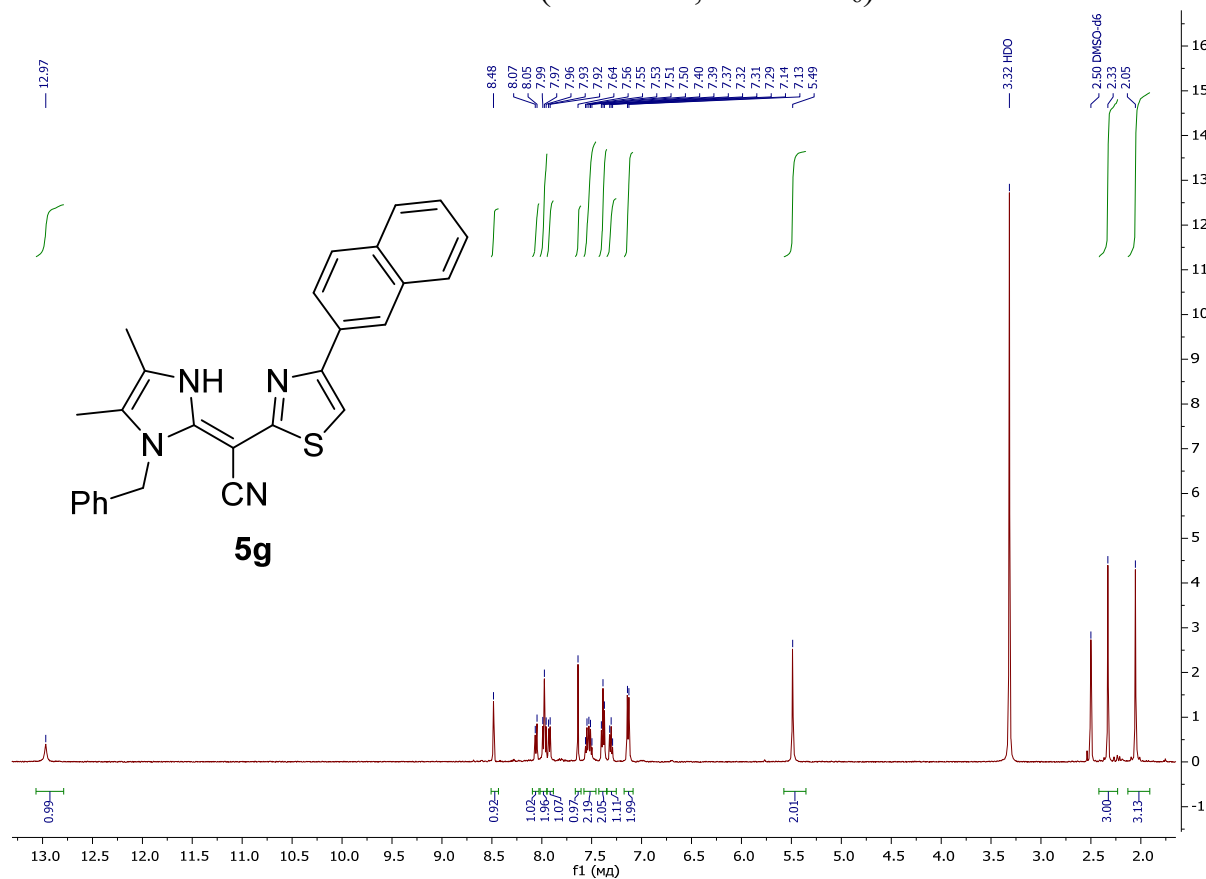


^{13}C NMR (151 MHz, $\text{DMSO-}d_6$)

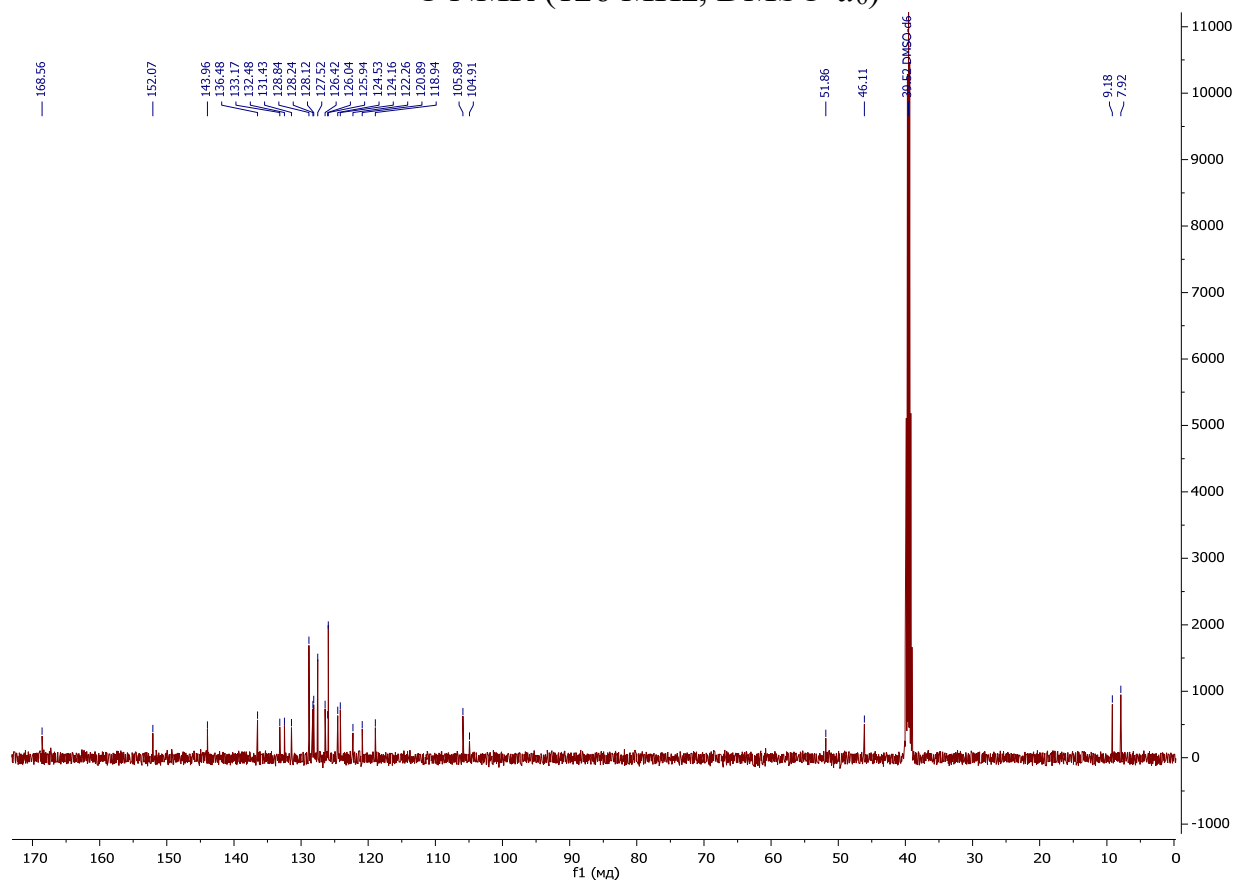


(*E*)-2-(1-benzyl-4,5-dimethyl-1,3-dihydro-2H-imidazol-2-ylidene)-2-(4-(naphthalen-2-yl)thiazol-2-yl)acetonitrile (**5g**)

^1H NMR (500 MHz, $\text{DMSO-}d_6$)

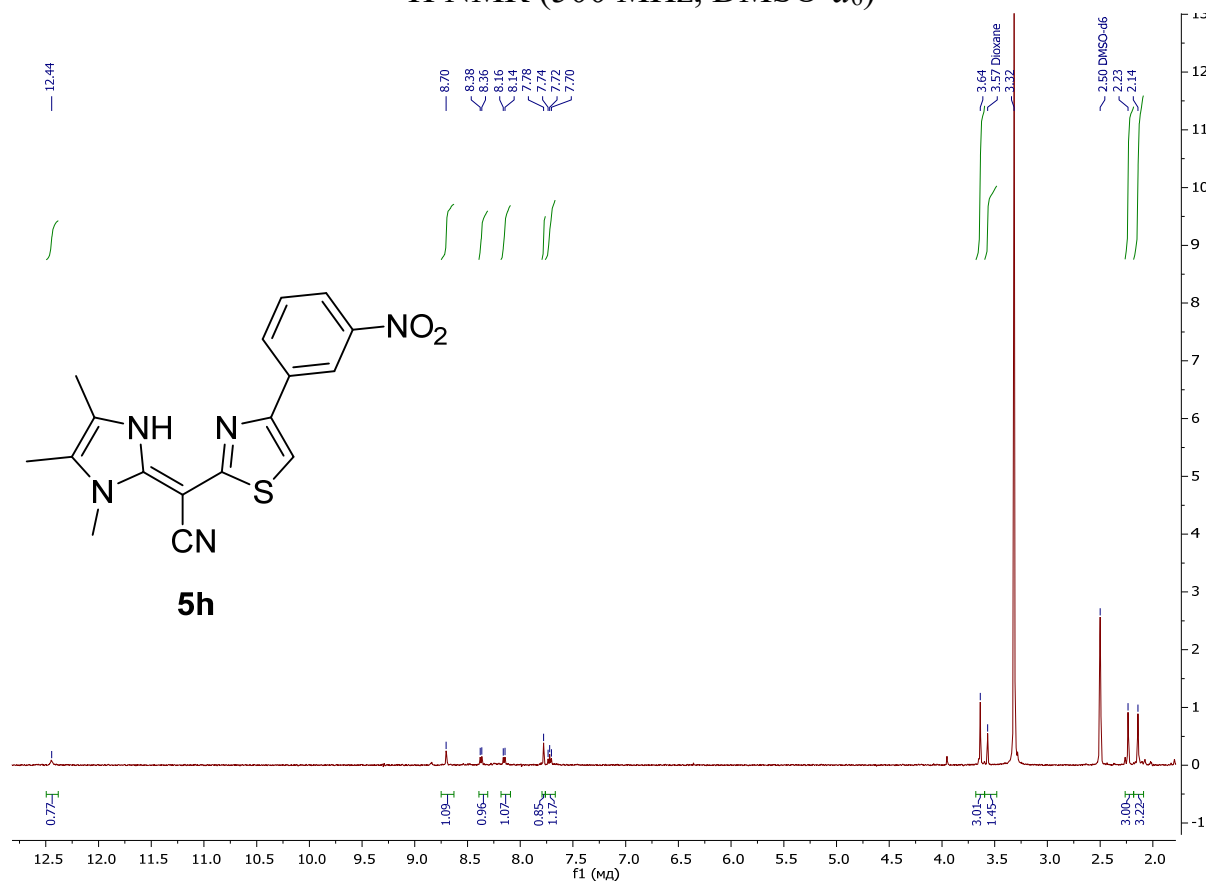


^{13}C NMR (126 MHz, $\text{DMSO-}d_6$)



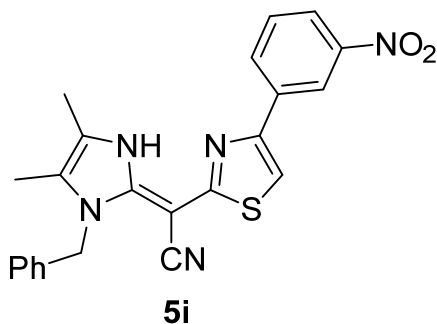
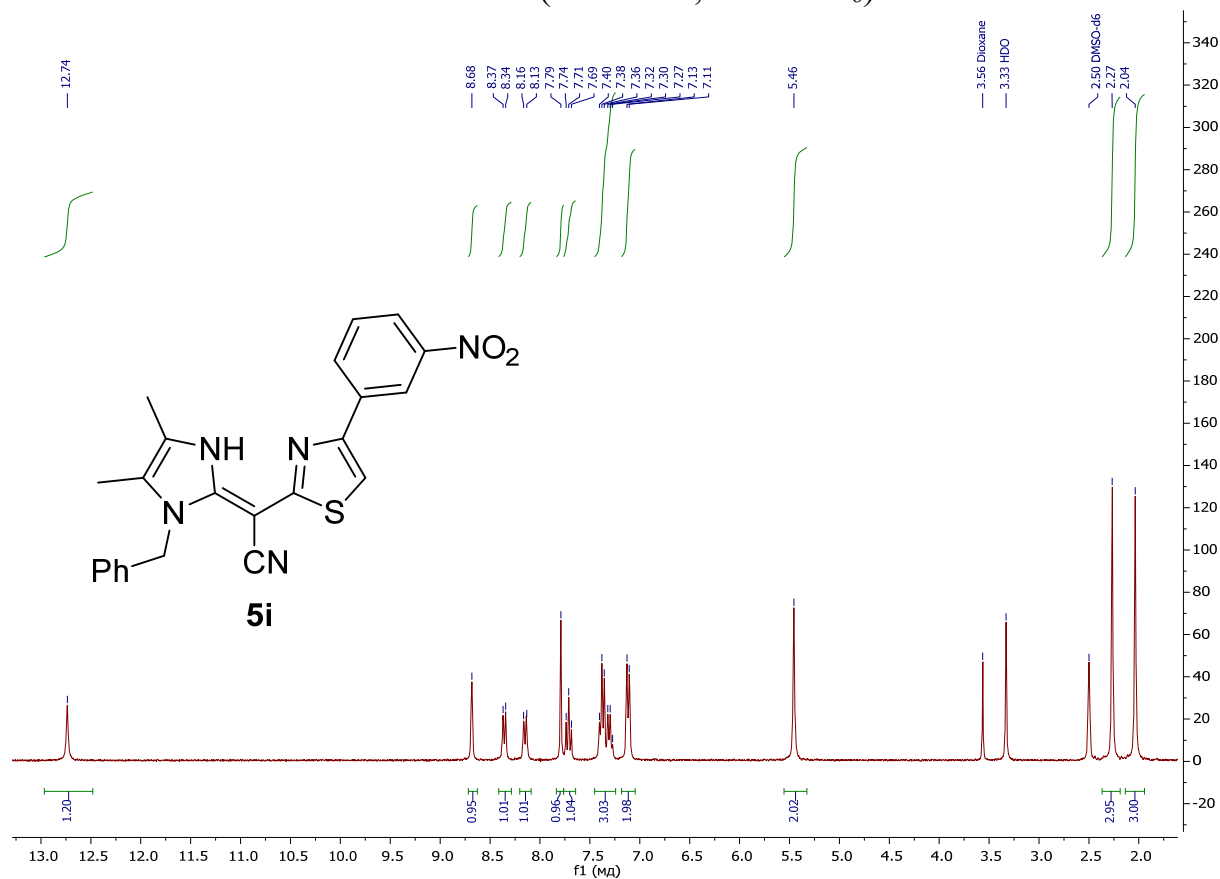
(*E*)-2-(4-(3-nitrophenyl)thiazol-2-yl)-2-(1,4,5-trimethyl-1,3-dihydro-2H-imidazol-2-ylidene)acetonitrile (**5h**)

$^1\text{H NMR}$ (500 MHz, $\text{DMSO-}d_6$)

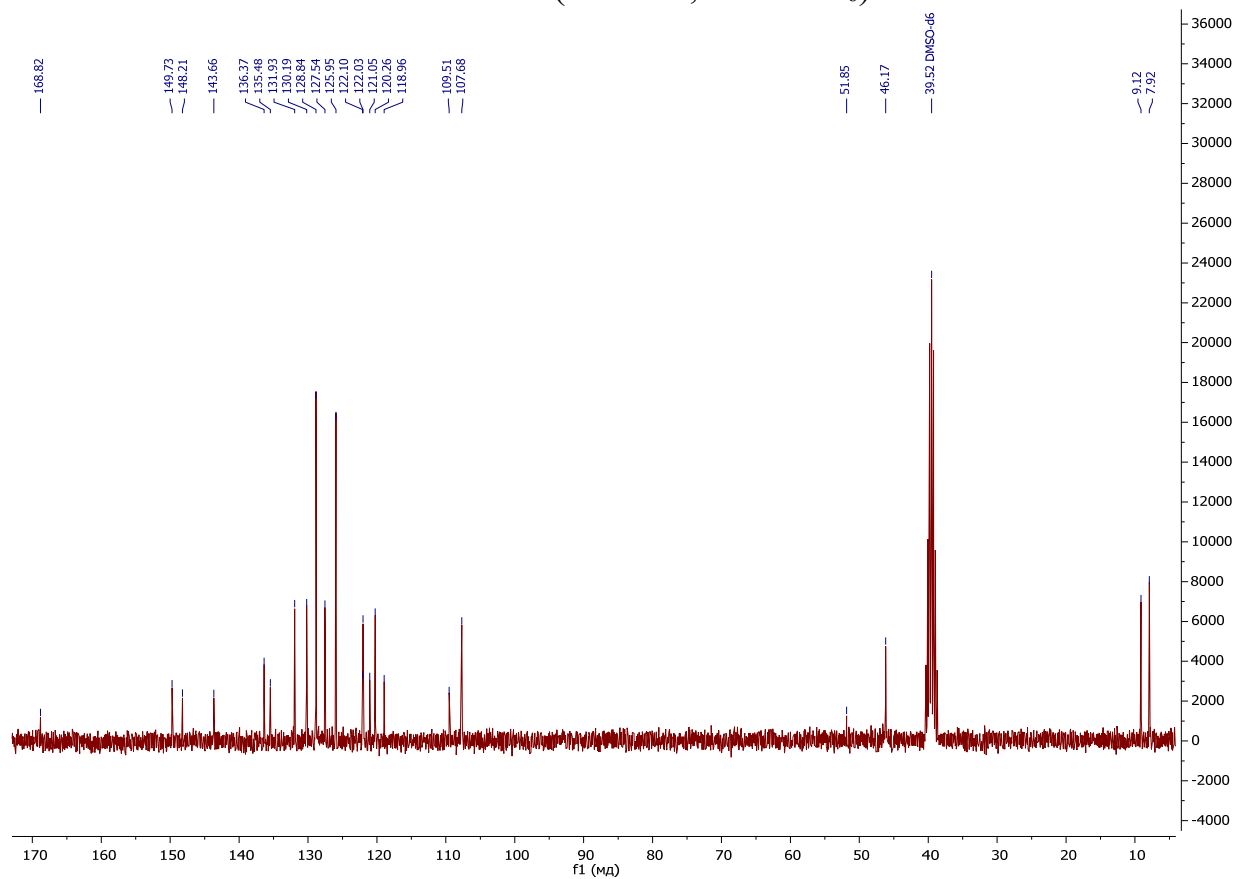


(*E*)-2-(1-benzyl-4,5-dimethyl-1,3-dihydro-2H-imidazol-2-ylidene)-2-(4-(3-nitrophenyl)thiazol-2-yl)acetonitrile (**5i**)

^1H NMR (300 MHz, $\text{DMSO-}d_6$)

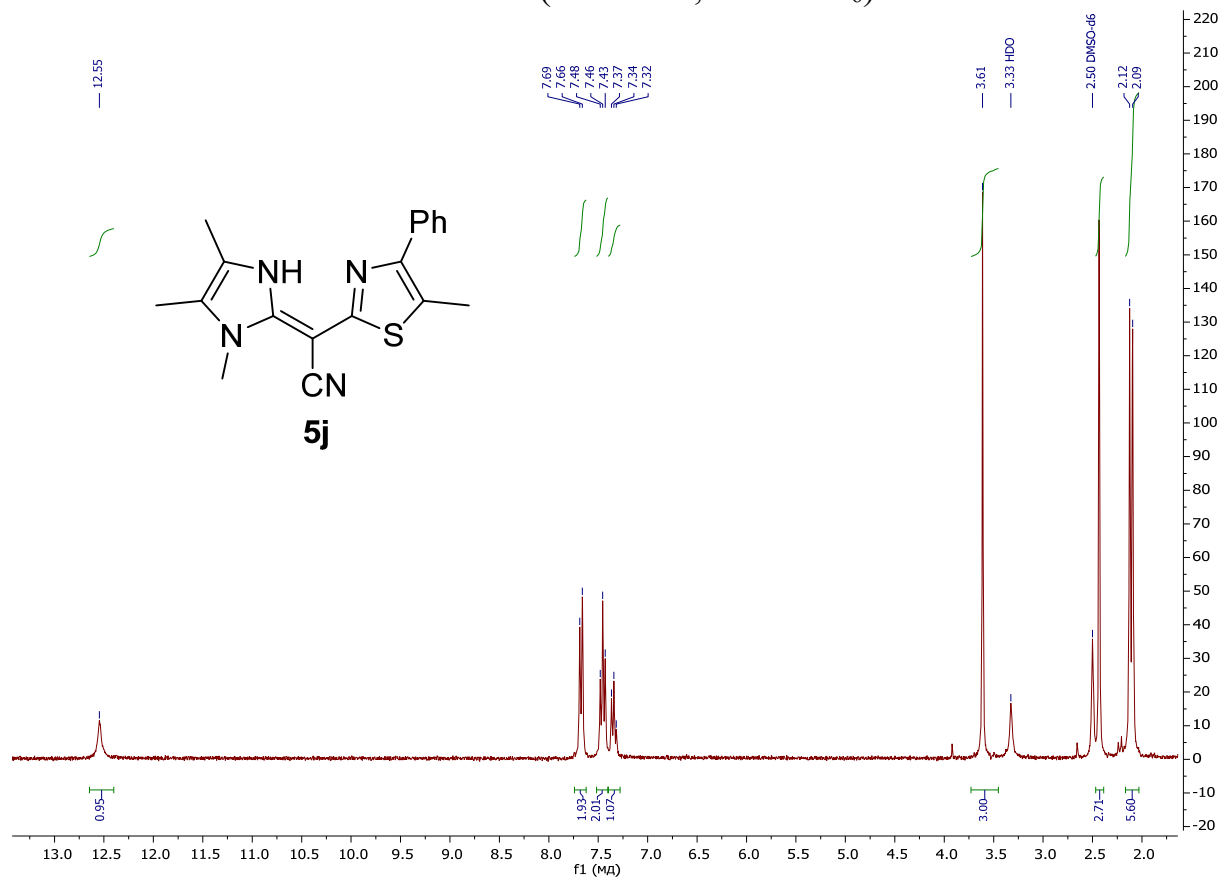


^{13}C NMR (75 MHz, $\text{DMSO-}d_6$)

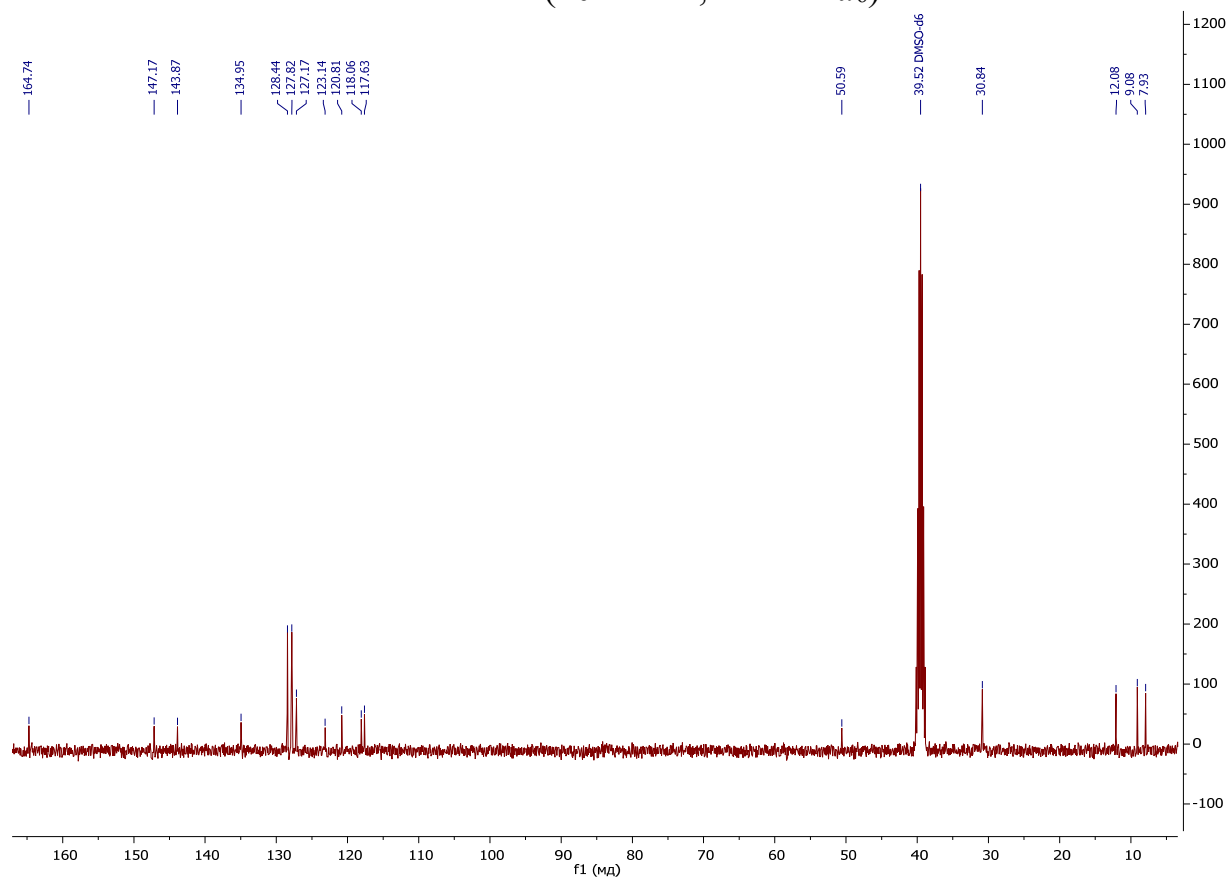


(*E*)-2-(5-methyl-4-phenylthiazol-2-yl)-2-(1,4,5-trimethyl-1,3-dihydro-2H-imidazol-2-ylidene)acetonitrile (**5j**)

^1H NMR (300 MHz, $\text{DMSO-}d_6$)

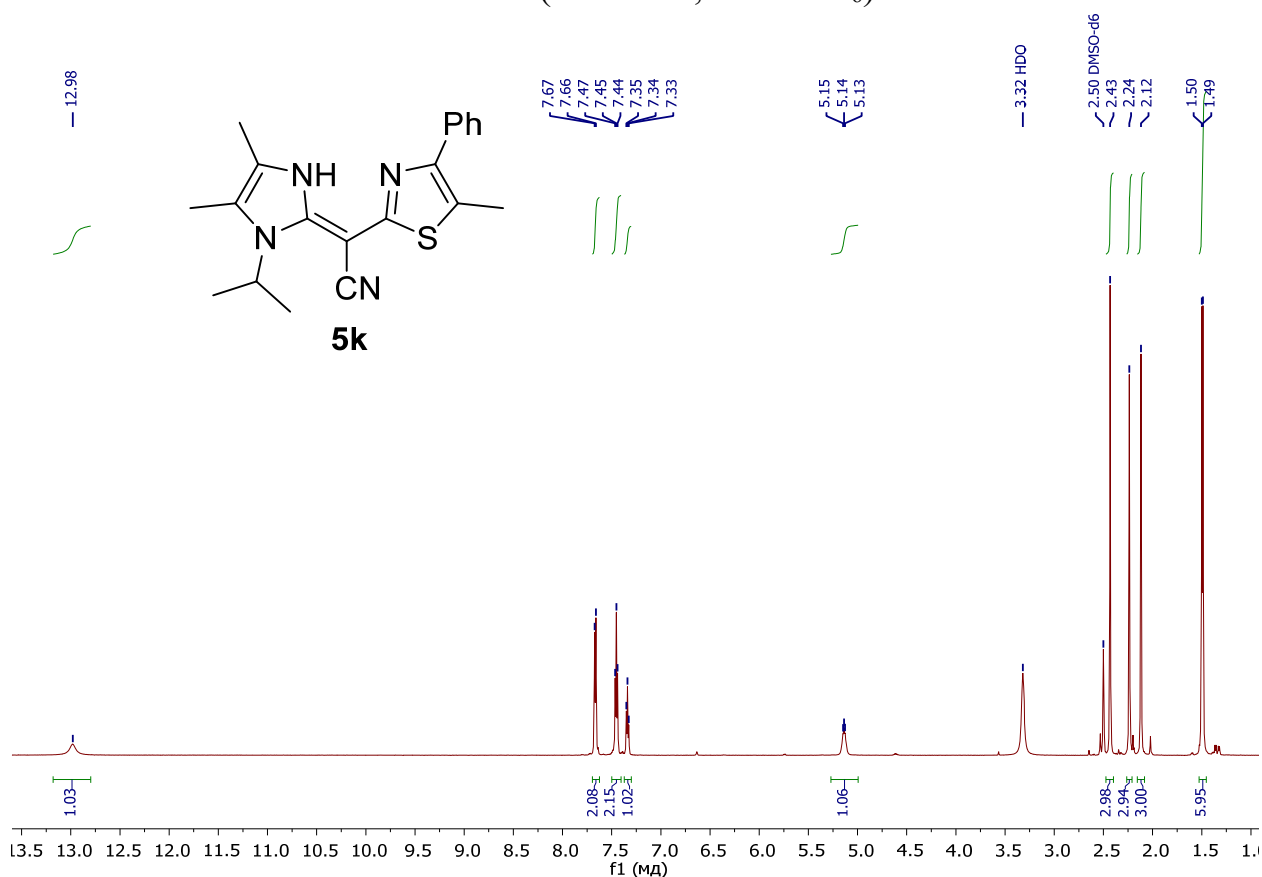


^{13}C NMR (101 MHz, $\text{DMSO-}d_6$)

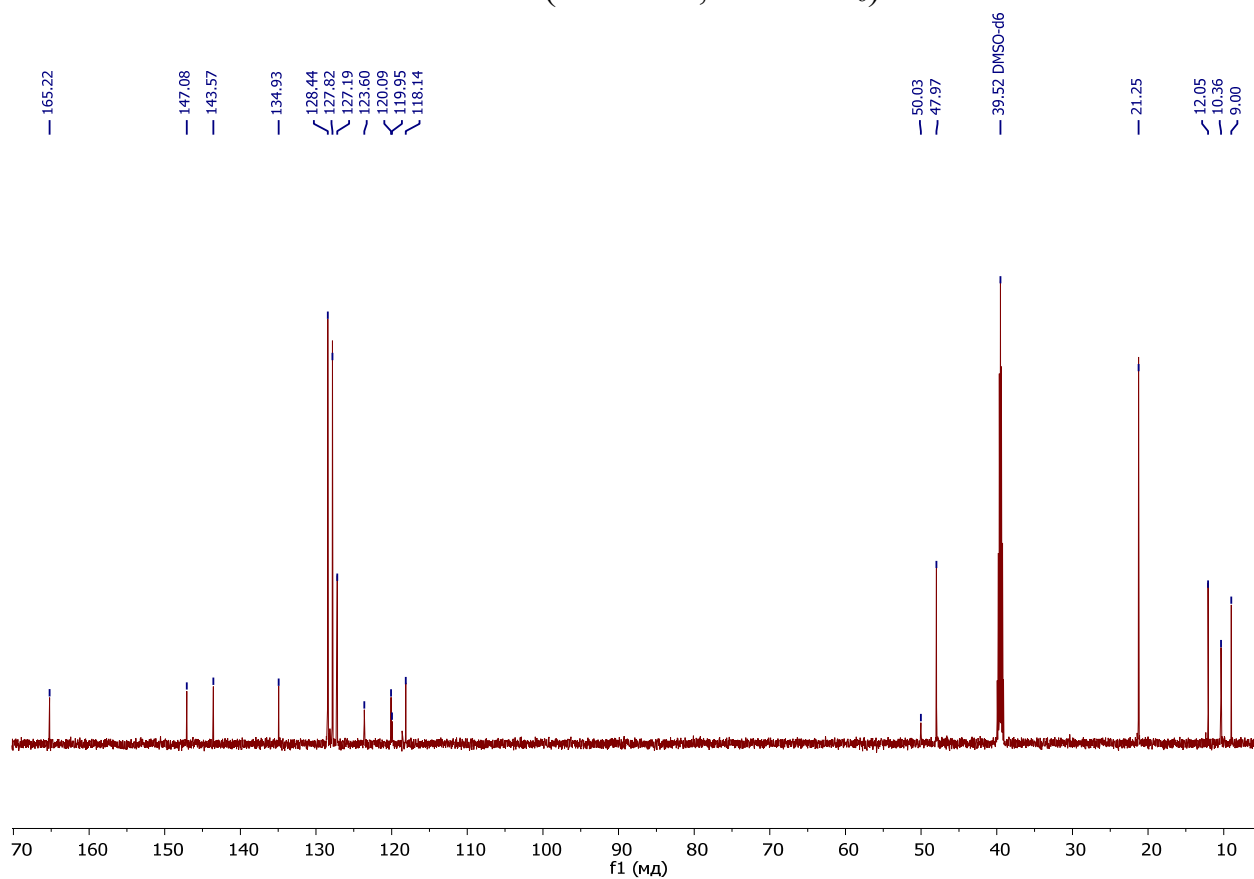


(*E*)-2-(1-isopropyl-4,5-dimethyl-1,3-dihydro-2H-imidazol-2-ylidene)-2-(5-methyl-4-phenylthiazol-2-yl)acetonitrile (**5k**)

^1H NMR (600 MHz, $\text{DMSO-}d_6$)

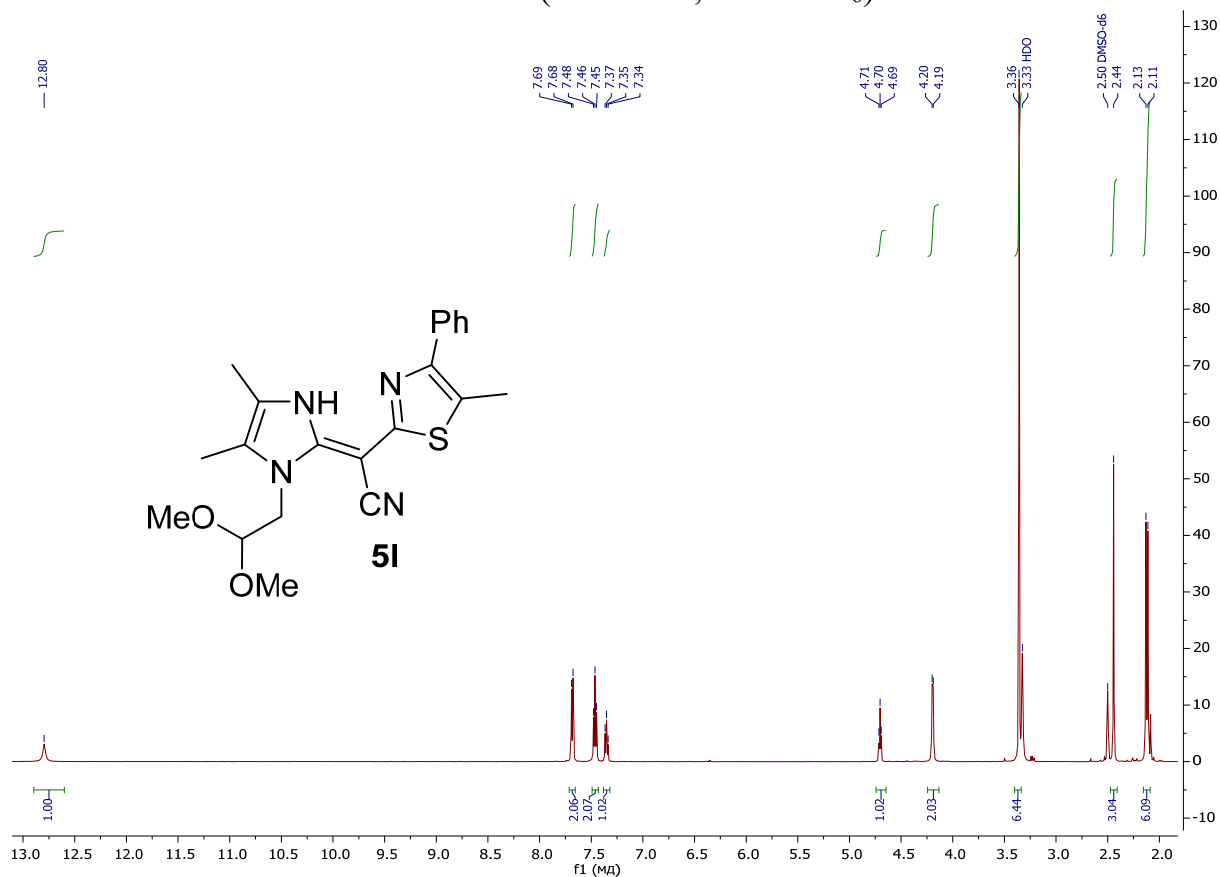


^{13}C NMR (151 MHz, $\text{DMSO-}d_6$)

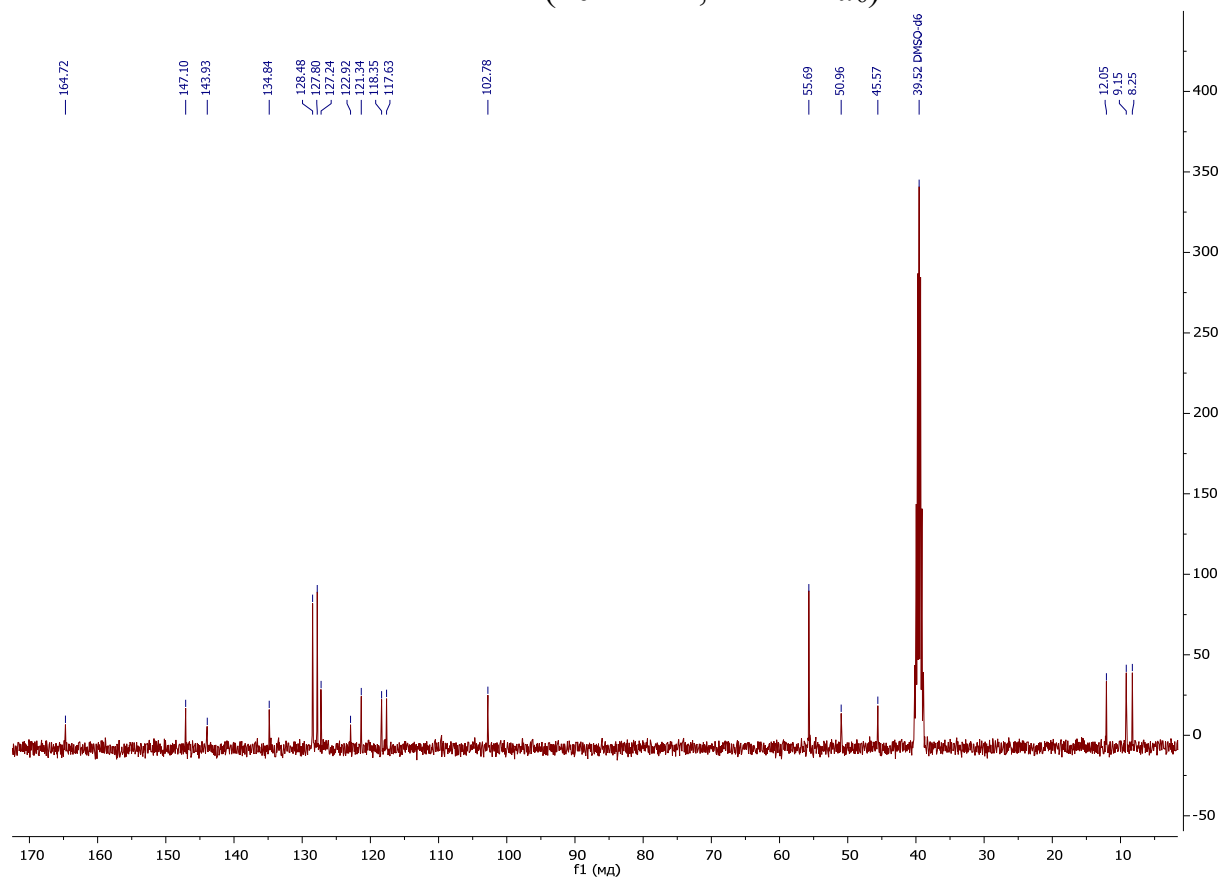


(*E*)-2-(1-(2,2-dimethoxyethyl)-4,5-dimethyl-1,3-dihydro-2H-imidazol-2-ylidene)-2-(5-methyl-4-phenylthiazol-2-yl)acetonitrile (**5I**)

^1H NMR (500 MHz, $\text{DMSO-}d_6$)

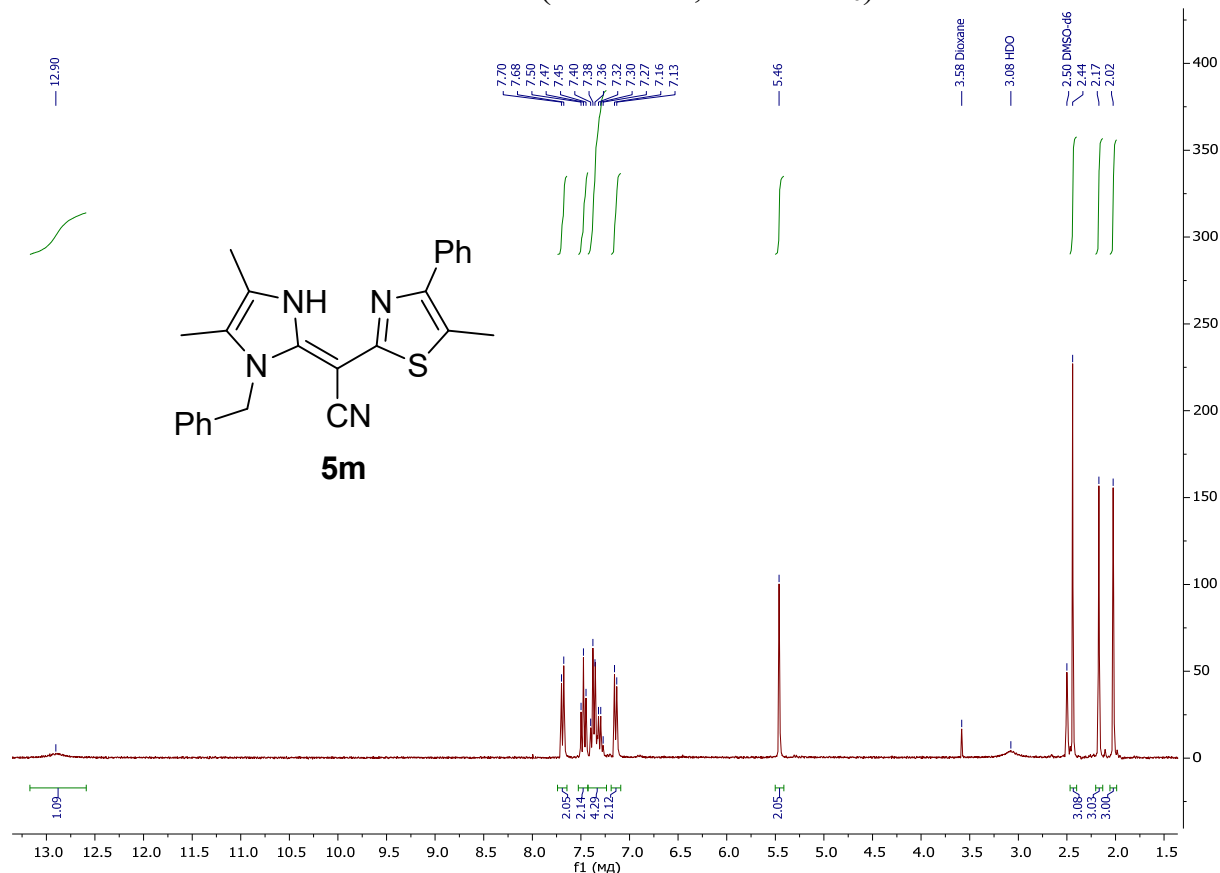


^{13}C NMR (101 MHz, $\text{DMSO-}d_6$)

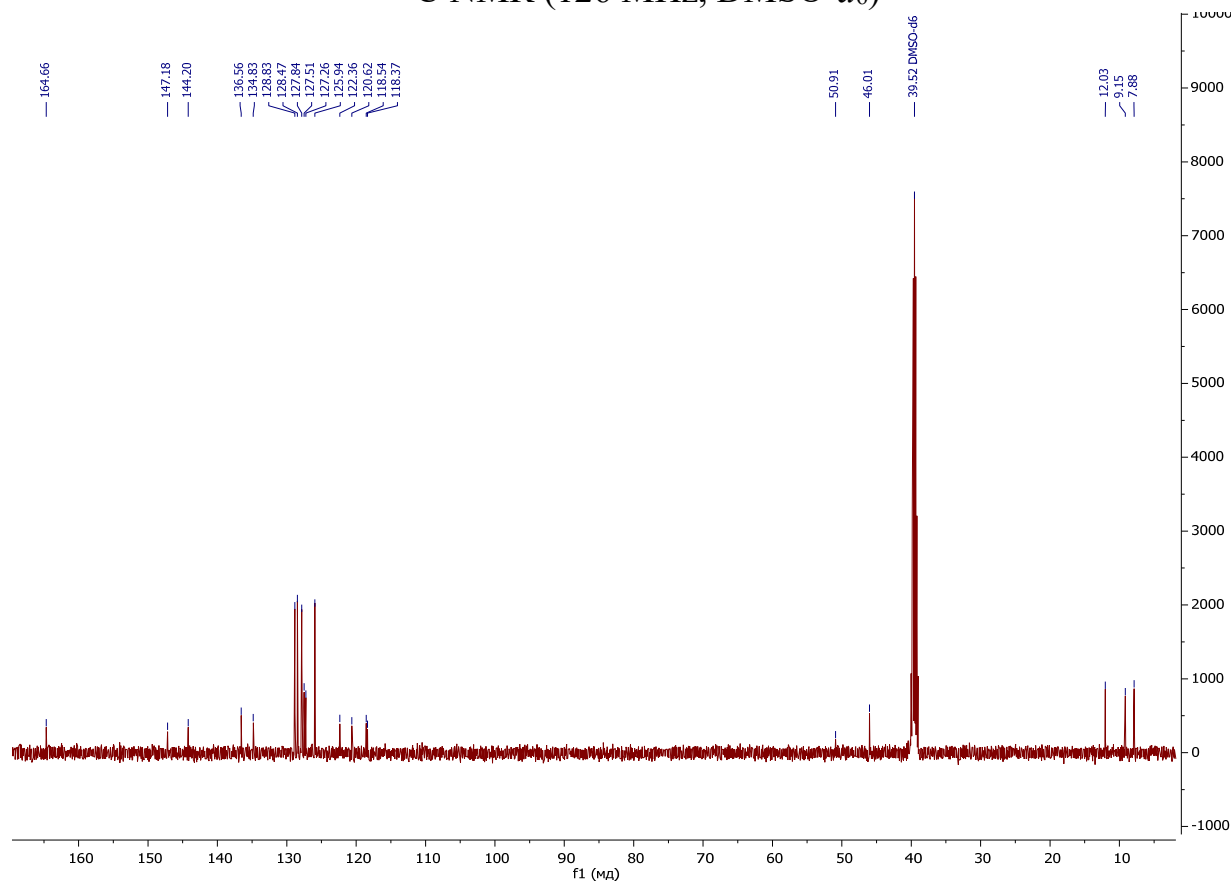


(*E*)-2-(1-benzyl-4,5-dimethyl-1,3-dihydro-2H-imidazol-2-ylidene)-2-(5-methyl-4-phenylthiazol-2-yl)acetonitrile (**5m**)

^1H NMR (300 MHz, $\text{DMSO-}d_6$)

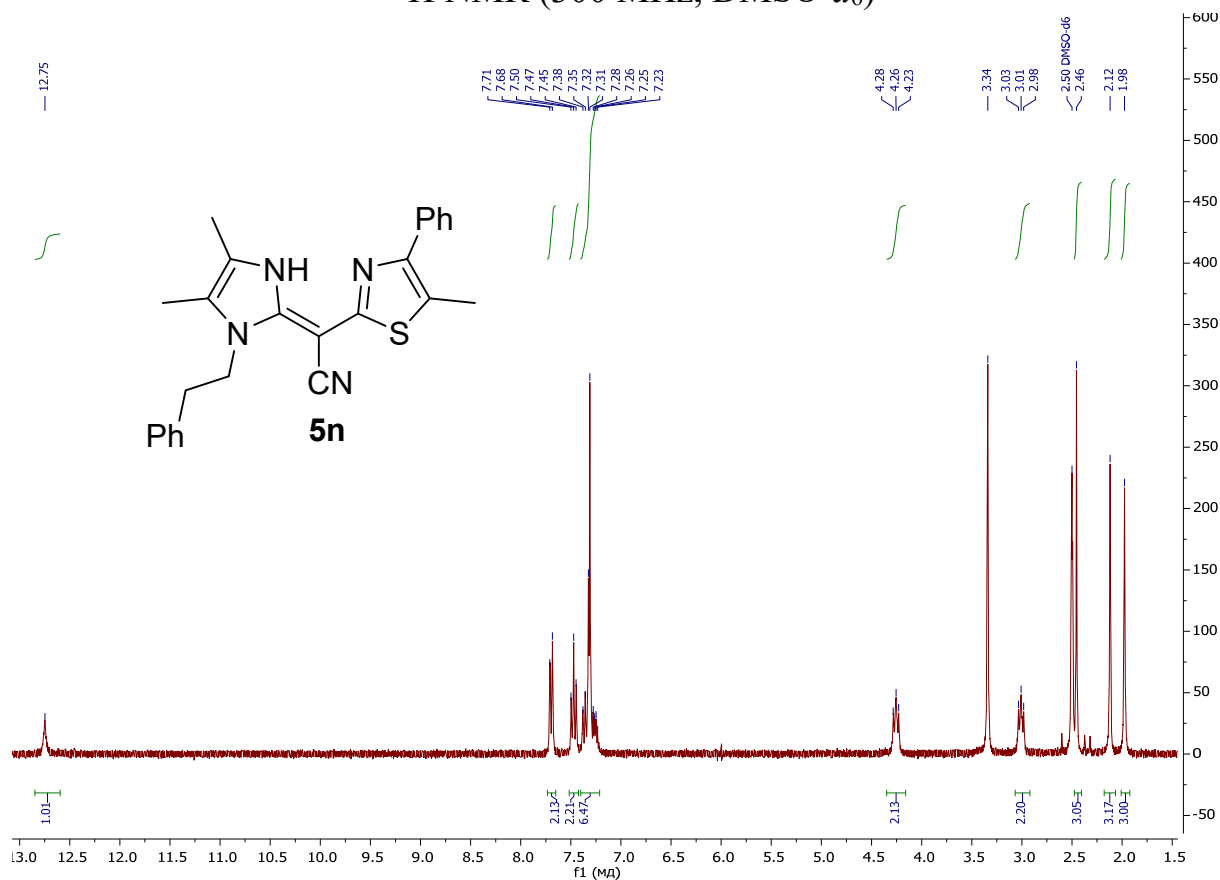


^{13}C NMR (126 MHz, $\text{DMSO-}d_6$)

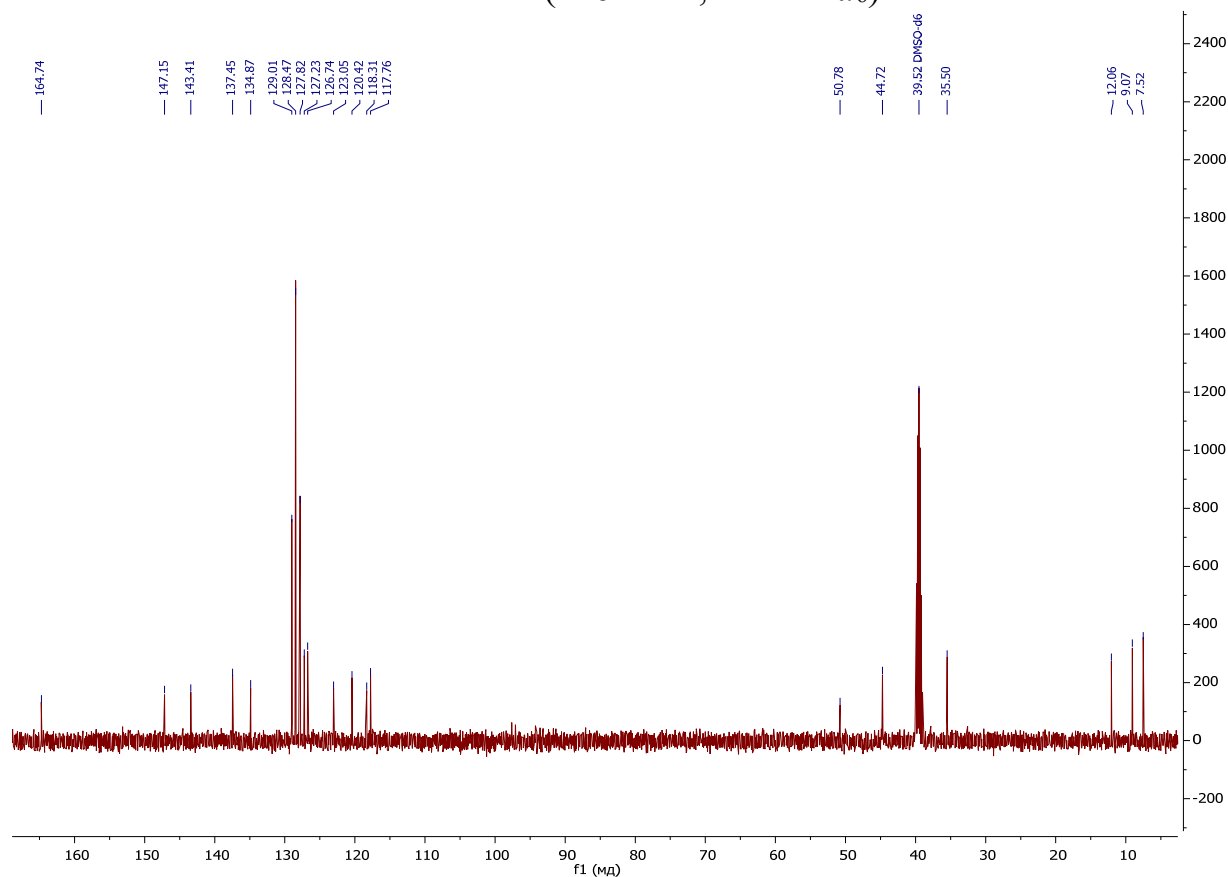


(*E*)-2-(4,5-dimethyl-1-phenethyl-1,3-dihydro-2H-imidazol-2-ylidene)-2-(5-methyl-4-phenylthiazol-2-yl)acetonitrile (**5n**)

^1H NMR (300 MHz, $\text{DMSO-}d_6$)

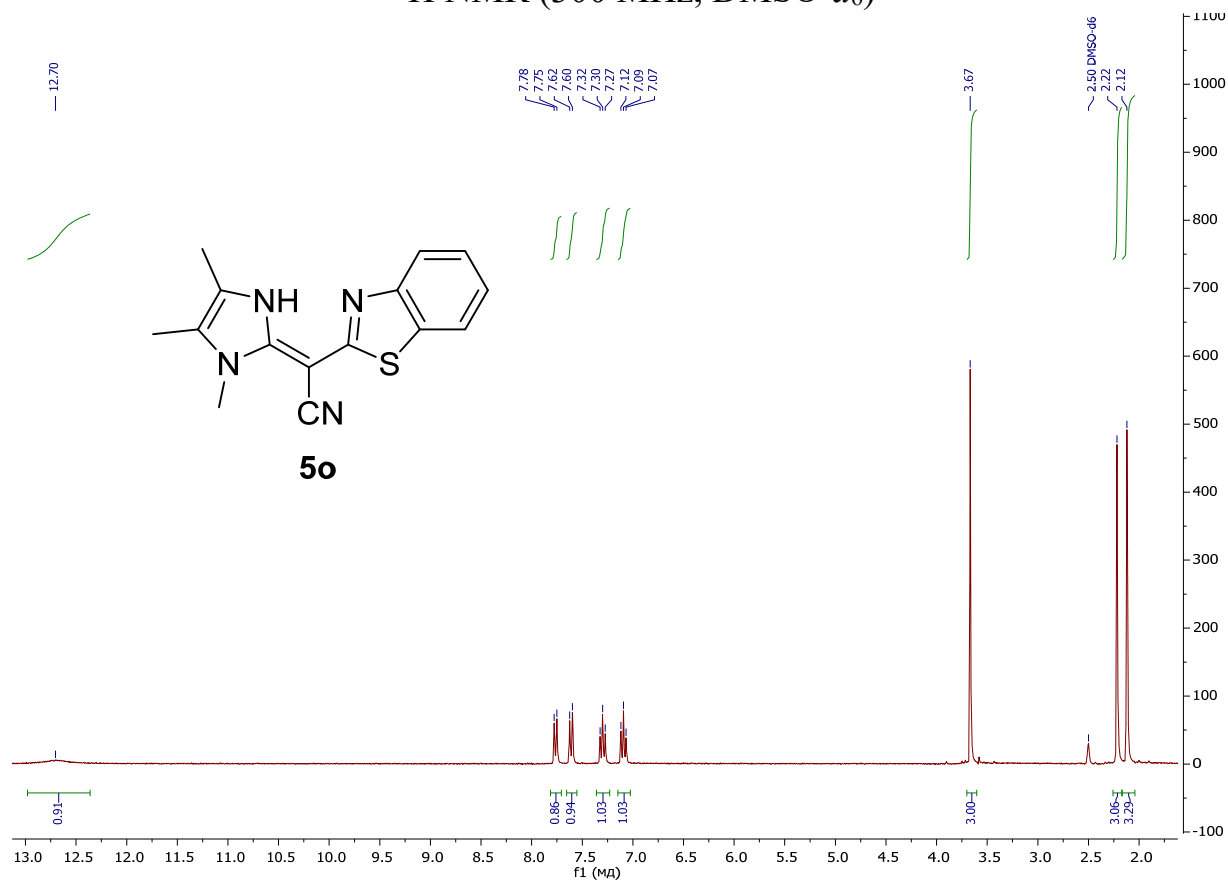


^{13}C NMR (126 MHz, $\text{DMSO-}d_6$)

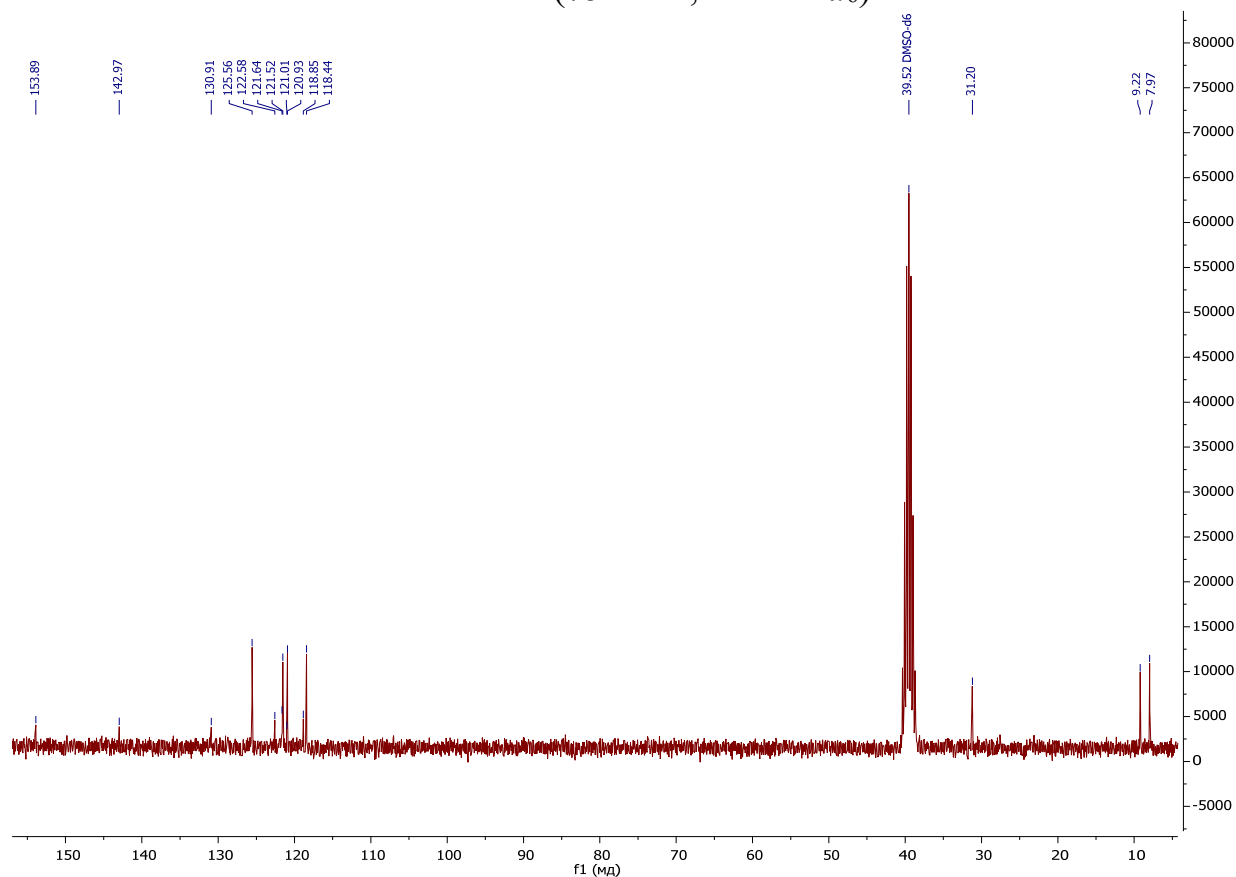


(*E*)-2-(benzo[d]thiazol-2-yl)-2-(1,4,5-trimethyl-1,3-dihydro-2H-imidazol-2-ylidene)acetonitrile (**5o**)

^1H NMR (300 MHz, $\text{DMSO-}d_6$)

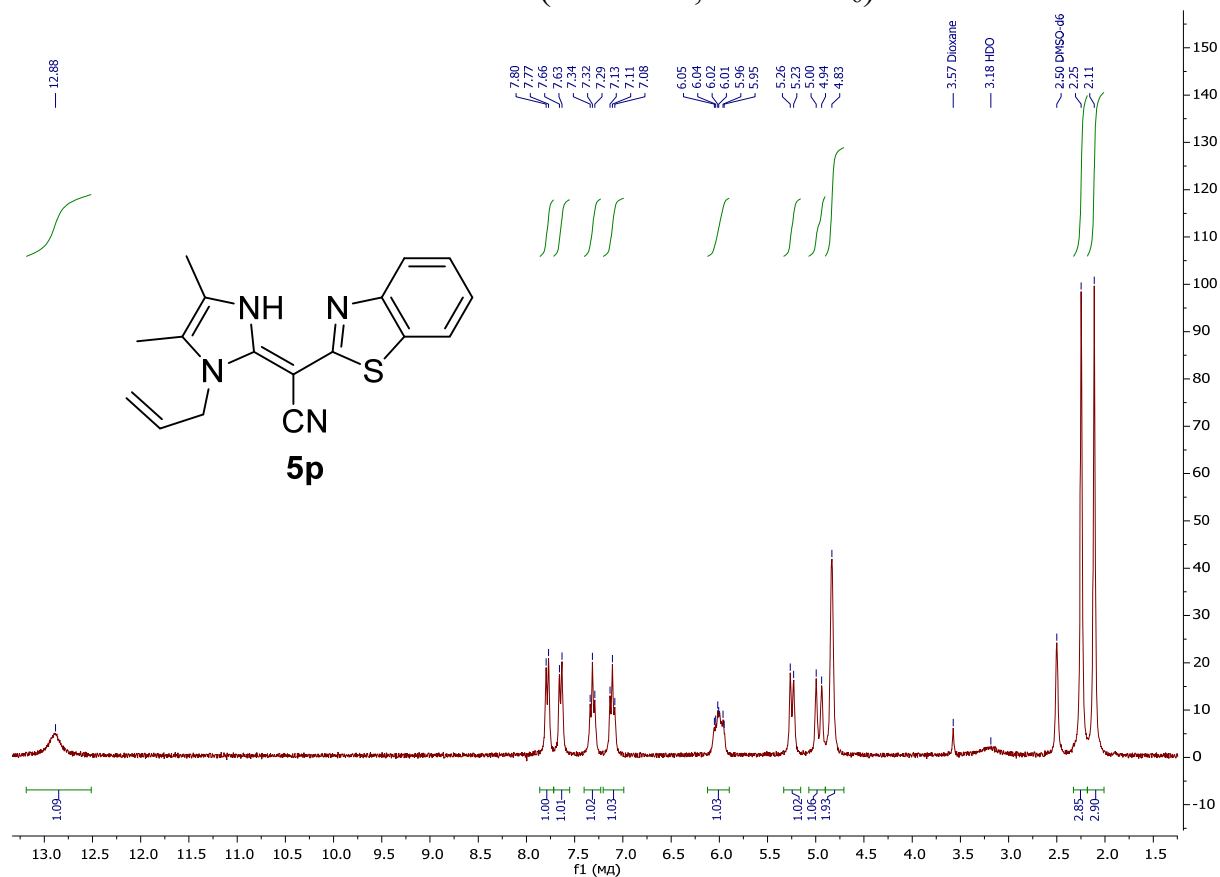


^{13}C NMR (75 MHz, $\text{DMSO-}d_6$)

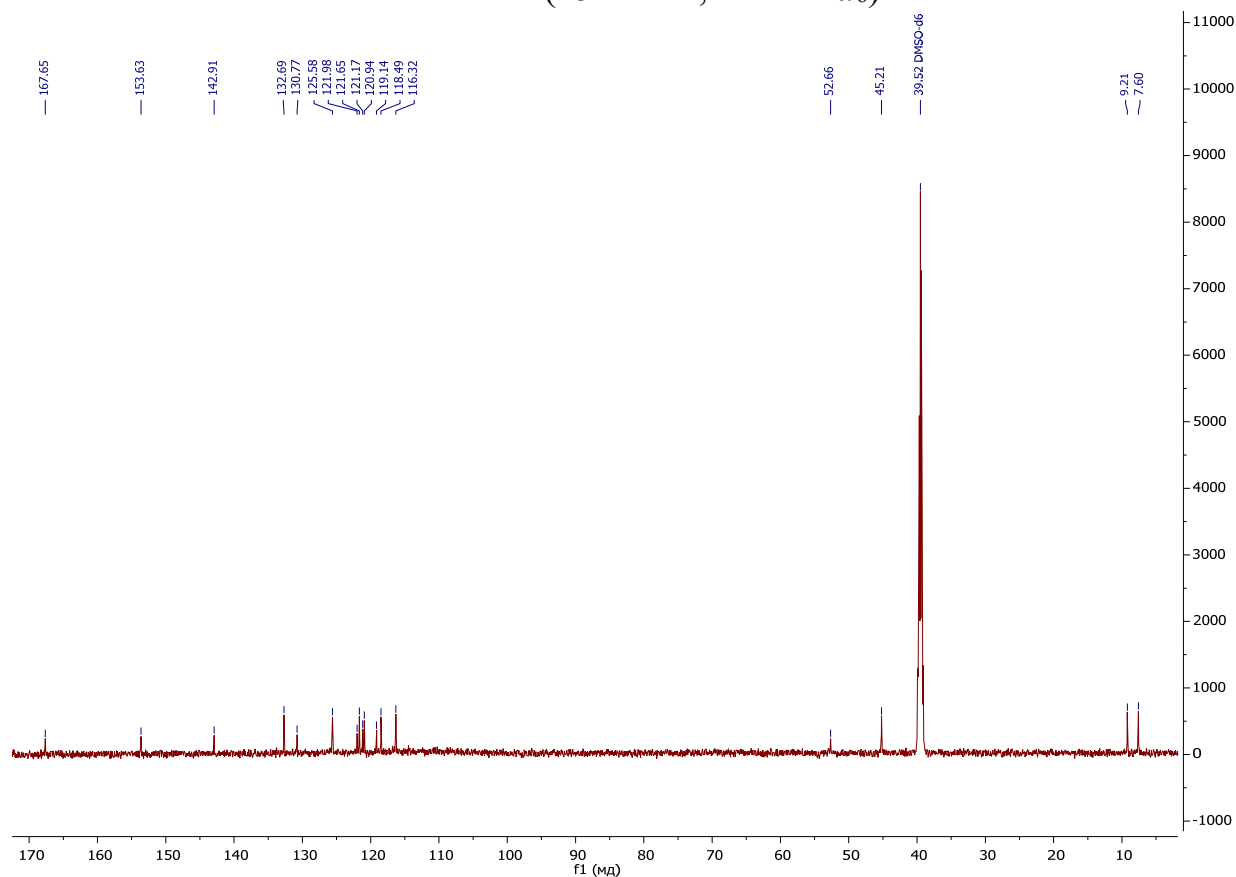


(*E*)-2-(1-allyl-4,5-dimethyl-1,3-dihydro-2H-imidazol-2-ylidene)-2-(benzo[d]thiazol-2-yl)acetonitrile (**5p**)

^1H NMR (300 MHz, $\text{DMSO-}d_6$)

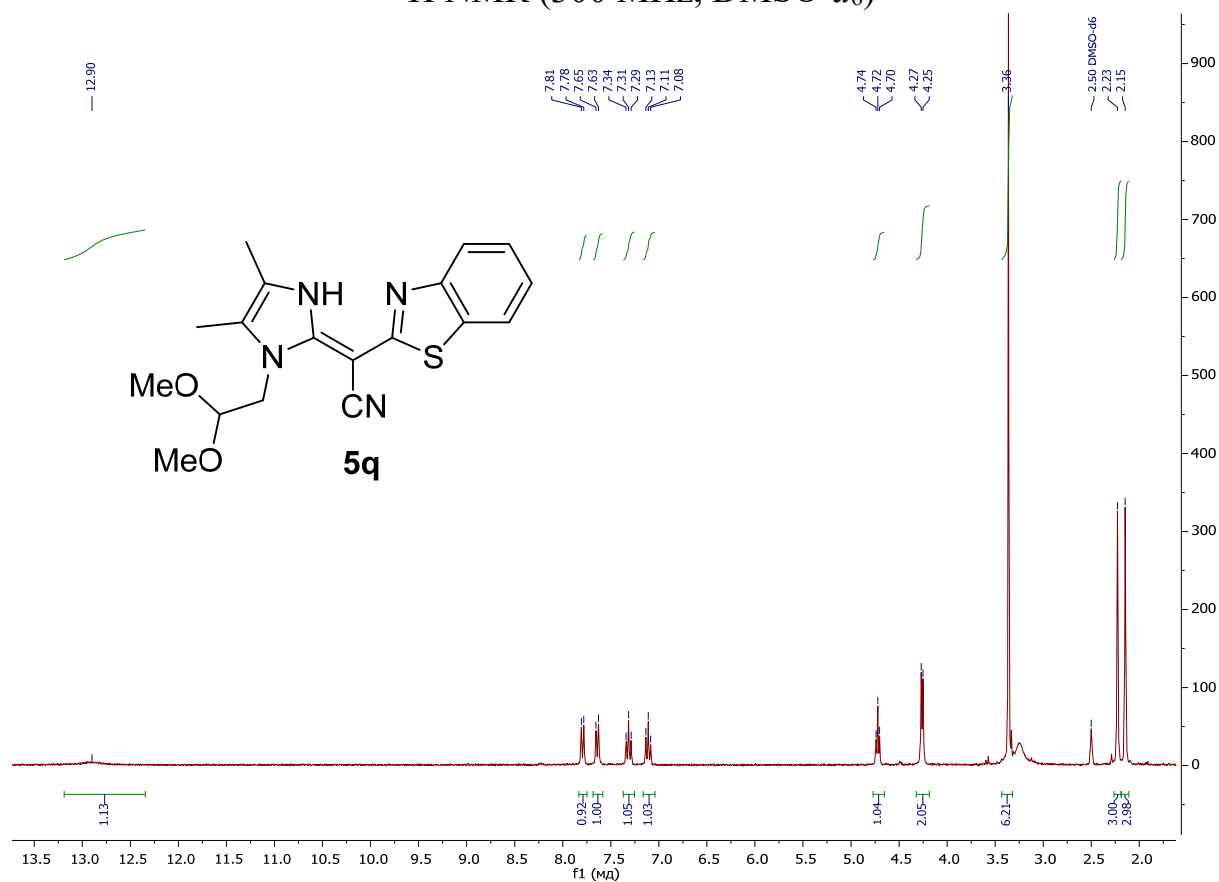


^{13}C NMR (151 MHz, $\text{DMSO-}d_6$)

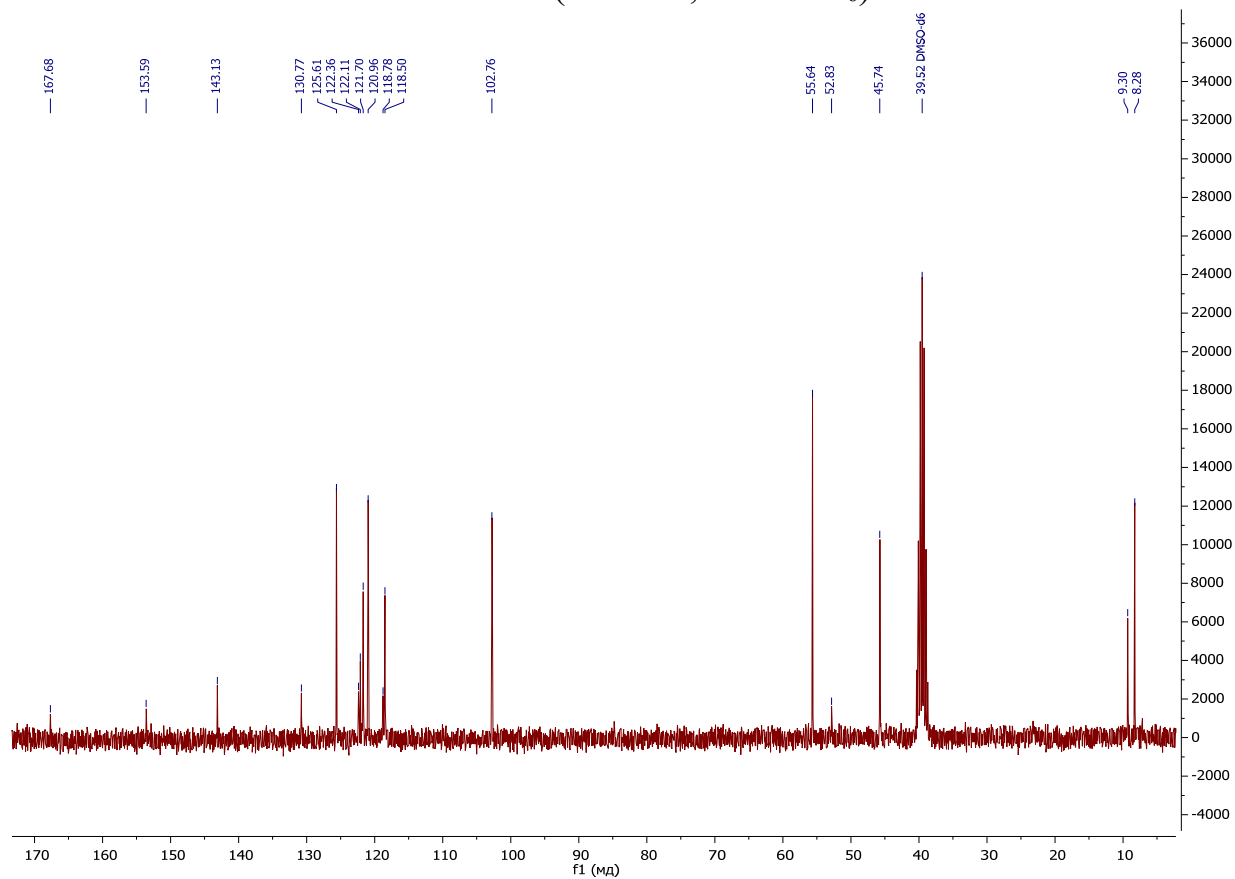


(*E*)-2-(benzo[d]thiazol-2-yl)-2-(1-(2,2-dimethoxyethyl)-4,5-dimethyl-1,3-dihydro-2H-imidazol-2-ylidene)acetonitrile (**5q**)

^1H NMR (300 MHz, $\text{DMSO-}d_6$)

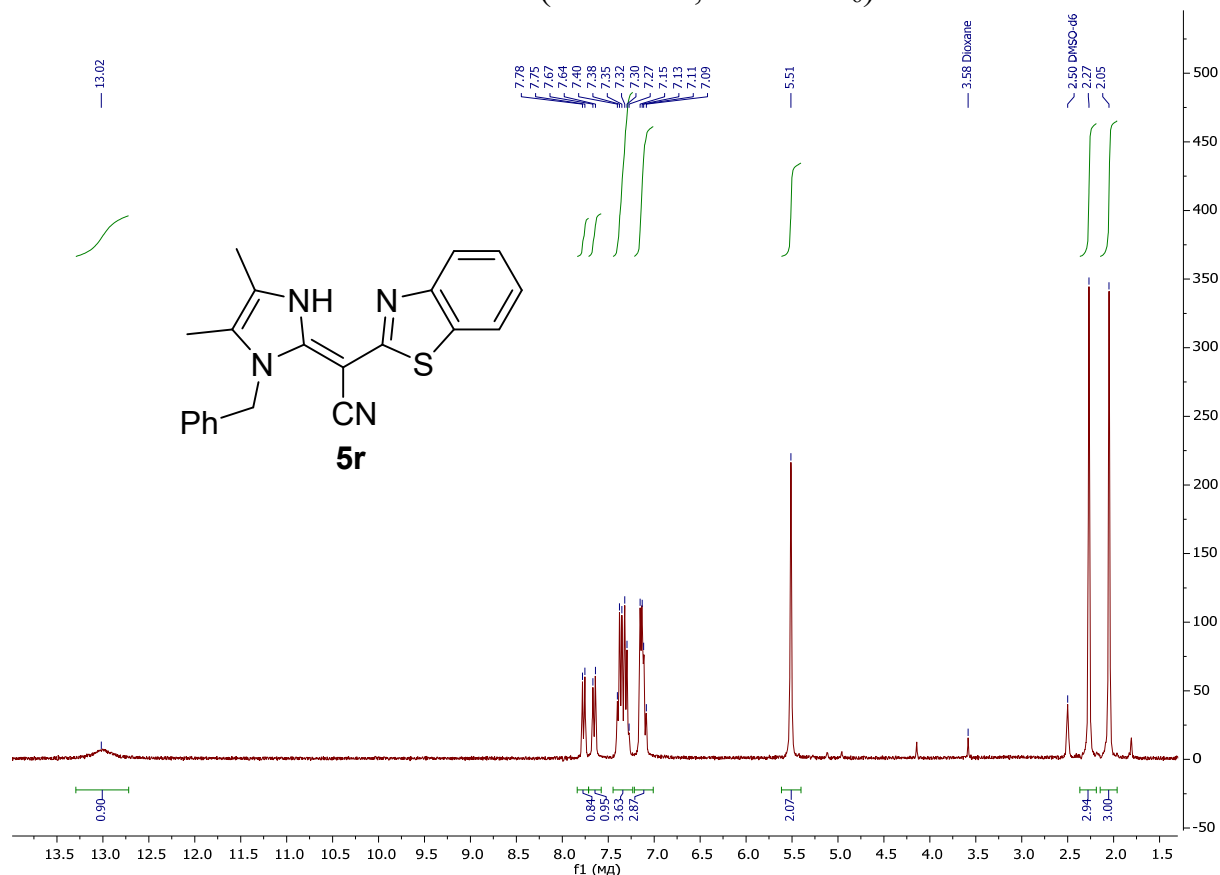


^{13}C NMR (75 MHz, $\text{DMSO-}d_6$)

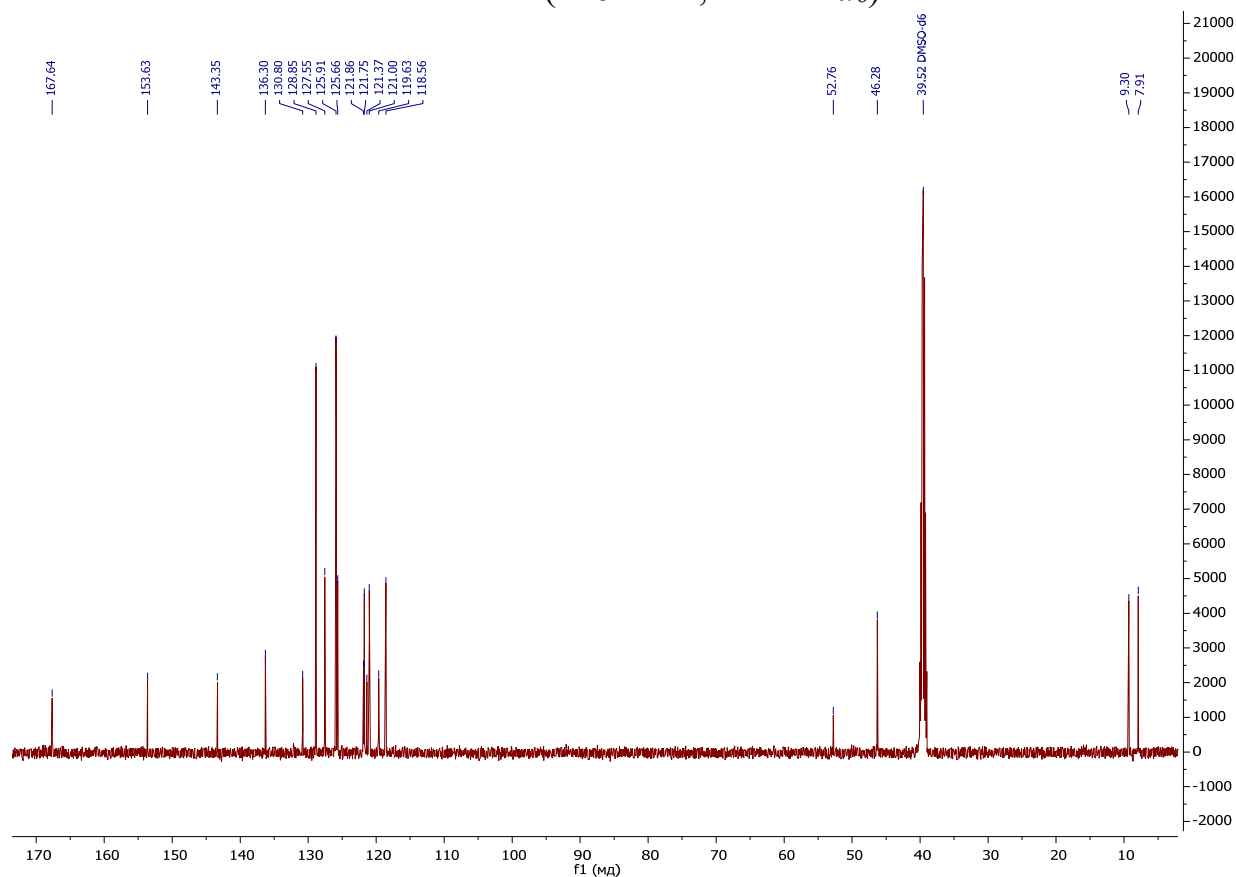


(*E*)-2-(benzo[d]thiazol-2-yl)-2-(1-benzyl-4,5-dimethyl-1,3-dihydro-2H-imidazol-2-ylidene)acetonitrile (**5r**)

^1H NMR (300 MHz, $\text{DMSO-}d_6$)

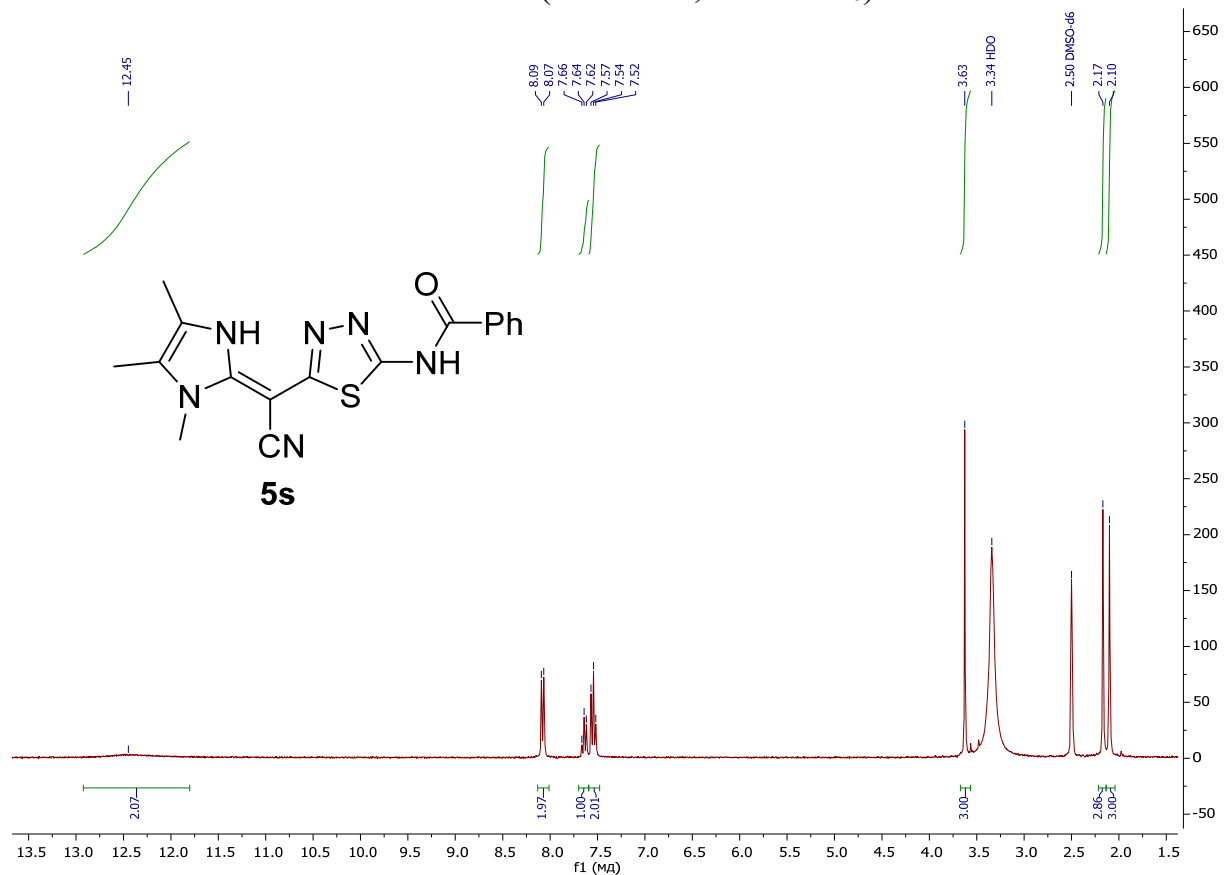


^{13}C NMR (126 MHz, $\text{DMSO-}d_6$)

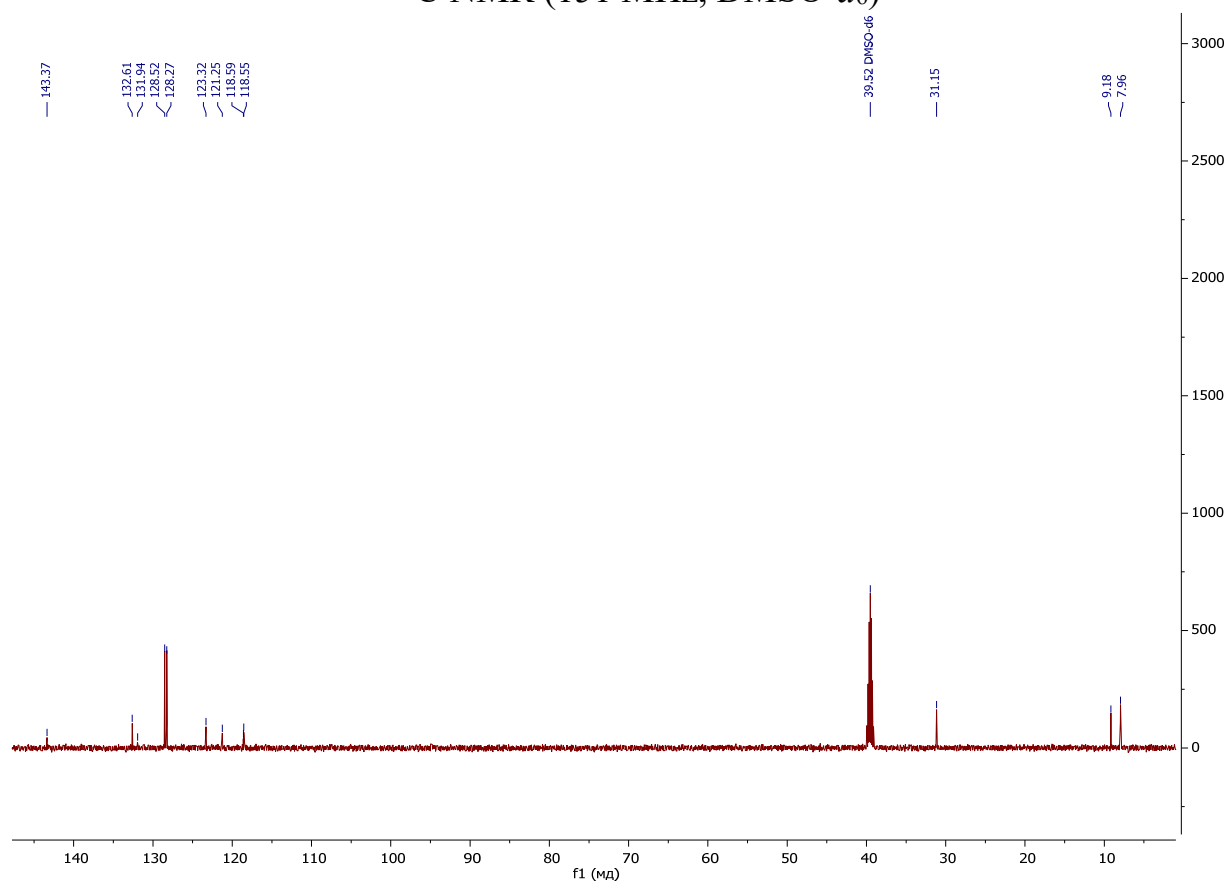


(*E*)-N-(5-(cyano(1,4,5-trimethyl-1,3-dihydro-2H-imidazol-2-ylidene)methyl)-1,3,4-thiadiazol-2-yl)benzamide (**5s**)

^1H NMR (300 MHz, $\text{DMSO-}d_6$)

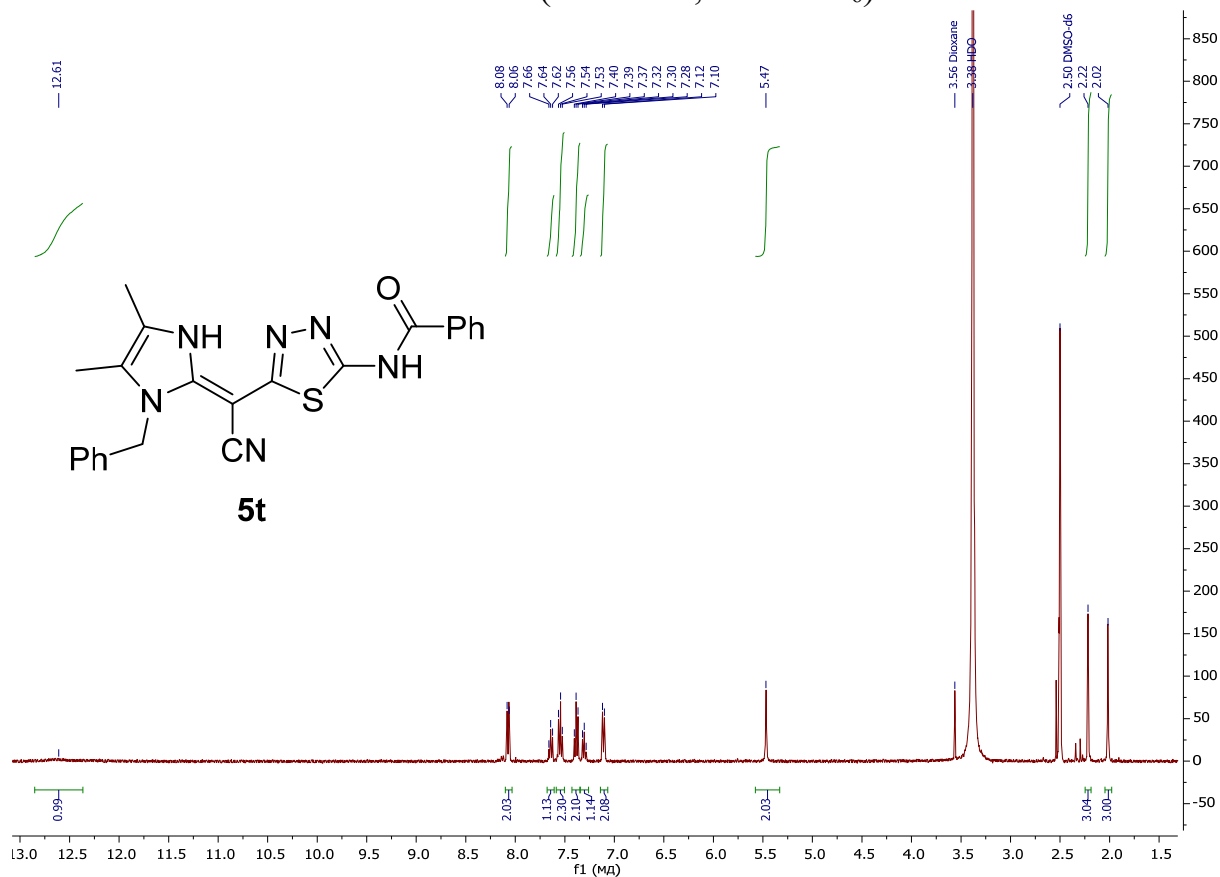


^{13}C NMR (151 MHz, $\text{DMSO-}d_6$)

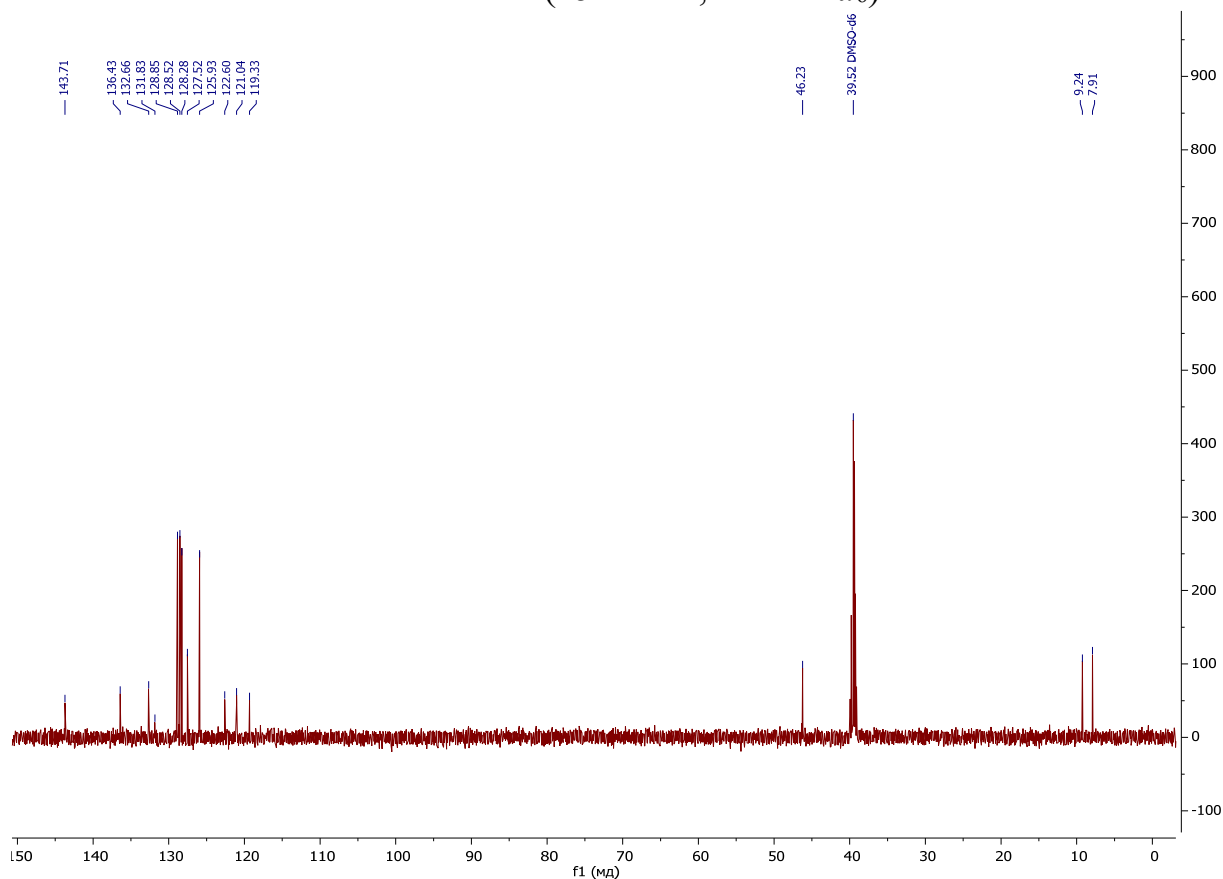


(*E*)-N-(5-((1-benzyl-4,5-dimethyl-1,3-dihydro-2H-imidazol-2-ylidene)(cyano)methyl)-1,3,4-thiadiazol-2-yl)benzamide (**5t**)

^1H NMR (300 MHz, $\text{DMSO-}d_6$)

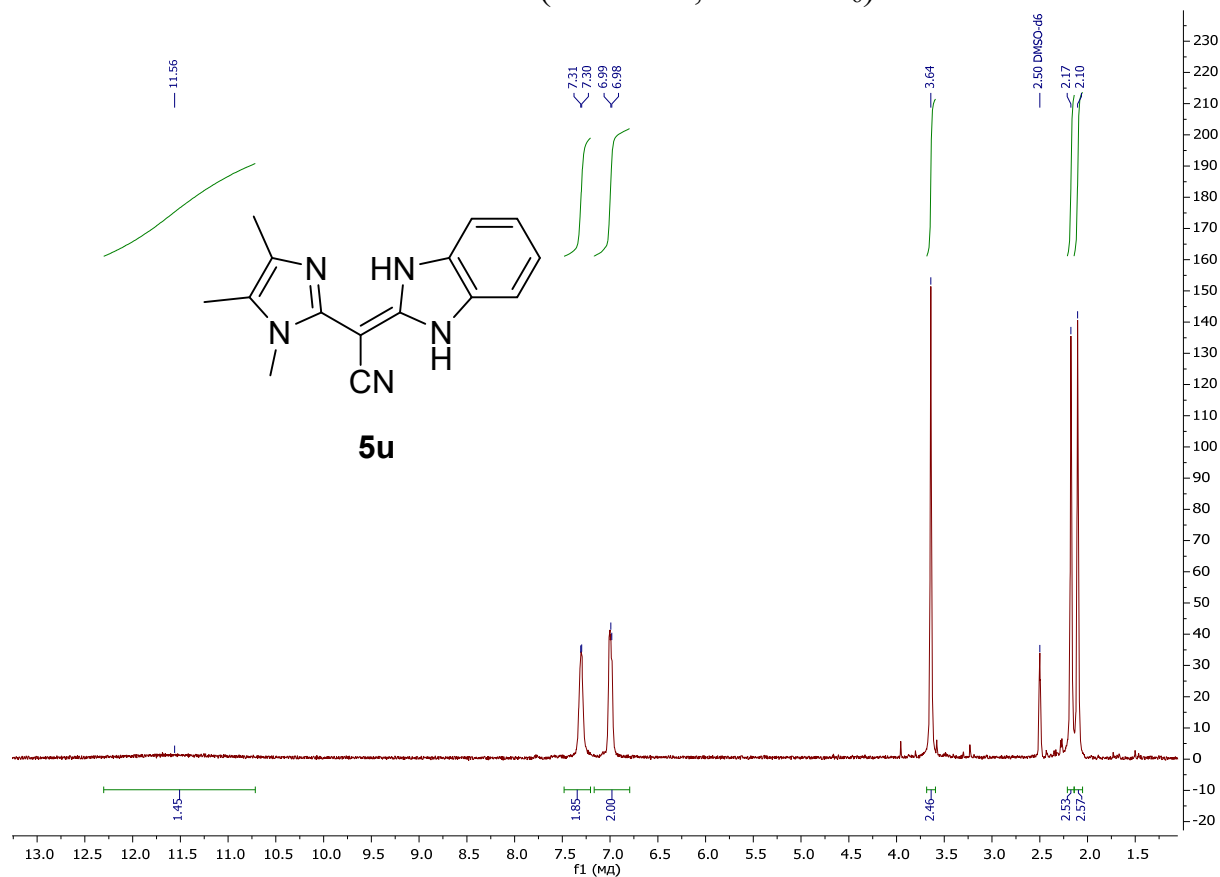


^{13}C NMR (151 MHz, $\text{DMSO-}d_6$)

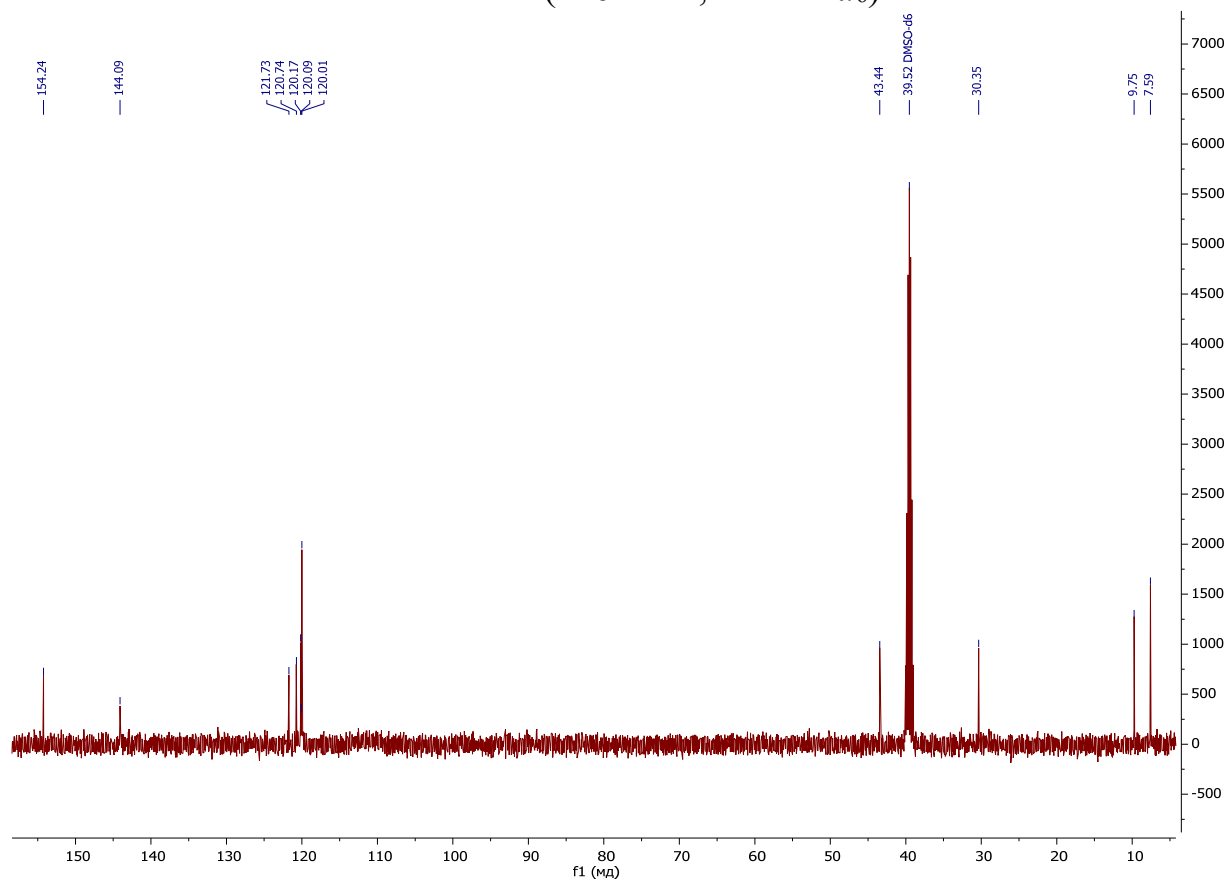


2-(1,3-Dihydro-2H-benzo[d]imidazol-2-ylidene)-2-(1,4,5-trimethyl-1H-imidazol-2-yl)acetonitrile (**5u**)

^1H NMR (300 MHz, $\text{DMSO-}d_6$)

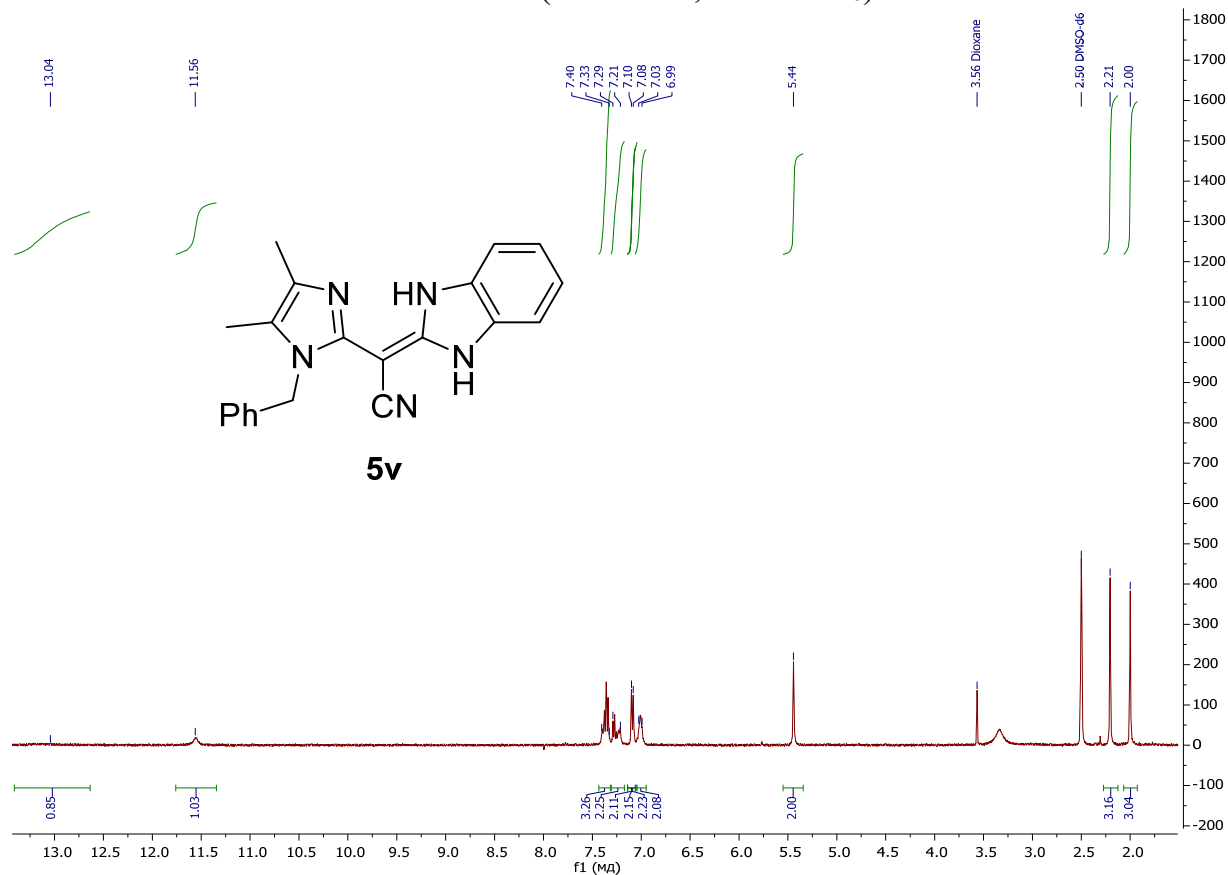


^{13}C NMR (126 MHz, $\text{DMSO-}d_6$)

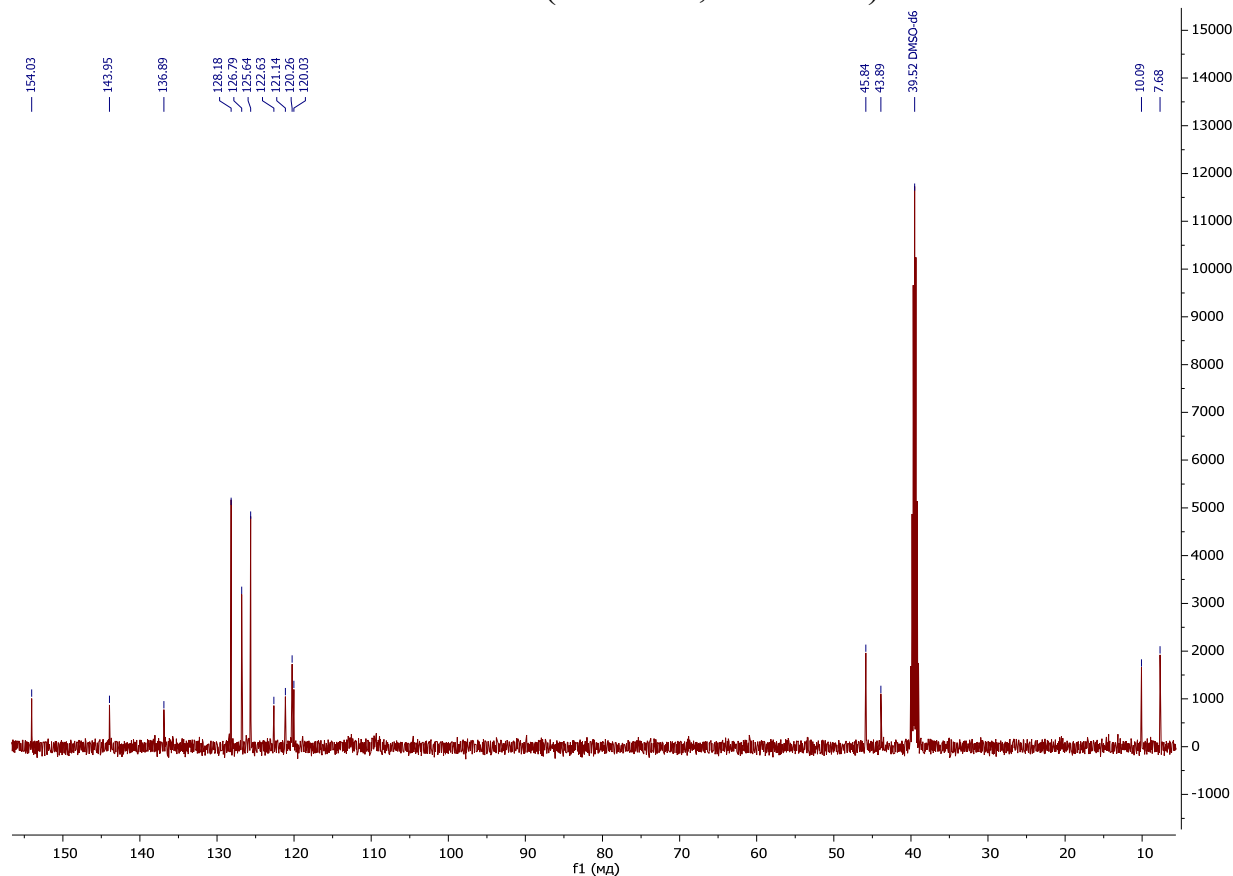


2-(1-Benzyl-4,5-dimethyl-1H-imidazol-2-yl)-2-(1,3-dihydro-2H-benzo[d]imidazol-2-ylidene)acetonitrile (**5v**)

^1H NMR (400 MHz, $\text{DMSO-}d_6$)

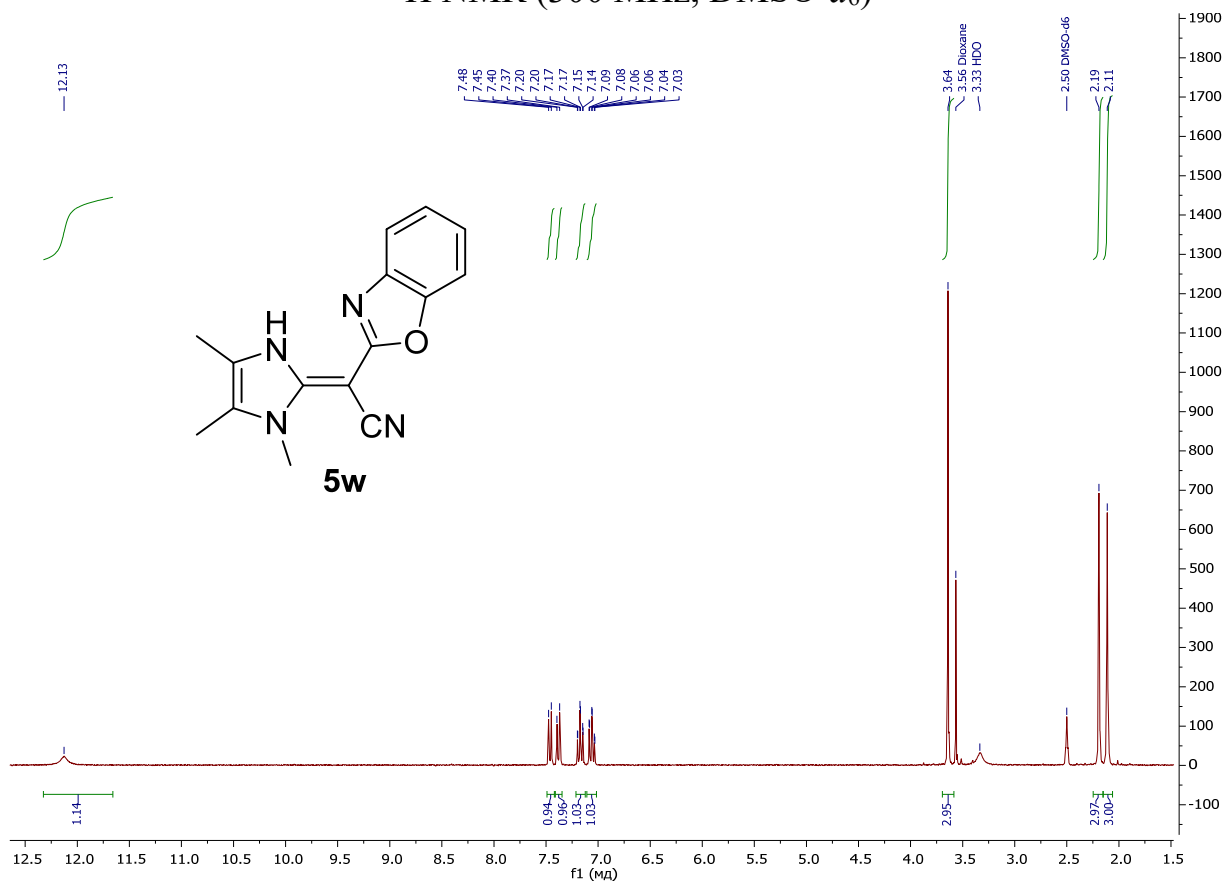


^{13}C NMR (126 MHz, $\text{DMSO-}d_6$)

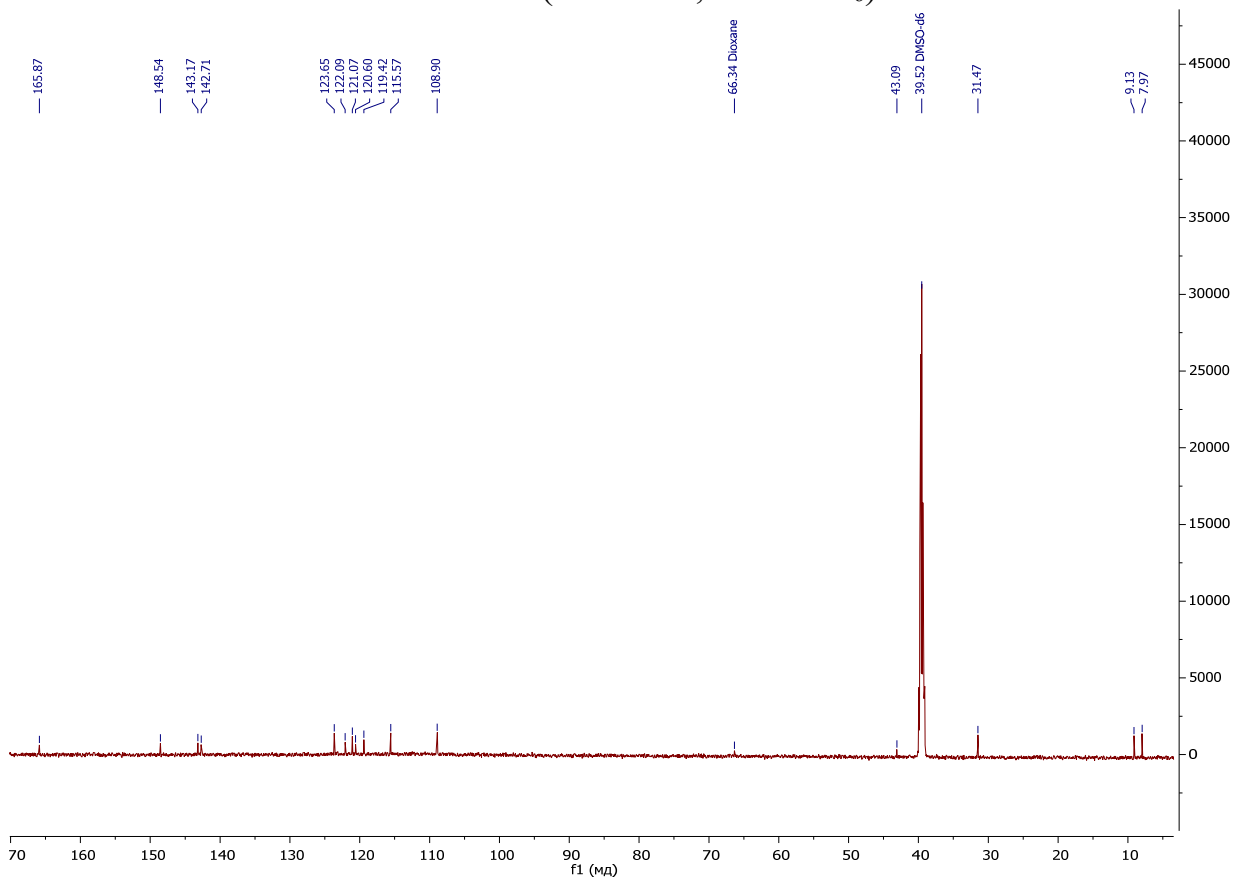


(*E*)-2-(benzo[d]oxazol-2-yl)-2-(1,4,5-trimethyl-1,3-dihydro-2H-imidazol-2-ylidene)acetonitrile (**5w**)

^1H NMR (300 MHz, $\text{DMSO-}d_6$)

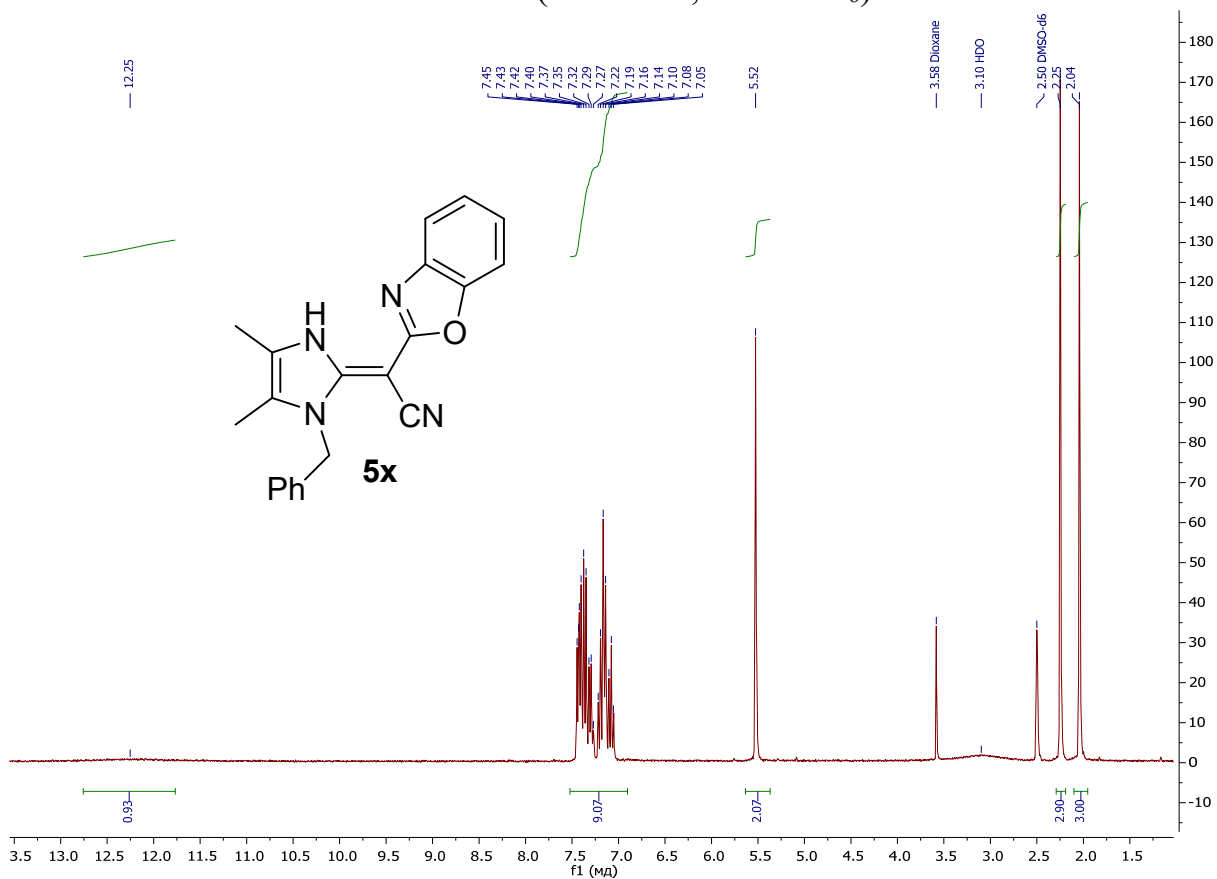


^{13}C NMR (151 MHz, $\text{DMSO-}d_6$)

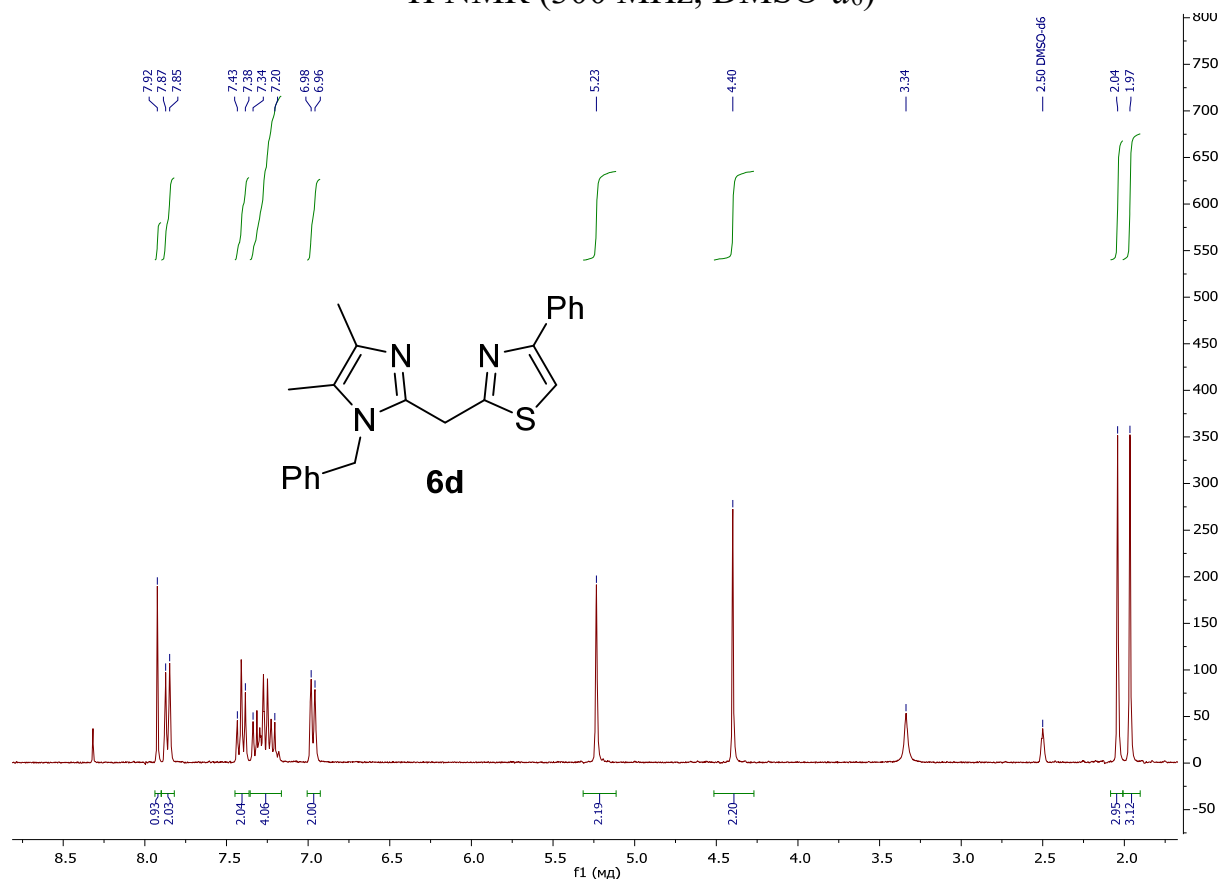


(*E*)-2-(benzo[d]oxazol-2-yl)-2-(1-benzyl-4,5-dimethyl-1,3-dihydro-2H-imidazol-2-ylidene)acetonitrile (**5x**)

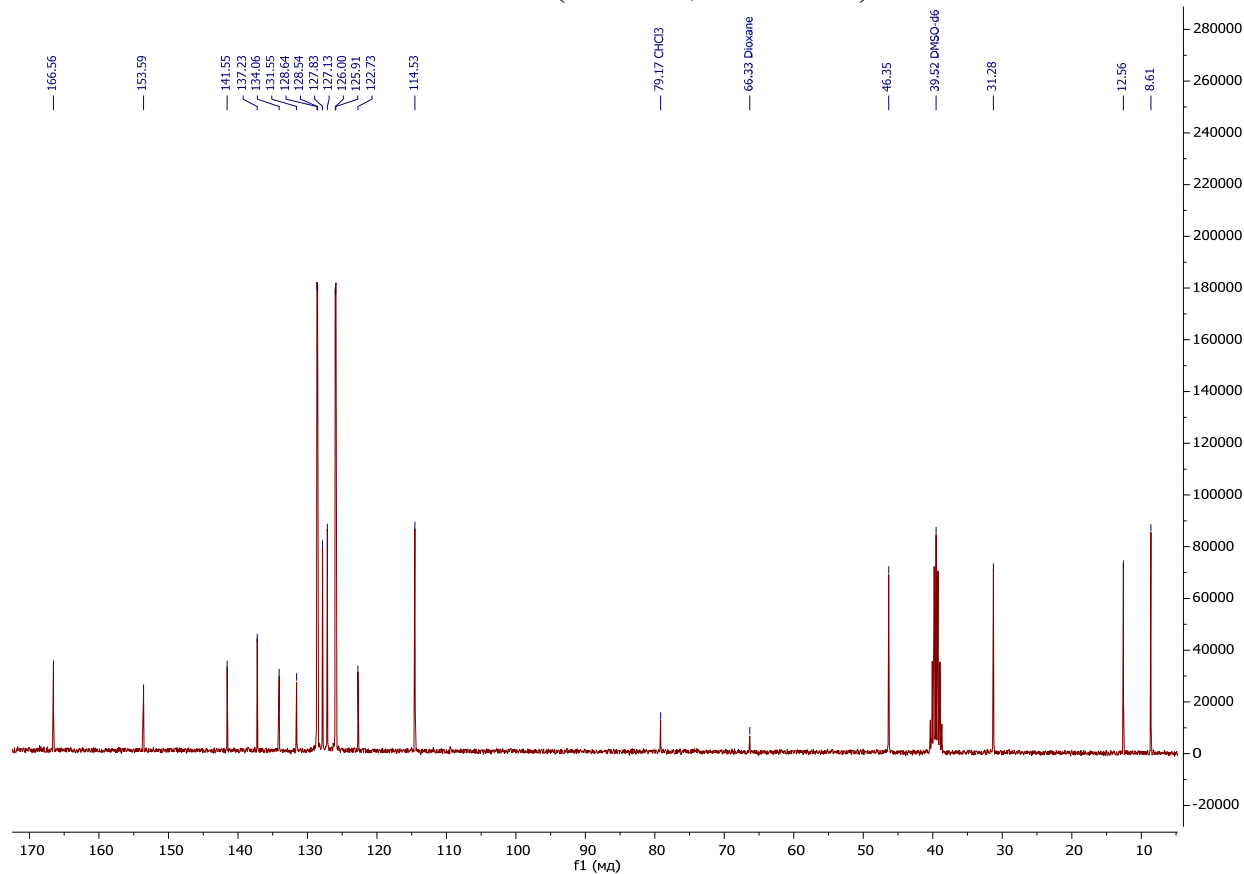
¹H NMR (300 MHz, DMSO-*d*₆)



2-((1-Benzyl-4,5-dimethyl-1H-imidazol-2-yl)methyl)-4-phenylthiazole (**6d**)
¹H NMR (300 MHz, DMSO-*d*₆)

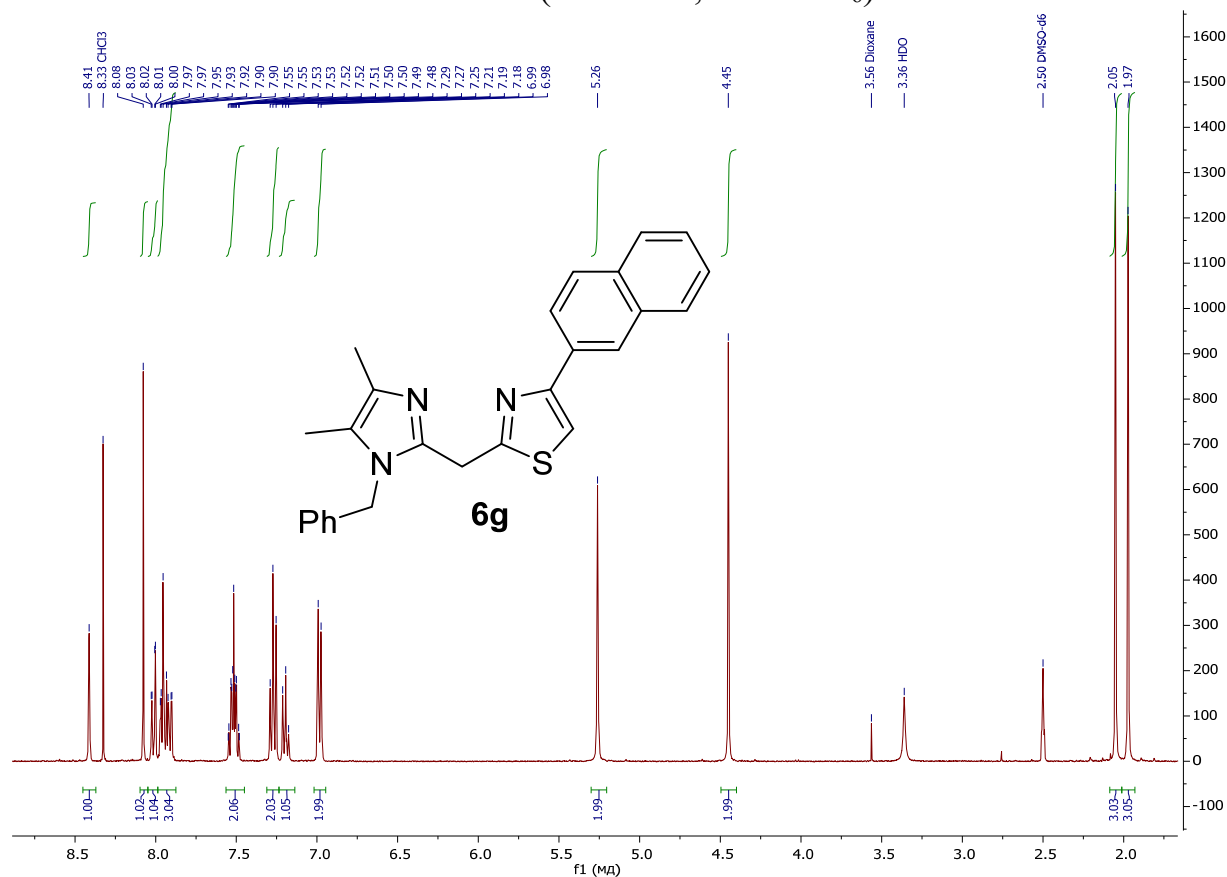


¹³C NMR (75 MHz, DMSO-*d*₆)

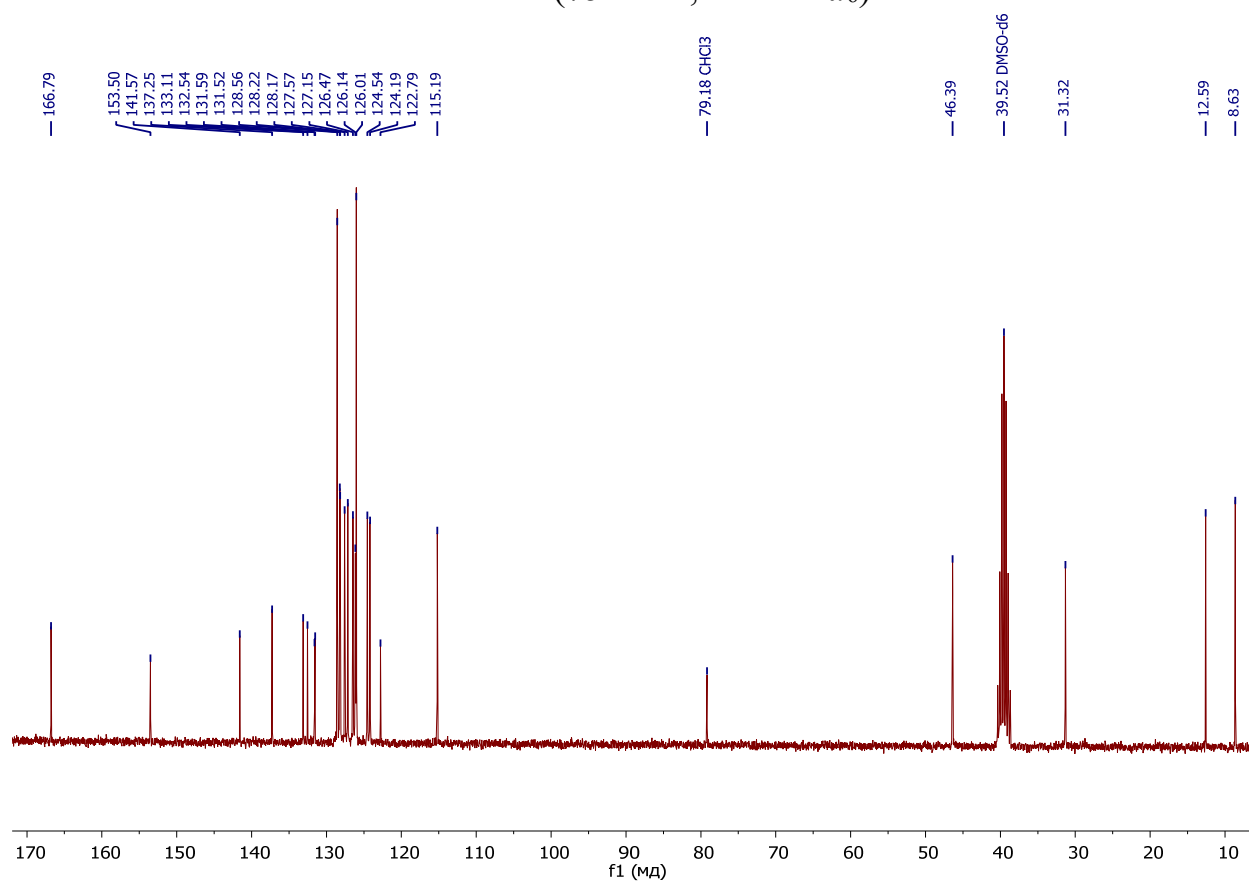


2-((1-Benzyl-4,5-dimethyl-1H-imidazol-2-yl)methyl)-4-(naphthalen-2-yl)thiazole (6g)

¹H NMR (400 MHz, DMSO-d₆)

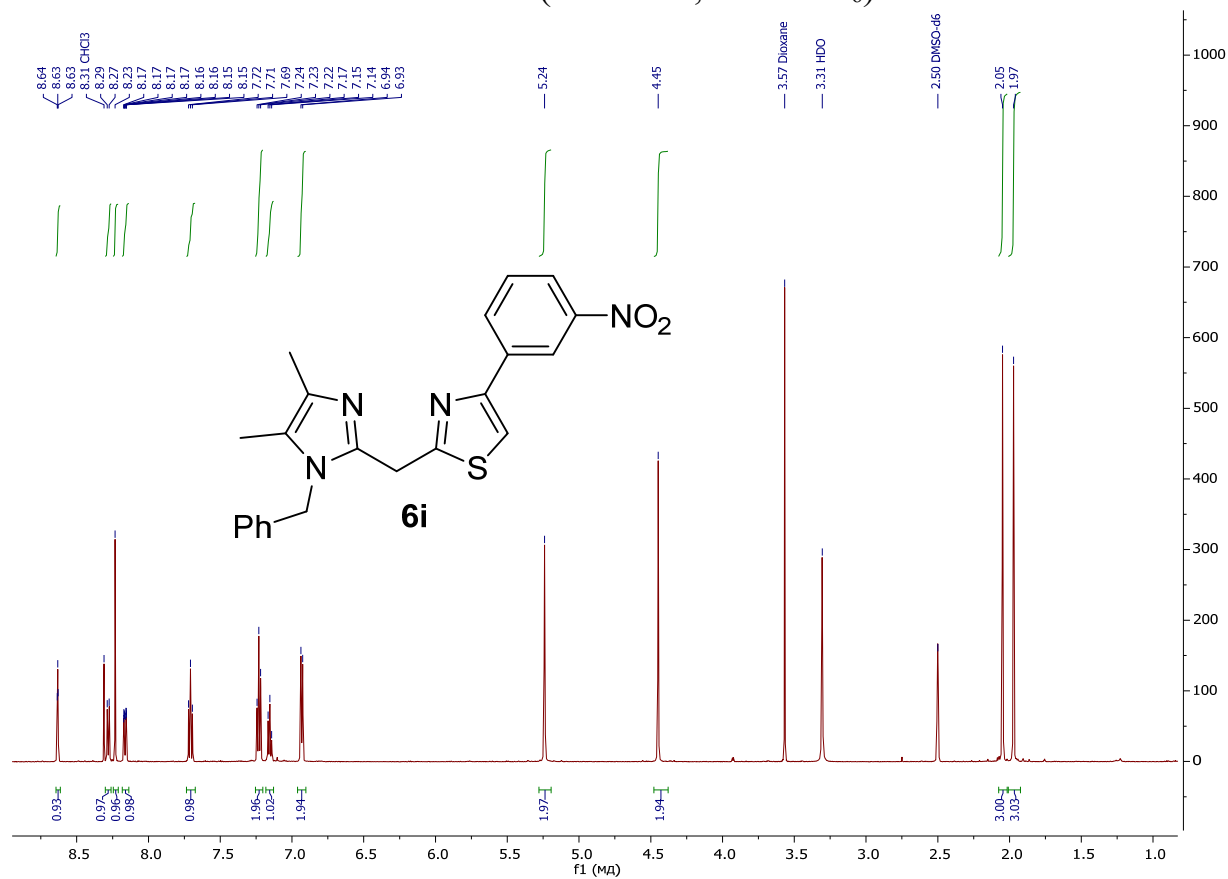


¹³C NMR (75 MHz, DMSO-d₆)

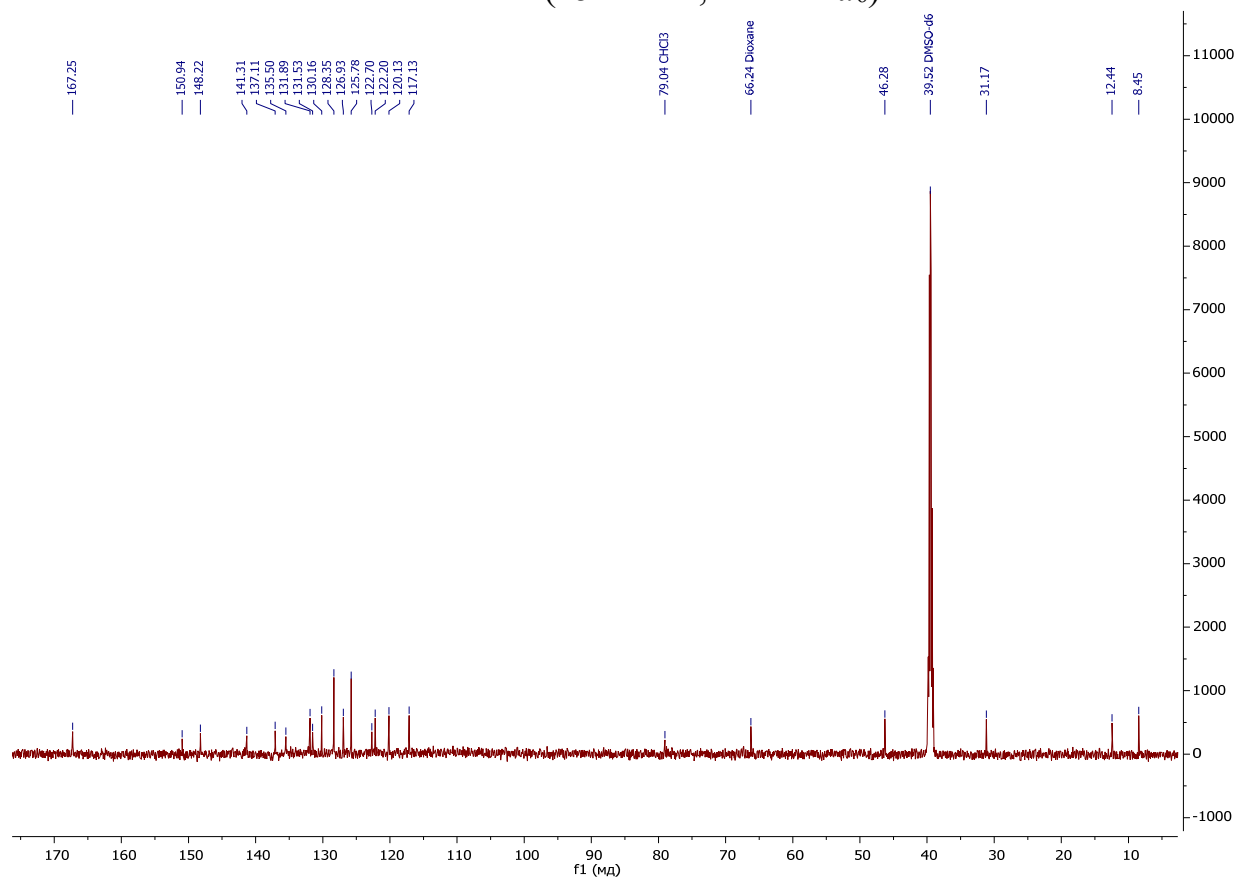


2-((1-Benzyl-4,5-dimethyl-1H-imidazol-2-yl)methyl)-4-(3-nitrophenyl)thiazole (6i)

$^1\text{H NMR}$ (600 MHz, $\text{DMSO-}d_6$)

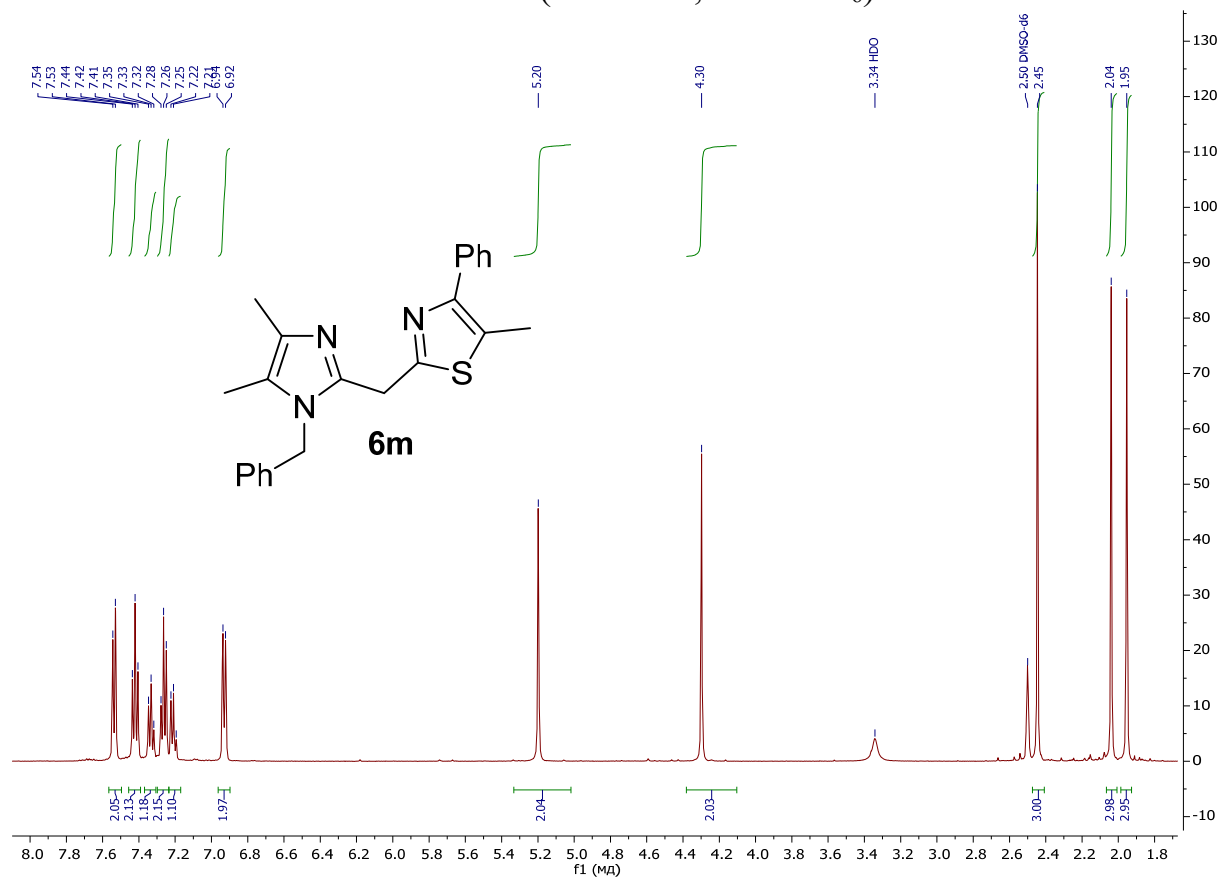


$^{13}\text{C NMR}$ (151 MHz, $\text{DMSO-}d_6$)

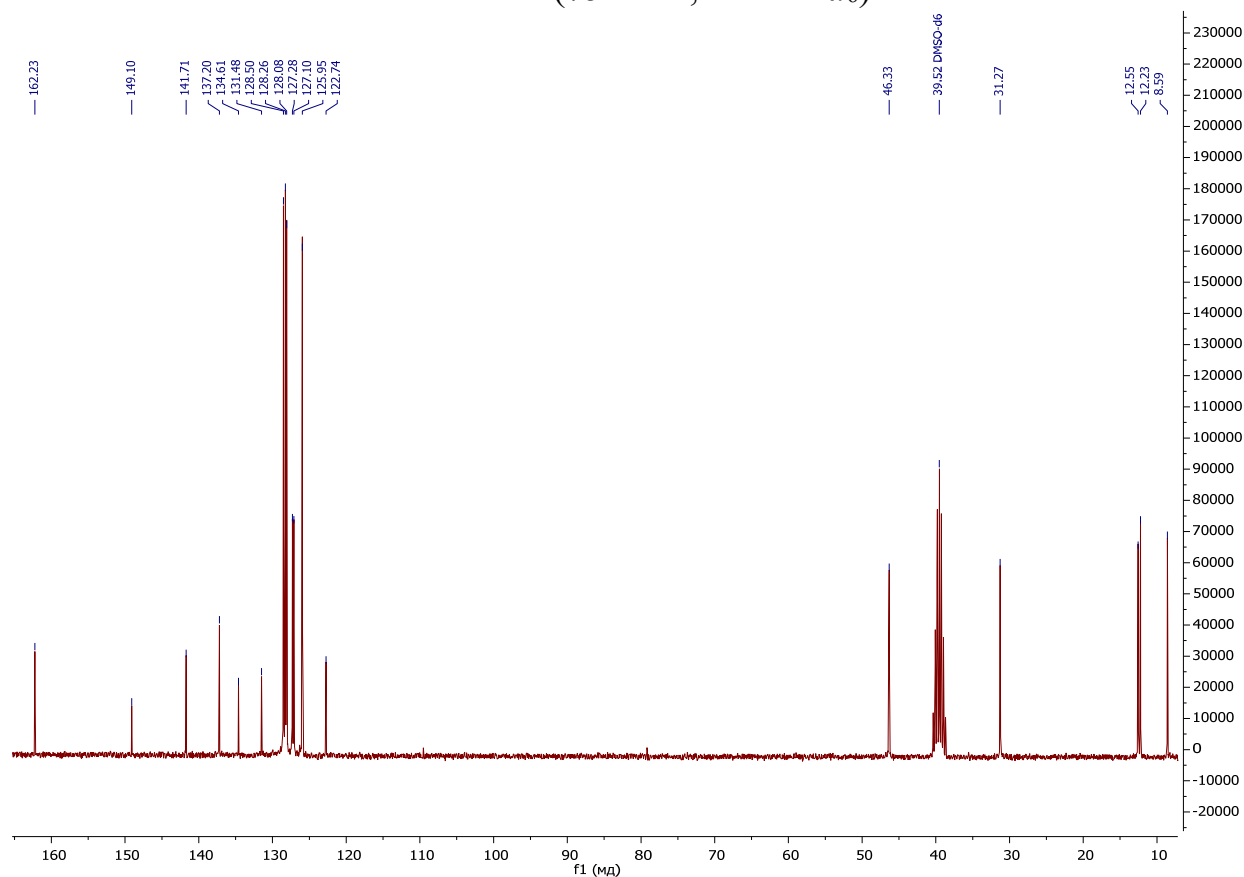


2-((1-Benzyl-4,5-dimethyl-1H-imidazol-2-yl)methyl)-5-methyl-4-phenylthiazole
(6m)

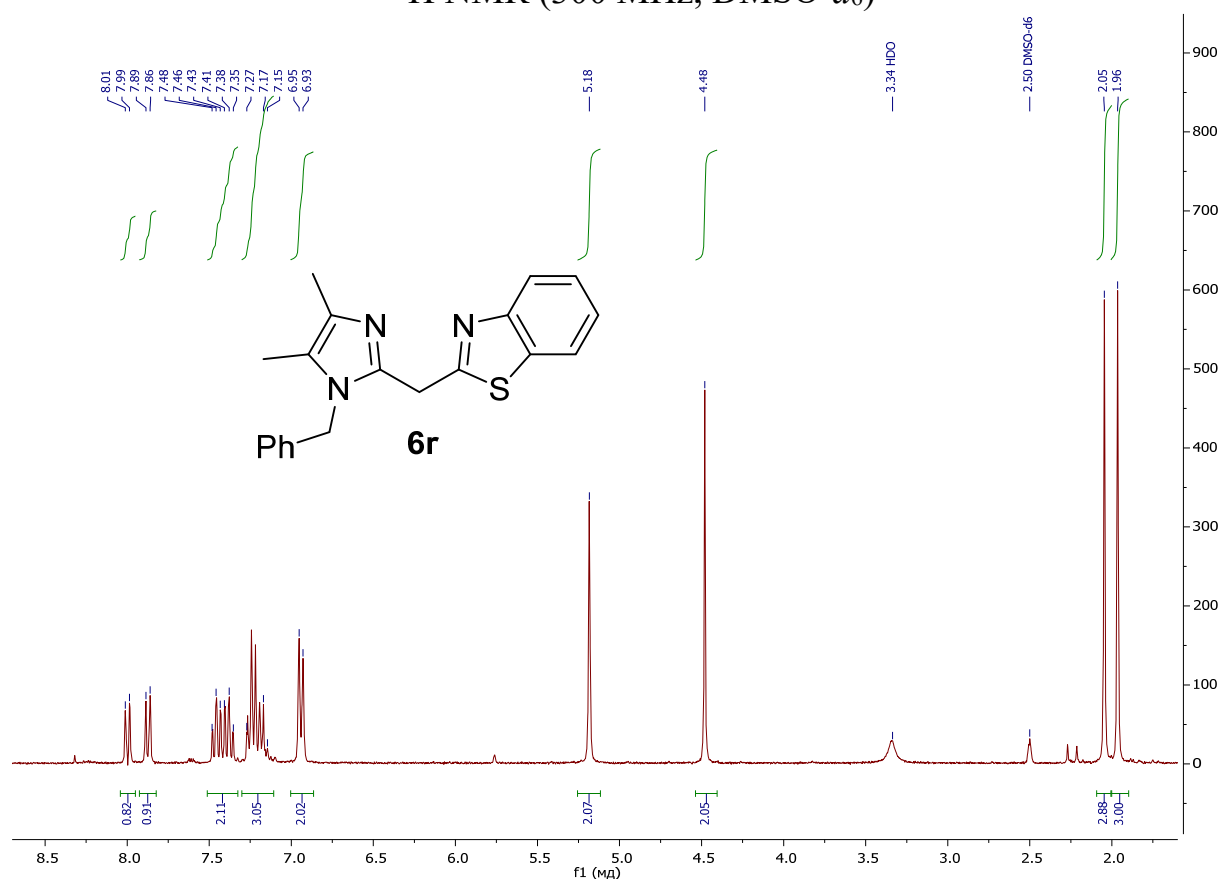
^1H NMR (500 MHz, $\text{DMSO-}d_6$)



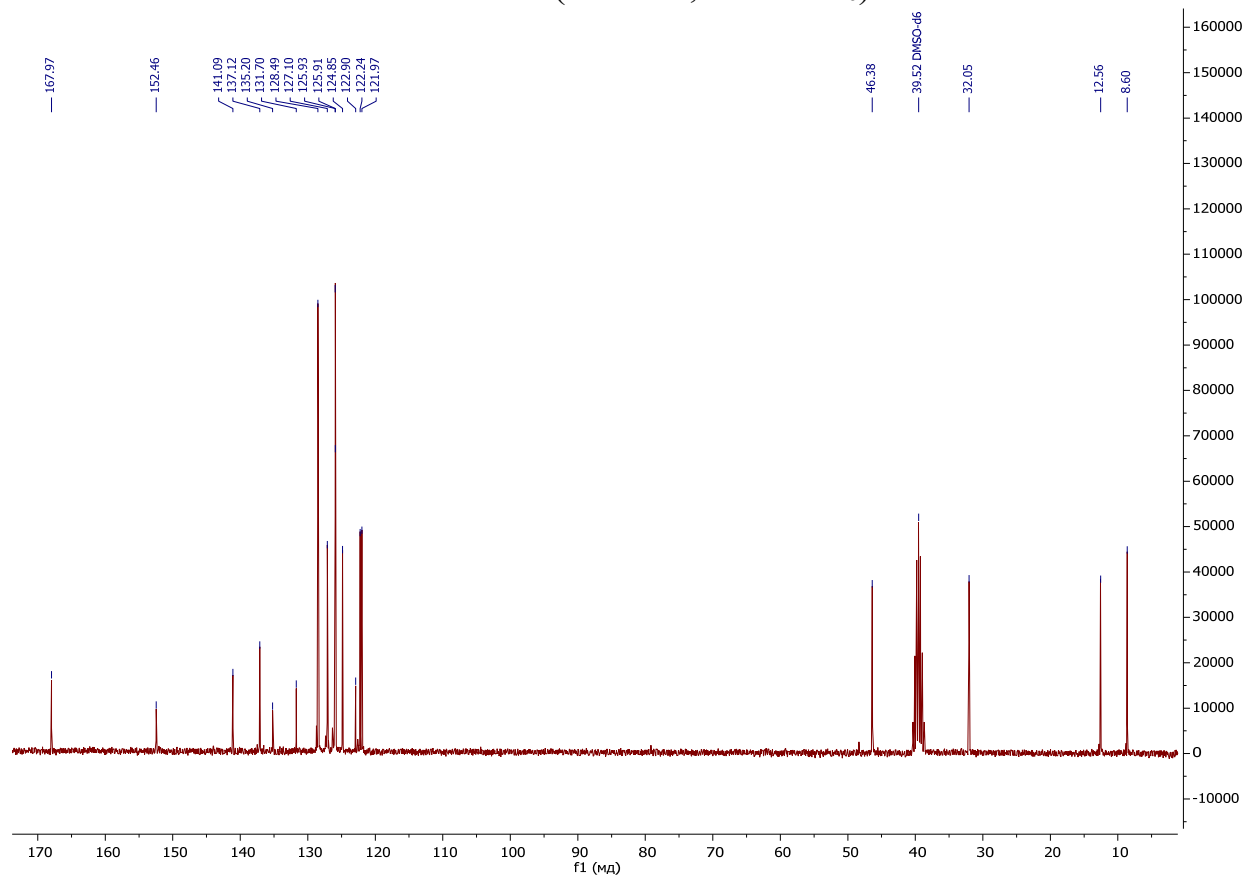
^{13}C NMR (75 MHz, $\text{DMSO-}d_6$)



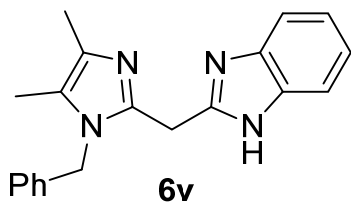
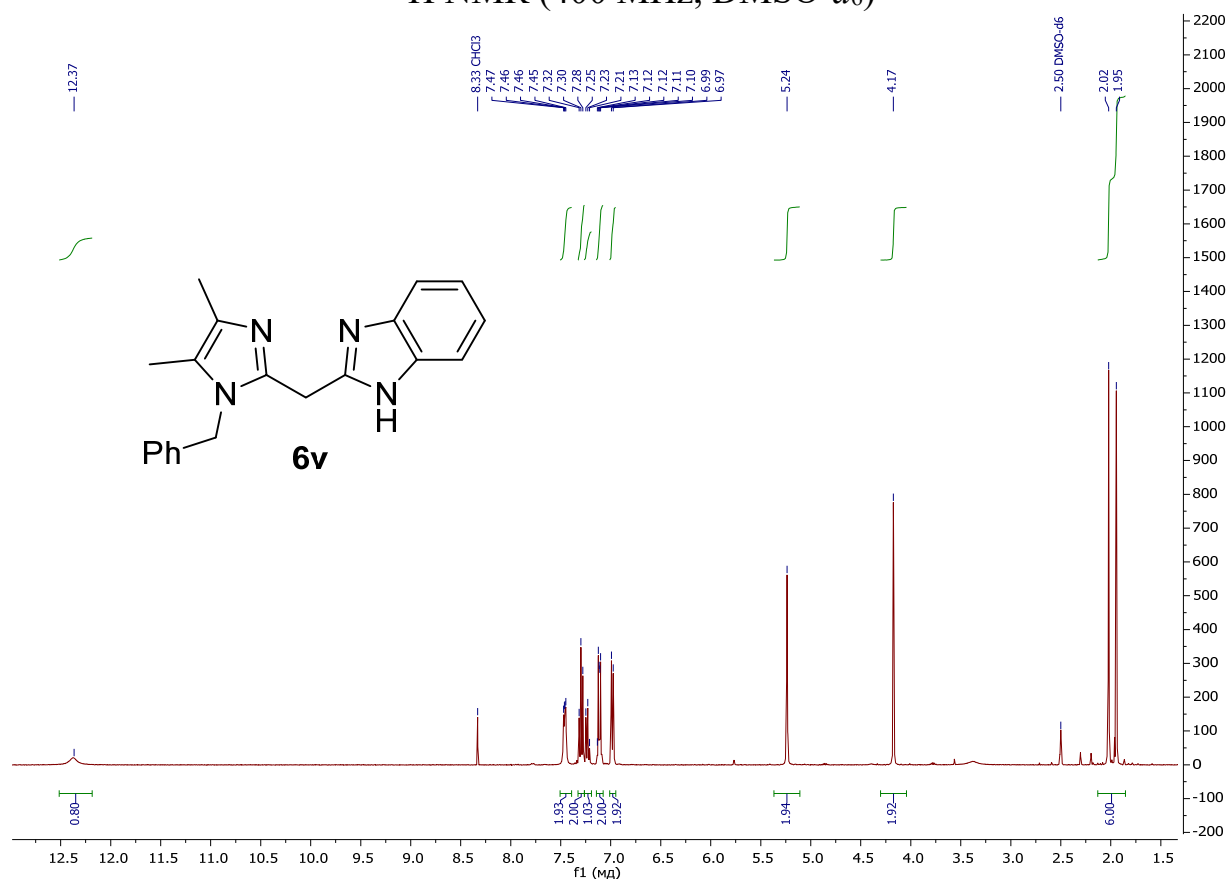
2-((1-Benzyl-4,5-dimethyl-1H-imidazol-2-yl)methyl)benzo[d]thiazole (**6r**)
¹H NMR (300 MHz, DMSO-*d*₆)



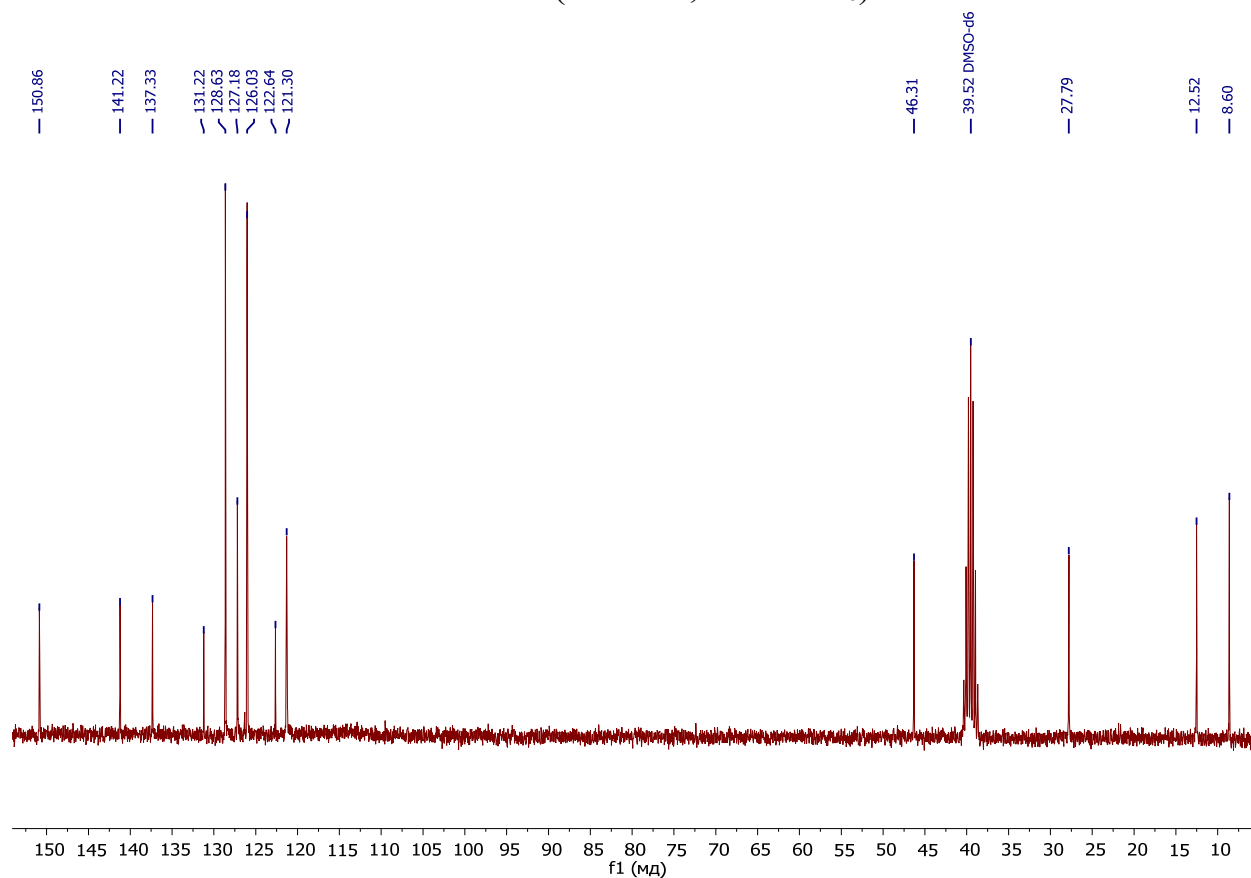
¹³C NMR (75 MHz, DMSO-*d*₆)



2-((1-Benzyl-4,5-dimethyl-1H-imidazol-2-yl)methyl)-1H-benzo[d]imidazole (**6v**)
¹H NMR (400 MHz, DMSO-*d*₆)



¹³C NMR (75 MHz, DMSO-*d*₆)



X-ray diffraction data

Single crystals of **5e** and **5o** were grown from DMF. Data collection for samples **5e** and **5o** were performed on a Bruker SMART APEX II diffractometer equipped with a Photon-II area-detector and a graphite monochromator for MoK α radiation ($\lambda = 0.71073 \text{ \AA}$, phi and omega scans). Frames were integrated using the Bruker SAINT software package^[1] by a narrow-frame algorithm. A semiempirical absorption correction was applied with the SADABS^[2] program using the intensity data of equivalent reflections. The structures were solved with a dual-space method with SHELXT program^[3] and refined by the full-matrix least-squares technique against F^2_{hkl} in anisotropic approximation for non-hydrogen atoms with SHELXL^[4] program. Hydrogen atoms connected to nitrogen atoms were found from difference Fourier synthesis and refined isotropically. Other H atoms were placed in calculated positions and refined in the riding model with $U_{\text{iso}}(\text{H}) = 1.5U_{\text{eq}}(\text{C}_m)$ for methyl groups and $1.2U_{\text{eq}}(\text{C}_i)$ for other carbon atoms to which corresponding H atoms are bonded.

Detailed crystallographic information is given in Table S1. Deposition Numbers 2093521-2093522 contain the supplementary crystallographic data for this paper. These data are provided free of charge by the joint Cambridge Crystallographic Data Centre and Fachinformationszentrum Karlsruhe Access Structures service www.ccdc.cam.ac.uk/structures.

1. Bruker, SAINT v8.40B, 2019.
2. Krause, L.; Herbst-Irmer, R.; Sheldrick, G. M.; Stalke, D. Comparison of silver and molybdenum microfocus X-ray sources for single-crystal structure determination. *J. Appl. Cryst.* **2015**, 48, 3–10.
<http://doi.org/10.1107/S1600576714022985>
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<http://doi.org/10.1107/S2053273314026370>
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<http://doi.org/10.1107/S2053229614024218>

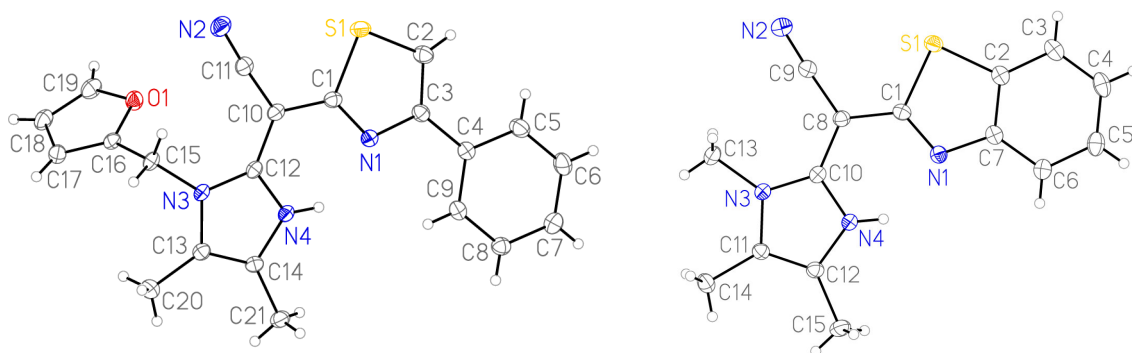


Figure S1. General view of crystal structures of **5e** and **5o** in thermal ellipsoid representation for non-hydrogen atoms ($p=50\%$).

Table S1. Crystal data and structure refinement for **5e** and **5o**.

	5e	5o
CCDC number	2093522	2093521
Empirical formula	$C_{21}H_{18}N_4OS$	$C_{15}H_{14}N_4S$
Formula weight	374.45	282.36
T, K	120	120
Crystal dimensions, mm	$0.26 \times 0.20 \times 0.18$	$0.30 \times 0.21 \times 0.17$
Crystal system	Monoclinic	Monoclinic
Space group	$P2_1/n$	$P2_1/n$
Z / Z'	4 / 1	4 / 1
a , Å	12.1703(4)	8.3093(4)
b , Å	8.7069(3)	7.7536(3)
c , Å	17.7917(6)	21.1019(9)
β , °	104.923(2)	94.235(2)
V , Å ³	1821.72(11)	1355.82(10)
d_{calc} , g cm ⁻³	1.365	1.383
μ , cm ⁻¹	1.97	2.34
$2\theta_{\text{max}}$, °	61.05	61.05
Refls collected	24031	17592
Independent refls [R_{int}]	5572 [0.0385]	4117 [0.0257]
Observed reflections [$I > 2\sigma(I)$]	4240	3525
Parameters	250	188
$R1$	0.0386	0.0341
$wR2$	0.1076	0.1001
GOF	1.038	1.030
Residual density, $\Delta\rho_{\text{max}} / \Delta\rho_{\text{min}}$ (e Å ⁻³)	0.312/-0.336	0.381/-0.369