Electronic supplementary information (ESI)

Synthesis and antitumor activity of novel N-substituted tetrahydro-β-carboline–imidazolium salt derivatives

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TABLE OF CONTENTS

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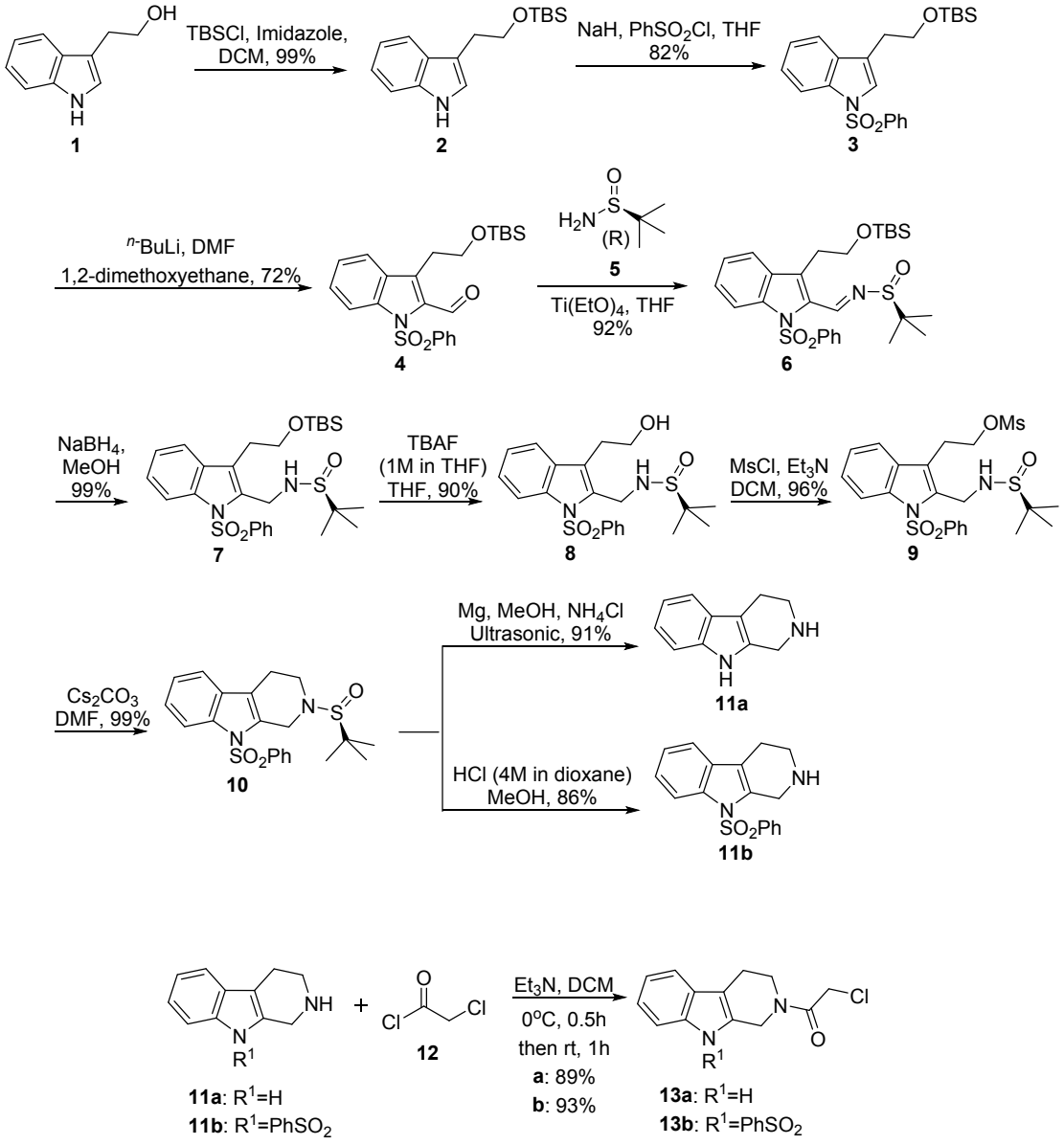
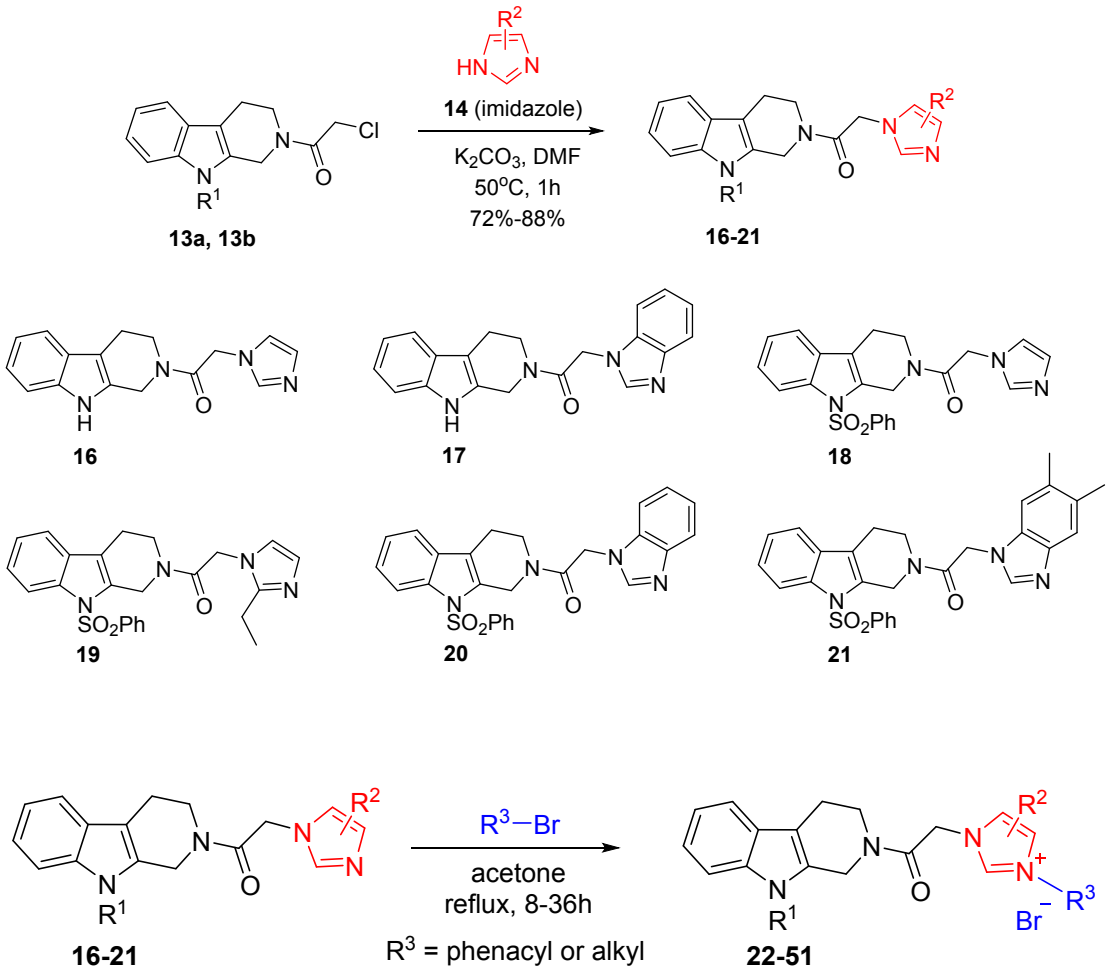
1. General Experimental

Melting points were obtained on a XT-4 melting-point apparatus and were uncorrected. Proton nuclear magnetic resonance (^{1}H-NMR) spectra were recorded on a Bruker Avance 400 (600) spectrometer at 400 (600) MHz. Carbon-13 nuclear magnetic resonance (^{13}C-NMR) was recorded on Bruker Avance 400 (400) spectrometer at 100 (120) MHz. Chemical shifts are reported as δ values in parts per million (ppm) relative to tetramethylsilane (TMS) for all recorded NMR spectra. Low-resolution Mass spectra were recorded on a VG Auto Spec-3000 magnetic sector MS spectrometer. High Resolution Mass spectra were taken on AB QSTAR Pulsar mass spectrometer. Elemental analysis (%CHN) was conducted on a Vario EL Ⅲ spectrometer.

Silica gel (200–300 mesh) for column chromatography and silica GF_{254} for TLC were produced by Qingdao Marine Chemical Company (China). All air- or moisture-sensitive reactions were conducted under an argon atmosphere. Starting materials and reagents used in reactions were obtained commercially from Acros, Aldrich, Fluka and were used without purification, unless otherwise indicated.

2. Experimental Procedures and Analytical Data





Synthesis of hybrid compounds **16-51**.

Entry	Compound No.	R^1	Imidazole ring	R^3	Molecular formula	mp (°C)	Yields (%)
1	**16**	H	imidazole	–	$C_{16}H_{16}N_4O$	85-86	85
2	**17**	H	benzimidazole	–	$C_{20}H_{18}N_4O$	275-276	88
3	**18**	$PhSO_2$	imidazole	–	$C_{22}H_{20}N_4O_3S$	77-79	82
4	**19**	$PhSO_2$	2-ethyl-imidazole	–	$C_{24}H_{24}N_4O_3S$	147-148	88
5	**20**	$PhSO_2$	benzimidazole	–	$C_{26}H_{22}N_4O_3S$	139-140	72
6	**21**	$PhSO_2$	5,6-dimethyl-benzimidazole	–	$C_{28}H_{26}N_4O_3S$	278-279	76
7	**22**	H	imidazole	phenacyl	$C_{28}H_{25}BrN_4O_2$	201-202	78
8	**23**	H	imidazole	1-(naphthalen-2-yl)ethan-1-one	$C_{28}H_{25}BrN_4O_2$	249-251	92
9	**24**	H	benzimidazole	phenacyl	$C_{28}H_{25}BrN_4O_2$	236-238	92
10	**25**	H	benzimidazole	4-methoxyphenacyl	$C_{29}H_{27}BrN_4O_3$	258-260	88
11	**26**	H	benzimidazole	4-bromophenacyl	$C_{28}H_{24}Br_2N_4O_2$	240-242	78
12	**27**	H	benzimidazole	1-(naphthalen-2-yl)ethan-1-one	$C_{32}H_{27}BrN_4O_2$	270-271	83
13	**28**	H	benzimidazole	4-bromobenzyl	$C_{27}H_{24}Br_2N_4O$	272-274	88
14	**29**	H	benzimidazole	4-nitrobenzyl	$C_{27}H_{24}BrN_5O_3$	279-280	82
15	**30**	H	benzimidazole	3-naphthylmethyl	$C_{31}H_{27}BrN_4O$	272-273	76
17	**31**	$PhSO_2$	imidazole	phenacyl	$C_{30}H_{27}BrN_4O_4S$	222-223	89
18	**32**	$PhSO_2$	imidazole	1-(naphthalen-2-yl)ethan-1-one	$C_{34}H_{29}BrN_4O_4S$	195-196	86
29	**33**	$PhSO_2$	2-ethyl-imidazole	phenacyl	$C_{32}H_{31}BrN_4O_4S$	272-273	86
20	**34**	$PhSO_2$	2-ethyl-imidazole	4-bromophenacyl	$C_{32}H_{30}Br_2N_4O_4S$	279-280	89
21	**35**	$PhSO_2$	2-ethyl-imidazole	1-(naphthalen-2-yl)ethan-1-one	$C_{36}H_{33}BrN_4O_4S$	273-274	78
22	**36**	$PhSO_2$	2-ethyl-imidazole	4-methylbenzyl	$C_{32}H_{33}BrN_4O_3S$	244-245	81
23	**37**	$PhSO_2$	2-ethyl-imidazole	3-naphthylmethyl	$C_{35}H_{33}BrN_4O_3S$	253-254	87
24	**38**	$PhSO_2$	benzimidazole	phenacyl	$C_{34}H_{29}BrN_4O_4S$	200-201	86
25	**39**	$PhSO_2$	benzimidazole	4-bromophenacyl	$C_{34}H_{28}Br_2N_4O_4S$	197-198	75
26	**40**	$PhSO_2$	benzimidazole	4-methoxyphenacyl	$C_{35}H_{31}BrN_4O_5S$	209-210	89
27	**41**	$PhSO_2$	benzimidazole	1-(naphthalen-2-yl)ethan-1-one	$C_{38}H_{31}BrN_4O_4S$	214-215	77
28	**42**	$PhSO_2$	benzimidazole	4-methylbenzyl	$C_{34}H_{31}BrN_4O_3S$	290-291	84
29	**43**	$PhSO_2$	benzimidazole	4-nitrobenzyl	$C_{33}H_{28}BrN_5O_5S$	272-273	86
30	**44**	$PhSO_2$	benzimidazole	3-naphthylmethyl	$C_{37}H_{31}BrN_4O_3S$	136-137	72
31	**45**	$PhSO_2$	5,6-dimethyl-benzimidazole	phenacyl	$C_{36}H_{33}BrN_4O_4S$	239-240	91
32	**46**	$PhSO_2$	5,6-dimethyl-benzimidazole	4-bromophenacyl	$C_{36}H_{32}Br_2N_4O_4S$	250-252	88
33	**47**	$PhSO_2$	5,6-dimethyl-benzimidazole	4-methoxyphenacyl	$C_{37}H_{35}BrN_4O_5S$	244-245	90
34	**48**	$PhSO_2$	5,6-dimethyl-benzimidazole	1-(naphthalen-2-yl)ethan-1-one	$C_{40}H_{35}BrN_4O_4S$	234-235	91
35	**49**	$PhSO_2$	5,6-dimethyl-benzimidazole	4-methylbenzyl	$C_{36}H_{35}BrN_4O_3S$	270-271	79
36	**50**	$PhSO_2$	5,6-dimethyl-benzimidazole	4-nitrobenzyl	$C_{35}H_{32}BrN_5O_5S$	227-228	89
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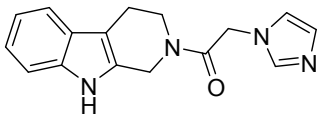

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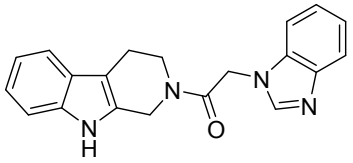

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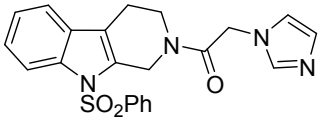

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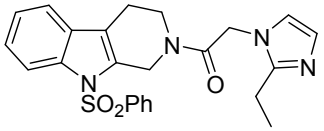

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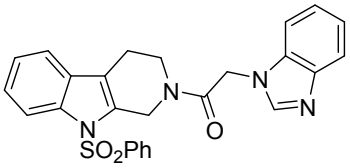

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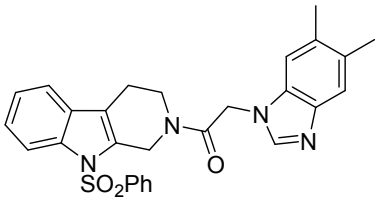

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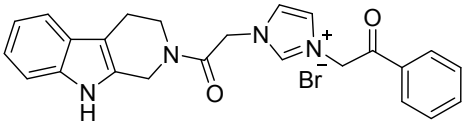

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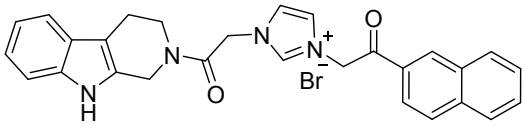

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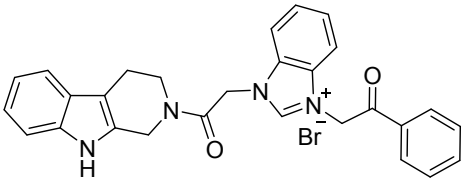

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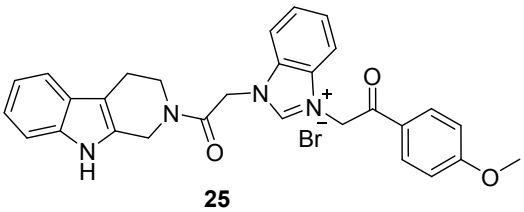

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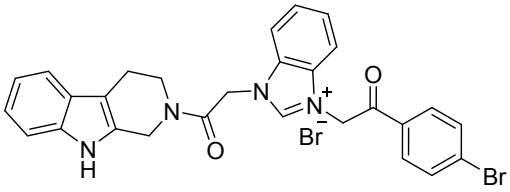

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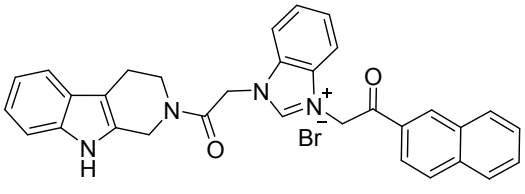

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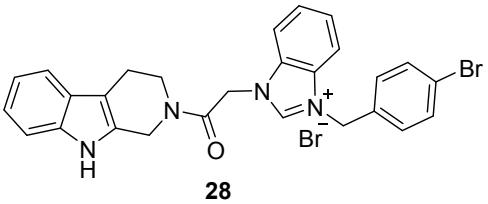

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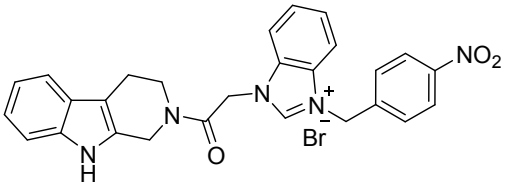

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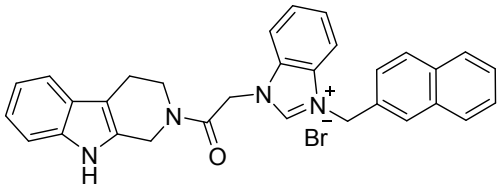

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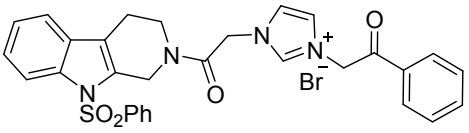

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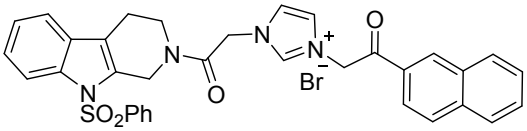

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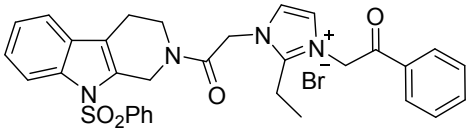

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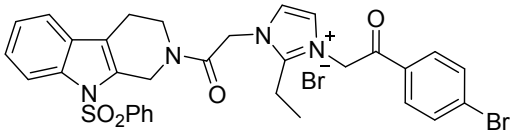

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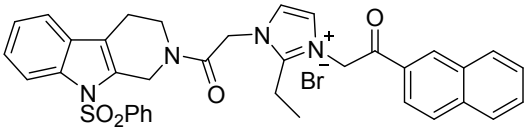

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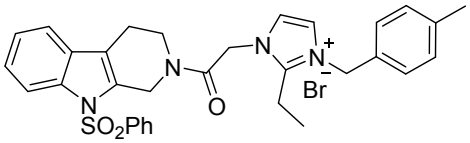

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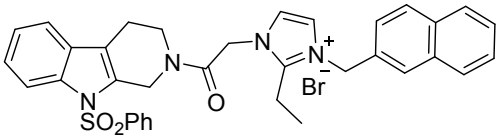

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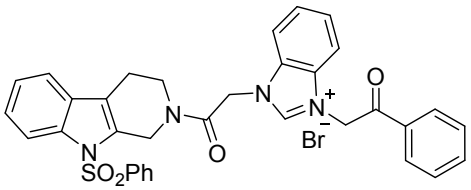

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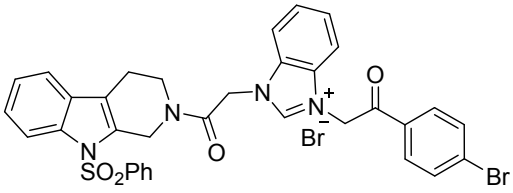

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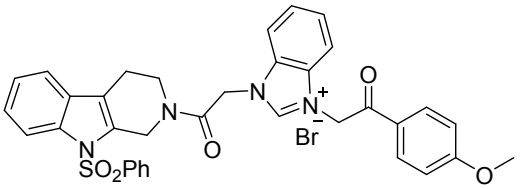

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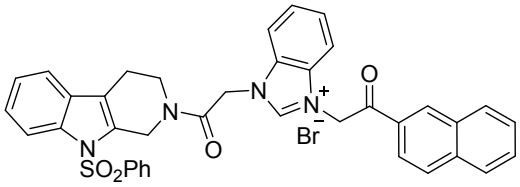

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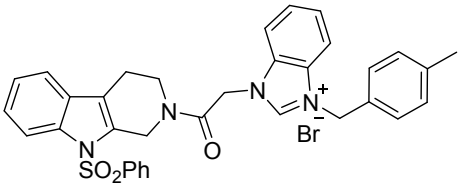

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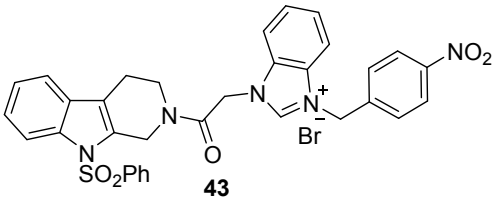

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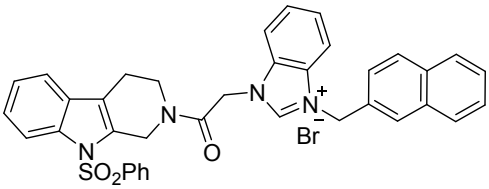

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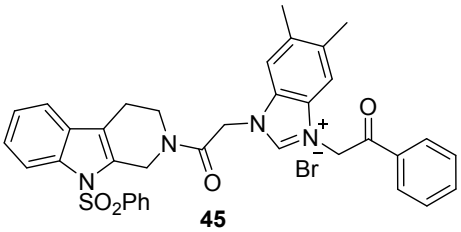

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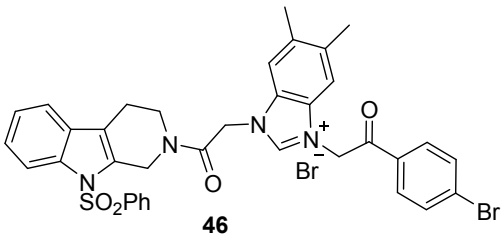

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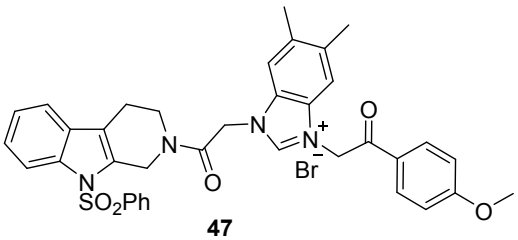

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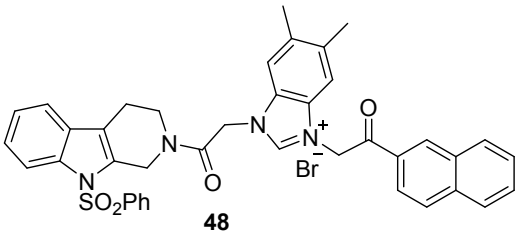

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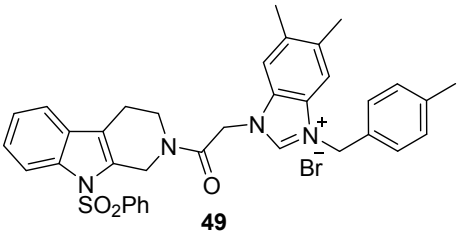

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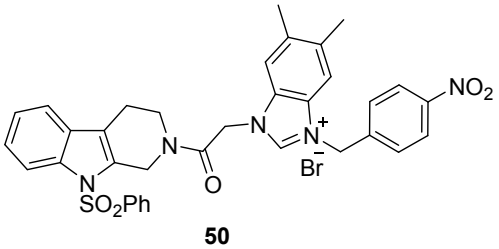

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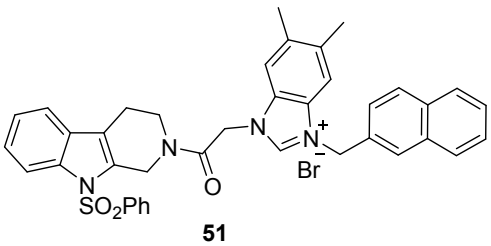
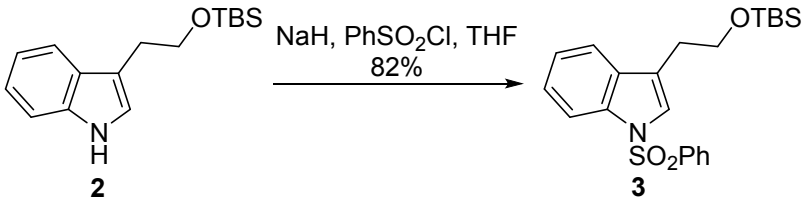


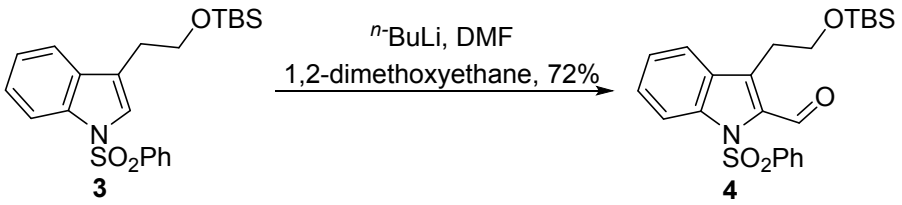
51

2.1 Synthesis of hybrid compounds

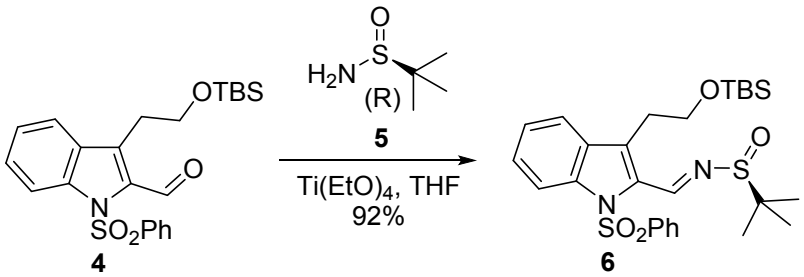
To a stirred solution of tryptophol **1** (1.00g, 6.2 mmol) and imidazole (0.63 g, 9.3 mmol) in dichloromethane (30 mL) at 0°C was added tert-Butyldimethylsilyl chloride (1.00 g, 6.8 mmol) in small portions over a period of 5 minutes, and then at ambient temperature for 1 hours. Reaction progress was monitored by TLC. A small amount of water was added and the mixture was stirred for 10 min. Mixture was washed by CH_2Cl_2 (3×30 mL). The combined organic phases was dried over Na_2SO_4 and concentrated. The residue was purified by column chromatography on silica gel (petroleum ether : EtOAc : Et_3N = 100/1/0.1 as eluant) affording the title compound **2** (1.68g, 99%) as a yellow oil.



Compound **2** (1.00 g, 3.6 mmol) dissolved in THF (20 mL) at 0°C under inert gas for 15 minutes, and then sodium hydride (60% dispersion in mineral oil, 218mg, 5.4mmol) was slowly added in small portions over a period of 15 minutes, then mixture kept 0°C for 45 minutes. In sequence, add benzenesulfonyl chloride (0.58mL, 4.6mmol) with a syringe to the mixture, and then mixture at ambient temperature overnight. Mixture quenched by NH_4Cl (aq., 5 mL), washed by EtOAc (3×30 mL), The combined organic phases was dried over Na_2SO_4 and concentrated. The residue was purified by column chromatography on silica gel (petroleum ether : EtOAc : Et_3N = 100/0.8/0.1 as eluant) affording compound **3** (1.24g, 82%) as a solid compound.

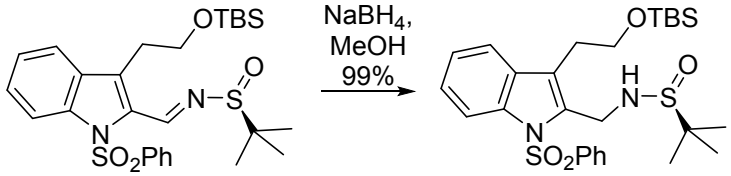


Compound **3** (1.00 g, 2.4 mmol) dissolved in 1,2-dimethoxyethane (20 mL) at -78°C under inert gas for 15 minutes, and then *n*-BuLi (1M solution in hexanes, 3.6mL, 3.6mmol) was slowly added with a syringe over a period of 5 minutes, then mixture kept -78°C for 45 minutes. Anhydrous DMF (1.1mL, 14.4mmol) was added quickly to the mixture. After 30 minutes, mixture warmed to ambient temperature for 2 hours. Mixture quenched by NH_4Cl (aq., 5 mL), washed by EtOAc (3×30 mL), The combined organic phases was dried over Na_2SO_4 and concentrated. The residue was purified by column chromatography on silica gel (petroleum ether : EtOAc : Et_3N = 100/1/0.1 as eluant) affording the title compound **4** (770 mg, 72%) as a solid compound. ^1H NMR (400 MHz, $CDCl_3$): δ = 10.58 (1H, s), 8.21 (1H, d, J= 8.0 Hz), 7.71-7.66 (3H, m), 7.54-7.48 (2H, m), 7.38-7.26 (3H, m), 3.78 (2H, t, J= 16 Hz), 3.17 (2H, t, J= 12 Hz), 0.69 (9H, s), -0.221 (6H, s).^{13}C NMR (100 MHz, $CDCl_3$): δ = 184.85, 137.55, 137.28, 134.58, 134.22, 133.27, 130.89, 129.26, 126.81, 124.68, 122.90, 115.64, 77.47, 77.16, 76.84, 63.21, 28.73, 25.87, 18.24.

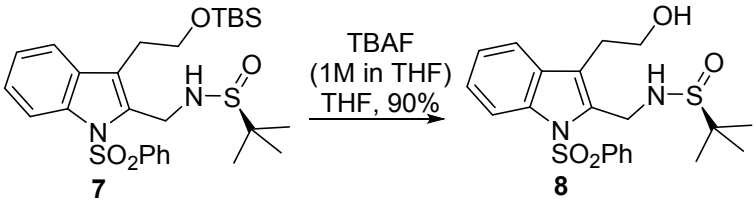


compound **4** (700 mg, 1.6 mmol), dissolved in THF(20 mL) under inert gas at room temperature, (R)-(+)-2-Methyl-2-propanesulfinamide (213mg, 1.76mmol) was added to the mixture, and titanium ethoxide (0.67mL, 3.2mmol) added in sequence. Reaction progress was monitored by TLC. Quench reaction by the adding of EtOAc (50 mL) while the mixture was stirred vigorously to prevent concretion. Mixture was stirred for 15 minutes followed by the washed of EtOAc (2×30 mL). The combined organic

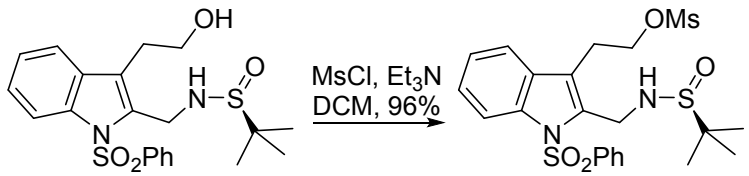
phases was dried over Na_2SO_4 and concentrated. The residue was purified by column chromatography on silica gel (petroleum ether : EtOAc : Et_3N = 10/1/0.1 as eluant) affording compound **6** (793mg, 92%) as a yellow solid. ^1H NMR (400 MHz, $CDCl_3$): δ = 9.31 (1H, s), 8.27 (1H, d, J=8.4 Hz), 7.76 (2H, d, J= 7.6 Hz), 7.65 (1H, d, J= 4.0 Hz), 7.52-7.44 (2H, m), 7.38 (2H, d, J= 7.6 Hz), 7.35- 7.26 (1H, m), 3.76 (2H, t, J= 13.2 Hz), 3.28-3.17 (2H, m), 1.27 (9H, s), 0.71 (9H, s), 0.23 (6H, s). ^{13}C NMR (100 MHz, $CDCl_3$): δ = 155.41, 138.17, 137.51, 134.10, 131.03, 130.72, 130.00, 129.33, 127.99, 126.81, 124.31, 121.79, 115.40, 77.47, 77.16, 76.84, 62.85, 57.98, 29.18, 15.88, 22.69, 18.27.



To a stirred solution of compound **6** (700 mg, 1.3 mmol) in MeOH (20 mL) at 0°C was added sodium borohydride (73 mg, 1.9 mmol) in small portions over a period of 10 minutes, and then mixture at 0°C for 1 hour. Reaction progress was monitored by TLC. A small amount of water was added and the mixture was stirred for 10 min. Mixture was washed by CH_2Cl_2 (3×30 mL). The combined organic phases was dried over Na_2SO_4 and concentrated. The residue was purified by column chromatography on silica gel (petroleum ether : EtOAc : Et_3N = 80/10/0.1 as eluant) affording the title compound **7** (700mg, 99%) as a yellow solid. ^1H NMR (400 MHz, $CDCl_3$): δ = 8.12 (1H, d, J=8.4 Hz), 7.78 (2H, d, J= 7.6 Hz), 7.53-7.48 (2H, m), 7.40 (2H, t), 7.33- 7.23 (3H, m), 4.65-4.60 (1H, m), 4.55-4.47 (2H, m), 3.76-3.74 (2H, m), 1.19 (9H, s), 0.77 (9H, s), -0.16 (6H, d, J= 7.6 Hz).

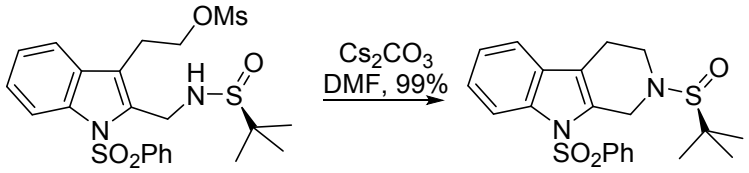


To a stirred solution of compound **7** (700 g, 1.3 mmol) in THF (20 mL) at 0°C was added TBAF (1M in THF, 2.6 mL, 2.6 mmol), and then mixture at room temperature for 1 hour. Reaction progress was monitored by TLC. Mixture was washed by EtOAc (2×50 mL). The combined organic phases was dried over Na_2SO_4 and concentrated. The residue was purified by column chromatography on silica gel (petroleum ether : EtOAc : Et_3N = 30/10/0.1 as eluant) affording the title compound **8** (500mg, 90%) as a yellow solid.



8 **9**

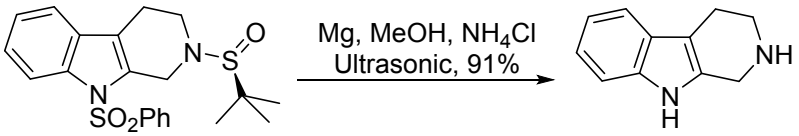
To a stirred solution of compound **8** (500mg, 1.2 mmol) and Et_3N (0.3mL, 2.3 mmol) in dichloromethane (30 mL) at 0°C was added methanesulfonyl chloride (0.1mL, 1.5 mmol) with a syringe over 5 minutes, and then at ambient temperature for 1 hour. Reaction progress was monitored by TLC. A small amount of water was added and the mixture was stirred for 10 min. Mixture was washed by CH_2Cl_2 (3×30 mL). The combined organic phases was dried over Na_2SO_4 and concentrated. The residue was purified by column chromatography on silica gel (petroleum ether : EtOAc : Et_3N = 10/1/0.1 as eluant) affording compound **9** (560 mg, 96%) as a yellow oil.



9 **10**

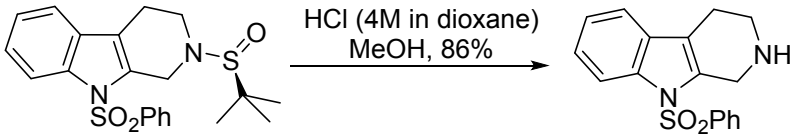
To a stirred solution of compound **9** (500 mg, 0.98 mmol) in DMF (20 mL) added Cs_2CO_3 (650 mg, 2 mmol), mixture at 50°C for 3 hours. Reaction progress was monitored by TLC. A small amount of water was added and the mixture was stirred for 10 min at room temperature. Mixture was washed by EtOAc (2×50 mL). The combined organic phases was dried over Na_2SO_4 and concentrated. The residue was

purified by column chromatography on silica gel (petroleum ether : EtOAc : Et_3N = 10/1/0.1 as eluant) affording the title compound **10** (400 mg, 99%) as a yellow solid. ^1H NMR (400 MHz, $CDCl_3$): δ = 8.06 (1H, d, J=8.4 Hz), 7.84 (2H, d, J = 4.0 Hz), 7.51 (1H, t, J = 8.0 Hz), 7.42 (2H, t, J = 8.0 Hz), 7.34 (1H, d, J = 7.6 Hz), 7.28-7.20 (3H, m), 4.82 (1H, d), 4.49 (1H, d), 3.55-3.51 (1H, m), 3.44-3.41 (1H, m), 2.80-2.75 (2H, m) 1.24 (9H, s).^{13}C NMR (100 MHz, $CDCl_3$): δ = 138.21, 135.87, 133.79, 131.70, 129.79, 129.30, 126.57, 124.63, 123.60, 118.33, 117.70, 114.24, 77.33, 77.02, 76.70, 60.40, 58.75, 44.65, 43.25, 22.99, 21.66, 21.05, 14.20.



10 **11a**

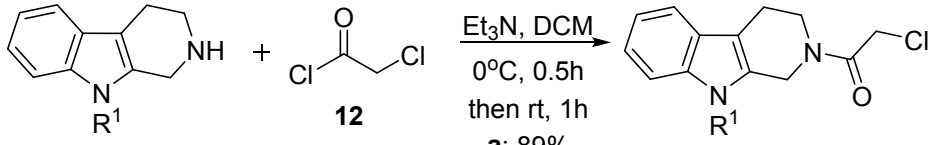
Compound **10** (400 mg, 0.96 mmol) in DMF (20 mL) added magnesium powder (200 mg) and NH_4Cl (5 mg, 0.096 mmol), mixture under ultrasonic equipment at room temperature under inert gas for 2 hours. Reaction progress was monitored by TLC. A small amount of water was added and the mixture was stirred for 10 min at room temperature. Mixture was washed by CH_2Cl_2 (2×50 mL). The combined organic phases was dried over Na_2SO_4 and concentrated. The residue was purified by column chromatography on silica gel (petroleum ether : EtOAc : Et_3N = 50/10/0.1 as eluant) affording compound **11a** (150mg, 91%) as a yellow solid.



10 **11b**

To a stirred solution of compound **10** (500 mg, 1.2 mmol) in MeOH (20 mL) at 0°C was added HCl (4M in dioxane, 3 mL, 12 mmol), and then mixture at room temperature for 3 hour. Reaction progress was monitored by TLC. Mixture was washed by EtOAc (2×50 mL). The combined organic phases was dried over Na_2SO_4 and concentrated. The residue was purified by column chromatography on silica gel

(petroleum ether : EtOAc : Et_3N = 80/10/0.1 as eluant) affording compound **11b** (350 mg, 86%) as a yellow solid. ^1H NMR (400 MHz, $CDCl_3$): δ = 8.13 (1H, d, J=8.0 Hz), 7.79 (2H, d, J= 7.6 Hz), 7.54-7.50 (1H, m), 7.43-7.22 (5H, m), 4.29 (2H, s), 3.12-3.10 (2H, m), 2.64 (2H, d, J= 4.0 Hz), 1.75 (1H, s).^{13}C NMR (100 MHz, $CDCl_3$): δ = 138.92, 136.00, 134.19, 133.81, 130.30, 129.43, 126.50, 124.52, 123.59, 118.33, 117.52, 114.34, 77.47, 77.15, 16.64, 44.63, 42.77, 22.78.



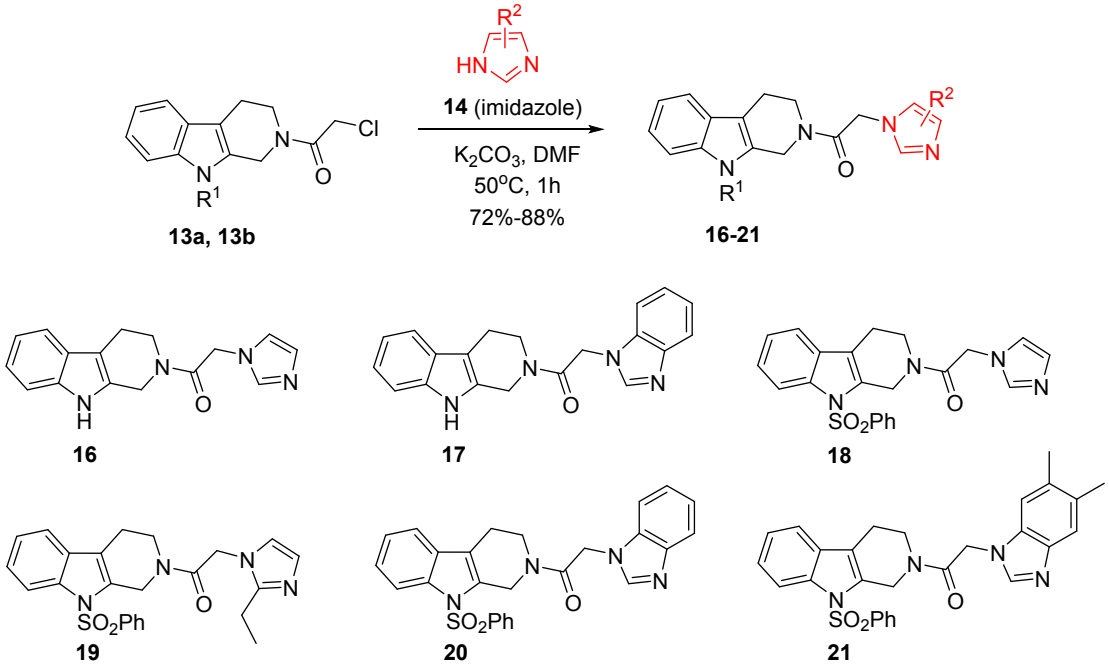
11a: R^1=H
11b: R^1=$PhSO_2$

13a: R^1=H
13b: R^1=$PhSO_2$

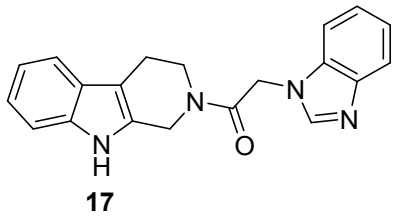
To a stirred solution of compound **11a**(173 mg, 1 mmol) and triethylamine (0.28mL, 2 mmol) in dichloromethane (10 mL) at 0°C was added chloroacetyl chloride (87 uL, 1.1 mmol) dropwise over a period of 10 minutes, and then at ambient temperature for 1 h. Reaction progress was monitored by TLC. A small amount of water was added and the mixture was stirred for 10 min. The aqueous phase was washed with CH_2Cl_2 (4×50 mL).The combined organic phases was dried over Na_2SO_4 and concentrated. The residue was purified by column chromatography on silica gel (petroleum ether : EtOAc : Et_3N = 80/10/0.1 as eluant) affording the title compound **13a** (220g, 89%) as a red solid.

To a stirred solution of compound **11b**(312mg, 1 mmol) and triethylamine (0.28mL, 2 mmol) in dichloromethane (10 mL) at 0°C was added chloroacetyl chloride (87 uL, 1.1 mmol) dropwise over a period of 10 minutes, and then at ambient temperature for 1 h. Reaction progress was monitored by TLC. A small amount of water was added and the mixture was stirred for 10 min. The aqueous phase was washed with CH_2Cl_2 (4×50 mL).The combined organic phases was dried over Na_2SO_4 and concentrated. The residue was purified by column chromatography on silica gel (petroleum ether : EtOAc : Et_3N = 80/10/0.1 as eluant) affording the title compound **13b** (360g, 93%) as a red solid.

2.2 Synthesis of hybrid compounds



A mixture of compound **13** (2 mmol) and imidazole or substituted imidazole (6 mmol) and K_2CO_3 (3 mmol) was stirred in DMF (20 ml) at 50°C for 1 h (monitored by TLC). After cooling to room temperature, the solvent was concentrated, and the residue was diluted with EtOAc (20 mL). The organic layer was washed with water (20 mL) and brine (20 mL), dried over anhydrous Na_2SO_4 and concentrated. The residue was purified by column chromatography (silica gel, petroleum ether : EtOAc : Et_3N = 1:1:0.1) to afford **16-21** in 72-88% yield as yellow solid.

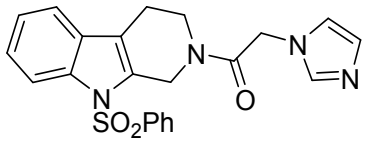


17

2-(1*H*-benzo[*d*]imidazol-1-yl)-1-(1,3,4,9-tetrahydro-2*H*-pyrido[3,4-*b*]indol-2-yl)ethan-1-one

Yield 88%. Yellow solid. Mp 275-276 °C. IR νmax (cm^{-1}): 3729.96, 3391.12, 3158.44, 3055.81, 2976.81, 2926.60, 2882.33, 2842.56, 2761.58, 2657.92, 2314.66, 1951.10, 1902.33, 1862.31, 1776.74, 1657.75, 1503.21, 1460.00, 1253.49, 1210.94, 1040.11, 890.19, 849.07, 806.18, 736.32. ^{1}H NMR (400 MHz, DMSO): δ = 10.94 (1H, d), 8.13 (1H, d), 7.65 (1H, d, J = 7.6 Hz), 7.50 (1H, d, J = 7.2 Hz), 7.44 (1H, d, J = 7.2

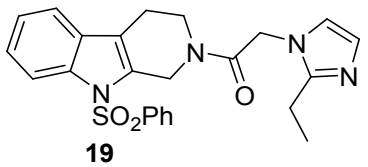
Hz), 7.37-7.30 (1H, m), 7.19 (2H, d, J = 5.2 Hz), 7.07-7.01 (1H, m), 6.98 (1H, t, J = 7.2 Hz), 5.46 (2H, d, J = 7.6 Hz), 4.79 (2H, d), 3.94-3.85 (2H, m), 2.92 (2H, s). ^{13}C NMR (100 MHz, DMSO): δ = 167.13, 166.96, 146.06, 145.99, 144.01, 137.13, 136.85, 135.74, 135.67, 131.68, 131.14, 127.45, 127.33, 123.07, 122.23, 121.79, 120.15, 119.51, 118.49, 112.00, 111.59, 111.47, 108.21, 107.54, 22.37, 21.51. HRMS (ESI-TOF) m/z Calcd for $C_{20}H_{18}N_4O$ $[M+H]^+$ 331.1553. found 331.1553.



18

2-(1*H*-imidazol-1-yl)-1-(9-(phenylsulfonyl)-1,3,4,9-tetrahydro-2*H*-pyrido[3,4-*b*]indol-2-yl)ethan-1-one

Yield 82%. Yellow solid. Mp 77-79 °C. IR νmax (cm^{-1}): 3398.76, 3106.331, 3061.73, 2923.87, 2855.41, 2663.50, 2589.61, 2472.49, 1811.20, 1667.08, 1511.55, 1451.83, 1370.47, 1297.24, 1223.09, 1178.93, 1138.54, 1088.49, 959.36, 800.59, 754.84, 602.77, 562.26. ^{1}H NMR (400 MHz, DMSO): δ = 8.16-8.09 (1H, m), 7.87 (1H, d, J = 8.0 Hz), 7.74 (1H, d, J = 7.6 Hz), 7.58-7.47 (2H, m), 7.45-7.28 (5H, m), 7.11 (1H, s), 6.97 (1H, s), 5.11 (1H, s), 4.89 (2H, d, J = 10.0 Hz), 3.92 (1H, t, J = 9.6 Hz), 3.74 (1H, t, J = 10.4 Hz), 2.74 (2H, s). ^{13}C NMR (100 MHz, DMSO): δ = 165.62, 165.37, 138.38, 138.22, 136.45, 134.37, 130.78, 129.88, 129.72, 129.63, 129.16, 129.09, 129.02, 126.70, 126.35, 125.53, 125.10, 124.19, 123.86, 120.33, 119.06, 118.92, 118.45, 116.07, 114.41, 53.55, 48.61, 48.56, 46.49, 44.17, 42.64, 42.23, 39.87, 22.16, 20.92. HRMS (ESI-TOF) m/z Calcd for $C_{22}H_{20}N_4O_3S$ $[M+H]^+$ 421.1328. found 421.1329.

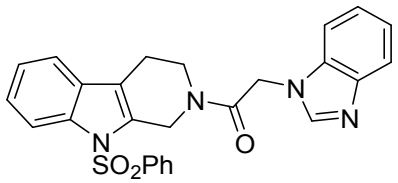


19

2-(2-ethyl-1*H*-imidazol-1-yl)-1-(9-(phenylsulfonyl)-1,3,4,9-tetrahydro-2*H*-pyrido[3,4-*b*]indol-2-yl)ethan-1-one

Yield 88%. Yellow solid. Mp 147-148 °C. IR νmax (cm^{-1}): 3874.17, 3832.90, 3729.52, 3390.04, 3101.13, 3062.02, 2976.98, 2927.11, 2314.59, 1759.46, 1665.86, 1451.48, 1370.30, 1221.98, 1179.24, 1087.08, 1053.64, 959.88, 885.61, 755.20,

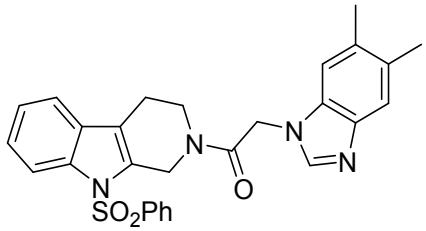
717.28, 680.70, 603.30, 587.29, 562.91. ^{1}H NMR (400 MHz, DMSO): δ = 8.13-7.99 (1H, m), 7.85 (1H,d, J= 8.0 Hz), 7.73 (1H, d, J= 7.6 Hz), 7.56-7.50 (1H, m), 7.46-7.39 (4H, m), 7.35-7.26 (1H, m), 6.98 (1H, m), 6.80 (1H, s), 5.10 (1H, s), 4.90 (1H, s), 4.76 (2H, d, J=8.4 Hz), 3.91 (1H, t, J= 11.2 Hz), 3.73 (1H, t, J= 11.2 Hz), 2.73 (2H, d, J= 6 Hz), 2.61-2.56 (2H, m), 1.32-1.24 (3H, m). ^{13}C NMR (100 MHz, DMSO): δ = 165.57, 165.38, 162.52, 149.97, 149.85, 138.21, 136.30, 135.95, 134.24, 134.01, 130.77, 129.58, 129.48, 129.05, 128.94, 127.54, 127.47, 126.57, 126.22, 125.39, 124.97, 124.07, 123.74, 120.17, 120.12, 118.97, 118.78, 118.32, 115.98, 114.29, 60.38, 47.55, 47.38, 44.00, 42.40, 42.15, 39.77, 36.46, 31.42, 22.05, 21.04, 20.83, 20.02, 14.19, 11.68. HRMS (ESI-TOF) m/z Calcd for $C_{24}H_{24}N_4O_3S$ $[M+H]^+$ 449.1641. found 449.1639. Anal. Cacld for $C_{24}H_{24}N_4O_3S$: C 64.27, H 5.39, 12.49; Found: C 63.90, H 5.45, N 12.54.



20

2-(1*H*-benzo[*d*]imidazol-1-yl)-1-(9-(phenylsulfonyl)-1,3,4,9-tetrahydro-2*H*-pyrido[3,4-*b*]indol-2-yl)ethan-1-one

Yield 72%. Yellow solid. Mp 139-140 °C. IR νmax (cm^{-1}): 3874.06, 3831.88, 3729.67, 3629.29, 3381.15, 3053.30, 2933.22, 2850.49, 2386.46, 2315.05, 1902.38, 1808.91, 1655.02, 1452.87, 1415.40, 1370.82, 1222.87, 1178.06, 1086.98, 960.29, 879.37, 752.70, 676.04, 600.49, 560.28. ^{1}H NMR (400 MHz, DMSO): δ = 8.12 (1H, t), 7.91 (1H, d, J= 2.8 Hz), 7.82 (2H, t), 7.74 (1H, d, J=7.6 Hz), 7.55-7.33 (10H, m), 5.09-4.98 (4H, m), 3.88 (1H, s), 3.77 (1H, s), 2.73 (2H, s). ^{13}C NMR (100 MHz, DMSO): δ = 165.23, 164.96, 143.78, 143.67, 143.50, 138.17, 136.32, 135.93, 134.25, 134.02, 130.67, 129.59, 129.48, 129.05, 128.92, 126.53, 126.22, 125.41, 124.97, 124.08, 123.73, 123.32, 122.39, 122.34, 120.53, 120.44, 119.00, 118.83, 118.35, 115.95, 114.27, 109.48, 109.32, 46.47, 16.17, 44.12, 42.48, 42.13, 39.78. HRMS (ESI-TOF) m/z Calcd for $C_{26}H_{22}N_4O_3S$ $[M+H]^+$ 471.1485. found 471.1486. Anal. Cacld for $C_{26}H_{22}N_4O_3S$: C 66.37, H 4.71, N 11.91; Found: C 66.20, H 4.83, N 12.02.

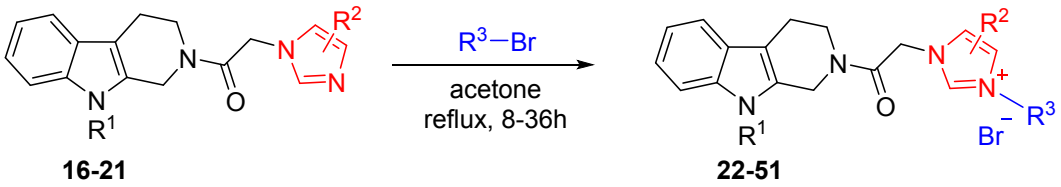


21

2-(5,6-dimethyl-1*H*-benzo[*d*]imidazol-1-yl)-1-(9-(phenylsulfonyl)-1,3,4,9-tetrahydro-2*H*-pyrido[3,4-*b*]indol-2-yl)ethan-1-one

Yield 76%. Yellow solid. Mp 278-279 °C. IR νmax (cm^{-1}): 3101.40, 3059.93, 3020.07, 2971.26, 2920.64, 2849.21, 2315.67, 1952.17, 1903.14, 1793.92, 1658.60, 1508.84, 1416.91, 1370.55, 1221.56, 1179.85, 1080.26, 880.44, 840.73, 791.34, 754.97, 715.54, 691.55, 604.57, 562.96. ^{1}H NMR (400 MHz, DMSO): δ = 8.05-7.87 (4H, m), 7.68-7.52 (4H, m), 7.42 (1H, s), 7.39-7.32 (1H, m), 7.30-7.26 (2H, m), 5.43 (2H, d), 5.15 (2H, s), 3.93-3.82 (2H, m), 2.90 (2H, s), 2.29 (6H, d, J= 6.0 Hz). ^{13}C NMR (100 MHz, DMSO): δ = 166.85, 144.62, 142.16, 137.47, 135.57, 135.20, 133.74, 131.44, 131.20, 130.40, 130.05, 129.55, 127.10, 126.78, 125.38, 124.36, 119.75, 119.42, 117.94, 114.23, 111.12, 111.09, 21.81, 20.57, 20.32. HRMS (ESI-TOF) m/z Calcd for $C_{28}H_{26}N_4O_3S$ $[M+H]^+$ 499.1798. found 499.1796.

2.3 Synthesis of compounds 22-51



16-21 **22-51**

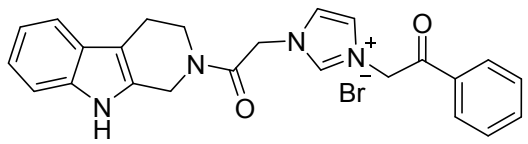
	R^1	R^2 (imidazole ring)
16	H,	imidazole
17	H,	benzimidazole
18	$PhSO_2$,	imidazole
19	$PhSO_2$,	2-Ethyl-imidazole
20	$PhSO_2$,	benzimidazole
21	$PhSO_2$,	5,6-dimethyl-benzimidazole

R^3 = phenacyl or benzyl or naphthylacyl or naphthylmethyl

75%-92%

A mixture of substituted imidazole **16-21** (0.25 mmol) and phenacylbromides or phenacyl or benzyl or naphthylacyl or naphthylmethyl (0.75 mmol) was stirred in

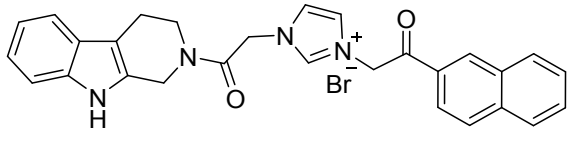
acetone (10 ml) at reflux 8-36 h. An insoluble substance was formed. After completion of the reaction as indicated by TLC, the precipitate was filteredand washed with acetone (3 × 10 ml), then dried to afford imidazolium salts **22-51** in 75–92% yields.



22

1-(2-(3,4-dihydro-1*H*-pyrido[3,4-*b*]indol-2(9*H*)-yl)-2-oxoethyl)-3-(2-oxo-2-phenylethyl)-1*H*-imidazol-3-ium bromide

Yield 78%. Yellow solid. Mp 201-202 °C. IR ν_{max} (cm^{-1}): 3413.84, 3150.03, 3113.89, 3051.00, 2999.56, 2904.48, 2853.30, 1700.60, 1659.21, 1479.58, 1417.24, 1351.58, 1225.65, 1172.21, 1045.57, 992.83, 813.01, 750.99, 684.37, 621.72. ^{1}H NMR (400 MHz, DMSO): δ = 10.97 (1H, s), 9.06 (1H, s), 8.07 (2H, d, J= 7.6 Hz), 7.76 (3H, d, J= 8.4 Hz), 7.64 (2H, t, J= 12.8 Hz), 7.44 (H, d, J= 7.2 Hz), 7.34 (1H, t, J= 14 Hz), 7.06 (1H, t), 6.99 (1H, t), 6.13 (2H, s), 5.63 (2H, d, J= 8.8 Hz), 4.76 (2H, s), 3.90-3.82 (2H, m), 2.91 (2H, s). ^{13}C NMR (100 MHz, DMSO): δ = 206.94, 191.73, 165.02, 164.88, 139.13, 136.63, 136.39, 134.97, 134.19, 130.87, 130.21, 129.56, 128.60, 126.92, 126.78, 124.32, 123.86, 121.53, 121.40, 119.09, 118.06, 118.01, 111.56, 107.67, 107.00, 79.81, 79.48, 79.15, 56.00, 51.00, 31.16, 21.77, 20.99. HRMS (ESI-TOF) *m/z* Calcd for $C_{28}H_{25}BrN_4O_2$ $[M-Br]^+$, 449.1972. found 449.1975.

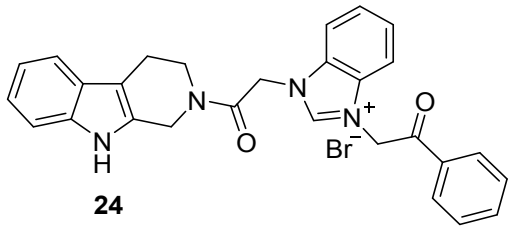


23

1-(2-(3,4-dihydro-1*H*-pyrido[3,4-*b*]indol-2(9*H*)-yl)-2-oxoethyl)-3-(2-(naphthalen-2-yl)-2-oxoethyl)-1*H*-imidazol-3-ium bromide

Yield 92%. Yellow solid. Mp 249-251 °C. IR ν_{max} (cm^{-1}): 3421.71, 3280.54, 3072.96, 2977.66, 2922.79, 2850.08, 1693.46, 1657.23, 1563.26, 1436.89, 1226.38, 1176.46, 1046.60, 812.82, 746.35, 647.12, 477.92. ^{1}H NMR (400 MHz, DMSO): δ = 10.97 (1H, d), 9.10 (1H, s), 8.83 (1H, s), 8.20 (1H, d, J= 8 Hz), 8.14 (1H, d, J= 8.8 Hz), 8.06 (2H, t), 7.80-7.68 (4H, m), 7.44 (1H, t, J= 2.4 Hz), 7.08-6.97 (2H, m), 6.26 (2H, s), 5.64 (2H, d, J= 8.4 Hz), 4.77 (2H, s), 3.92-3.83 (2H, m), 2.92 (2H, s). ^{13}C NMR (100 MHz,

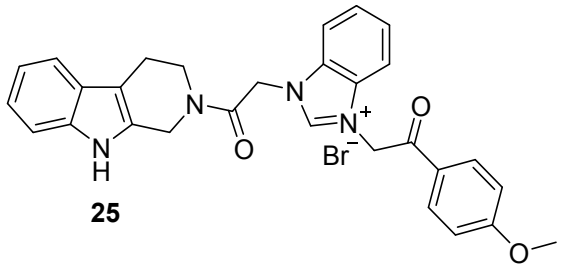
DMSO): δ = 191.64, 165.03, 164.90, 139.19, 136.64, 136.39, 135.99, 132.50, 131.51, 130.91, 130.88, 130.21, 130.21, 130.13, 129.80, 129.26, 128.36, 127.89, 126.92, 126.78, 124.38, 123.92, 123.66, 121.54, 121.41, 119.10, 118.07, 118.02, 111.57, 107.69, 107.01, 79.80, 79.47, 79.14, 56.04, 54.14, 51.02, 21.77, 21.00. HRMS (ESI-TOF) *m/z* Calcd for $C_{28}H_{25}BrN_4O_2$ $[M-Br]^+$, 399.1815. found 399.1814.



24

1-(2-oxo-2-(1,3,4,9-tetrahydro-2*H*-pyrido[3,4-*b*]indol-2-yl)ethyl)-3-(2-oxo-2-phenylethyl)-1*H*-benzo[*d*]imidazol-3-ium bromide

Yield 92%. Yellow solid. Mp 236-238 °C. IR ν_{max} (cm^{-1}): 3872.82, 3831.06, 3728.97, 3385.38, 3242.16, 3044.78, 2986.56, 2984.12, 2923.21, 2811.05, 2315.21, 1697.14, 1666.83, 1565.33, 1481.06, 1233.45, 1044.26, 984.62, 749.84, 683.08. ^{1}H NMR (400 MHz, DMSO): δ = 11.00 (1H, d), 9.65 (1H, d), 8.15-8.09 (4H, m), 7.80 (1H, t, J= 14.4 Hz), 7.68 (4H, t, J= 14.4 Hz), 7.46 (1H, t), 7.40-7.32 (1H, m), 7.07 (1H, t), 7.00 (1H, t, J= 14.4 Hz), 6.49 (1H, s), 5.98 (2H, d, J= 12 Hz), 4.84 (2H, d), 3.93 (2H, d), 3.00 (2H, d). ^{13}C NMR (100 MHz, DMSO): δ = 192.10, 165.22, 165.02, 145.60, 145.50, 137.14, 136.89, 135.55, 134.74, 132.67, 132.60, 132.49, 131.28, 130.80, 130.03, 129.39, 127.63, 127.42, 127.29, 122.04, 121.92, 119.60, 118.56, 114.98, 114.90, 112.07, 108.17, 107.56, 54.32, 22.31, 21.51. HRMS (ESI-TOF) *m/z* Calcd for $C_{28}H_{25}BrN_4O_2$ $[M-Br]^+$ 449.1972. found 449.1972.

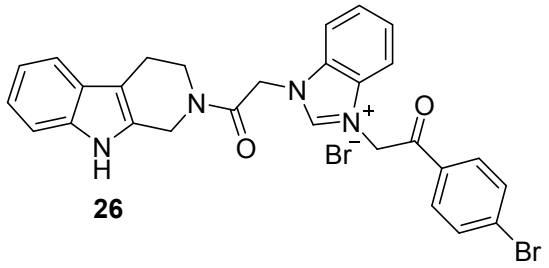


25

3-(2-(4-methoxyphenyl)-2-oxoethyl)-1-(2-oxo-2-(1,3,4,9-tetrahydro-2*H*-pyrido[3,4-*b*]indol-2-yl)ethyl)-1*H*-benzo[*d*]imidazol-3-ium bromide

Yield 88%. Yellow solid. Mp 258-260 °C. IR ν_{max} (cm^{-1}): 3874.29, 3729.79, 3393.09, 3226.77, 3002.79, 2922.01, 2849.00, 2313.76, 1677.56, 1603.84, 1563.77, 1424.79, 1255.33, 1235.52, 1173.63, 1037.62, 978.96, 844.64, 752.82. ^{1}H NMR (400 MHz,

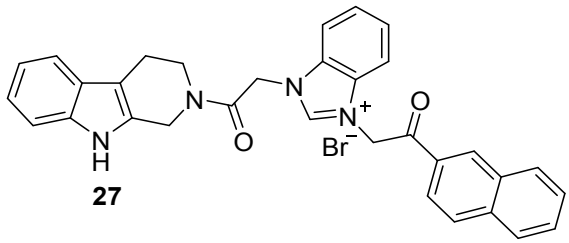
DMSO): δ = 10.99 (1H, d), 9.63 (1H, d), 8.12-8.05 (4H, m), 7.68 (2H, d, J= 8.8 Hz), 7.46 (1H, t), 7.39-7.32 (1H, m), 7.20 (2H, d, J= 8.4 Hz), 7.09 (1H, t), 7.05-6.98 (1H, m), 6.42 (2H, s), 5.95 (2H, d, J= 11.6 Hz), 4.83 (2H, d), 3.96- 3.91 (5H, m), 2.92 (2H, d). ^{13}C NMR (100 MHz, DMSO): δ = 190.31, 165.19, 165.03, 145.67, 137.15, 136.90, 132.66, 132.60, 132.50, 131.84, 131.29, 130.80, 127.62, 127.43, 127.30, 122.06, 121.91, 119.62, 118.57, 115.30, 114.85, 112.08, 108.20, 107.57, 56.79, 53.87, 22.31, 21.52. HRMS (ESI-TOF) *m/z* Calcd for $C_{29}H_{27}BrN_4O_3$ $[M-Br]^+$, 479.2077. found 479.2080. Anal. Cacld for $C_{29}H_{27}BrN_4O_3$: C 62.26, H 4.86, N 10.01; Found: C 62.18, H 4.76, N 10.03.



26

3-(2-(4-bromophenyl)-2-oxoethyl)-1-(2-oxo-2-(1,3,4,9-tetrahydro-2*H*-pyrido[3,4-*b*]indol-2-yl)ethyl)-1*H*-benzo[*d*]imidazol-3-ium bromide

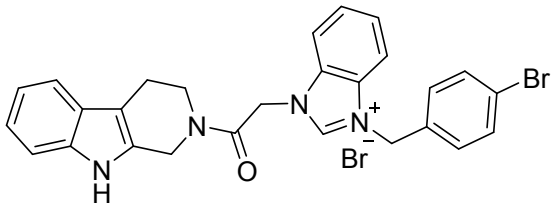
Yield 78%. Yellow solid. Mp 240-242 °C. IR ν_{max} (cm^{-1}): 3873.89, 3729.56, 3386.89, 3253.00, 2991.69, 2923.63, 2810.72, 2717.25, 2314.06, 1918.02, 1695.49, 1663.80, 1575.83, 1480.66, 1430.65, 1231.84, 1074.53, 981.49, 820.60, 752.61, 492.27. ^{1}H NMR (400 MHz, DMSO): δ = 11.01 (1H, d), 9.64 (1H, d), 8.07 (4H, t), 7.91 (2H, d, J= 8.0 Hz), 7.69 (2H, s), 7.45 (1H, t), 7.39-7.31 (1H, m), 7.06 (1H, t, J= 15.6 Hz), 7.00 (1H, t, J= 14.4 Hz), 6.47 (2H, s), 5.98 (2H, d, J= 12.8 Hz), 4.83 (2H, d), 3.92 (2H, d), 2.86 (2H, d). ^{13}C NMR (100 MHz, DMSO): δ = 191.54, 165.24, 165.03, 145.57, 145.47, 137.16, 136.90, 133.83, 133.13, 132.68, 132.61, 132.48, 131.37, 131.30, 130.82, 129.68, 127.66, 127.44, 127.30, 122.06, 121.94, 119.63, 118.59, 115.03, 114.94, 112.10, 108.19, 107.59, 54.35, 22.33, 21.53. HRMS (ESI-TOF) *m/z* Calcd for $C_{28}H_{24}Br_2N_4O_2$ $[M-Br]^+$, 527.1077. found 527.1077.



27

3-(2-(naphthalen-2-yl)-2-oxoethyl)-1-(2-oxo-2-(1,3,4,9-tetrahydro-2*H*-pyrido[3,4-*b*]indol-2-yl)ethyl)-1*H*-benzo[*d*]imidazol-3-ium bromide

Yield 83%. Yellow solid. Mp 270-271 °C. IR ν_{max} (cm^{-1}): 3229.02, 2994.73, 2921.54, 2812.44, 1674,51, 1563.99, 1478.47, 1430.66, 1359.03, 1270.95, 1230.36, 1189.35, 1130.44, 1041.11, 859.37, 814.10, 751.64 . ^{1}H NMR (400 MHz, DMSO): δ = 11.01 (1H, d), 9.71 (1H, d), 8.94 (1H, s), 8.23 (1H, s), 8.17-8.08 (10H, m), 7.73 (1H, t), 7.48-7.34 (1H, m), 7.07 (1H, t, J= 15.2 Hz), 7.00 (1H, t, J= 14.4 Hz), 6.63 (2H, s), 6.00 (2H, d, J= 12.8 Hz), 4.83 (2H, d), 3.93 (2H, d), 2.89 (2H, d). ^{13}C NMR (100 MHz, DMSO): δ = 191.98, 165.21, 165.01, 145.64, 145.54, 137.14, 136.89, 136.52, 132.97, 132.69, 132.62, 132.52, 132.05, 131.81, 131.27, 130.78, 130.64, 130.33, 129.66, 128.86, 128.38, 127.63, 127.42, 127.28, 124.31, 122.01, 121.90, 119.58, 118.53, 114.93, 114.88, 112.05, 108.17, 107.56, 54.34, 22.30, 21.49. HRMS (ESI-TOF) *m/z* Calcd for $C_{32}H_{27}BrN_4O_2$ $[M-Br]^+$, 499.2128. found 499.2128.

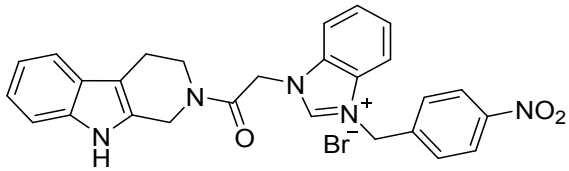


28

3-(4-bromobenzyl)-1-(2-oxo-2-(1,3,4,9-tetrahydro-2*H*-pyrido[3,4-*b*]indol-2-yl)ethyl)-1*H*-benzo[*d*]imidazol-3-ium bromide

Yield 88%. Yellow solid. Mp 272-274 °C. IR ν_{max} (cm^{-1}): 3436.05, 3227.03, 3120.74, 3059.87, 2961.26, 2925.59, 2857.06, 2792.86, 1837.25, 1657.34, 1610.15, 1563.20, 1520.23, 1431.47, 1350.03, 1224.37, 849.46, 802.90, 745.35. ^{1}H NMR (400 MHz, DMSO): δ = 10.99 (1H, d), 9.80 (1H, d, J= 7.2 Hz), 8.06-8.01 (2H, m), 7.68-7.37 (8H, m), 7.33-7.31 (1H, m), 7.07 (1H, t, J= 15.6 Hz), 7.00 (1H, t, J= 14.8 Hz), 5.86 (4H, t, J= 14.8 Hz), 4.81 (2H, d), 3.90 (2H, t), 2.98 (2H, d). ^{13}C NMR (100 MHz, DMSO): δ = 164.76, 164.55, 144.27, 136.63, 136.37, 133.75, 133.70, 132.67, 132.63, 132.49, 131.06, 131.00, 130.81, 130.76, 130.25, 127.33, 127.18, 126.90, 126.77, 122.70, 122.66, 121.55, 121.44, 119.12, 118.05, 114.60, 114.53, 114.27, 111.58, 107.65, 107.03, 49.67, 48.84, 31.17, 21.79, 21.00. HRMS (ESI-TOF) *m/z* Calcd for

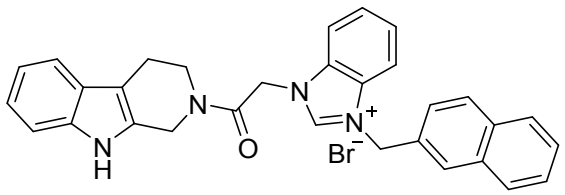
$C_{27}H_{24}Br_2N_4O$ $[M\text{-}Br]^+$ 499.1112. found 499.1113. Anal. Cacld for $C_{27}H_{24}Br_2N_4O$: C 55.88, H 4.17, N 9.65; Found: C 55.56, H 4.10, N 9.76.



29

3-(4-nitrobenzyl)-1-(2-oxo-2-(1,3,4,9-tetrahydro-2*H*-pyrido[3,4-*b*]indol-2-yl)ethyl)-1*H*-benzo[*d*]imidazol-3-ium bromide

Yield 82%. Yellow solid. Mp 279-280 °C. IR ν_{max} (cm^{-1}): 3436.05, 3227.03, 3120.74, 3059.87, 2961.26, 2925.59, 2857.06, 2792.86, 1837.25, 1657.34, 1610.15, 1563.20, 1520.23, 1431.47, 1350.03, 1224.37, 849.46, 802.90, 745.35, 657.30 . ^{1}H NMR (400 MHz, DMSO): δ = 11.00 (1H, d), 9.90 (1H, d, J= 8.4 Hz), 8.29 (2H, d, J= 4.8 Hz), 8.09 (1H, d, J= 6.8 Hz), 7.98 (1H, t, J= 13.6 Hz), 7.76-7.67 (4H, m), 7.46 (1H, t), 7.33 (1H, d, J= 7.6 Hz), 7.07 (1H, t), 7.00 (1H, t, J= 14.8 Hz), 6.07 (2H, s), 5.91 (2H, d, J= 11.2 Hz), 4.83 (2H, d), 3.96-3.90 (2H, m), 2.99 (2H, d). ^{13}C NMR (100 MHz, DMSO): δ = 164.73, 164.53, 148.11, 144.69, 141.80, 141.74, 136.66, 136.39, 132.69, 132.64, 130.83, 130.80, 130.76, 130.26, 129.85, 129.78, 127.41, 127.31, 126.91, 126.79, 124.58, 121.55, 121.44, 119.12, 118.04, 114.71, 114.63, 114.20, 111.58, 107.66, 107.04, 49.55, 48.94, 21.82, 21.01. HRMS (ESI-TOF) *m/z* Calcd for $C_{27}H_{24}BrN_5O_3$ $[M\text{-}Br]^+$ 466.1873. found 466.1871.

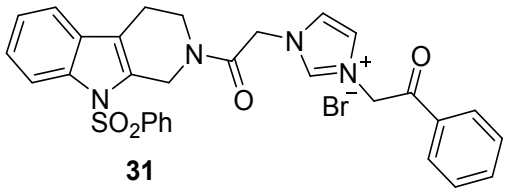


30

3-(naphthalen-2-ylmethyl)-1-(2-oxo-2-(1,3,4,9-tetrahydro-2*H*-pyrido[3,4-*b*]indol-2-yl)ethyl)-1*H*-benzo[*d*]imidazol-3-ium bromide

Yield 76%. Yellow solid. Mp 272-273 °C. IR ν_{max} (cm^{-1}): 3703.56, 3274.28, 3116.03, 3056.46, 2972.08, 2927.07, 2860.44, 2314.51, 1955.55, 1922.65, 1828.18, 1655.36, 1559.56, 1431.58, 1370.52, 1321.18, 1179.82, 860.11, 818.21, 744.11, 474.59. ^{1}H NMR (400 MHz, DMSO): δ = 11.07-10.93 (1H, d), 9.91-9.88 (1H, d), 8.12-7.93 (7H, m), 7.68-7.56 (6H, m), 7.47-7.32 (2H, m), 6.06-6.04 (2H, d), 5.93-5.90 (2H, d), 4.90-4.75 (2H, d), 3.94-3.89 (2H, t), 2.98-2.76 (2H, d). ^{13}C NMR (100 MHz, DMSO): δ =

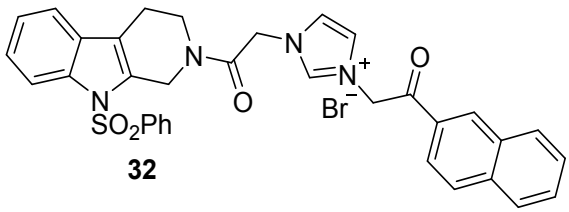
165.30, 165.08, 144.81, 137.14, 136.84, 133.70, 133.65, 133.17, 132.21, 131.47, 131.25, 129.86, 128.80, 128.65, 128.58, 127.76, 127.62, 126.54, 122.00, 121.89, 119.58, 118.51, 115.02, 114.82, 112.05, 108.13, 107.52, 51.07, 49.38, 49.17, 43.91, 43.22, 40.86, 40.66, 40.45, 40.24, 40.03, 22.29, 21.47. HRMS (ESI-TOF) *m/z* Calcd for $C_{31}H_{27}BrN_4O$ $[M\text{-}Br]^+$ 471.2179. found 471.2176.



31

1-(2-oxo-2-(9-(phenylsulfonyl)-1,3,4,9-tetrahydro-2*H*-pyrido[3,4-*b*]indol-2-yl)ethyl)-3-(2-oxo-2-phenylethyl)-1*H*-imidazol-3-ium bromide

Yield 89%. Yellow solid. Mp 222-223 °C. IR ν_{max} (cm^{-1}): 3873.54, 3729.78, 3396.85, 3359.58, 3149.29, 3094.30, 3055.49, 2973.11, 2933.63, 2314.14, 2009.53, 1934.15, 1897.58, 1803.97, 1758.75, 1692.11, 1653.28, 1568.79, 1412.74, 1367.21, 1301.87, 1226.12, 1176.29, 995.51, 964.07, 793.55, 755.22, 678.68, 603.14, 565.09. ^{1}H NMR (400 MHz, DMSO): δ = 9.11 (1H, s), 8.09-8.03 (4H, m), 7.91 (1H, d, J= 7.6 Hz), 7.79 (3H, d, J= 9.6 Hz), 7.69-7.53 (6H, m), 7.37-7.31 (2H, m), 6.18 (2H, s), 5.71 (2H, d), 5.08 (2H, s), 3.86 (2H, s), 2.91 (1H, s), 2.08 (1H, s). ^{13}C NMR (100 MHz, DMSO): δ = 191.77, 165.18, 139.10, 137.46, 135.56, 135.26, 134.97, 134.20, 131.08, 130.47, 129.57, 129.47, 128.63, 127.18, 126.80, 125.46, 124.41, 124.32, 123.91, 119.46, 117.93, 114.21, 56.06, 51.02, 31.17, 21.72. HRMS (ESI-TOF) *m/z* Calcd for $C_{30}H_{27}BrN_4O_4S$ $[M\text{-}Br]^+$ 539.1747. found 539.1746. Anal. Cacld for $C_{30}H_{27}BrN_4O_4S$: C 58.16, H 4.39, N 9.04; Found: C 58.60, H 4.39, N 9.12.

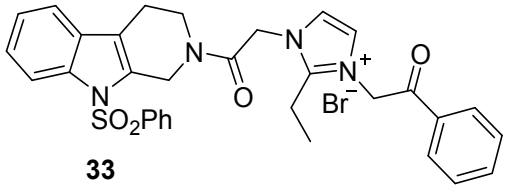


32

3-(2-(naphthalen-2-yl)-2-oxoethyl)-1-(2-oxo-2-(9-(phenylsulfonyl)-1,3,4,9-tetrahydro-2*H*-pyrido[3,4-*b*]indol-2-yl)ethyl)-1*H*-imidazol-3-ium bromide

Yield 86%. Yellow solid. Mp 195-196 °C. IR ν_{max} (cm^{-1}): 3470.30, 3392.33, 3161.56, 3122.50, 3066.33, 3000.48, 2968.98, 2911.92, 2407.12, 2387.40, 2314.59, 1919.57, 1700.57, 1659.42, 1564.70, 1439.46, 1366.77, 1221.92, 1178.35, 798.89, 753.45,

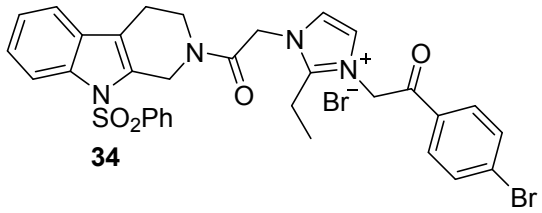
689.59, 602.83, 563.66, 484.63. ^{1}H NMR (400 MHz, DMSO): δ = 8.22 (1H, d, J= 8.0 Hz), 8.15 (1H, d, J= 8.0 Hz), 8.09-8.03 (5H, m), 7.99-7.90 (5H, m), 7.64-7.51 (3H, m), 7.38 (1H, t, J= 15.2 Hz), 7.31 (1H, t, J= 14.0 Hz), 6.29 (2H, s), 5.76-5.65 (2H, m), 5.09 (2H, s), 3.91-3.85 (2H, m), 2.91 (2H, d). ^{13}C NMR (100 MHz, DMSO): δ = 191.67, 165.20, 139.16, 137.48, 136.00, 135.56, 135.27, 132.51, 131.51, 131.09, 130.94, 130.14, 129.82, 129.47, 129.27, 128.37, 127.89, 126.80, 125.47, 124.41, 123.97, 123.67, 119.46, 117.91, 114.22, 56.08, 51.02, 21.72. HRMS (ESI-TOF) *m/z* Calcd for $C_{34}H_{29}BrN_4O_4S$ $[M-Br]^+$ 589.1904. found 589.1904.



33

2-ethyl-1-(2-oxo-2-(9-(phenylsulfonyl)-1,3,4,9-tetrahydro-2*H*-pyrido[3,4-*b*]indol-2-yl)ethyl)-3-(2-oxo-2-phenylethyl)-1*H*-imidazol-3-ium bromide

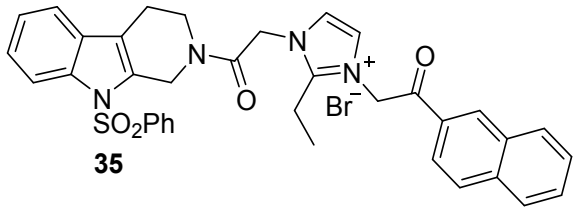
Yield 86%. Yellow solid. Mp 272-273 °C. IR ν_{max} (cm^{-1}): 3833.26, 3729.72, 3643.81, 3395.33, 3176.84, 3137.42, 3057.15, 3044.79, 2975.39, 2925.05, 2666.32, 2386.47, 2314.07, 1955.94, 1907.55, 1759.04, 1690.49, 1652.76, 1522.40, 1450.92, 1415.38, 1368.82, 1232.28, 1178.60, 960.99. 888.28, 757.16, 683.78, 601.26, 563.63. ^{1}H NMR (400 MHz, DMSO): δ = 8.10 (2H, d, J= 7.2 Hz), 8.03 (1H, t, J= 14.8 Hz), 7.90 (1H, d, J= 7.6 Hz), 7.78 (1H, d, J= 7.2 Hz), 7.71-7.54 (9H, m), 7.38-7.29 (2H, m), 6.14 (2H, s), 5.64 (2H, d, J= 13.6 Hz), 5.08 (2H, d, J= 9.6 Hz), 3.87 (2H, d, J= 5.2 Hz), 3.02 (2H, d, J= 7.6 Hz), 2.93 (2H, s), 1.04 (3H, t, J= 15.2 Hz). ^{13}C NMR (100 MHz, DMSO): δ = 191.98, 165.02, 150.64, 137.44, 135.59, 135.25, 135.01, 134.23, 130.98, 130.44, 129.47, 128.86, 127.15, 126.79, 125.48, 124.44, 123.57, 123.14, 119.46, 117.97, 114.26, 54.96, 21.70, 16.48, 11.83, 77.76. HRMS (ESI-TOF) *m/z* Calcd for $C_{32}H_{30}BrN_4O_4S$ $[M-Br]^+$ 567.2060. found 567.2060. Anal. Cacld for $C_{32}H_{31}BrN_4O_4S$: C 59.35, H 4.83, N 8.65; Found: C 59.50, H 4.58, N 8.62.



34

3-(2-(4-bromophenyl)-2-oxoethyl)-2-ethyl-1-(2-oxo-2-(9-(phenylsulfonyl)-1,3,4,9-tetrahydro-2*H*-pyrido[3,4-*b*]indol-2-yl)ethyl)-1*H*-imidazol-3-ium bromide

Yield 89%. Yellow solid. Mp 279-280 °C. IR ν_{max} (cm^{-1}): 3369.77, 3137.68, 3055.29, 3023.94, 2976.87, 2936.13, 1940.53, 1695.79, 1653.20, 1578.64, 1521.15, 1451.09, 1412.19, 1367.01, 1223.09, 1177.02, 1077.14, 1059.07, 996.87, 959.62, 882.71, 823.75, 756.99, 672.12, 599.95, 561.05. ^{1}H NMR (400 MHz, DMSO): δ = 8.04-7.88 (7H, m), 7.71-7.53 (6H, m), 7.39-7.29 (2H, m), 6.11 (2H, s), 5.63 (2H, d, J= 14.4 Hz), 5.08 (2H, d, J= 9.2 Hz), 3.87 (2H, d, J= 5.2 Hz), 3.01 (2H, d, J= 7.2 Hz), 2.93 (2H, s), 1.03 (3H, t). ^{13}C NMR (100 MHz, DMSO): δ = 191.37, 165.00, 150.66, 137.44, 135.59, 135.25, 133.32, 132.54, 130.98, 130.81, 130.44, 129.49, 129.11, 127.14, 126.78, 125.48, 124.44, 123.59, 123.10, 119.46, 117.96, 114.26, 54.88, 49.86, 21.70, 16.47, 11.85, 11.78. HRMS (ESI-TOF) *m/z* Calcd for $C_{32}H_{30}Br_2N_4O_4S$ $[M\text{-}Br]^+$ 645.1165. found 645.1164. Anal. Cacld for $C_{32}H_{30}Br_2N_4O_4S$: C 52.91, H 4.16, N 7.71; Found: C 52.75, H 4.26, N 7.90.

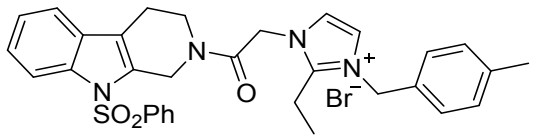


35

2-ethyl-3-(2-(naphthalen-2-yl)-2-oxoethyl)-1-(2-oxo-2-(9-(phenylsulfonyl)-1,3,4,9-tetrahydro-2*H*-pyrido[3,4-*b*]indol-2-yl)ethyl)-1*H*-imidazol-3-ium bromide

Yield 78%. Yellow solid. Mp 273-274 °C. IR ν_{max} (cm^{-1}): 3399.10, 3053.33, 3047.20, 3018.90, 2926.89, 2358.20, 2314.82, 1931.80, 1783.96, 1691.05, 1654.22, 1584.53, 1523.44, 1461.05, 1373.80, 1222.50, 1180.27, 1086.23, 957.33, 755.42, 677.71, 604.22, 561.60. ^{1}H NMR (400 MHz, DMSO): δ = 8.86 (1H, s), 8.21 (1H, d, J= 8 Hz), 8.15 (1H, d, J= 8.4 Hz), 8.09-7.89 (5H, m), 7.73-7.54 (8H, m), 6.26 (2H, s), 5.64 (2H, d), 5.08 (2H, s), 3.78 (2H, s), 3.06 (2H, s), 2.93 (2H, s), 1.10-1.05 (3H, m). ^{13}C NMR (100 MHz, DMSO): δ = 191.88, 165.03, 150.68, 137.45, 136.01, 135.59, 135.26, 132.45, 131.57, 131.22, 130.99, 130.45, 130.11, 129.83, 129.49, 129.14, 128.38, 127.91, 127.14, 126.79, 125.50, 124.44, 123.85, 123.62, 123.21, 119.47, 117.96,

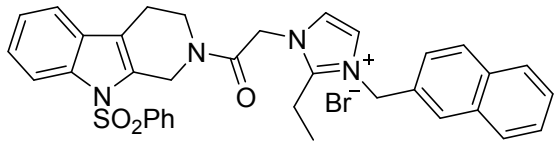
114.27, 54.96, 49.85, 21.70. 16.50, 11.80. HRMS (ESI-TOF) *m/z* Calcd for $C_{36}H_{33}BrN_4O_4S$ $[M\text{-}Br]^+$ 617.2217. found 617.2216.



36

2-ethyl-3-(4-methylbenzyl)-1-(2-oxo-2-(9-(phenylsulfonyl)-1,3,4,9-tetrahydro-2*H*-pyrido[3,4-*b*]indol-2-yl)ethyl)-1*H*-imidazol-3-ium bromide

Yield 81%. Yellow solid. Mp 244-245 °C. IR ν_{max} (cm^{-1}): 3729.06, 3631.84, 3392.44, 3162.53, 3088.99, 3051.37, 2981.70, 2933.56, 2860.48, 2387.69, 2315.06, 1905.57, 1793.26, 1662.77, 1579.47, 1512.96, 1435.32, 1412.93, 1369.44, 1300.47, 1222.29, 1177.77, 1152.43, 963.10, 821.85, 754.52, 691.60, 606.20, 588.19, 566.29, 489.54. ^{1}H NMR (400 MHz, DMSO): δ = 8.01-7.85 (3H, m), 7.70-7.49 (6H, m), 7.35-7.22 (6H, m), 5.50 (4H, t), 5.04 (2H, d, J= 9.6 Hz), 3.86-3.81 (2H, m), 3.13-3.01 (2H, m), 2.69 (2H, s), 2.31 (3H, s). ^{13}C NMR (100 MHz, DMSO): δ = 165.69, 150.48, 150.31, 139.29, 139.24, 138.25, 138.19, 136.40, 135.85, 135.79, 132.78, 131.63, 131.37, 131.02, 130.99, 130.73, 130.22, 130.12, 128.75, 128.66, 127.76, 127.45, 126.09, 125.07, 124.55, 124.43, 122.69, 120.03, 119.43, 118.64, 114.98, 80.33, 80.00, 79.67, 22.33, 21.68, 21.60, 17.46, 12.18, 12.09. HRMS (ESI-TOF) *m/z* Calcd for $C_{32}H_{33}BrN_4O_3S$ $[M\text{-}Br]^+$ 553.2267. found 553.2265. Anal. Cacld for $C_{32}H_{33}BrN_4O_3S$: C 60.66, H 5.25, N 8.84; Found: C 60.50, H 5.09, N 9.02.

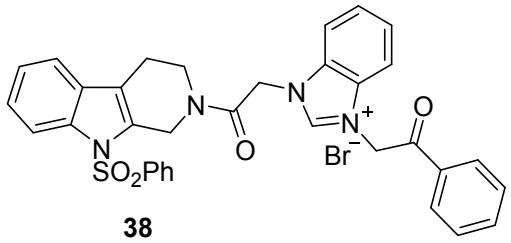


37

2-ethyl-3-(naphthalen-2-ylmethyl)-1-(2-oxo-2-(9-(phenylsulfonyl)-1,3,4,9-tetrahydro-2*H*-pyrido[3,4-*b*]indol-2-yl)ethyl)-1*H*-imidazol-3-ium bromide

Yield 87%. Yellow solid. Mp 253-254 °C. IR ν_{max} (cm^{-1}): 3873.86, 3729.92, 3579.06, 3401.33, 3146.73, 3037.64, 3036.41, 2996.52, 2946.23, 2904.79, 2660.03, 2536.06, 2314.30, 1948.99, 1810.66, 1757.68, 1661.31, 518.44, 1440.92, 1363.44, 1215.85, 1179.70, 874.86, 753.70, 602.31, 564.49, 483.68. ^{1}H NMR (400 MHz, DMSO): δ = 8.01-7.83 (8H, m), 7.69-7.45 (8H, m), 7.37-7.28 (2H, m), 5.70 (2H, s), 5.58 (2H, d), 5.06 (2H, d, J= 10.4 Hz), 3.84 (2H, s), 3.10 (2H, d, J= 6.8 Hz), 2.91 (2H, s), 1.03-0.95

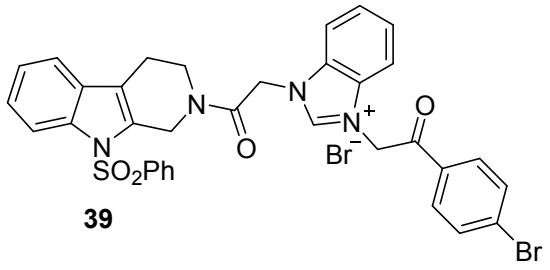
(3H, m). ^{13}C NMR (100 MHz, DMSO): δ = 165.05, 149.81, 137.42, 135.58, 135.21, 133.20, 133.08, 132.72, 130.95, 130.44, 130.39, 129.48, 129.35, 128.27, 127.31, 127.23, 127.12, 126.92, 126.77, 125.60, 125.49, 124.43, 124.01, 122.23, 119.45, 117.95, 114.26, 51.35, 49.80, 21.66, 16.81, 11.73, 11.61. HRMS (ESI-TOF) *m/z* Calcd for $C_{35}H_{33}BrN_4O_3S$ $[M+1]^+$ 589.2267. found 589.2267.



38

1-(2-oxo-2-(9-(phenylsulfonyl)-1,3,4,9-tetrahydro-2*H*-pyrido[3,4-*b*]indol-2-yl)ethyl)-3-(2-oxo-2-phenylethyl)-1*H*-benzo[*d*]imidazol-3-ium bromide

Yield 86%. Yellow solid. Mp 200-201 °C. IR ν_{max} (cm^{-1}): 3611.88, 3399.75, 3014.40, 2967.24, 2920.78, 2315.42, 1816.28, 1698.03, 1657.45, 1566.02, 1483.95, 1441.11, 1372.90, 1299.79, 1228.24, 1181.92, 1152.37, 1088.37, 992.59, 960.65, 893.04, 755.05, 683.31, 602.66, 588.05, 565.04. ^{1}H NMR (400 MHz, DMSO): δ = 8.05-7.8 (9H,m), 7.57 (6H, t), 7.46 (2H, s), 7.36-7.28 (2H,m), 5.96 (4H, s), 5.18-5.08 (2H, m), 3.97 (1H, s), 3.31 (1H, d, J=7.6 Hz), 2.78 (2H, s). ^{13}C NMR (100 MHz, DMSO): δ = 164.59, 138.32, 136.19, 134.93, 134.78, 133.72, 133.57, 131.36, 130.77, 130.62, 130.24, 130.10, 129.89, 129.57, 128.52, 128.29, 127.68, 127.58, 127.45, 127.09, 126.84, 125.84, 125.50, 124.42, 119.16, 117.64, 114.64, 114.51, 114.14, 51.51, 49.32, 49.11, 49.01, 48.90, 48.82, 48.69, 48.47, 22.30, 21.31. HRMS (ESI-TOF) *m/z* Calcd for $C_{34}H_{29}BrN_4O_4S$ $[M-Br]^+$ 639.1904. found 639.1903.

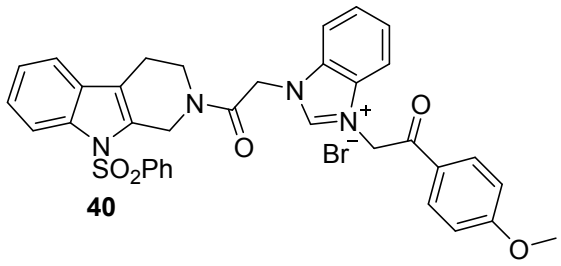


39

3-(2-(4-bromophenyl)-2-oxoethyl)-1-(2-oxo-2-(9-(phenylsulfonyl)-1,3,4,9-tetrahydro-2*H*-pyrido[3,4-*b*]indol-2-yl)ethyl)-1*H*-benzo[*d*]imidazol-3-ium bromide

Yield 75%. Yellow solid. Mp 197-198 °C. IR ν_{max} (cm^{-1}): 3874.44, 3729.21, 3390.00, 3052.81, 3015,65, 2967.72, 2922.05, 2672.15, 2587.67, 2314.31, 1953.03, 1920.51,

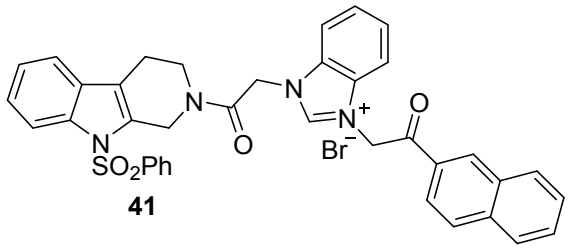
1810.95, 1698.58, 1656.15, 1575.20, 1484.00, 1440.11, 1370.22, 1228.38, 1181.09, 1080.47, 993.52, 894.09, 823.86, 755.78, 690.05, 603.01, 587.87, 564.12. ^{1}H NMR (400 MHz, DMSO): δ = 9.64 (1H, t), 8.11-8.03 (6H, m), 7.93-7.88 (3H, m), 7.71-7.56 (6H, m), 7.38-7.32 (2H, m), 6.47 (2H, s), 5.98 (2H, s), 5.13 (2H, d), 3.95 (2H, s), 3.38 (3H, d, J= 11.6 Hz), 2.98 (2H, s). ^{13}C NMR (100 MHz, DMSO): δ = 164.77, 145.04, 137.49, 135.60, 135.24, 133.34, 132.62, 132.09, 131.98, 130.97, 130.84, 130.44, 129.48, 129.17, 127.15, 126.78, 125.47, 124.41, 119.47, 117.95, 114.49, 114.42, 114.23, 79.79, 79.46, 79.13, 67.48, 60.21, 25.59, 21.75, 14.55. HRMS (ESI-TOF) *m/z* Calcd for $C_{34}H_{28}Br_2N_4O_4S$ $[M\text{-}Br]^+$ 667.1009. found 667.1010. Anal. Cacld for $C_{34}H_{28}Br_2N_4O_4S$: C 54.56, H 3.77, N 7.49; Found: C 54.05, H 3.85, N 7.60.



40

3-(2-(4-methoxyphenyl)-2-oxoethyl)-1-(2-oxo-2-(9-(phenylsulfonyl)-1,3,4,9-tetrahydro-2*H*-pyrido[3,4-*b*]indol-2-yl)ethyl)-1*H*-benzo[*d*]imidazol-3-ium bromide

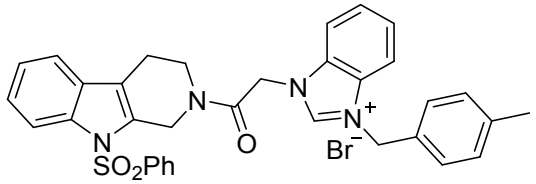
Yield 89%. Yellow solid. Mp 209-210 °C. IR ν_{max} (cm^{-1}): 3397.65, 3126.41, 3010.29, 2973.73, 2933.01, 2846.23, 1811.70, 1697.41, 1656.47, 1606.07, 1564.15, 1519.44, 1440.62, 1419.28, 1375.46, 1259.06, 1232.07 , 1180.69, 1086.02, 1031.74, 895.31, 845.57, 756.66, 566.52. ^{1}H NMR (400 MHz, DMSO): δ = 9.65 (1H, d), 8.13-8.03 (6H, m), 7.89 (1H, d, J= 7.6 Hz), 7.73-7.54 (6H, m), 7.40-7.30 (2H, m), 7.20 (2H, d, J= 8.8 Hz), 6.45 (2H, s), 6.02 (2H, d), 5.14 (2H, d), 3.94 (3H, d), 2.99 (2H, s), 2.08 (2H, s). ^{13}C NMR (100 MHz, DMSO): δ = 189.83, 164.80, 164.68, 145.09, 137.44, 135.64, 135.57, 135.27, 132.22, 132.09, 132.01, 131.36, 130.97, 130.77, 130.46, 129.49, 127.14, 127.07, 126.79, 125.49, 124.43, 119.49, 117.97, 114.80, 114.48, 114.36, 114.23, 56.29, 53.43, 48.78, 31.17, 21.75. HRMS (ESI-TOF) *m/z* Calcd for $C_{35}H_{31}BrN_4O_5S$ $[M\text{-}Br]^+$ 619.2009. found 619.2008. Anal. Cacld for $C_{35}H_{31}BrN_4O_5S$: C 60.09, H 4.47, N 8.01; Found: C 60.08, H 4.34, N 8.20.



41

3-(2-(naphthalen-2-yl)-2-oxoethyl)-1-(2-oxo-2-(9-(phenylsulfonyl)-1,3,4,9-tetrahydro-2*H*-pyrido[3,4-*b*]indol-2-yl)ethyl)-1*H*-benzo[*d*]imidazol-3-ium bromide

Yield 77%. Yellow solid. Mp 214-215 °C. IR ν_{max} (cm^{-1}): 3729.41, 3378.09, 3062.82, 3051.26, 3019.38, 2980.10, 2928.76, 2667.24, 2386.34, 2313.55, 1926.53, 1809.47, 1696.56, 1658.33, 1621.81, 1563.70, 1482.29, 1439.78, 1367.69, 1224.74, 1179.81, 1087.08, 995.03, 754.82, 690.01, 604.36, 587.74, 566.11. ^{1}H NMR (400 MHz, DMSO): δ = 9.68 (1H, d), 8.93 (1H, s), 8.25-8.03 (8H, m), 7.90-7.54 (10H, m), 7.40-7.30 (2H, m), 6.36 (2H, s), 6.03 (2H, d), 5.14 (2H, d), 3.93 (2H, d), 2.99 (2H,s). ^{13}C NMR (100 MHz, DMSO): δ = 191.98, 165.27, 137.95, 136.52, 136.06, 135.73, 132.97, 132.61, 132.53, 132.05, 131.45, 130.93, 129.96, 129.68, 128.86, 128.39, 127.62, 127.26, 125.96, 124.89, 124.31, 119.96, 118.43, 114.98, 114.71, 54.34, 49.28, 22.22. HRMS (ESI-TOF) *m/z* Calcd for $C_{38}H_{31}BrN_4O_4S$ $[M-Br]^+$ 639.2060. found 639.2058. Anal. Cacld for $C_{35}H_{31}BrN_4O_5S$: C 60.09, H 4.47, N 8.01; Found: C 60.08, H 4.34, N 8.20.

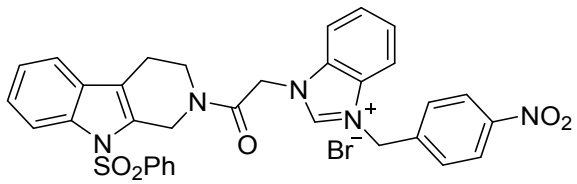


42

3-(4-methylbenzyl)-1-(2-oxo-2-(9-(phenylsulfonyl)-1,3,4,9-tetrahydro-2*H*-pyrido[3,4-*b*]indol-2-yl)ethyl)-1*H*-benzo[*d*]imidazol-3-ium bromide

Yield 84%. Yellow solid. Mp 290-291 °C. IR ν_{max} (cm^{-1}): 3874.15, 3832.88, 3729.67, 3393.33, 3134.04, 3077.05, 3066.32, 3021.59, 2924.11, 2410.07, 2314.50, 2009.68, 1907.43, 1819.17, 1782.54, 1664.02, 1567.21, 1439.56, 1421.17, 1369.17, 1351.67, 1297.92, 1265.57, 1228.37, 1177.30, 1163.18, 1086.99, 962.87, 784.34, 728.86, 683.47, 605.03, 565.05. ^{1}H NMR (400 MHz, DMSO): δ = 9.81 (1H, s), 8.04 (4H, t), 7.88 (1H, d), 7.34-7.24 (12H, m), 5.96-5.83 (4H, m), 5.12 (2H, d), 3.91 (2H, d), 2.97 (2H, s), 2.29 (3H, s). ^{13}C NMR (100 MHz, DMSO): δ = 164.88, 144.00, 138.81, 137.44, 135.58, 135.24, 132.65, 131.27, 130.98, 130.88, 130.43, 130.09, 129.47,

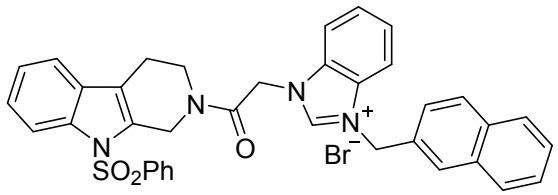
128.87, 128.79, 127.24, 126.80, 125.48, 124.42, 119.48, 117.95, 114.55, 114.37, 114.23, 50.22, 48.65, 21.75, 21.19. HRMS (ESI-TOF) *m/z* Calcd for $C_{34}H_{31}BrN_4O_3S$ $[M\text{-}Br]^+$ 575.2111. found 575.2113. Anal. Cacld for $C_{34}H_{31}BrN_4O_3S$: C 62.29, H 4.77, N 8.55; Found: C 62.05, H 4.37, N 8.62.



43

3-(4-nitrobenzyl)-1-(2-oxo-2-(9-(phenylsulfonyl)-1,3,4,9-tetrahydro-2*H*-pyrido[3,4-*b*]indol-2-yl)ethyl)-1*H*-benzo[*d*]imidazol-3-ium bromide

Yield 86%. Yellow solid. Mp 272-273 °C. IR ν_{max} (cm^{-1}): 3873.55, 3832.65, 3729.61, 3105.66, 3026.50, 2982.57, 2907.93, 2846.96, 2750.14, 2670.88, 2601.40, 2452.74, 2390.21, 2314.20, 1997.64, 1921.28, 1796.87, 1650.10, 1610.43, 1560.29, 1521.44, 1417.55, 1377.58, 1352.51, 1226.03, 1178.17, 1156.04, 965.82, 855.20, 800.33, 754.71, 715.41, 681.23, 601.98, 562.41. ^{1}H NMR (400 MHz, DMSO): δ = 7.94-7.88 (1H, m), 7.81-7.76 (4H, m), 7.63-7.29 (8H, m), 7.27-7.19 (2H, m), 5.92 (2H, s), 5.09 (2H, s), 4.56 (2H, s), 3.91 (2H, t, J=11.6 Hz), 2.91 (2H, s). ^{13}C NMR (100 MHz, DMSO): δ = 166.55, 150.48, 142.82, 142.78, 139.94, 138.12, 136.60, 136.47, 134.78, 133.06, 132.54, 131.78, 131.69, 131.55, 131.26, 131.20, 129.51, 129.46, 129.36, 128.74, 128.54, 127.17, 127.05, 126.27, 126.10, 120.89, 120.80, 119.81, 116.25, 116.14, 115.96, 115.63, 23.53. HRMS (ESI-TOF) *m/z* Calcd for $C_{33}H_{28}BrN_5O_5S$ $[M\text{-}Br]^+$ 606.1805. found 606.1803.

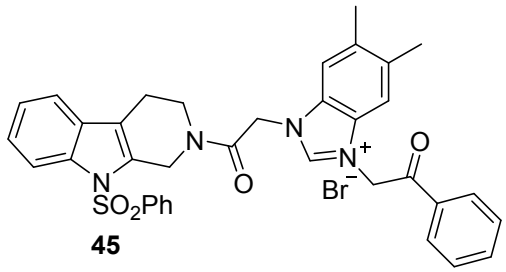


44

3-(naphthalen-2-ylmethyl)-1-(2-oxo-2-(9-(phenylsulfonyl)-1,3,4,9-tetrahydro-2*H*-pyrido[3,4-*b*]indol-2-yl)ethyl)-1*H*-benzo[*d*]imidazol-3-ium bromide

Yield 72%. Yellow solid. Mp 136-137 °C. IR ν_{max} (cm^{-1}): 3874.14, 3832.84, 3729.56, 3601.40, 3388.56, 3132.48, 2976.93, 2902.35, 2386.58, 2314.99, 2255.34, 2187.56, 1915.46, 1817.10, 1795.15, 1700.69, 1660.57, 1563.29, 1439.36, 1368.17, 1226.34, 1179.47, 1084.82, 957.64, 752.69, 718.07, 681.37, 602.30, 588.21, 563.07. ^{1}H NMR

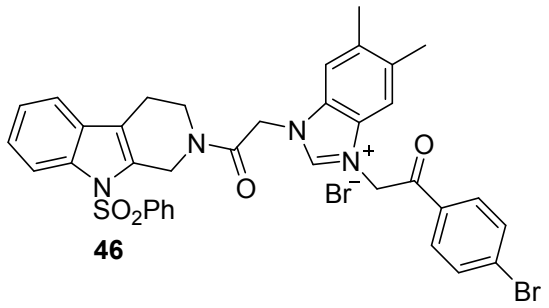
(400 MHz, DMSO): δ = 10.41 (1H, s), 8.00-7.95 (5H, m), 7.78 (2H, s), 7.50-7.18 (13H, m), 6.35 (2H, d), 6.11 (2H, s), 3.81 (2H, d), 2.94-2.85 (2H, m). ^{13}C NMR (100 MHz, DMSO): δ = 189.92, 163.84, 162.53, 143.92, 137.92, 135.88, 134.73, 133.95, 133.29, 131.93, 131.33, 129.83, 129.72, 129.46, 129.21, 129.08, 128.55, 127.19, 127.08, 126.99, 126.82, 126.34, 124.97, 124.81, 123.79, 118.81, 118.68, 117.33, 114.38, 114.05, 113.88, 113.17, 112.96, 53.59, 49.45, 49.13, 43.97, 42.68, 42.17, 39.71, 36.46, 31.41, 30.91, 22.10, 20.59. HRMS (ESI-TOF) *m/z* Calcd for $C_{37}H_{31}BrN_4O_3S$ $[M\text{-}Br]^+$ 611.2073. found 611.2073.



45

5,6-dimethyl-1-(2-oxo-2-(9-(phenylsulfonyl)-1,3,4,9-tetrahydro-2*H*-pyrido[3,4-*b*]indol-2-yl)ethyl)-3-(2-oxo-2-phenylethyl)-1*H*-benzo[*d*]imidazol-3-ium bromide

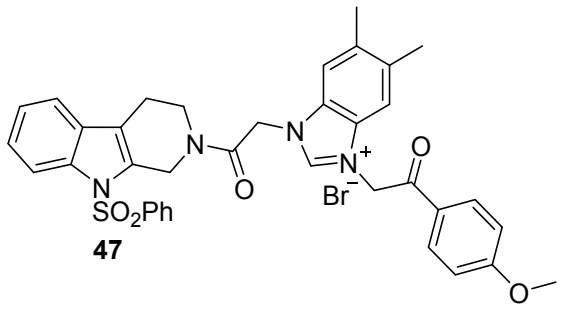
Yield 91%. Yellow solid. Mp 239-240 °C. IR ν_{max} (cm^{-1}): 3729.60, 3390.26, 3121.27, 3055.00, 3007.50, 2974.01, 2901.43, 2410.55, 2314.60, 1961.08, 1913.30, 1791.30, 1703.27, 1700.74, 1658.66, 1564.82, 1443.25, 1378.63, 1223.38, 1180.06, 962.61, 880.94, 796.83, 756.58, 692.09, 605.72, 563.76. ^{1}H NMR (400 MHz, DMSO): δ = 8.12-7.95 (3H, m), 7.85-7.75 (2H, m), 7.68-7.55 (7H, m), 7.50-7.30 (5H, m), 5.17 (2H, s), 4.01 (2H, t, J= 11.6 Hz), 3.34 (3H, s), 3.01 (2H, s), 2.44 (6H, s). ^{13}C NMR (100 MHz, DMSO): δ = 192.71, 166.73, 140.03, 139.66, 138.32, 136.67, 136.39, 136.22, 136.08, 132.75, 132.61, 132.39, 131.62, 131.59, 131.46, 131.08, 130.40, 128.64, 128.45, 126.89, 125.99, 120.72, 120.61, 119.83, 116.26, 115.08, 114.93, 23.52, 21.36, 21.33. HRMS (ESI-TOF) *m/z* Calcd for $C_{36}H_{33}BrN_4O_4S$ $[M\text{-}Br]^+$ 617.2217. found 617.2216.



46

3-(2-(4-bromophenyl)-2-oxoethyl)-5,6-dimethyl-1-(2-oxo-2-(9-(phenylsulfonyl)-1,3,4,9-tetrahydro-2*H*-pyrido[3,4-*b*]indol-2-yl)ethyl)-1*H*-benzo[*d*]imidazol-3-ium bromide

Yield 88%. Yellow solid. Mp 250-252 °C. IR ν_{max} (cm^{-1}): 3729.23, 3397.11, 3127.34, 3055.27, 2943.04, 2784.12, 2580.89, 2314.22, 1913.09, 1794.21, 1702.52, 1661.33, 1575.12, 1484.52, 1441.25, 1226.07, 1179.79, 1007.36, 963.16, 828.57, 755.75, 606.68, 564.11. ^{1}H NMR (400 MHz, DMSO): δ = 9.47 (1H, s), 8.05 (4H, t), 7.92-7.84 (5H, m), 7.73-7.40 (4H, m), 7.38-7.30 (2H, m), 6.41 (2H, s), 5.94 (2H, d), 5.12 (2H, d), 3.91 (2H, t), 2.98 (2H, s), 2.41 (6H,d). ^{13}C NMR (100 MHz, DMSO): δ = 191.04, 164.84, 143.77, 137.46, 137.37, 136.85, 136.57, 135.25, 133.34, 132.60, 130.98, 130.83, 130.62, 130.48, 130.45, 129.47, 129.13, 127.16, 126.79, 125.47, 124.42, 119.48, 118.69, 117.95, 114.23, 113.84, 79.80, 79.46, 79.13, 53.70, 31.17, 21.74, 20.45. HRMS (ESI-TOF) *m/z* Calcd for $C_{36}H_{32}Br_2N_4O_4S$ $[M-Br]^+$ 695.1322. found 695.1324.

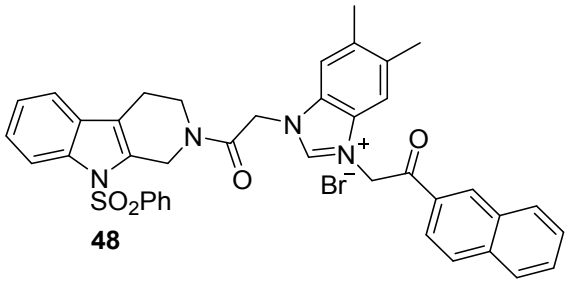


47

3-(2-(4-methoxyphenyl)-2-oxoethyl)-5,6-dimethyl-1-(2-oxo-2-(9-(phenylsulfonyl)-1,3,4,9-tetrahydro-2*H*-pyrido[3,4-*b*]indol-2-yl)ethyl)-1*H*-benzo[*d*]imidazol-3-ium bromide

Yield 90%. Yellow solid. Mp 244-245 °C. IR ν_{max} (cm^{-1}): 3407.32, 3128.16, 3054.10, 2914.73, 2784.27, 1663.66, 1604.87, 1664.90, 1372.20, 1235.23, 1179.39, 1022.82, 963.70, 838.29, 756.09, 604.34, 563.77. ^{1}H NMR (400 MHz, DMSO): δ = 9.55 (1H, d), 8.08 (2H, d, J= 8.8 Hz), 8.06-7.86 (5H, m), 7.68-7.56 (4H, m), 7.39-7.29 (2H, m), 7.19 (2H, d, J= 8.4 Hz), 6.41 (2H, s), 5.98 (2H, d), 5.13 (2H, d), 3.93 (5H, t), 2.98 (2H, s), 2.40 (6H, t). ^{13}C NMR (100 MHz, DMSO): δ = 189.88, 164.89, 164.65, 143.84, 137.47, 136.79, 136.75, 135.59, 135.24, 131.34, 131.00, 130.64, 130.53, 130.45,

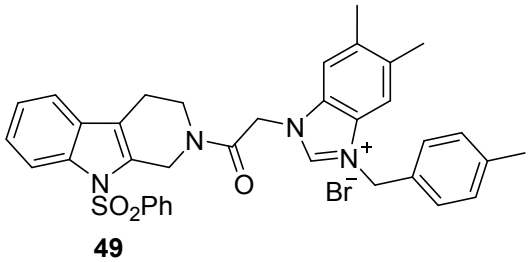
129.49, 127.19, 127.11, 126.78, 125.46, 124.42, 119.48, 117.98, 114.77, 114.22, 113.79, 56.28, 53.33, 48.64, 21.76, 20.44, 20.41. HRMS (ESI-TOF) *m/z* Calcd for $C_{37}H_{35}BrN_4O_5S$ $[M+1]^+$ 647.2322. found 647.2324.



48

5,6-dimethyl-3-(2-(naphthalen-2-yl)-2-oxoethyl)-1-(2-oxo-2-(9-(phenylsulfonyl)-1,3,4,9-tetrahydro-2*H*-pyrido[3,4-*b*]indol-2-yl)ethyl)-1*H*-benzo[*d*]imidazol-3-ium bromide

Yield 91%. Yellow solid. Mp 234-235 °C. IR ν_{max} (cm^{-1}): 3410.12, 3127.23, 3053.62, 2935.80, 2789.85, 1661.25, 1564.31, 1441.81, 1371.01, 1224.05, 1180.64, 967.38, 755.51, 685.00, 604.64, 563.63, 480.64. ^1H NMR (400 MHz, DMSO): δ = 9.58 (1H, d), 8.94 (1H, s), 8.24 (1H, d, J= 8 Hz), 8.16 (1H, d, J= 8 Hz), 7.93-7.87 (6H, m), 7.76-7.55 (6H, m), 7.40-7.30 (2H, m), 6.59 (2H, s), 5.99 (2H, d), 5.18 (2H, d), 3.94 (2H, t), 2.99 (2H, s), 2.42 (6H, t). ^{13}C NMR (100 MHz, DMSO): δ = 191.55, 164.89, 143.88, 137.50, 136.87, 136.82, 136.03, 135.60, 135.24, 132.51, 131.60, 131.32, 131.01, 130.78, 130.68, 130.57, 130.45, 130.16, 129.82, 129.49, 129.16, 128.38, 127.89, 127.17, 126.79, 125.47, 124.41, 123.85, 119.48, 117.97, 114.23, 113.86, 79.82, 79.49, 79.16, 53.77, 21.76, 20.46, 20.43. HRMS (ESI-TOF) *m/z* Calcd for $C_{40}H_{35}BrN_4O_4S$ $[M-Br]^+$ 746.1562. found 667.2373.

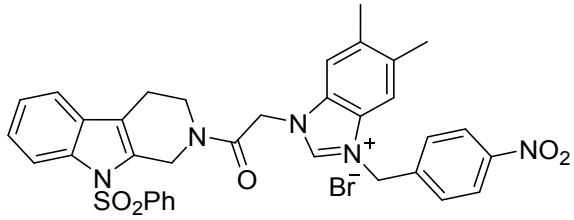


49

5,6-dimethyl-3-(4-methylbenzyl)-1-(2-oxo-2-(9-(phenylsulfonyl)-1,3,4,9-tetrahydro-2*H*-pyrido[3,4-*b*]indol-2-yl)ethyl)-1*H*-benzo[*d*]imidazol-3-ium bromide

Yield 79%. Yellow solid. Mp 270-271 °C. IR ν_{max} (cm^{-1}): 3874.20, 3833.29, 3729.85, 3394.55, 3121.05, 2975.91, 2909.85, 2387.24, 2314.68, 2106.64, 2387.24, 2314.68, 2106.64, 1660.44, 1560.72, 1375.10, 1221.15, 1178.77, 876.89, 754.56, 683.75, 605.84. ^1H NMR (400 MHz, DMSO): δ = 9.74 (1H, s), 8.07-8.05 (2H, d), 7.92-7.86

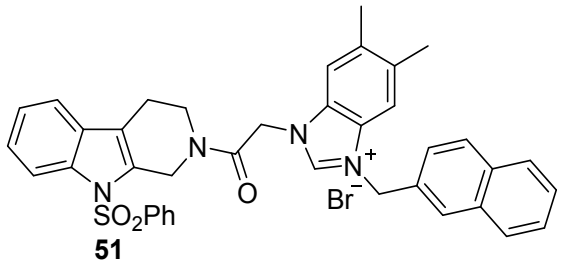
(4H, m), 7.71-7.56 (4H, m), 7.43-7.34 (4H, m), 7.28-7.26 (2H, d), 5.92-5.87 (2H, d), 5.80-5.78 (2H, d), 5.19-5.07 (2H, d), 3.96-3.90 (4H, m), 2.42-2.41 (6H, d), 2.32 (3H, s). ^{13}C NMR (120 MHz, DMSO): δ = 164.51, 142.35, 138.29, 137.00, 136.61, 136.41, 135.13, 134.83, 131.06, 130.72, 130.56, 130.06, 130.01, 129.65, 129.62, 129.04, 128.97, 128.26, 128.17, 126.72, 126.38, 125.08, 124.02, 119.05, 117.53, 113.80, 113.48, 113.28, 49.55, 48.04, 41.66, 41.40, 40.03, 39.92, 39.78, 39.64, 39.50, 39.36, 39.22, 39.08, 21.30, 20.75, 20.07, 20.02. HRMS (ESI-TOF) *m/z* Calcd for $C_{36}H_{35}BrN_4O_3S$ $[M+1]^+$ 603.2411. found 603.2411.



50

5,6-dimethyl-3-(4-nitrobenzyl)-1-(2-oxo-2-(9-(phenylsulfonyl)-1,3,4,9-tetrahydro-2*H*-pyrido[3,4-*b*]indol-2-yl)ethyl)-1*H*-benzo[*d*]imidazol-3-ium bromide

Yield 89%. Yellow solid. Mp 227-228 °C. IR ν_{max} (cm^{-1}): 3730.28, 3412.09, 3113.71, 2987.60, 2911.69, 2857.06, 2314.26, 2105.73, 1798.10, 1656.98, 1611.81, 1562.75, 1522.33, 1442.12, 1346.80, 1224.56, 1179.08, 962.41, 797.89, 754.36, 714.45, 605.32, 562.32. ^{1}H NMR (400 MHz, DMSO): δ = 9.83 (1H, s), 8.29 (2H, d, J= 8.4 Hz), 8.01 (4H, t), 7.89-7.78 (1H, m), 7.72-7.53 (6H, m), 7.39-7.29 (2H, m), 6.03 (2H, s), 5.91 (2H, d), 5.11 (2H, d), 3.92 (2H, t), 2.97 (2H, s), 2.44 (6H, d). ^{13}C NMR (100 MHz, DMSO): δ = 164.88, 148.05, 143.41, 142.02, 137.46, 137.18, 137.08, 135.57, 135.23, 131.14, 130.96, 130.43, 129.63, 129.56, 129.45, 129.35, 127.15, 126.79, 125.47, 124.56, 124.42, 119.48, 117.94, 114.21, 114.10, 113.55, 49.33, 48.61, 21.75, 20.46. HRMS (ESI-TOF) *m/z* Calcd for $C_{35}H_{32}BrN_5O_5S$ $[M+1]^+$ 606.2157. found 606.2157.



51

5,6-dimethyl-3-(naphthalen-2-ylmethyl)-1-(2-oxo-2-(9-(phenylsulfonyl)-1,3,4,9-tetrahydro-2*H*-pyrido[3,4-*b*]indol-2-yl)ethyl)-1*H*-benzo[*d*]imidazol-3-ium bromide

Yield 82%. Yellow solid. Mp 252-254 °C. IR ν_{max} (cm^{-1}): 3421.91, 3122.92, 2973.32, 2927.60, 1659.90, 1562.65, 1441.69, 1369.75, 1224.68, 1179.96, 963.00, 754.51. ^{1}H NMR (400 MHz, DMSO): δ = 9.73 (1H, s), 8.06-7.84 (9H, m), 7.66-7.53 (7H, m), 7.39-7.29 (2H, m), 5.99 (2H, s), 5.87 (2H, d), 5.10 (2H, d), 3.90 (2H, d), 2.95 (2H, s), 2.37 (6H, s). ^{13}C NMR (100 MHz, DMSO): δ = 164.95, 143.05, 137.42, 137.05, 136.89, 135.54, 135.24, 133.17, 131.98, 131.18, 130.98, 130.42, 129.54, 129.45, 129.36, 128.32, 128.19, 127.89, 127.74, 127.28, 127.14, 126.79, 125.98, 125.48, 124.42, 119.46, 117.94, 114.22, 113.97, 113.71, 79.80, 79.68, 79.47, 79.14, 60.23, 50.34, 21.72, 20.49, 20.46, 14.55. HRMS (ESI-TOF) *m/z* Calcd for $C_{39}H_{35}BrN_4O_3S$ $[M+1]^+$ 639.2424. found 639.2427.

3. Biological Assay Procedures and Results

3.1 Cytotoxicity assay

The assay was in five kinds of cell lines (HL-60, SMMC-7721, A549, MCF-7 and SW480). Cells were cultured at 37 ^{o}C under a humidified atmosphere of 5% CO_2 in RPMI 1640 medium supplemented with 10% fetal serum and dispersed in replicate 96-well plates. Compounds were then added. After 48 h exposure to the compounds, cells viability were determined by the [3-(4,5-dimethylthiazol-2-yl)-2,5-diphenyl-tetrazoliumbromide] (MTT) cytotoxicity assay by measuring the absorbance at 570 nm with a microplate spectrophotometer. Each test was performed in triplicate.

3.2 Cytotoxic activities of hybrid compounds 17–54 invitro[b] (IC_{50}, μM[a])

Table 2 Cytotoxic activities of hybrid compounds **17-54** in vitro[b] (IC_{50}, μM[a])

Entry	Compound No.	HL-60	SMMC-7721	A-549	MCF-7	SW480
1	**17**	>40	>40	>40	>40	>40
2	**18**	>40	>40	>40	>40	>40
3	**19**	17.81	>40	28.16	21.00	29.80
4	**20**	36.73	>40	>40	>40	>40
5	**21**	>40	>40	>40	>40	>40
6	**22**	>40	>40	>40	>40	>40
7	**23**	>40	>40	>40	>40	>40
8	**24**	>40	>40	>40	>40	>40
9	**25**	>40	>40	>40	>40	>40
10	**26**	21.81	27.59	>40	20.47	32.35
11	**27**	11.09	19.80	>40	17.56	16.69
12	**28**	10.68	30.39	>40	19.51	>40
13	**29**	>40	>40	>40	>40	>40
14	**30**	3.54	13.23	18.02	12.24	17.46
15	**31**	>40	>40	>40	>40	>40
16	**32**	3.32	12.11	14.21	3.74	11.80
17	**33**	>40	>40	>40	>40	>40
18	**34**	11.87	16.77	>40	8.28	35.62
19	**35**	2.47	10.67	13.39	10.44	10.14
20	**36**	2.56	12.48	22.13	3.37	11.84
21	**37**	2.77	12.81	14.46	2.61	12.81
22	**38**	14.39	24.60	21.41	16.44	13.60
23	**39**	10.61	17.28	31.23	16.59	11.81
24	**40**	3.97	14.95	18.27	11.34	13.58
25	**41**	3.24	15.03	8.78	8.05	11.01
26	**42**	3.04	14.78	17.01	7.68	11.70
27	**43**	13.58	23.35	35.36	17.42	12.44
28	**44**	4.34	14.74	17.28	10.33	11.76
29	**45**	10.18	14.50	22.75	11.26	13.19
30	**46**	3.75	15.30	>40	4.97	10.47
31	**47**	3.39	13.18	23.70	8.23	16.37
32	**48**	3.08	14.77	>40	3.90	16.17
33	**49**	4.30	15.13	29.52	10.17	14.20
34	**50**	12.81	33.19	>40	10.81	>40
35	**51**	2.61	14.15	17.13	2.79	9.46
36	DDP (MW 300)	2.27	9.98	8.25	14.69	15.11
37	Taxol	<0.008	<0.008	<0.008	<0.008	<0.008

[a] Cytotoxicity as IC_{50} for each cell line, is the concentration of compound which reduced by 50% the optical density of treated cells with respect to untreated cells using the MTT assay.

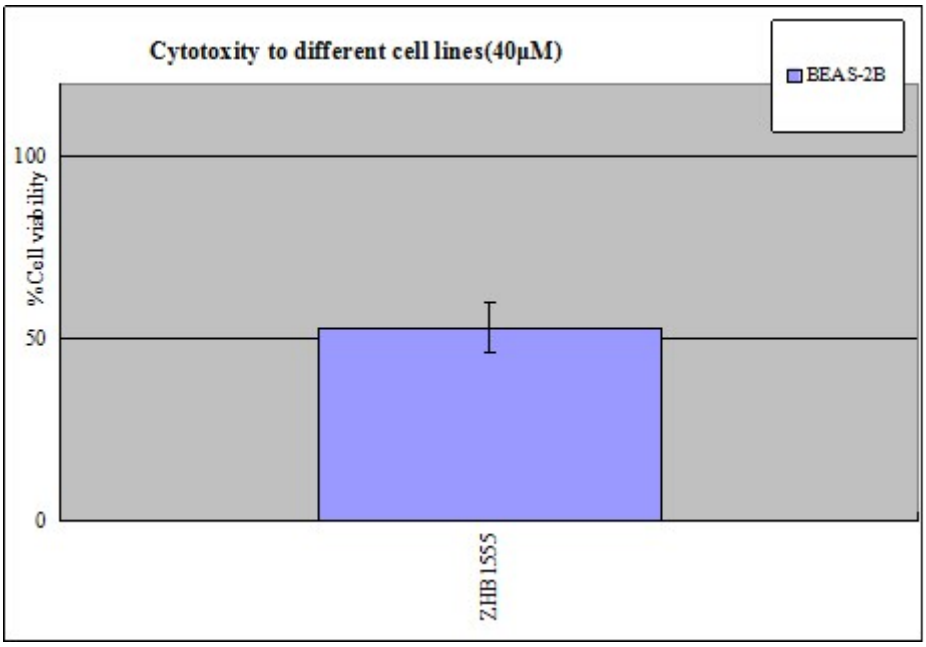
[b] Data represent the mean values of three independent determinations.

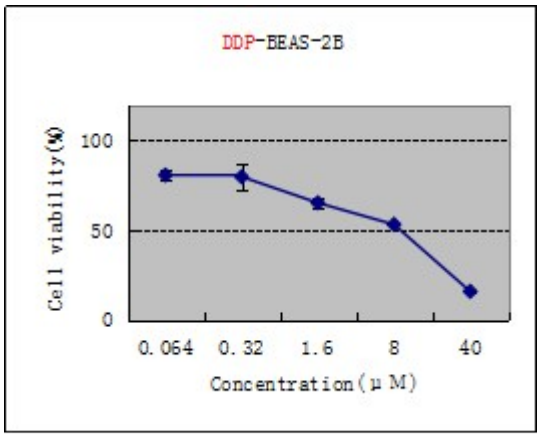
3.3 Cytotoxicity of the representative compound 51 against human normal lung epithelial cell line (BEAS-2B)

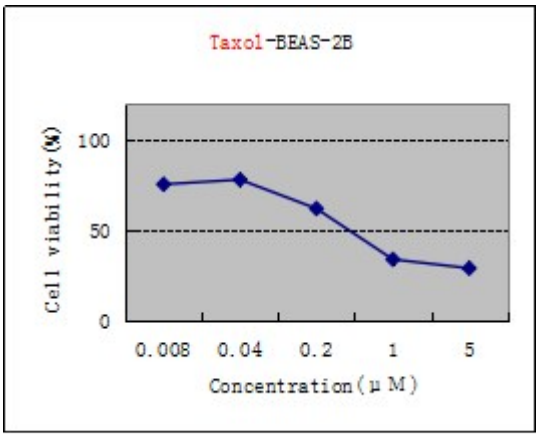
By comparing the IC_{50} values of the tested compounds towards cancer cell lines with those towards the normal lung epithelial cells BEAS-2B.

Table 3 Cytotoxicity of compound **15** against A549 and BEAS-2B cells in vitro (IC_{50}, μM)

Entry	Compound no.	BEAS-2B	A549
1	**51**	>40	17.13
2	DDP	9.12	8.25







4. Cell apoptosis and cell cycle analysis

4.1 Cell apoptosis analysis

Cell apoptosis was analyzed using the Annexin V-FITC/PI Apoptosis kit (BD Biosciences, Franklin Lakes, NJ) according to the manufacturer's protocols. Cells were seeded in 6-well plates at a density of 1.2 × 10^6 cells/well. After 48 h of compound treatment at the indicated concentrations, cells were collected and then washed twice with cold PBS, and then resuspended in a binding buffer containing Annexin V-FITC and propidium iodine (PI). After incubation for 15 min at room temperature in the dark, the fluorescent intensity was measured using a FACSCalibur flow cytometer (BD Biosciences, Franklin Lakes, NJ).

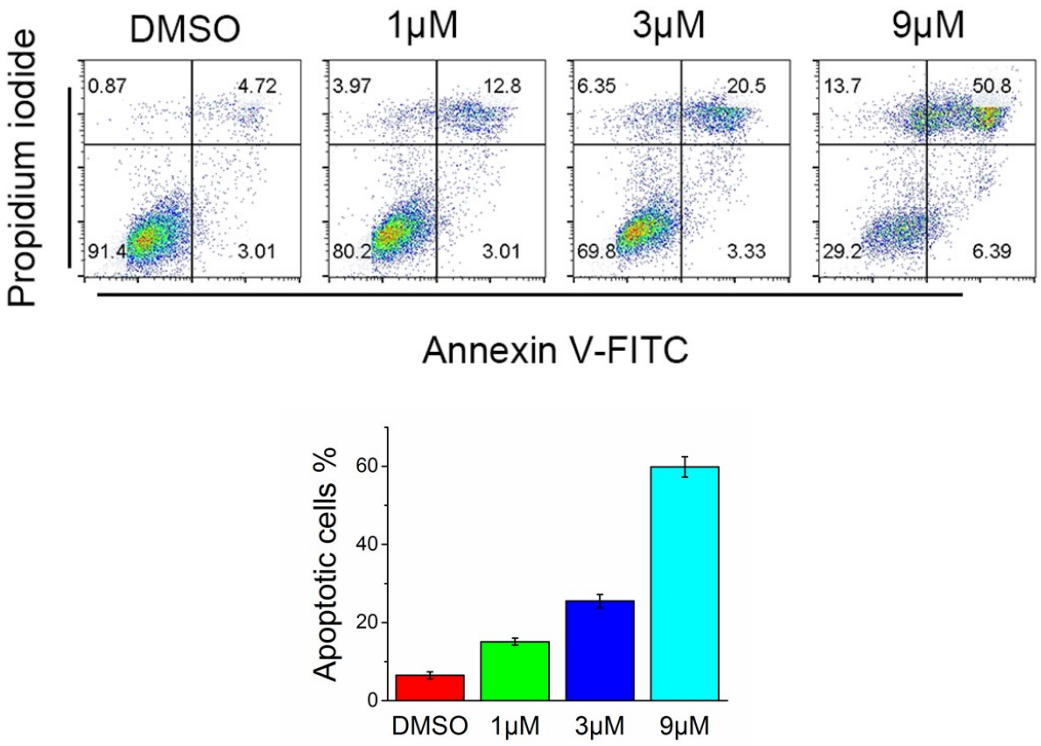
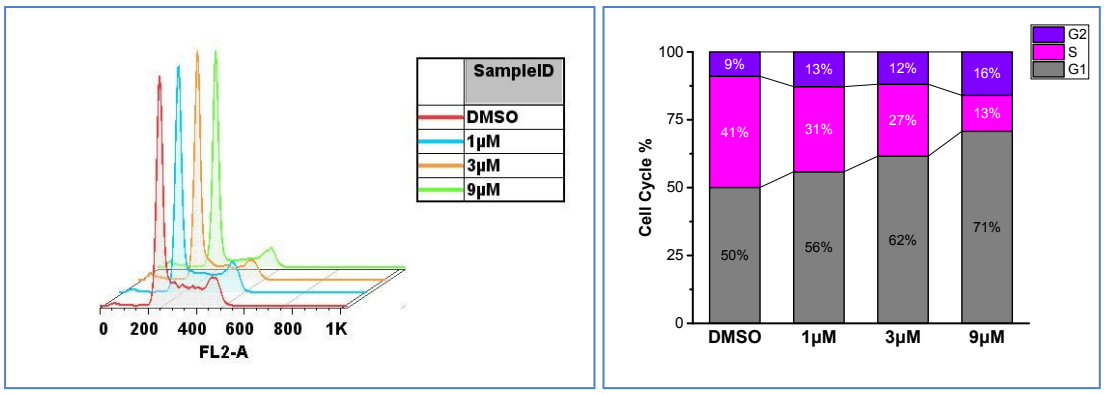


Fig. 1 Compound **51** caused significant apoptosis of SMMC-7721 cells. (A) Cells were treated with 4, 8 and 16 μM compound **51** for 48 h. Cell apoptosis was determined by Annexin V-FITC/PI double-staining assay. (B) The quantification of cell apoptosis. Data represents the mean ± S.D. of three independent experiments.

4.2 Cell cycle analysis

To analyze the DNA content by flow cytometry, cells were collected and washed twice with PBS. Cells were fixed with 70% ethanol overnight. Fixed cells were washed with PBS, and then stained with a 50 μg/ml propidium iodide (PI) solution containing 50 μg/ml RNase A for 30 min at room temperature. Fluorescence intensity was analyzed by FACSCalibur flow cytometer (BD Biosciences, San Jose, CA, USA). The percentages of the cells distributed in different phases of the cell cycle were determined using ModFIT LT 2.0.

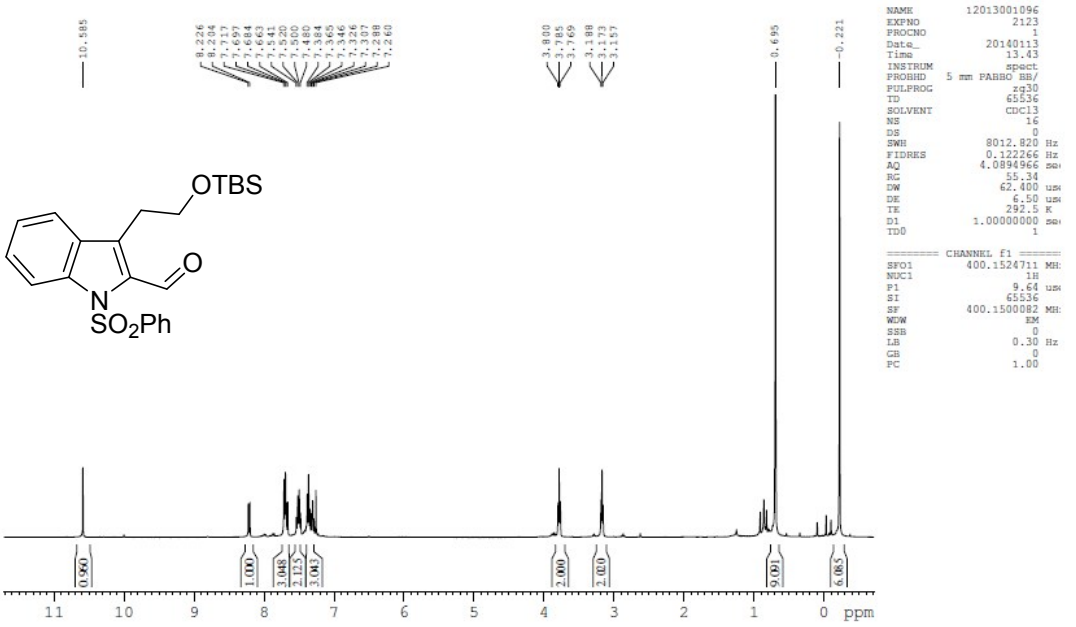


Treatment	Cells (%)		
	G0/G1	S	G2/M
DMSO	49.1±2.7	40.2±2.9	8.8±0.2
Compound **25** (1 μM)	52.9±1.3	29.7±0.7	12.1±1.8
Compound **25** (3 μM)	57.4±1.7	24.7±1.1	11.1±0.4
Compound **25** (9 μM)	66.7±2.3	12.5±1.2	15.1±1.3

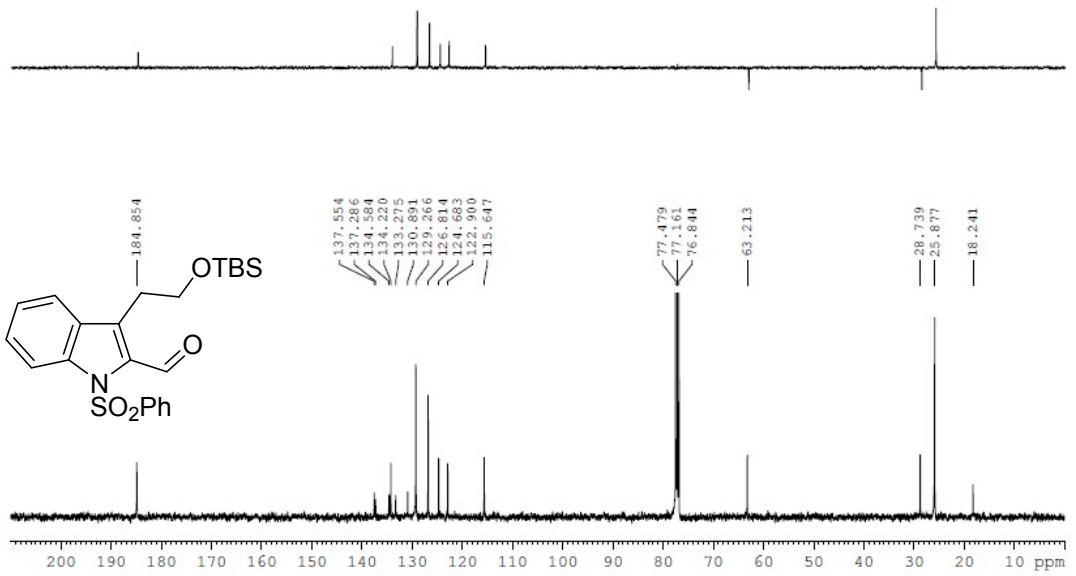
Fig. 2 Compound **51** induces S phase arrest in SMMC-7721 cells. (A) Cells were treated with 1, 2 and 4 μM of compound **51** for 24 h. Cell cycle was determined by PI staining and cell cytometry. (B) The percentages of cells in different phases were quantified. At least three independent experiments were performed and data of one representative experiment is shown.

5. ^{1}H-NMR and ^{13}C-NMR Spectral of New Compounds

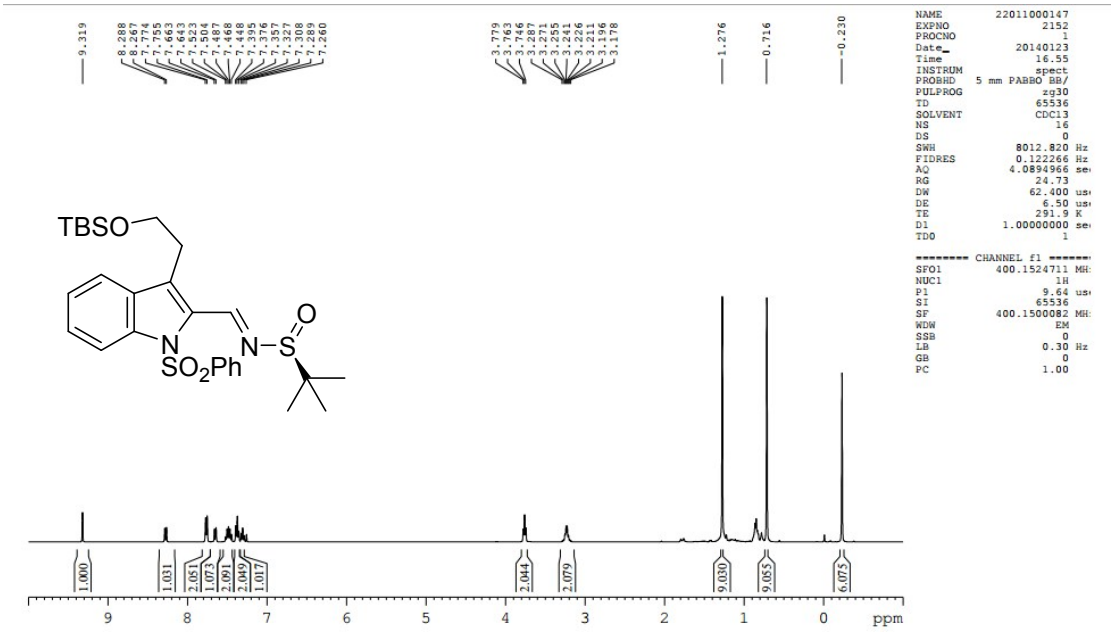
Compound **4** ^{1}H-NMR 400M $CDCl_3$



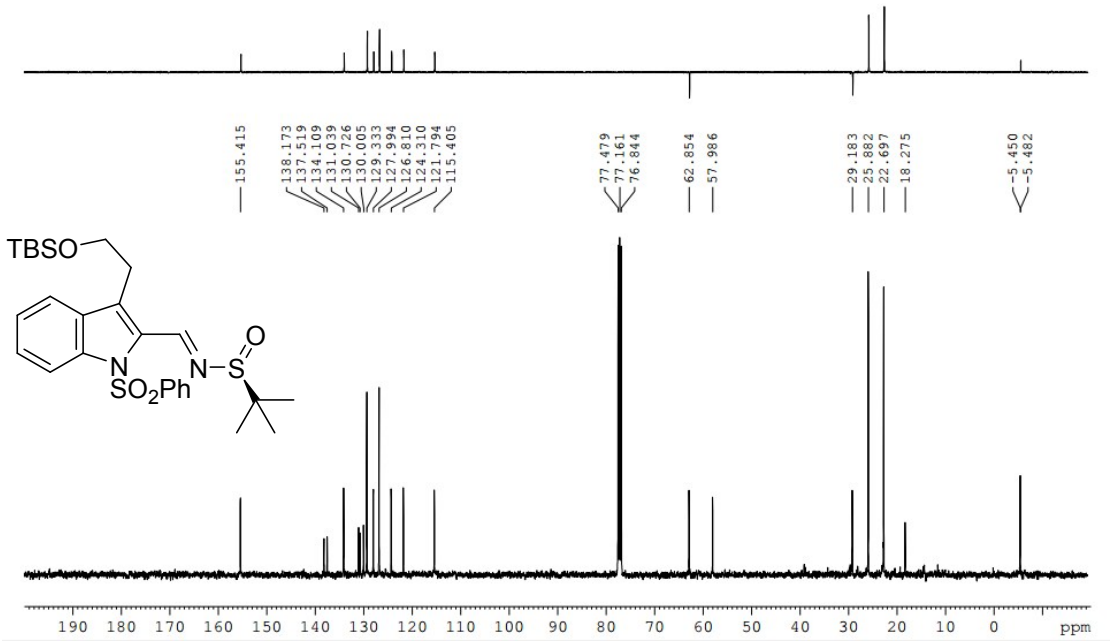
Compound **4** ^{13}C-NMR 100M $CDCl_3$



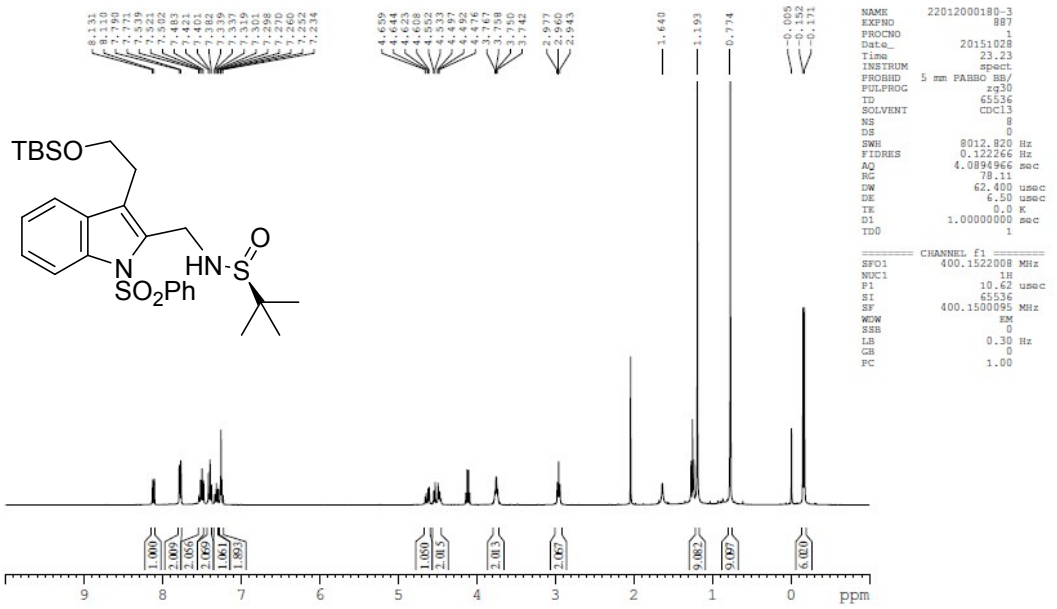
Compound **6** ^{1}H-NMR 400M $CDCl_3$



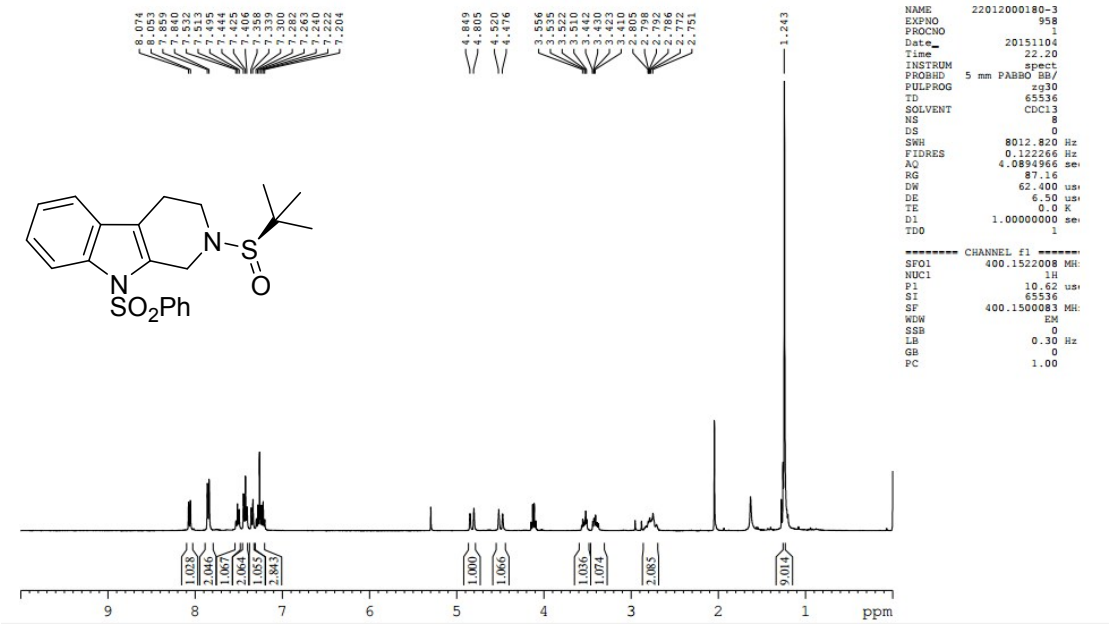
Compound **6** ^{13}C-NMR 100M $CDCl_3$



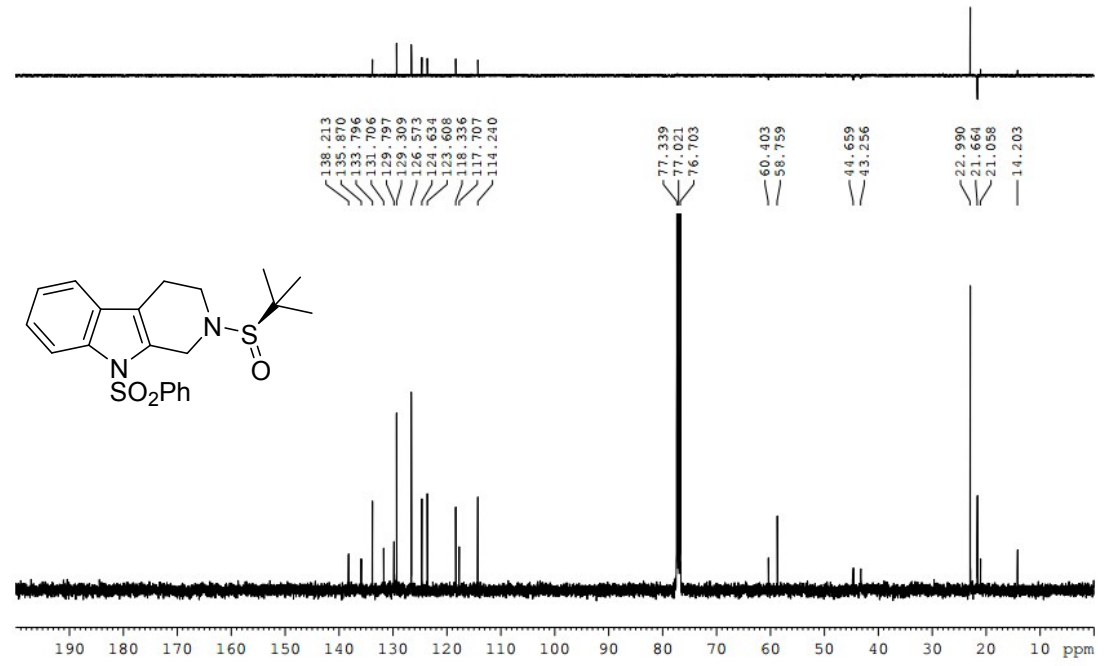
Compound **7** ^{1}H-NMR 400M $CDCl_3$



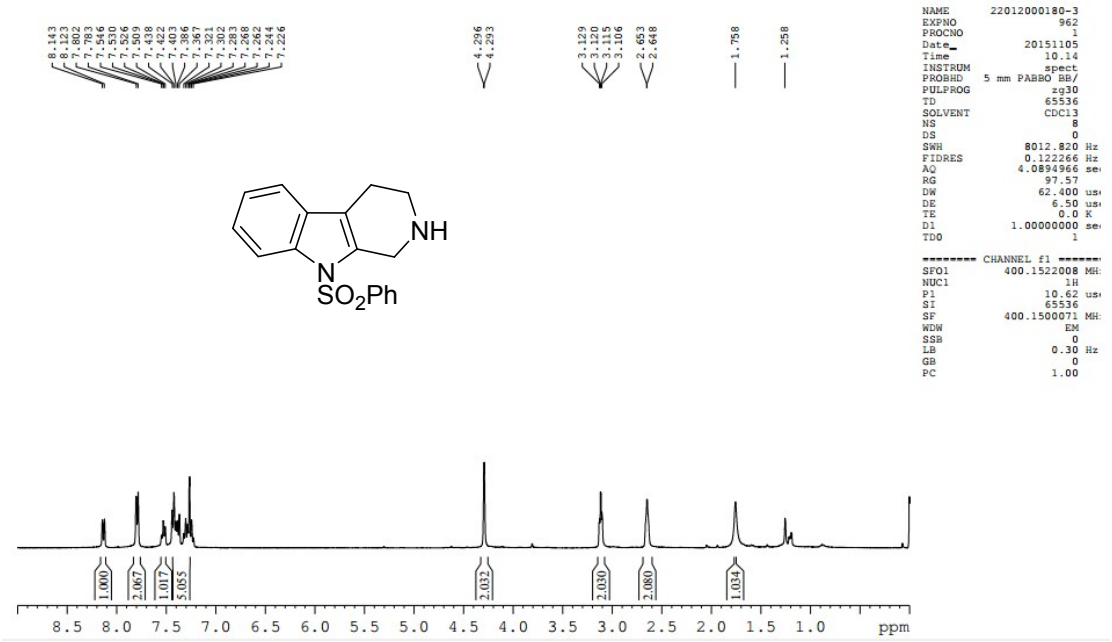
Compound **10** ^{1}H-NMR 400M $CDCl_3$



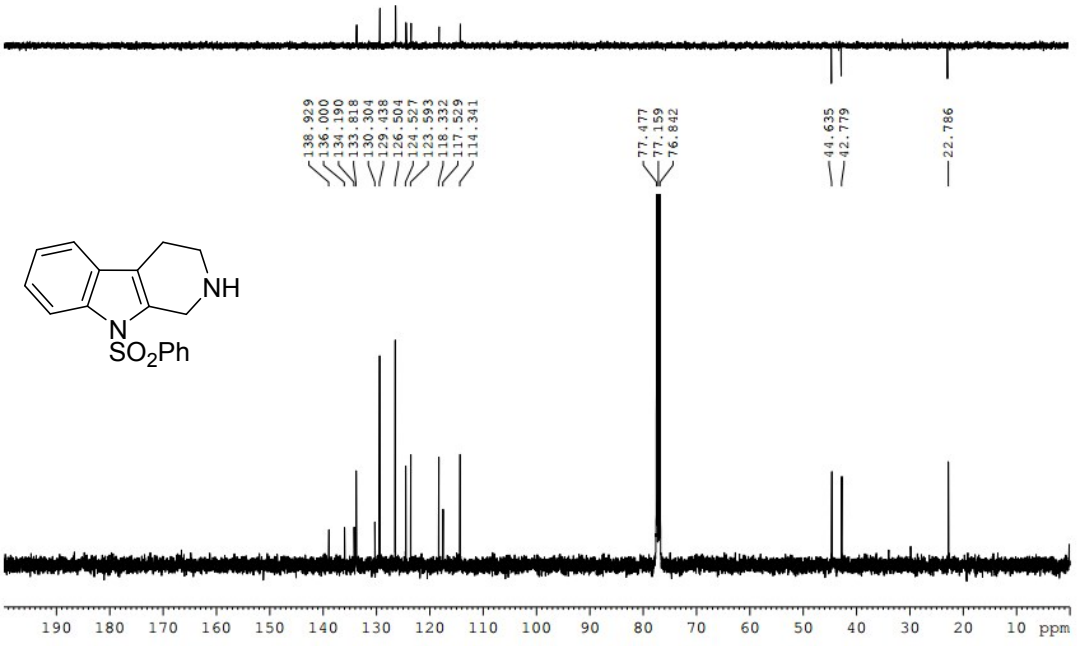
Compound **8** ^{13}C-NMR 100M $CDCl_3$



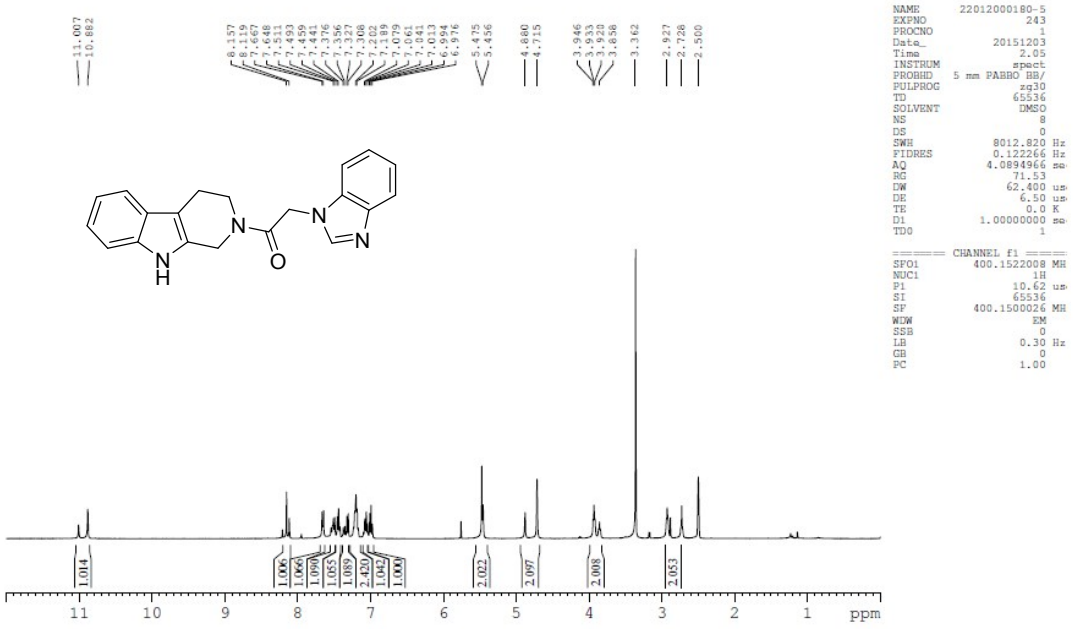
Compound **11b** ^{1}H-NMR 400M $CDCl_3$



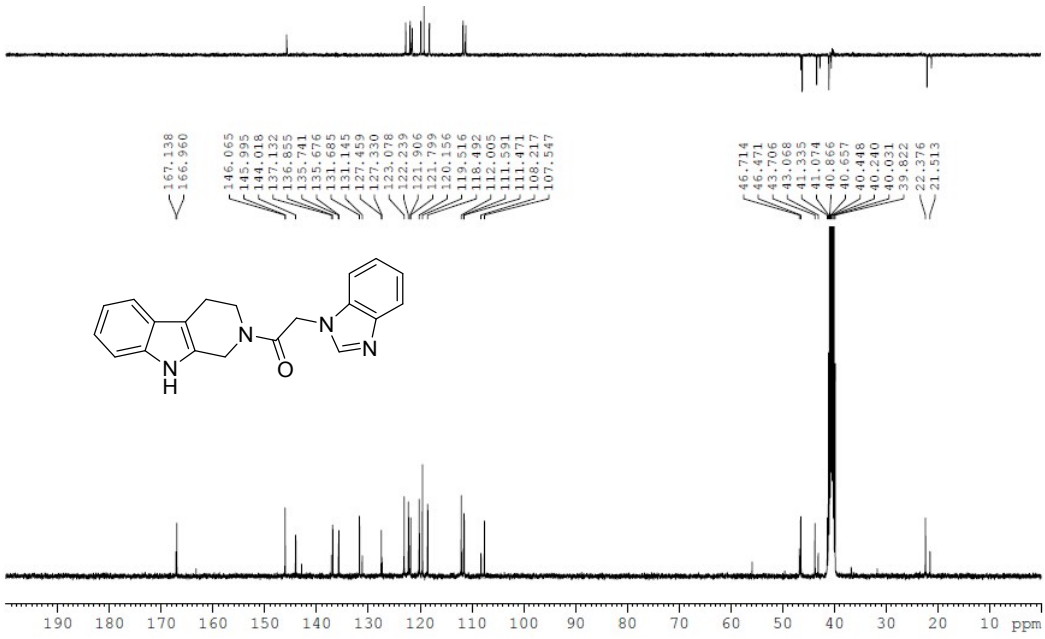
Compound **11b** ^{13}C-NMR 100M $CDCl_3$



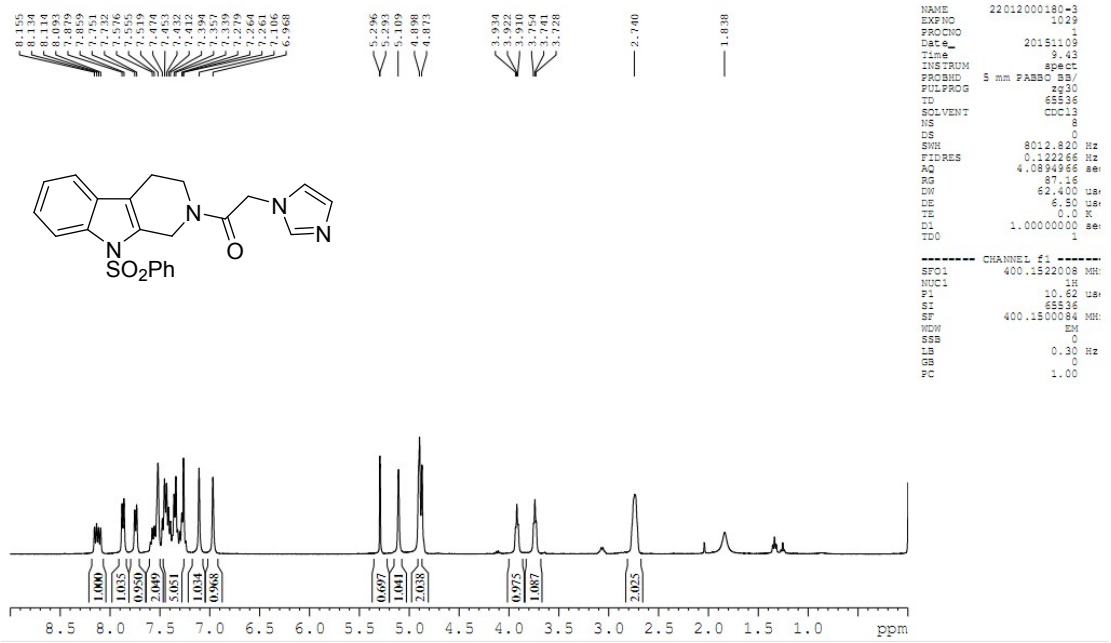
Compound **17** ^{1}H-NMR 400M DMSO



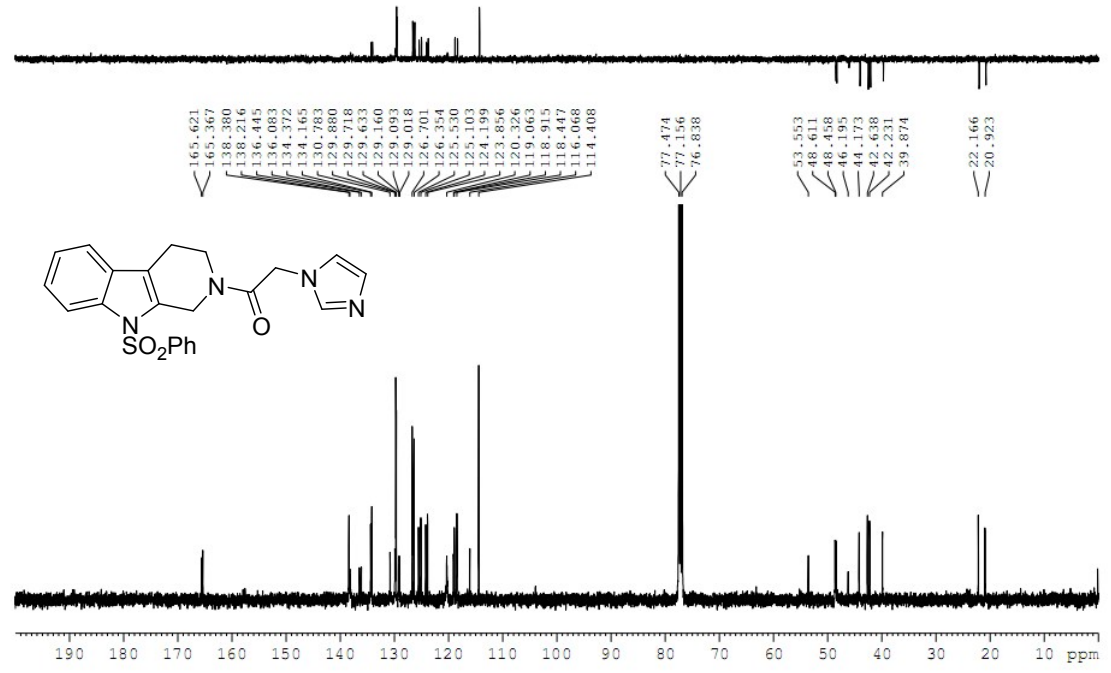
Compound **17** ^{13}C-NMR 100M DMSO



Compound **18** ^{1}H-NMR 400M DMSO



Compound **18** ^{13}C-NMR 100M DMSO



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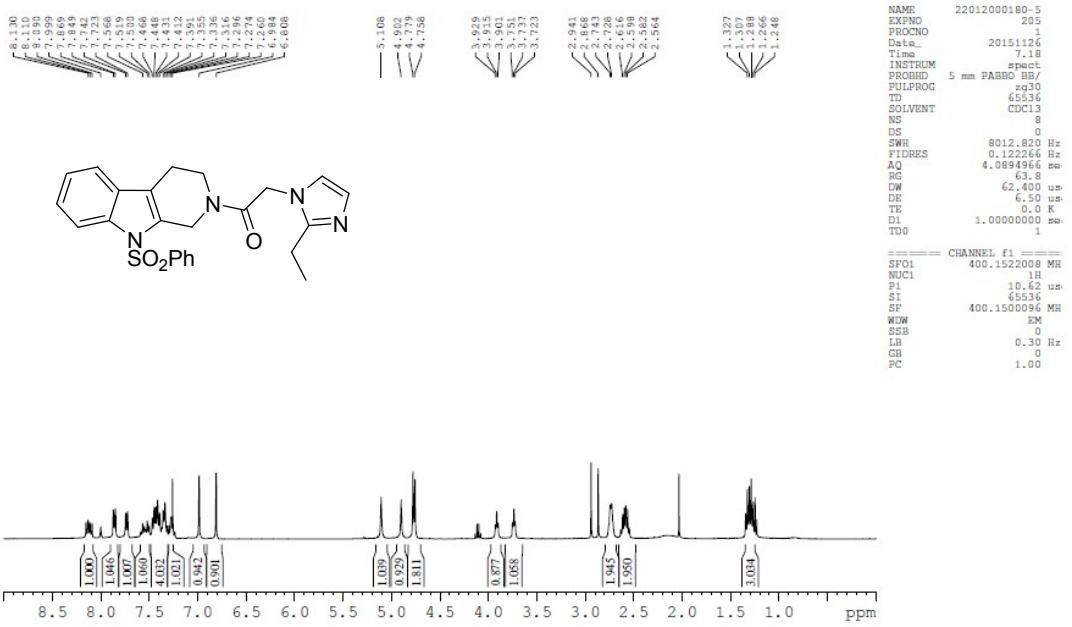

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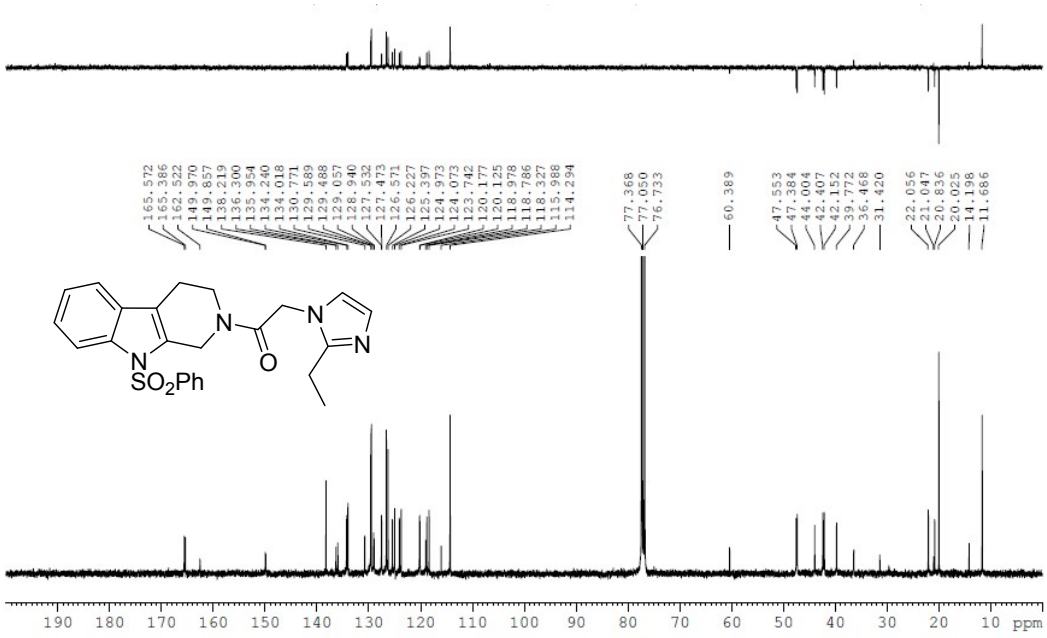
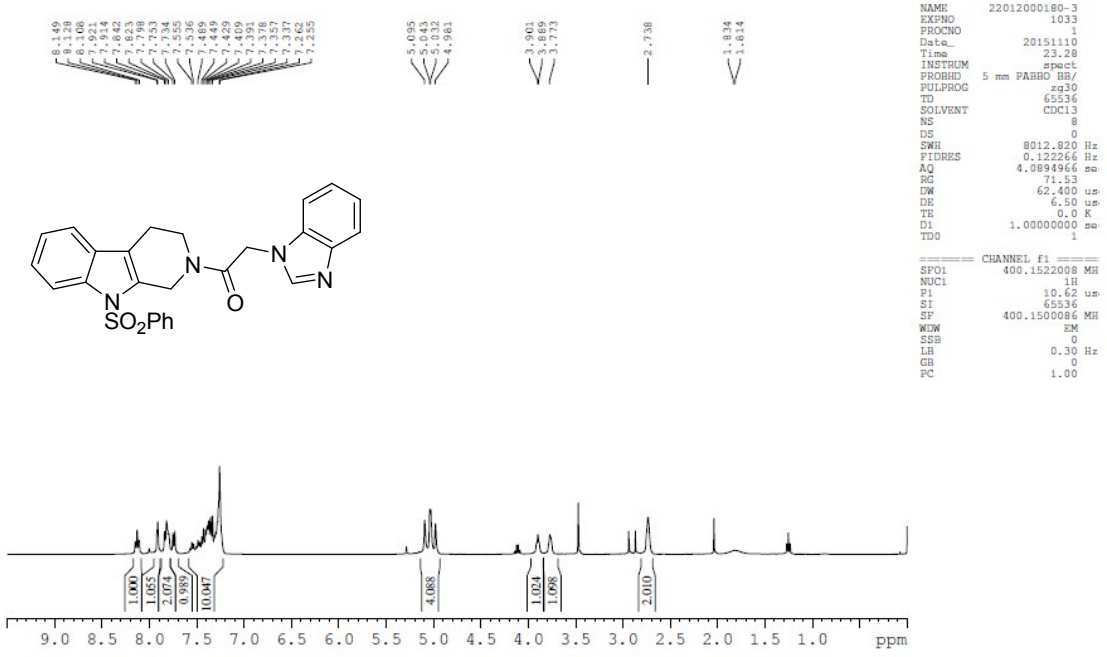


Compound **20** ^{1}H-NMR 400M DMSO



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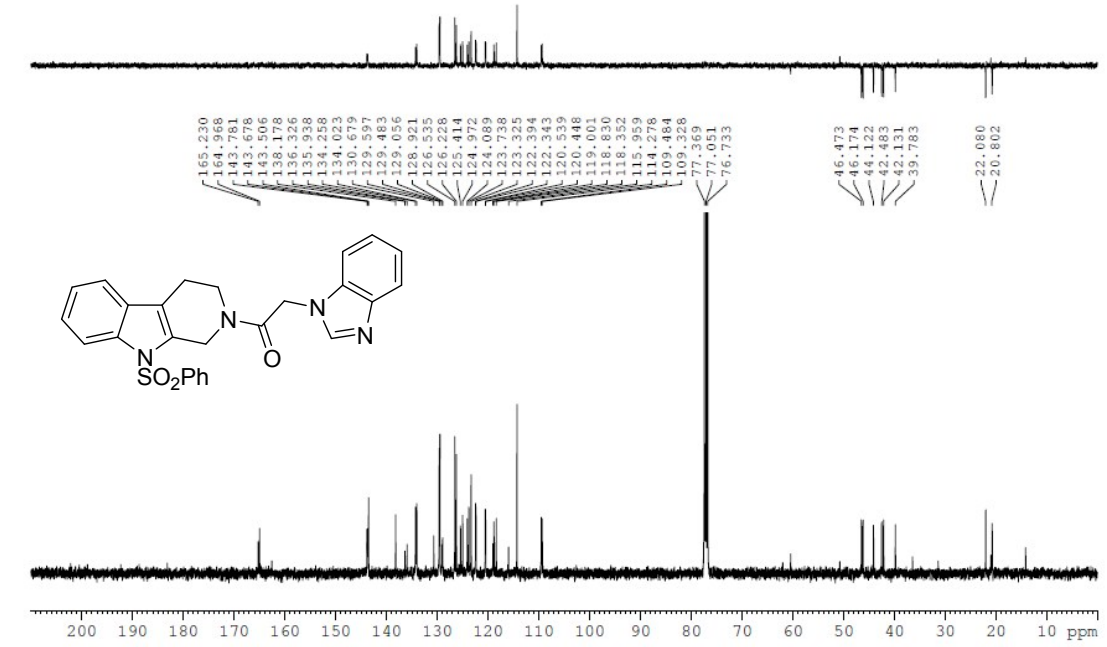
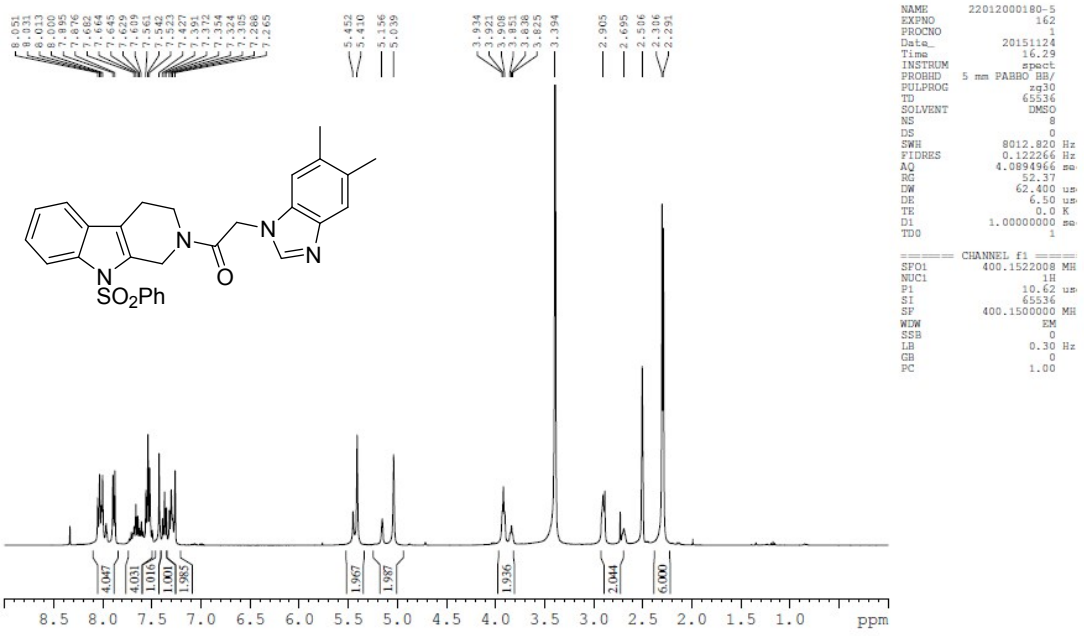


Compound **21** ^{1}H-NMR 400M DMSO

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RG                52.37
DW               62.400 usec
DE                6.50 usec
TE                 0.0 K
D1            1.00000000 sec
TD0                   1

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NUC1                 1H
P1                10.62 usec
SI                65536
SF           400.1500000 MHz
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SSB                   0
LB                 0.30 Hz
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PC                 1.00
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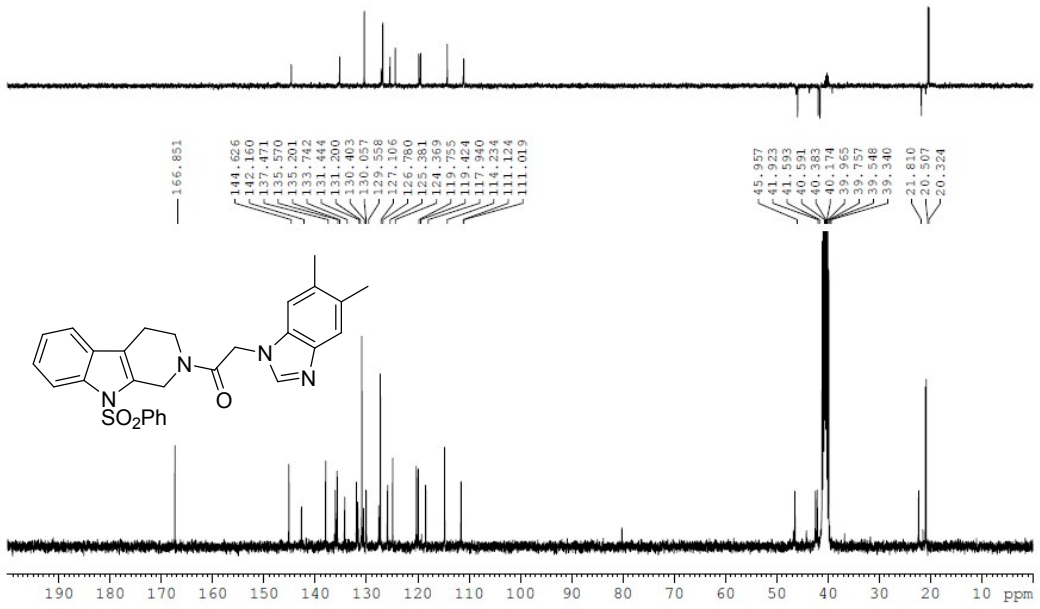
Compound **21** ^{13}C-NMR 100M DMSO



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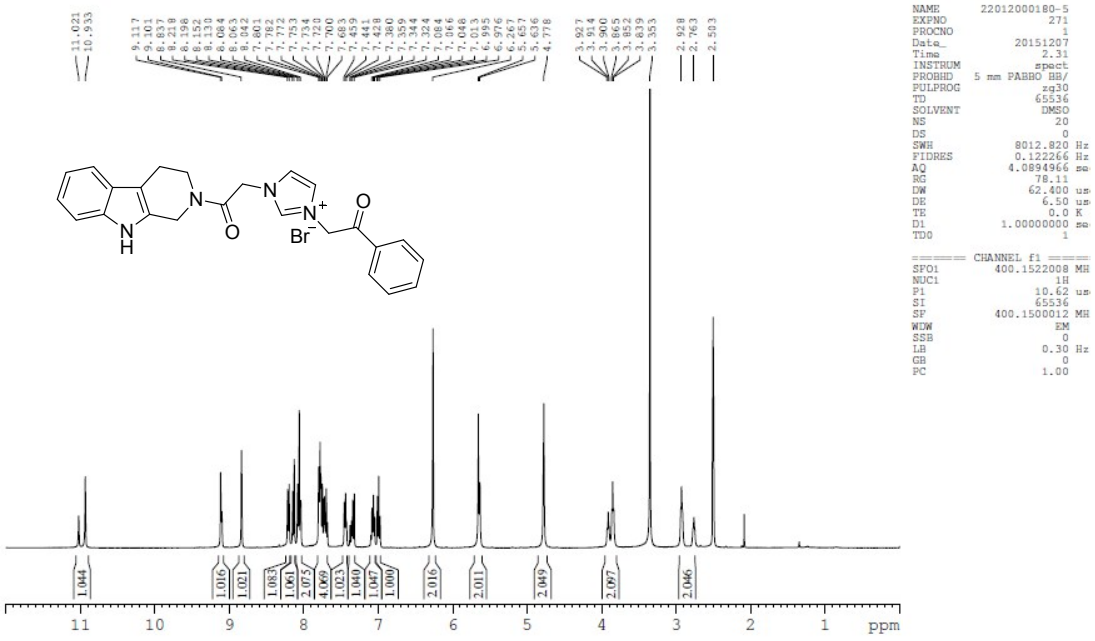

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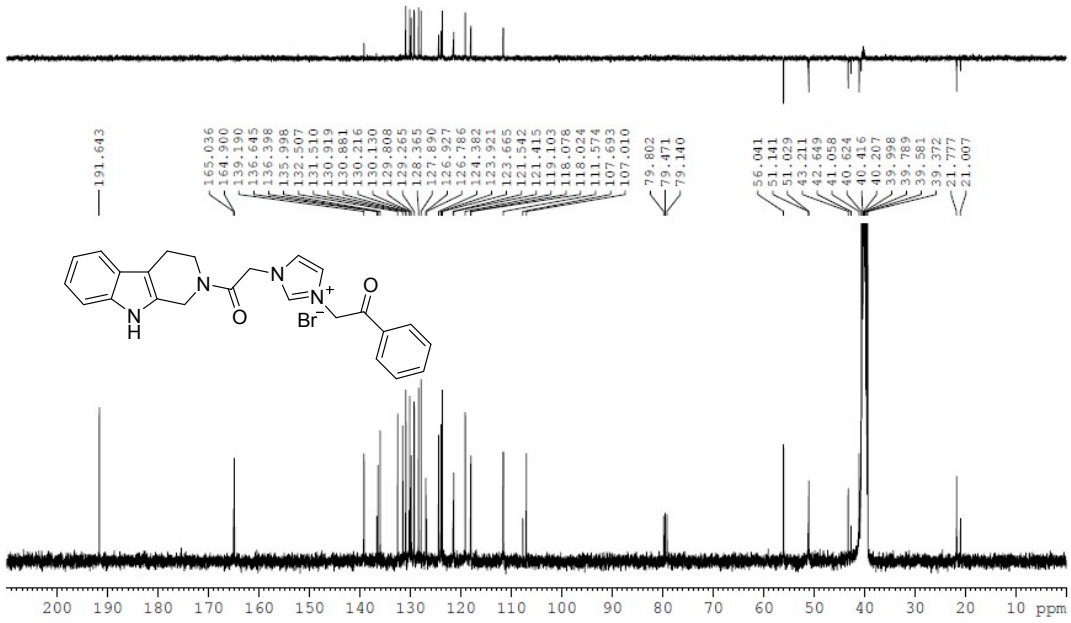

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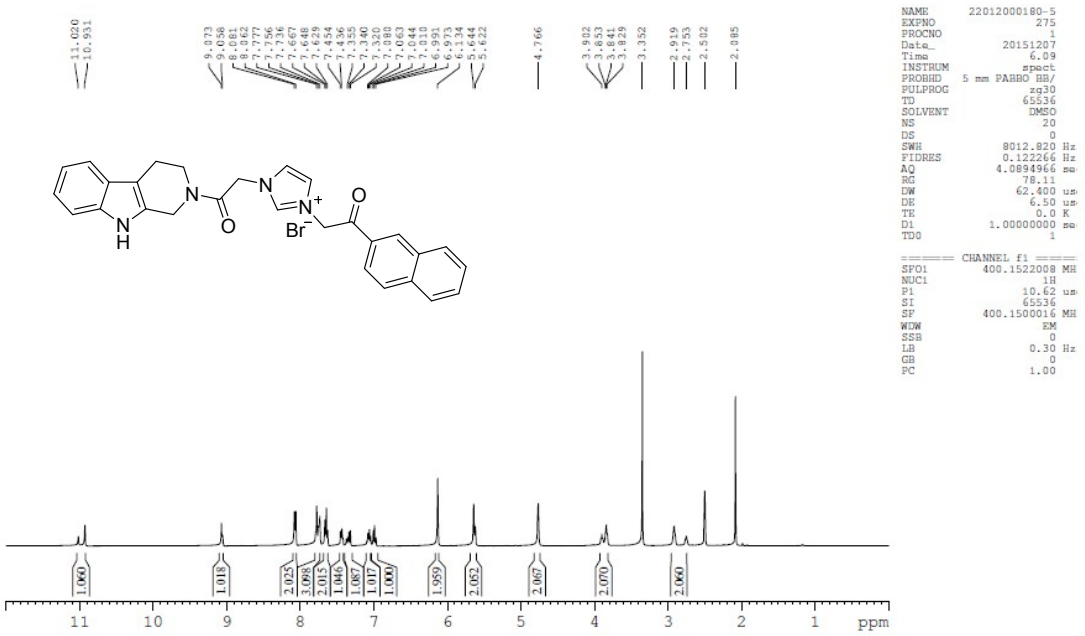

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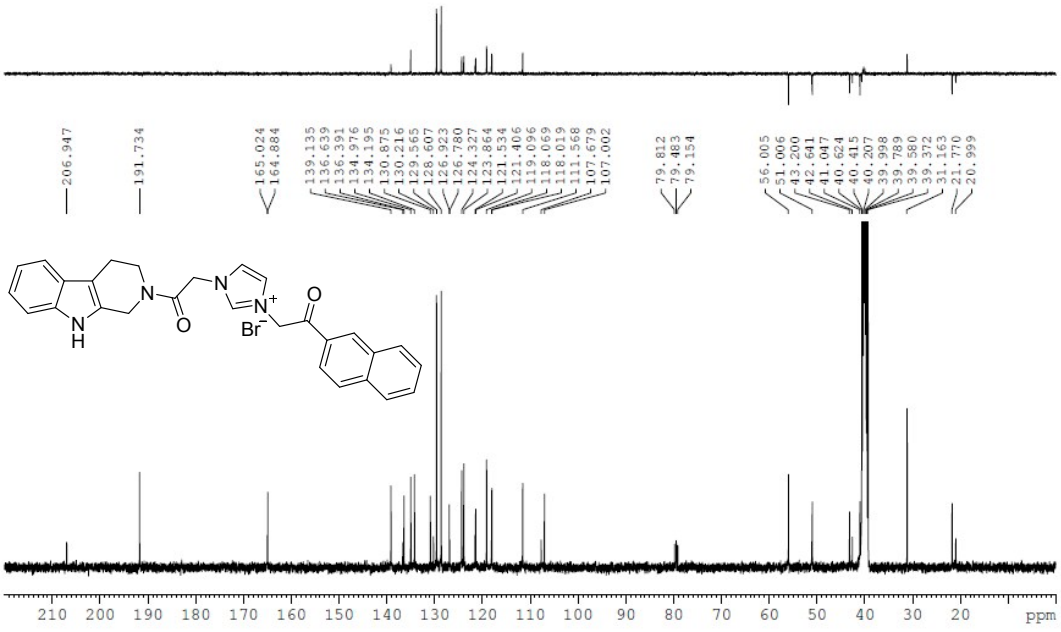

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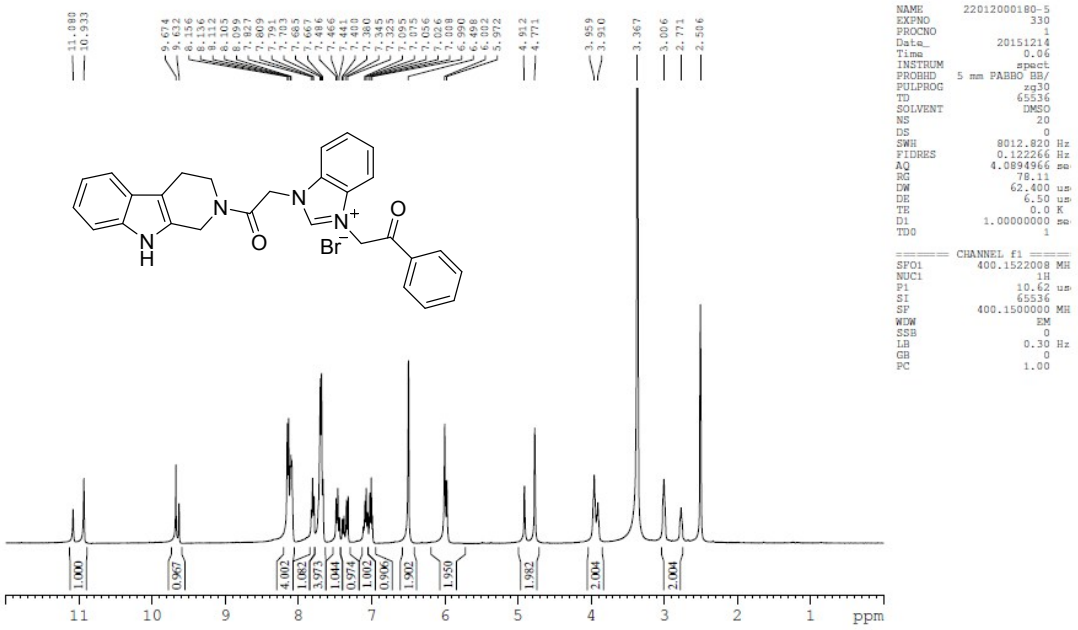

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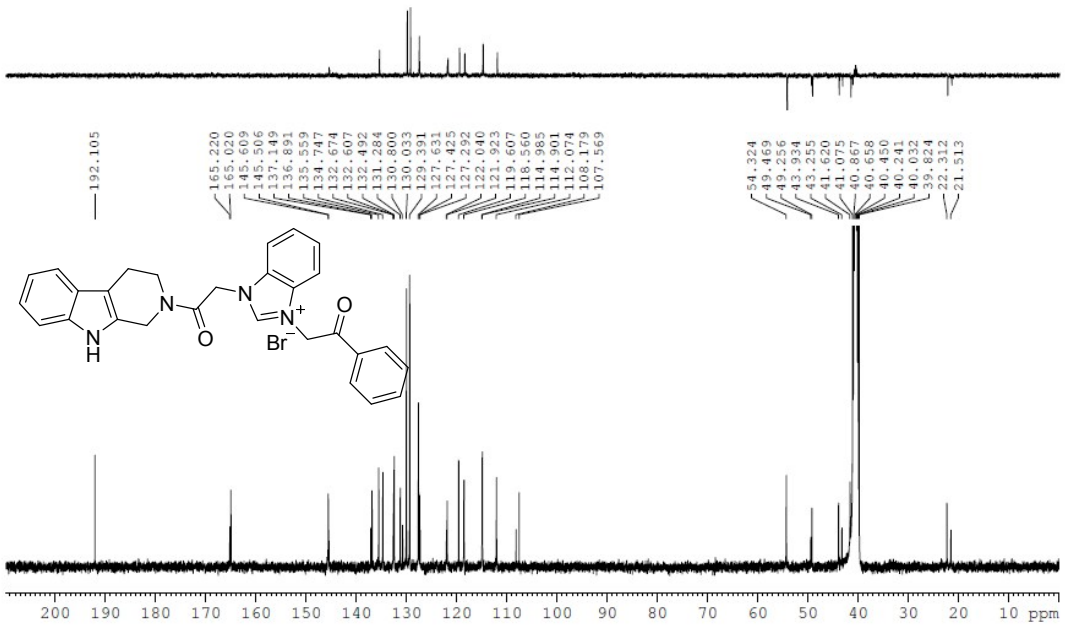

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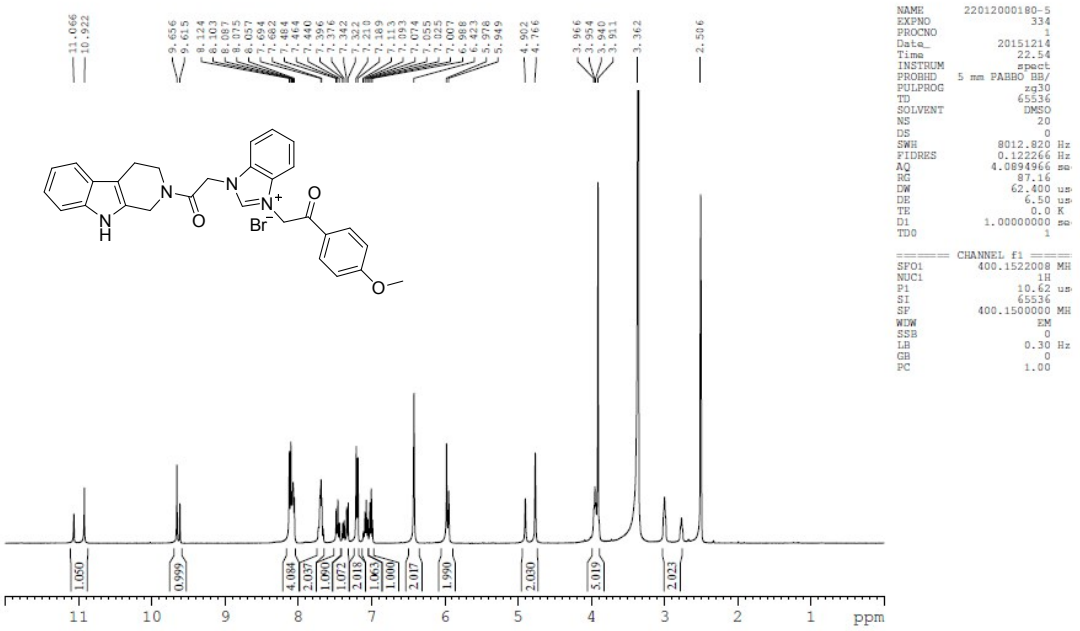

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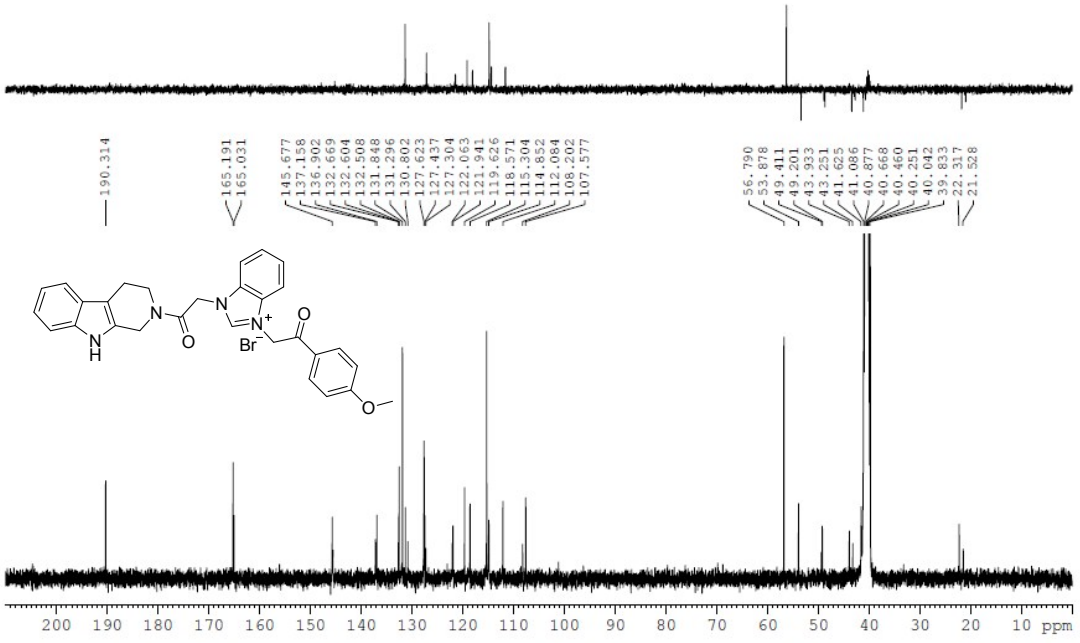

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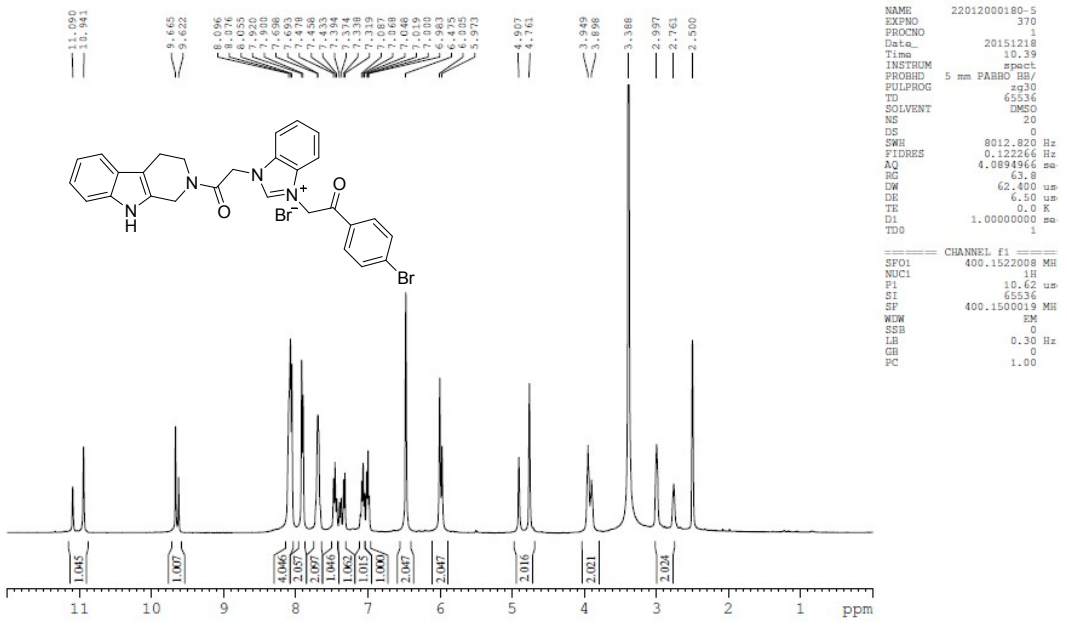

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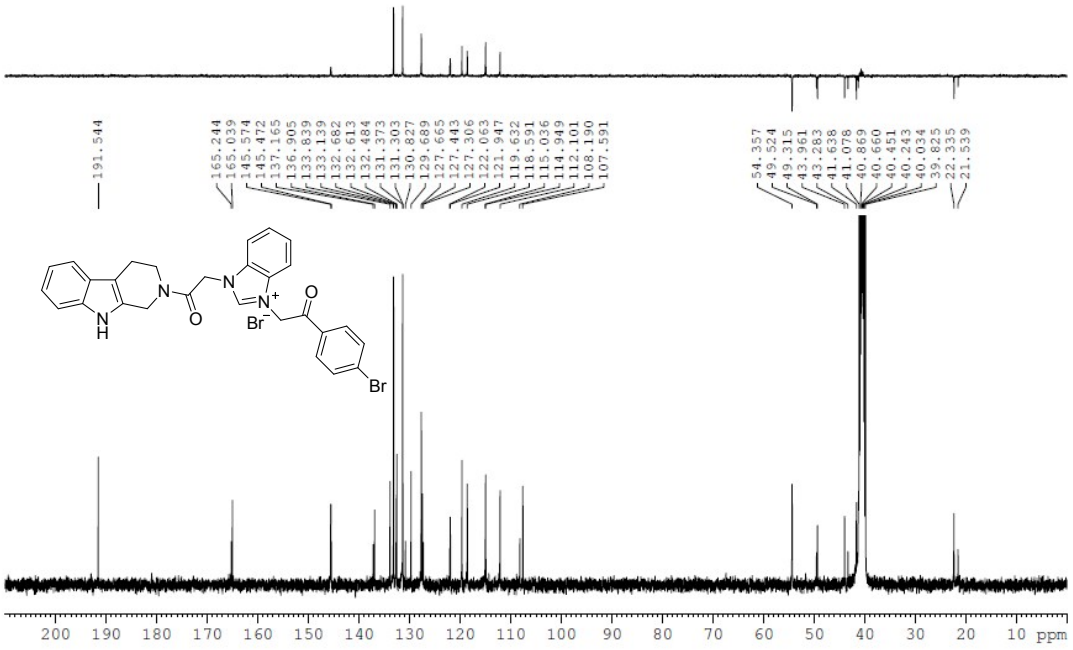

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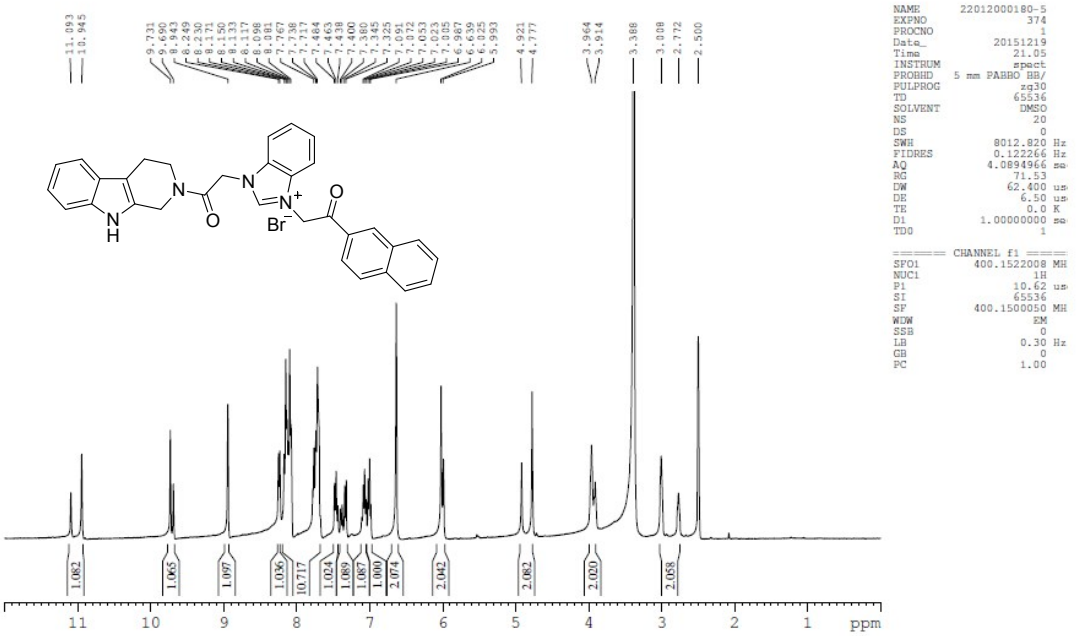

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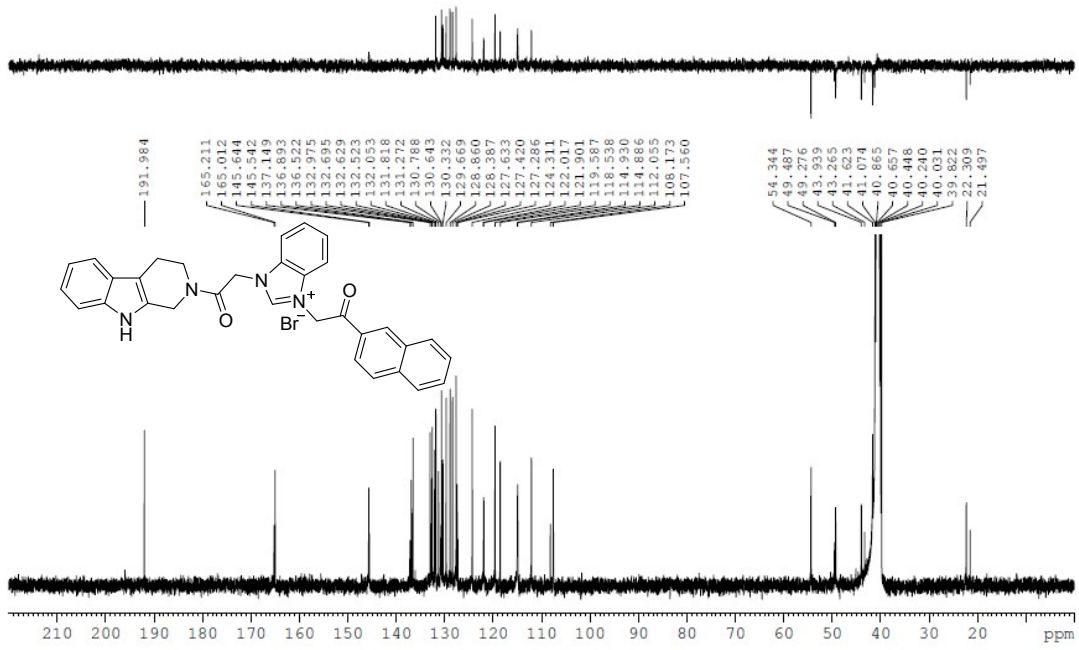

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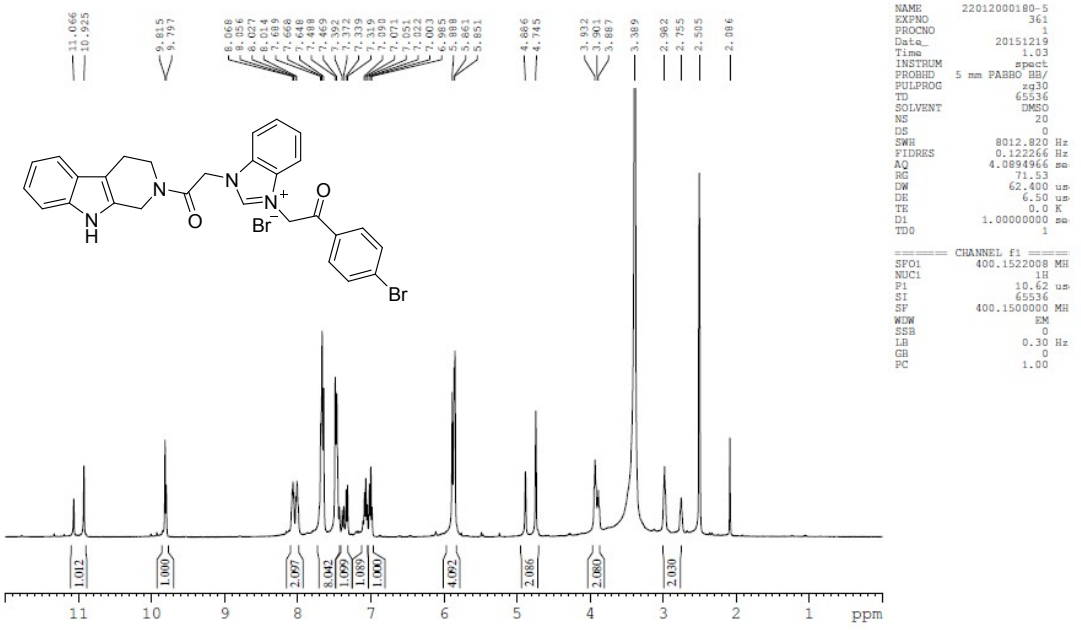

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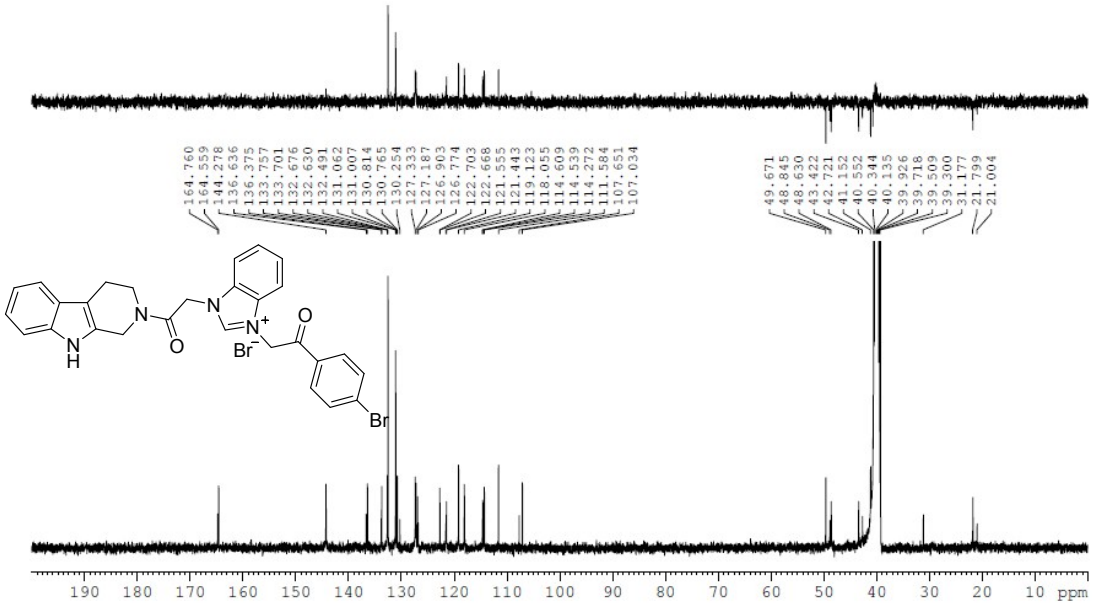

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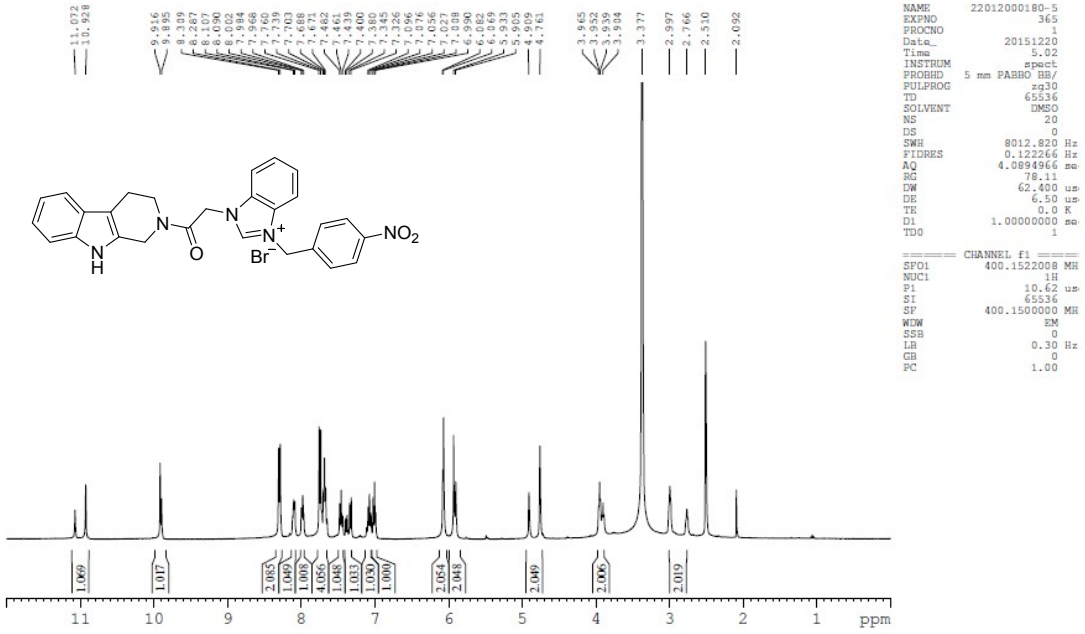

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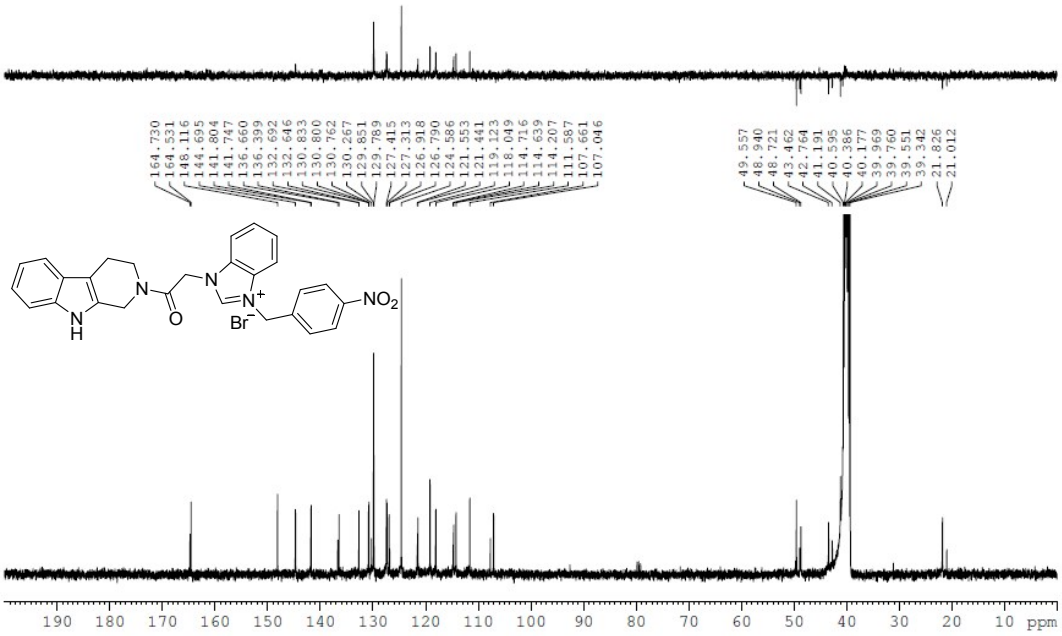

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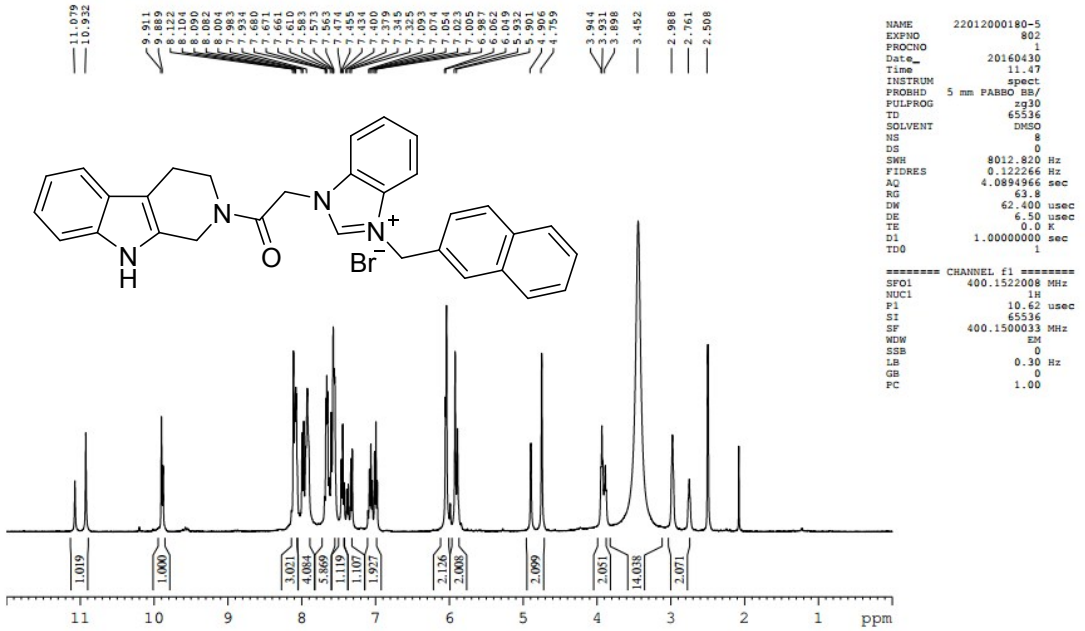

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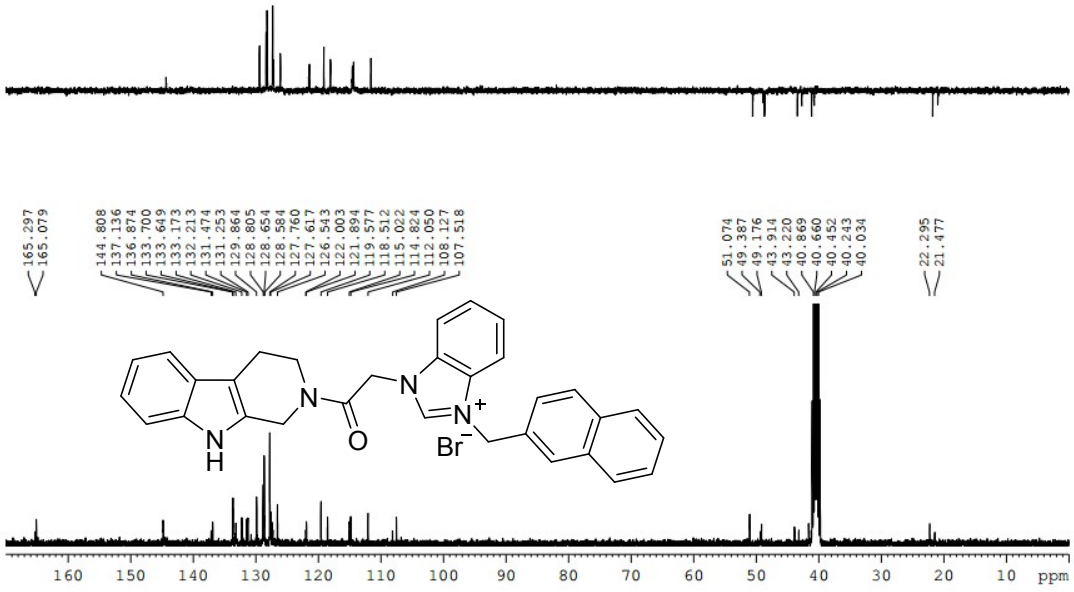
Compound **30** ^{13}C-NMR 100M DMSO



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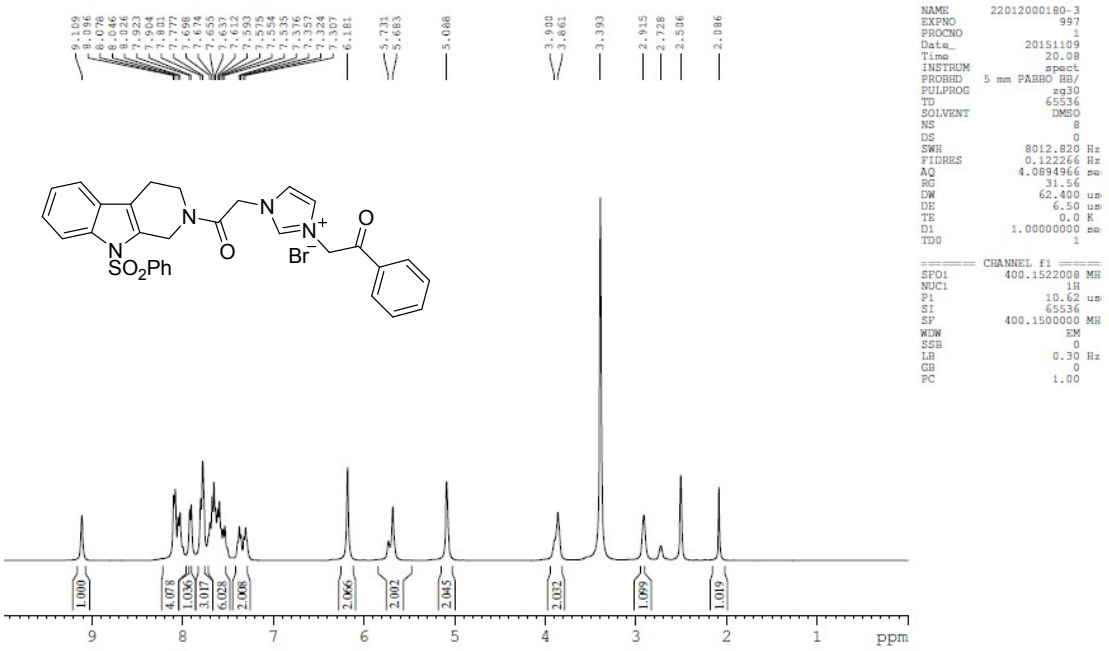
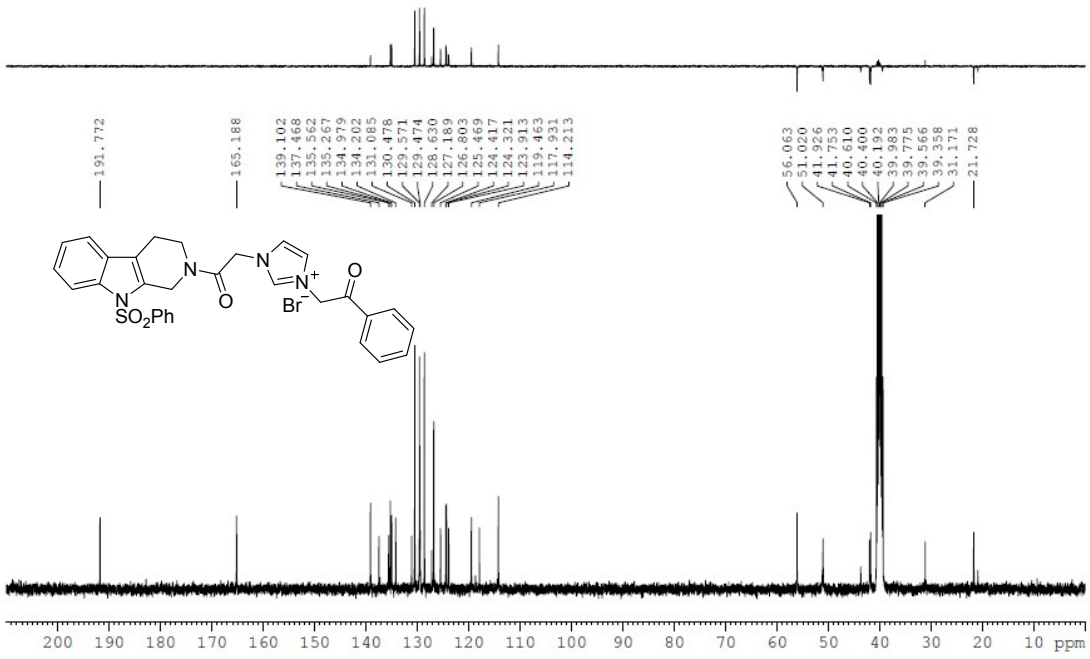
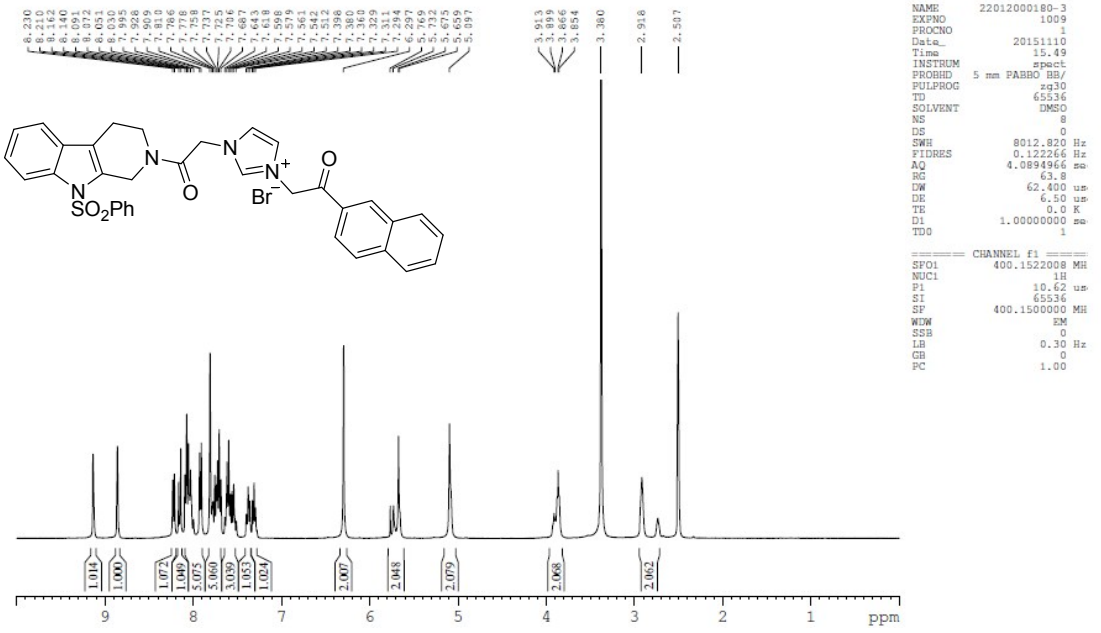


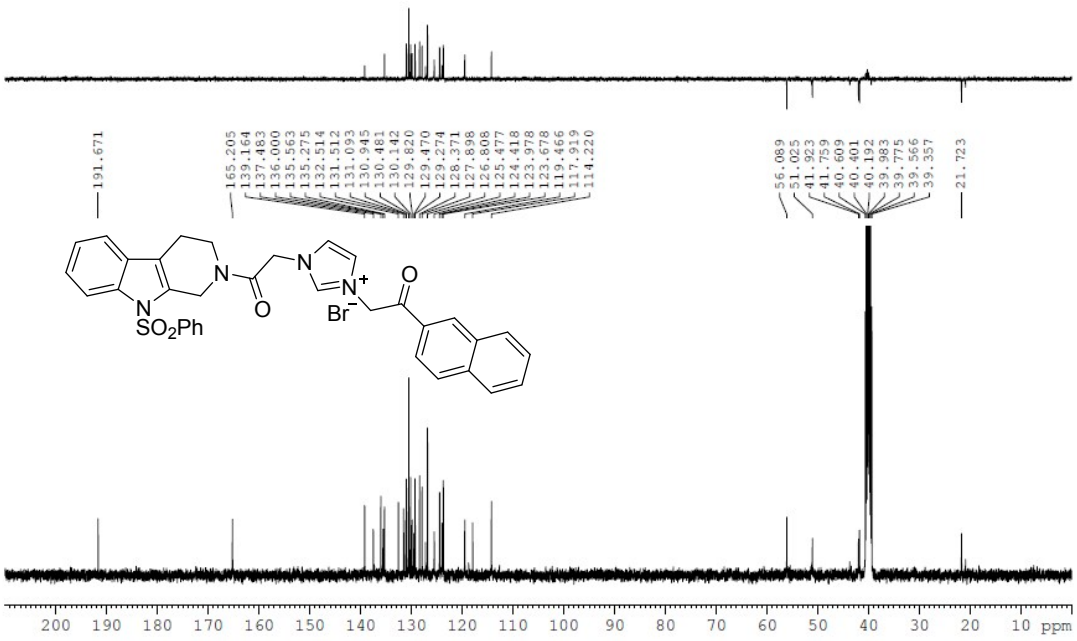
Compound **31** ^{13}C-NMR 100M DMSO



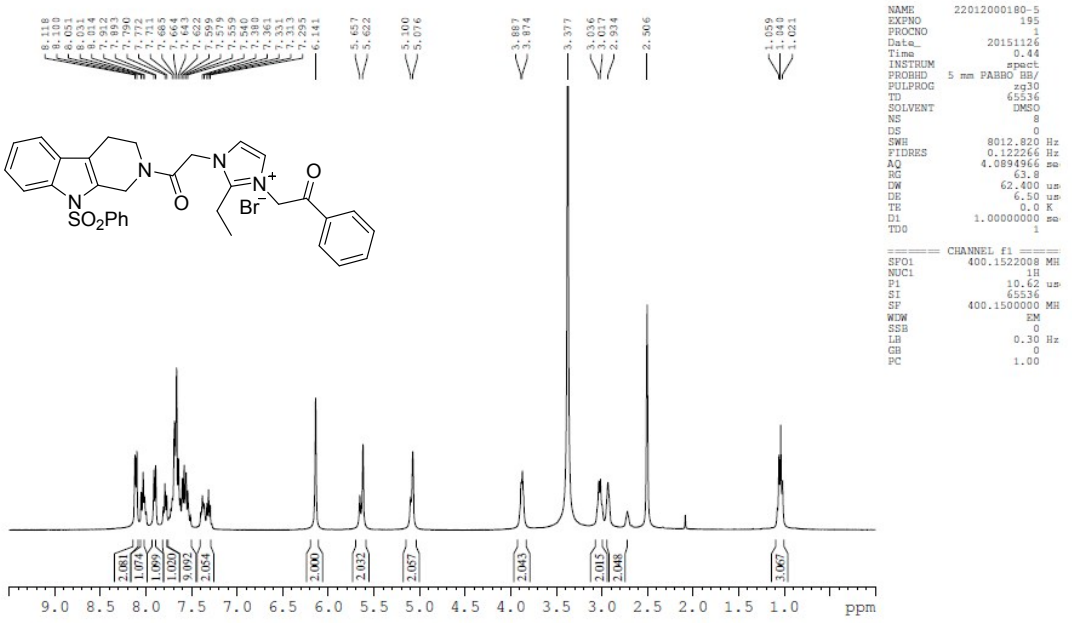
Compound **32** ^{1}H-NMR 400M DMSO



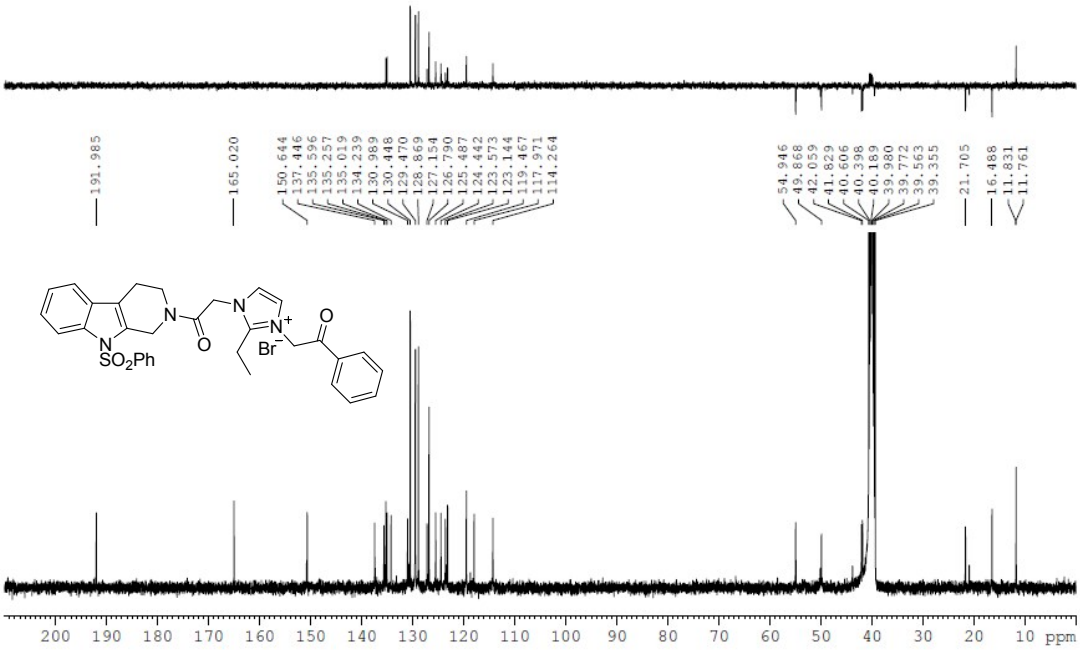
Compound **32** ^{13}C-NMR 100M DMSO



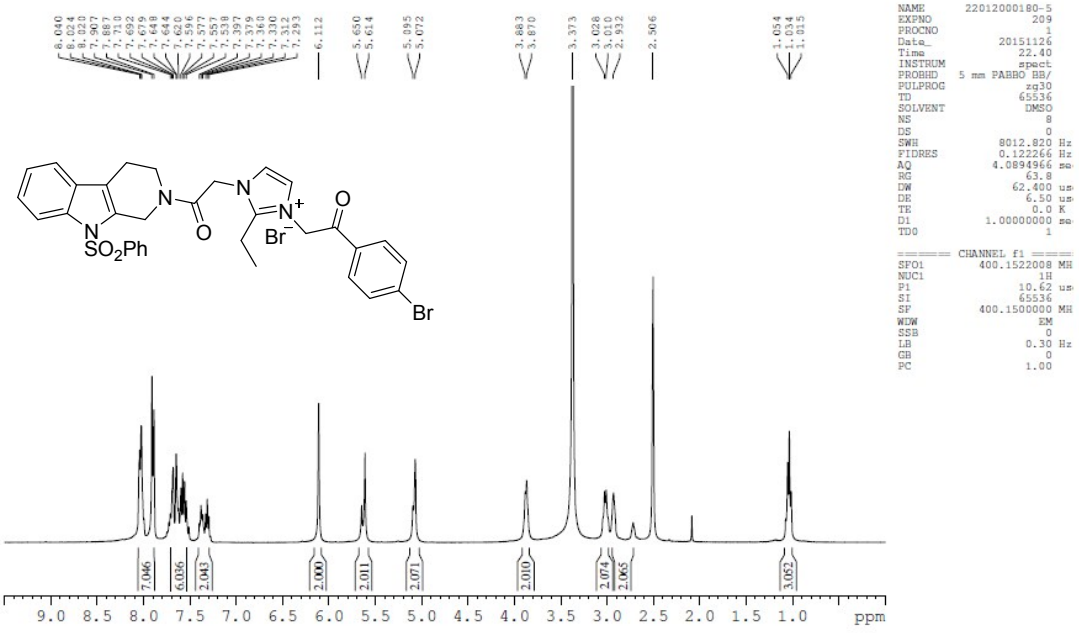
Compound **33** ^{1}H-NMR 400M DMSO



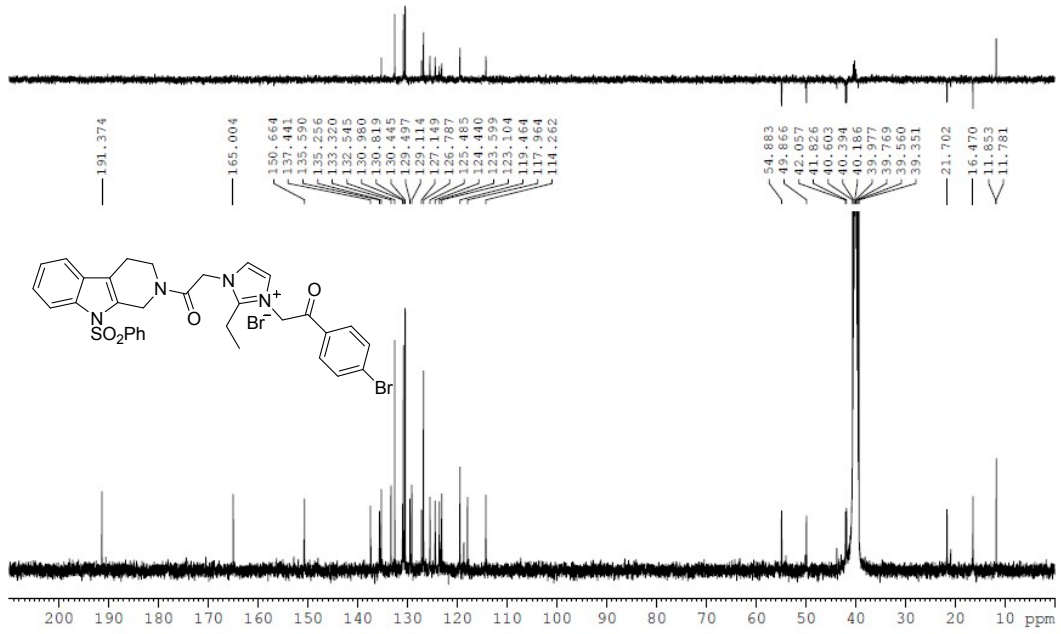
Compound **33** ^{13}C-NMR 100M DMSO



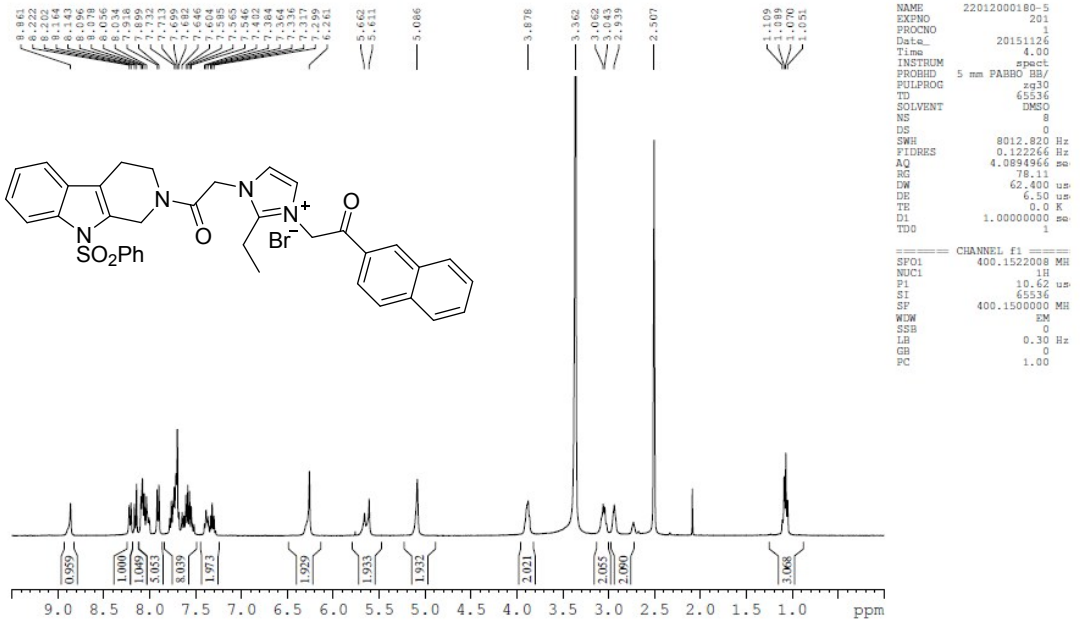
Compound **34** ^{1}H-NMR 400M DMSO



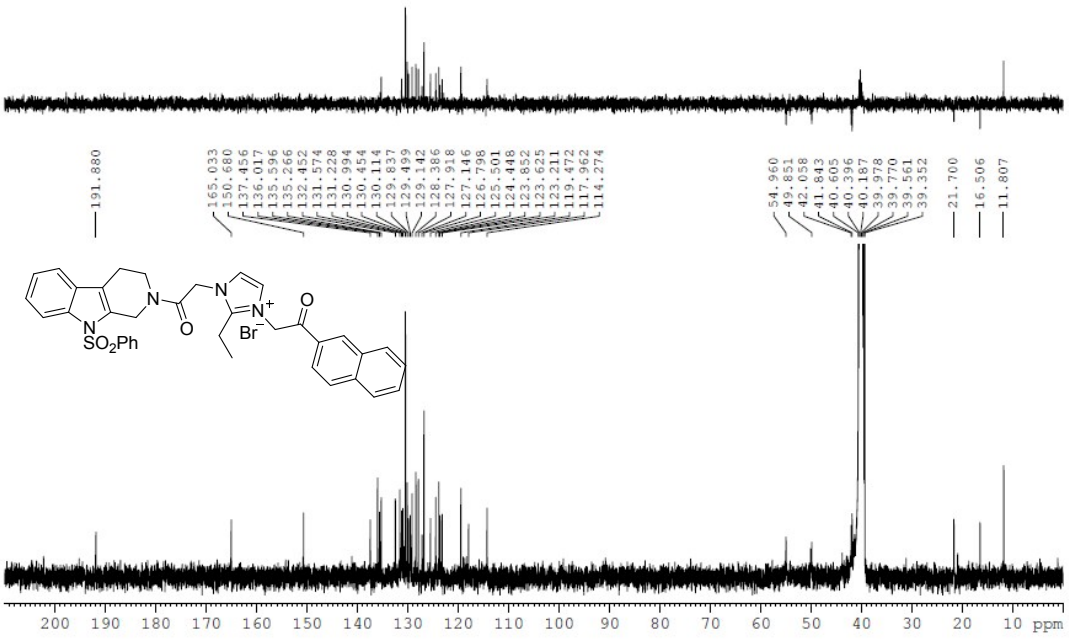
Compound **34** ^{13}C-NMR 100M DMSO



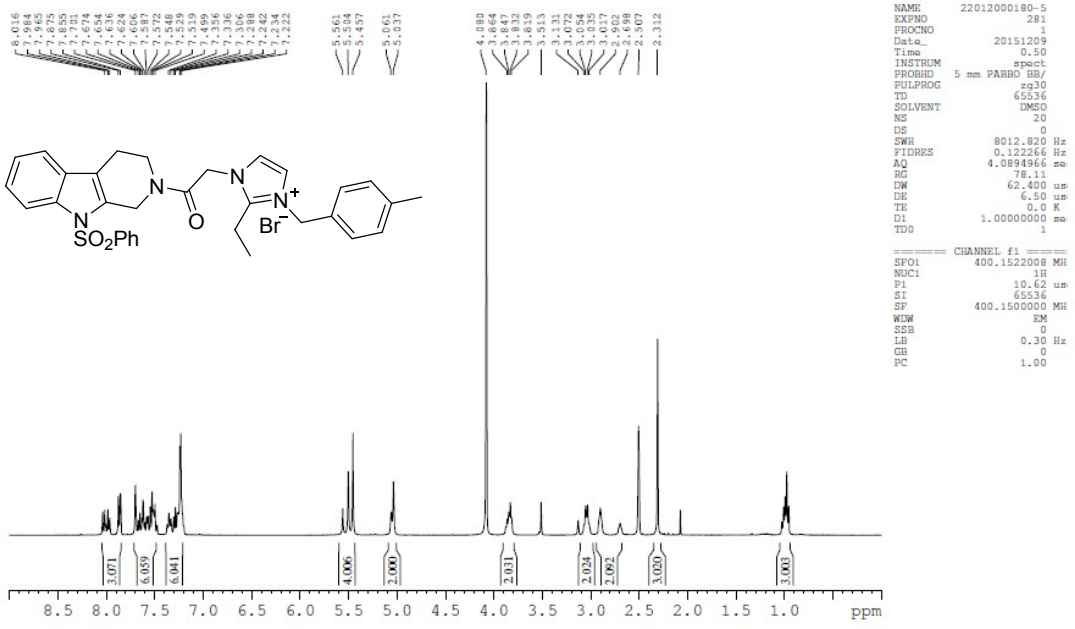
Compound **35** ^{1}H-NMR 400M DMSO



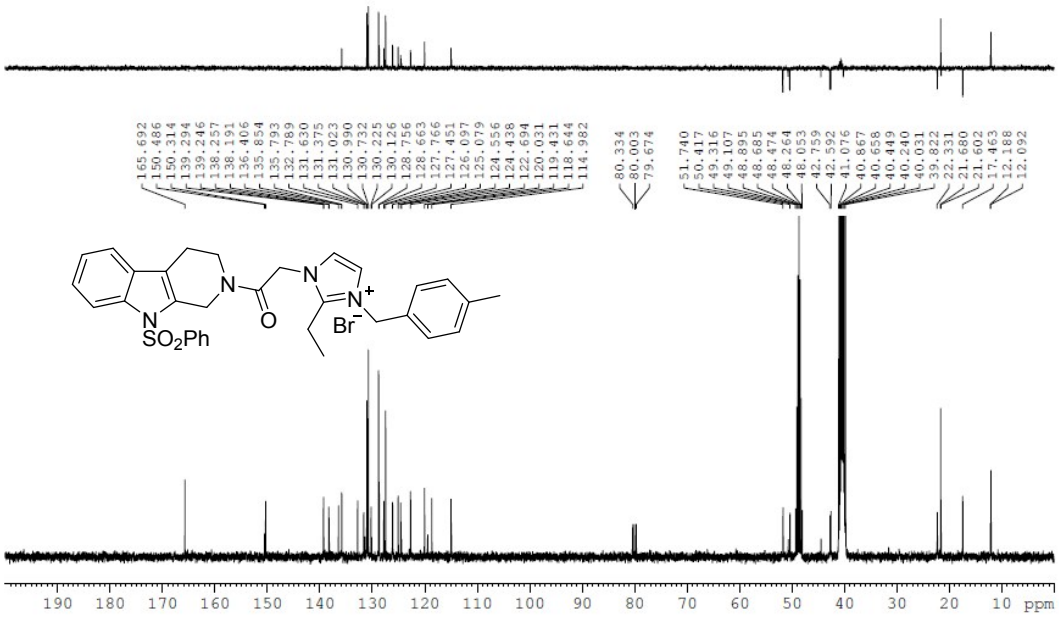
Compound **35** ^{13}C-NMR 100M DMSO



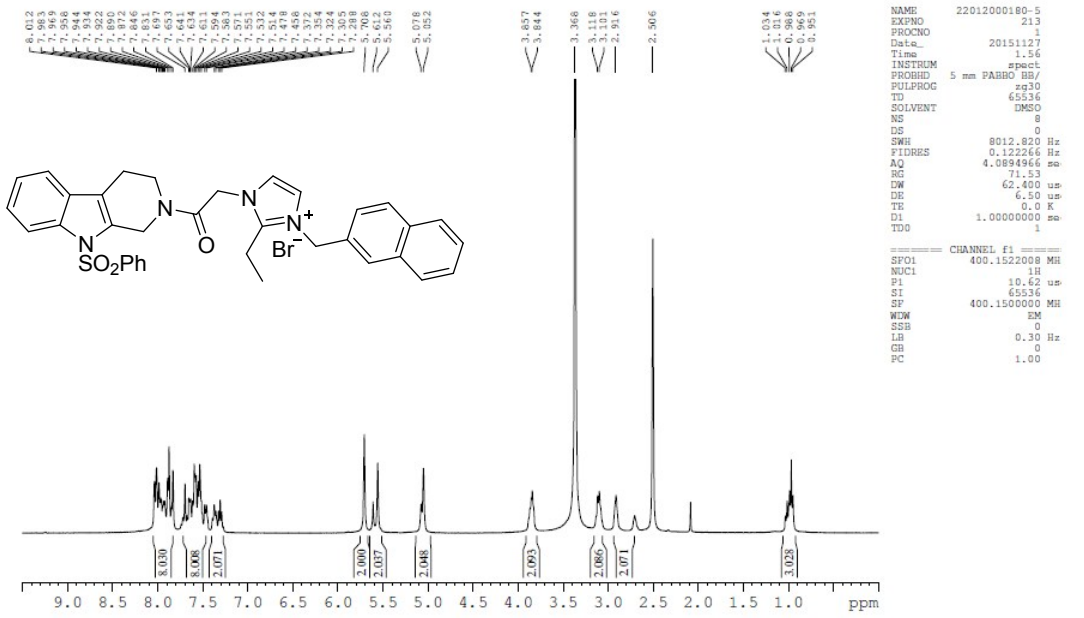
Compound **36** ^{1}H-NMR 400M DMSO



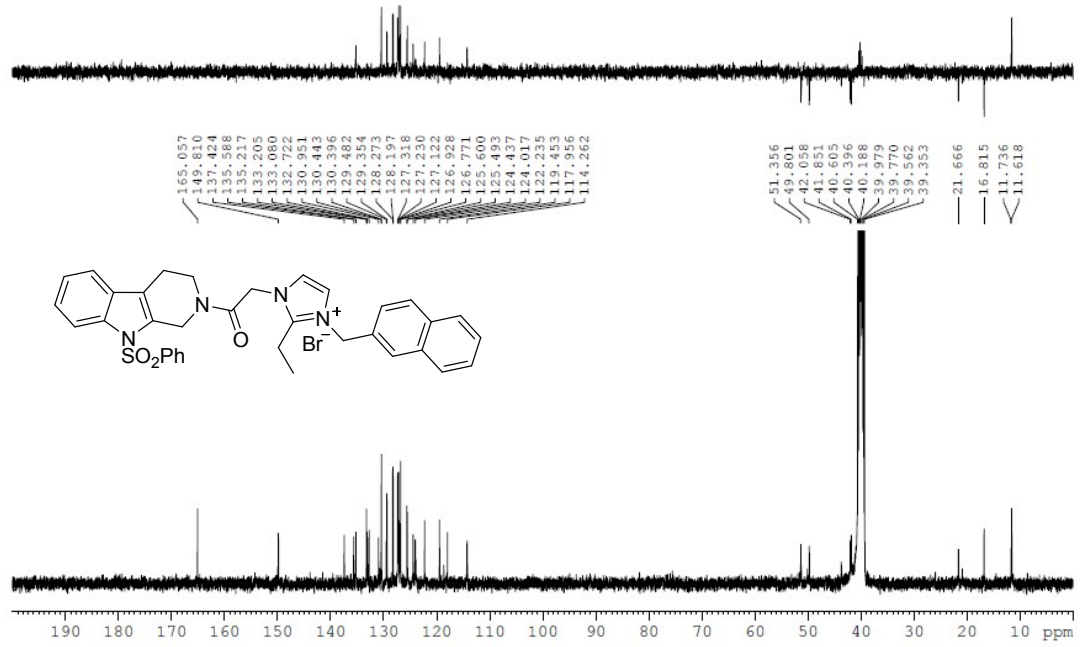
Compound **36** ^{13}C-NMR 100M DMSO



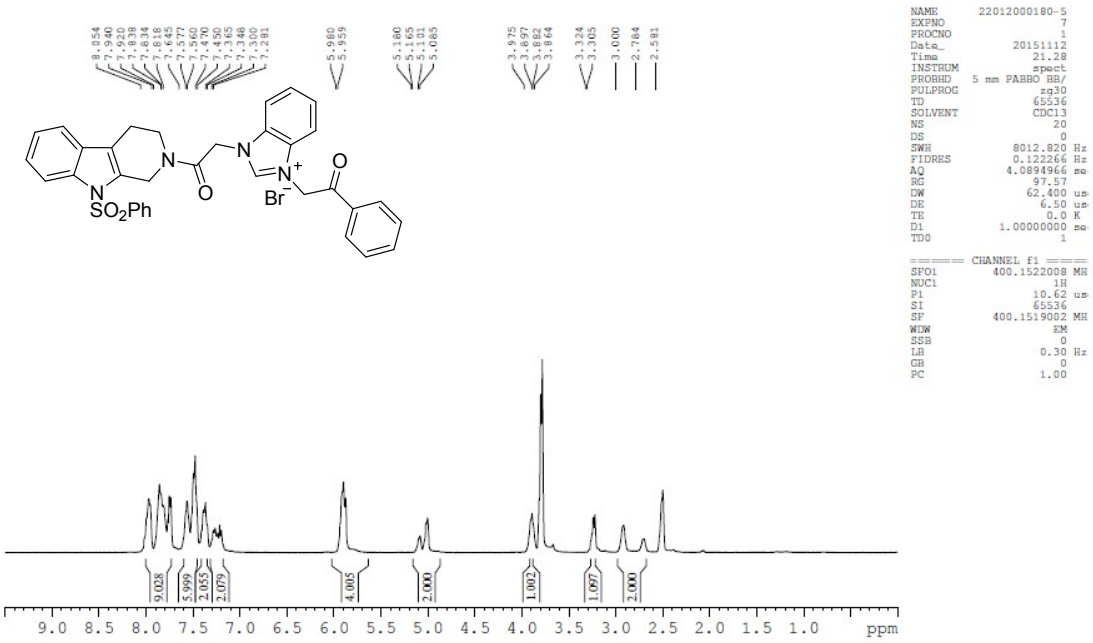
Compound **37** ^{1}H-NMR 400M DMSO



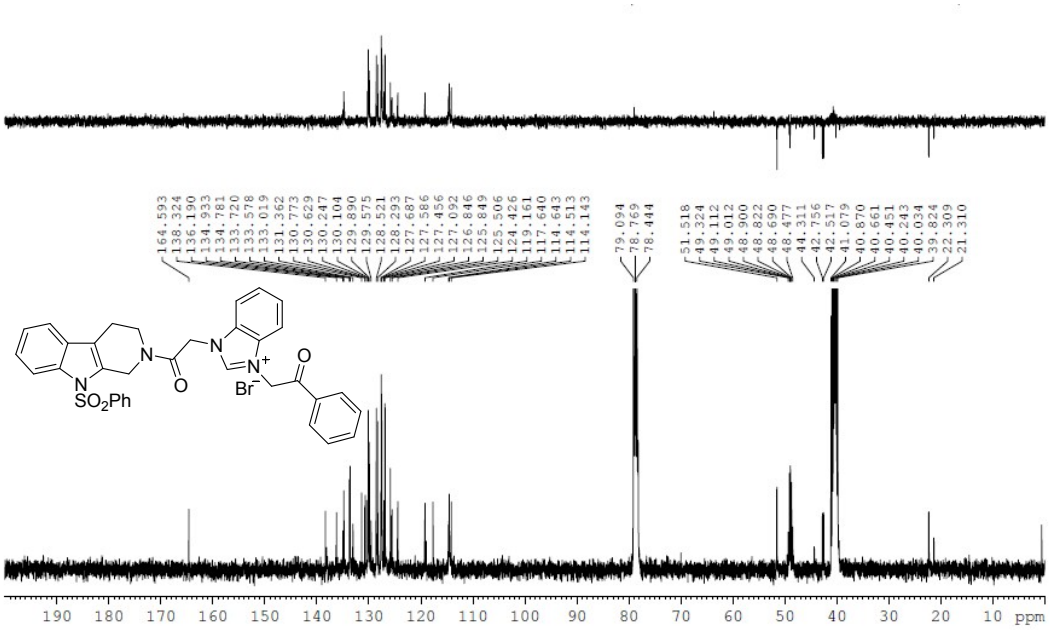
Compound **37** ^{13}C-NMR 100M DMSO



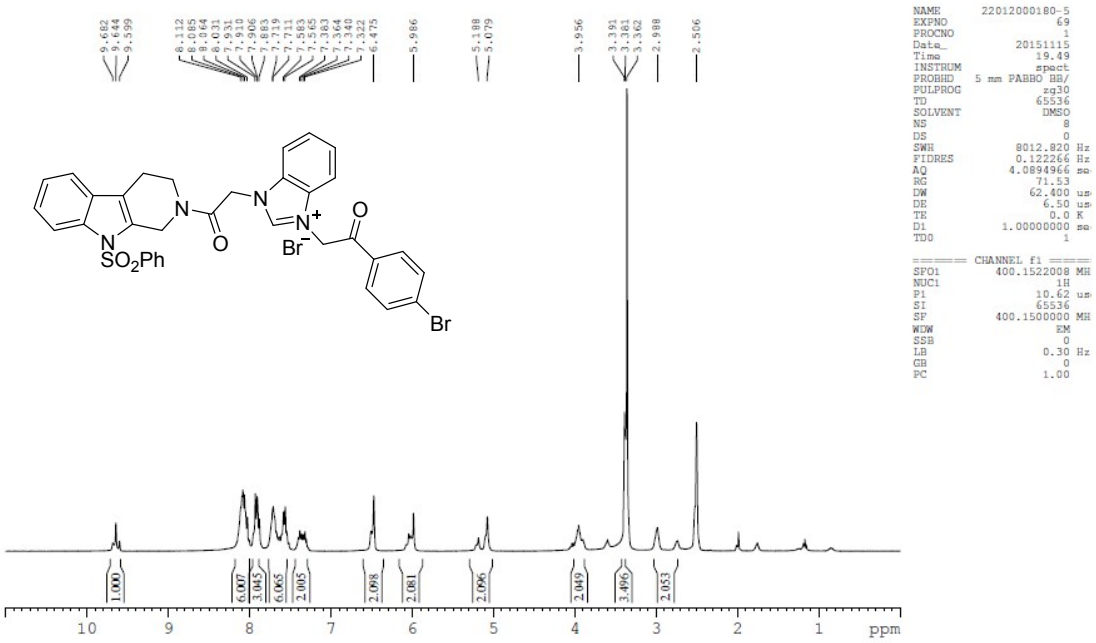
Compound **38** ^{1}H-NMR 400M DMSO



Compound **38** ^{13}C-NMR 100M DMSO



Compound **39** ^{1}H-NMR 400M DMSO

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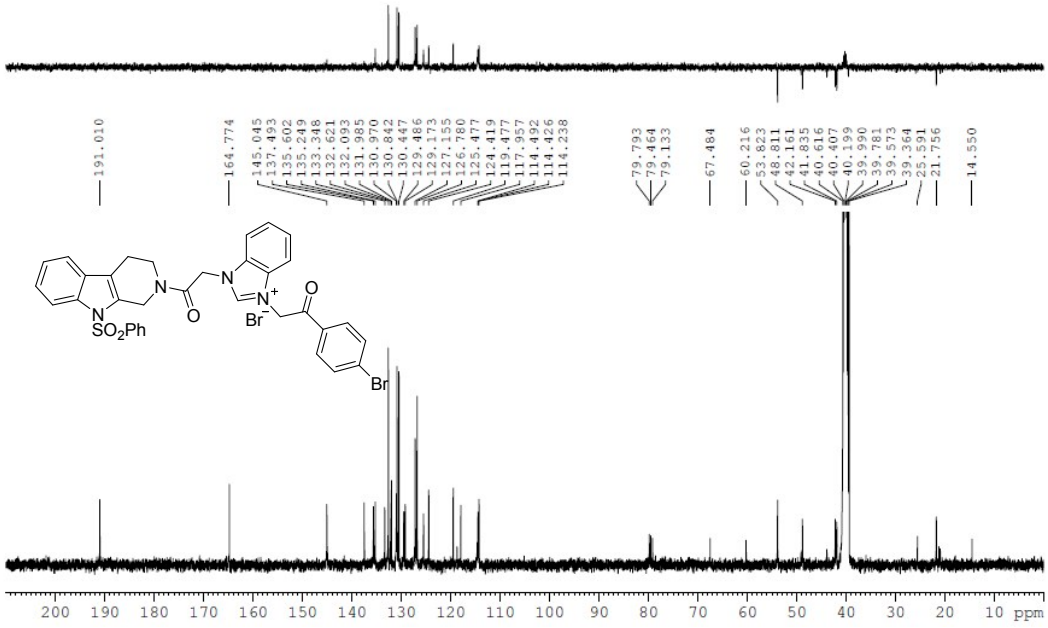
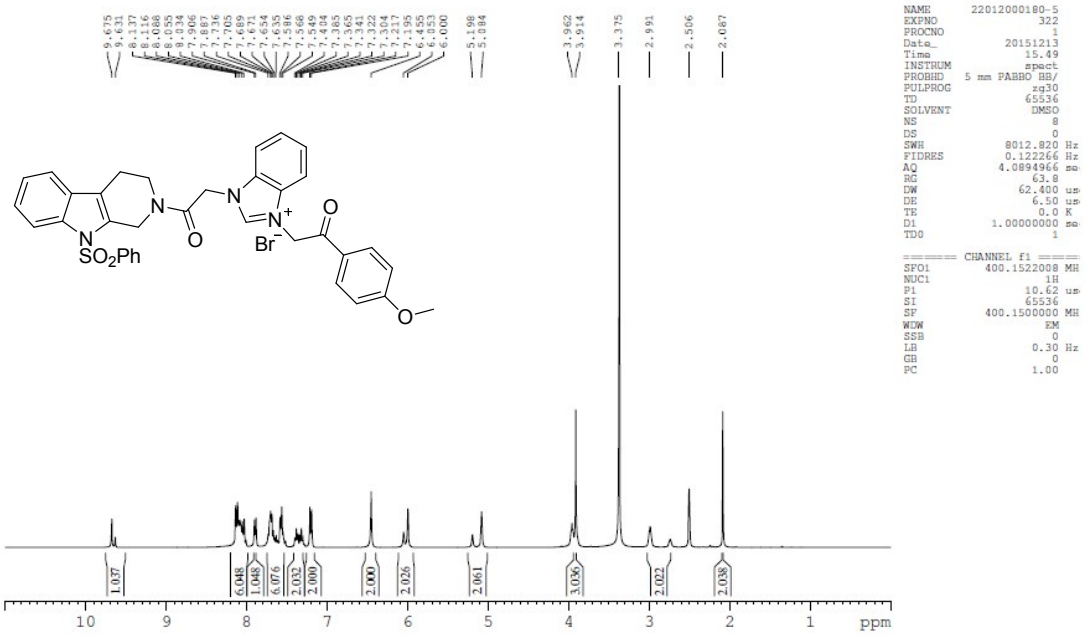
EXPNO                    69
PROCNO                    1
Date_              20151115
Time                  19.49
INSTRUM               spect
PROBHD    5 mm PABBO BB/
PULPROG                zg30
TD                    65536
SOLVENT                DMSO
NS                        8
DS                        0
SWH                8012.820 Hz
FIDRES            0.122266 Hz
AQ                4.0894966 se
RG                    71.53
DW                   62.400 us
DE                    6.50 us
TE                     0.0 K
D1                1.00000000 se
TD0                       1

====== CHANNEL f1 ======
SFO1           400.1522008 MH
NUC1                    1H
P1                   10.62 us
SI                    65536
SF             400.1500000 MH
WDW                     EM
SSB                      0
LB                    0.30 Hz
GB                       0
PC                    1.00
```

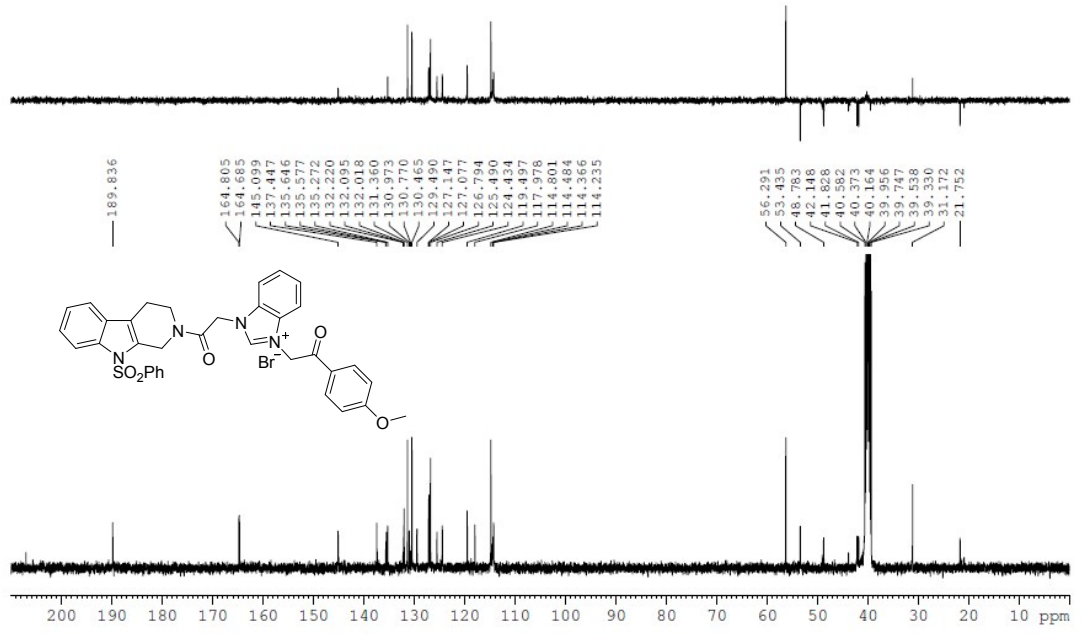
Compound **39** ^{13}C-NMR 100M DMSO



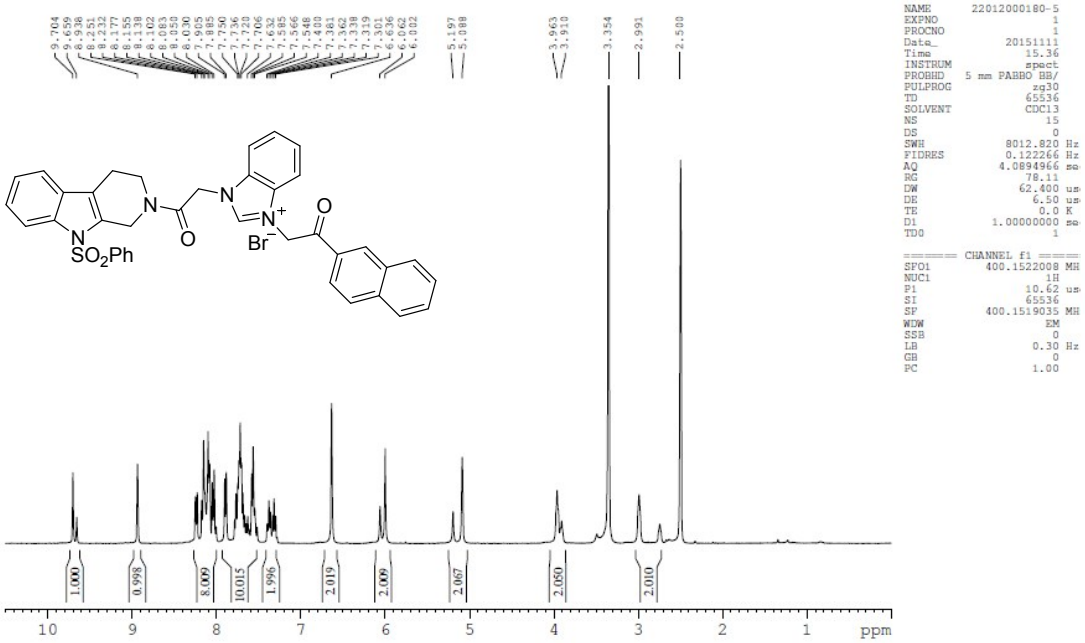
Compound **40** ^{1}H-NMR 400M DMSO



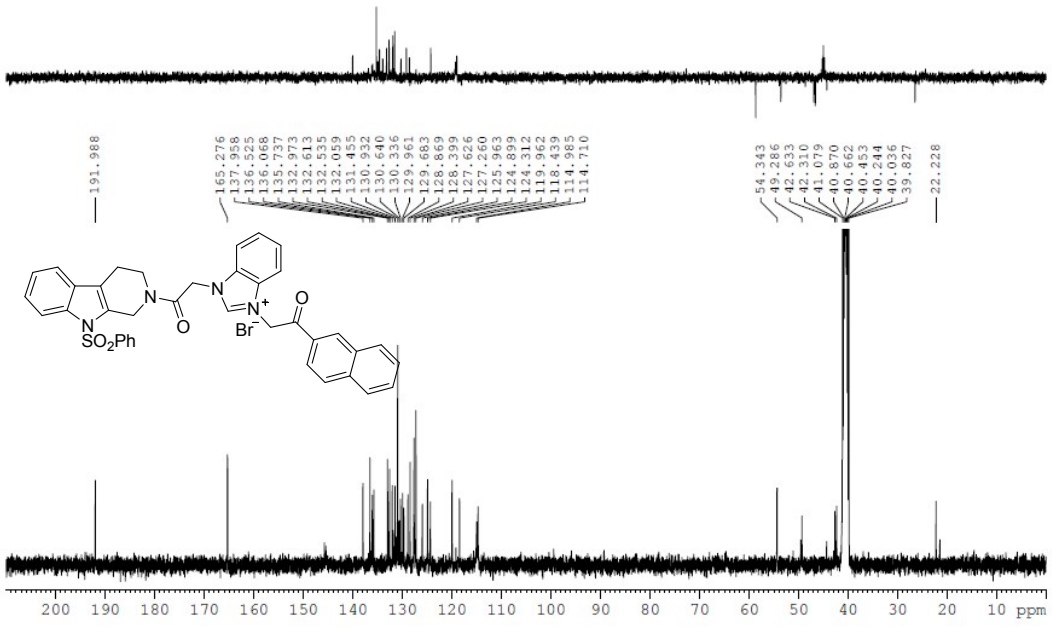
Compound **40** ^{13}C-NMR 100M DMSO



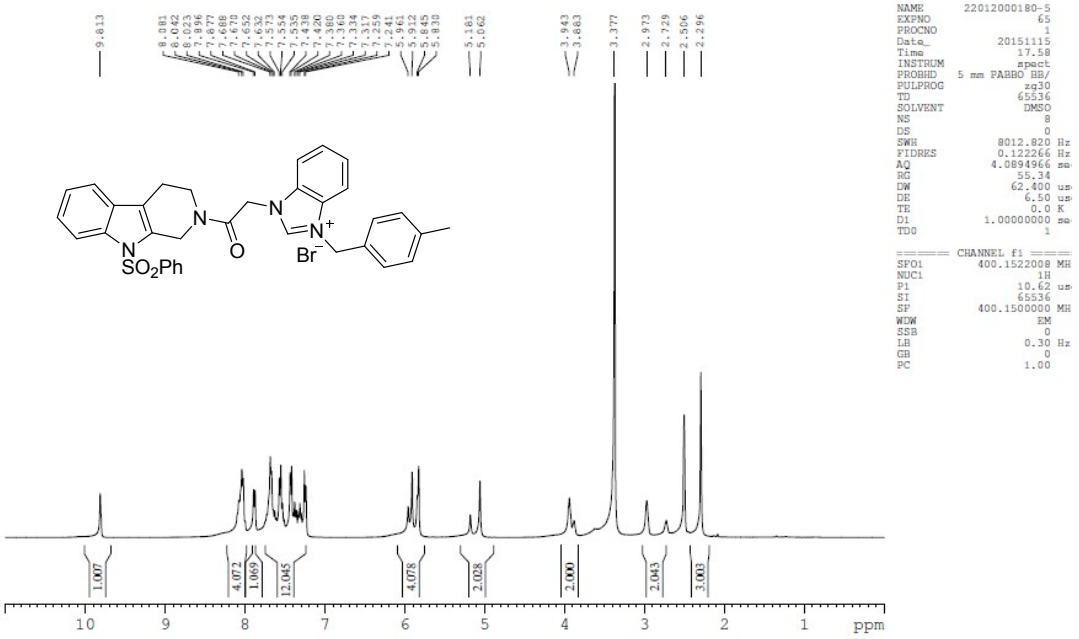
Compound **41** ^{1}H-NMR 400M DMSO



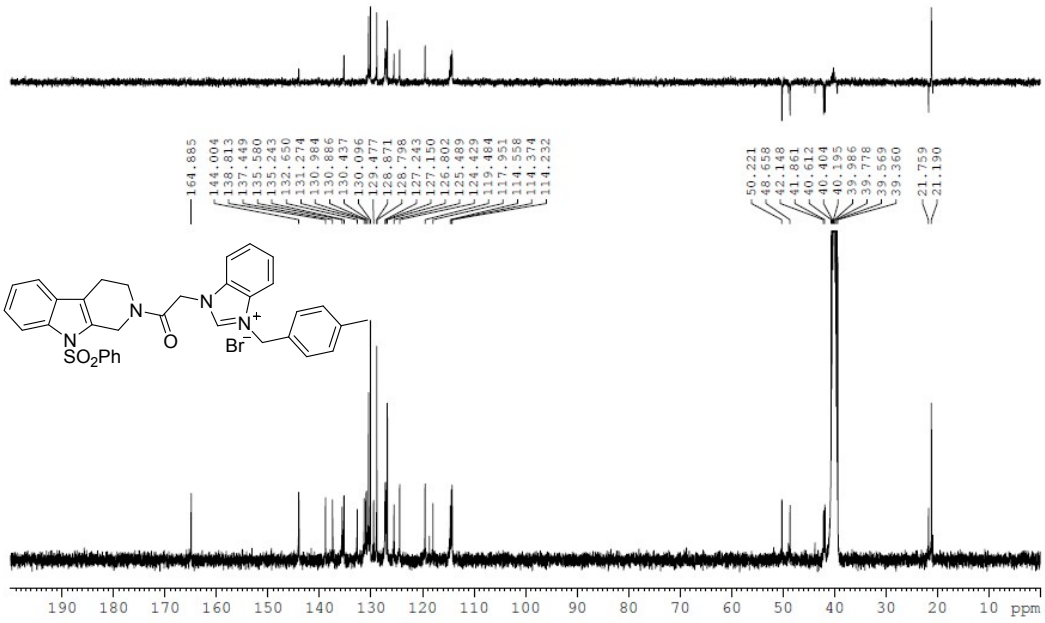
Compound **41** ^{13}C-NMR 100M DMSO



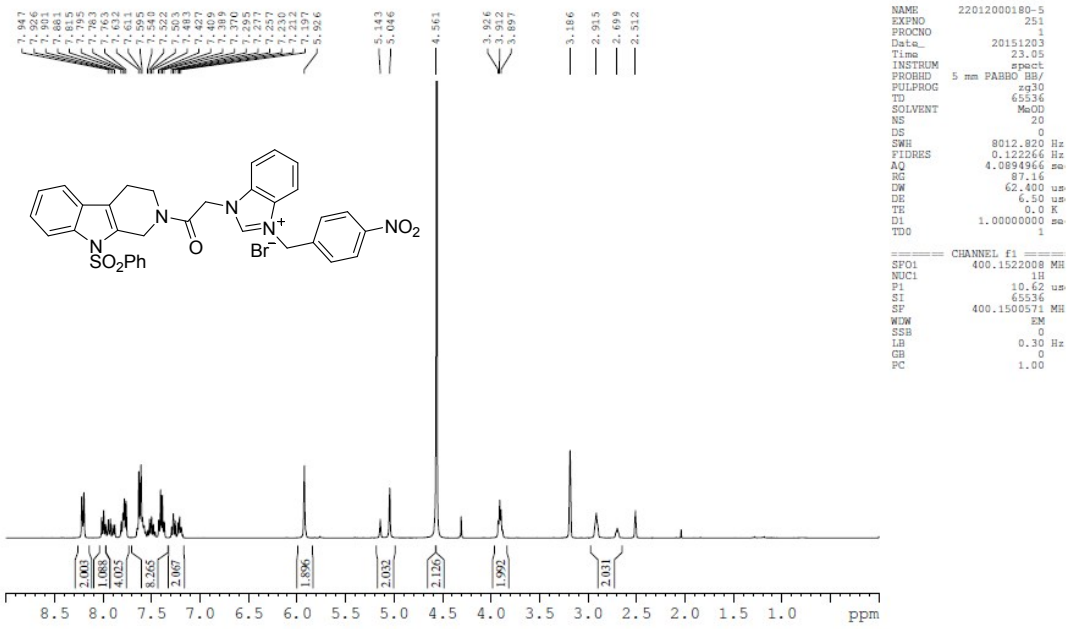
Compound **42** ^{1}H-NMR 400M DMSO



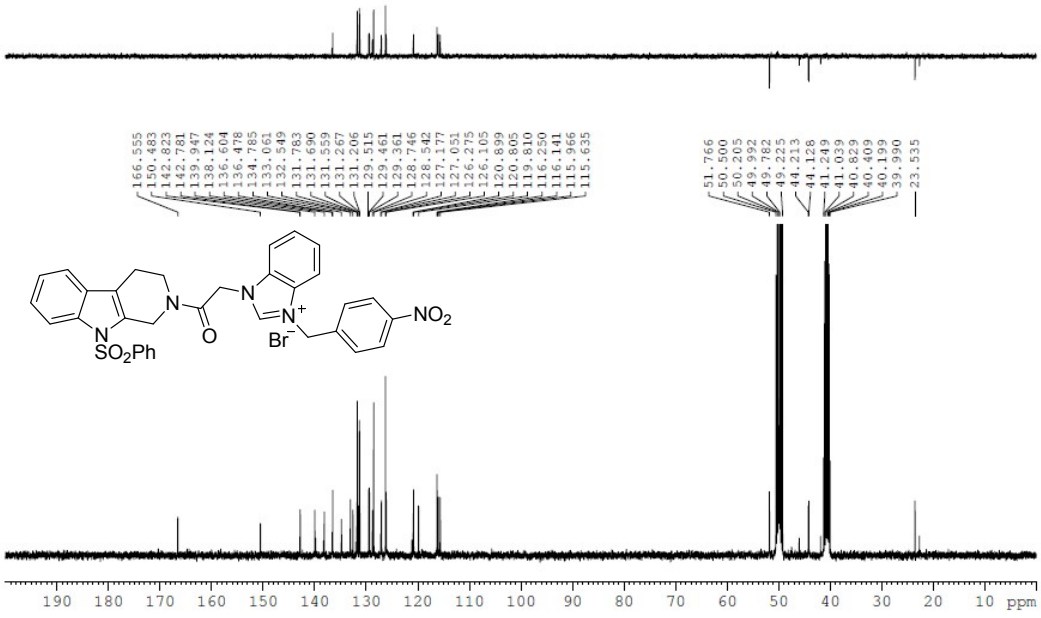
Compound **42** ^{13}C-NMR 100M DMSO



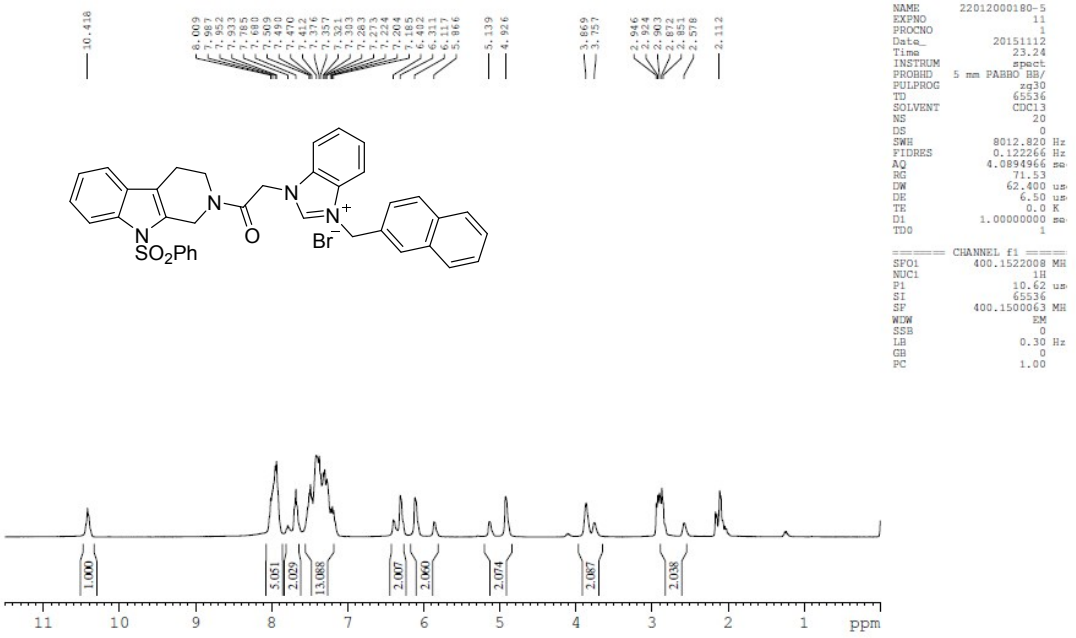
Compound **43** ^{1}H-NMR 400M DMSO



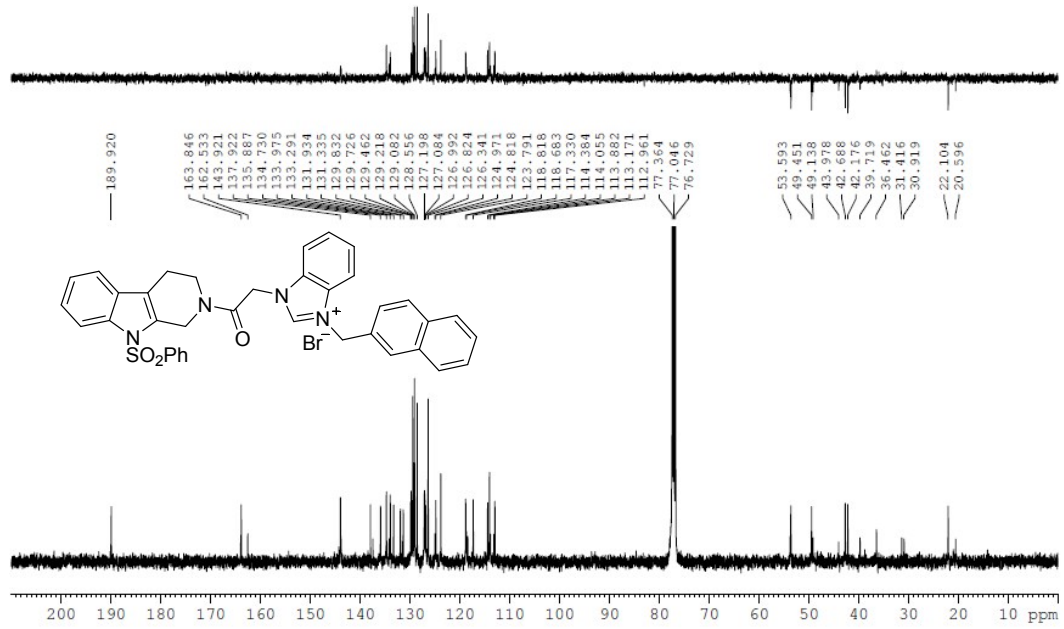
Compound **43** ^{13}C-NMR 100M DMSO



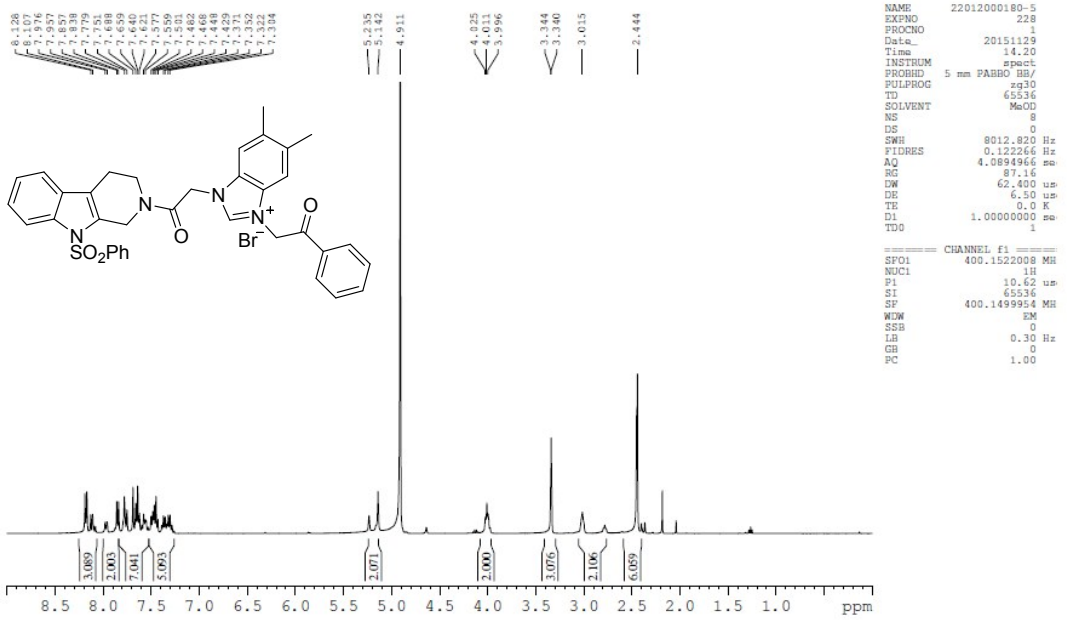
Compound **44** ^{1}H-NMR 400M DMSO



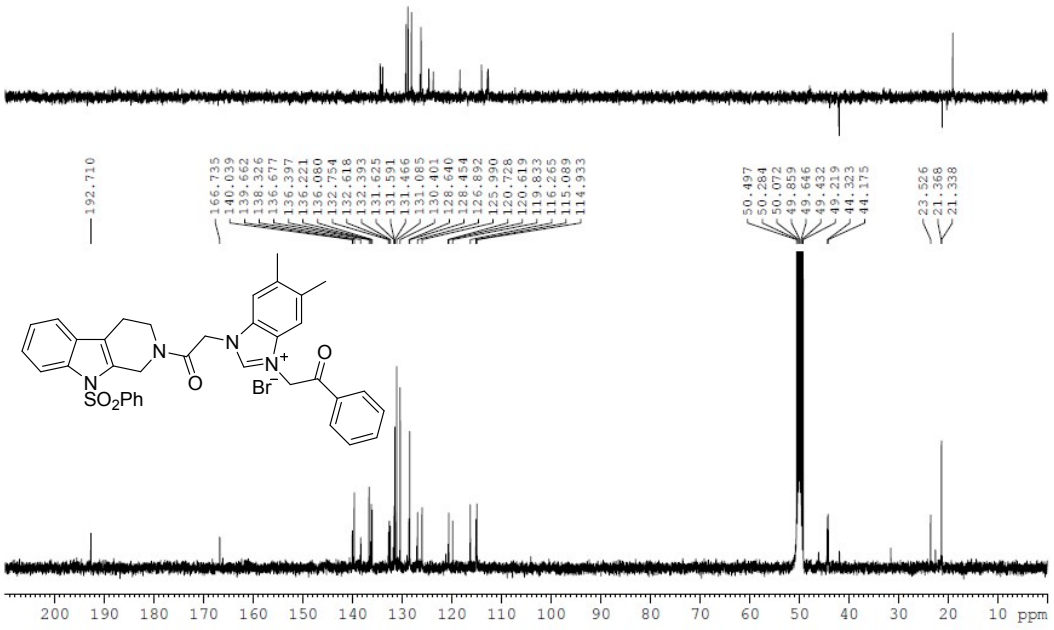
Compound **44** ^{13}C-NMR 100M DMSO



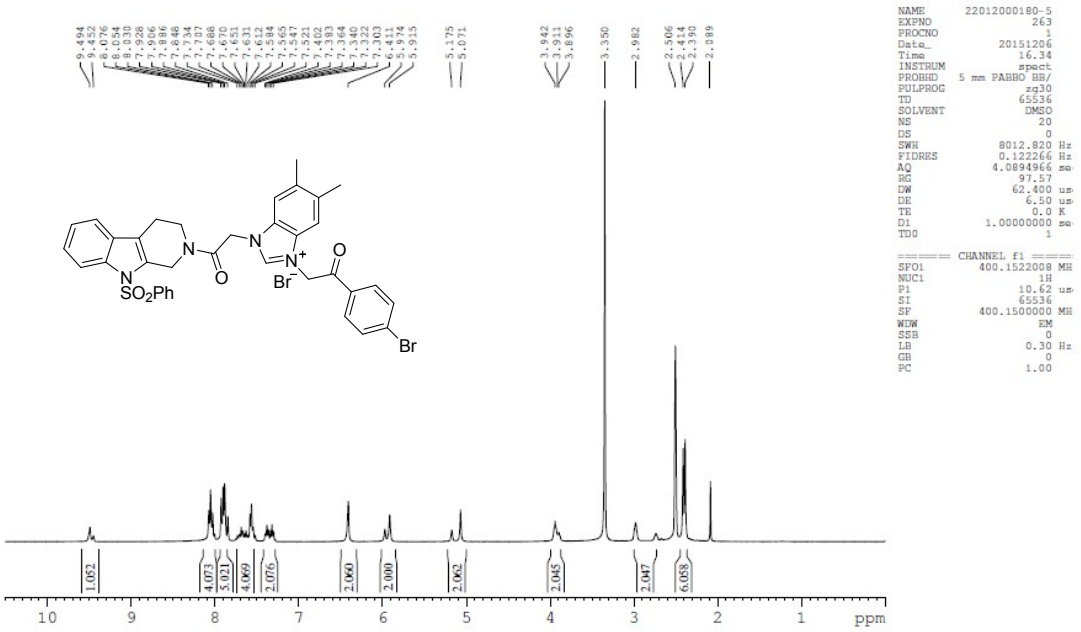
Compound **45** ^{1}H-NMR 400M DMSO



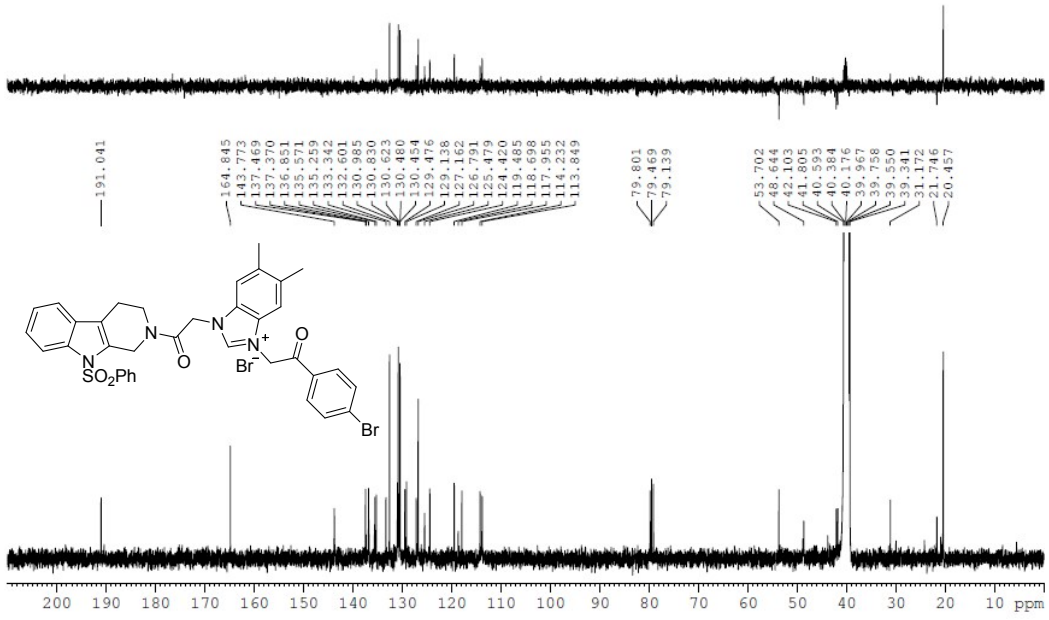
Compound **45** ^{13}C-NMR 100M DMSO



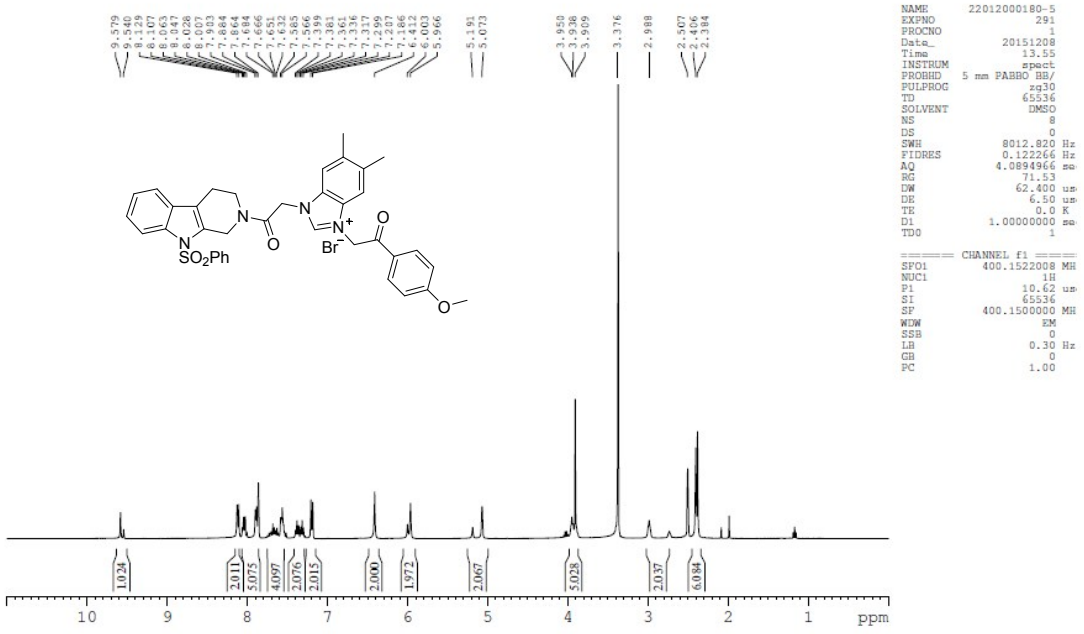
Compound **46** ^{1}H-NMR 400M DMSO



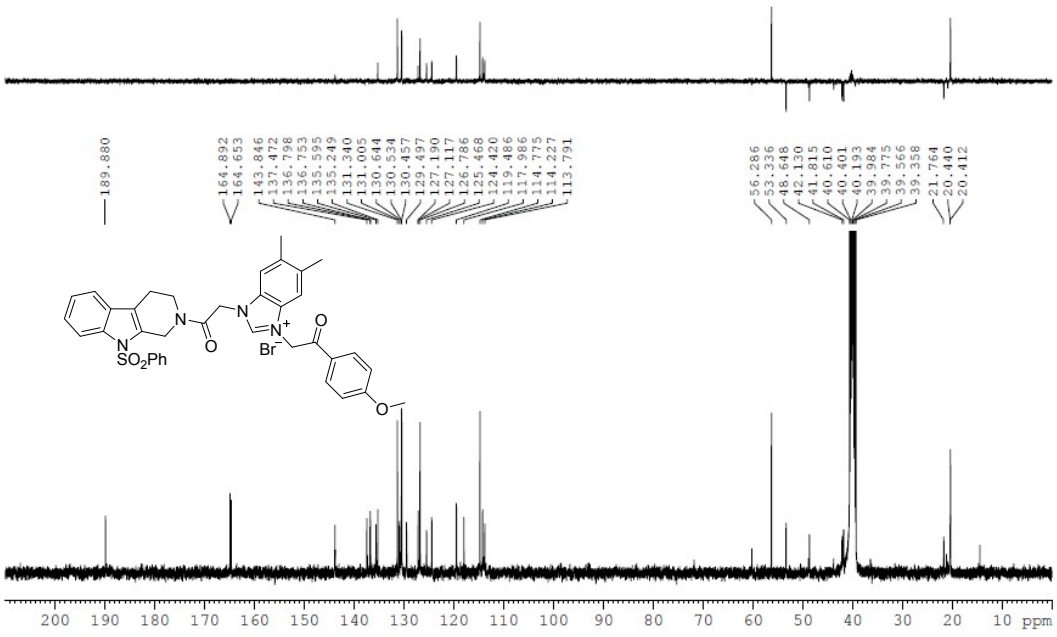
Compound **46** ^{13}C-NMR 100M DMSO



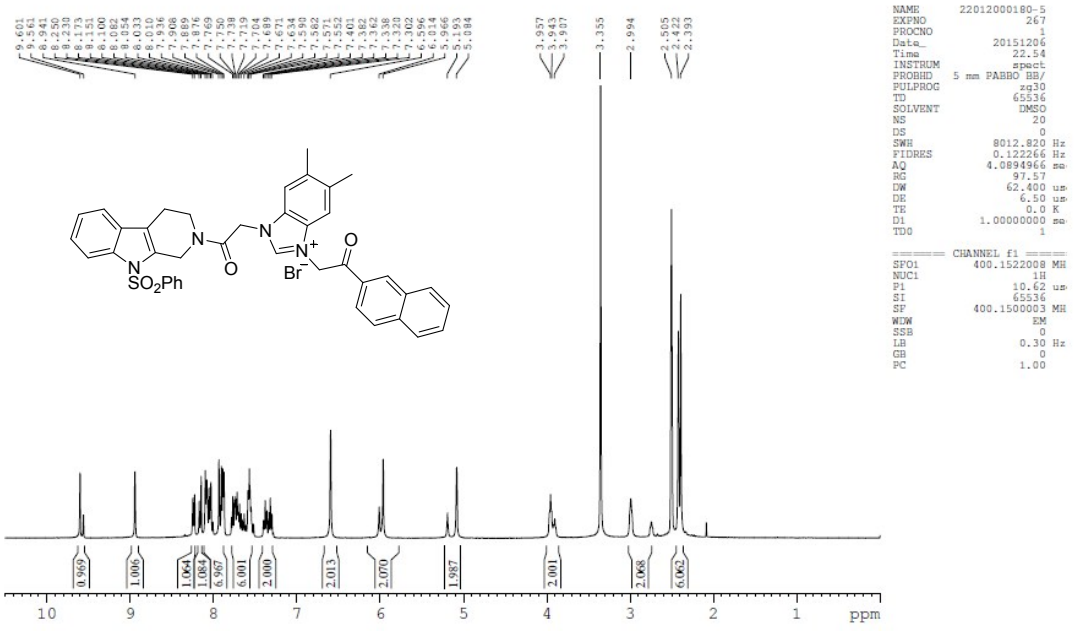
Compound **47** ^{1}H-NMR 400M DMSO



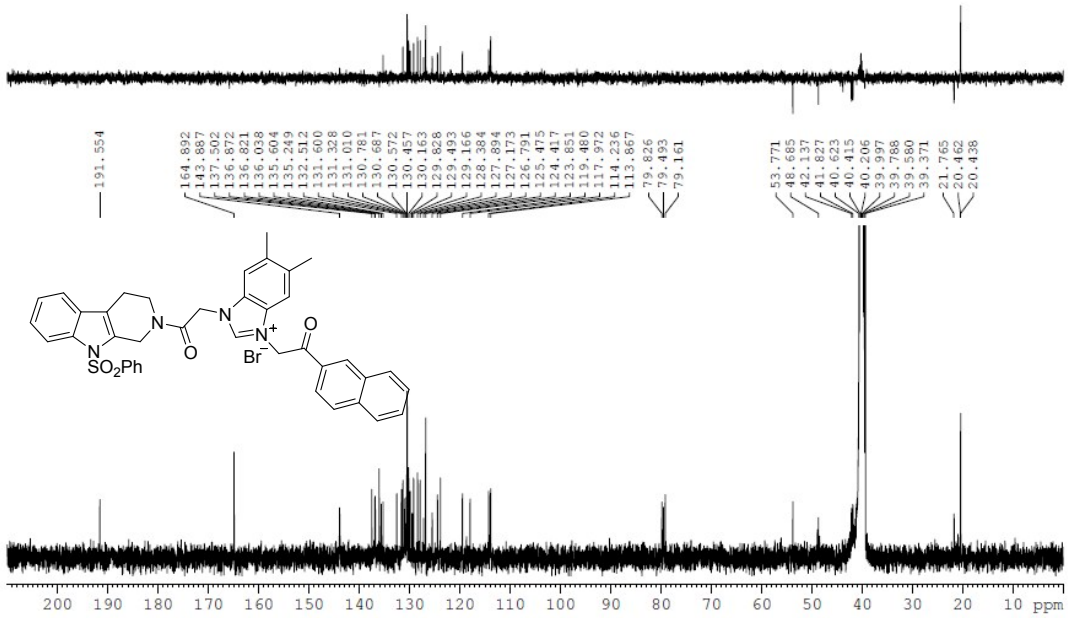
Compound **47** ^{13}C-NMR 100M DMSO



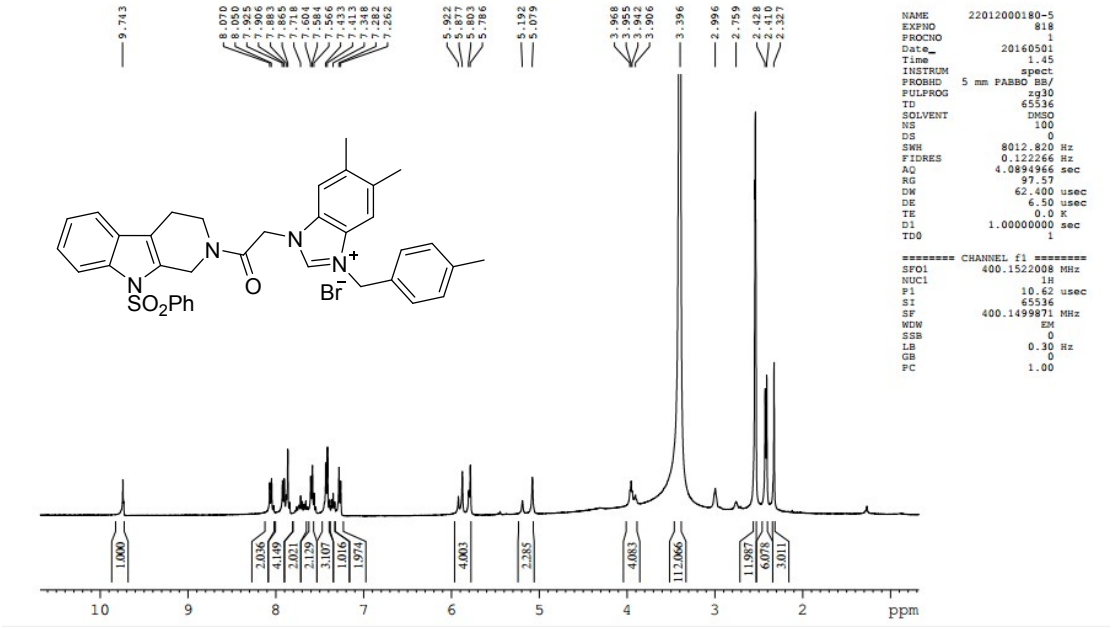
Compound **48** ^{1}H-NMR 400M DMSO



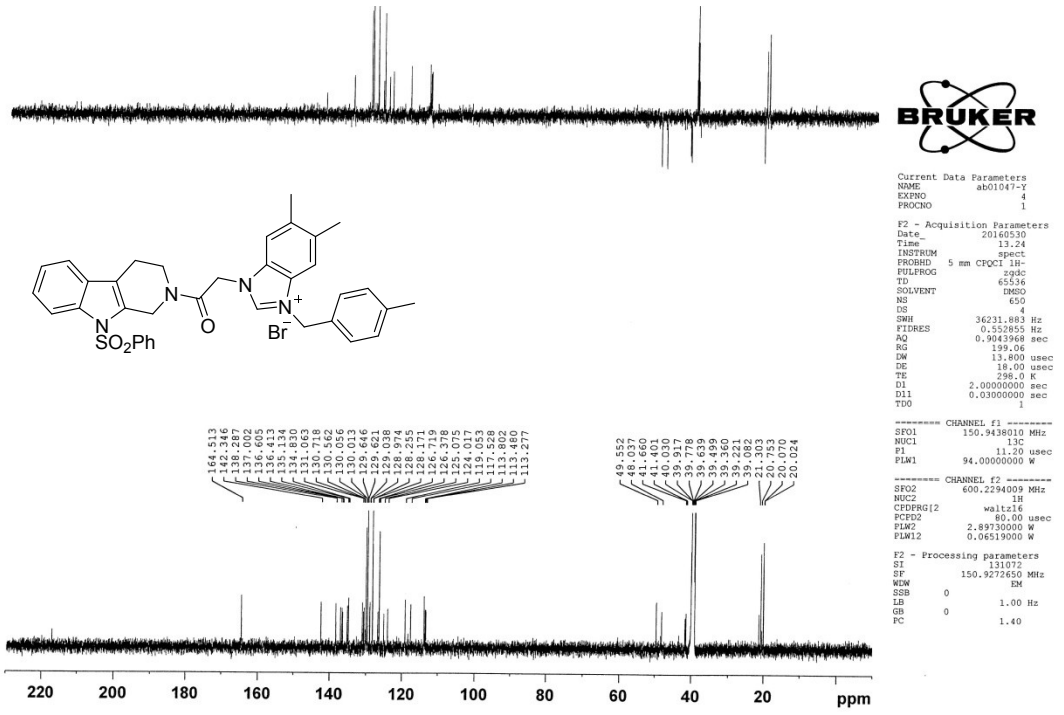
Compound **48** ^{13}C-NMR 100M DMSO



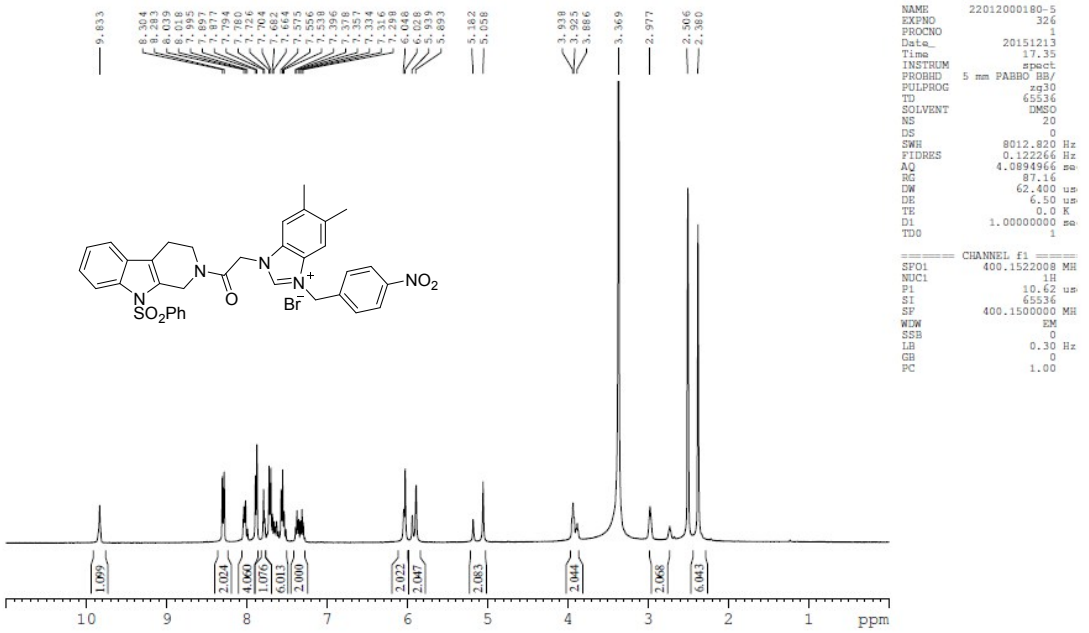
Compound **49** ^{1}H-NMR 400M DMSO



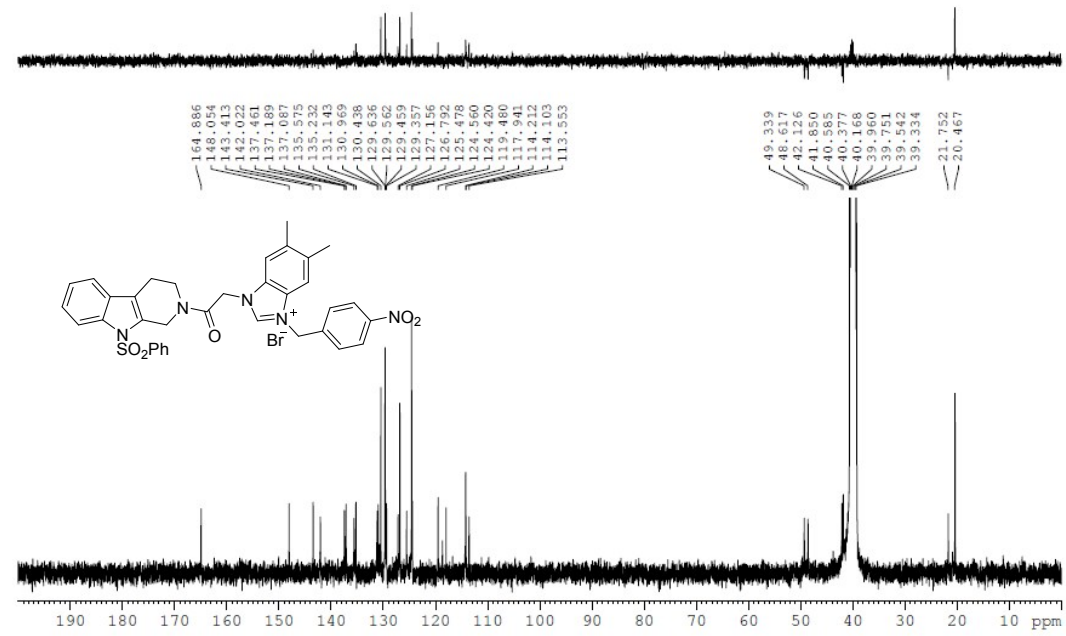
Compound **49** ^{13}C-NMR 120M DMSO



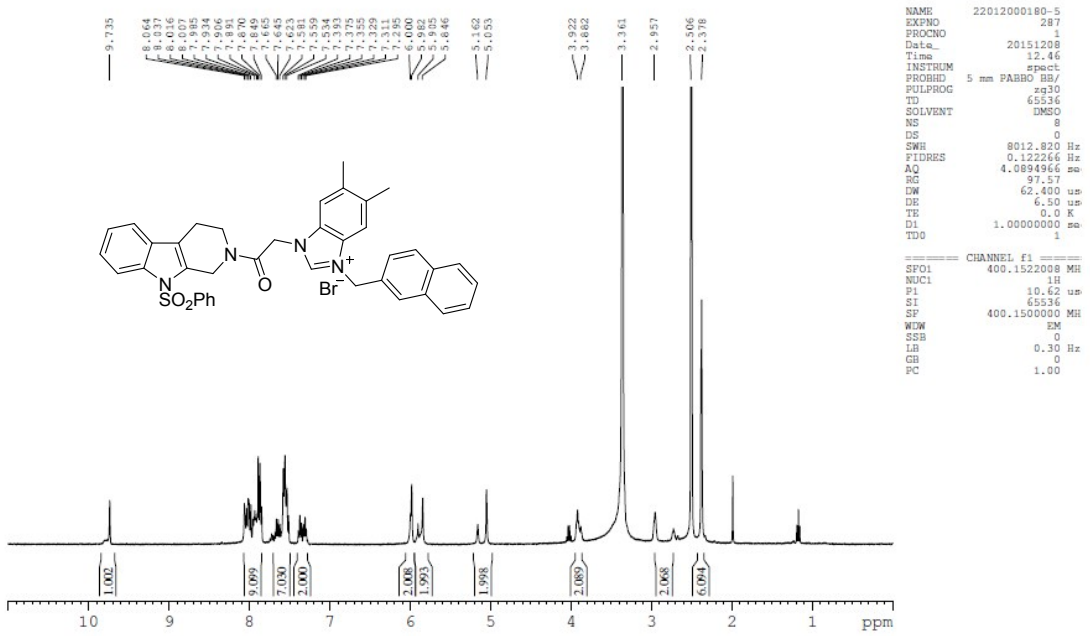
Compound **50** ^{1}H-NMR 400M DMSO



Compound **50** ^{13}C-NMR 100M DMSO



Compound **51** ^{1}H-NMR 400M DMSO



Compound **51** ^{13}C-NMR 100M DMSO