Electronic Supporting Information (ESI)

Covalently anchored sulfamic acid on cellulose as heterogeneous solid acid catalyst for the synthesis of structurally symmetrical and unsymmetrical 1,4-dihydropyridine derivatives

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Experimental:

Dimedone (Thomas Baker), (3-aminopropyl)trimethoxysilane (Sigma Aldrich), chlorosulphonic acid (spectrochem), ethylacetoacetate (spectrochem) and aryl aldehydes (Spectrochem and Thomas Baker) were used as received. The NMR spectra were recorded on Bruker AC (300 MHz and 400 MHz for ^{1}H NMR and 75 MHz and 100 MHz for ^{13}C NMR) spectrometer using TMS as an internal standard in DMSO-d_6 or $CDCl_3$. Chemical shifts (δ) are expressed in ppm. Solid state CP/MAS ^{13}C-NMR spectrum was recorded on JEOL-ECX400 spectrometer. The FT-IR spectra were recorded on ALPHA Bruker FT-IR spectrophotometer. The size and morphology of Cell-Pr-$NHSO_3H$ were observed by using FESEM of MIRA3 TESCAN microscope with an accelerating voltage of 10 kV.

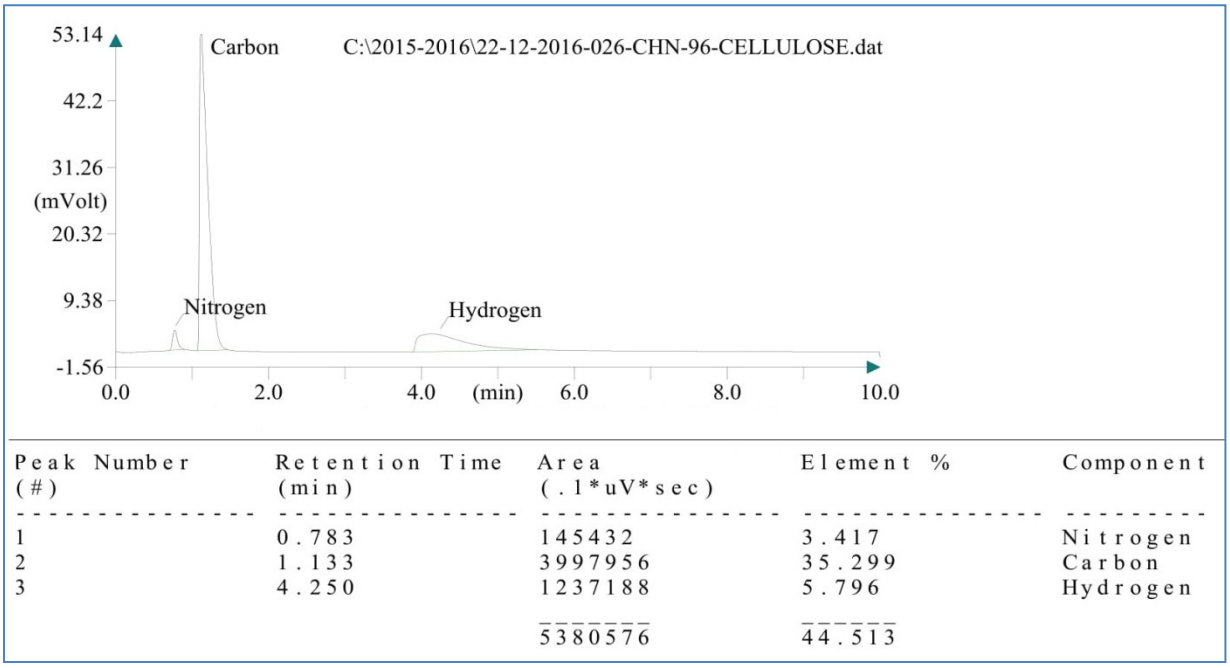
General procedure for the synthesis of polyhydroquinoline derivatives:

A mixture of ethylacetoacetate (1 mmol), dimedone (1 mmol), NH_4OAc (1.2 mmol), aryl aldehyde and Cell-Pr-$NHSO_3H$ (0.05 g, 0.0076 mmol) was refluxed in ethanol (4 mL). Upon the

completion of reaction (monitored by TLC), reaction mixture was diluted with hot ethanol (10 mL) and filtered to remove the catalyst. The evaporation of solvent in *vacuo* afforded the crude product which was recrystallized from ethanol to get the desired polyhydroquinolines.

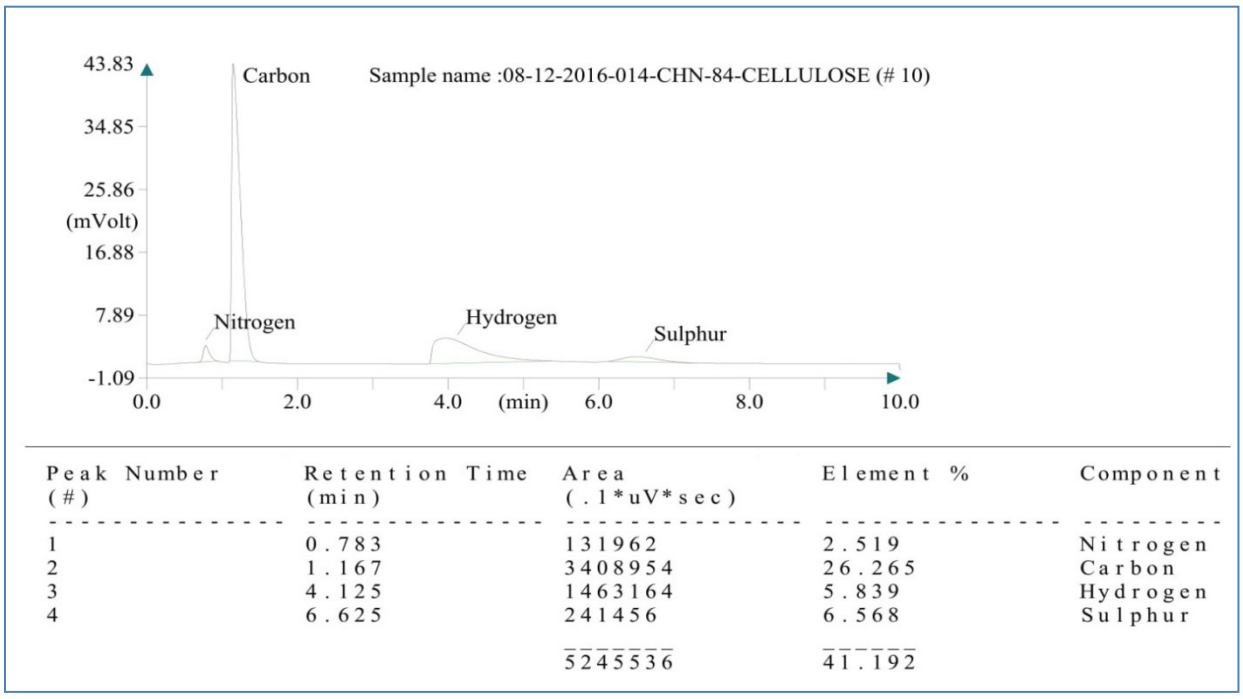
General procedure for the synthesis of 1,8-dioxo-decahydroacridine derivatives:

In a 25 mL round bottomed flask, Cell-Pr-$NHSO_3H$ (0.05 g, 0.0076 mmol) was added to the mixture of dimedone (2 mmol), aromatic aldehyde (1 mmol), and NH_4OAc (1.2 mmol) in ethanol (4 mL). The resulting mixture was refluxed for an appropriate time. Upon the completion of reaction (monitored by TLC), reaction mixture was diluted with hot ethanol (10 mL) and filtered to remove the catalyst. The evaporation of solvent in *vacuo,* afforded the crude product which was recrystallized from ethanol to obtain the desired 1,8-dioxo-decahydroacridines.



Peak Number (#)	Retention Time (min)	Area (.1*uV*sec)	Element %	Component
1	0.783	145432	3.417	Nitrogen
2	1.133	3997956	35.299	Carbon
3	4.250	1237188	5.796	Hydrogen
		5380576	44.513	

Fig. 1: CHN analysis of Cell-Pr-NH_2



Peak Number (#)	Retention Time (min)	Area (.1*uV*sec)	Element %	Component
1	0.783	131962	2.519	Nitrogen
2	1.167	3408954	26.265	Carbon
3	4.125	1463164	5.839	Hydrogen
4	6.625	241456	6.568	Sulphur
		5245536	41.192	

Fig. 2: CHNS analysis of Cell-Pr-$NHSO_3H$

Spectral data of representative compounds:

Ethyl 4-phenyl-2,7,7-trimethyl-5-oxo-1,4,5,6,7,8-hexahydroquinoline-3-carboxylate (Table 2, entry 1):

Yield 90%, Mp. 201-203°C, (Mp. 203-204°C)[1]; FT-IR (KBr) (cm^{-1}): 3283, 3216, 3079, 2929, 1696, 1642, 1479, 1276, 1066, 993, 836, 713, 694; ^{1}H NMR (300 MHz, DMSO-d_6): δ (ppm) 9.08 (s, 1H, NH), 7.15 (s, 5H, Ar-H), 4.85 (s, 1H, CH), 3.95-3.99 (q, 2H, CH_2), 2.30-2.44 (q, 2H, CH_2), 2.27 (s, 3H, CH_3), 2.13-2.19 (d, 2H, *J* = 16.2 *Hz*, CH_2), 1.94-1.99 (d, 2H, *J* = 16.2 *Hz*, CH_2), 1.09-1.13 (t, 3H, *J* = 6.9 *Hz*, 6.9 *Hz*, CH_3), 0.99 (s, 1H, CH_3), 0.83 (s, 1H, CH_3); ^{13}C NMR (75 MHz, DMSO-d_6): δ (ppm) 14.5, 18.6, 26.8, 29.5, 32.5, 36.3, 50.6, 59.6, 104.2, 110.3, 126.2, 127.8, 128.2, 145.4, 148.0, 150.3, 167.4, 195.1.

Ethyl 4-(4-nitrophenyl)-2,7,7-trimethyl-5-oxo-1,4,5,6,7,8-hexahydroquinoline-3-carboxylate (Table 2, entry 2):

Yield 92%, Mp. 246-248°C, (Mp. 245-247°C)[1]; FT-IR (KBr) (cm^{-1}): 3272, 3185, 3071, 2962, 2929, 1700, 1604, 1487, 1377, 1287, 1069, 864, 829, 603; ^{1}H NMR (400 MHz, DMSO-d_6): δ (ppm) 8.08-8.10 (d, 2H, *J* = 6.6 *Hz*, Ar-H), 7.48-7.51 (d, 2H, *J* = 6.6 *Hz*, Ar-H), 6.49 (s, 1H, NH), 5.17 (s, 1H, CH), 4.02-4.11 (m, 2H, CH_2), 2.40 (s, 3H, CH_3), 2.17-2.36 (q, 4H, CH_2), 1.17-1.20 (t, 3H, *J* = 7.2 Hz, 7.2 *Hz*, CH_3), 1.09 (s, 3H, CH_3), 0.91 (s, 1H, CH_3); ^{13}C NMR (100 MHz, DMSO-d_6): δ (ppm) 14.1, 19.46, 27.0, 29.3, 32.7, 37.2, 40.9, 50.6, 60.0, 104.8, 111.0, 123.3, 128.9, 144.5, 146.2, 148.8, 154.4, 166.8, 195.4.

Ethyl 4-(4-methoxyphenyl)-2,7,7-trimethyl-5-oxo-1,4,5,6,7,8-hexahydroquinoline-3-carboxylate (Table 2, entry 6):

Yield 86%, Mp. 257-259°C, (Mp. 258-259°C)[1]; FT-IR (KBr) (cm^{-1}): 3272, 3189, 3071, 2954, 2833, 1698, 1647, 1485, 1211, 1029, 847, 761, 610; ^{1}H NMR (300 MHz, DMSO-d_6): δ (ppm) 8.85 (s, 1H, NH), 7.05-7.07 (d, 2H, *J* = 7.5 *Hz*, Ar-H), 6.67 (s, 2H, Ar-H), 4.78 (s, 1H, CH), 3.95-3.97 (s, 2H, CH_2),

3.65 (s, 3H, OCH_3), 2.25-2.32 (m, 5H, CH_3, CH_2), 1.99-2.09 (q, 2H, CH_2), 1.12-1.16 (t, 3H, *J* = 6.6 *Hz*, 6.6 *Hz*, CH_3), 1.01 (s, 3H, CH_3), 0.86 (s, 1H, CH_3); ^{13}C NMR (75 MHz, DMSO-d_6): δ (ppm) 14.6, 18.6, 26.9, 29.5, 32.4, 35.4, 50.7, 55.1, 59.5, 104.7, 110.7, 113.3, 128.8, 140.3, 144.9, 150.2, 157.6, 167.5, 195.4.

Ethyl 4-(2,5-Dimethoxyphenyl)-2,7,7-trimethyl-5-oxo-1,4,5,6,7,8-hexahydroquinoline-3-carboxylate (Table 2, entry 9):

Yield 84%, Mp. 191-192°C, (Mp. 190-192°C)[2]; FT-IR (KBr) (cm^{-1}): 3298, 3206, 3076, 2957, 2833, 1687, 1606, 1494, 1210, 1025, 717, 595; ^{1}H NMR (400 MHz, DMSO-d_6): δ (ppm) 8.11 (s, 1H, NH), 6.75-6.76 (d, 1H, *J* = 2.8 *Hz*, Ar-H), 6.61-6.63 (d, 1H, *J* = 8.8 *Hz*, Ar-H), 6.50-6.53 (dd, J_1 = 8.8 Hz, J_2 = 3.2 *Hz*, Ar-H), 5.08 (s, 1H, CH), 3.89-3.95 (m, 2H, CH_2), 3.65 (s, 6H, OCH_3), 2.14-2.26 (m, 5H, CH_3, CH_2), 1.94-2.09 (q, 2H, CH_2), 1.08-1.12 (t, 3H, *J* = 6.8 *Hz*, 7.2 *Hz*, CH_3), 0.96 (s, 3H, CH_3), 0.84 (s, 1H, CH_3); ^{13}C NMR (100 MHz, DMSO-d_6): δ (ppm) 14.2, 18.6, 26.8, 29.5, 32.3, 33.4, 40.5, 50.8, 55.4, 56.1, 59.2, 104.0, 109.9, 111.7, 117.2, 136.5, 144.4, 150.1, 151.9, 152.9, 168.0, 195.2;

1,8-dioxo-decahydroacridines

3,3,6,6-Tetramethyl-9-(phenyl)-1,8-dioxo-decahydroacridine (Table 3, entry 1):

Yield 90%, Mp. 190-192°C, (Mp. 190-191°C)[3]; FT-IR (KBr) (cm^{-1}): 3313, 3073 2939, 1632, 1595, 855, 749; ^{1}H NMR (300 MHz, $CDCl_3$): δ (ppm) 11.95 (s, 1H, NH), 7.12-7.31 (m, 5H, Ar-H), 5.57 (s, 1H, CH), 2.37-2.44 (m, 8H, CH_2), 1.26 (s, 6H, CH_3), 1.12 (s, 6H, CH_3); ^{13}C NMR (75 MHz, DMSO-d_6): δ (ppm) 27.4, 29.6, 31.4, 32.7, 115.5, 125.8, 126.8, 128.2, 138.1, 189.3, 190.4.

3,3,6,6-Tetramethyl-9-(4-nitrophenyl)-1,8-dioxo-decahydroacridine (Table 3, entry 5):

Yield 90%, Mp. 283-285°C, (Mp. 284-286°C)[3]; FT-IR (KBr) (cm^{-1}): 3108, 2957, 2666, 1702, 1658, 1582, 1372, 1251, 1044, 963, 928, 850, 733, 675, 587; ^{1}H NMR (300 MHz, $CDCl_3$): δ (ppm) 11.80 (s, 1H, NH), 8.12-8.15 (d, 2H, *J*= 8.7 *Hz*, Ar-H), 7.24-7.27 (d, 2H, *J*= 8.7 *Hz*, Ar-H), 5.55 (s, 1H, CH),

2.37-2.47 (m, 8H, CH_2), 1.24 (s, 6H, CH_3), 1.12 (s, 6H, CH_3); ^{13}C NMR (75 MHz, $CDCl_3$): δ (ppm) 27.4, 29.5, 31.4, 33.2, 46.4, 46.9, 114.9, 123.5, 127.6, 146.1, 146.5, 189.5, 190.9.

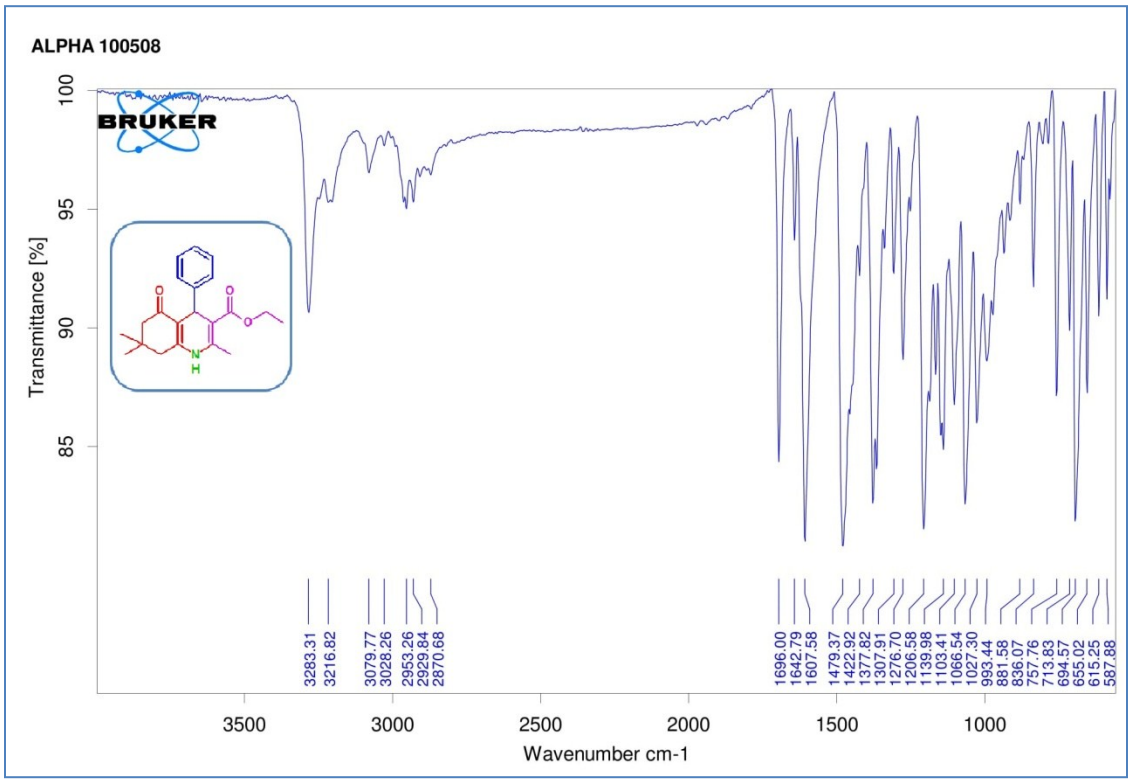
3,3,6,6-Tetramethyl-9-(4-bromophenyl)-1,8-dioxo-decahydroacridine (Table 3, entry 7):

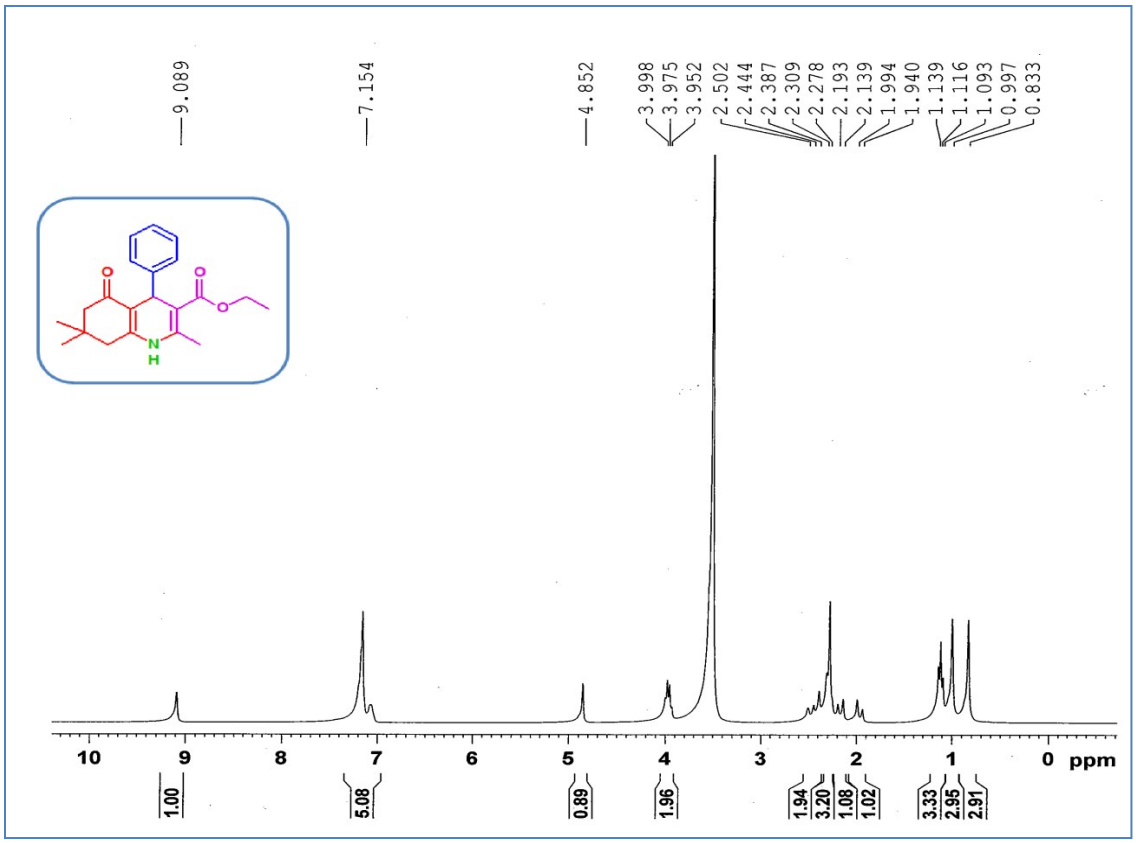
Yield 84%, Mp. > 300°C, (Mp. 310-312°C)[4]; FT-IR (KBr) (cm^{-1}): 3203, 3079, 2955, 1691, 1657, 1450, 1239, 1127, 1007, 894, 775, 657, 584; ^1H NMR (300 MHz, $CDCl_3$): δ (ppm) 11.89 (s, 1H, NH), 7.38-7.40 (d, 2H, *J*= 8.7 *Hz*, Ar-H), 6.96-6.98 (d, 2H, *J*= 8.1 *Hz*, Ar-H), 5.46 (s, 1H, CH), 2.35-2.45 (m, 8H, CH_2), 1.23 (s, 6H, CH_3), 1.11 (s, 6H, CH_3); ^{13}C NMR (75 MHz, $CDCl_3$): δ (ppm) 27.4, 29.5, 31.4, 32.4, 115.2, 119.6, 128.6, 131.2, 137.3, 189.4, 190.6.

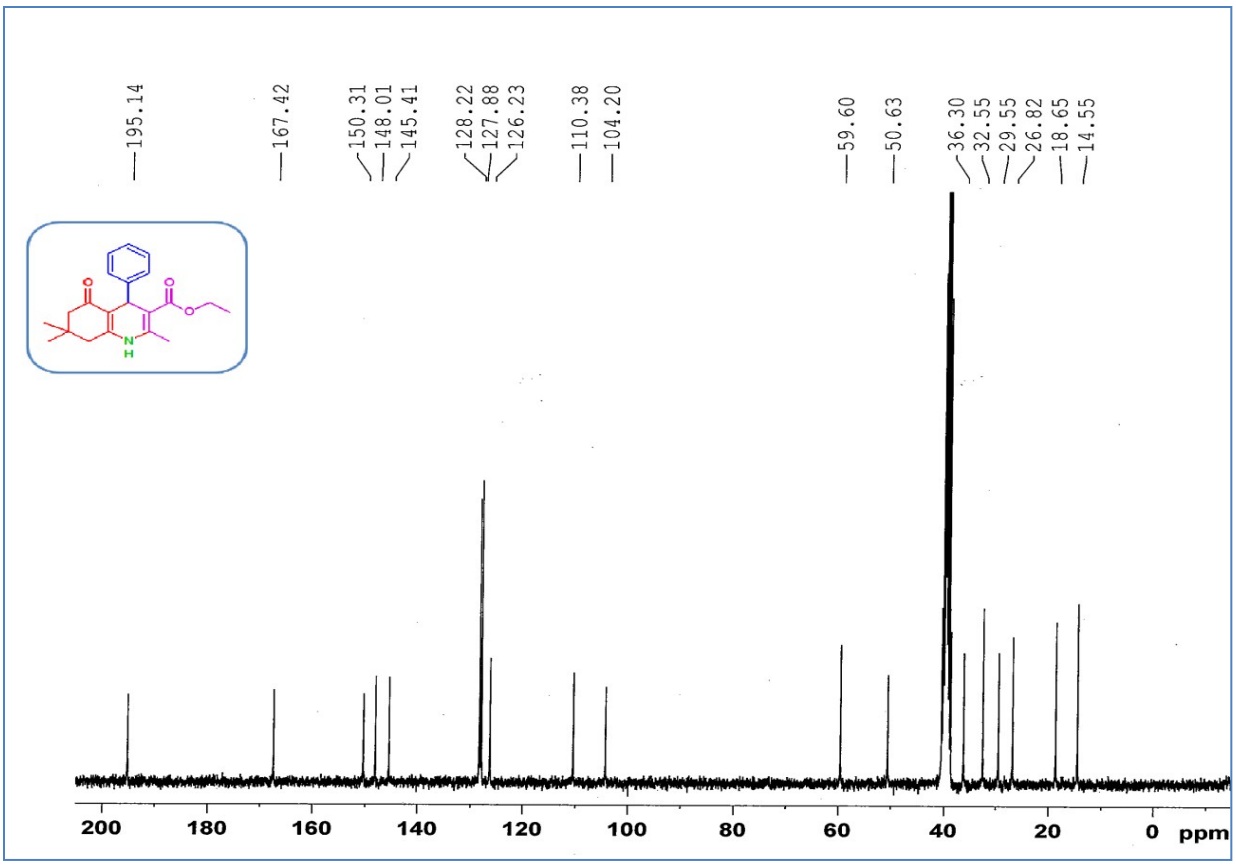
3,3,6,6-Tetramethyl-9-(3,4,5-trimethoxyphenyl)-1,8-dioxo-decahydroacridine (Table 3, entry 9):

Yield 80%, Mp. 260-262°C, (Mp. 258-261°C)[5]; FT-IR (KBr) (cm^{-1}): 3204, 2952, 2928, 2867, 1662, 1584, 1450, 1371, 1153, 1006, 875, 768, 606, ^1H NMR (300 MHz, $CDCl_3$): δ (ppm) 12.02 (s, 1H, NH), 6.35 (s, 2H, Ar-H), 5.50 (s, 1H, CH), 2.36-2.42 (m, 8H, CH_2), 1.24 (s, 6H, CH_3), 1.12 (s, 6H, CH_3); ^{13}C NMR (75 MHz, $CDCl_3$): δ (ppm) 26.8, 29.9, 31.0, 32.7, 46.3, 47.0, 55.8, 60.8, 104.2, 115.5, 133.7, 135.9, 152.8, 189.2, 190.3.

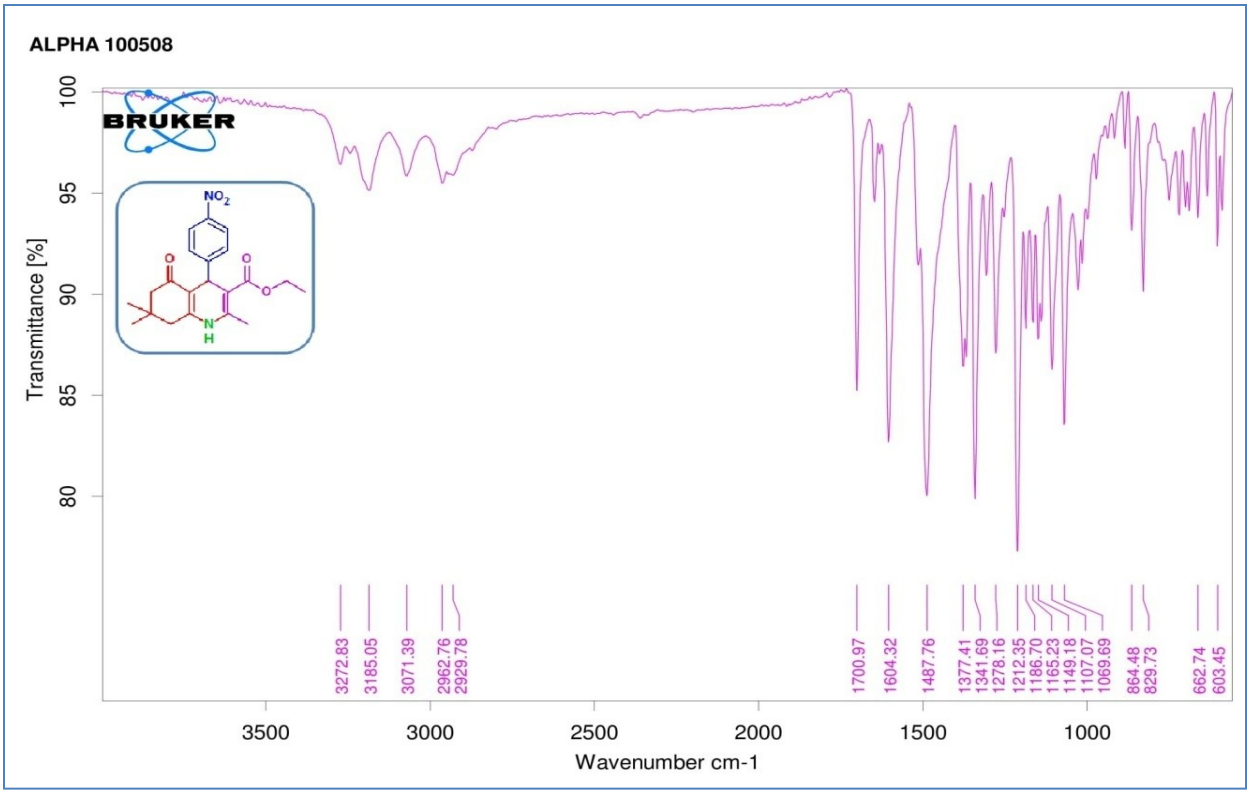
FT-IR, ^{1}H-NMR and ^{13}C-NMR Spectra of Ethyl 4-phenyl-2,7,7-trimethyl-5-oxo-1,4,5,6,7,8-hexahydroquinoline-3-carboxylate (Table 2, entry 1):

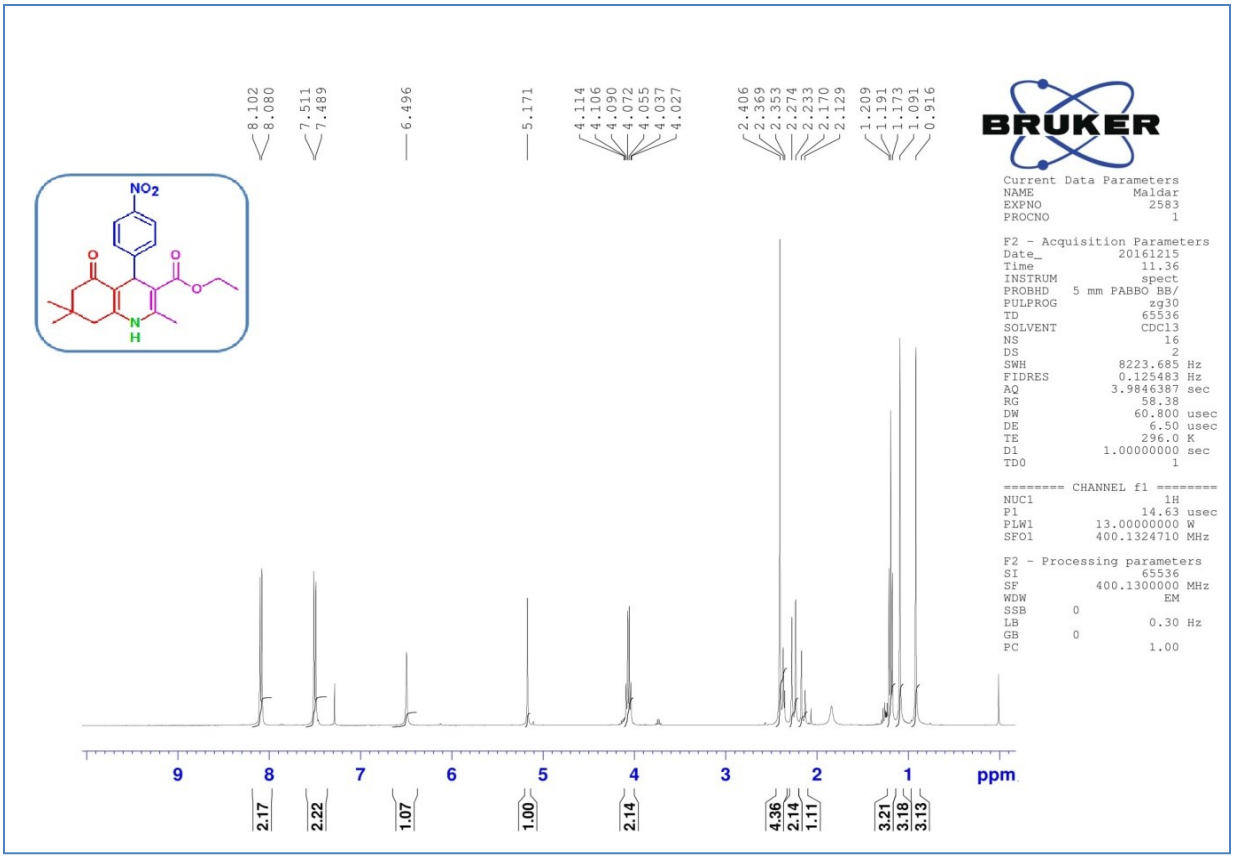






FT-IR, ^{1}H-NMR and ^{13}C-NMR Spectra of Ethyl 4-(4-nitrophenyl)-2,7,7-trimethyl-5-oxo-1,4,5,6,7,8-hexahydroquinoline-3-carboxylate (Table 2, entry 2):

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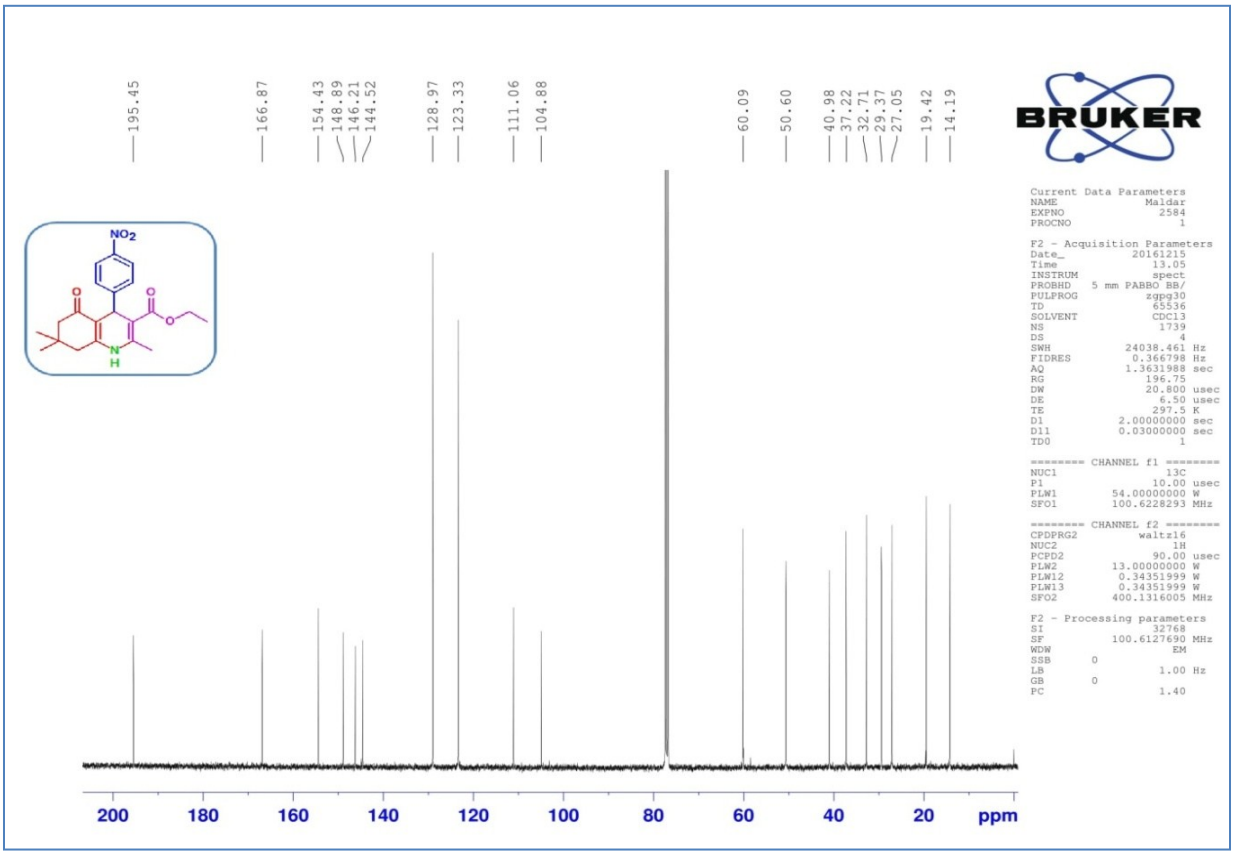
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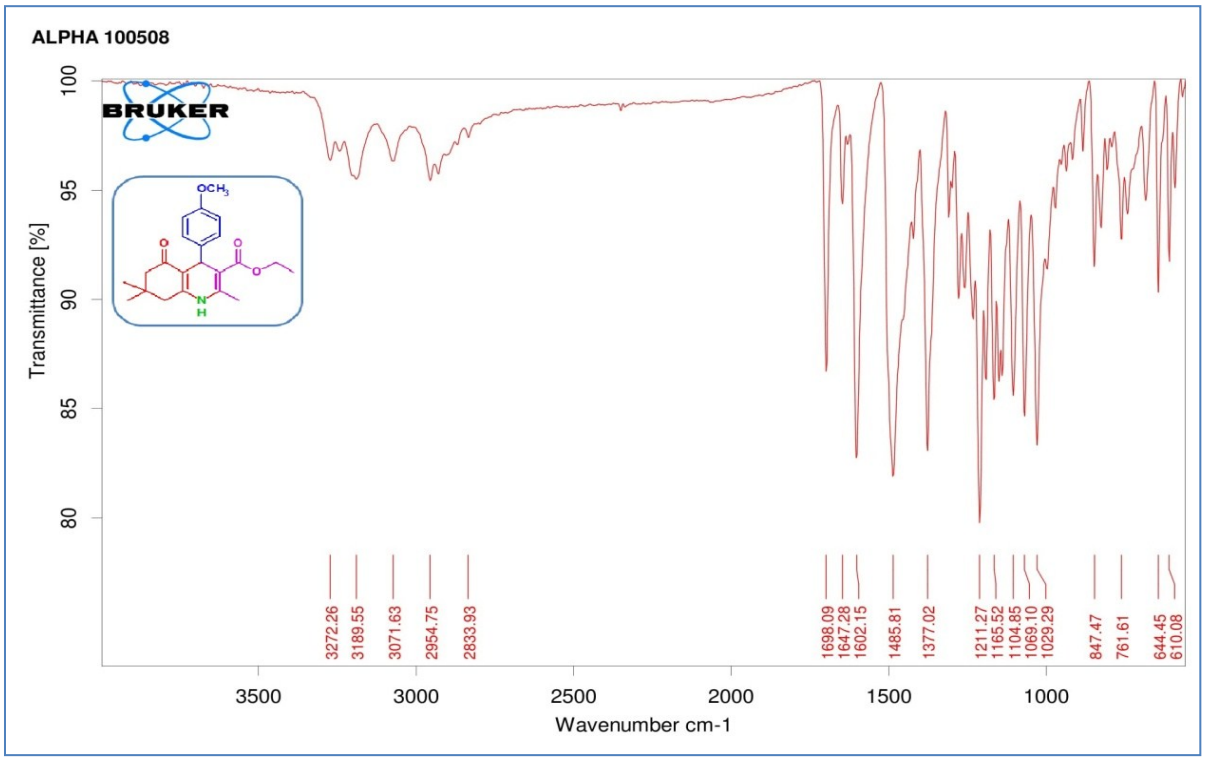
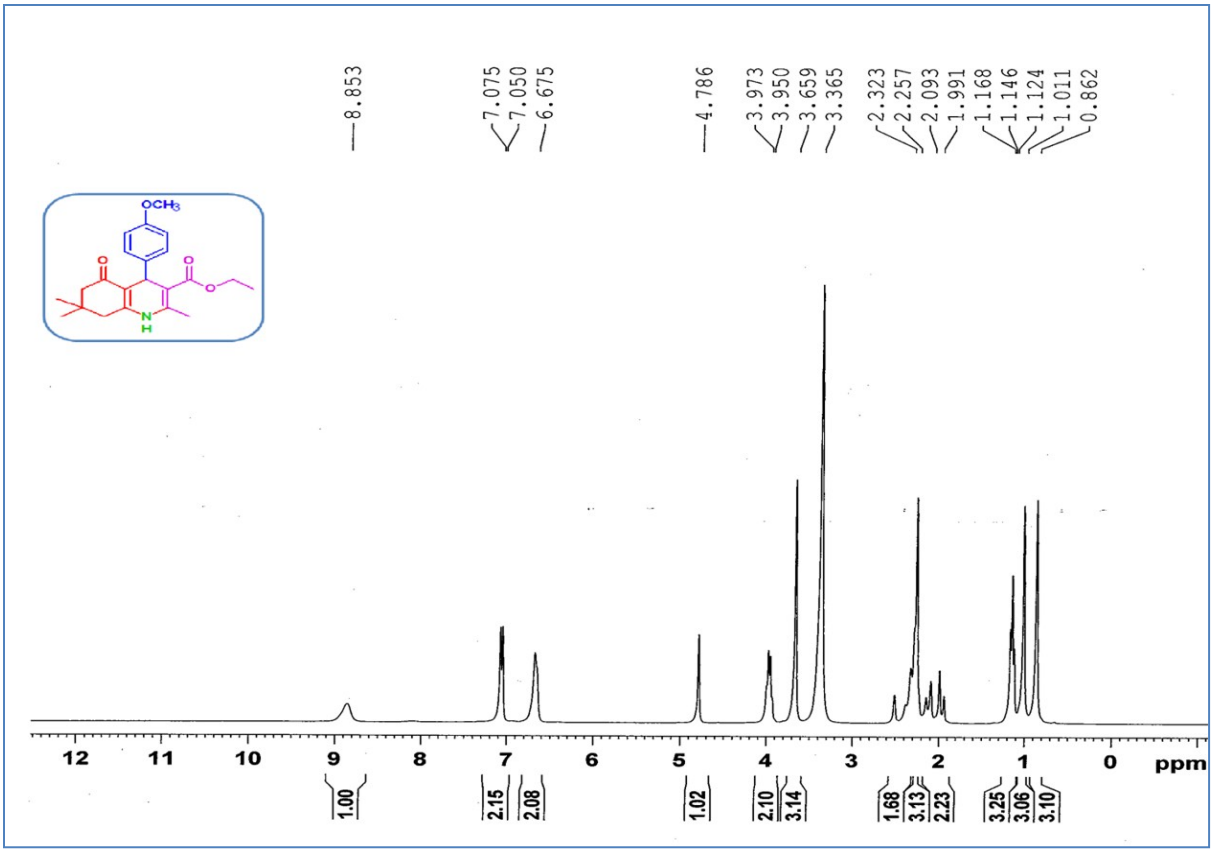
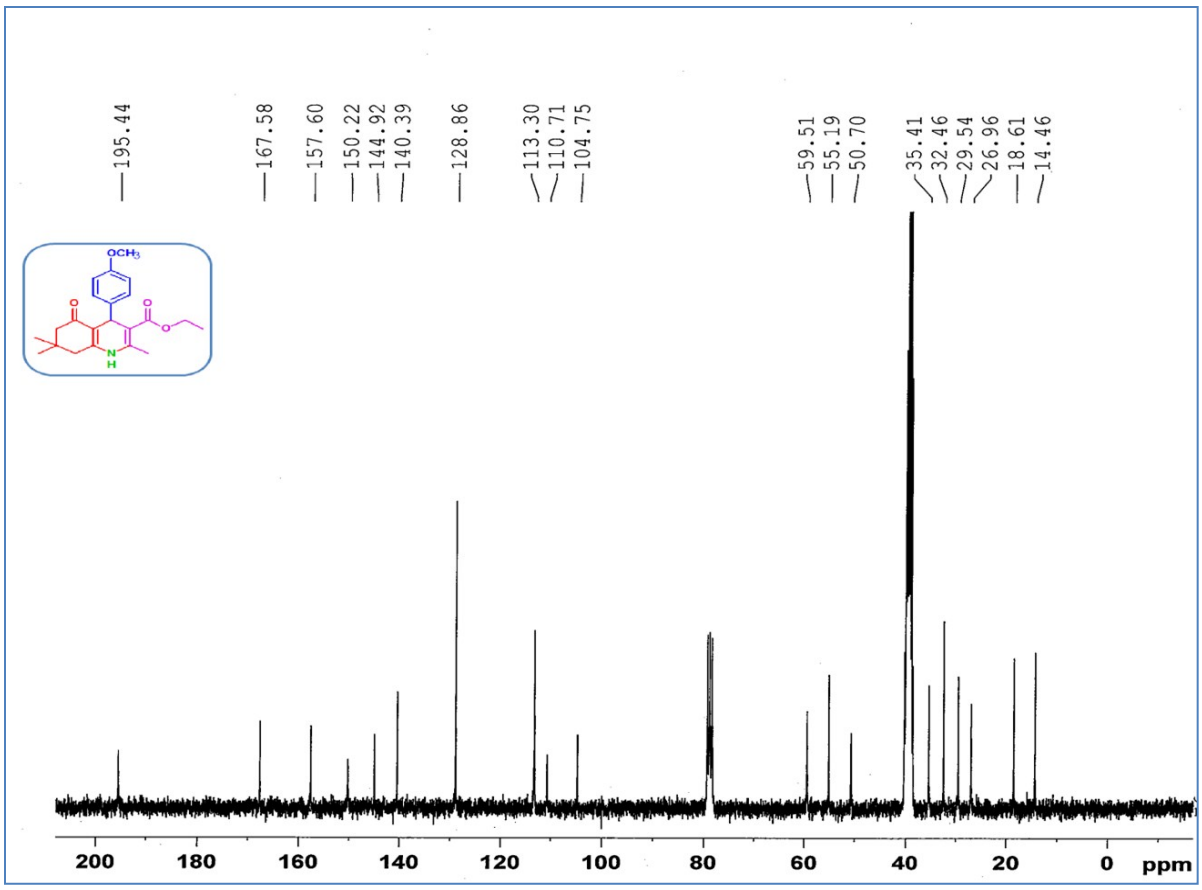
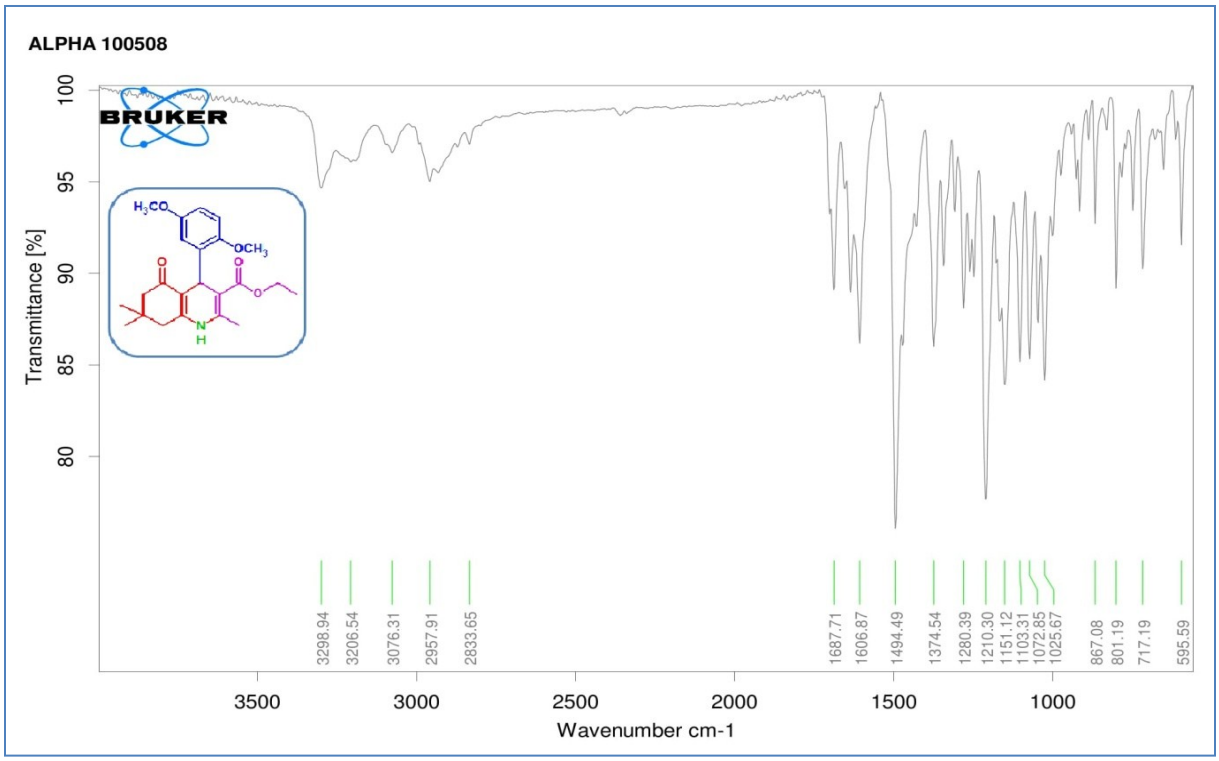
FT-IR, ^{1}H-NMR and ^{13}C-NMR Spectra of Ethyl 4-(4-methoxyphenyl)-2,7,7-trimethyl-5-oxo-1,4,5,6,7,8-hexahydroquinoline-3-carboxylate (Table 2, entry 6):

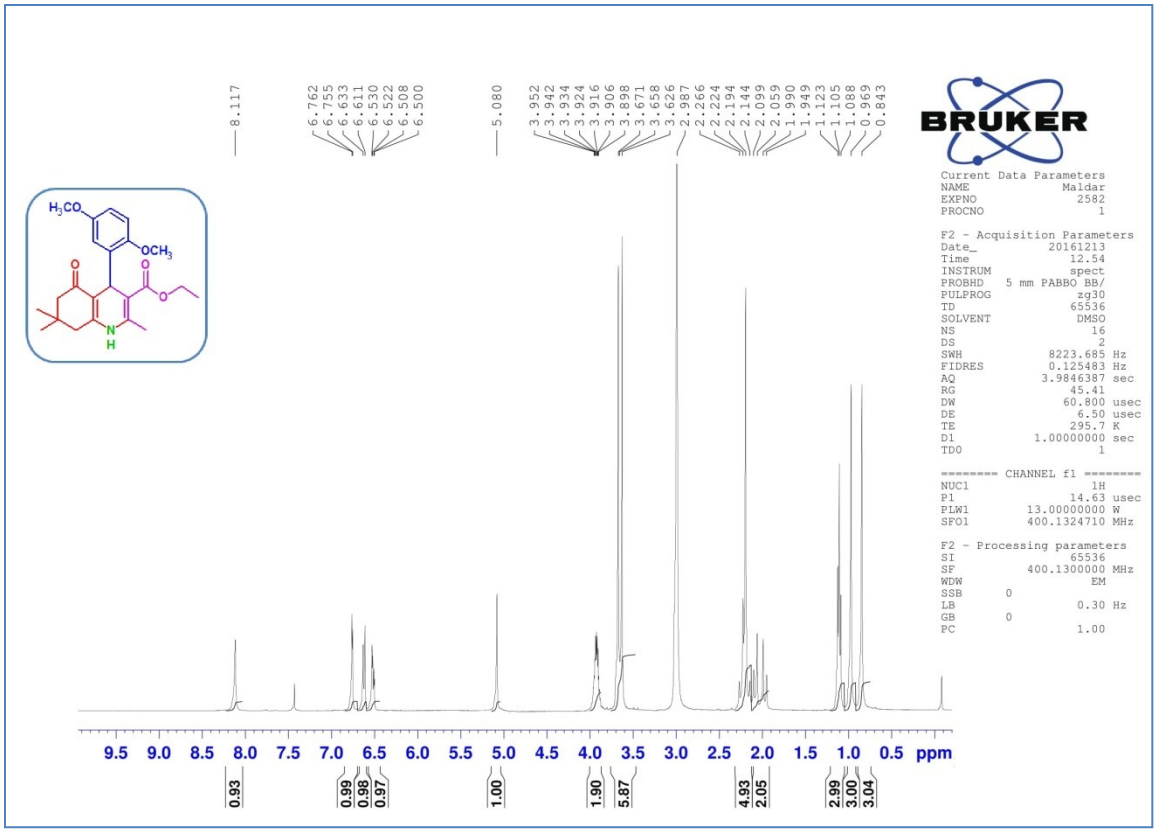






FT-IR, ^{1}H-NMR and ^{13}C-NMR Spectra of Ethyl 4-(2,5-Dimethoxyphenyl)-2,7,7-trimethyl-5-oxo-1,4,5,6,7,8-hexahydroquinoline-3-carboxylate (Table 2, entry 9):

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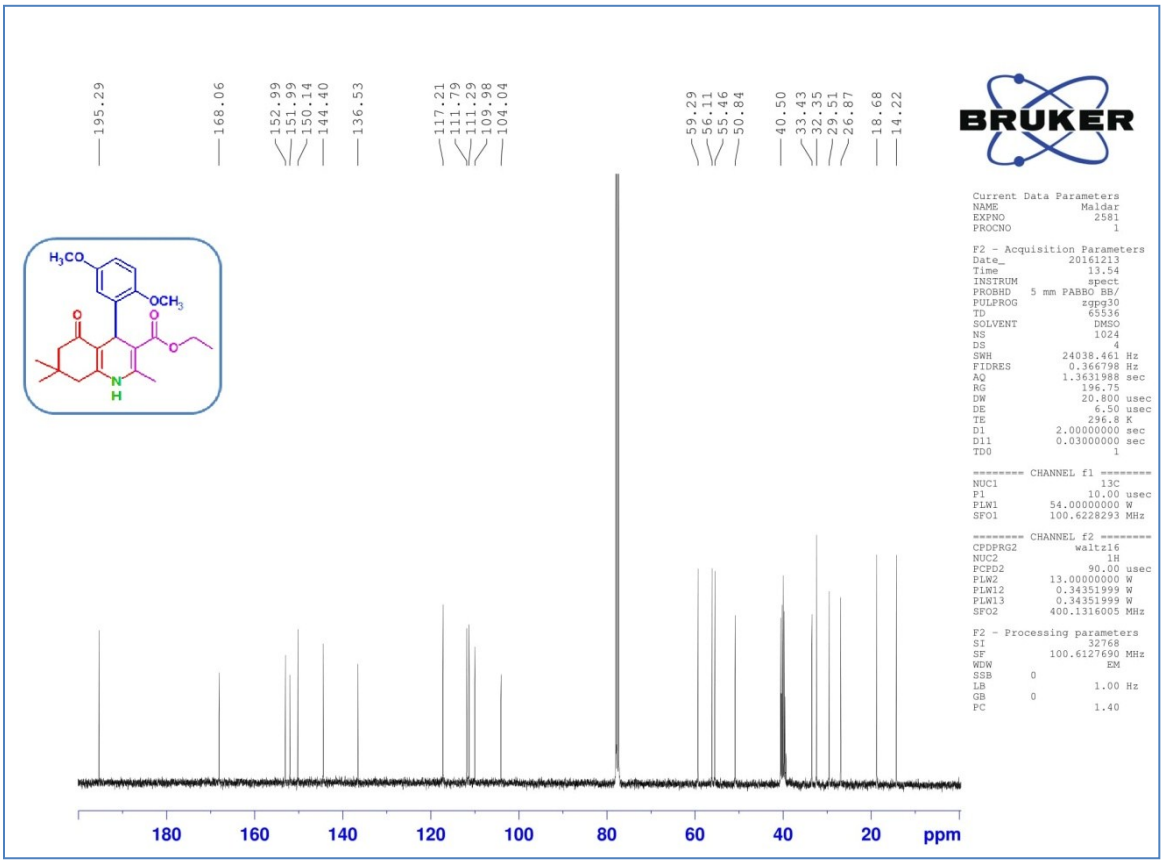
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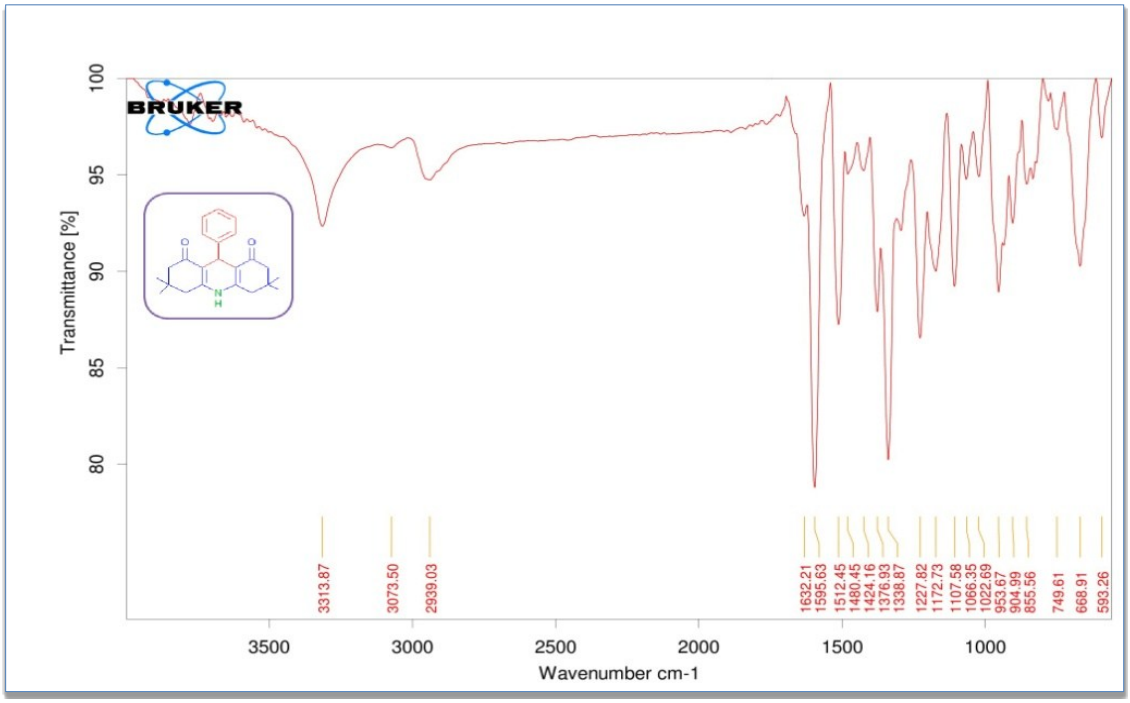
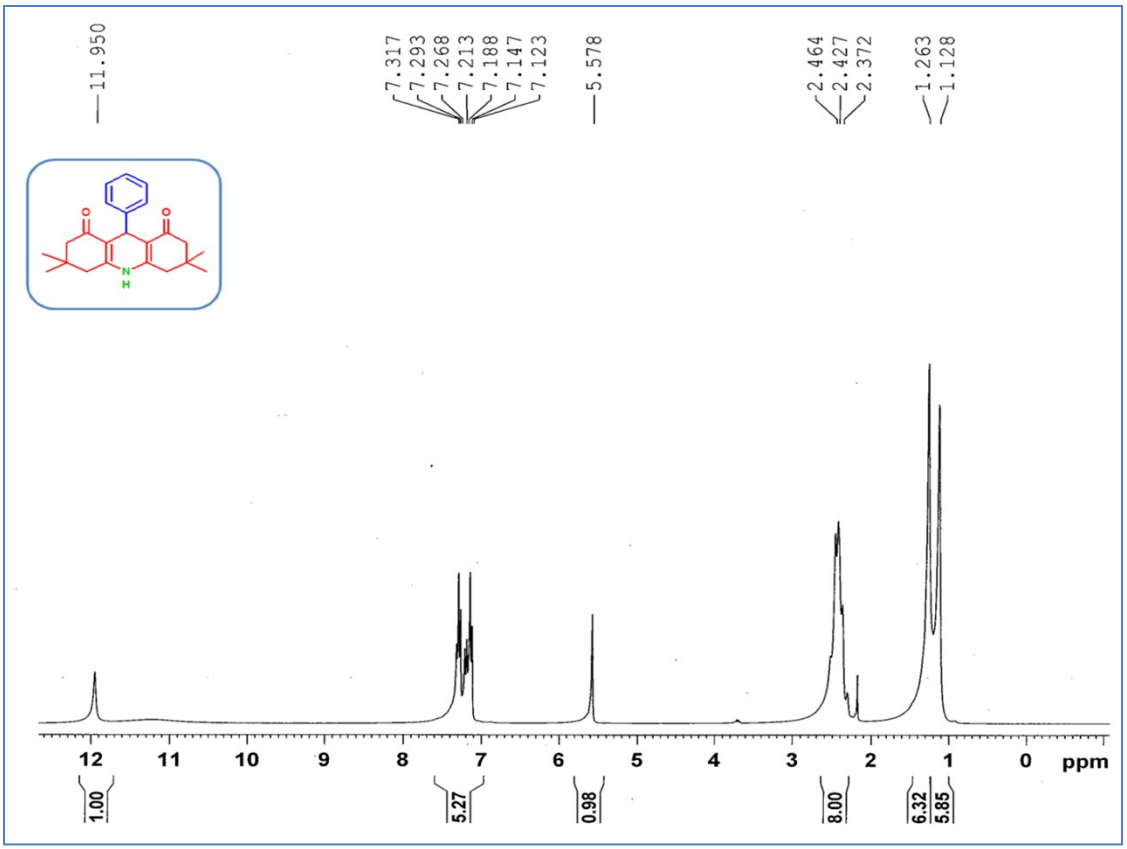
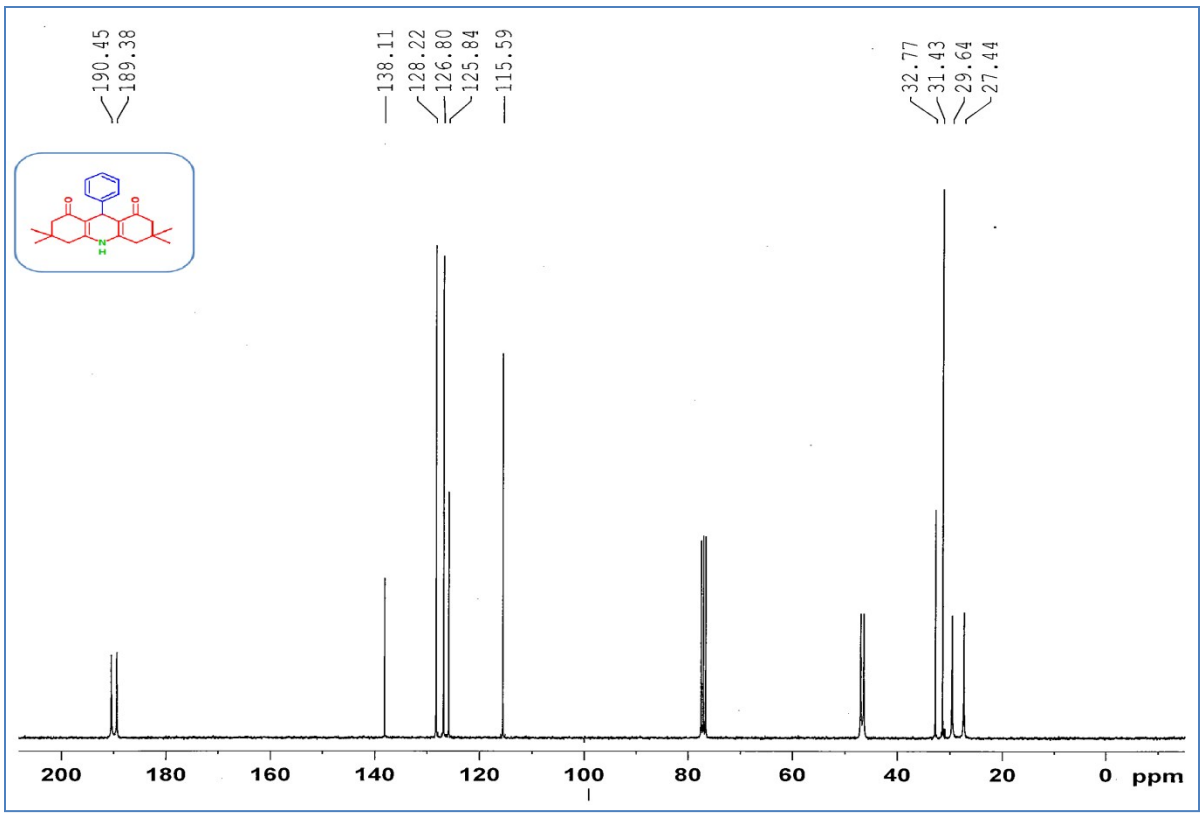
SFO2 400.1316005 MHz
F2 - Processing parameters
SI 32768
SF 100.6127690 MHz
WDW EM
SSB 0
LB 1.00 Hz
GB 0
PC 1.40
180 160 140 120 100 80 60 40 20 ppm

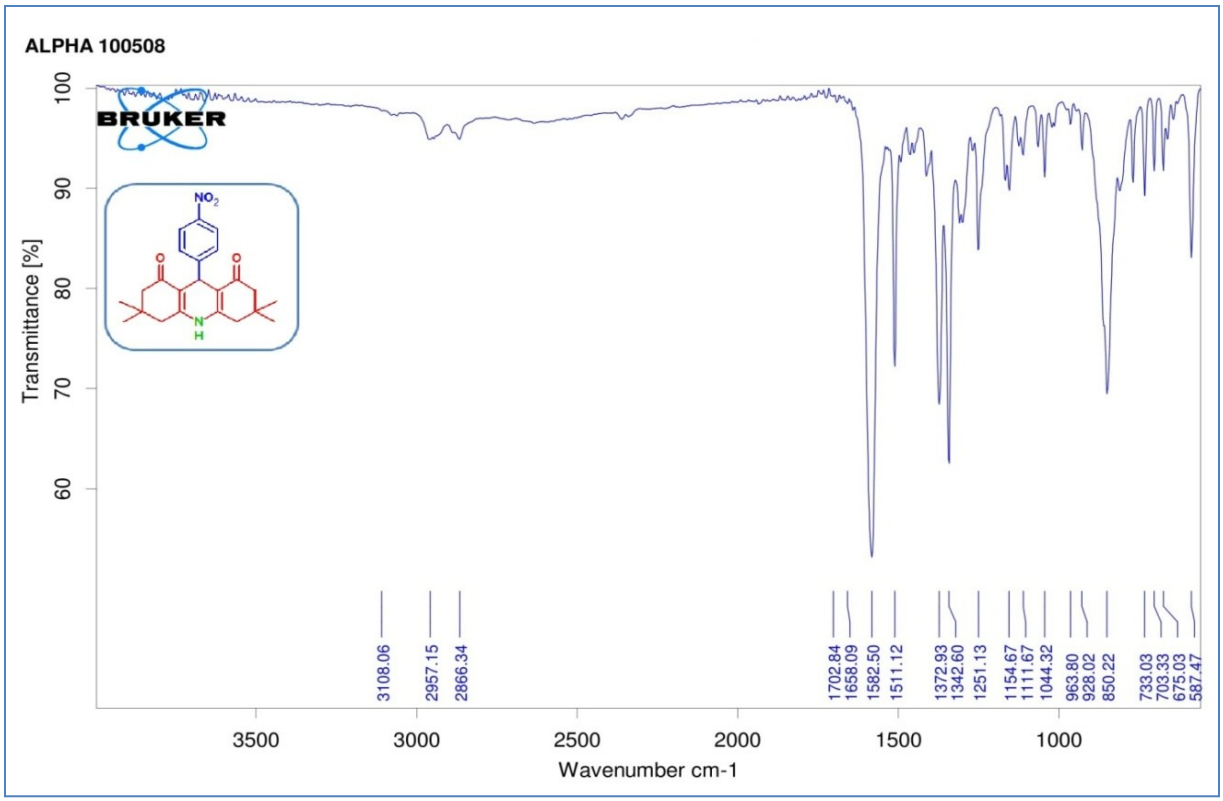
FT-IR, ^{1}H-NMR and ^{13}C-NMR Spectra of 3,3,6,6-Tetramethyl-9-(phenyl)-1,8-dioxo-decahydroacridine (Table 3, entry 1):

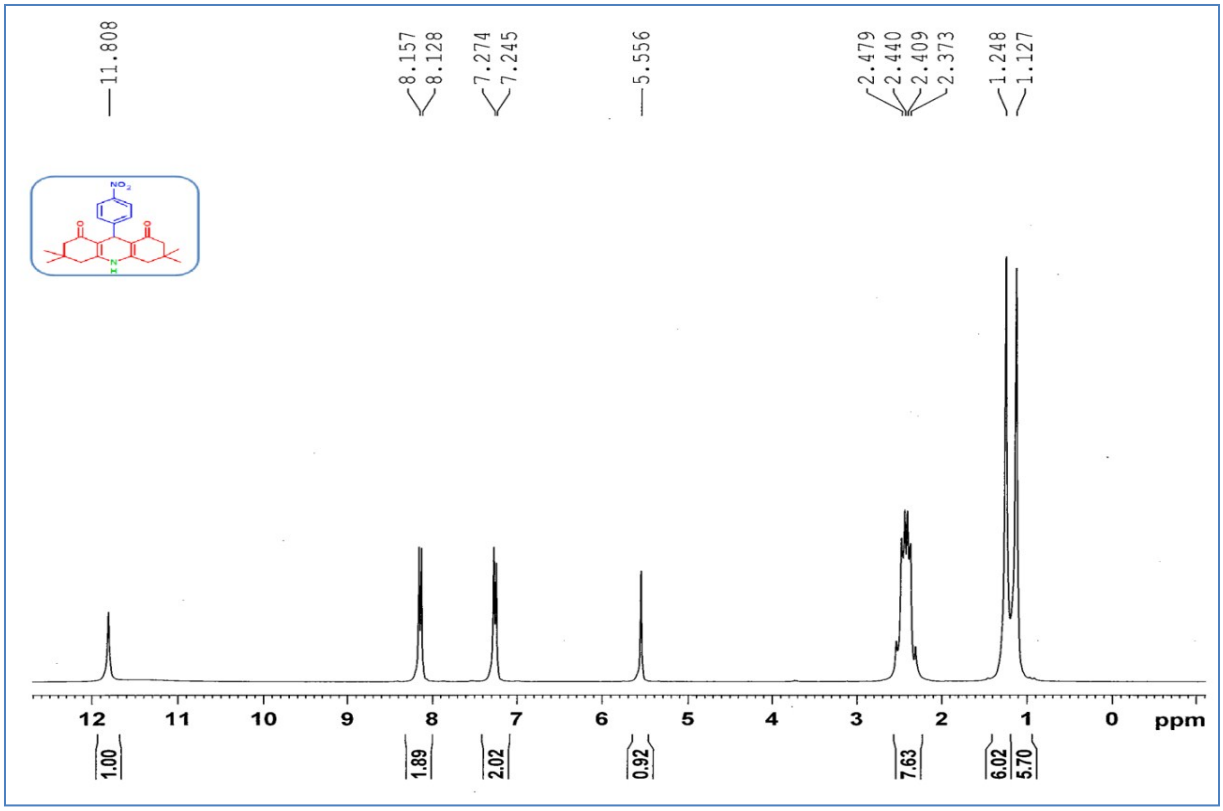


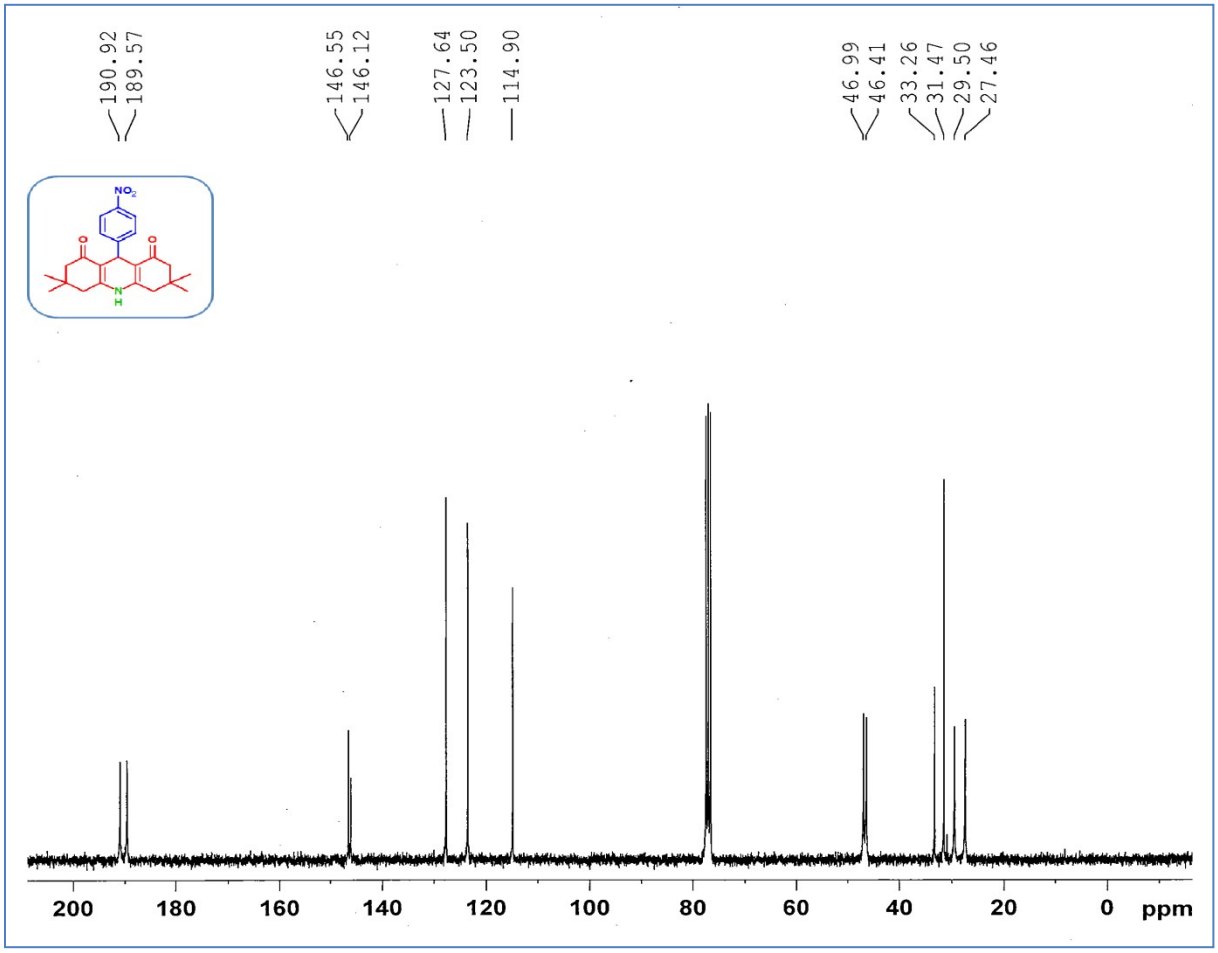




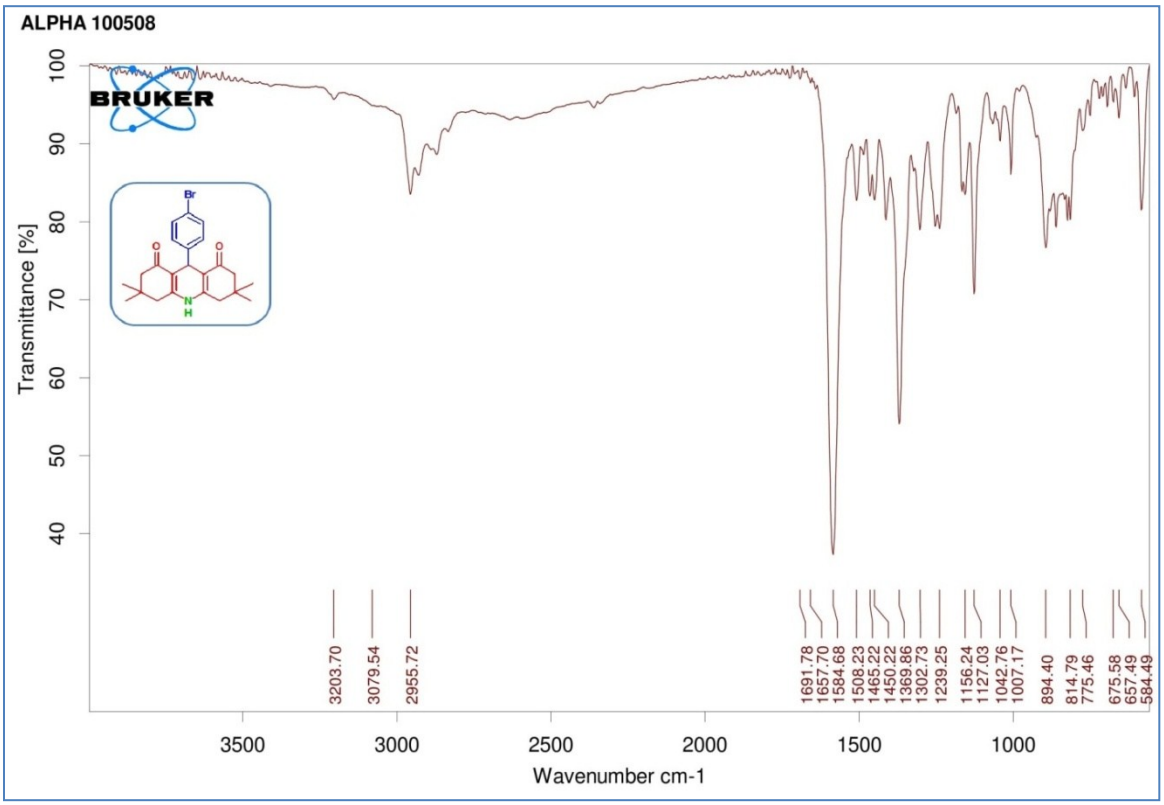
FT-IR, ^{1}H-NMR and ^{13}C-NMR Spectra of 3,3,6,6-Tetramethyl-9-(4-nitrophenyl)-1,8-dioxo-decahydroacridine (Table 3, entry 5):

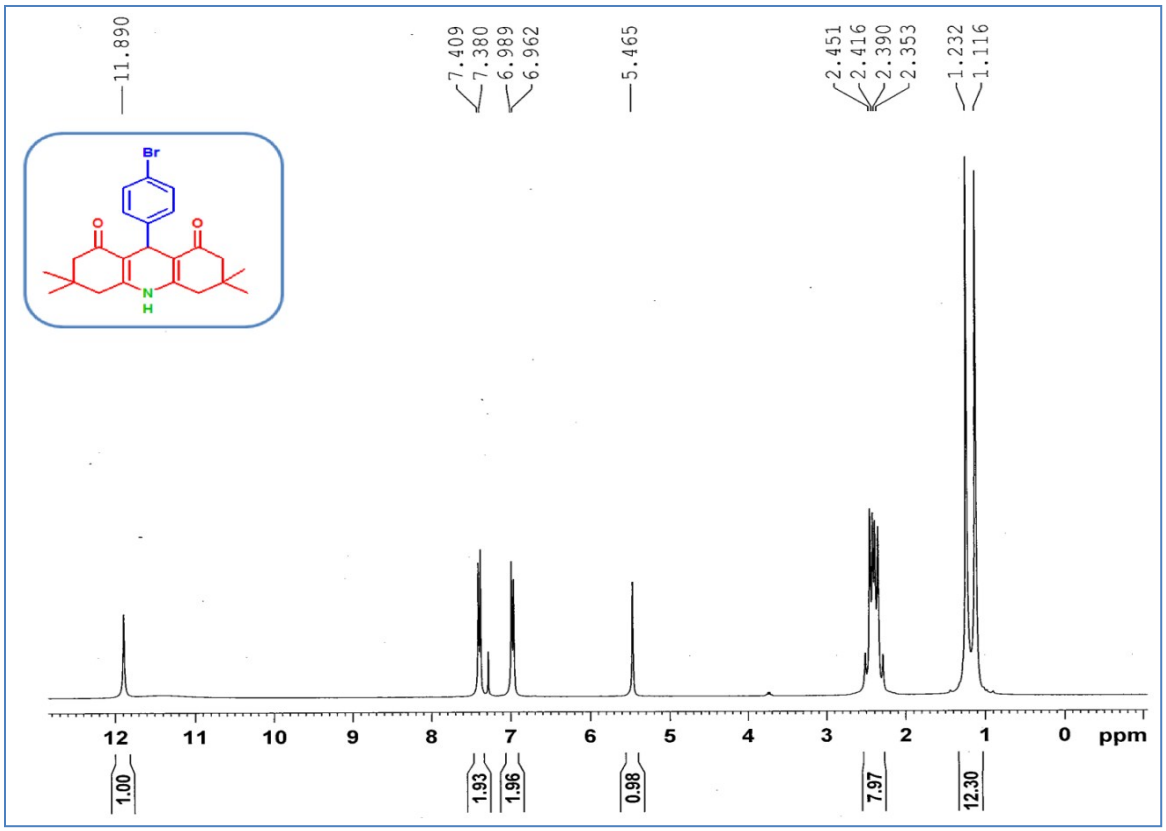


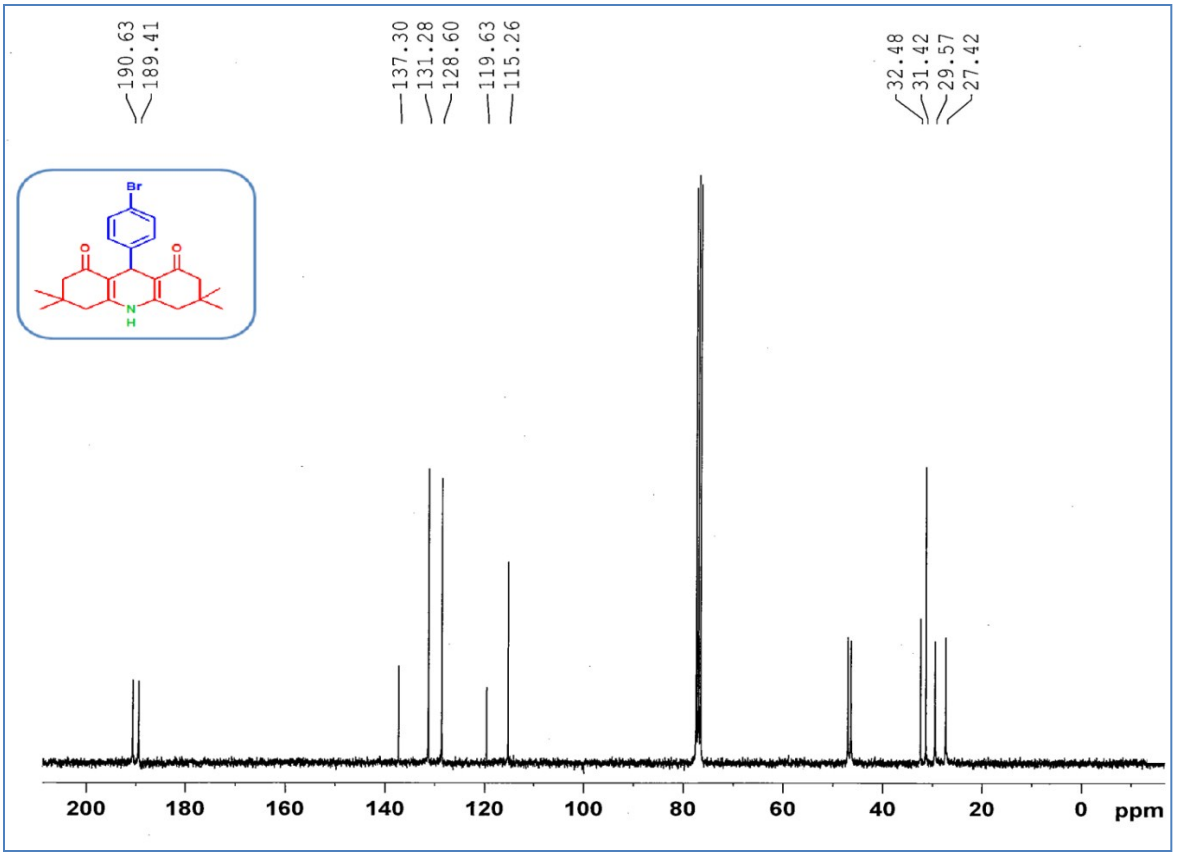

11.808
8.157
8.128
7.274
7.245
5.556
2.479
2.440
2.409
2.373
1.248
1.127
12
11
10
9
8
7
6
5
4
3
2
1
0
ppm
1.00
1.89
2.02
0.92
7.63
6.02
5.70


190.92
189.57
146.55
146.12
127.64
123.50
114.90
46.99
46.41
33.26
31.47
29.50
27.46
200
180
160
140
120
100
80
60
40
20
0
ppm

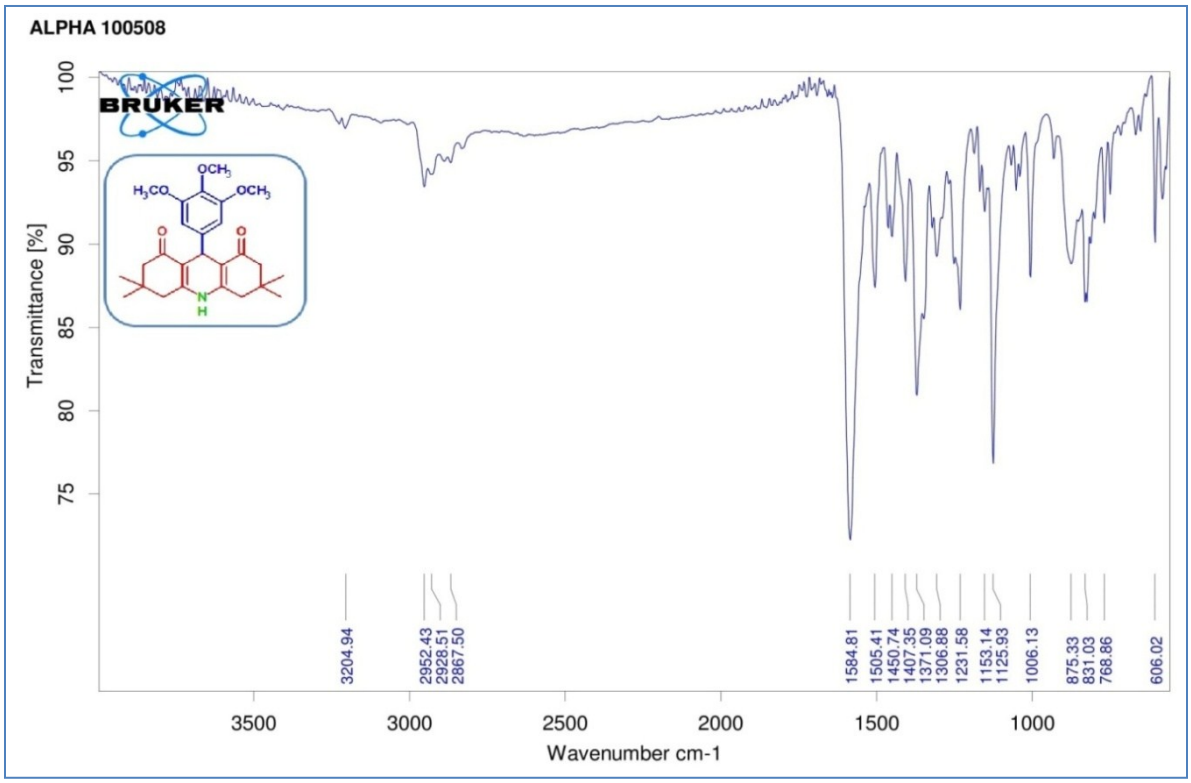
FT-IR, ^{1}H-NMR and ^{13}C-NMR Spectra of 3,3,6,6-Tetramethyl-9-(4-bromophenyl)-1,8-dioxo-decahydroacridine (Table 3, entry 7):

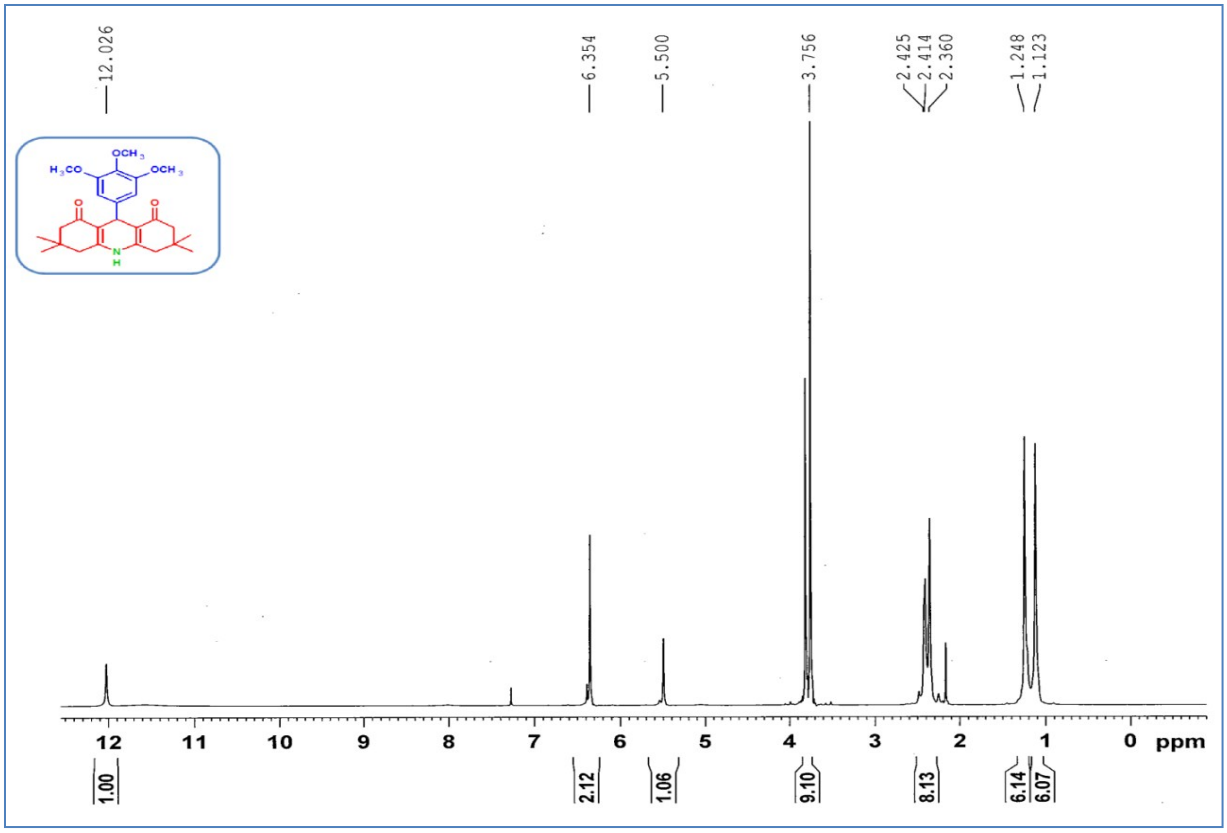


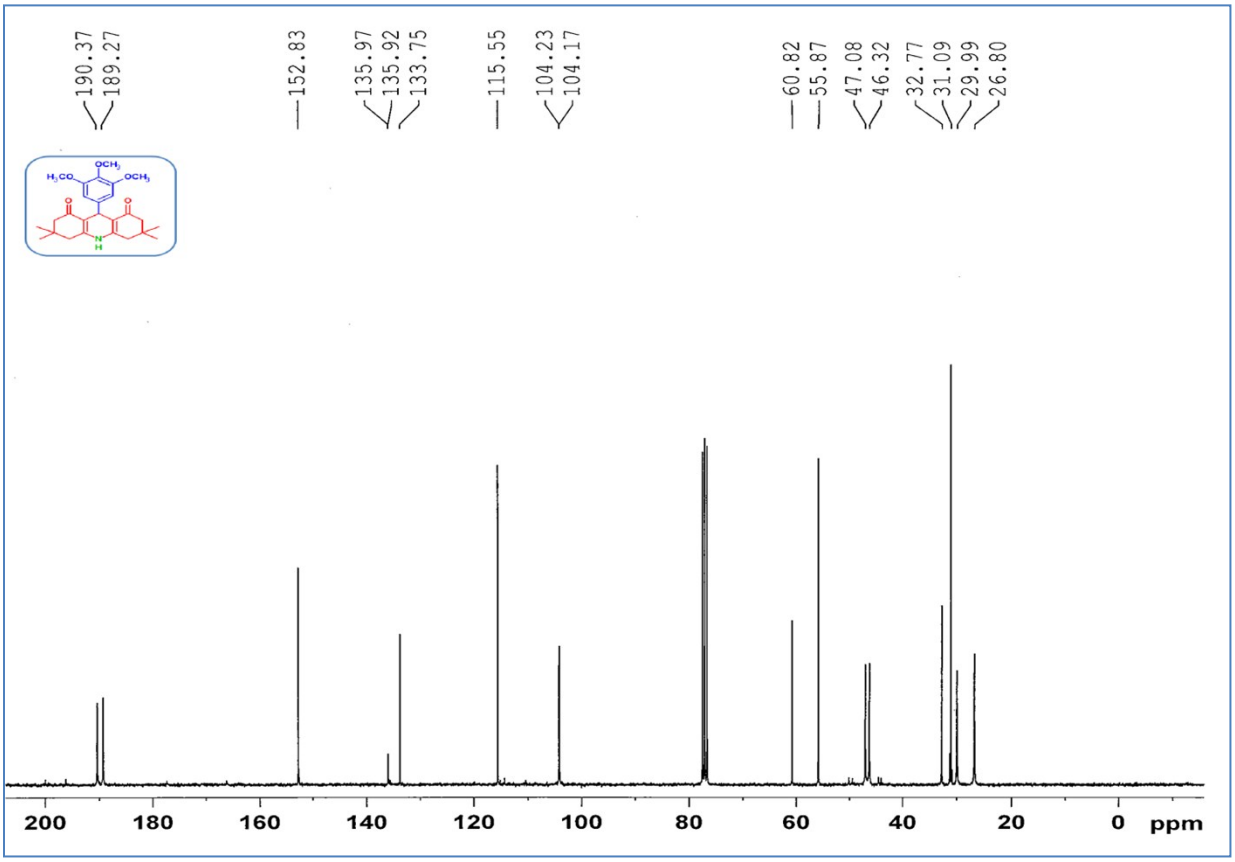




FT-IR, ^{1}H-NMR and ^{13}C-NMR Spectra of 3,3,6,6-Tetramethyl-9-(3,4,5-trimethoxyphenyl)-1,8-dioxo-decahydroacridine (Table 3, entry 10):




12.026
6.354
5.500
3.756
2.425
2.414
2.360
1.248
1.123
12
11
10
9
8
7
6
5
4
3
2
1
0
ppm
1.00
2.12
1.06
9.10
8.13
6.14
6.07


190.37
189.27
152.83
135.97
135.92
133.75
115.55
104.23
104.17
60.82
55.87
47.08
46.32
32.77
31.09
29.99
26.80
200
180
160
140
120
100
80
60
40
20
0
ppm

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1. Z. Zarnegar, J. Safari and Z. M. Kafroudi, *New J. Chem.*, 2015, **39**, 1445-1451.
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