
One-pot double intramolecular homolytic aromatic substitution routes to dialicyclic ring fused imidazobenzimidazolequinones and preliminary analysis of anti-cancer activity

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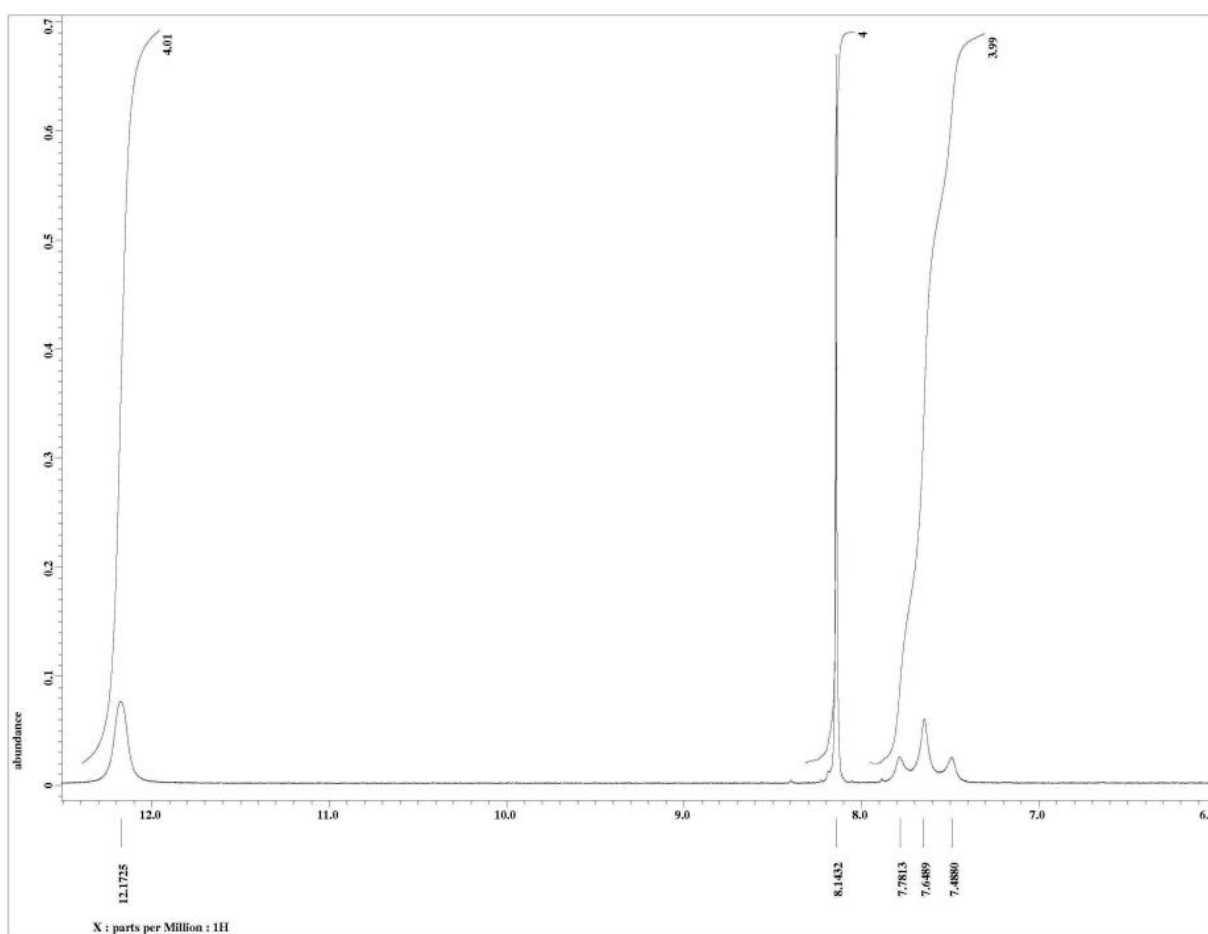
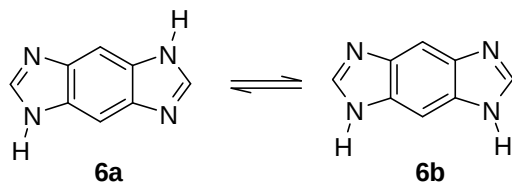
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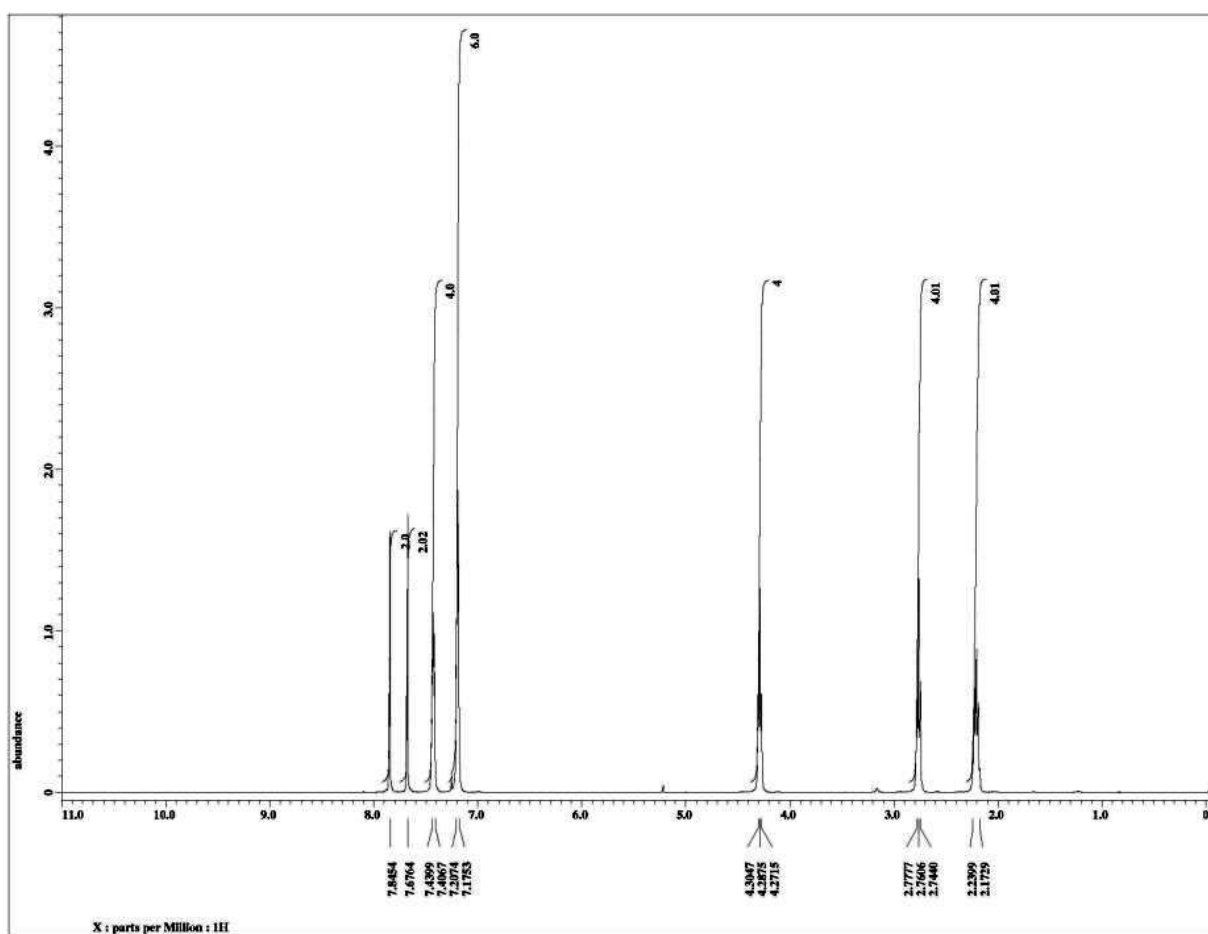
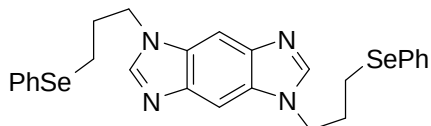
Imidazo[4,5(5,4)-f]benzimidazole (6)

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



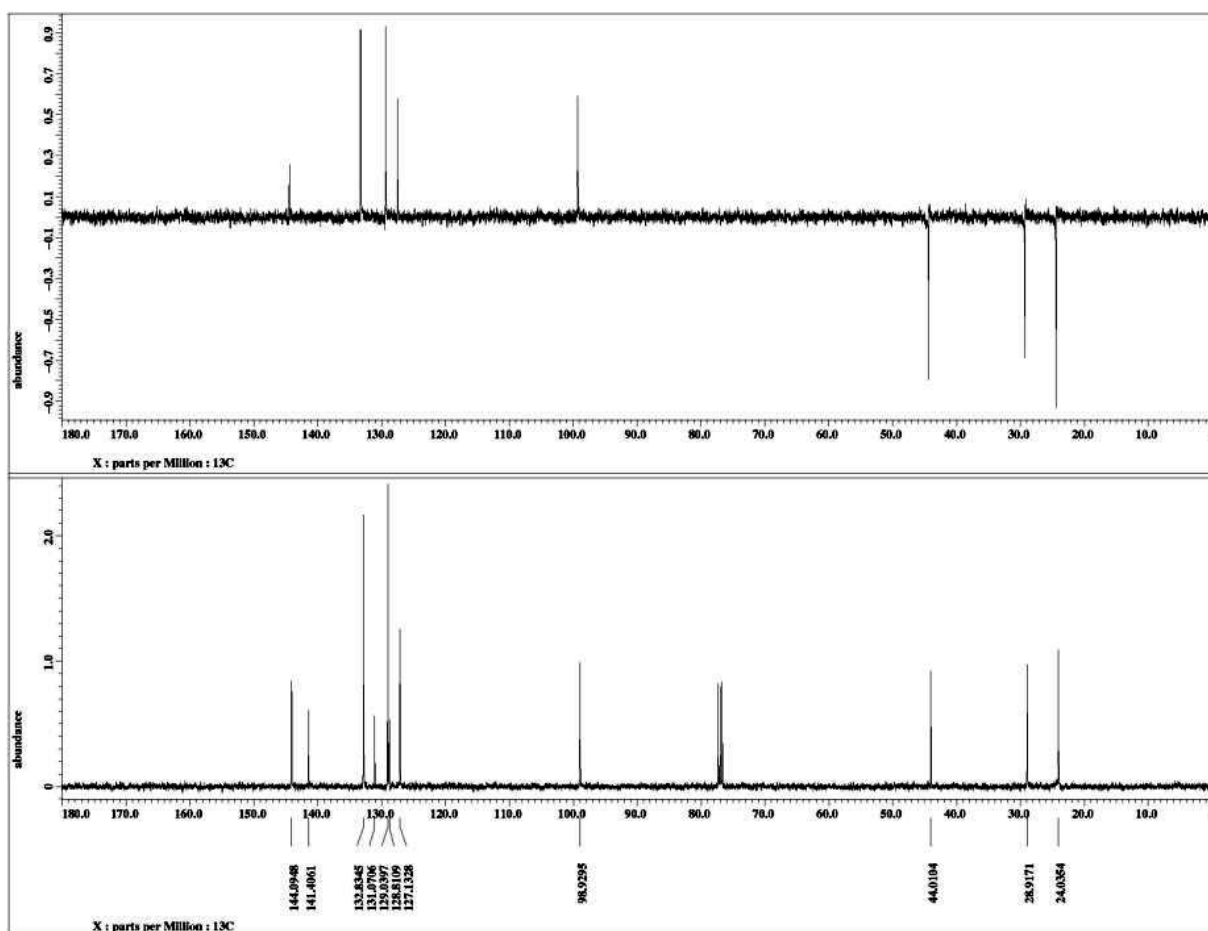
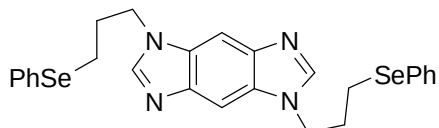
1,5-Di(3-(phenylselano)propyl)imidazo[5,4-f]benzimidazole (7a)

^1H NMR, 400 MHz, CDCl_3



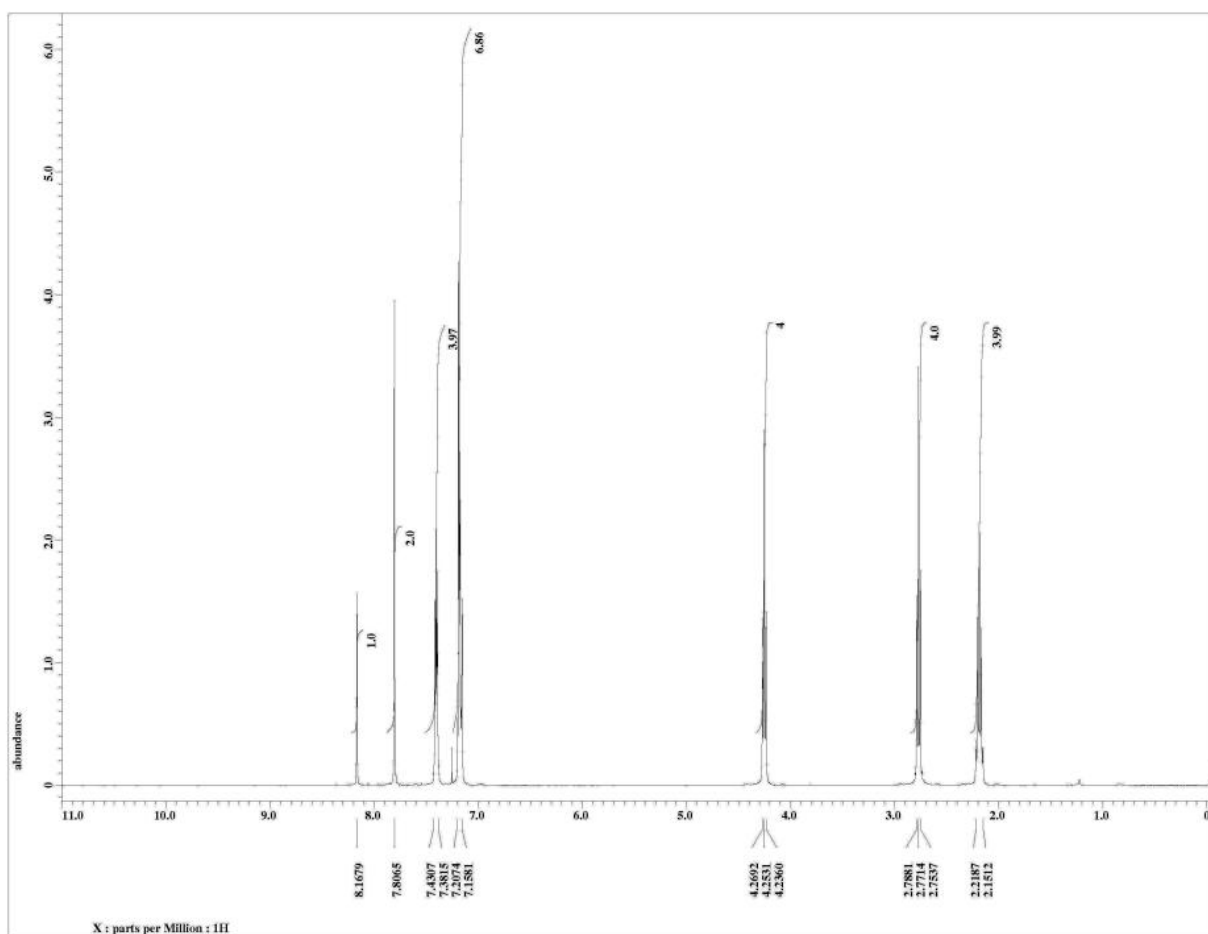
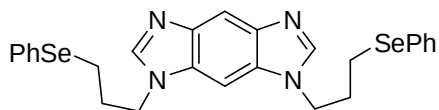
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^{13}C NMR, 100 MHz, CDCl_3



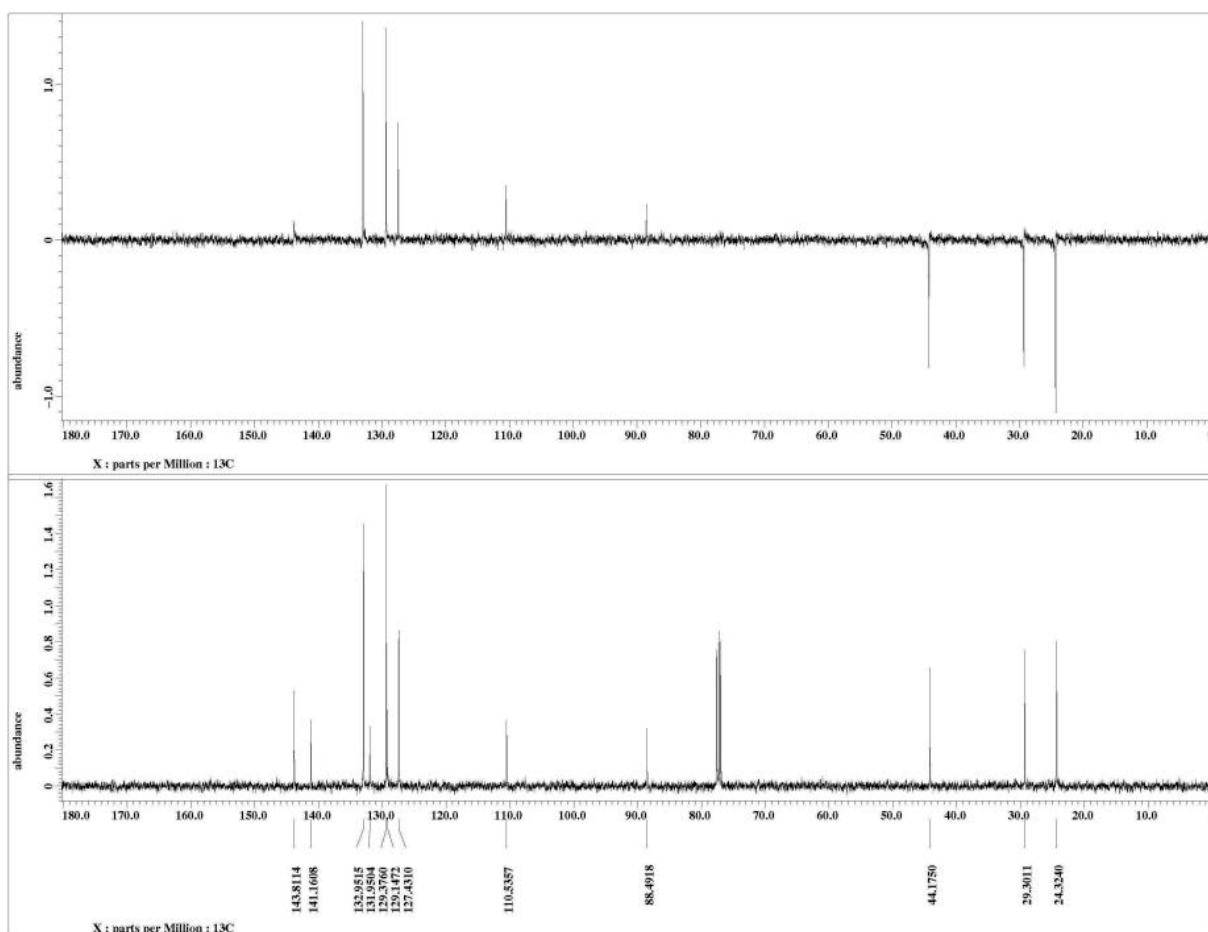
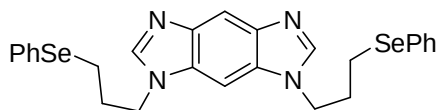
1,7-Di(3-(phenylselano)propyl)imidazo[4,5-f]benzimidazole (8a)

^1H NMR, 400 MHz, CDCl_3



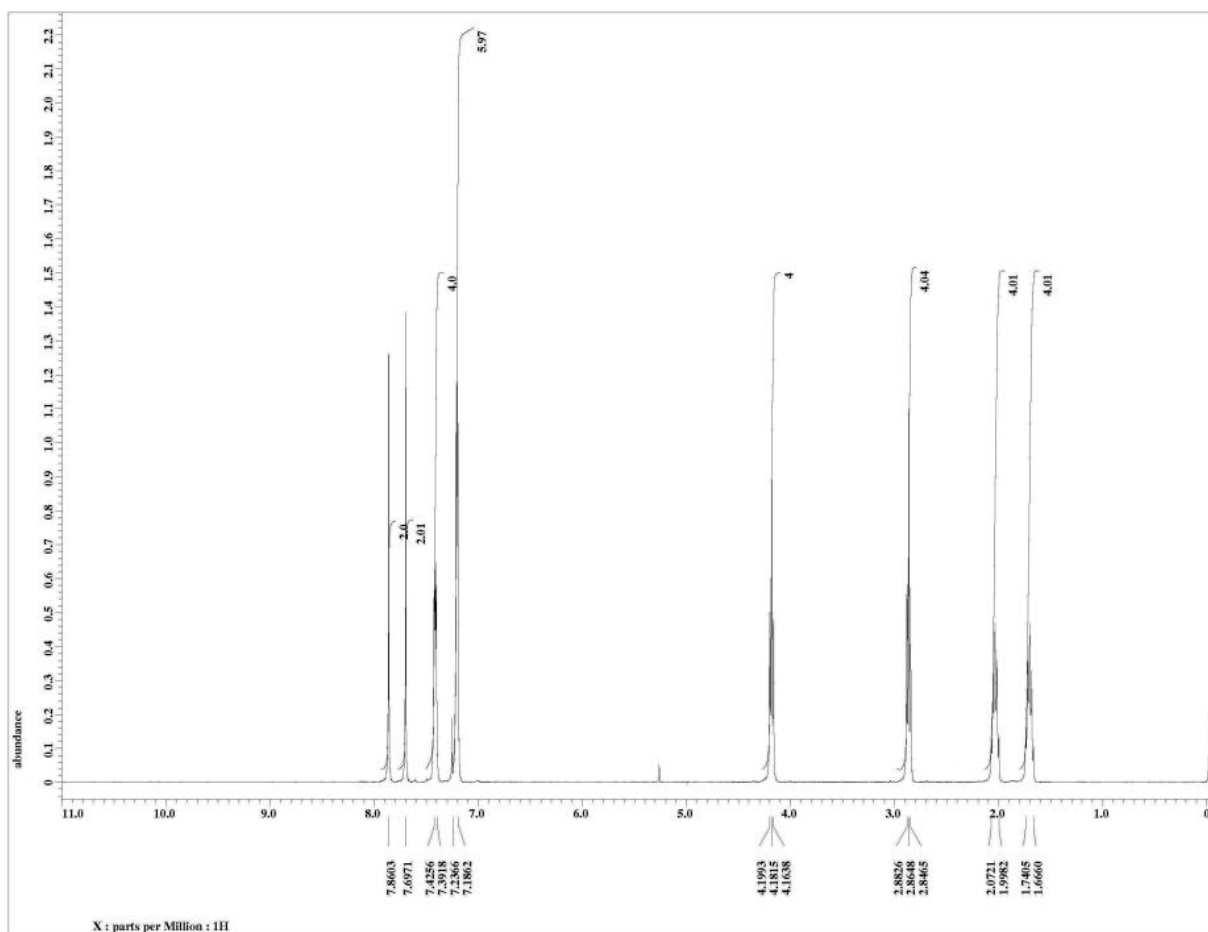
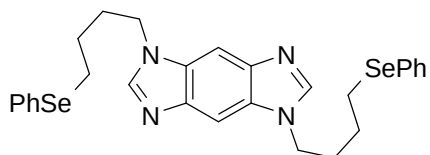
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¹³C NMR, 100 MHz, CDCl₃



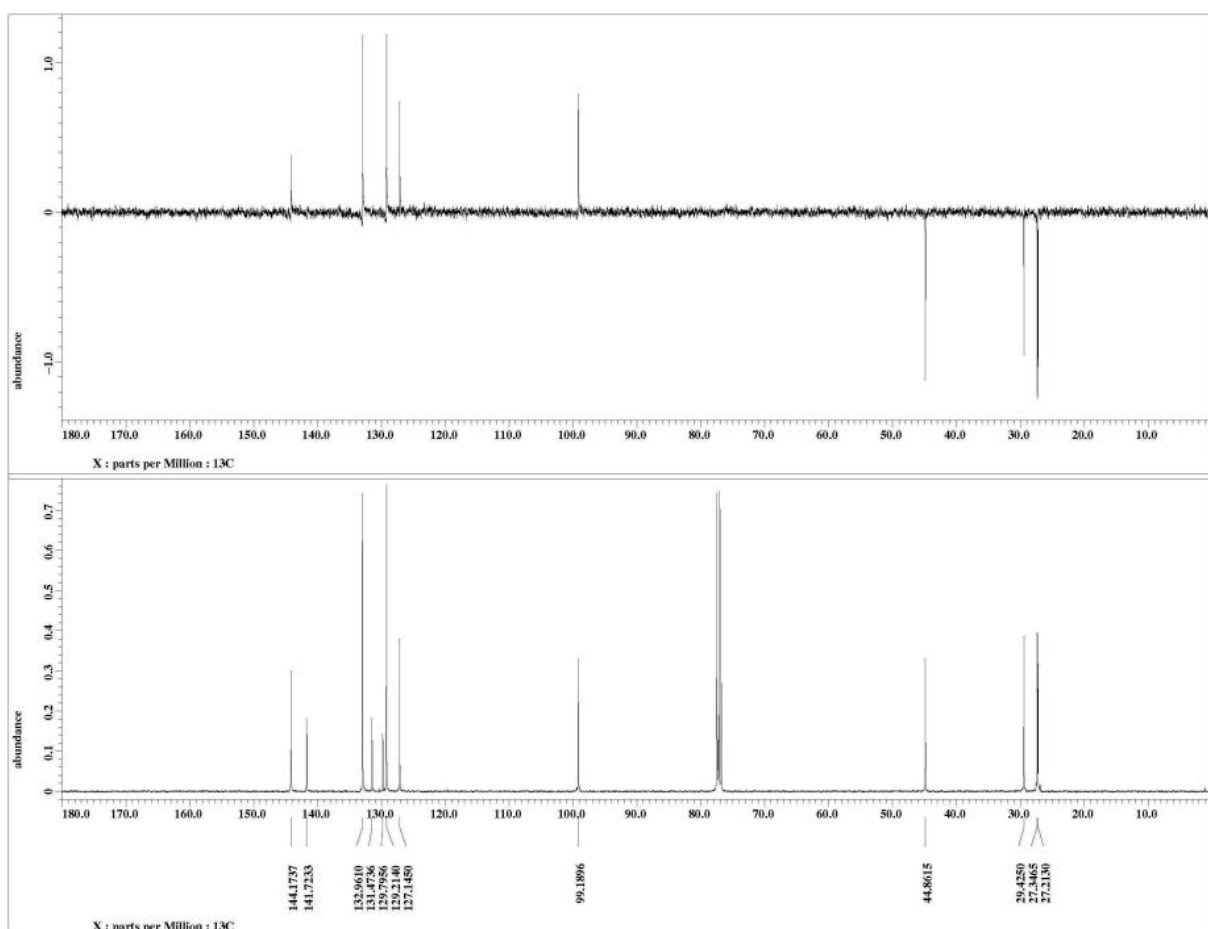
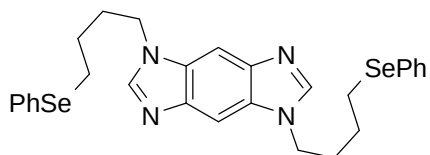
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¹H NMR, 400 MHz, CDCl₃



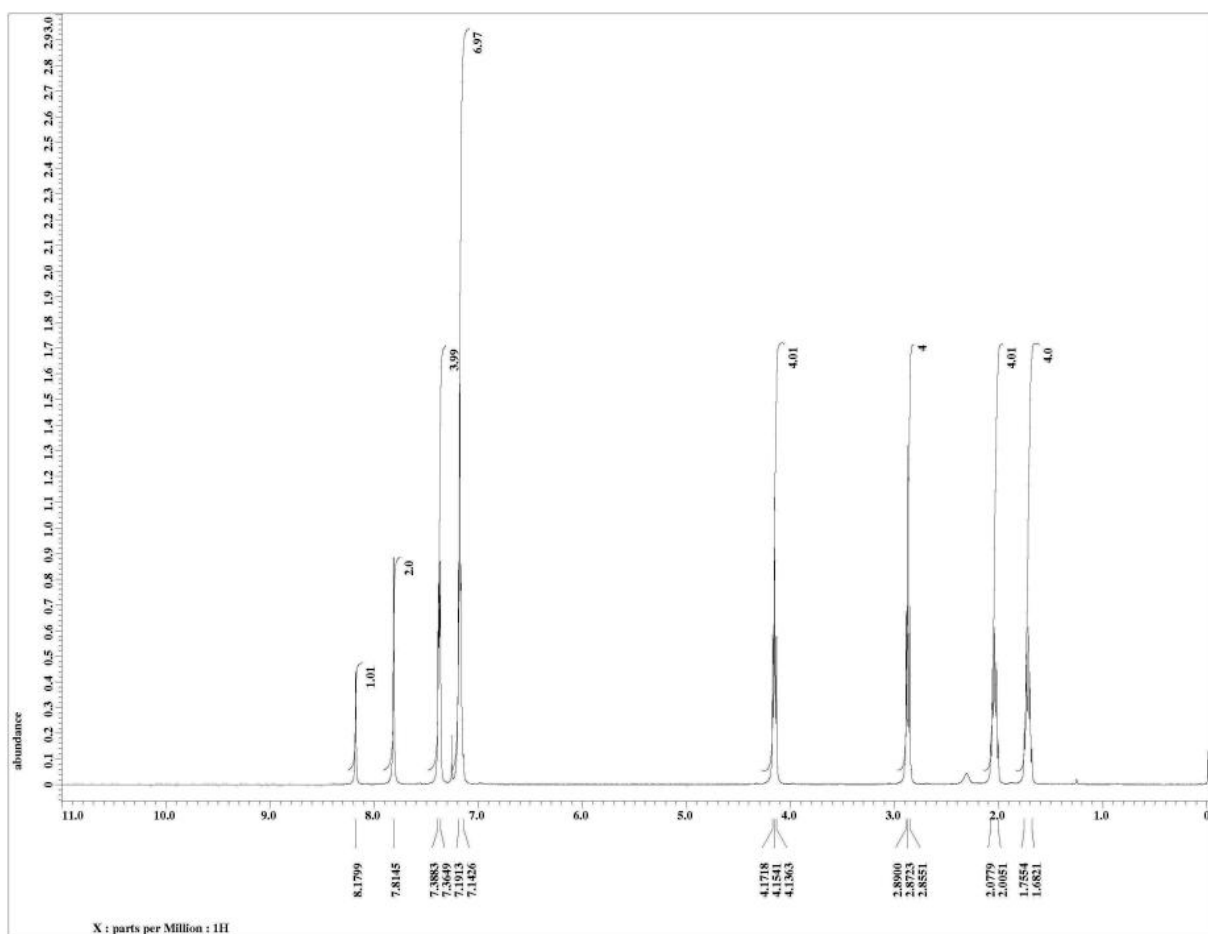
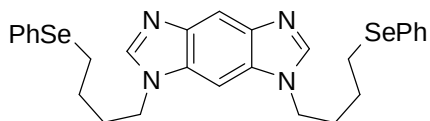
1,5-Di(4-(phenylselano)butyl)imidazo[5,4-f]benzimidazole (7b)

^{13}C NMR, 100 MHz, CDCl_3



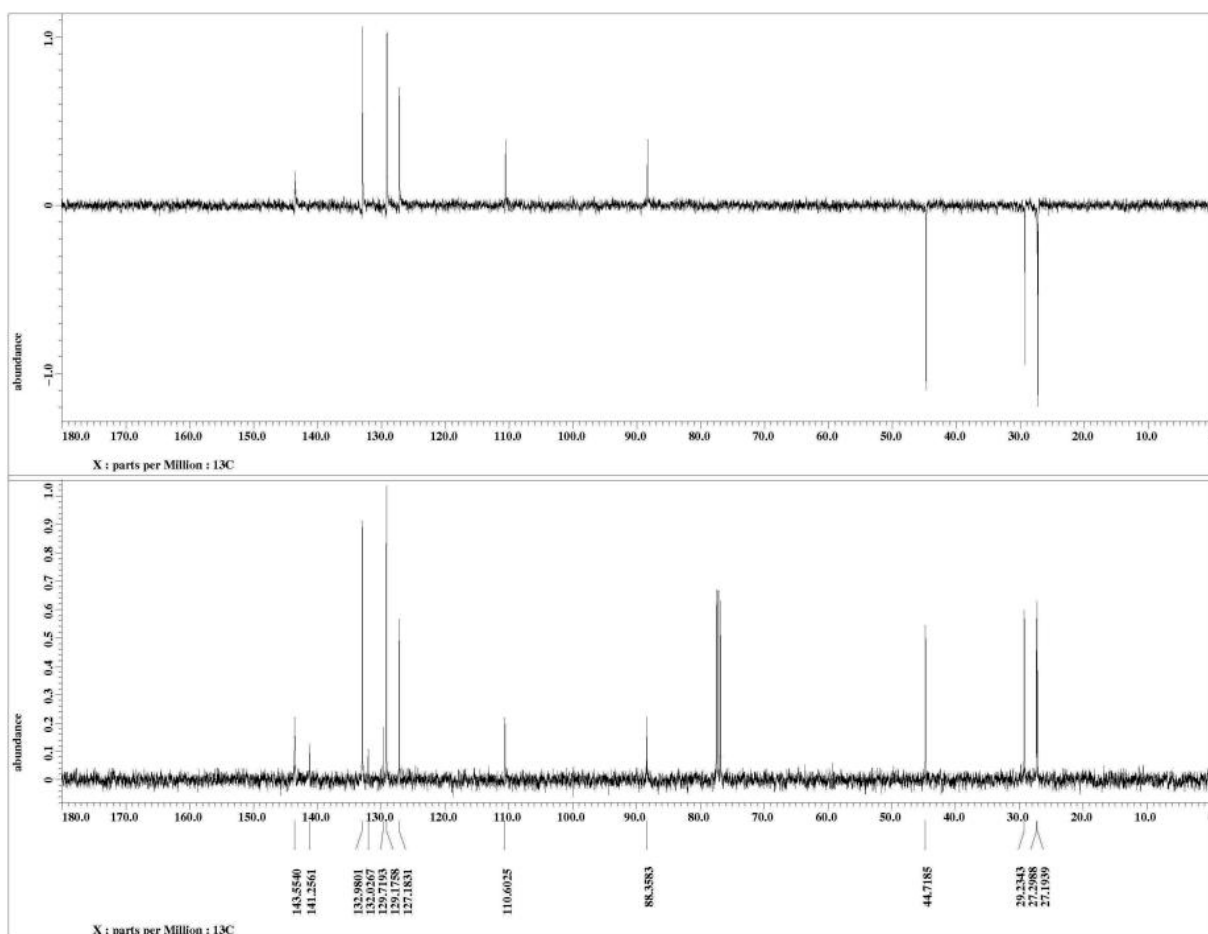
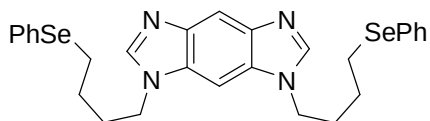
1,7-Di(4-(phenylselano)butyl)imidazo[4,5-f]benzimidazole (8b)

¹H NMR, 400 MHz, CDCl₃



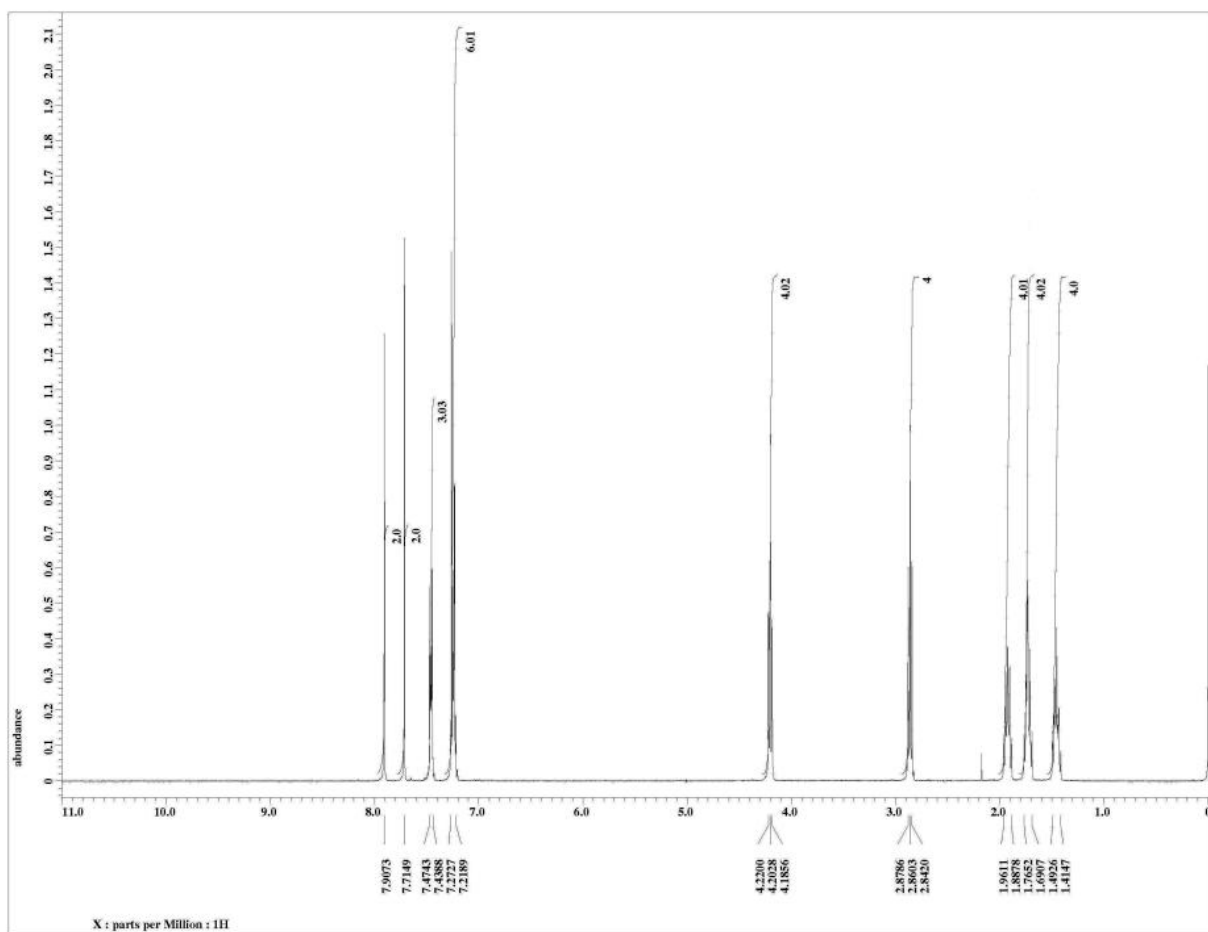
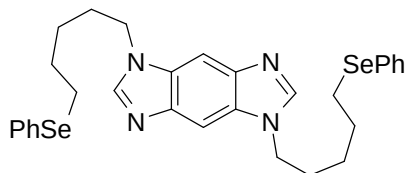
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^{13}C NMR, 100 MHz, CDCl_3



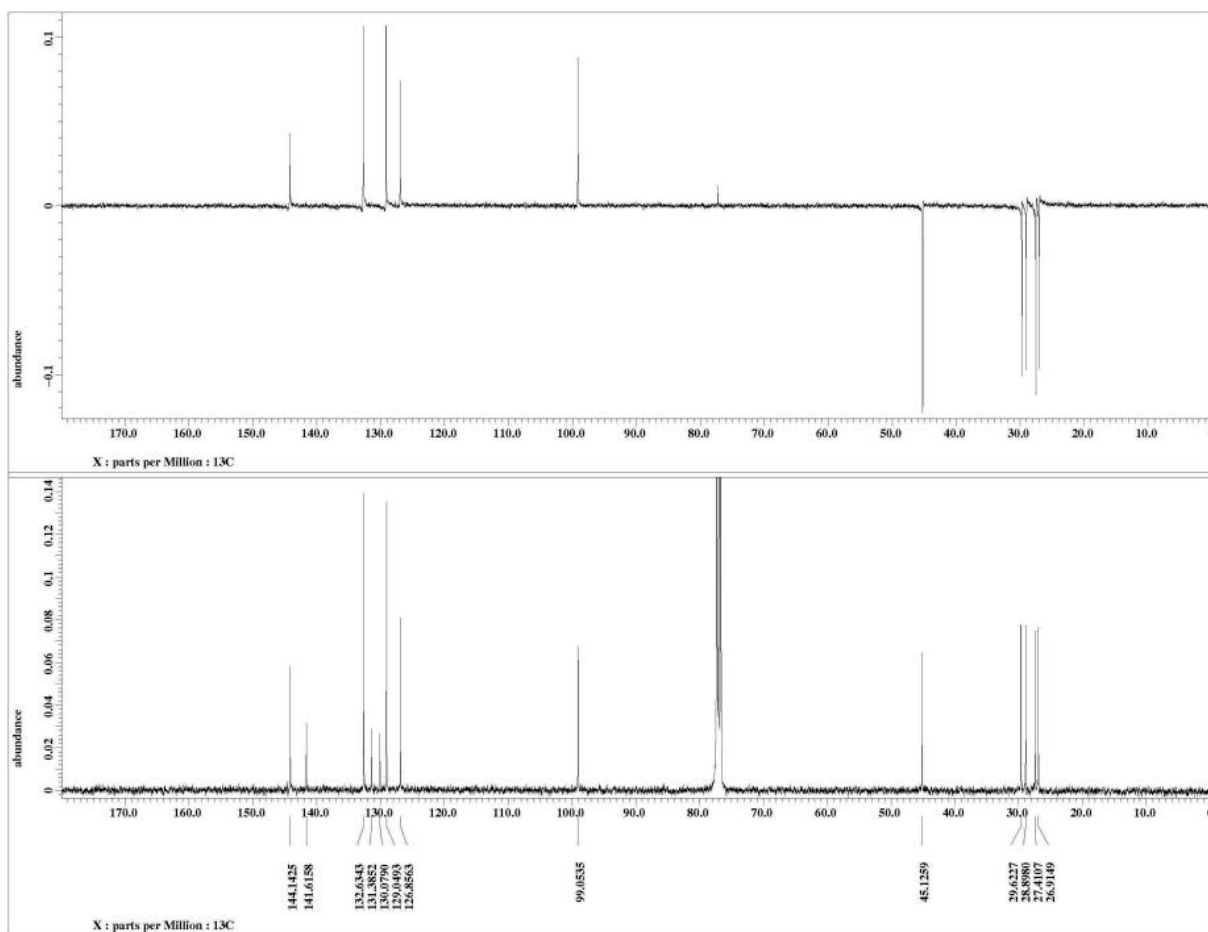
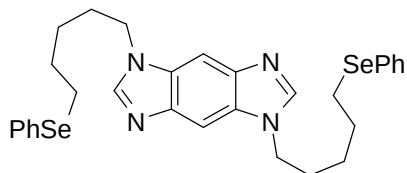
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^1H NMR, 400 MHz, CDCl_3



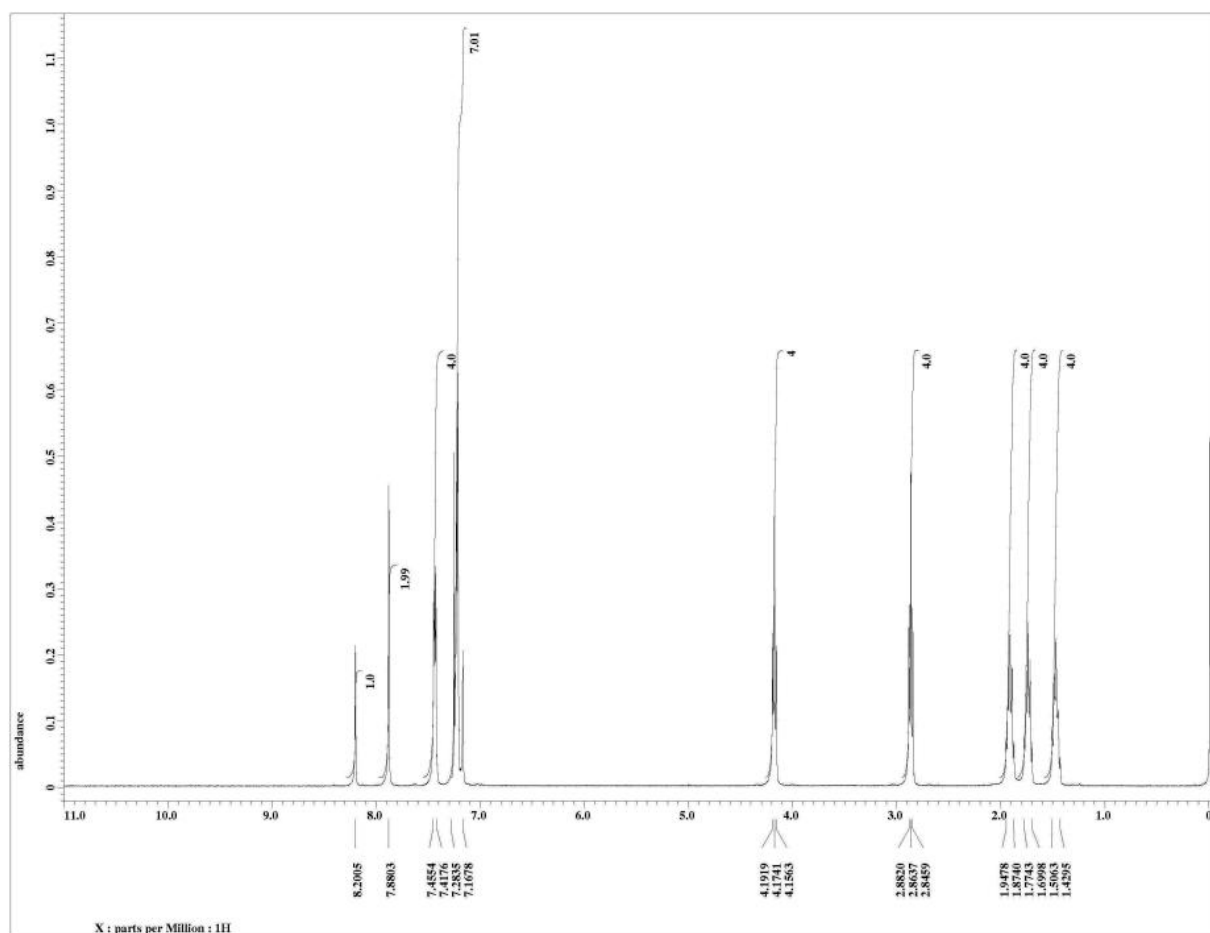
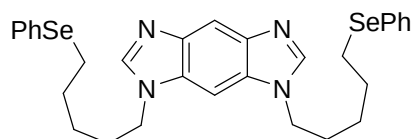
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^{13}C NMR, 100 MHz, CDCl_3



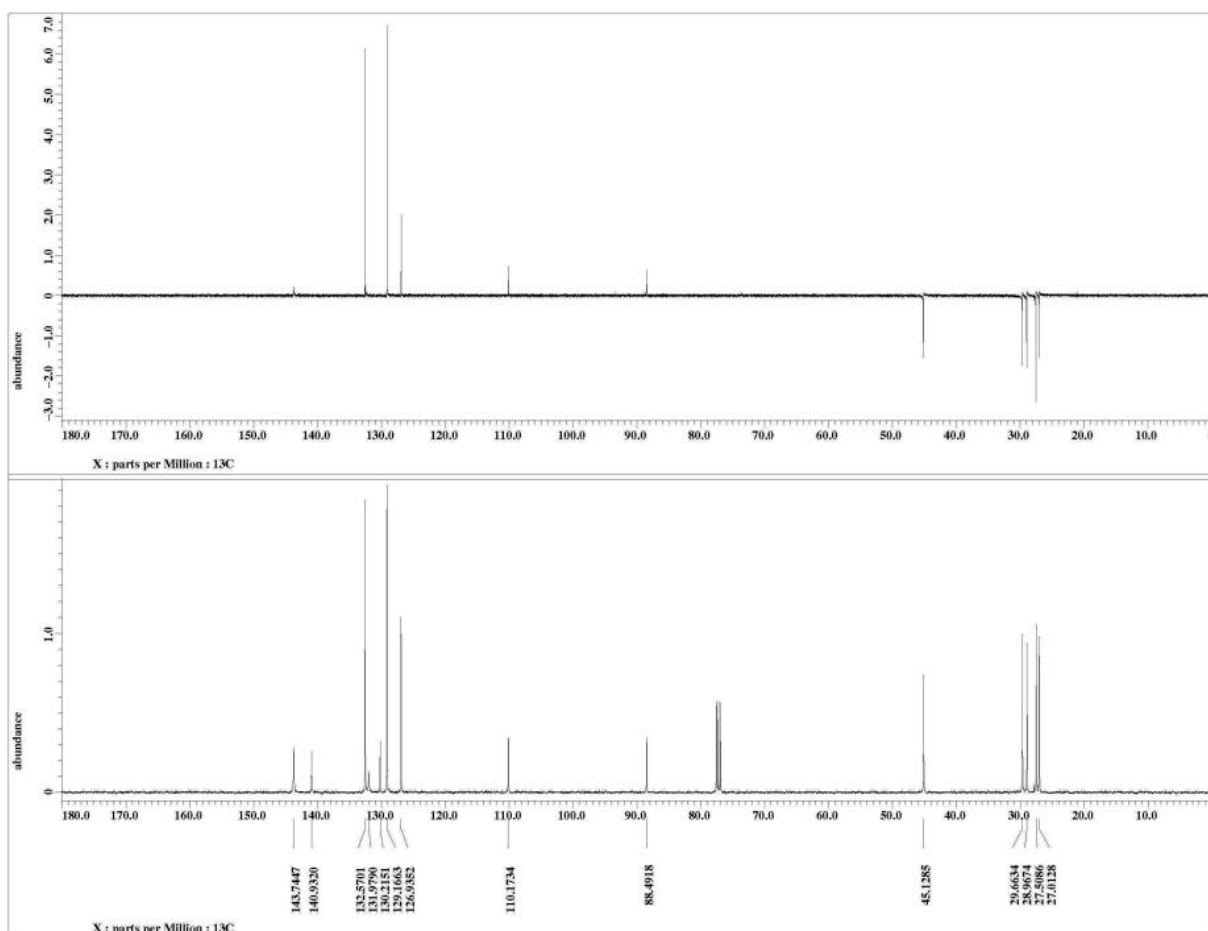
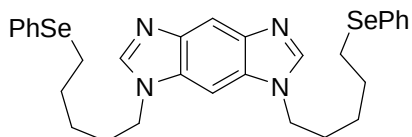
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^1H NMR, 400 MHz, CDCl_3



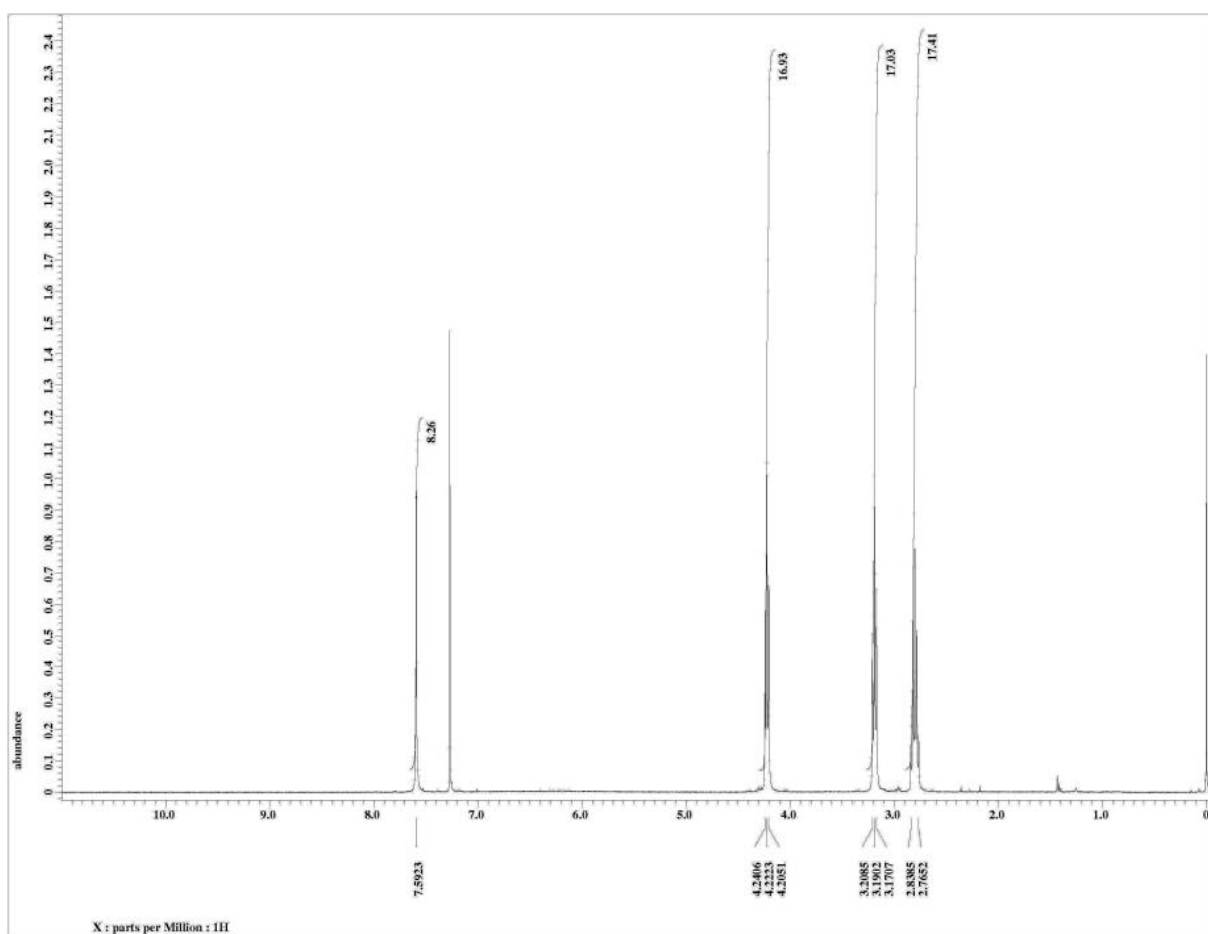
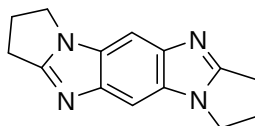
1,7-Di(5-(phenylselano)pentyl)imidazo[4,5-f]benzimidazole (8c)

^{13}C NMR, 100 MHz, CDCl_3



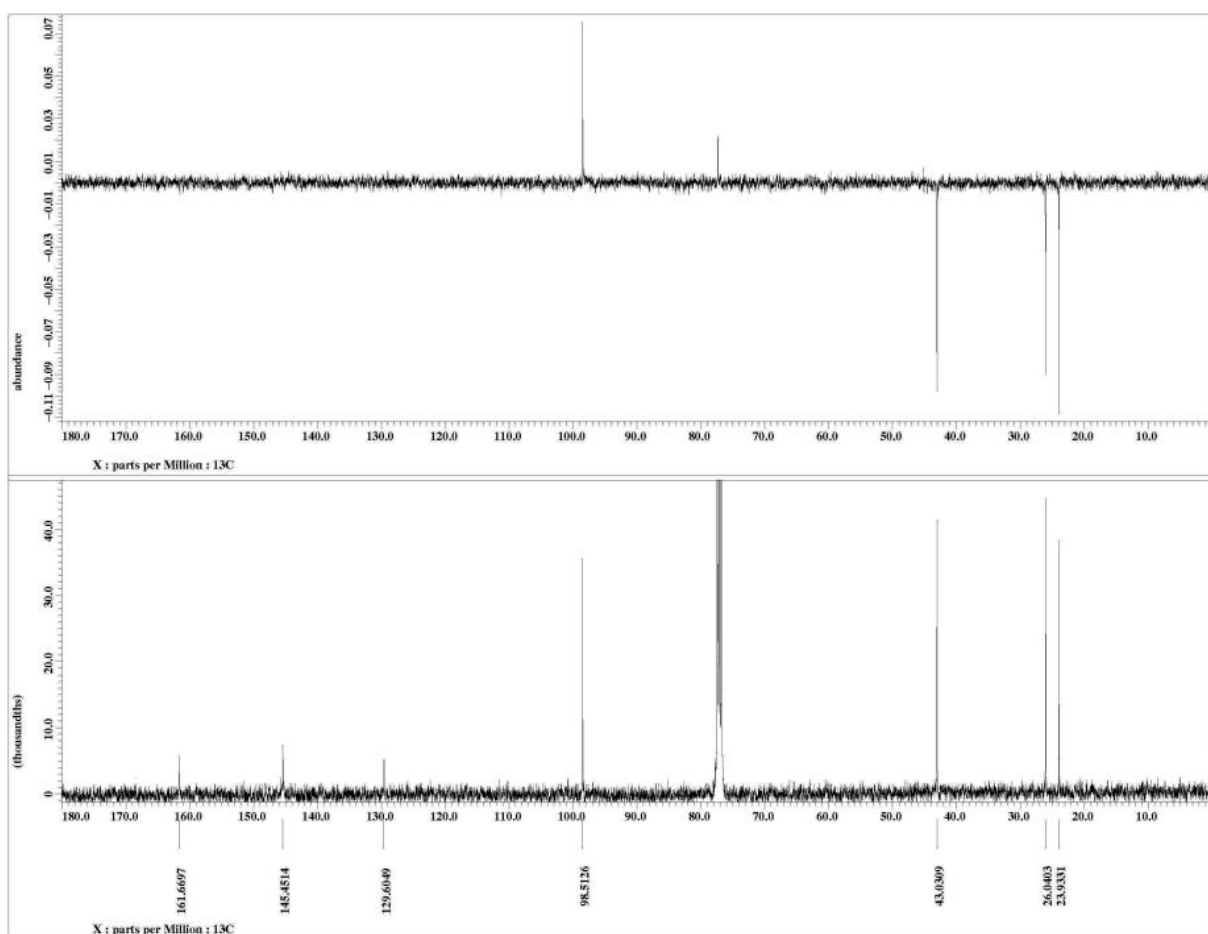
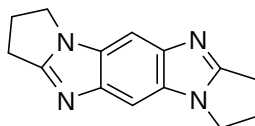
2,3,8,9-Tetrahydro-1*H*,7*H*-pyrrolo[1,2-*a*]pyrrolo[1',2':1,2]imidazo[5,4-*f*]benzimidazole (9a)

¹H NMR, 400 MHz, CDCl₃



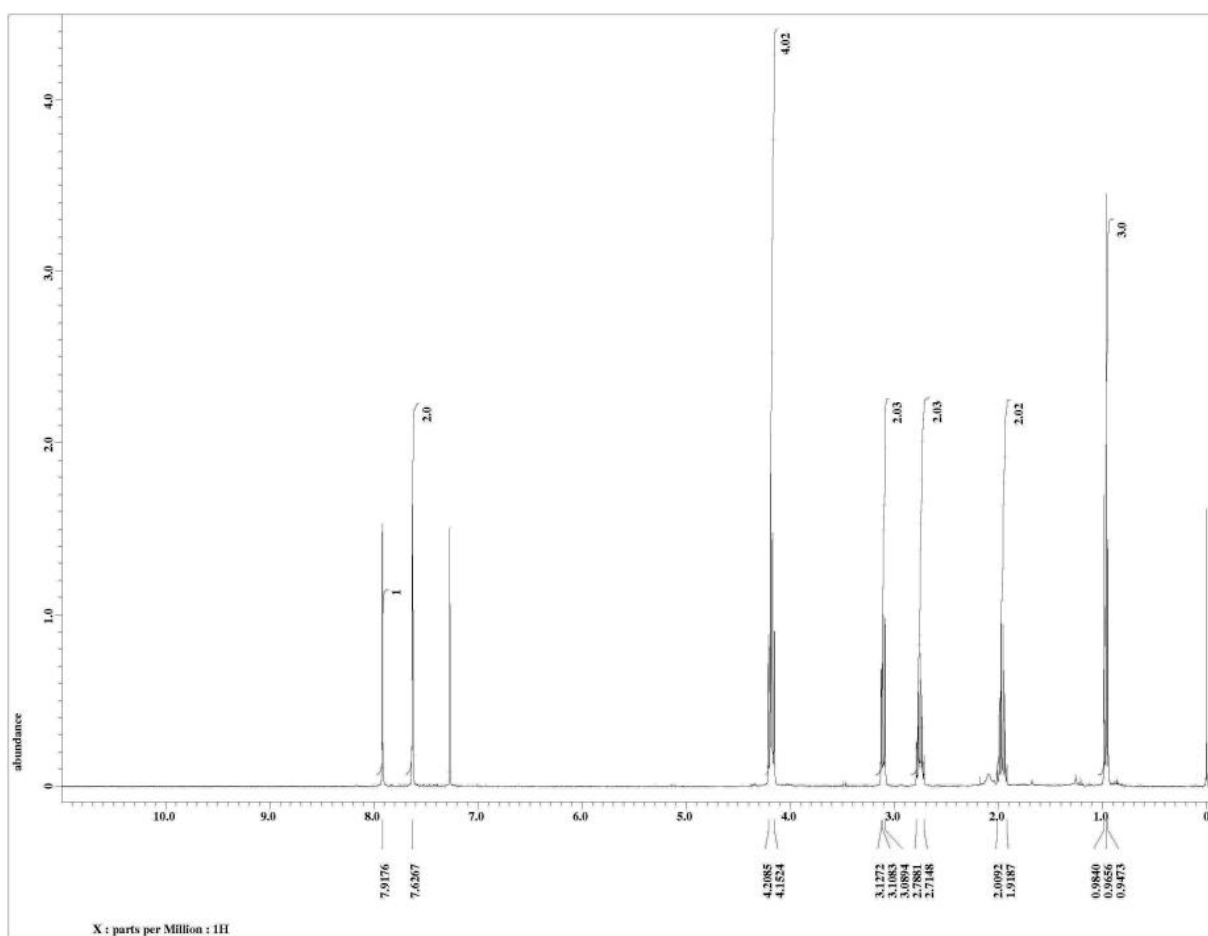
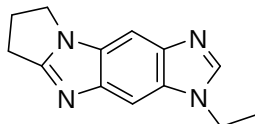
2,3,8,9-Tetrahydro-1*H*,7*H*-pyrrolo[1,2-*a*]pyrrolo[1',2':1,2]imidazo[5,4-*f*]benzimidazole (9a)

¹³C NMR, 100 MHz, CDCl₃



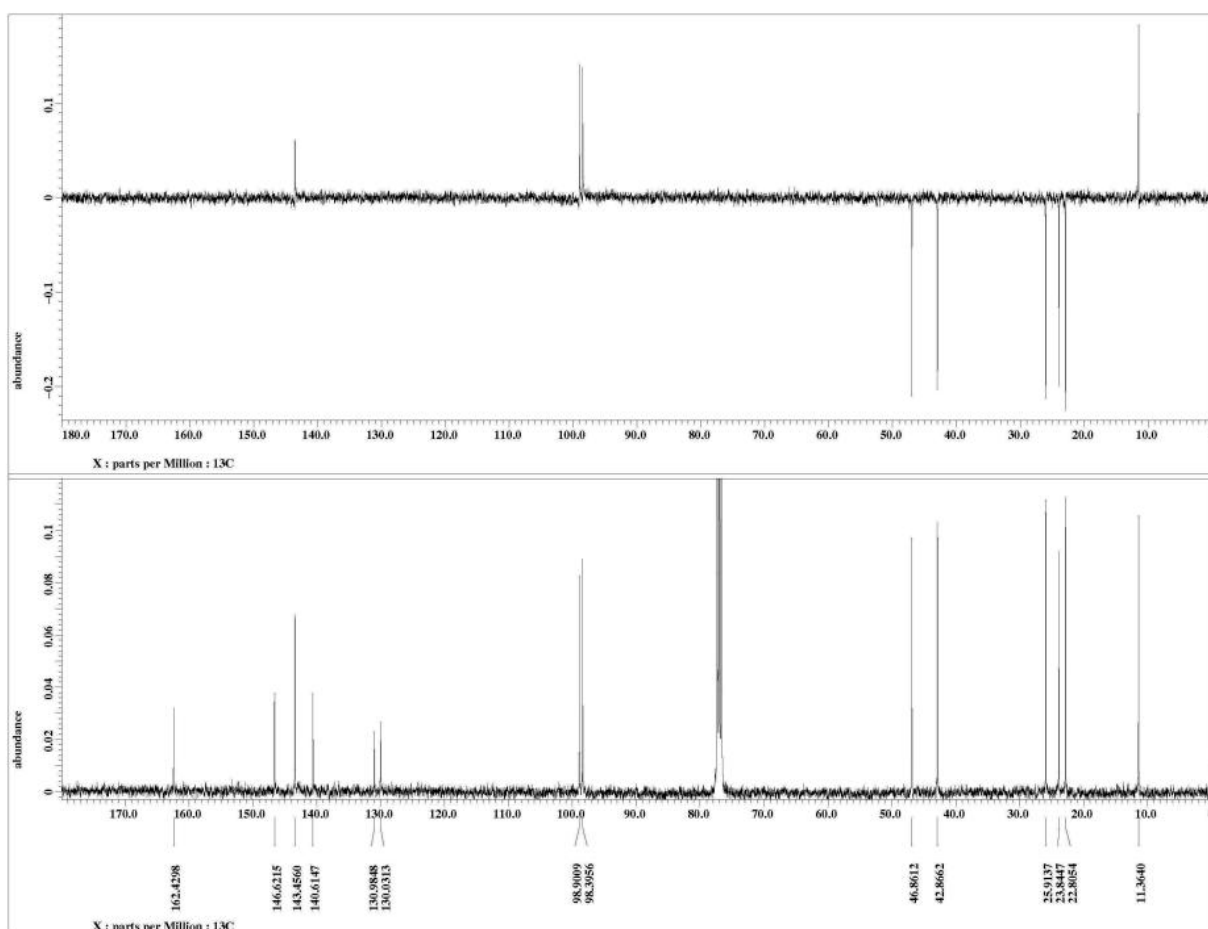
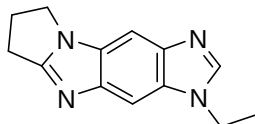
1-Propyl-7,8-dihydro-6H-imidazo[5,4-f]pyrrolo[1,2-a]benzimidazole (10a)

¹H NMR, 400 MHz, CDCl₃



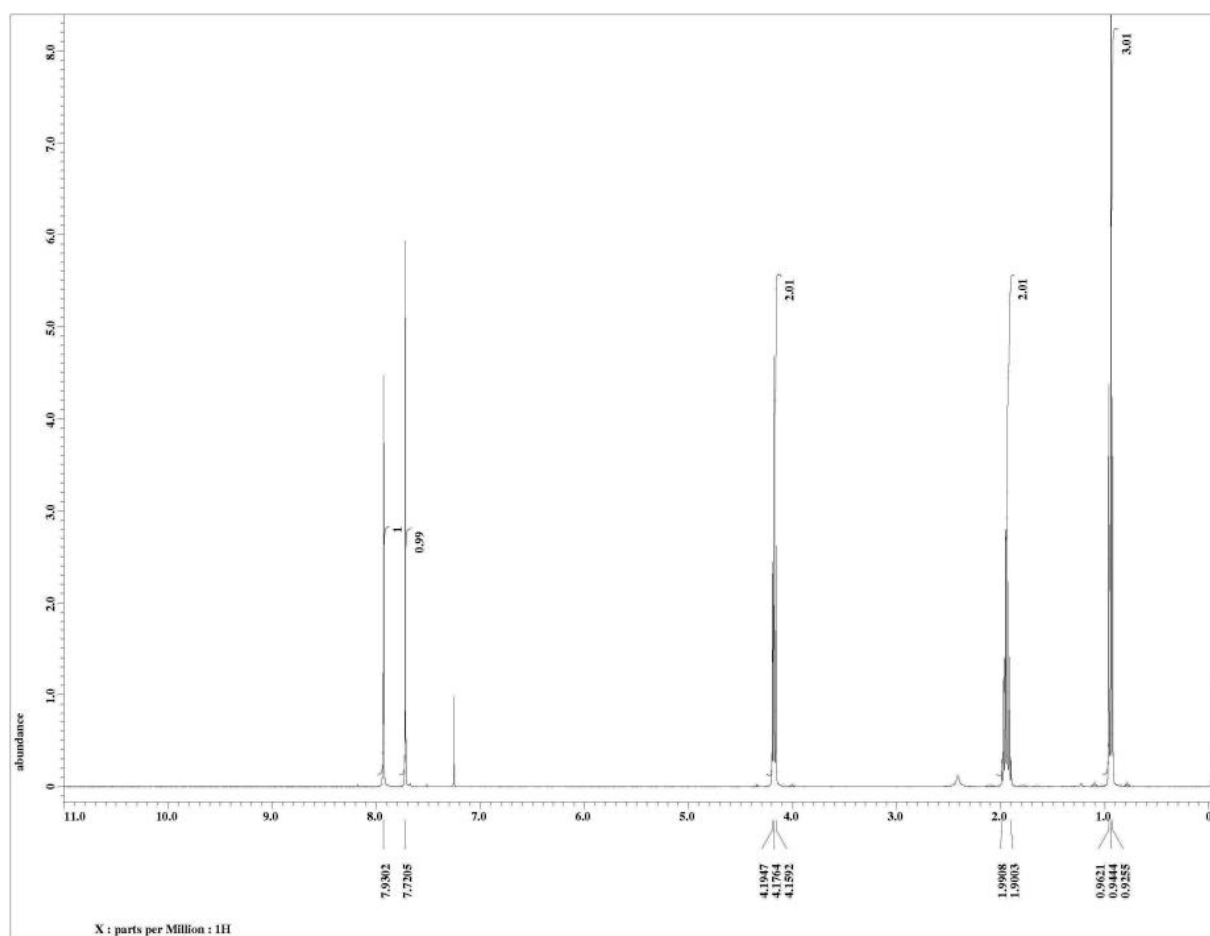
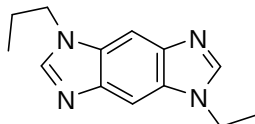
1-Propyl-7,8-dihydro-6H-imidazo[5,4-f]pyrrolo[1,2-a]benzimidazole (10a)

¹³C NMR, 100 MHz, CDCl₃



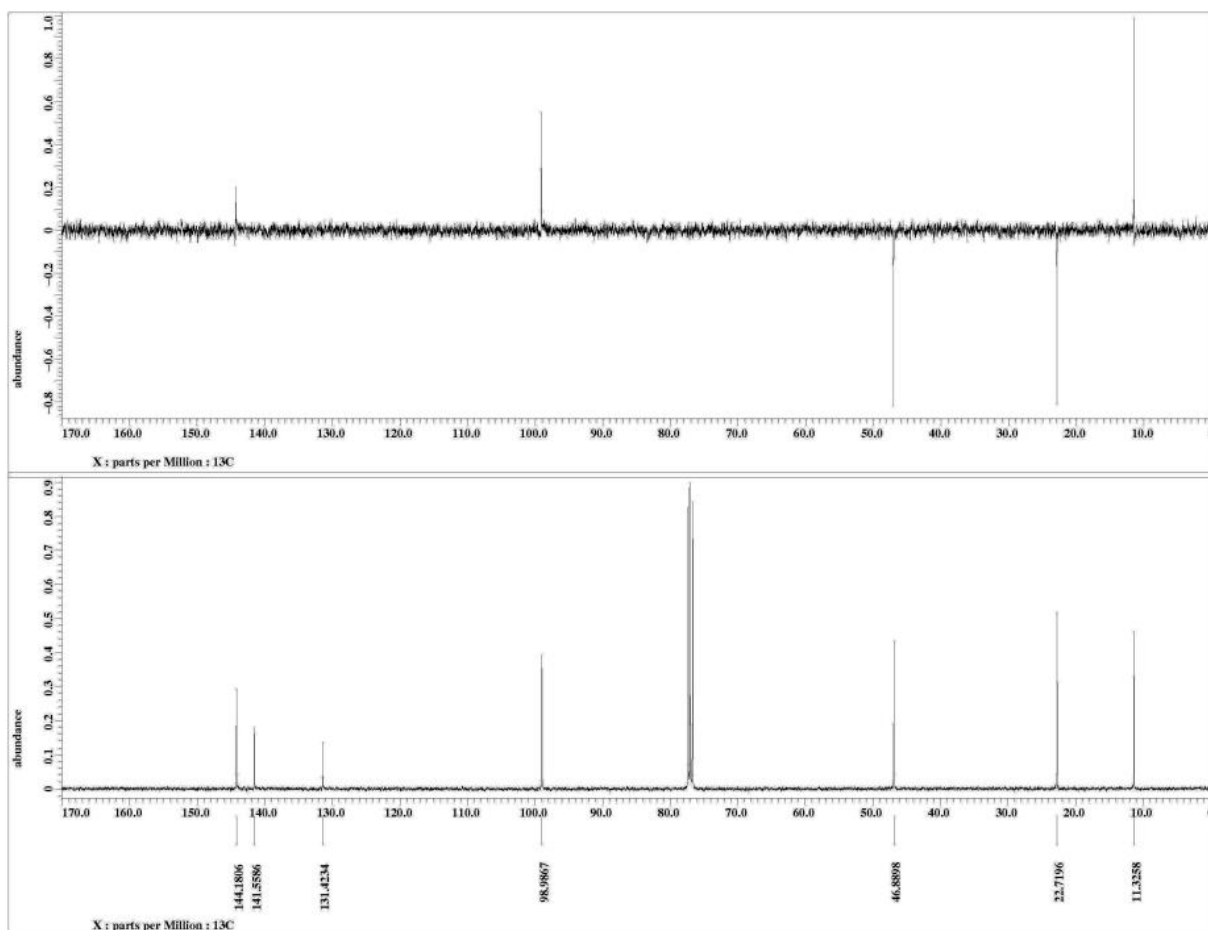
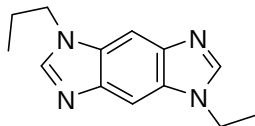
1,5-Dipropyylimidazo[5,4-*f*]benzimidazole (11a)

¹H NMR, 400 MHz, CDCl₃



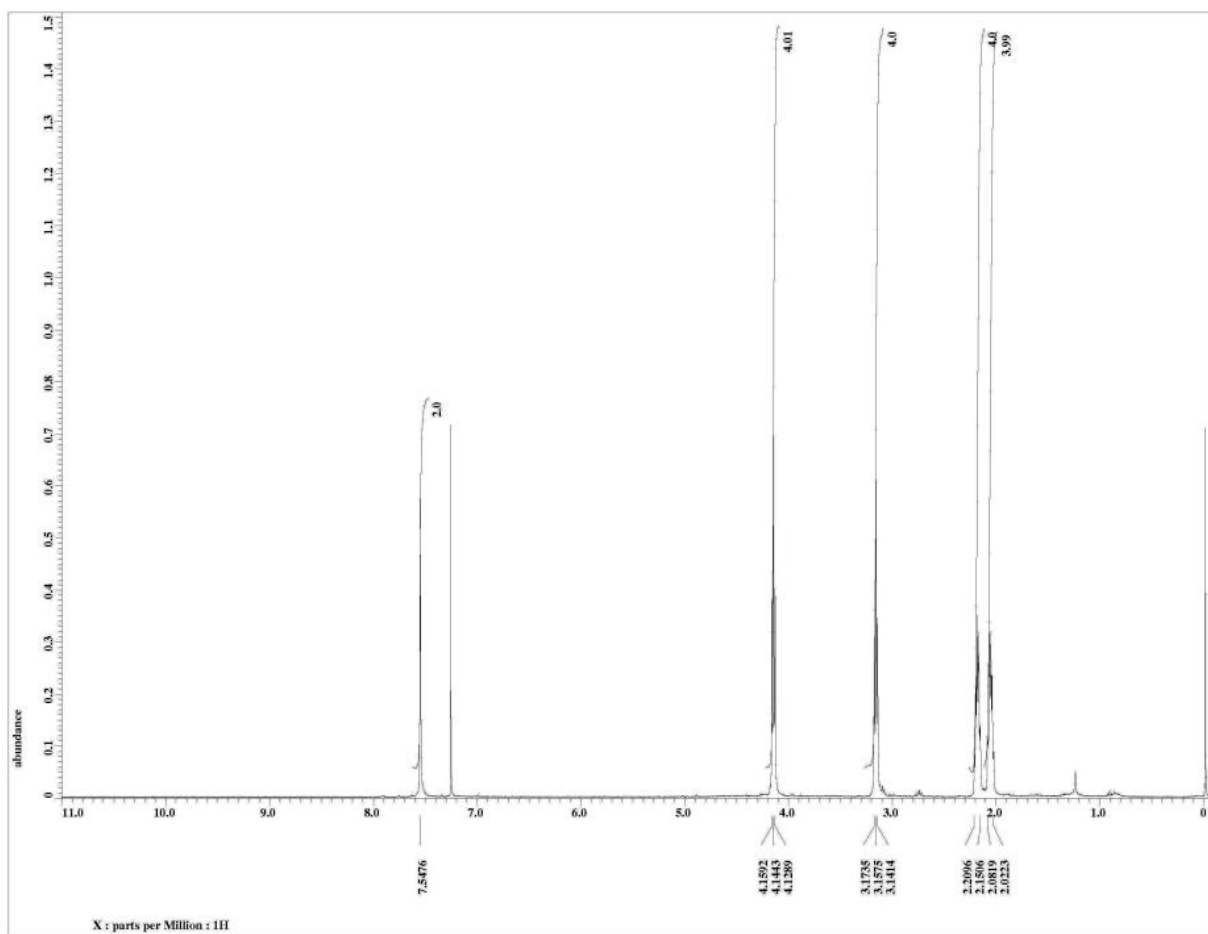
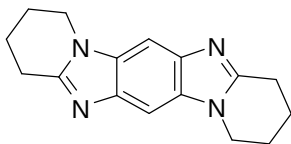
1,5-Dipropylimidazo[5,4-*f*]benzimidazole (11a)

¹³C NMR, 100 MHz, CDCl₃



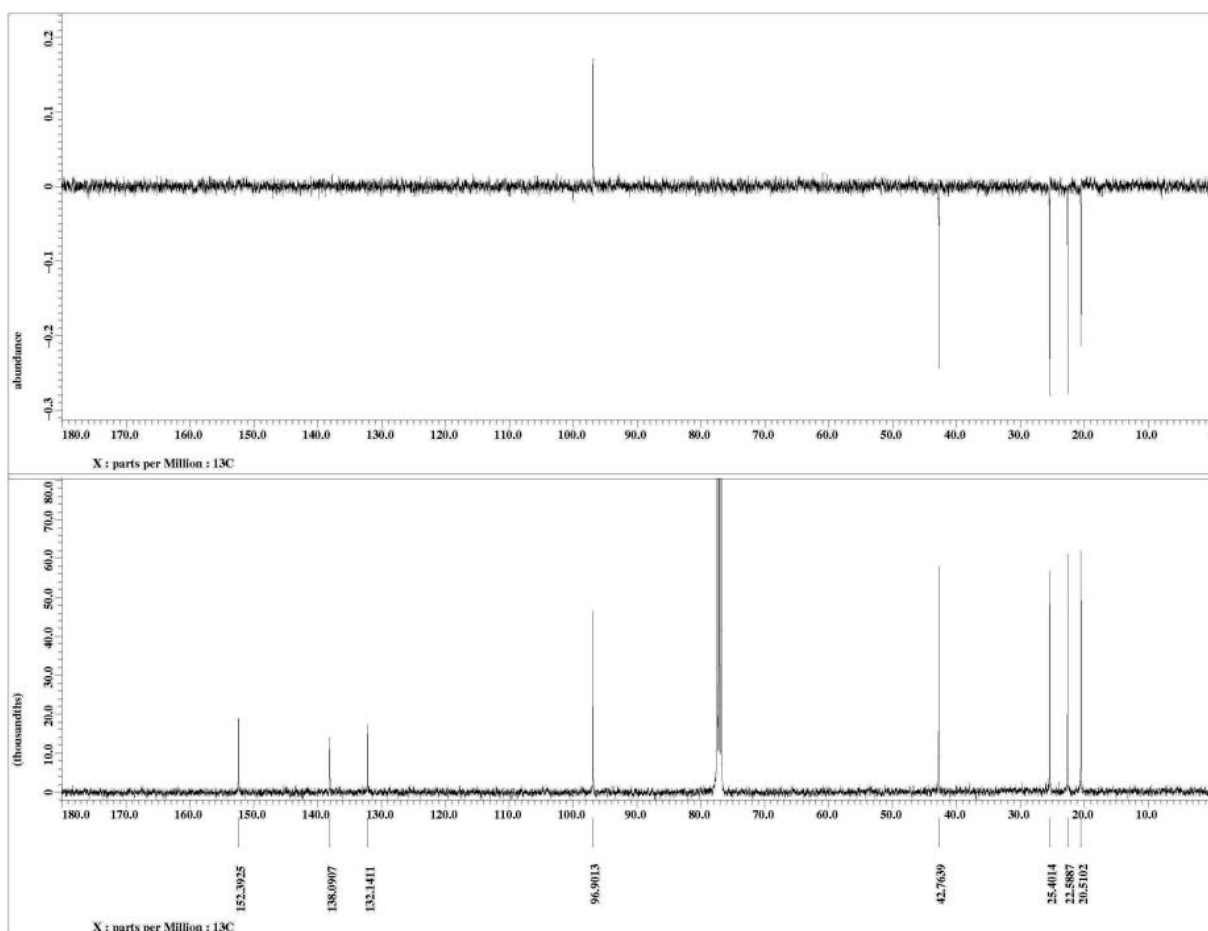
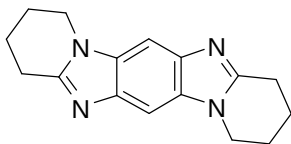
**1,2,3,4,8,9,10,11-Octahydropyrido[1,2-*a*]pyrido[1',2':1,2]imidazo[5,4-*f*]
benzimidazole (9b)**

¹H NMR, 400 MHz, CDCl₃



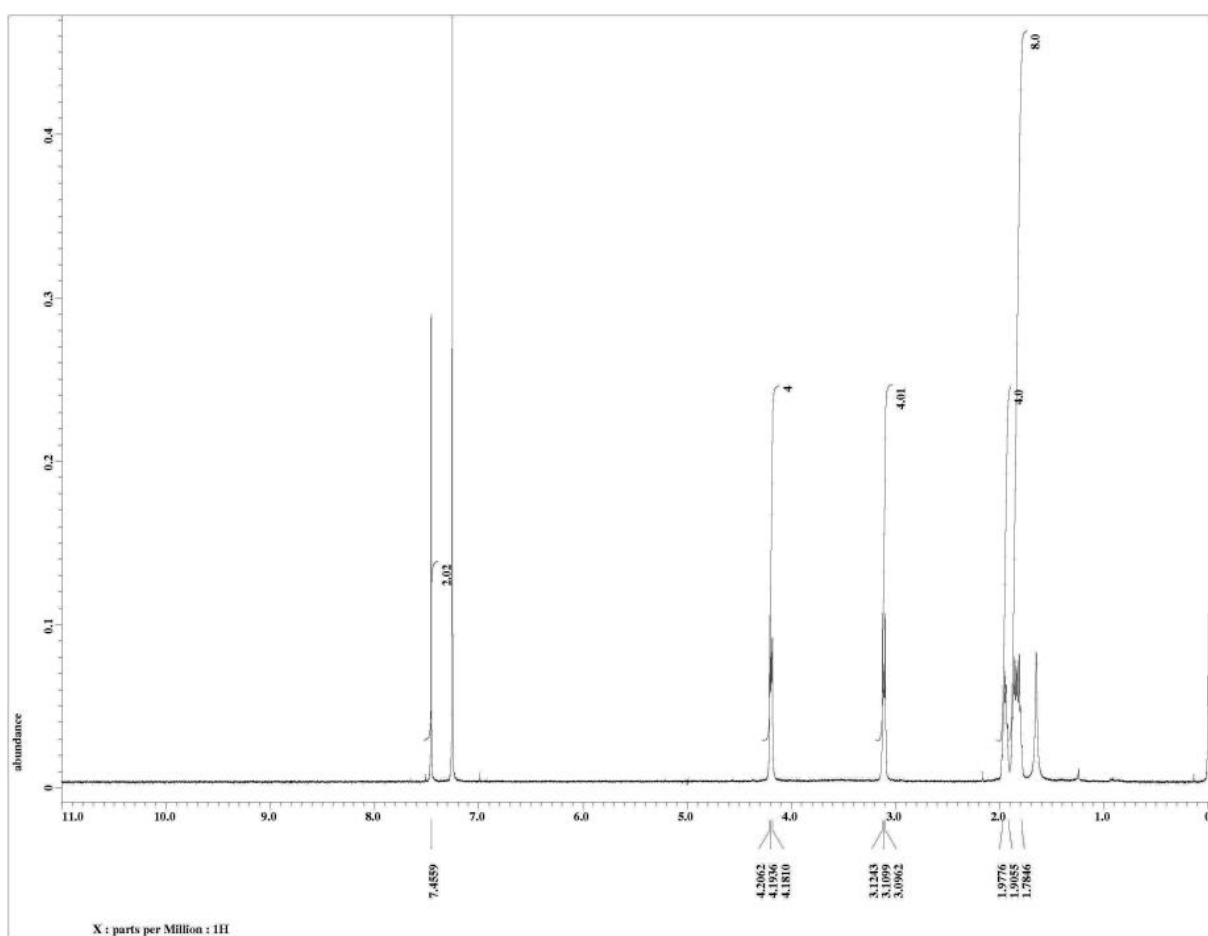
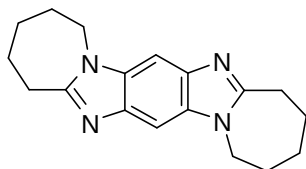
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benzimidazole (9b)**

^{13}C NMR, 100 MHz, CDCl_3



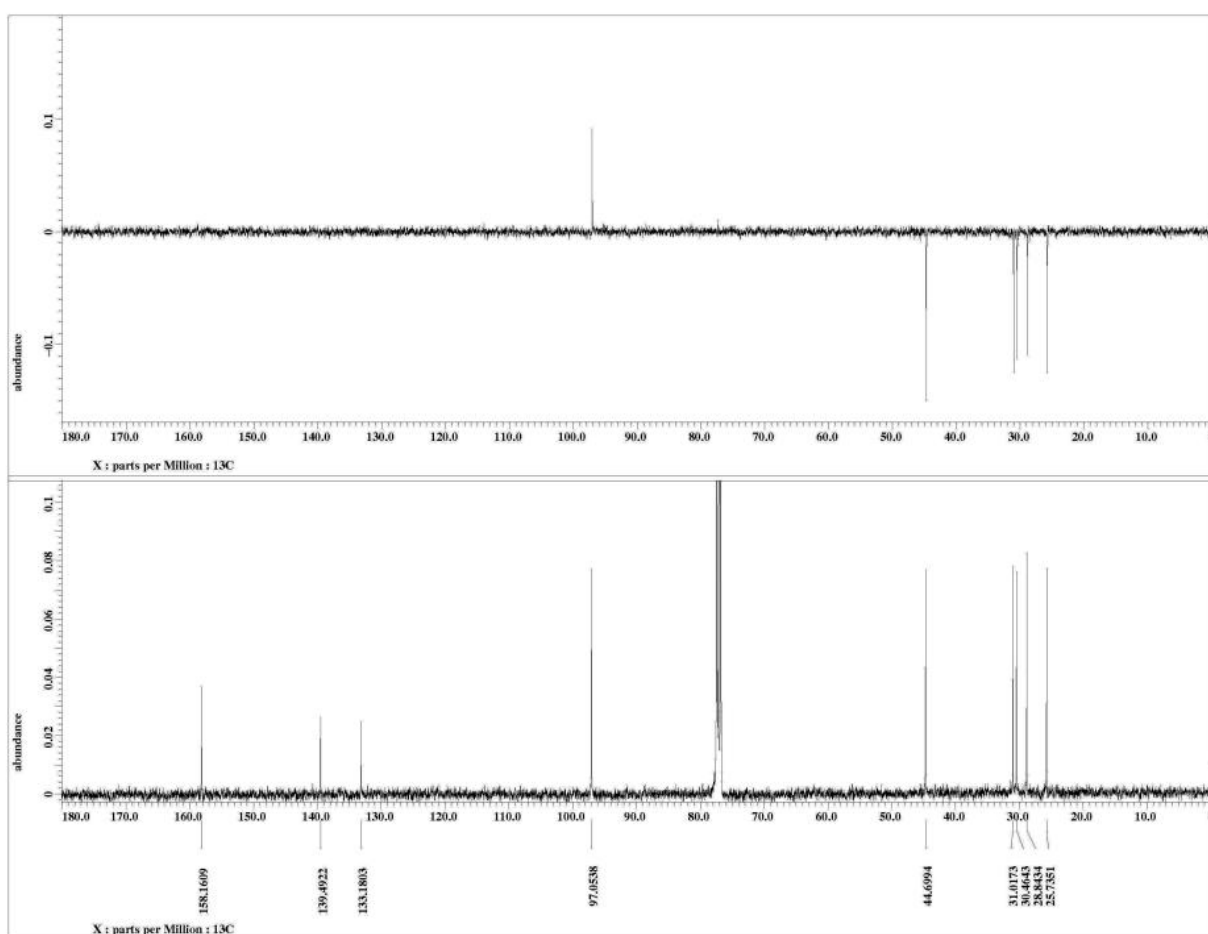
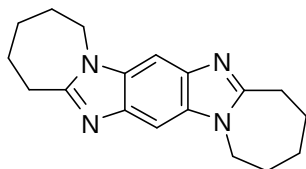
2,3,4,5,10,11,12,13-Octahydro-1*H*,9*H*-azepino[1,2-*a*]azepino[1',2':1,2]imidazo[5,4-*f*]benzimidazole (9c)

¹H NMR, 400 MHz, CDCl₃



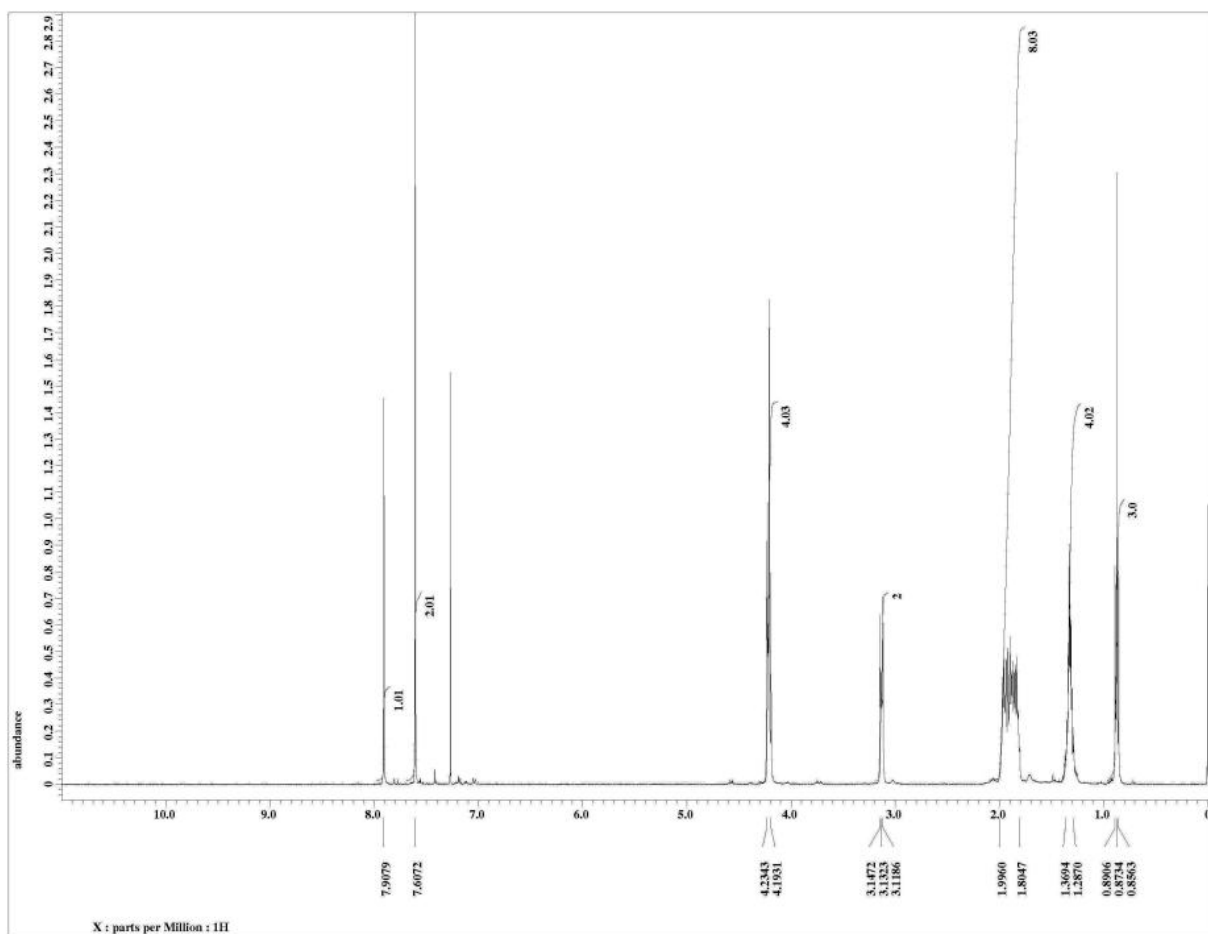
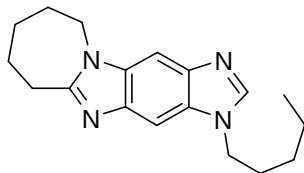
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¹³C NMR, 100 MHz, CDCl₃



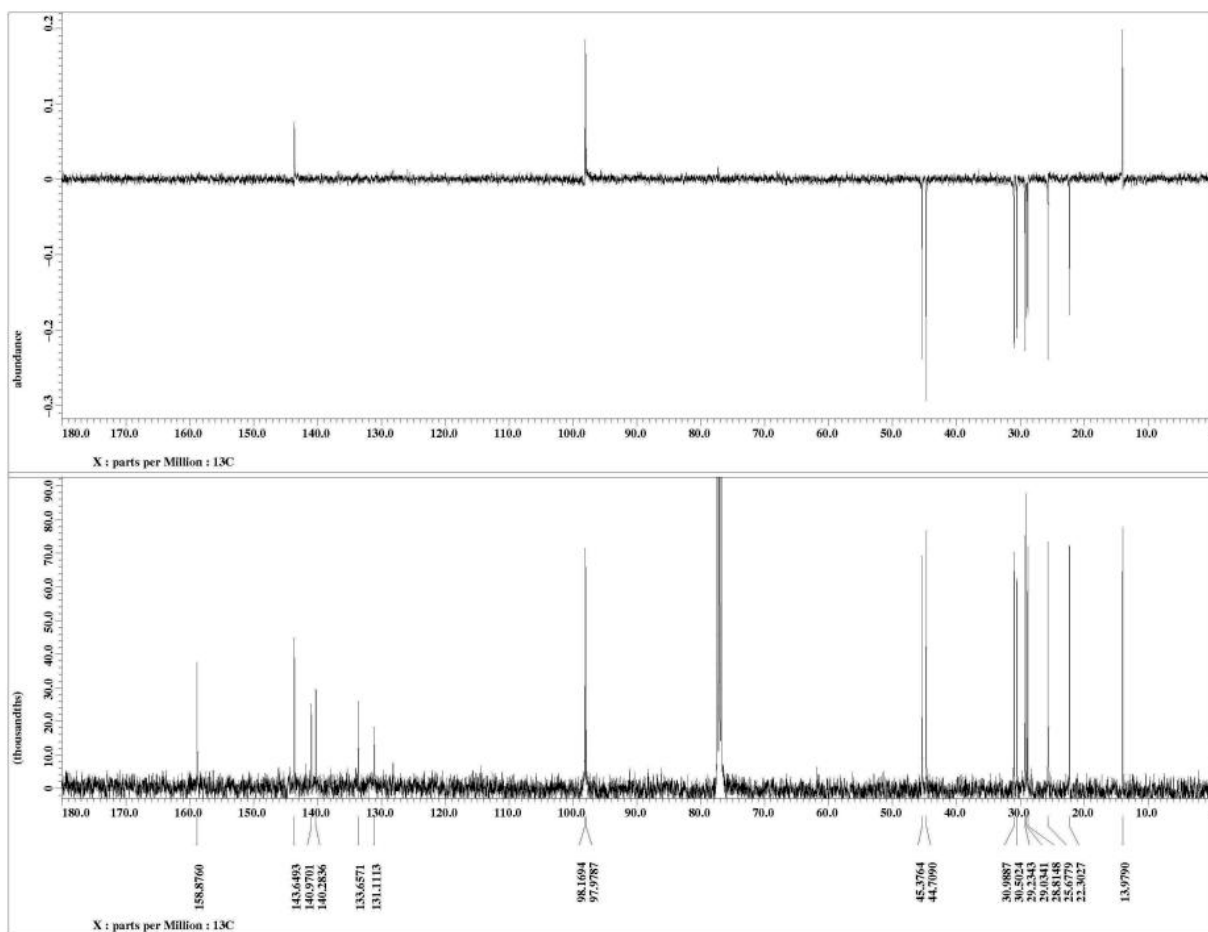
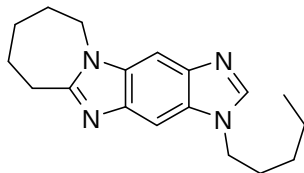
1-Pentyl-7,8,9,10-tetrahydro-6H-azepino[1,2-a]imidazo[5,4-f]benzimidazole (10c)

¹H NMR, 400 MHz, CDCl₃



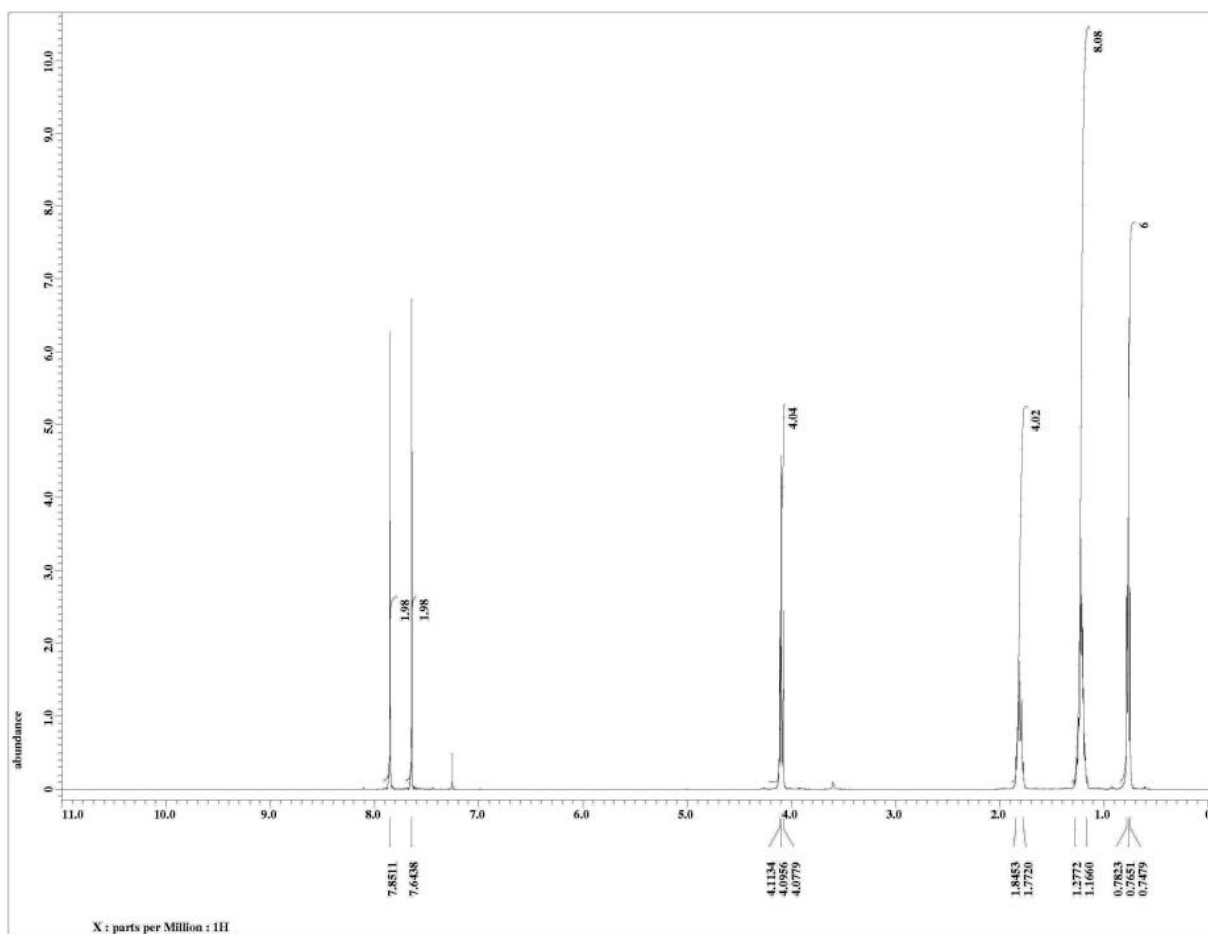
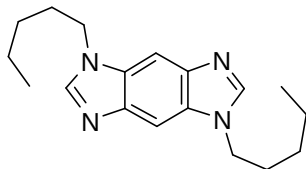
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¹³C NMR, 100 MHz, CDCl₃



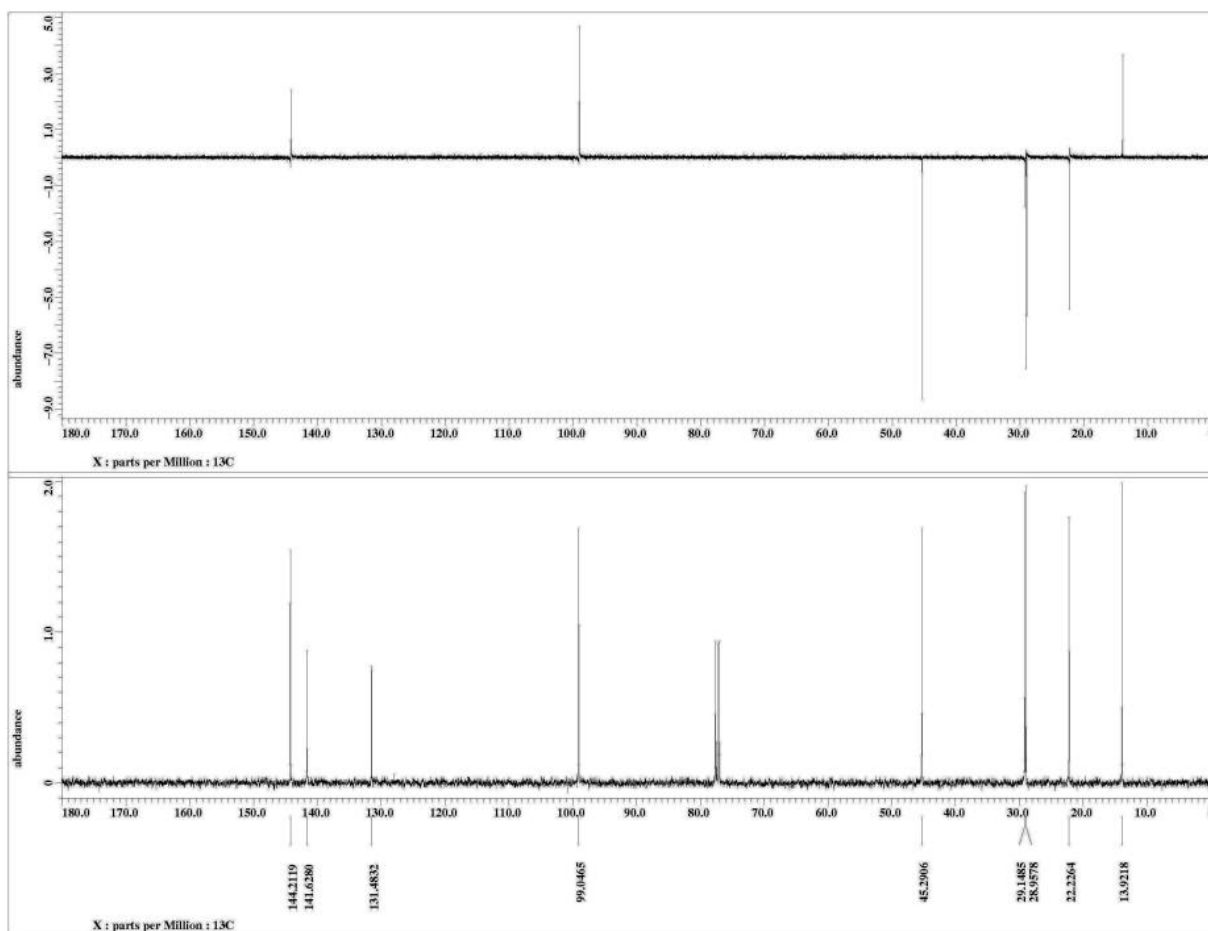
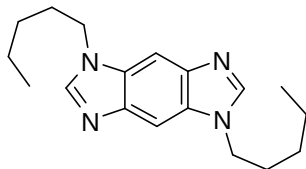
1,5-Dipropylimidazo[5,4-f]benzimidazole (11c)

^1H NMR, 400 MHz, CDCl_3



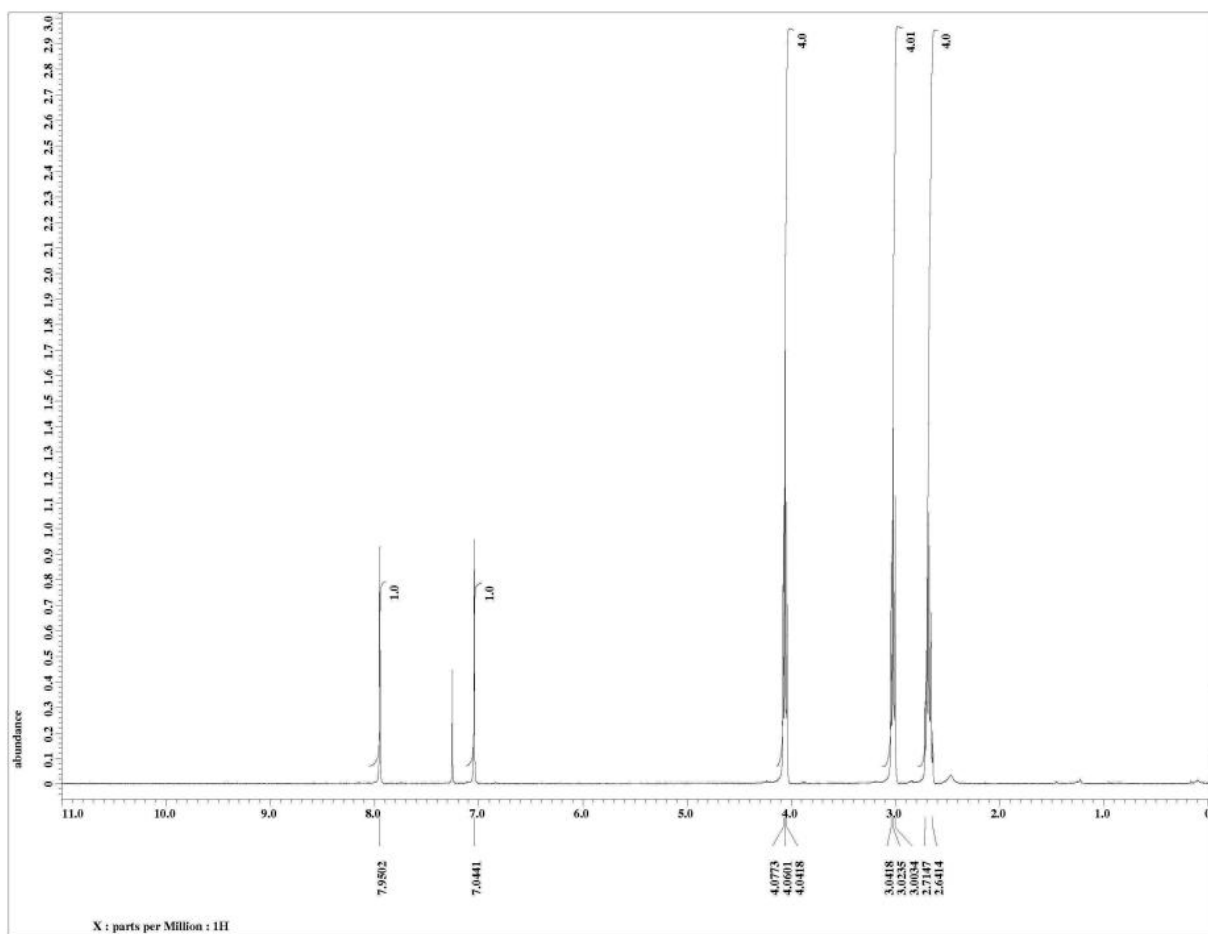
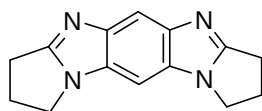
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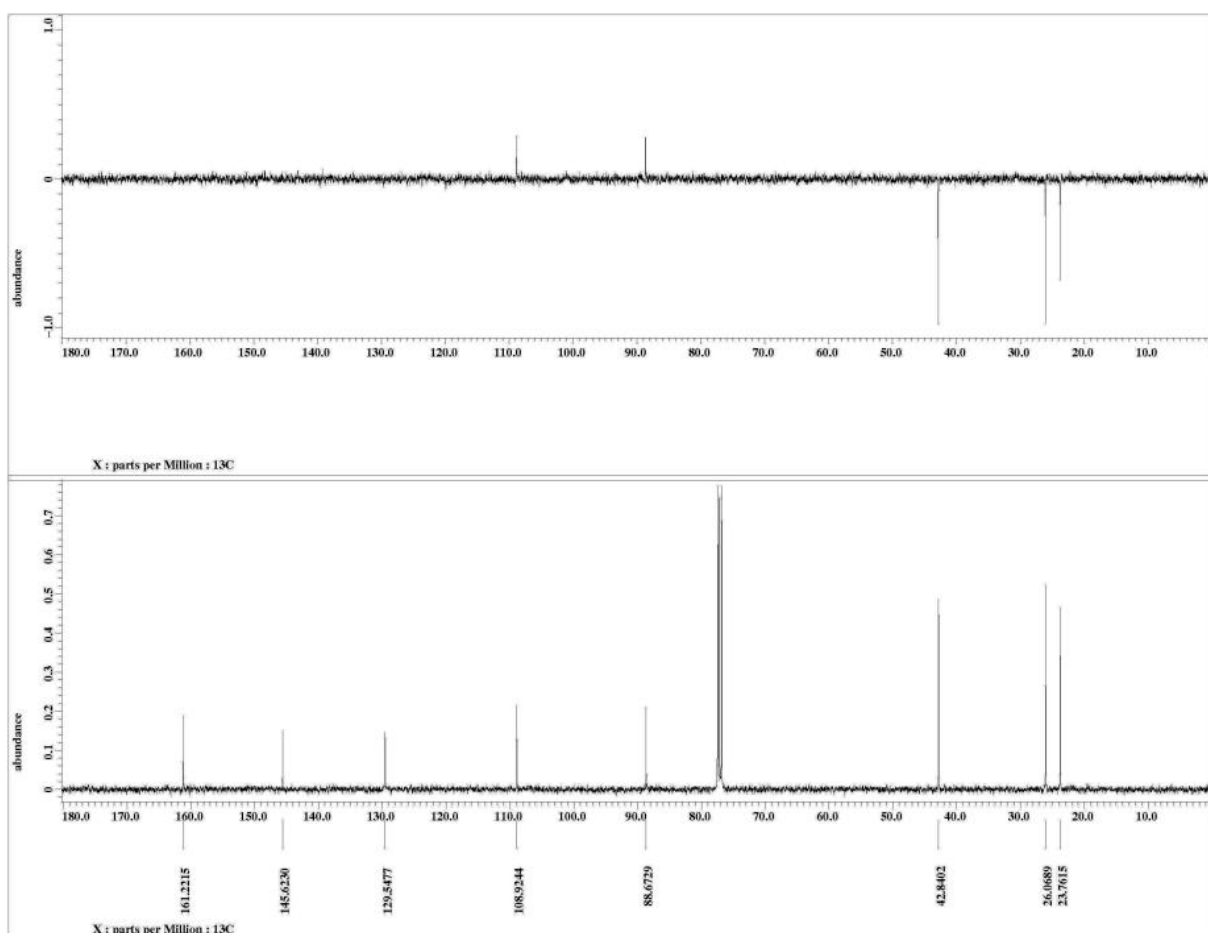
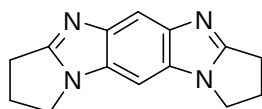
2,3,8,9-Tetrahydro-1*H*,7*H*-pyrrolo[1,2-*a*]pyrrolo[1',2':1,2]imidazo[4,5-*f*]benzimidazole (12a)

¹H NMR, 400 MHz, CDCl₃



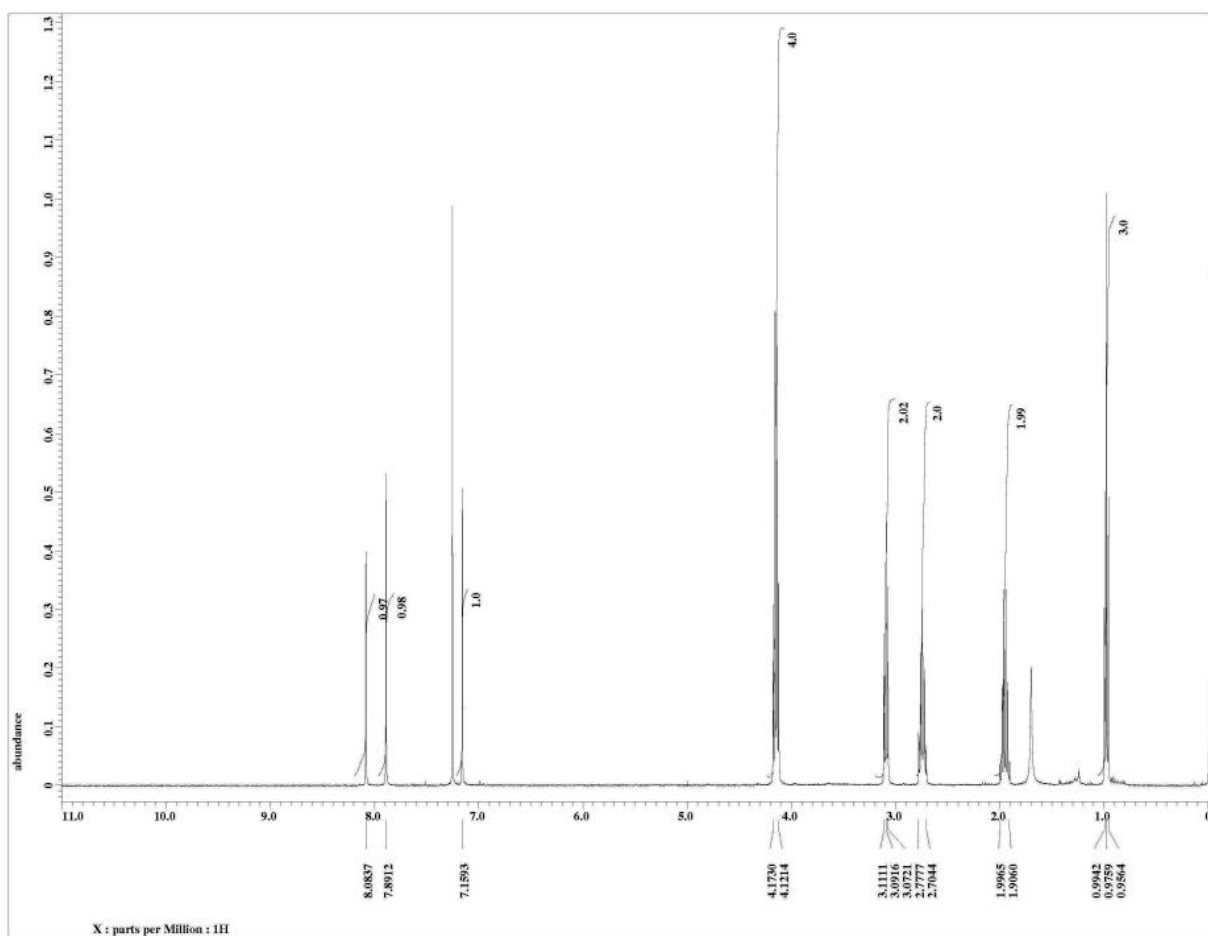
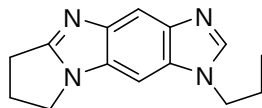
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¹³C NMR, 100 MHz, CDCl₃



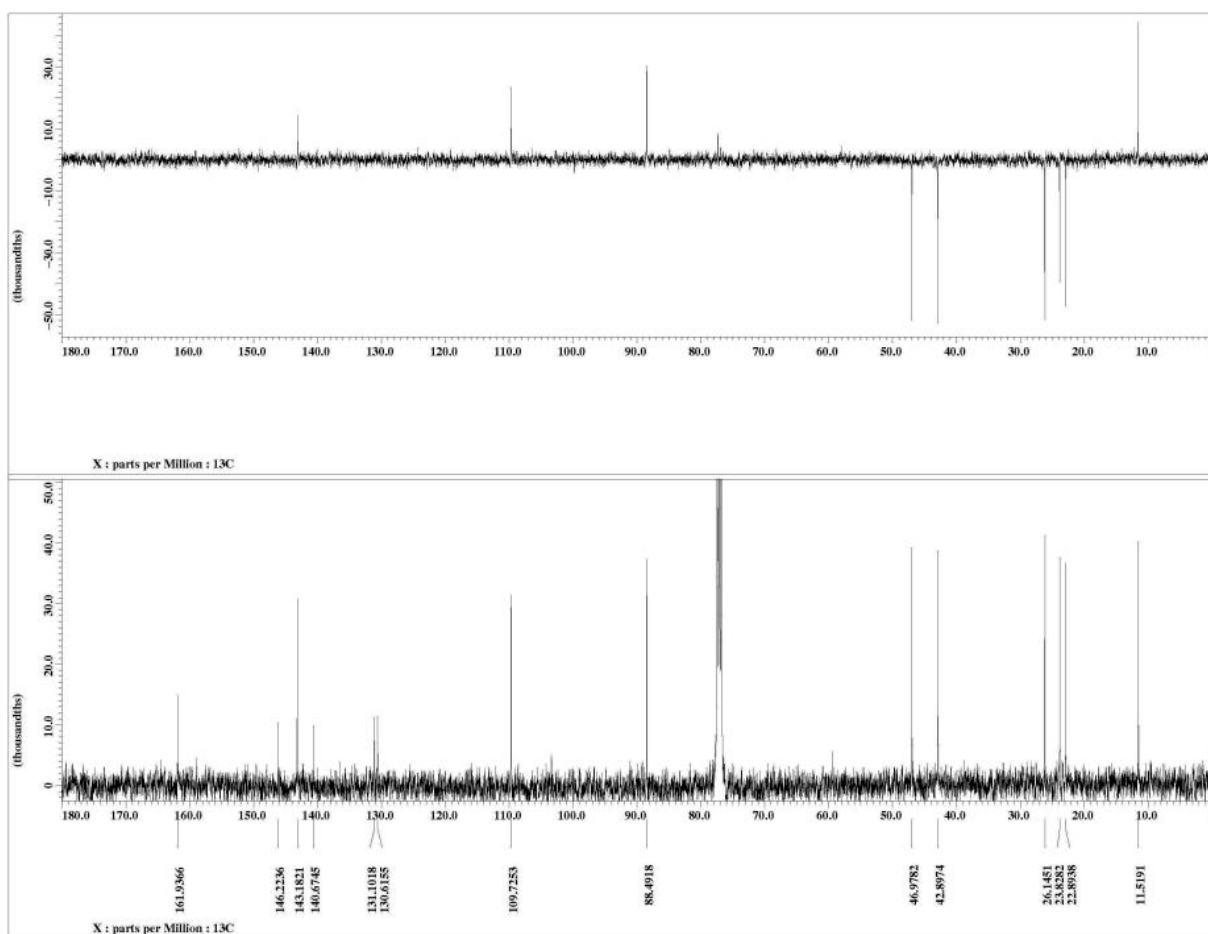
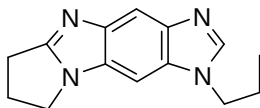
1-Propyl-7,8-dihydro-6H-imidazo[4,5-f]pyrrolo[1,2-a]benzimidazole (13a)

¹H NMR, 400 MHz, CDCl₃



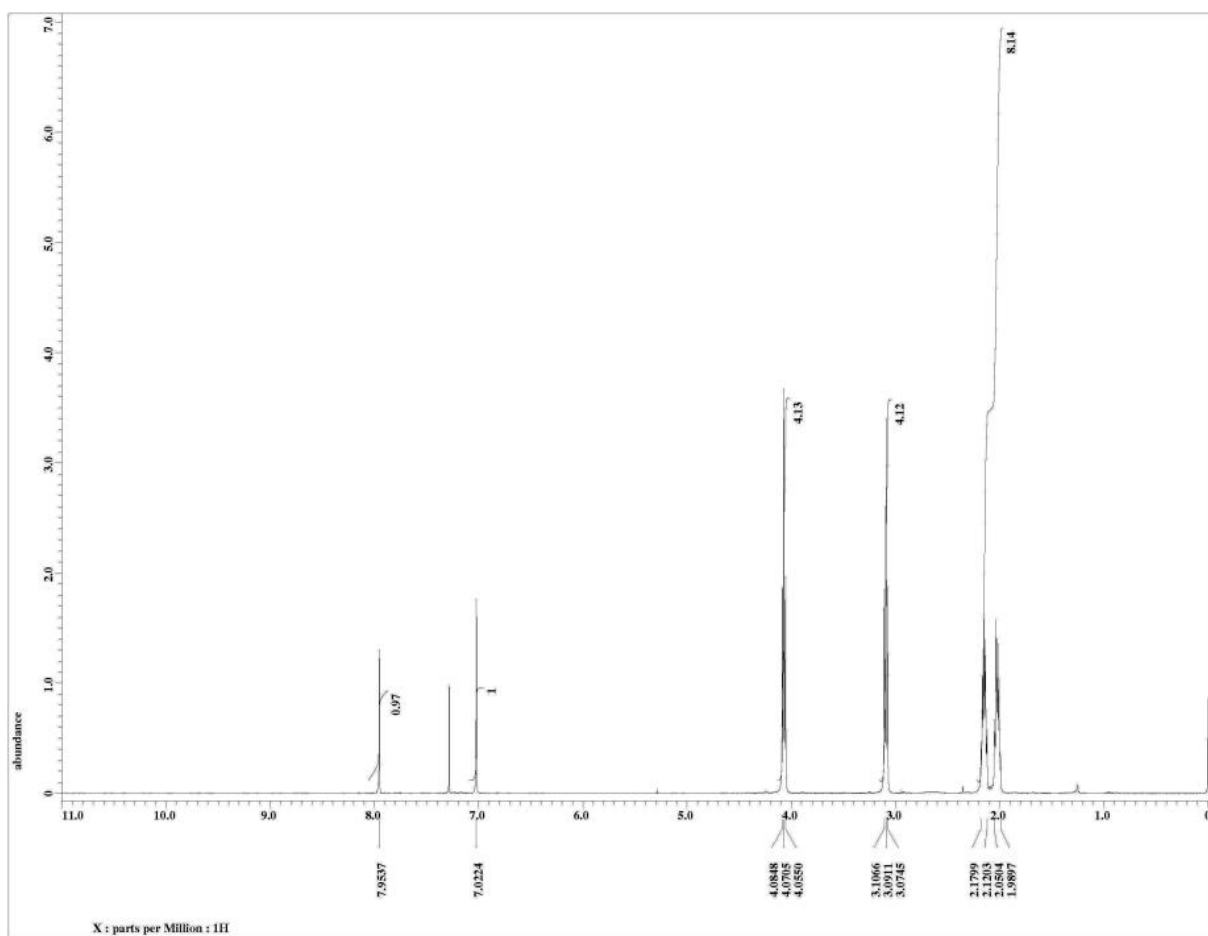
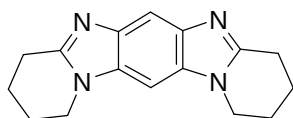
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¹³C NMR, 100 MHz, CDCl₃



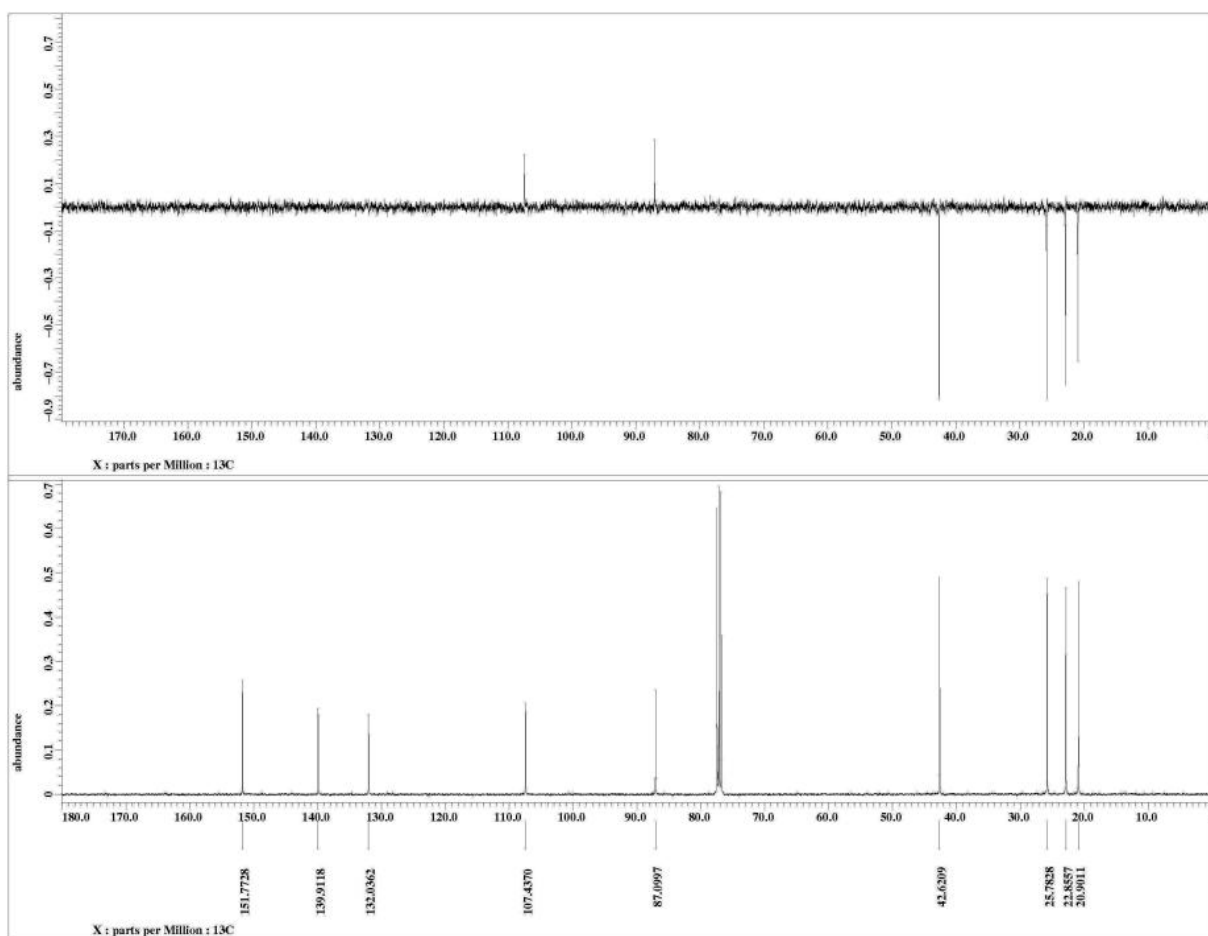
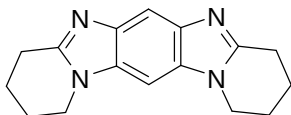
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benzimidazole (12b)**

¹H NMR, 400 MHz, CDCl₃



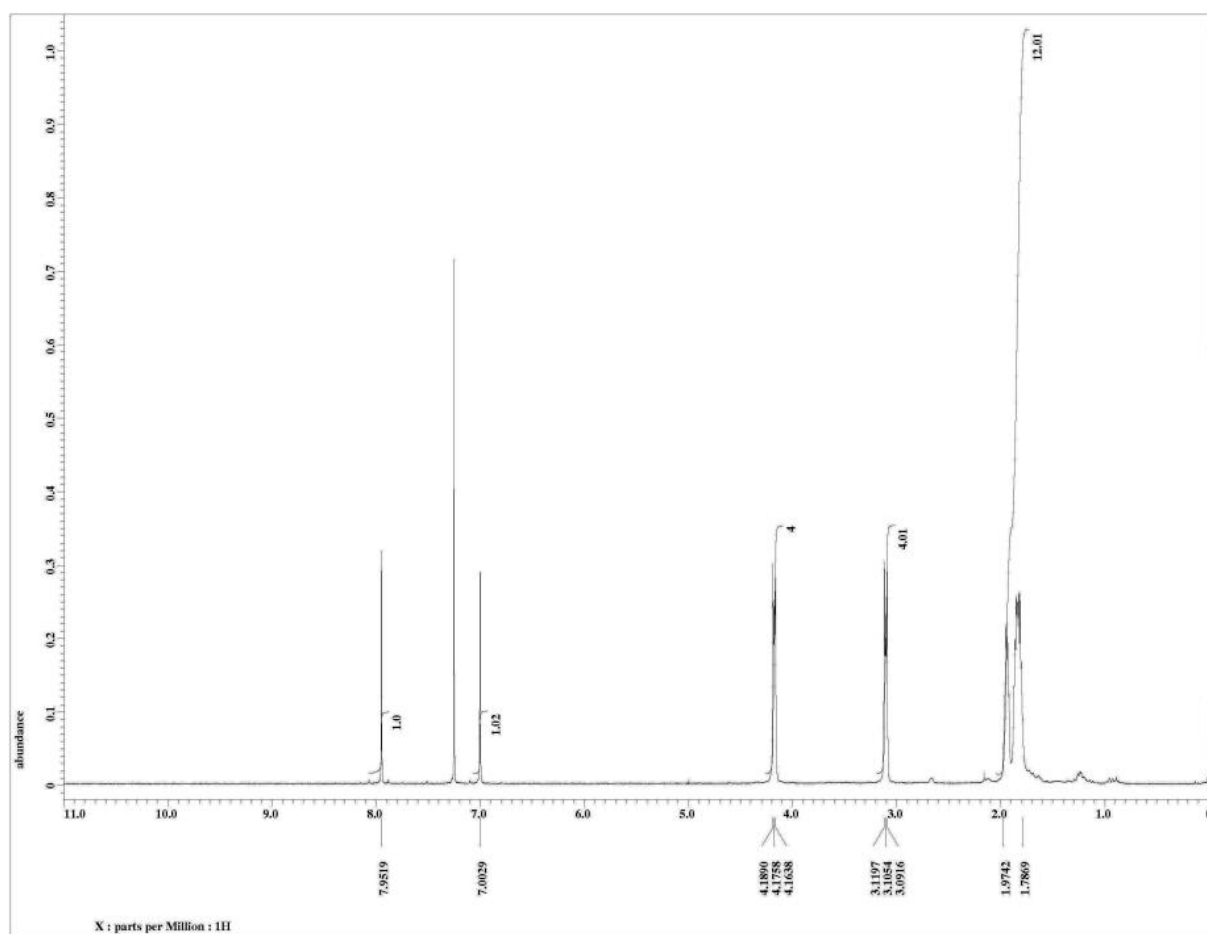
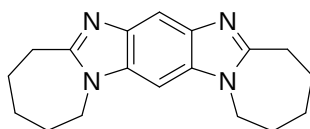
1,2,3,4,8,9,10,11-Octahydropyrido[1,2-*a*]pyrido[1',2':1,2]imidazo[4,5-*f*]benzimidazole (12b)

¹³C NMR, 100 MHz, CDCl₃



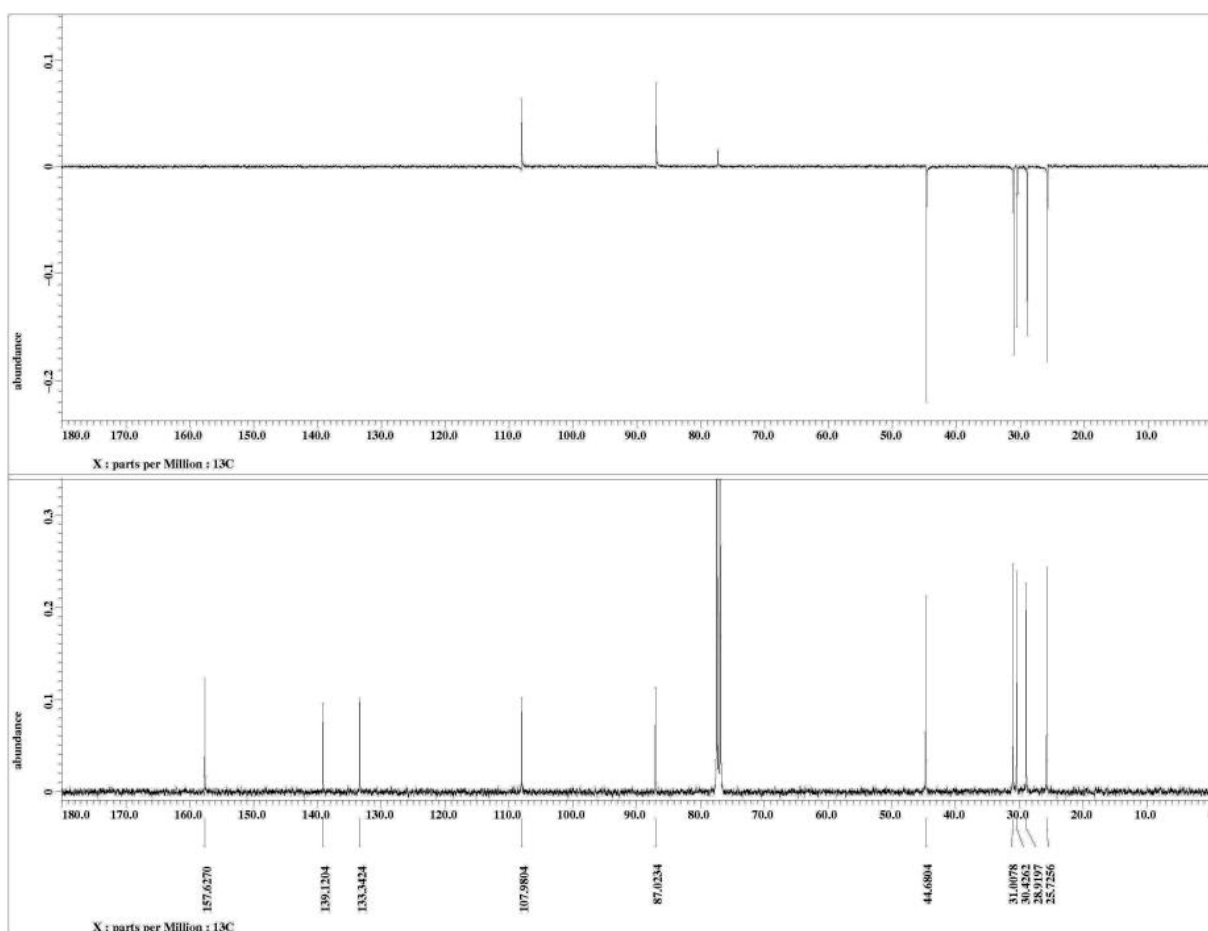
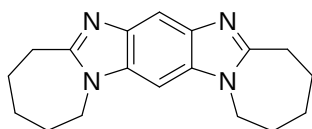
2,3,4,5,10,11,12,13-Octahydro-1*H*,9*H*-azepino[1,2-*a*]azepino[1',2':1,2]imidazo[4,5-*f*]benzimidazole (12c)

¹H NMR, 400 MHz, CDCl₃



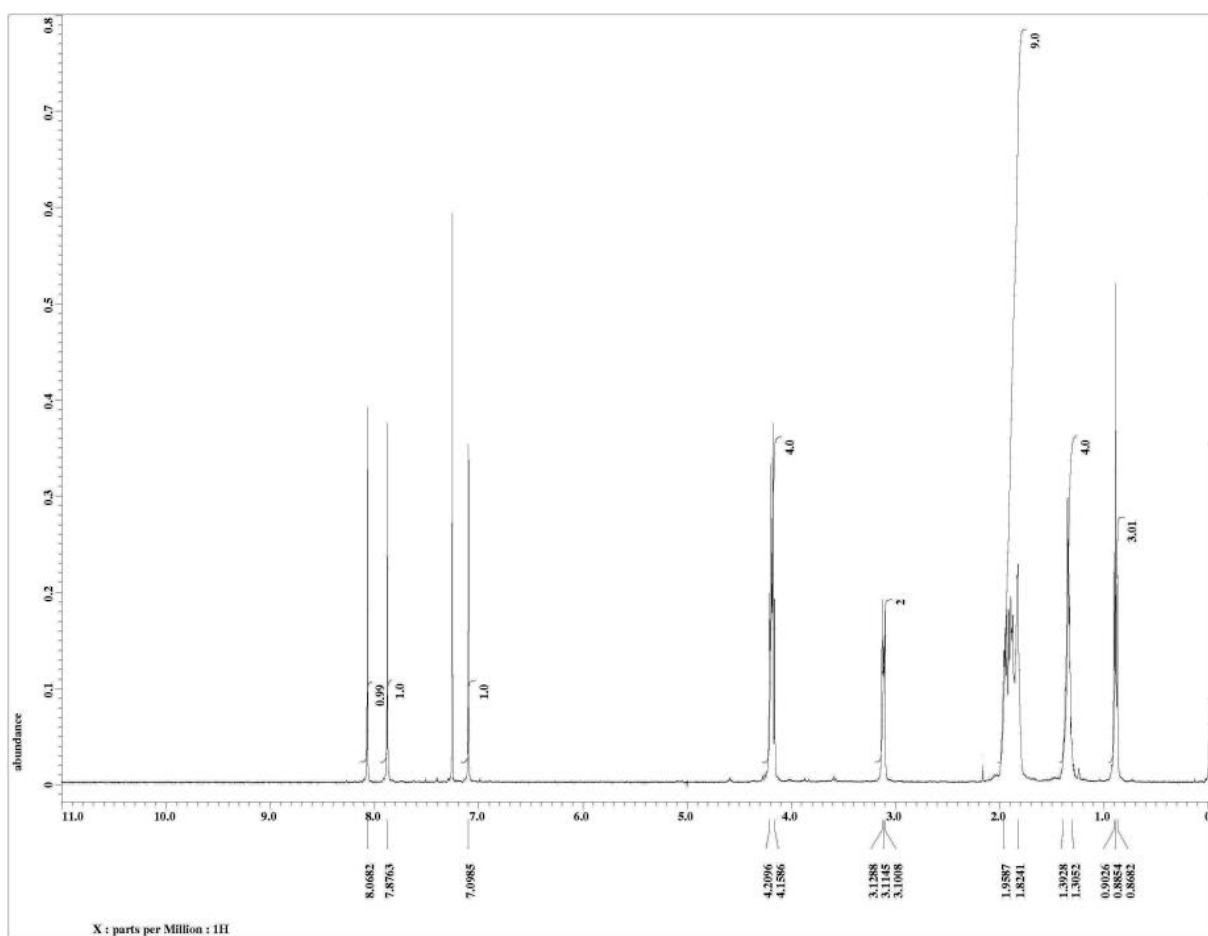
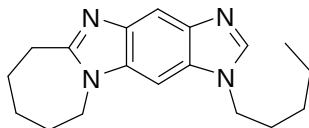
2,3,4,5,10,11,12,13-Octahydro-1*H*,9*H*-azepino[1,2-*a*]azepino[1',2':1,2]imidazo[4,5-*f*]benzimidazole (12c)

¹³C NMR, 100 MHz, CDCl₃



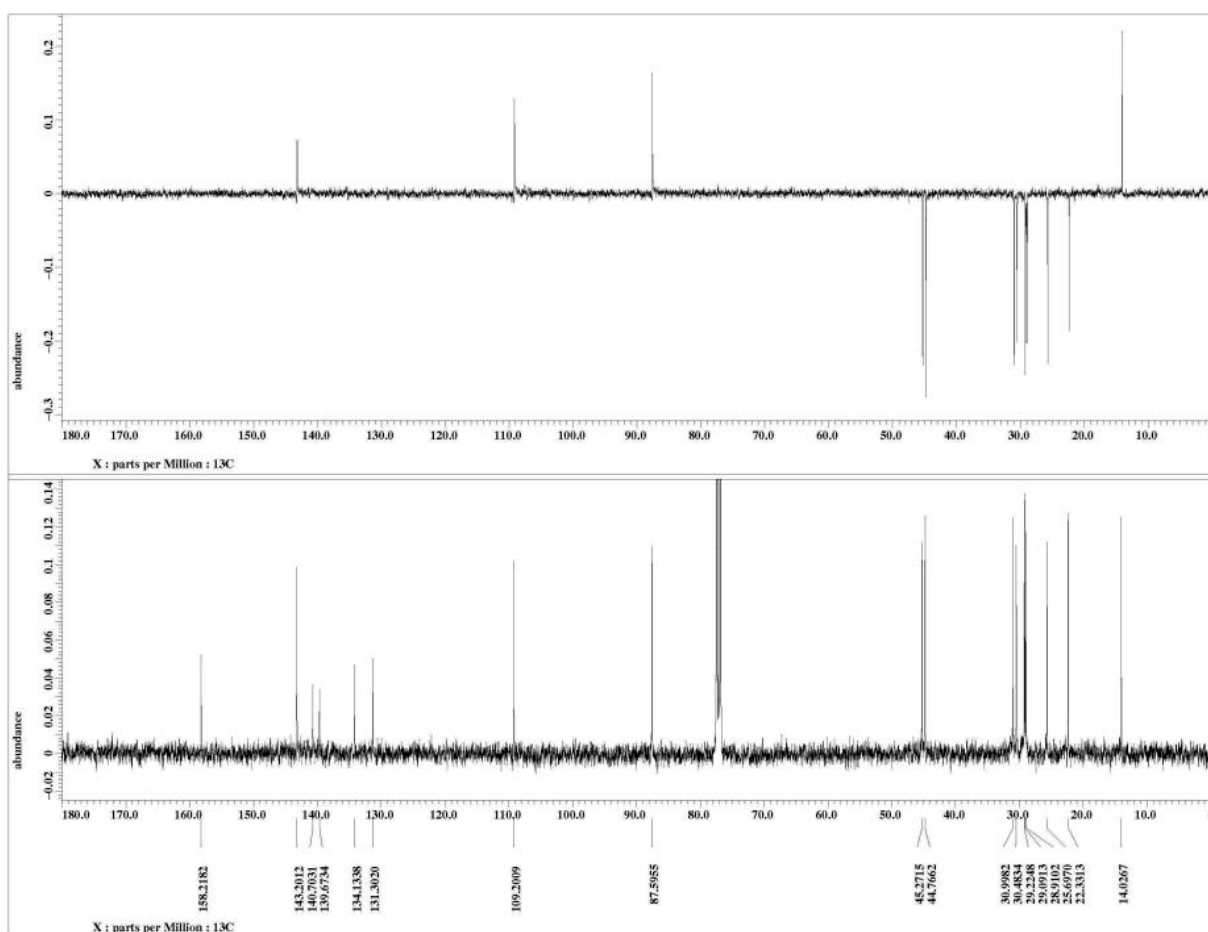
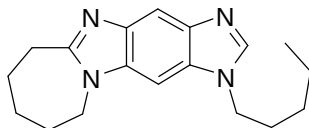
1-Pentyl-7,8,9,10-tetrahydro-6H-azepino[1,2-a]imidazo[4,5-f]benzimidazole (13c)

¹H NMR, 400 MHz, CDCl₃



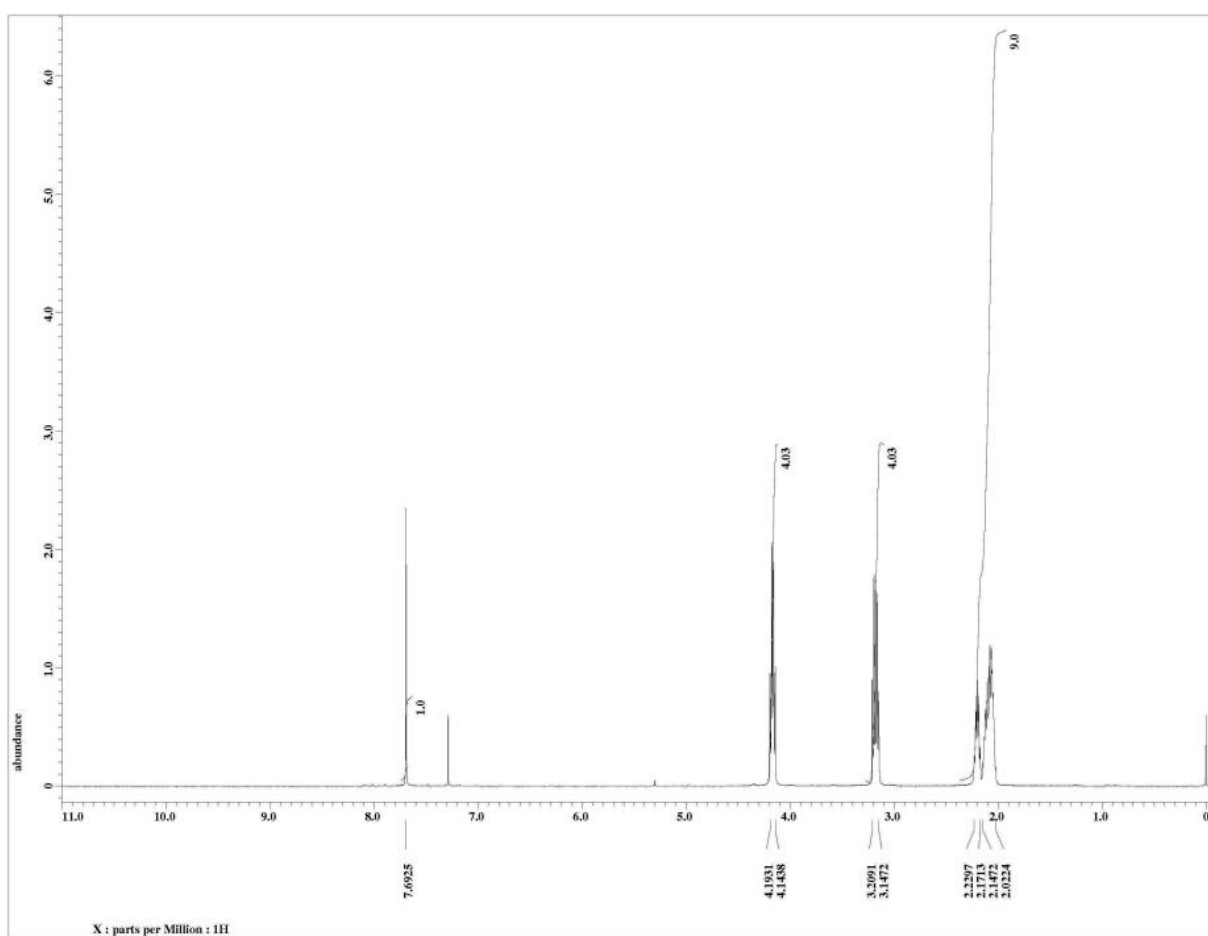
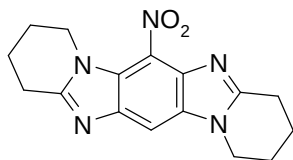
1-Pentyl-7,8,9,10-tetrahydro-6H-azepino[1,2-a]imidazo[4,5-f]benzimidazole (13c)

^{13}C NMR, 100 MHz, CDCl_3



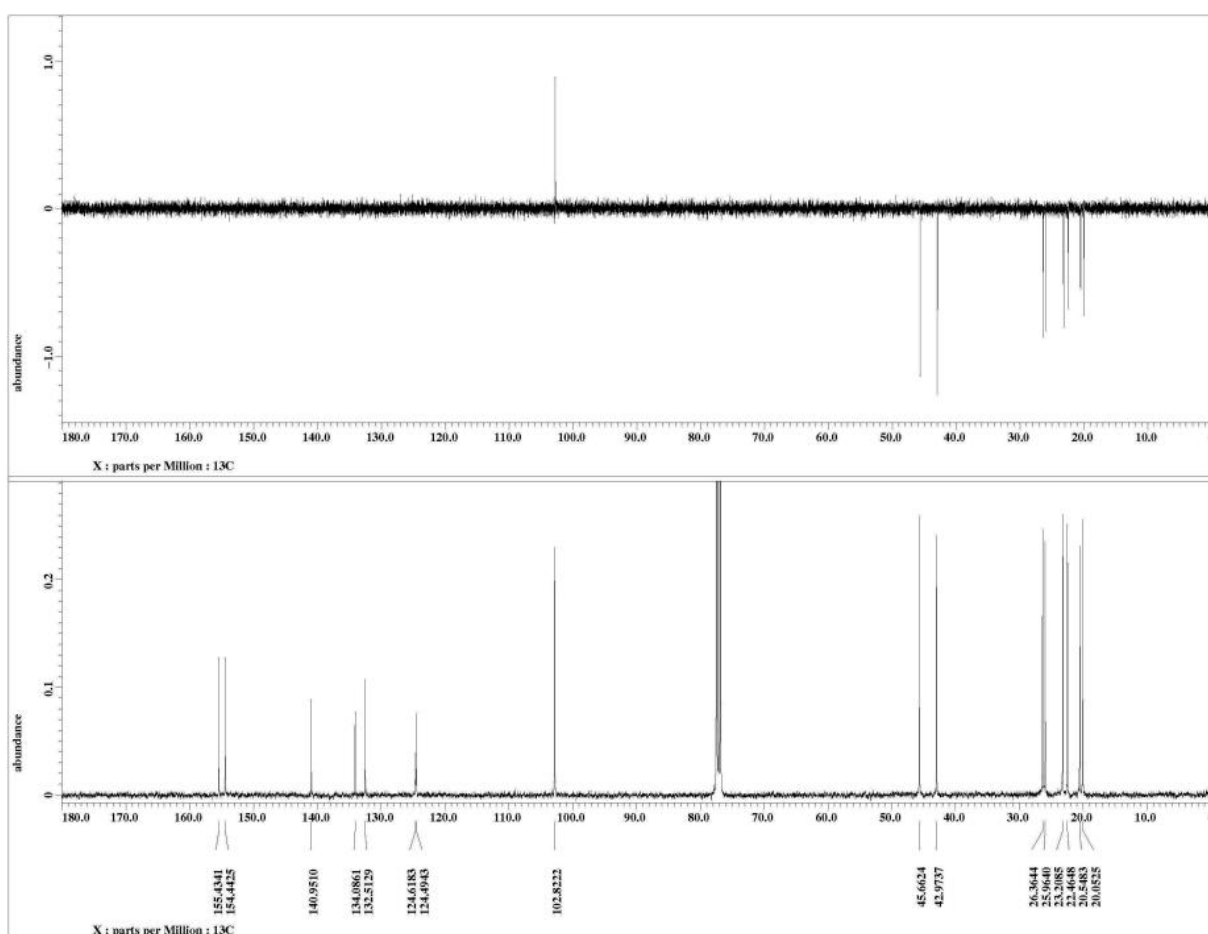
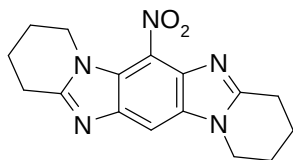
6-Nitro-1,2,3,4,8,9,10,11-octahydropyrido[1,2-*a*]pyrido[1',2':1,2]imidazo[5,4-*f*]benzimidazole (15)

¹H NMR, 400 MHz, CDCl₃



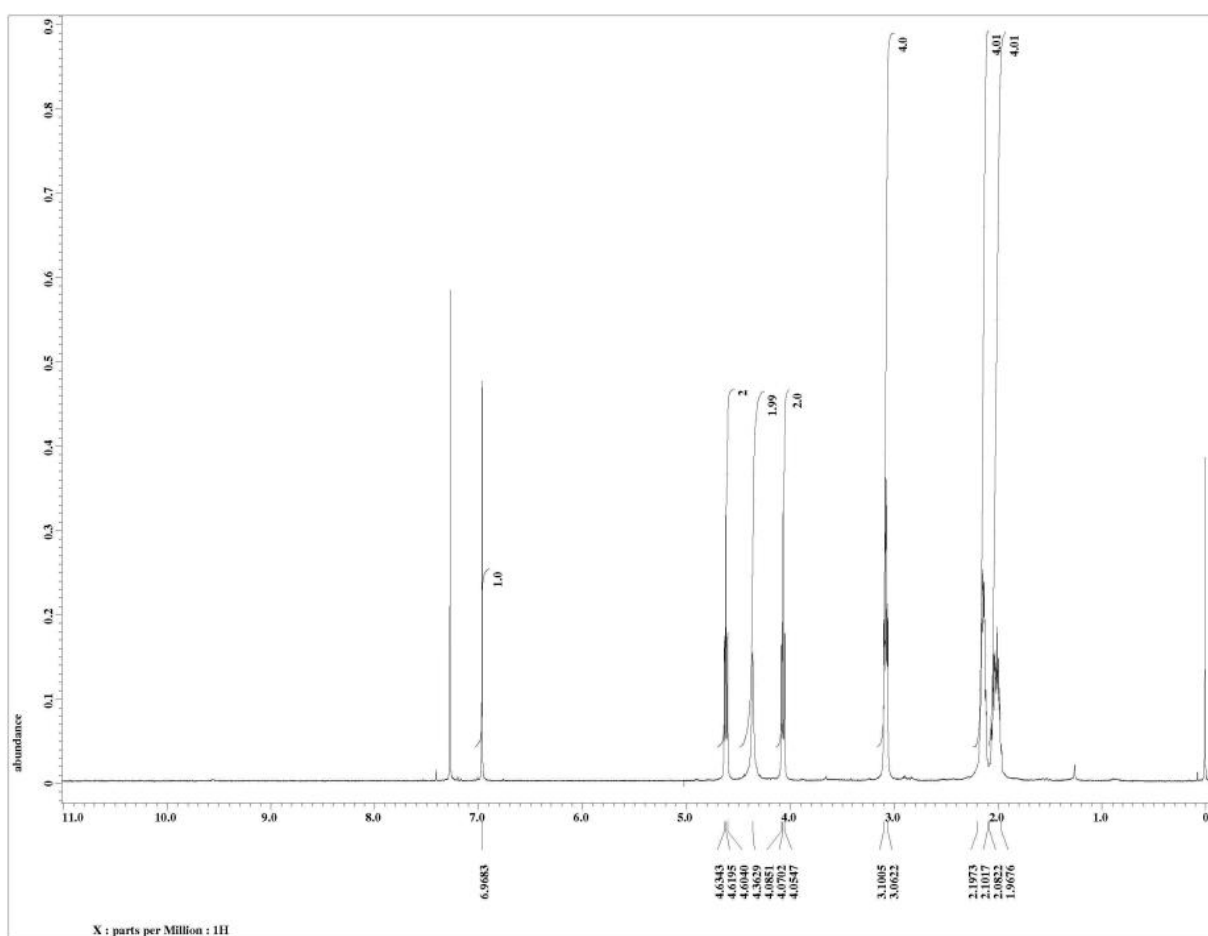
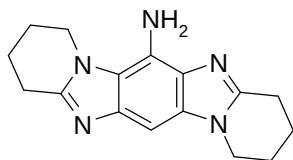
6-Nitro-1,2,3,4,8,9,10,11-octahydropyrido[1,2-*a*]pyrido[1',2':1,2]imidazo[5,4-*f*]benzimidazole (15)

¹³C NMR, 100 MHz, CDCl₃



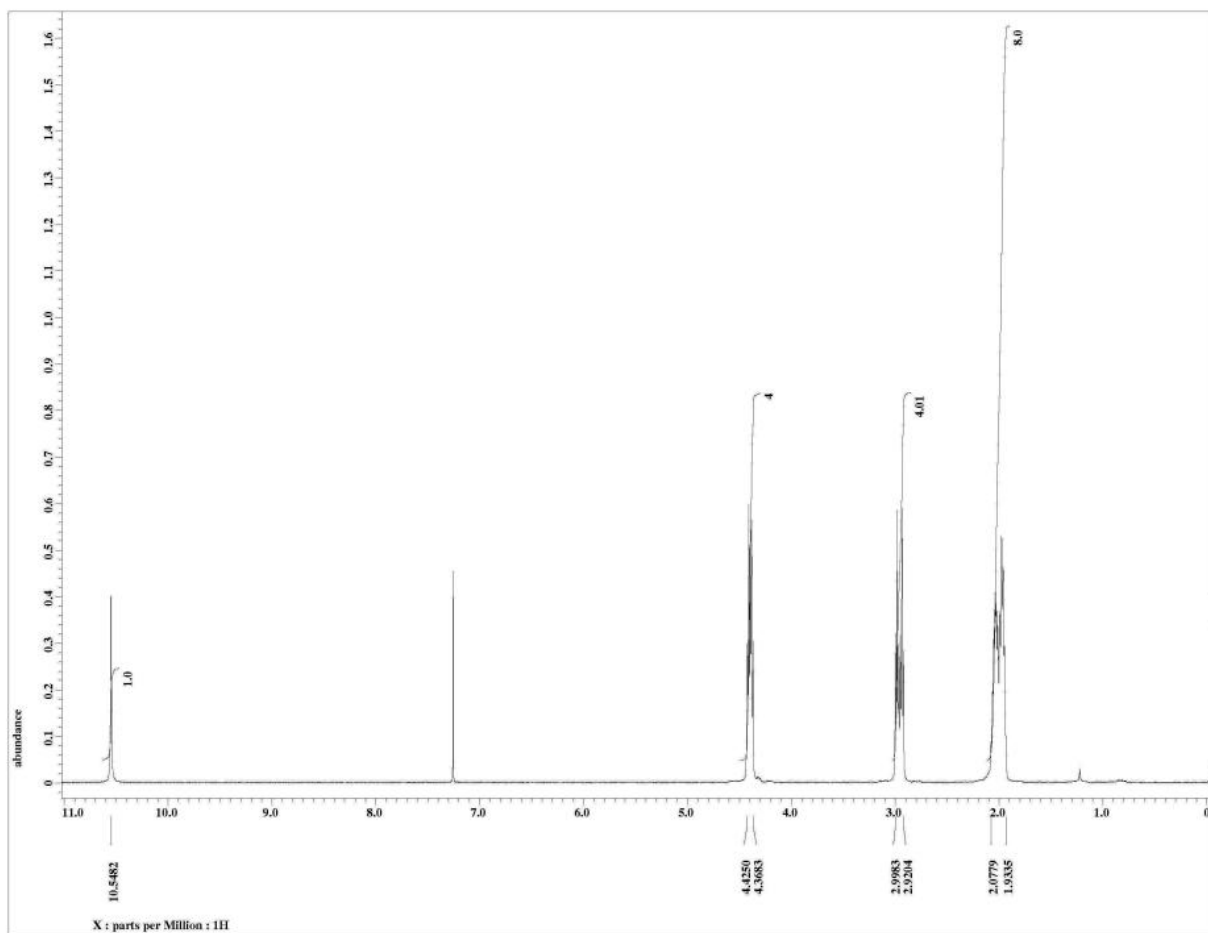
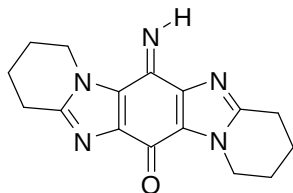
6-Amino-1,2,3,4,8,9,10,11-octahydropyrido[1,2-*a*]pyrido[1',2':1,2]imidazo[5,4-*f*]benzimidazole (16)

¹H NMR, 400 MHz, CDCl₃



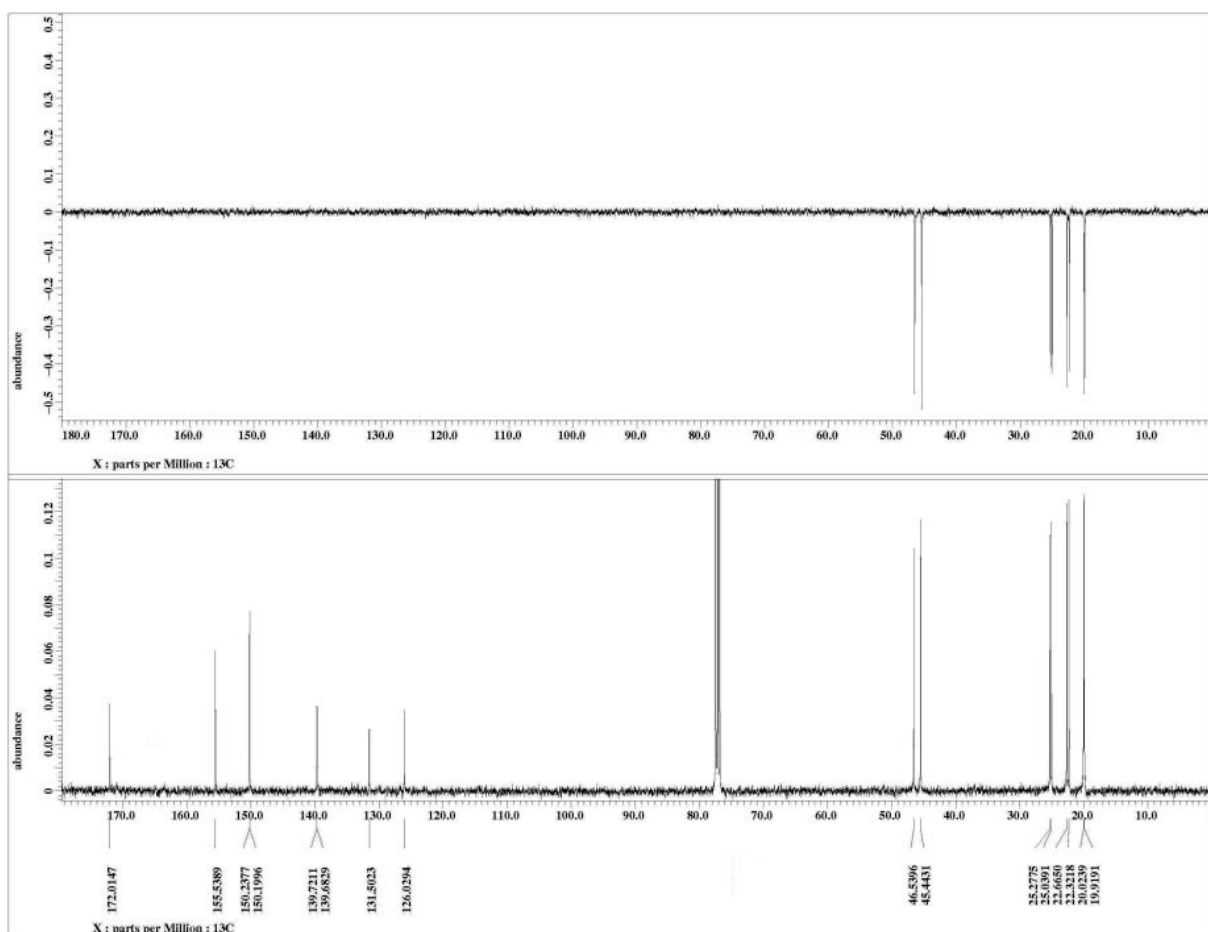
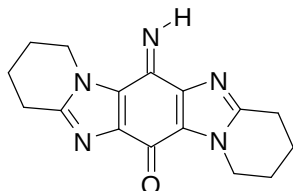
6-imino-1,2,3,4,8,9,10,11-octahydropyrido[1,2-*a*]pyrido[1',2':1,2]imidazo[5,4-*f*]benzimidazol-13-one (17)

¹H NMR, 400 MHz, CDCl₃



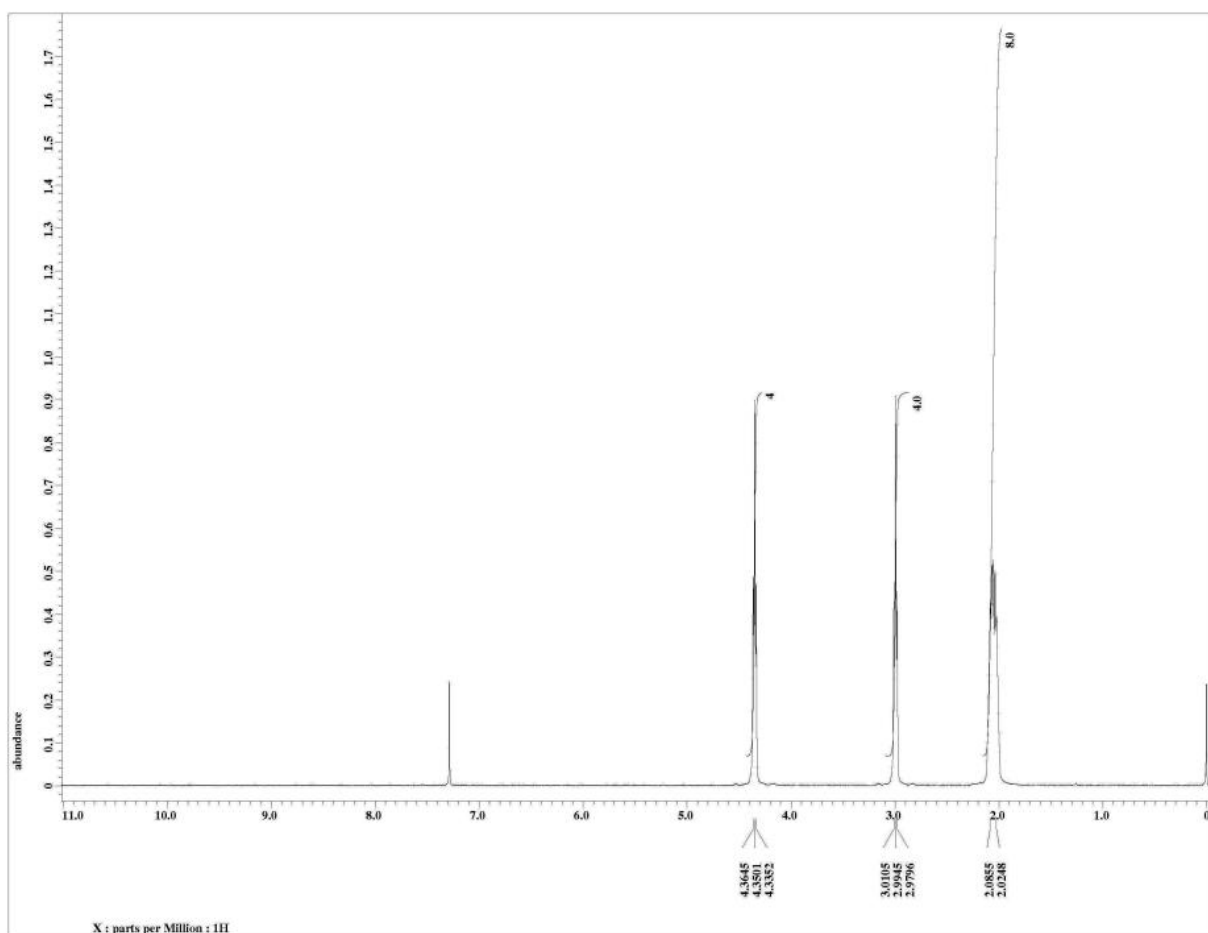
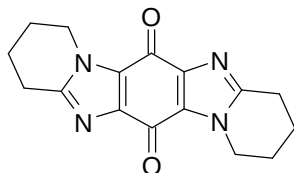
6-imino-1,2,3,4,8,9,10,11-octahydropyrido[1,2-*a*]pyrido[1',2':1,2]imidazo[5,4-*f*]benzimidazol-13-one (17)

¹³C NMR, 100 MHz, CDCl₃



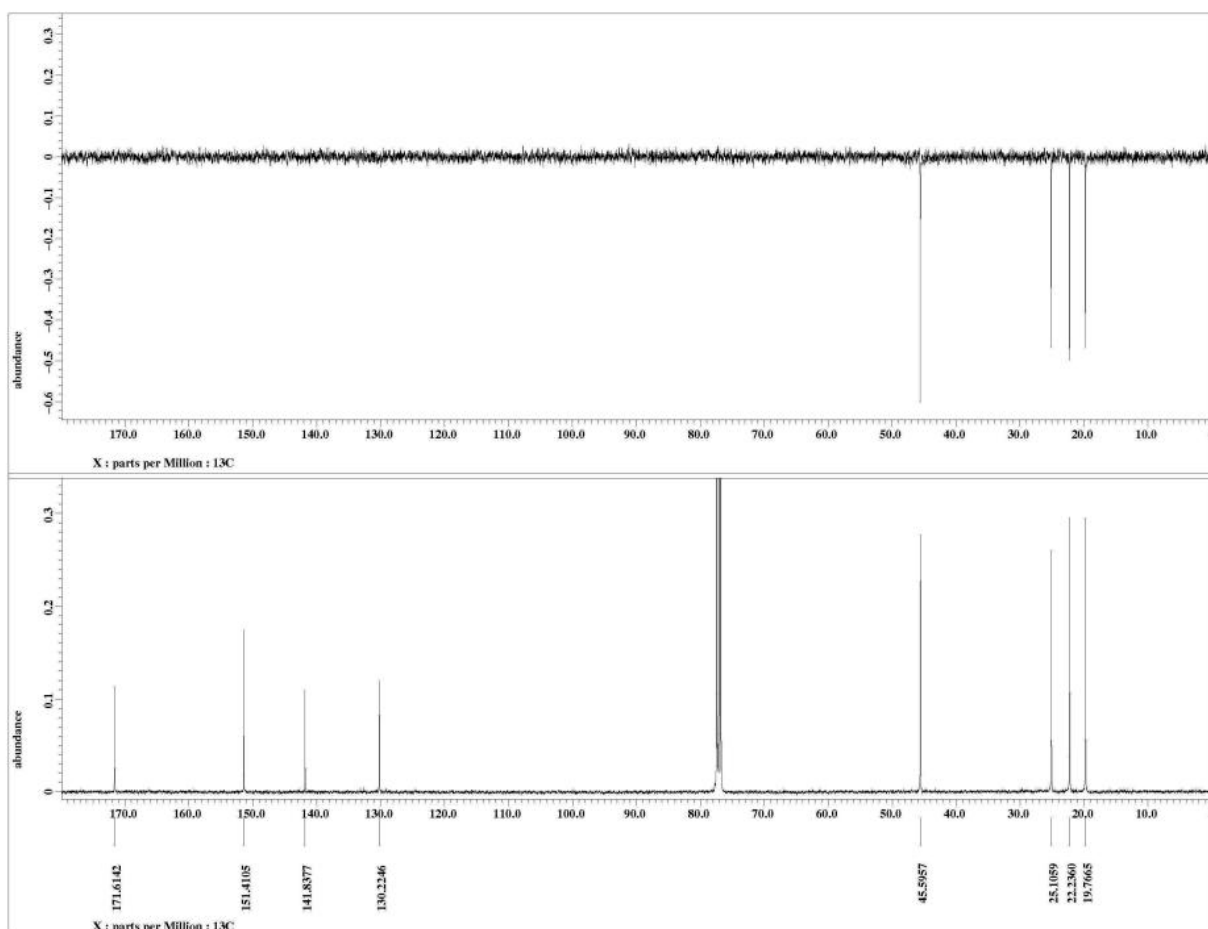
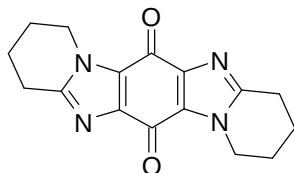
**1,2,3,4,8,9,10,11-octahydropyrido[1,2-*a*]pyrido[1',2':1,2]imidazo[5,4-*f*]benzimidazol-
6,13-dione (4)**

¹H NMR, 400 MHz, CDCl₃



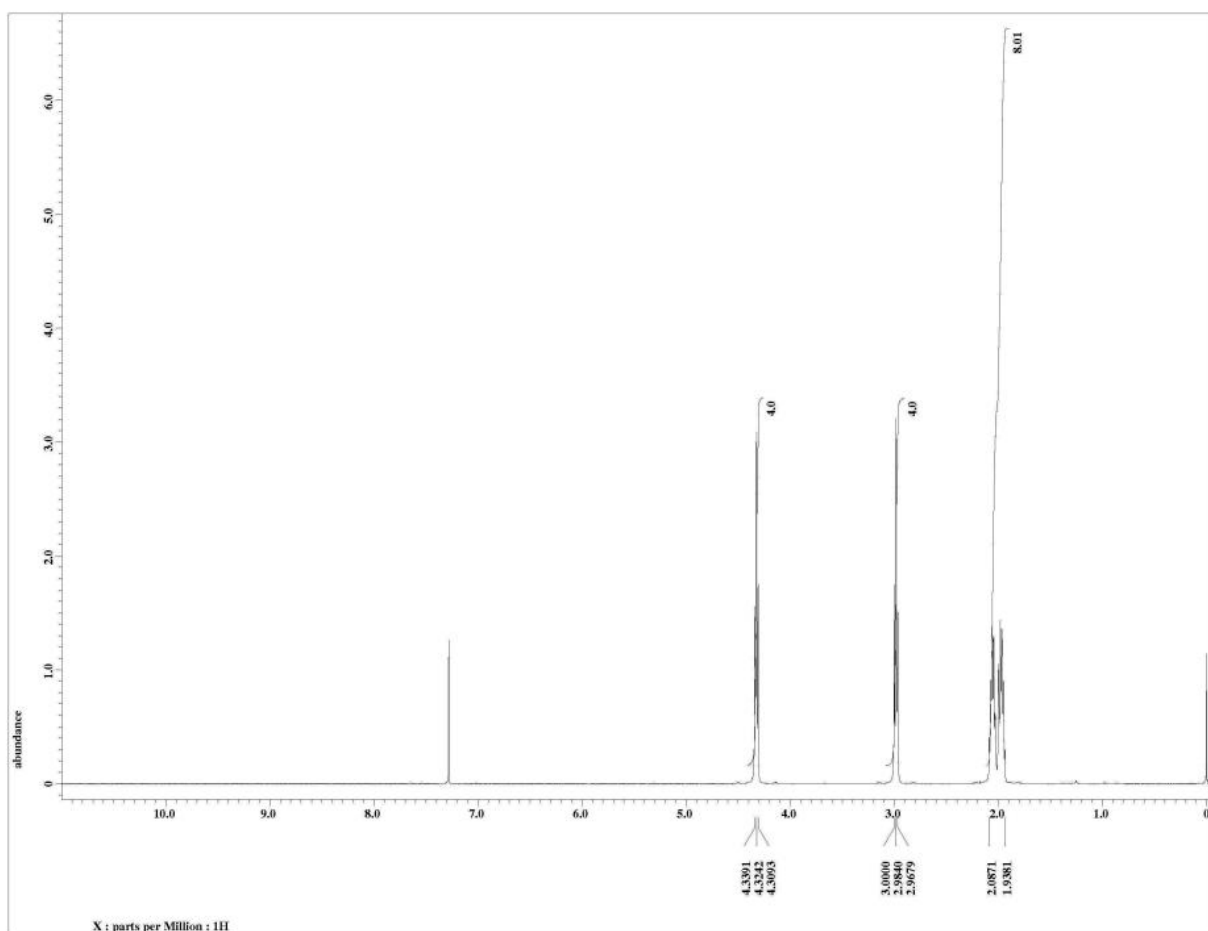
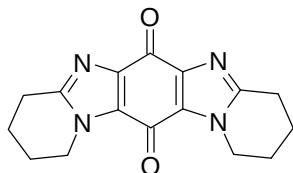
**1,2,3,4,8,9,10,11-octahydropyrido[1,2-*a*]pyrido[1',2':1,2]imidazo[5,4-*f*]benzimidazol-
6,13-dione (4)**

^{13}C NMR, 100 MHz, CDCl_3



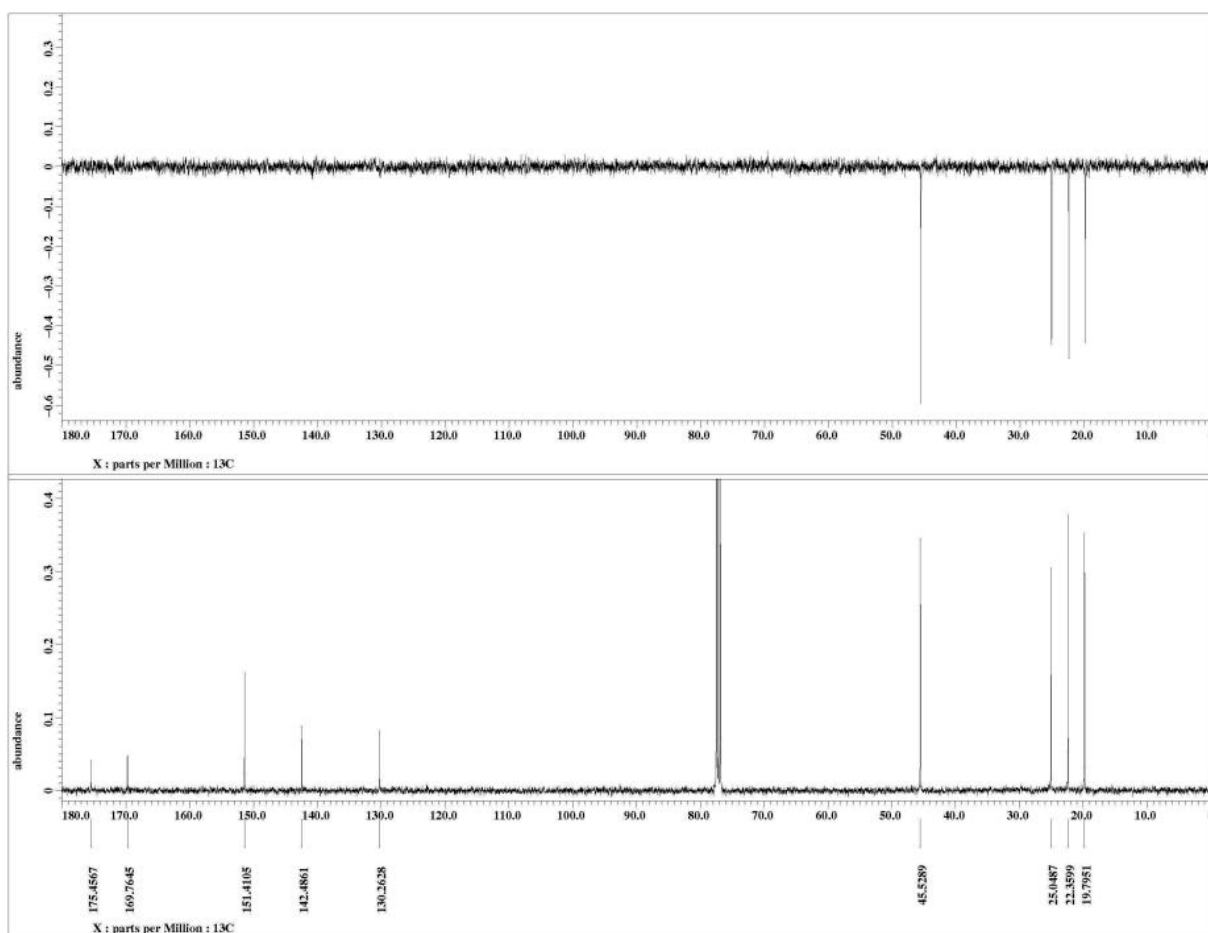
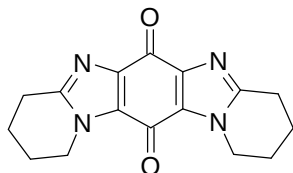
**1,2,3,4,8,9,10,11-octahydropyrido[1,2-*a*]pyrido[1',2':1,2]imidazo[4,5-*f*]benzimidazol-
6,13-dione (5)**

¹H NMR, 400 MHz, CDCl₃



**1,2,3,4,8,9,10,11-octahydropyrido[1,2-*a*]pyrido[1',2':1,2]imidazo[4,5-*f*]benzimidazol-
6,13-dione (5)**

¹³C NMR, 100 MHz, CDCl₃



HPLC Chromatograms

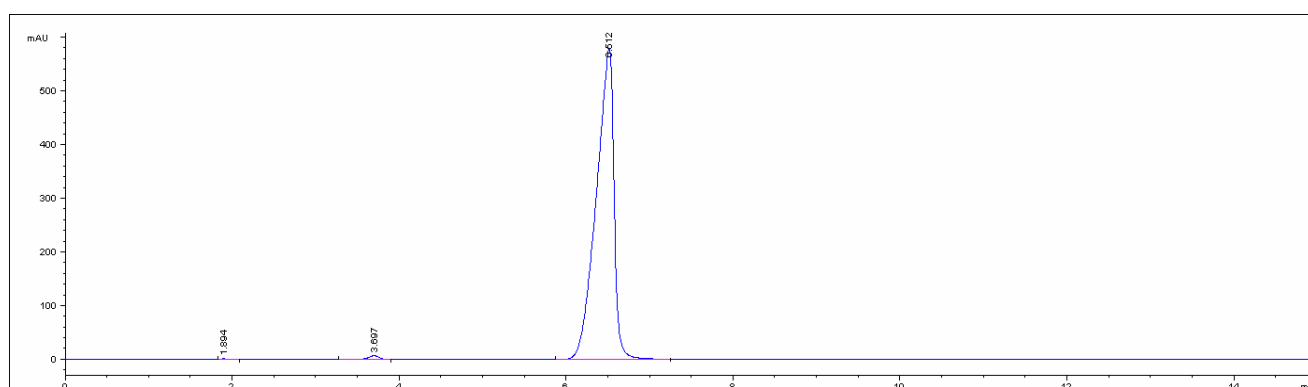
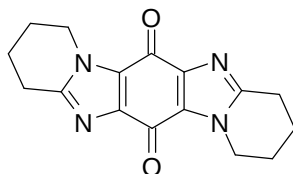
HPLC chromatograms were recorded using an Aligent Technologies 1200 series instrument with UV detector at 300 nm.

Column: Hyperclone 5u ODS (C18) 120A, 250 x 4.6 mm

Eluent: Methanol/water (1:1) and 1% triethylamine.

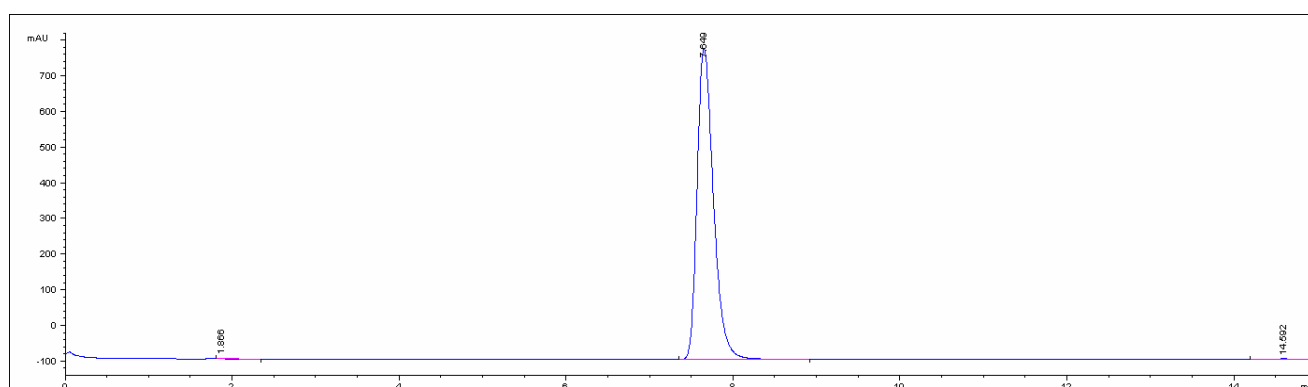
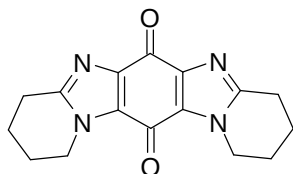
Flow rate: 1 mLmin⁻¹

1,2,3,4,8,9,10,11-octahydropyrido[1,2-*a*]pyrido[1',2':1,2]imidazo[5,4-*f*]benzimidazol-6,13-dione (4)



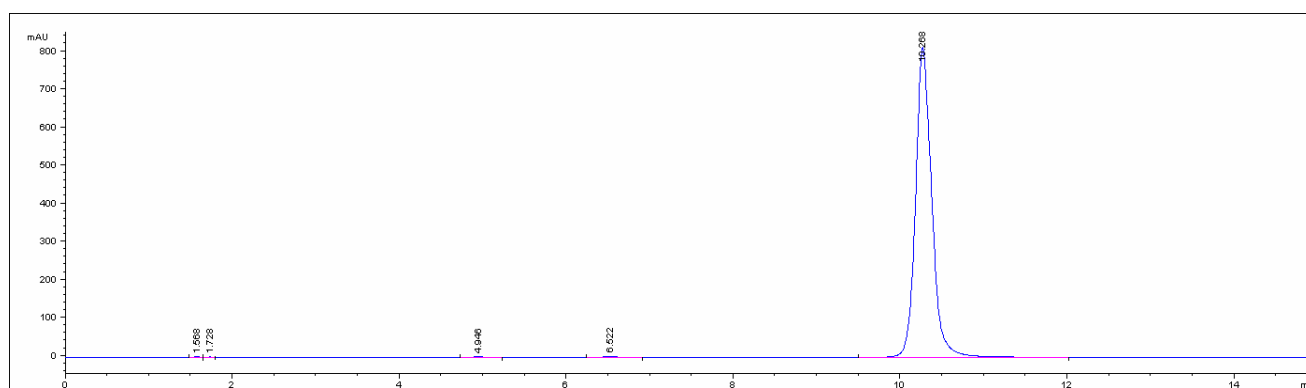
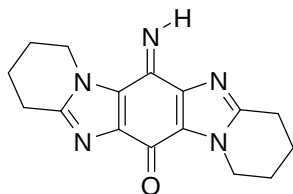
Peak No.	Ret Time (min)	Type	Width (min)	Area (mAU)	Height (mAU)	Area %
1	1.894	VB	0.0729	8.88021	1.73132	0.1026
2	3.697	BV	0.1439	70.89214	7.20718	0.8189
3	6.512	BB	0.2161	8577.00000	580.48566	99.0785
Totals:				8656.77235	589.42415	

1,2,3,4,8,9,10,11-octahydropyrido[1,2-*a*]pyrido[1',2':1,2]imidazo[4,5-*f*]benzimidazol-6,13-dione (5)



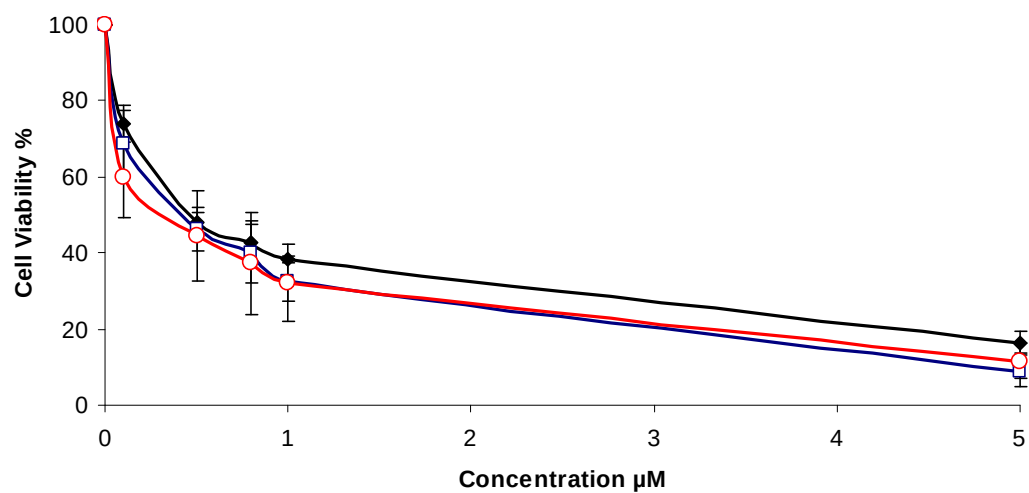
Peak No.	Ret Time (min)	Type	Width (min)	Area (mAU)	Height (mAU)	Area %
1	1.866	VB	0.0721	13.41817	2.65273	0.1119
2	7.649	BB	0.2102	1.19291e ⁴	874.09351	99.4510
3	14.592	BBA	0.3211	52.43866	2.52352	0.4372
Totals:				1.19950e ⁴	879.26976	

6-imino-1,2,3,4,8,9,10,11-octahydropyrido[1,2-*a*]pyrido[1',2':1,2]imidazo[5,4-*f*]benzimidazol-13-one (17)



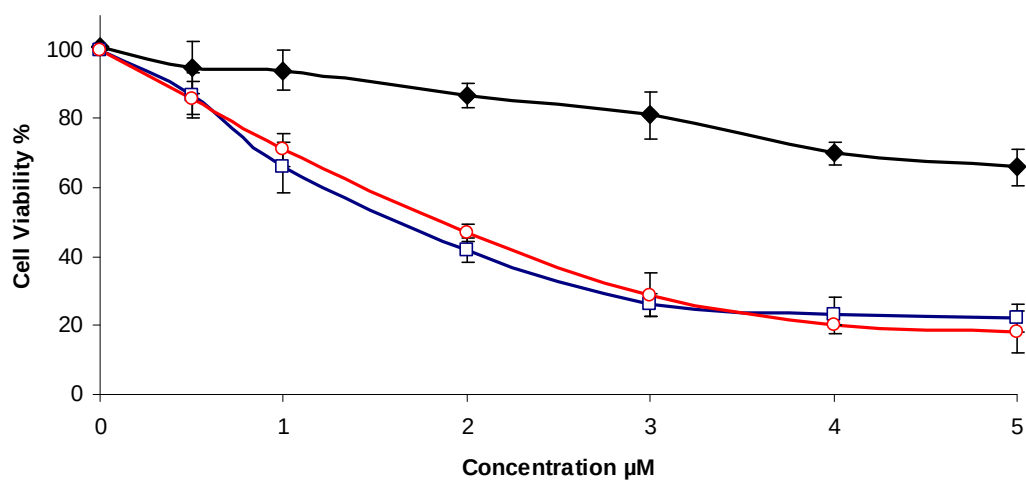
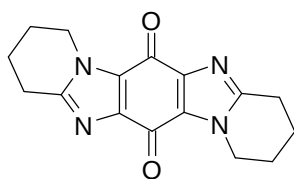
Peak No.	Ret Time (min)	Type	Width (min)	Area (mAU)	Height (mAU)	Area %
1	1.568	BV	0.0716	14.52291	3.04899	0.1297
2	1.728	VV	0.0937	13.13554	2.09127	0.1173
3	4.946	BB	0.1644	31.22771	2.91184	0.2789
4	6.522	BB	0.2164	49.64029	3.56277	0.4434
5	10.268	BB	0.1919	1.10865e ⁴	816.65125	99.0306
Totals:				1.11950e ⁴	828.26612	

Cell Viability after treatment with MMC



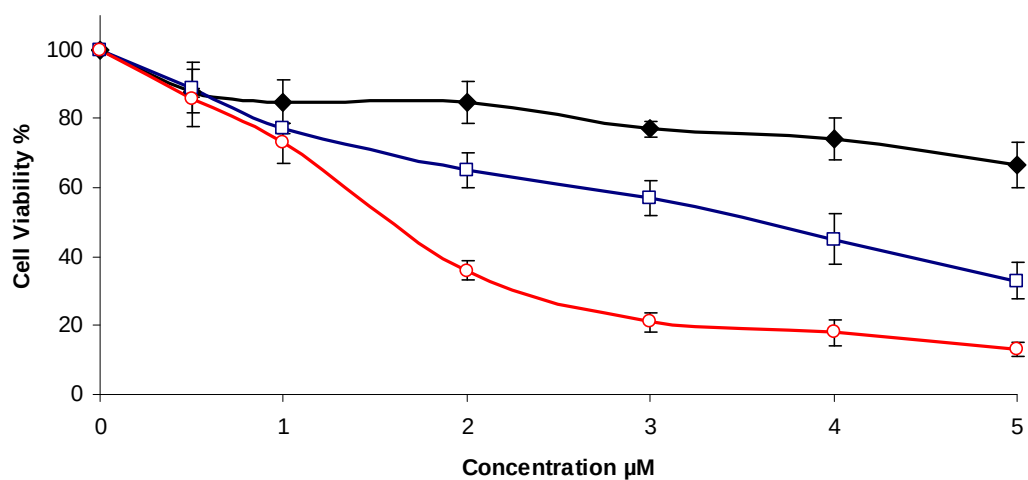
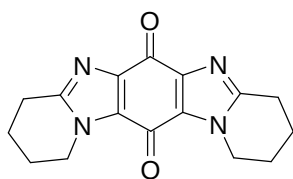
Viability of human normal skin fibroblast (GM00637) ($\blacklozenge$), HeLa (CCL-2) ($\square$) and DU145 ($\circ$) cell lines determined using the MTT assay following treatment with **MMC** under aerobic conditions for 72 h at 37 °C. Each data point is the mean of at least three independent experiments $\pm$ one standard deviation.

Cell Viability after treatment with Compound 4



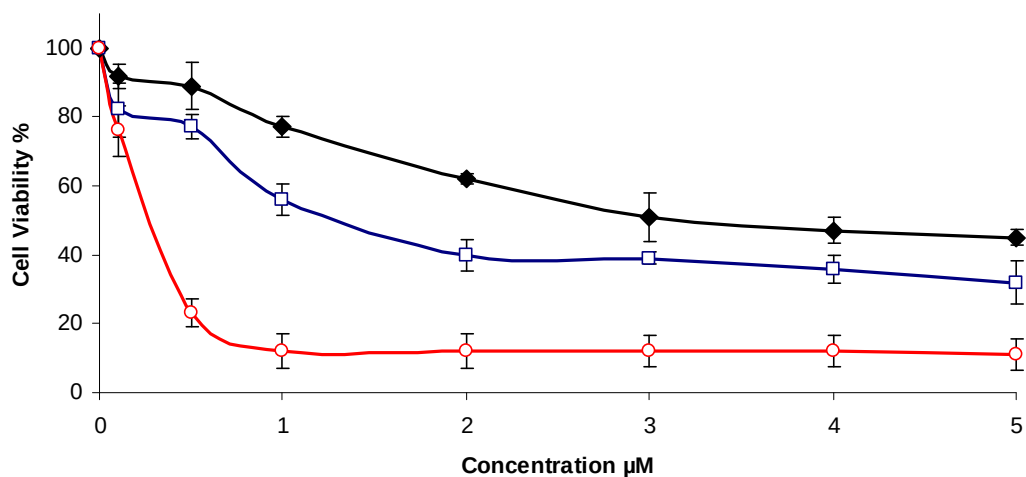
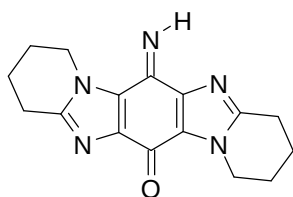
Viability of human normal skin fibroblast (GM00637) (◆), HeLa (CCL-2) (□) and DU145 (○) cell lines determined using the MTT assay following treatment with pyrido[1,2-*a*]pyrido[1',2':1,2]imidazo[5,4-*f*]benzimidazol-6,13-dione (**4**) under aerobic conditions for 72 h at 37 °C. Each data point is the mean of at least three independent experiments ± one standard deviation.

Cell Viability after treatment with Compound 5



Viability of human normal skin fibroblast (GM00637) (◆), HeLa (CCL-2) (□) and DU145 (○) cell lines determined using the MTT assay following treatment with pyrido[1,2-*a*]pyrido[1',2':1,2]imidazo[4,5-*f*]benzimidazol-6,13-dione (**5**) under aerobic conditions for 72 h at 37 °C. Each data point is the mean of at least three independent experiments ± one standard deviation.

Cell Viability after treatment with Compound 17



Viability of human normal skin fibroblast (GM00637) (◆), HeLa (CCL-2) (□) and DU145 (○) cell lines determined using the MTT assay following treatment with 6-imino-1,2,3,4,8,9,10,11-octahydropyrido[1,2-*a*] pyrido[1',2':1,2]imidazo[5,4-*f*]benzimidazol-13-one (**17**) under aerobic conditions for 72 h at 37 °C. Each data point is the mean of at least three independent experiments $\pm$ one standard deviation.