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Chemical Cascades in Water for the Synthesis of Functionalized Aromatics from Furfurals

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One-pot synthetic routes from furfurals to polysubstituted aromatic compounds have been developed in water, without the need for any organic solvents. The reaction proceeds via an uncatalysed, one-pot reaction cascade through formation of a hydrazone derivative, in situ cycloaddition with a dienophile, then aromatisation. A range of substituted phthalimides can be accessed with complete control over the substitution pattern. The reaction was also extended to other dienophiles and the diene 2-furylacrolein. The phthalimide products were further elaborated to produce a variety of polysubstituted benzenes including pharmaceutically relevant compounds.

Introduction

Furfural **1a** and 5-(hydroxymethylfurfural) (5-HMF) **1b** are renewable chemical feedstocks obtained from the hydrolysis and dehydration of cellulosic biomass, which is available from plant waste matter.[1] The use of furans in Diels-Alder cycloaddition reactions has been well documented: in general good yields have been observed in reactions between electron rich furans such as 2,5-dialkylated furans or 3-alkoxyfurans and electron deficient dieneophiles.[2] However, for many substrates Lewis acid catalysts, high temperatures/pressures or a large excess of the furan are required.[3] Of particular recent interest is the use of biomass-derived furans such as 2,5-dimethylfuran for the preparation of *p*-xylene for applications in polyethylene terephthalate (PET) synthesis, and one of the first synthetic routes required a lengthy reaction sequence using multiple reagents/catalysts (Scheme 1a).[3a] A more recent strategy employed the direct reaction of 2,5-dimethylfuran and ethylene in the presence of Lewis acid or heterogeneous acid catalysts at high temperature and pressure to generate *p*-xylene.[3b] Since 2,5-dimethylfuran is generated by the reduction of 5-HMF **1b**, a new strategy has been reported involving first the oxidation of **1b**, then reaction with ethylene at high temperature to generate 4-(hydroxymethyl)benzoic acid for subsequent conversion into PET precursors.[4] An alternative approach to the use of catalysts or forcing reaction conditions in furan Diels-Alder cycloadditions, is modification of the electron-withdrawing aldehyde moiety in biomass derived furans. For example, furfural dimethylhydrazone **2a**, prepared from furfural **1a**, was reacted with maleic anhydride or *N*-ethyl maleimide **3a** in chloroform to give aromatic products via a Diels-Alder-dehydration cascade in 65%-94% yield (Scheme 1b).[5] The approach utilising **2a** and maleic anhydride was subsequently used to generate phthalimides for the treatment of cutaneous lupus, and thalidomide analogues developed for the treatment of hematological cancers.[6,7]

We are interested in developing non-petrochemical routes to functionalized pharmaceutically relevant aromatics using renewable chemical feedstocks and environmentally benign solvents such as water,[8] together with reaction cascades. It was envisaged that hydrazones such as **2a** had significant potential for developing an efficient route to polysubstituted benzenes from sustainable furfural building blocks, if efficient reaction conditions could be developed which avoided the need to employ toxic organic solvents or catalysts. Furthermore, it should be noted that polysubstituted benzenes (>3 substituents) are still often extremely difficult to prepare regioselectively, despite the fact that they have numerous applications in medicinal chemistry. Herein the synthesis of polysubstituted phthalimides is described from furfurals via a one-pot reaction cascade, which does not require organic solvents for either the reaction or for product purification. We also demonstrate subsequent modifications of the phthalimide products to access a selection of polysubstituted aromatic compounds (Scheme 1c).

Results and discussion

Initial studies using furfural **1a**, dimethylhydrazine **4** and *N*-ethylmaleimide **3a** focused on establishing the synthesis of the hydrazone **2a** and then the Diels-Alder-aromatisation two-step reaction in the same solvent - one with a good environmental profile for subsequent combination into a reaction cascade.[9]

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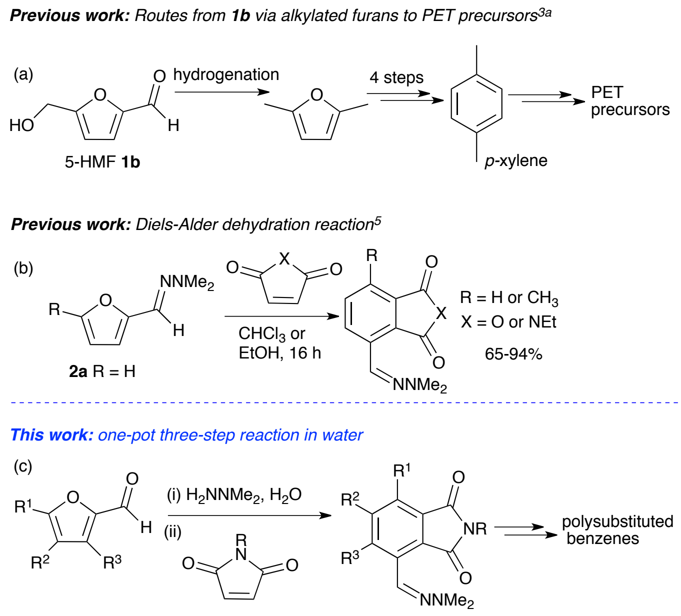
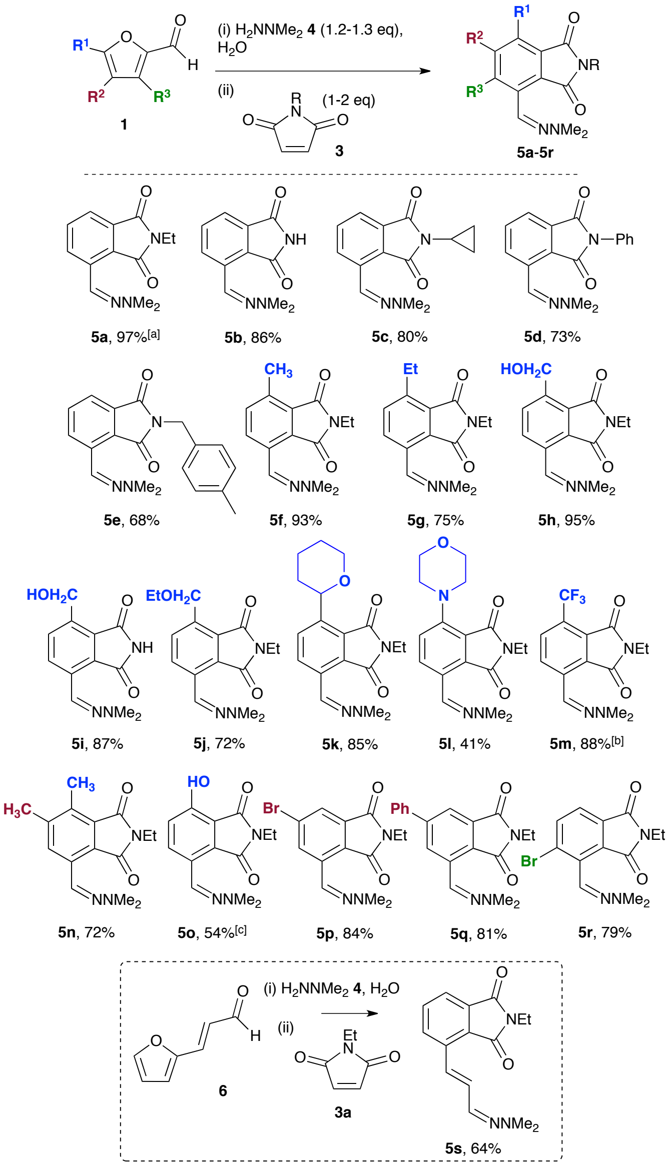
†Electronic Supplementary Information (ESI) available: Experimental procedures, ^{1}H NMR and ^{13}C NMR spectra, and compound characterisation data. See DOI: 10.1039/x0xx00000x



Scheme 1. Use of furfurals and derivatives in routes to aromatic compounds

While hydrazones are traditionally prepared by heating at reflux in organic solvents under dehydrating conditions, they have also been prepared in refluxing aqueous–alcoholic solutions.[10] Interestingly, the formation of hydrazone **2a** was achieved in 76% yield at 50 °C in water, despite the fact that the reaction involves a dehydration; although the product required isolation via an organic extraction. Pleasingly, however, reaction of **2a** with maleimide **3a** in water[11] (also at 50 °C, pH 6) gave phthalimide **5a** in 94% yield, giving a combined 2-step yield of 71%. When performed as a one-pot sequential reaction under the same conditions (Scheme 2), **5a** was formed in 95% yield and could be isolated directly as it precipitated out of the aqueous reaction mixture. Scaling the reaction up to 20 g (of **1a**) gave **5a** in 97% isolated yield. This suggests that the cycloaddition reaction can drive the initial hydrazone formation to completion by consuming **2a**, as the two-step yield was considerably higher than that observed for the hydrazone formation alone in water. The simultaneous addition of all three reaction components (**1a**, **3a**, and **4**) gave **5a** in approximately 10% lower yield due to side reactions; for this reason the reaction with other substrates was performed as a one-pot reaction by initially mixing **1** + **4**, before adding **3** after allowing time for hydrazone formation to reach equilibrium. The general utility of the reaction sequence was exemplified using five maleimides (**3a**-**3e**) and 13 furfural derivatives (**1a**, **1f**-**1r**) to give phthalimides **5a**-**5r**. In most cases, the total reaction time was less than 5 h for the conversion of **1** to **5** (Scheme 2). In addition, products were isolated by filtration with no organic solvents being used, making the reactions very amenable for scale-up. A range of different maleimides could readily be utilized, including **3b** (R=H) giving **5b** and **5i** in high yields (>85%). Phthalimides **5f**-**5m** were obtained in good to excellent yields from furfurals **1** with alkyl or heterocyclic groups at R^1, and from a dialkylated furfural (**5n**).

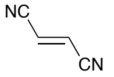
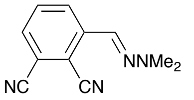
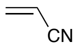
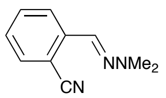
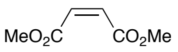
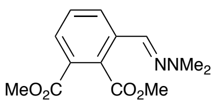


Scheme 2. Phthalimides **5a**-**5s** formed in the reaction cascade in water (pH 6), at 50 °C unless indicated otherwise; [a]20 g scale; [b]the reaction was heated at 80 °C after addition of the maleimide; [c]4-bromo-furfural was used.

When R^1=Br (**1o**), the phenolic product **5o** was generated due to the elimination of bromide during the aromatization step. With substituents at C-3 in the furfural (R^3=Br) or C-4 (R^2=Br, Ph), the corresponding phthalimides **5p**-**5r** were also formed in good yield. No reaction was observed with an aryl substituent at R^1.

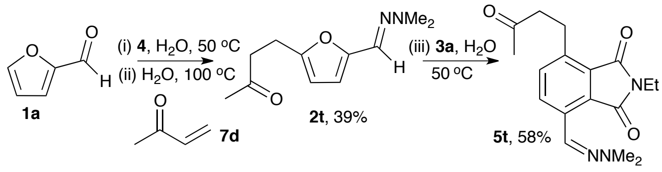
The one-pot three-step cascade was also extended to furfuryl acrolein **6** to give **5s** in 64% isolated yield. In addition, a selection of non-maleimide dienophiles were examined (Table 1). Fumaronitrile **7a** has previously been reacted with hydrazone **2a** in refluxing benzene with $SnCl_4$ catalyst, and **8a** was formed in only 13% yield due to extensive polymerisation.[5,12] With no catalyst, hydrazone **2a** reacted with **7a** in water to give **8a** in 68% isolated yield (Table 1). Acrylonitrile **7b** and dimethyl maleate **7b** were also used in reactions with the hydrazone **2a** or furfural **1a**, and **8b**/**8c** respectively were formed but in lower yield.

Table 1 Use of other dienophiles in the Diels-Alder dehydration cascade

Dienophile	Reaction conditions	Product	Yield
 **7a**	100 °C 48 h	 **8a**	68%[a]
 **7b**	100 °C 24 h	 **8b**	24%[a]
 **7c**	100 °C 24 h	 **8c**	19%[b]

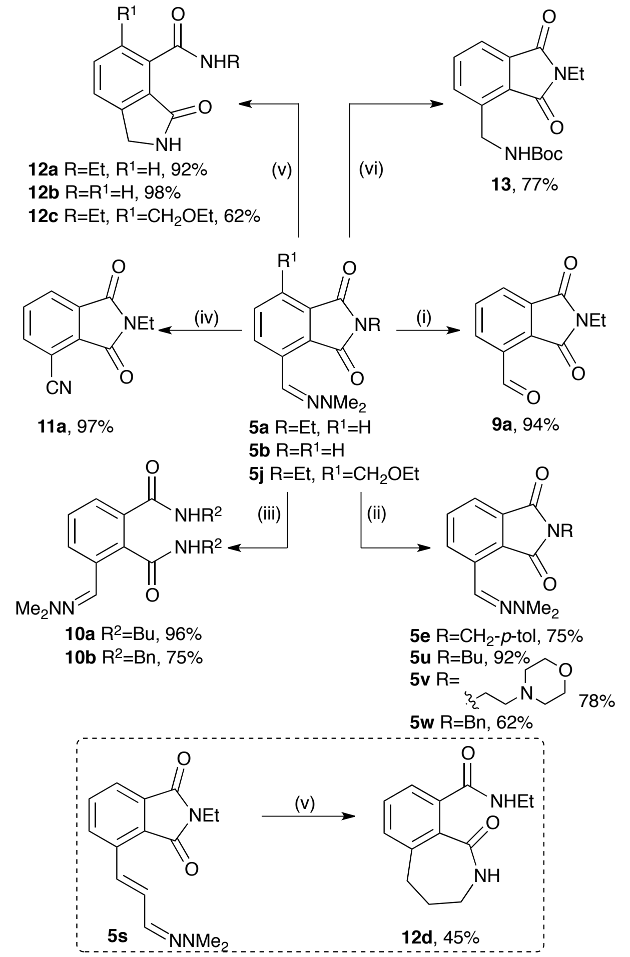
[a]Yield from the hydrazone **2a** (**2a**:dienophile, 1:2); [b]Yield from furfural **1a**.

When the dimethylhydrazone **2a** was reacted with methyl vinyl ketone **7d** in water, a Michael-addition took place instead of a cycloaddition to give hydrazone **2t**. Optimisation of the first 2 steps gave **2t** in 39% yield (from **1a**), and subsequent cycloaddition and aromatisation gave **5t** in 58% yield that was readily isolated by filtration (Scheme 3). Hydrazone **2a** has previously been reported to undergo Michael addition to 1,4-naphthoquinone in boiling benzene,[5,12] however, it is notable here that conjugate addition to a less activated Michael-acceptor could be achieved in water without a catalyst.



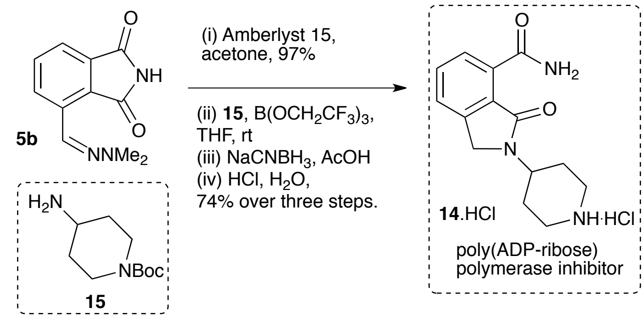
Scheme 3. One-pot formation of hydrazone **2t** in water and subsequent Diels-Alder cycloaddition and aromatisation in water.

Modification of phthalimide-hydrazones **5a**-**5b** was investigated to demonstrate the versatility of the hydazones for the synthesis of polysubstituted benzenes. Hydrazone **5a** could be hydrolysed in excellent yield to the aldehyde **9a** (Scheme 4); **5b** readily underwent transamidation to a range of other phthalimides (**5e**, **5u**-**5w**) in 62%-92% yield using catalytic boric acid.[13] Notably, this reaction could be performed using **5b** isolated by filtration (but not dried) from the one-pot cascade. The phthalimide **5a** could also be ring opened with excess amine to give the diamides **10a**-**10b** in excellent yields. Oxidation of **5a** to the nitrile **11** was readily achieved in 97% yield, as was hydrogenation to the amine, which was either converted to lactams **12a-c** in 62-98% yield or directly isolated as the Boc-amine **13** in 77% yield. In a similar fashion hydrazone **5s** was reduced to tetrahydrobenzoazepin-1one **12d** in 45% isolated yield (Scheme 4).



Scheme 4. (i) Amberlyst 15, acetone; (ii) From **5b**, $B(OH)_3$, toluene/dioxane/2 eq H_2O, RNH_2, 100 °C; (iii) excess RNH_2; (iv) magnesium monoperoxyphthalate (MMPP), MeOH, 0 °C; (v) H_2O/MeOH/HCO_2H, Pd/C, H_2; (vi) H_2O/MeOH/HCO_2H, Pd/C, H_2, then $(Boc)_2O$.

Finally, synthesis of the poly(ADP-ribose) polymerase inhibitor and potential cancer chemotherapeutic **14**[14] was carried out using hydrazone **5b** (Scheme 5). Hydrolysis to the aldehyde **9b** was followed by imine formation with **15**/$B(OCH_2CF_3)_3$,[15] reduction then acid mediated Boc-deprotection and lactam formation to give the target compound **14** as the hydrochloride salt in 72% yield over the four step sequence.



Scheme 5. Synthesis of poly(ADP-ribose) polymerase inhibitor **14**·HCl from furfural-derived phthalimide **5b**.

Conclusions

In conclusion, one-pot cascade reaction sequences in water which provide access to polysubstituted phthalimides have been developed, without the need for organic solvents for either the reaction or product purification. The products generated are useful precursors to a range of polysubstituted benzenes including medicinally relevant compounds.

Acknowledgements

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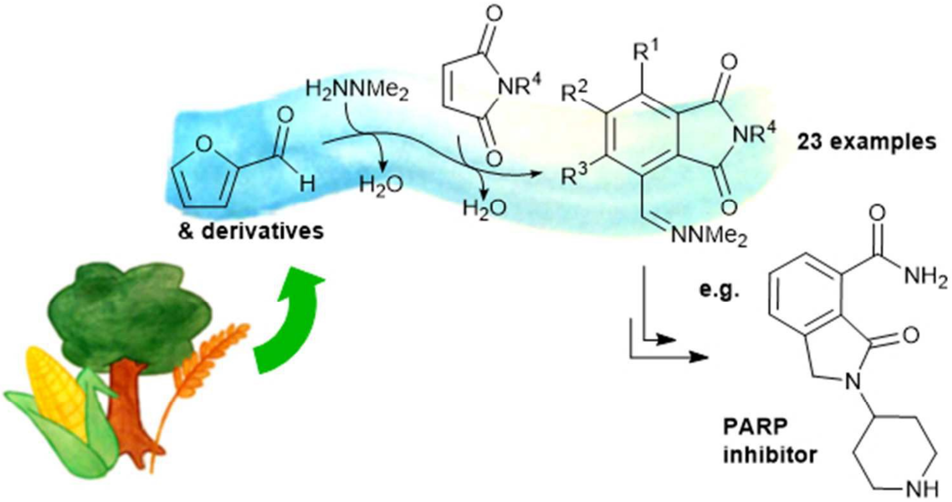


160x80mm (96 x 96 DPI)

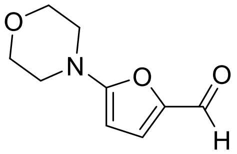
General

All reagents were obtained from commercial sources and used as received unless otherwise stated. Amberlyst® 15 was obtained from Sigma Aldrich in the hydrogen form. Analytical thin layer chromatography was performed on aluminium-backed plates coated with silica gel (Merck Kieselgel 60 F_{254}) and compounds visualised by exposure to UV light, potassium permanganate solution, phosphomolybdic acid or ninhydrin solution. Flash column chromatography was carried out using silica gel 60, SDS, 0.04–0.06 mm.

^{1}H and ^{13}C NMR spectra were recorded at 298 K at the field indicated using Avance 500 and Avance 600 machines. Chemical shifts were measured in ppm (δ) relative to the residual solvent signal (^{1}H NMR, 7.26 ppm ($CDCl_3$), 3.31 ppm (CD_3OD), 2.50 ppm ($(CD_3)_2SO$) or 2.05 ppm ($(CD_3)_2CO$); ^{13}C NMR, 77.16 ppm ($CDCl_3$), 49.00 ppm (CD_3OD), 39.52 ppm (($(CD_3)_2SO$ or 29.84 ppm ($(CD_3)_2CO$)). Coupling (*J*) constants were measured in Hertz (Hz) and splitting patterns are abbreviated as follows: singlet (s), doublet (d), triplet (t), quartet (q), quintet (qn), sextet (sx), multiplet (m), broad (br), apparent (app) and combinations thereof. IR spectra were recorded on a Nicolet FT-IT spectrometer. Mass spectra were recorded on Thermo Finnegan MAT 900XP and Micro Mass Quattro LC electrospray mass spectrometers VG ZAB 2SE. Melting points were established using a Stuart SMP11 analogue apparatus and are uncorrected.

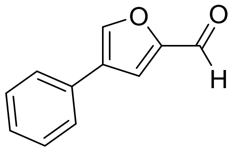
1. Preparation of Furfurals 1

5-Morpholinofuran-2-carbaldehyde 1l[1]



Synthesised according to a literature procedure.[1] R_f 0.25 (Pet. Ether 40-60/EtOAc, 1:1); IR (film, cm^{-1}) 3120, 2961, 2893, 2850, 1642, 1569, 1527; ^1H NMR ($CDCl_3$; 600 MHz) 3.37 (4H, br s, 2 x CH_2N), 3.74 (4H, m, 2 x CH_2O), 5.30 (1H, d, J = 3.6 Hz, 4-H), 7.18 (1H, br s, 3-H); 9.02 (1H, br s, CHO); ^{13}C NMR ($CDCl_3$; 151 MHz) 46.0 (2 x CH_2N), 65.9 (2 x CH_2O), 87.1 (C-4), 130.8 (C-3), 144.7 (C), 163.1 (C), 172.0 (CHO); *m/z* HRMS (ESI+) found $[MH]^+$ 182.0815, $C_9H_{12}NO_3$ requires 182.0817.

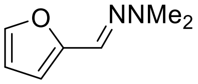
4-Phenylfuran-2-carbaldehyde 1q[2]



Synthesised according to a literature procedure.[2] R_f 0.34 (Pet. Ether 40-60/EtOAc, 9:1); ^1H NMR ($CDCl_3$; 600 MHz) 7.35 (1H, t, J = 7.2, Ar-H), 7.43 (2H, t, J = 7.2, Ar-H), 7.52 (2H, d, J = 7.2, Ar-H), 7.53 (1H, s, 3-H), 7.96 (1H, s, 5-H), 9.71 (1H, s, CHO); ^{13}C NMR ($CDCl_3$; 151 MHz) 119.0 (CH), 126.1 (2 x CH); 128.3 (C); 129.3 (2 x CH), 129.4 (C), 130.5 (C), 143.8 (C), 153.7 (C), 178.3 (CHO); *m/z* HRMS (ESI+) found $[M]^+$ 172.0519, $C_{11}H_8O_2$ requires 172.0524.

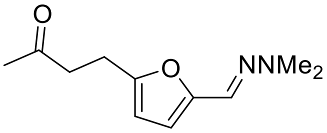
2. Preparation of Furfural Hydrazones 2

2-Furaldehyde dimethylhydrazone 2a^3



To a solution of furfural **1a** (28.8 mg, 25.4 μL, 300 μmol) in water (6 mL), *N*,*N*-dimethylhydrazine **4** (24.0 mg, 30.4 μL, 400 μmol) was added and the mixture was stirred at rt for 40 min. The organic component was extracted with ether (3 x 30 mL), dried with $MgSO_4$, and the solvent removed under vacuum to give **2a** as a red-brown liquid (36.5 mg, 76%). R_f 0.67 (Pet. Ether 40-60/EtOAc, 1:1); IR (film, cm^{-1}) 2850, 1524, 1445; ^{1}H NMR ($CDCl_3$; 600 MHz) 2.95 (s, 6H, 2 x CH_3), 6.37 (1H, d, *J* = 3.3 Hz, 3-H), 6.39 (1H, dd, *J* = 3.3, 1.6 Hz, 4-H), 7.10 (1H, s, N=CH), 7.39 (1H, d, *J* = 1.6 Hz, 5-H); ^{13}C NMR ($CDCl_3$; 151 MHz) 42.7 (2 x CH_3), 107.1 (C-4), 111.2 (C-3), 123.2 (C=N), 141.8 (C-2), 152.1 (C-5);

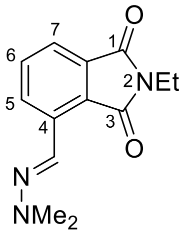
4-(5-((2,2-Dimethylhydrazono)methyl)furan-2-yl)butan-2-one 2t



To a solution of furfural **1a** (192 mg, 166 μL, 2.00 mmol) in water (10 mL), *N*,*N*-dimethylhydrazine **4** (144 mg, 183 μL, 2.40 mmol) was added and the mixture was stirred at 50 °C for 30 min. The solution was heated to reflux and methyl vinyl ketone **7d** (701 mg, 834 μL, 10 mmol) added dropwise over 5 h. The solution was stirred at reflux for a further 1 h then cooled to rt, and the organic component extracted with ethyl acetate (3 x 50 mL), dried with $MgSO_4$, and the solvent removed under vacuum. The crude reaction mixture was dry-loaded onto silica and purified by flash column chromatography (Pet. Ether 40-60/EtOAc, 5:95) to give **2t** as a yellow oil (162 mg, 39%). R_f 0.21 (Pet. Ether 40-60/EtOAc, 4:1); IR (film, cm^{-1}) 2925, 1713, 1674; ^{1}H NMR ($CDCl_3$; 600 MHz) 2.11 (3H, s, C(O)CH_3), 2.76 (2H, t, *J* = 7.5 Hz, CH_2CH$_2$), 2.86-2.91 (m, 8H, 2 x CH_3 and CH$_2$CH_2), 5.97 (1H, d, *J* = 3.3 Hz, 3-H), 6.21 (1H, d, *J* = 3.3 Hz, 4-H), 7.03 (1H, s, N=CH); ^{13}C NMR ($CDCl_3$; 151 MHz) 22.5, 30.1, 41.9, 43.0 (2 x CH_3), 107.4 (C-3), 108.8 (C-4), 124.3 (C=N), 150.9 (5), 154.6 (C-2), 207.8 (C=O); *m/z* HRMS (ESI+) found [MH]$^+$ 209.1289, $C_{11}H_{17}N_2O_2$ requires 209.1290.

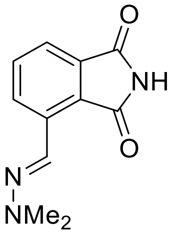
3. Preparation of Phthalimides 5

4-((2,2-Dimethylhydrazono)methyl)-2-ethylisoindoline-1,3-dione 5a[4]



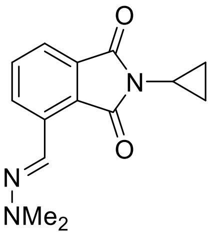
To a solution of furfural **1a** (20.0 g, 17.2 mL, 208 mmol) in water (500 mL, pH 6), *N*,*N*-dimethylhydrazine (15.0 g, 19.0 mL, 250 mmol) was added and the mixture was stirred at 50 °C for 30 min. *N*-Ethyl maleimide **3a** (26.0 g, 208 mmol) was added and the reaction stirred at 50 °C for 2 h. The mixture was cooled and the precipitate was collected by filtration, washed with cold water (2 x 100 mL) and dried to give **5a** as yellow needles (49.6 g, 97%). R_f 0.22 (Pet. Ether 40-60/EtOAc, 17:3); M.p. 142-143 °C (water), Lit[4] 141-142 °C ($CHCl_3$); IR (film, cm^{-1}) 2920, 2875, 1755, 1695, 1590; ^1H NMR ($CDCl_3$; 600 MHz) 1.27 (3H, t, J = 7.3 Hz, CH_2CH_3), 3.14 (6H, s, 2 x CH_3), 3.72 (2H, q, J = 7.3 Hz, CH_2CH_3), 7.55 (1H, t, J = 7.7 Hz, 6-H), 7.61 (1H, dd, J = 7.7, 1.1 Hz, 7-H), 8.14 (1H, s, N=CH), 8.22 (1H, dd, J = 7.7, 1.1 Hz, 5-H); ^{13}C NMR ($CDCl_3$; 151 MHz) 14.1 (CH_3), 32.9 (CH_2), 42.9 (2 x CH_3), 120.9 (CH), 124.7 (N=CH), 124.9 (C), 129.0 (C), 132.6 (C), 133.4 (CH), 136.4 (C), 168.4 (C=O), 169.4 (C=O); *m/z* HRMS (ESI+) found $[MH]^+$ 246.1341, $C_{13}H_{16}N_3O_2$ requires 246.1243.

4-((2,2-Dimethylhydrazono)methyl)isoindoline-1,3-dione 5b



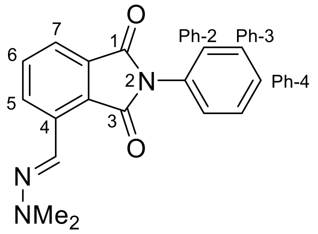
To a solution of furfural **1a** (4.81 g, 4.13 mL, 50.0 mmol) in water (100 mL, pH 6), *N*,*N*-dimethylhydrazine (3.60 g, 4.56 mL, 60.0 mmol) was added and the mixture was stirred at 50 °C for 30 min. Maleimide **3b** (7.32 g, 75.0 mmol) was added and the reaction stirred at 50 °C for 2 h. The mixture was cooled and the precipitate was collected by filtration, washed with cold water (2 x 500 mL) and dried to give **5b** as yellow needles (9.33 g, 86%). R_f 0.41 (Pet. Ether 40-60/EtOAc, 3:2); M.p. 238-240 °C (water); IR (film, cm^{-1}) 3196, 1759, 1715, 1544; ^1H NMR ($CDCl_3$; 600 MHz) 3.13 (6H, s, 2 x CH_3), 7.55 (1H, s br, NH), 7.60 (1H, t, J = 7.4 Hz, 6-H), 7.62 (1H, dd, J = 7.4, 1.1 Hz, 7-H), 8.05 (1H, s, N=CH), 8.27 (1H, dd, J = 7.4, 1.1 Hz, 5-H); ^{13}C NMR ($CDCl_3$; 151 MHz) 42.8 (2 x CH_3), 121.2 (CH), 124.1 (N=CH), 125.1 (C), 129.4 (C), 133.0 (C), 133.8 (CH), 137.0 (C), 168.1 (C=O), 169.0 (C=O); *m/z* HRMS (ESI+) found $[MH]^+$ 218.0940, $C_{11}H_{14}N_3O_2$ requires 218.0930.

2-Cyclopropyl-4-((2,2-dimethylhydrazono)methyl)isoindoline-1,3-dione 5c



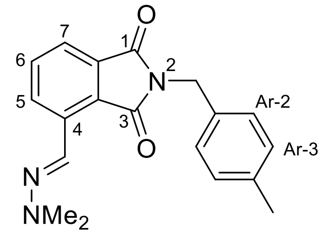
To a solution of furfural **1a** (33.7 mg, 29.0 μL, 350 μmol) in water (2 mL, pH 6), *N*,*N*-dimethylhydrazine (25.2 mg, 32.0 μL, 420 μmol) was added and the mixture was stirred at 50 °C for 30 min. *N*-Cyclopropyl maleimide **3c** (96.0 mg, 700 μmol) was added and the reaction stirred at 50 °C for 2 h. The mixture was cooled and the precipitate was collected by filtration, washed with cold water (2 x 25 mL) and dried to give **5c** as yellow needles (72.0 mg, 80%). R_f 0.30 (Pet. Ether 40-60/EtOAc, 4:1); M.p. 174-176 °C (water); IR (film, cm^{-1}) 2861, 1764, 1706, 1548; ^{1}H NMR ($CDCl_3$; 600 MHz) 1.01 (4H, m, 2 x CH_2), 2.67 (1H, m, CH), 3.12 (6H, s, 2 x CH_3), 7.55 (1H, t, *J* = 7.6 Hz, 6-H), 7.59 (1H, dd, *J* = 7.6, 1.1 Hz, 7-H), 8.11 (1H, s, N=CH), 8.22 (1H, dd, *J* = 7.6, 1.1 Hz, 5-H); ^{13}C NMR ($CDCl_3$; 151 MHz) 5.3 (2 x CH_2), 20.9 (CH), 42.7 (2 x CH_3), 120.9 (CH), 124.4 (C), 124.7 (N=CH), 129.1 (CH), 132.2 (C), 133.5 (CH), 136.5 (C), 169.1 (C=O), 170.2 (C=O); *m/z* HRMS (ESI+) found $[MH]^+$ 258.1240, $C_{14}H_{17}N_3O_2$ requires 258.1242.

4-((2,2-Dimethylhydrazono)methyl)-2-phenylisoindoline-1,3-dione 5d[5]



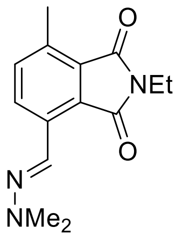
To a solution of furfural **1a** (67.4 mg, 48.0 μL, 700 μmol) in water (2 mL, pH 6), *N*,*N*-dimethylhydrazine (50.4 mg, 64.0 μL, 840 μmol) was added and the mixture was stirred at 50 °C for 30 min. *N*-Phenyl maleimide **3d** (121 mg, 700 μmol) was added and the reaction stirred at 50 °C for 2 h. The mixture was cooled and the precipitate was collected by filtration, washed with cold water (2 x 25 mL) and dried to give **5d** as yellow needles (150 mg, 73%). R_f 0.34 (Pet. Ether 40-60/EtOAc, 4:1); M.p. 210-212 °C (water), Lit[5] 206 °C (EtOAc); IR (film, cm^{-1}) 2941, 1766, 1710, 1687; ^{1}H NMR ($CDCl_3$; 600 MHz) 3.13 (6H, s, 2 x CH_3), 7.40 (1H, tt, *J* = 7.3, 1.3 Hz, Ph-4-H), 7.43 (2H, dd, *J* = 7.3, 1.3 Hz, Ph-2-H), 7.50 (2H, t, *J* = 7.3 Hz, Ph-3-H), 7.64 (1H, t, *J* = 7.6 Hz, 6-H), 7.72 (1H, d, *J* = 7.6 Hz, 7-H), 8.16 (1H, s, N=CH), 8.31 (1H, d, *J* = 7.6 Hz, 5-H); ^{13}C NMR ($CDCl_3$; 151 MHz) 42.7 (2 x CH_3), 120.8 (C), 121.4 (CH), 124.2 (C), 124.4 (N=CH), 126.8 (CH), 128.1 (CH), 129.2 (CH), 129.4 (CH), 131.9 (C), 132.1 (C), 133.9 (CH), 137.0 (C), 167.5 (C=O), 168.5 (C=O); *m/z* HRMS (ESI+) found $[MH]^+$ 294.1251, $C_{17}H_{16}N_3O_2$ requires 294.1243.

4-((2,2-Dimethylhydrazono)methyl)-2-(4-methylbenzyl)isoindoline-1,3-dione 5e



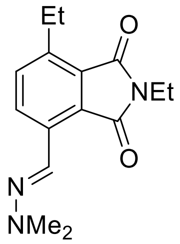
To a solution of furfural **1a** (67.4 mg, 48.0 μL, 700 μmol) in water (2 mL, pH 6), *N*,*N*-dimethylhydrazine (50.4 mg, 64.0 μL, 840 μmol) was added and the mixture was stirred at 50 °C for 30 min. *N*-(4-Methylbenzyl) maleimide **3e** (141 mg, 700 μmol) was added and the reaction stirred at 50 °C for 2 h. The mixture was cooled and the precipitate was collected by filtration, washed with cold water (2 x 25 mL) and dried to give **5e** as yellow needles (153 mg, 68%). R_f 0.40 (Pet. Ether 40-60/EtOAc, 4:1); M.p. 135-137 °C (water); IR (film, cm^{-1}) 2928, 1758, 1697; ^{1}H NMR ($CDCl_3$; 600 MHz) 2.31 (3H, s, CH_3), 3.11 (6H, s, 2 x CH_3), 4.79 (2H, s, CH_2), 7.13 (2H, d, J = 7.9 Hz, Ar-3-H), 7.33 (2H, d, J = 7.9 Hz, Ar-2-H), 7.54 (1H, t, J = 7.7 Hz, 6-H), 7.60 (1H, d, J = 7.7 Hz, 7-H), 8.12 (1H, s, N=CH), 8.21 (1H, d, J = 7.7 Hz, 5-H); ^{13}C NMR ($CDCl_3$; 151 MHz) 42.8 (2 x CH_3), 121.1 (CH), 124.9 (C), 125.2 (CH), 128.7 (CH), 129.1 (CH), 129.5 (CH), 132.5 (C), 133.4 (CH), 133.8 (C), 136.5 (C), 137.6 (C), 167.6 (C=O), 168.6 (C=O); *m/z* HRMS (ESI+) found $[MH]^+$ 322.1567, $C_{19}H_{20}N_3O_2$ requires 322.1556.

4-((2,2-Dimethylhydrazono)methyl)-2-ethyl-7-methylisoindoline-1,3-dione 5f[4]



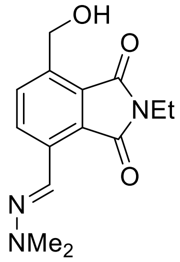
To a solution of 5-methylfurfural **1f** (110 mg, 99.5 μL, 1.00 mmol) in water (4 mL, pH 6), *N*,*N*-dimethylhydrazine (72.0 mg, 91.2 μL, 1.20 mmol) was added and the mixture was stirred at 50 °C for 2 h. *N*-Ethyl maleimide **3a** (250 mg, 2.00 mmol) was added and the reaction stirred at 50 °C for 2 h. The mixture was cooled and the precipitate was collected by filtration, washed with cold water (2 x 25 mL) and dried to give **5f** as yellow needles (260 mg, 93%). R_f 0.70 (Pet. Ether 40-60/EtOAc, 17:3); M.p. 144-146 °C ($CDCl_3$), Lit[4] 145-146 °C ($CHCl_3$); IR (film, cm^{-1}) 2976, 2937, 2868, 1750, 1685, 1590; ^{1}H NMR ($CDCl_3$; 600 MHz) 1.26 (3H, t, J = 7.3 Hz, CH_2CH_3), 2.65 (3H, s, Ar-CH_3), 3.09 (6H, s, 2 x CH_3), 3.70 (2H, q, J = 7.3 Hz, CH_2CH_3), 7.32 (1H, d, J = 8.2 Hz, 6-H), 8.09 (1H, d, J = 8.2 Hz, 5-H), 8.17 (1H, s, N=CH); ^{13}C NMR ($CDCl_3$; 151 MHz) 14.1 (CH_3), 17.7 (Ar-CH_3), 32.7 (CH_2), 42.9 (2 x CH_3), 125.3 (C), 125.6 (N=CH), 128.7 (C), 128.8 (CH), 134.1 (C), 135.7 (C), 136.2 (CH), 169.1 (C=O), 169.3 (C=O); *m/z* HRMS (ESI+) found $[MH]^+$ 260.1480, $C_{14}H_{18}N_3O_2$ requires 260.1399.

4-((2,2-Dimethylhydrazono)methyl)-2,7-diethylisoindoline-1,3-dione, 5g



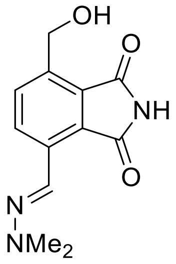
To a solution of 5-ethyl-2-furaldehyde (124 mg, 1.0 mmol) in water (4 mL, pH 6) *N,N*-dimethylhydrazine (78 mg, 99 µL, 1.3 mmol) was added and the mixture was stirred at 50 °C. After 2.5 h *N*-ethyl maleimide (250 mg, 2.0 mmol) was added and the reaction stirred at the same temperature with a yellow precipitate forming within 5 min. After 4 h, the mixture was cooled to rt and the precipitate collected by filtration, washed with cold water (100 mL), and dried in vacuo to give **5g** as yellow needles (205 mg, 75%). R_f = 0.38 (Pet. Ether 40-60/EtOAc, 9:1); IR (film, cm^{-1}) 2935, 2879, 2864, 2785, 1748, 1690, 1545, 1439; M.p. 109-111 °C (water); ^{1}H NMR ($CDCl_3$; 600 MHz) 1.26 (6H, m, 2 x CH_2CH_3), 3.08 (6H, s, 2 × CH_3), 3.09 (2H, m, CH_2CH_3), 3.70 (2H, q, J = 7.2 Hz, CH_2CH_3), 7.36 (1H, d, J = 8.4 Hz, 6-H), 8.12 (1H, d, J = 8.4 Hz, 5-H), 8.17 (1H, s, N=CH); ^{13}C NMR ($CDCl_3$; 151 MHz) 14.1 (CH_2CH_3), 15.1 (CH_2CH_3), 24.4 (CH_2), 32.6 (CH_2), 42.8 (2 x CH_3), 125.4 (C), 125.7 (N=CH), 128.1 (C), 129.1 (CH), 134.1 (C), 134.7 (CH), 142.4 (C), 168.9 (C=O), 169.4 (C=O); *m/z* HRMS (ESI+) found $[MH]^+$ 274.1559, $C_{15}H_{20}N_3O_2$ requires 274.1555.

4-((2,2-Dimethylhydrazono)methyl)-2-ethyl-7-(hydroxymethyl)isoindoline-1,3-dione 5h



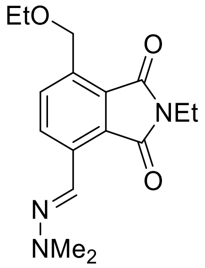
To a solution of 5-hydroxymethylfurfural **1h** (126 mg, 97.8 µL, 1.00 mmol) in water (4 mL, pH 6), *N*,*N*-dimethylhydrazine (72.0 mg, 91.2 µL, 1.20 mmol) was added and the mixture was stirred at 50 °C for 2 h. *N*-Ethyl maleimide **3a** (250 mg, 2.00 mmol) was added and the reaction stirred at 50 °C for 30 min. The mixture was cooled and the precipitate was collected by filtration, washed with cold water (2 x 25 mL) and dried to give **5h** as yellow needles (251 mg, 95%). R_f 0.14 (Pet. Ether 40-60/EtOAc, 17:3); M.p. 152-154 °C ($CDCl_3$); IR (film, cm^{-1}) 3306 (br), 2937, 2871, 1750, 1682, 1592; ^{1}H NMR ($CDCl_3$; 600 MHz) 1.27 (3H, t, J = 7.2 Hz, CH_2CH_3), 3.12 (6H, s, 2 x CH_3), 3.72 (2H, q, J = 7.2 Hz, CH_2CH_3), 4.89 (2H, s, Ar-CH_2OH), 7.45 (1H, d, *J* = 8.2 Hz, 6-H), 8.14 (1H, s, N=CH), 8.18 (1H, d, *J* = 8.2 Hz, 5-H); ^{13}C NMR ($CDCl_3$; 151 MHz) 14.1 (CH_3), 33.0 (CH_2), 42.7 (2 x CH_3), 62.7 (Ar-CH_2OH), 124.3 (N=CH), 125.2 (C), 129.4 (CH), 133.2 (CH), 134.3 (C), 136.0 (C), 138.5 (C), 169.2 (C=O), 170.2 (C=O); *m/z* HRMS (ESI+) found [MH]$^+$ 275.1268, $C_{14}H_{18}N_3O_3$ requires 275.1270.

4-((2,2-Dimethylhydrazono)methyl)-7-(hydroxymethyl)isoindoline-1,3-dione 5i



To a solution of hydroxymethylfurfural **1h** (1.00 g, 775 µL, 7.94 mmol) in water (20 mL, pH 6), *N*,*N*-dimethylhydrazine (572 mg, 1.16 mL, 9.52 mmol) was added and the mixture was stirred at 50 °C for 40 min. Maleimide **3b** (2.33 g, 15.9 mmol) was added and the reaction stirred at 50 °C for 3 h. The mixture was cooled and the precipitate was collected by filtration, washed with cold water (2 x 100 mL) and dried to give **5i** as yellow needles (1.71 g, 87%). R$_f$ 0.50 (Pet. Ether 40-60/EtOAc, 1:2); M.p. 202-204 °C (water); IR (film, cm^{-1}) 3187 (br), 3045, 1752, 1688, 1650, 1537; ^{1}H NMR (CD_3OD; 600 MHz) 3.06 (6H, s, 2 x CH_3), 4.98 (2H, s, CH_2), 7.69 (1H, d, *J* = 8.4 Hz, 6-H), 8.05 (1H, s, N=CH), 8.14 (1H, d, *J* = 8.4 Hz, 5-H); ^{13}C NMR (CD_3OD; 151 MHz) 42.7 (2 x CH_3), 60.5 (CH_2), 125.7 (CH), 126.9 (C), 129.7 (C), 129.9 (CH), 133.2 (CH), 136.5 (C), 140.2 (C), 171.2 (C=O), 171.6 (C=O); *m/z* HRMS (ESI+) found [MH]$^+$ 248.1032, $C_{12}H_{14}N_3O_3$ requires 248.1035.

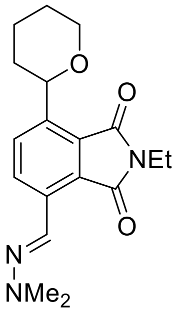
4-((2,2-Dimethylhydrazono)methyl)-7-(ethoxymethyl)-2-ethylisoindoline-1,3-dione 5j



To a solution of 5-(ethoxymethyl)-2-furaldehyde (154 mg, 1.0 mmol) in water (4 mL, pH 6) *N*,*N*-dimethylhydrazine (78 mg, 99 µL, 1.3 mmol) was added and the mixture was stirred at 50 °C. After 4 h *N*-ethyl maleimide (250 mg, 2.0 mmol) was added and the reaction stirred at the same temperature with a yellow precipitate forming within 5 min. After 1 h, the mixture was cooled to rt and the precipitate collected by filtration, washed with cold water (100 mL), and dried in vacuo to give **5j** as yellow solid (217 mg, 72%). R$_f$ = 0.40 (Pet. Ether 40-60/EtOAc, 9:1); IR (film, cm^{-1}) 2980, 2938, 2870, 2795, 1751, 1692, 1543, 1437; M.p. 104-106 °C (water); ^{1}H NMR ($CDCl_3$; 600 MHz) 1.25 (3H, t, *J* = 7.2 Hz, NCH_2CH_3), 1.28 (3H, t, *J*

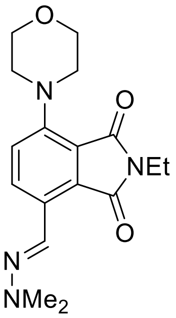
= 7.0 Hz, OCH_2CH_3), 3.11 (6H, s, 2 x CH_3), 3.64 (2H, q, *J* = 7.0 Hz, OCH_2CH_3), 3.69 (2H, q, *J* = 7.2 Hz, NCH_2CH_3), 4.97 (2H, s, CH_2Ar), 7.70 (1H, d, *J* = 8.4 Hz, 6-H), 8.14 (1H, s, N=CH), 8.20 (1H, d, *J* = 8.4 Hz, 5-H); ^{13}C NMR ($CDCl_3$; 151 MHz) 14.1 (CH_3), 15.4 (CH_3), 32.7 (NCH_2CH_3), 42.7 (2 x CH_3), 66.6 (OCH_2CH_3), 67.4 (Ar-CH_2), 124.9 (C), 125.0 (N=CH), 127.9 (C), 129.1 (CH), 132.7 (CH), 135.3 (C), 136.4 (C), 168.7 (C=O), 169.4(C=O); *m/z* HRMS (ESI+) found $[MH]^+$ 304.1653, $C_{16}H_{22}N_3O_3$ requires 304.1661.

4-((2,2-Dimethylhydrazono)methyl)-2-ethyl-7-(tetrahydro-2H-pyran-2-yl)isoindoline-1,3-dione 5k



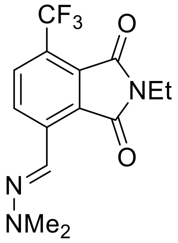
To a solution of 5-(tetrahydropyran-2-yl)-2-furaldehyde (180 mg, 1.0 mmol) in water (4 mL, pH 6) *N*,*N*-dimethylhydrazine (99 µL, 1.3 mmol) was added and the mixture was stirred at 50 °C. After 4 h *N*-ethyl maleimide (250 mg, 2.0 mmol) was added and the reaction stirred at the same temperature with a yellow precipitate forming within 5 min. After 1 h, the mixture was cooled to rt and the precipitate collected by filtration, washed with cold water (100 mL), and dried in vacuo to give **5k** as yellow solid (278 mg, 85%). R_f = 0.42 (Pet. Ether 40-60/EtOAc, 9:1); IR (film, cm^{-1}) 2931, 2857, 2833, 2780, 1754, 1697, 1545, 1438; M.p. 108-110 °C (water); ^1H NMR ($CDCl_3$; 600 MHz) 1.25 (3H, t, *J* = 7.2 Hz, CH_2CH_3), 1.41 (1H, m, CH*H*), 1.60 (1H, m, CH*H*), 1.69 (1H, m, CH*H*), 1.78 (1H, m, CH*H*), 1.92 (2H, m, CH_2), 3.09 (6H, s, 2 x CH_3), 3.67 (3H, m, CH_2CH_3 + CH), 4.14 (1H, m, CH*H*), 5.31 (1H, d, *J* = 10.8 Hz, OCH), 7.75 (1H, d, *J* = 8.4 Hz, 6-H), 8.14 (1H, s, N=CH), 8.18 (1H, d, *J* = 8.4 Hz, 5-H); ^{13}C NMR ($CDCl_3$; 151 MHz) 14.1 (CH_3), 24.0 (CH_2), 25.9 (CH_2), 32.7 (CH_2), 33.9 (CH_2), 42.7 (2 x CH_3), 69.0 (CH_2), 74.8 (CH), 124.6 (CH), 125.1 (C), 126.5 (CH), 129.4 (C), 131.0 (CH), 135.1 (C), 141.2 (C), 168.6 (C=O), 169.3 (C=O); *m/z* HRMS (ESI+) found $[MH]^+$ 330.1824, $C_{18}H_{24}N_3O_3$ requires 330.1818.

4-((2,2-Dimethylhydrazono)methyl)-2-ethyl-7-morpholinoisoindoline-1,3-dione 5l



To a solution of 5-morpholino-2-furaldehyde (181 mg, 1.0 mmol) in water (4 mL, pH 6) *N*,*N*-dimethylhydrazine (78 mg, 99 µL, 1.3 mmol) was added and the mixture was stirred at 50 °C. After 2.5 h *N*-ethyl maleimide (250 mg, 2.0 mmol) was added and the reaction stirred at the same temperature with a precipitate forming within 5 min. After 5 h, the mixture was cooled to rt and the precipitate collected by filtration, washed with cold water (100 mL), and dried in vacuo to give **5l** as brown-red solid (134 mg, 41%). R_f = 0.38 (Pet. Ether 40-60/EtOAc, 9:1); IR (film cm^{-1}) 2965, 2859, 2828, 1738, 1683, 1435; M.p. 112-114 °C (water); ^{1}H NMR ($CDCl_3$; 600 MHz) 1.24 (3H, t, *J* = 7.2 Hz, $\mathrm{CH_2C}\mathit{H_3}$), 3.06 (6H, s, 2 x CH_3), 3.32 (4H, m, 2 x NCH_2), 3.68 (2H, q, *J* = 7.2 Hz, $\mathrm{C}\mathit{H_2}\mathrm{CH_3}$), 3.94 (4H, m, 2 x OCH_2), 7.09 (1H, d, *J* = 9.0 Hz, 6-H), 8.15 (1H, d, *J* = 9.0 Hz, 5-H), 8.21 (1H, s, N=CH); ^{13}C NMR ($CDCl_3$, 151 MHz) 14.1 (CH_2CH_3), 32.7 ($\mathit{C}\mathrm{H_2CH_3}$), 42.9 (2 x CH_3), 51.7 (2 x CH_2N), 67.1 (2 x CH_2O), 117.8 (C), 123.1 (6-C), 126.4 (N=CH), 127.0 (C), 129.4 (C), 131.4 (5-C), 148.6 (C), 167.7 (C=O), 169.2 (C=O); *m/z* HRMS (ESI+) found $[MH]^+$ 331.1774, $C_{17}H_{23}N_4O_3$ requires 331.1770.

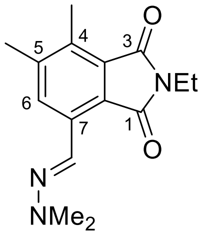
4-((2,2-Dimethylhydrazono)methyl)-2-ethyl-7-(trifluoromethyl)isoindoline-1,3-dione 5m



To a solution of 5-(trifluoromethyl)-2-furaldehyde (164 mg, 1.0 mmol) in water (4 mL, pH 6) *N*,*N*-dimethylhydrazine (78 mg, 99 µL, 1.3 mmol) was added and the mixture was stirred at 50 °C. After 4 h *N*-ethyl maleimide (250 mg, 2.0 mmol) was added and the reaction stirred at the same temperature with a precipitate forming within 5 min. After 24 h, the temperature was increased to 80 °C and the mixture stirred overnight. The mixture was cooled to rt and the precipitate collected by filtration, washed with cold water (100 mL), and dried in vacuo to give **5m** as yellow needles (213 mg, 88%). R_f = 0.38 (Pet. Ether 40-60/EtOAc, 9:1); IR (film, cm^{-1}) 2943, 2794, 1758, 1699, 1612, 1532, 1442; M.p. 194-196 °C (water); ^{1}H NMR ($CDCl_3$; 600 MHz) 1.28 (3H, t, *J* = 7.2 Hz, $\mathrm{CH_2C}\mathit{H_3}$), 3.19 (6H, s, 2 x CH_3), 3.74 (2H, q, *J* = 7.2 Hz,

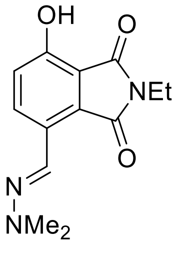
$\mathrm{C}H_2\mathrm{CH}_3$), 7.75 (1H, d, J = 8.4 Hz, 6-H), 8.11 (1H, s, N=CH), 8.29 (1H, d, J = 8.4 Hz, 5-H); ^{13}C NMR ($CDCl_3$; 151 MHz) 13.9 (CH_3), 33.2 (CH_2), 42.7 (2 x CH_3), 122.4 (N=CH), 122.5 (q, J = 273.0 Hz, CF_3), 123.4 (q, J = 35.5 Hz, C-3a), 125.7 (C), 128.2 (C), 128.7 (CH-5), 130.1 (q, J = 5.4 Hz, CH-6), 139.5 (C-4), 165.1 (C=O), 168.4 (C=O); *m/z* HRMS (ESI+) found $[MH]^+$ 314.1118, $C_{14}H_{15}N_3O_2F_3$ requires 314.1118.

7-((2,2-Dimethylhydrazono)methyl)-2-ethyl-4,5-methylisoindoline-1,3-dione 5n



To a solution of 4,5-dimethylfurfural **1n** (124 mg, 122 µL, 1.00 mmol) in water (4 mL, pH 6), *N*,*N*-dimethylhydrazine (72.0 mg, 91.2 mL, 1.20 mmol) was added and the mixture was stirred at 50 °C for 2 h. *N*-Ethyl maleimide **3a** (250 mg, 2.00 mmol) was added and the reaction stirred at 50 °C for 2 h. The mixture was cooled and the precipitate was collected by filtration, washed with cold water (2 x 25 mL) and dried to give **5n** as yellow needles (195 mg, 72%). R_f 0.10 (Pet. Ether 40-60/EtOAc, 4:1); M.p. 153-154 °C ($CDCl_3$); IR (film, cm^{-1}) 2938, 2864, 1748, 1691, 1546; ^{1}H NMR ($CDCl_3$; 600 MHz) 1.25 (3H, t, J = 7.1 Hz, $\mathrm{CH}_2\mathrm{C}H_3$), 2.36 (3H, s, Ar-$CH_3$), 2.61 (3H, s, Ar-$CH_3$), 3.09 (6H, s, 2 x CH_3), 3.69 (2H, q, J = 7.1 Hz, $\mathrm{C}H_2\mathrm{CH}_3$), 7.97 (1H, s, 6-H), 8.15 (1H, s, N=CH); ^{13}C NMR ($CDCl_3$; 151 MHz) 13.9 (CH_3), 14.1 (Ar-CH_3), 20.1 (Ar-CH_3), 32.6 (CH_2), 42.8 (2 x CH_3), 123.5 (C), 126.1 (N=CH), 129.0 (C), 129.3 (CH), 133.5 (C), 135.6 (C), 144.5 (C), 169.2 (C=O), 169.6 (C=O); *m/z* HRMS (ESI+) found $[MH]^+$ 274.1552, $C_{15}H_{20}N_3O_2$ requires 274.1556.

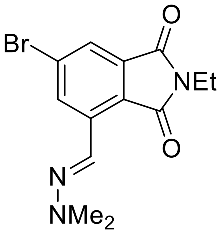
4-((2,2-Dimethylhydrazono)methyl)-2-ethyl-7-hydroxyisoindoline-1,3-dione 5o



To a solution of either 5-chloro-2-furaldehyde (131 mg, 1.0 mmol) or 5-bromo-2-furaldehyde (175 mg, 1.0 mmol) in water (4 mL, pH 6) *N*,*N*-dimethylhydrazine (78 mg, 99 µL, 1.3 mmol) was added and the mixture was stirred at 50 °C. After 2 h *N*-ethyl maleimide (125 mg, 1.0 mmol) was added and the reaction stirred at the same temperature with a precipitate forming within 5 min. After 2 h, the mixture was cooled to rt and the precipitate collected by filtration, washed with cold water (100 mL), and dried in vacuo to give **5o** as a brown-orange solid either from 5-chloro-2-furaldehyde (101 mg, 39%) or 5-bromo-2-furaldehyde (141 mg, 54%).

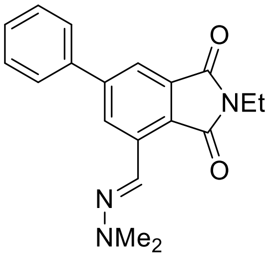
R_f = 0.45 (Pet. Ether 40-60/EtOAc, 9:1); IR (film, cm^{-1}) 3175, 2987, 2942, 2918, 1748, 1670, 1546, 1439; M.p. 164-166 °C (water); ^{1}H NMR ($CDCl_3$; 600 MHz) 1.26 (3H, t, *J* = 7.2 Hz, CH_2CH_3), 3.06 (6H, s, 2 x CH_3), 3.69 (2H, q, *J* = 7.2 Hz, CH_2CH_3), 7.06 (1H, d, *J* = 8.9 Hz, 6-H), 7.78 (1H, s broad, OH), 8.07 (1H, s, N=CH), 8.15 (1H, d, *J* = 8.9 Hz, 5-H); ^{13}C NMR ($CDCl_3$; 151 MHz) 14.0 (CH_3), 32.7 (CH_2), 42.8 (2 x CH_3), 113.5 (C), 123.2 (CH), 124.2 (C), 125.4 (C), 129.7 (C), 132.4 (CH), 153.7 (C), 168.6 (C=O), 170.4 (C=O); *m/z* HRMS (ESI+) found $[MH]^+$ 262.1192, $C_{13}H_{16}N_3O_3$ requires 262.1198.

6-Bromo-4-((2,2-dimethylhydrazono)methyl)-2-ethylisoindoline-1,3-dione 5p



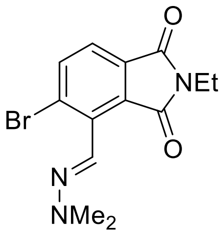
To a solution of 4-bromo-2-furaldehyde (175 mg, 1.0 mmol) in water (4 mL, pH 6) *N*,*N*-dimethylhydrazine (78 mg, 99 µL, 1.3 mmol) was added and the mixture was stirred at 50 °C. After 3.5 h *N*-ethyl maleimide (125 mg, 1.0 mmol) was added and the reaction stirred at the same temperature with a precipitate forming within 5 min. After 1.5 h, the mixture was cooled to rt and the precipitate collected by filtration, washed with cold water (100 mL), and dried in vacuo to give **5p** as a yellow solid (273 mg, 84%). R_f = 0.45 (Pet. Ether 40-60/EtOAc, 9:1); IR (film, cm^{-1}) 2918, 2864, 1751, 1696, 1586, 1431; M.p. 166-168 °C (water); ^{1}H NMR ($CDCl_3$; 600 MHz) 1.25 (3H, t, *J* = 7.2 Hz, CH_2CH_3), 3.14 (6H, s, 2 x CH_3), 3.69 (2H, q, *J* = 7.2 Hz, CH_2CH_3), 7.65 (1H, s, 6-H), 7.92 (1H, s, N=CH), 8.31 (1H, s, 7-H); ^{13}C NMR ($CDCl_3$; 151 MHz) 14.0 (CH_3), 32.9 (CH_2), 42.7 (2 x CH_3), 122.3 (N=CH), 123.0 (C), 123.6 (CH), 128.3 (C), 131.1 (CH), 134.1 (C), 137.9 (C), 167.2 (C=O), 168.7 (C=O); *m/z* HRMS (ESI+) found $[MH]^+$ 324.0343, $C_{13}H_{15}{}^{79}BrN_3O_2$ requires 324.0348.

4-((2,2-Dimethylhydrazono)methyl)-2-ethyl-6-phenylisoindoline-1,3-dione 5q



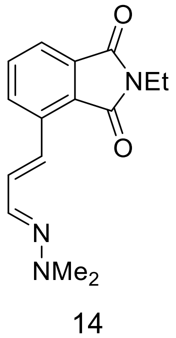
To a solution of 4-phenyl-2-furaldehyde (179 mg, 1.0 mmol) in water (4 mL, pH 6) *N*,*N*-dimethylhydrazine (78 mg, 99 µL, 1.3 mmol) was added and the mixture was stirred at 50 °C. After 4 h *N*-ethyl maleimide (250 mg, 2.0 mmol) was added and the reaction stirred at the same temperature with a precipitate forming within 5 min. After 4 h, the mixture was cooled to rt and the precipitate collected by filtration, washed with cold water (100 mL), and purified by flash column chromatography (Pet. Ether 40-60/EtOAc, 5:95) to give **5q** as a yellow solid (260 mg, 81%). R_f = 0.34 (Pet. Ether 40-60/EtOAc, 9:1); IR (film, cm^{-1}) 2979, 2921, 2868, 2850, 1752, 1694, 1549; M.p. 153-155 °C (EtOAc); ^1H NMR ($CDCl_3$; 600 MHz) 1.29 (3H, t, *J* = 7.2 Hz, CH_2CH_3), 3.14 (6H, s, 2 x CH_3), 3.74 (2H, q, *J* = 7.2 Hz, CH_2CH_3), 7.42 (1H, t, *J* = 7.4 Hz, Ph-4-H), 7.48 (2H, t, *J* = 7.6 Hz, Ph-3-H), 7.67 (2H, d, *J* = 7.4 Hz, Ph-2-H), 7.84 (1H, d, *J* = 1.2 Hz, 7-H), 8.13 (1H, s, N=CH), 8.43 (1H, d, *J* = 1.2 Hz, 5-H); ^{13}C NMR ($CDCl_3$; 151 MHz) 14.1 (CH_2CH_3), 32.9 (CH_2CH_3), 42.7 (2 x CH_3), 119.7 (7-CH), 123.6 (C), 124.6 (N=CH), 127.1 (5-CH), 127.5 (CH), 128.6 (CH), 129.1 (CH), 133.5 (C), 136.6 (C), 139.7 (C), 146.6 (C), 168.4 (C=O), 169.3 (C=O); *m/z* HRMS (ESI+) found $[MH]^+$ 322.1555, $C_{19}H_{20}N_3O_2$ requires 322.1556.

5-Bromo-4-((2,2-dimethylhydrazono)methyl)-2-ethylisoindoline-1,3-dione 5r



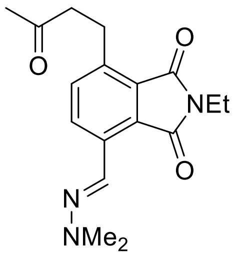
To a solution of 3-bromo-2-furaldehyde (175 mg, 1.0 mmol) in water (4 mL, pH 6) *N*,*N*-dimethylhydrazine (78 mg, 99 µL, 1.3 mmol) was added and the mixture was stirred at 50 °C. After 3.5 h *N*-ethyl maleimide (125 mg, 1.0 mmol) was added and the reaction stirred at the same temperature with a precipitate forming within 5 min. After 2.5 h, the mixture was cooled to rt and the precipitate collected by filtration, washed with cold water (100 mL), and dried in vacuo to give **5r** as a yellow solid (256 mg, 79%). R_f = 0.4 (Pet. Ether 40-60/EtOAc, 9:1); IR (film, cm^{-1}) 2921, 2864, 2792, 1758, 1693, 1546, 1437; M.p. 112-114 °C (water); ^1H NMR ($CDCl_3$; 600 MHz) 1.23 (3H, t, *J* = 7.2 Hz, NCH_2CH_3), 3.12 (6H, s, 2 x CH_3), 3.68 (2H, q, *J* = 7.2 Hz, OCH_2CH_3), 7.42 (1H, d, *J* = 7.8 Hz, 6-H), 7.80 (1H, s, N=CH), 7.86 (1H, d, *J* = 7.8 Hz, 7-H); ^{13}C NMR ($CDCl_3$; 151 MHz) 14.0 (CH_3), 33.1 (NCH_2CH_3), 42.5 (2 x CH_3), 120.9 (CH), 123.5 (N=CH), 126.5 (C), 128.2 (C), 131.9 (CH), 135.3 (CH), 139.4 (CH), 167.4 (C=O), 167.8 (C=O); *m/z* HRMS (ESI+) found $[MH]^+$ 324.0343, $C_{13}H_{15}{}^{79}BrN_3O_2$ requires 324.0348.

4-(3-(2,2-Dimethylhydrazono)prop-1-en-1-yl)-2-ethylisoindoline-1,3-dione 5s



To a solution of 2-furfurylacrolein **1k** (104 mg, 850 μmol) in water (4 mL, pH 6), *N*,*N*-dimethylhydrazine (61.3 mg, 77.6 μL, 1.02 mmol) was added and the mixture was stirred at 50 °C for 30 min. *N*-Ethyl maleimide **3a** (189 mg, 1.70 mmol) was added and the reaction stirred at 50 °C for 18 h. The mixture was cooled and the precipitate was collected by filtration, washed with cold water (2 x 25 mL) and dried to give **5k** as yellow needles (147 mg, 64%). R$_f$ 0.56 (Pet. Ether 40-60/EtOAc, 2:3); M.p. 145-146 °C ($CDCl_3$); IR (film, cm^{-1}) 2919, 2864, 1764, 1695, 1608; ^{1}H NMR ($CDCl_3$; 600 MHz) 1.26 (3H, t, *J* = 7.2 Hz, CH_2CH_3), 3.00 (6H, s, 2 x CH_3), 3.72 (2H, q, *J* = 7.2 Hz, CH_2CH_3), 7.12-7.19 (2H, m, C*H*C*H*CNNMe$_2$), 7.58 (1H, t, *J* = 7.3 Hz, 6-H), 7.64 (1H, d, *J* = 7.3 Hz, 7-H), 7.70 (1H, d, *J* = 14.3 Hz, N=CH), 7.88 (1H, d, *J* = 7.3 Hz, 5-H); ^{13}C NMR ($CDCl_3$; 151 MHz) 14.1 (CH_3), 32.9 (CH_2), 42.7 (2 x CH_3), 121.4 (CH), 123.7 (N=CH), 126.0 (C), 129.4 (CH), 132.7 (CH), 133.0 (C), 133.4 (CH), 133.6 (CH), 136.8 (C), 168.3 (C=O), 169.3 (C=O); *m/z* HRMS (ESI+) found [MH]$^+$ 272.1403, $C_{15}H_{18}N_3O_2$ requires 272.1399.

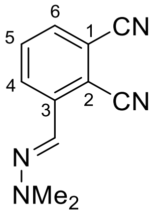
4-((2,2-Dimethylhydrazono)methyl)-2-ethyl-7-(3-oxobutyl)isoindoline-1,3-dione 5t



To a solution of 4-(5-((2,2-dimethylhydrazono)methyl)furan-2-yl)butan-2-one **2t** (208 mg, 1.00 mmol) in water (4 mL, pH 6), *N*-ethyl maleimide **3a** (250 mg, 2.00 mmol) was added and the reaction stirred at 50 °C for 4 h. The mixture was cooled and the precipitate was collected by filtration, washed with cold water (2 x 25 mL) and dried to give **5t** as yellow needles (184 mg, 58%). R$_f$ 0.32 (Pet. Ether 40-60/EtOAc, 4:1); M.p. 132-133 °C (H_2O); IR (film, cm^{-1}) 2936, 1754, 1694, 1545, 1441; ^{1}H NMR ($CDCl_3$; 600 MHz) 1.26 (3H, t, *J* = 7.2 Hz, CH_2CH_3), 2.16 (3H, s, C(O)CH_3), 2.82 (2H, t, *J* = 7.6 Hz, C*H*$_2$C(O)Me), 3.10 (6H, s, 2 x CH_3), 3.28 (2H, t, *J* = 7.6 Hz, ArCH_2), 3.70 (2H, q, *J* = 7.2 Hz, CH_2CH_3), 7.37 (1H, d, *J* = 8.4 Hz, 6-H), 8.11 (1H, d, *J* = 8.4 Hz, 5-H), 8.13 (1H, s, N=CH); ^{13}C NMR ($CDCl_3$; 151 MHz) 14.1 (CH_2CH_3), 25.8 (CH_2), 30.0 (C(O)CH_3), 32.7 (CH_2CH_3), 42.8 (2 x CH_3), 44.3 (CH_2), 125.2 (C), 125.4 (C), 128.6 (C), 129.2 (CH), 134.8 (CH), 135.7 (CH), 138.9 (C), 168.9 (C=O), 169.3 (C=O); *m/z* HRMS (ESI+) found [MH]$^+$ 316.1653, $C_{17}H_{23}N_3O_3$ requires 316.1661.

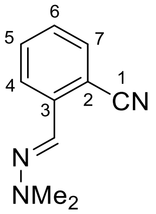
4. Preparation of Aromatics 8

3-((2,2-Dimethylhydrazono)methyl)phthalonitrile 8a[4]



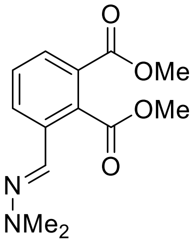
To a solution of 2-furaldehyde dimethylhydrazone **2a** (48.6 mg, 46.4 μL, 350 μmol) in water (2 mL, pH 6), fumaronitrile **7a** (54.6 mg, 700 μmol) was added and the reaction stirred at reflux for 48 h. The mixture was cooled to rt and the organic component extracted with ethyl acetate (3 x 50 mL), dried with $MgSO_4$, and the solvent removed under vacuum. The crude reaction mixture was dry-loaded onto silica and purified by flash column chromatography (Pet. Ether 40-60/EtOAc, 5:95) to give **8a** as pale green needles (47.6 mg, 68%). R_f 0.22 (Pet. Ether 40-60/EtOAc, 17:3); M.p. 168-169 °C (EtOAc), Lit[1] 165-166 °C ($CHCl_3$); IR (film, cm^{-1}) 2219, 1570, 1546; ^1H NMR ($CDCl_3$; 600 MHz) 3.16 (6H, s, 2 x CH_3), 7.29 (1H, s, N=CH), 7.52 (1H, dd, *J* = 7.4, 1.4 Hz, 6-H), 7.55 (1H, m, 5-H), 8.19 (1H, dd, *J* = 8.0, 1.4 Hz, 4-H); ^{13}C NMR ($CDCl_3$; 151 MHz) 42.7 (2 x CH_3), 110.7 (C), 115.0 (C), 116.1 (CN), 116.2 (CN), 122.3 (CH), 128.3 (CH), 130.5 (CH), 132.4 (CH), 142.6 (C); *m/z* HRMS (ESI+) found $[MH]^+$ 199.0979, $C_{11}H_{11}N_4$ requires 199.0984.

3-((2,2-Dimethylhydrazono)methyl)benzonitrile 8b



To a solution of 2-furaldehyde dimethylhydrazone **2a** (48.6 mg, 46.4 μL, 350 μmol) in water (2 mL, pH 6), acrylonitrile **7b** (35.9 mg, 46.4 μL, 700 μmol) was added and the reaction stirred at reflux for 24 h. The mixture was cooled to rt and the organic component extracted with ethyl acetate (3 x 50 mL), dried with $MgSO_4$, and the solvent removed under vacuum. The crude reaction mixture was dry-loaded onto silica and purified by flash column chromatography (Pet. Ether 40-60/EtOAc, 5:95) to give **8b** as a pale green oil (8.5 mg, 24%). R_f 0.66, 0.74 (Pet. Ether 40-60/EtOAc, 3:2); IR (film, cm^{-1}) 2219, 1570; ^1H NMR ($CDCl_3$; 600 MHz) 3.09 (6H, s, 2 x CH_3), 7.21 (1H, t, *J* = 7.8 Hz, 5-H), 7.37 (1H, s, N=CH), 7.48 (1H, t, *J* = 7.8 Hz, 6-H), 7.56 (1H, d, *J* = 7.8 Hz, 7-H), 7.95 (1H, d, *J* = 7.8 Hz, 4-H); ^{13}C NMR ($CDCl_3$; 151 MHz) 42.7 (2 x CH_3), 109.0 (C), 118.3 (CN), 124.4 (C), 125.7 (CH), 126.6 (CH), 132.7 (CH), 132.8 (CH), 140.4 (C); *m/z* HRMS (ESI+) found $[MH]^+$ 174.1023, $C_{10}H_{12}N_2$ requires 174.1031.

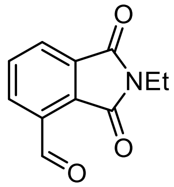
Dimethyl-3-((2,2-dimethylhydrazono)methyl)phthalate 8c



To a solution of furfural **1a** (96.1 mg, 82.9 μL, 1.00 mmol) in water (2 mL, pH 6), *N*,*N*-dimethylhydrazine (72.1 mg, 91.4 μL, 1.20 mmol) was added and the mixture was stirred at 50 °C for 30 min. Dimethyl maleate **7c** (288 mg, 250 μL, 2.00 mmol) was added and the reaction stirred at reflux for 24 h. The mixture was cooled to rt and the organic component extracted with ethyl acetate (3 x 50 mL), dried with $MgSO_4$, and the solvent removed under vacuum. The crude reaction mixture was dry-loaded onto silica and purified by flash column chromatography (Pet. Ether 40-60/EtOAc, 5:95) to give **8c** as a yellow oil (44.8 mg, 19%). R_f 0.39 (Pet. Ether 40-60/EtOAc, 3:2); IR (film, cm^{-1}) 1721 (str), 1555; ^1H NMR ($CDCl_3$; 600 MHz) 2.99 (6H, s, 2 x CH_3), 3.88 (3H, s, OCH_3), 3.93 (3H, s, OCH_3), 7.12 (1H, s, N=CH), 7.40 (1H, t, *J* = 7.9 Hz, 5-H), 7.81 (1H, dd, *J* = 7.9, 1.1 Hz, 6-H), 8.02 (1H, dd, *J* = 7.9, 1.1 Hz, 4-H); ^{13}C NMR ($CDCl_3$; 151 MHz) 42.7 (2 x CH_3), 52.6 (OCH_3), 52.7 (OCH_3), 127.1 (N=CH), 128.4 (C), 128.4 (CH), 129.3 (CH), 129.5 (CH), 132.4 (C), 134.9 (C), 136.4 (C), 166.5 (C=O), 169.7 (C=O); *m/z* HRMS (ESI+) found $[MH]^+$ 265.1182, $C_{13}H_{17}N_2O_4$ requires 265.1188.

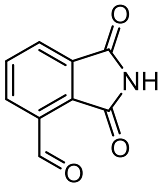
5. Preparation of Aldehydes 9

2-Ethyl-1,3-dioxoisoindoline-4-carbaldehyde 9a



To a solution of 4-((2,2-dimethylhydrazono)methyl)-2-ethylisoindoline-1,3-dione **5a** (245 mg, 1.00 mmol) in acetone (30 mL), Amberlyst® 15 (1.00g) was added, and the mixture was stirred at rt for 3 h. The Amberlyst was removed by filtration and the solvent removed under vacuum to give **9a** as an off-white solid (192 mg, 94%). R$_f$ 0.44 (Pet. Ether 40-60/EtOAc, 2:1); M.p. 126-127 °C (Acetone); IR (film, cm^{-1}) 1773, 1692, 1610; ^{1}H NMR (CDCl$_3$; 600 MHz) 1.31 (3H, t, *J* = 7.3 Hz, CH$_2$C*H*$_3$), 3.80 (2H, q, *J* = 7.3 Hz, C*H*$_2$CH$_3$), 7.84 (1H, t, *J* = 7.5 Hz, 6-H), 8.02 (1H, d, *J* = 7.5 Hz, 7-H), 8.24 (1H, d, *J* = 7.5 Hz, 5-H), 11.05 (1H, s, CHO); ^{13}C NMR (CDCl$_3$; 151 MHz) 14.0 (CH$_3$), 33.4 (CH$_2$), 128.0 (CH), 131.4 (CH), 132.3 (C), 133.1 (C), 133.7 (C), 134.3 (CH), 167.3 (C=O), 167.7 (C=O), 188.9 (CHO); *m/z* HRMS (ESI+) found [MH]$^+$ 204.0652, $C_{11}H_{10}NO_3$ requires 204.0661.

1,3-Dioxoisoindoline-4-carbaldehyde 9b

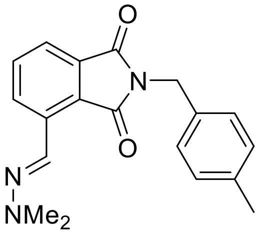


To a solution of 4-((2,2-dimethylhydrazono)methyl)isoindoline-1,3-dione **5b** (217 mg, 1.00 mmol) in acetone (70 mL), Amberlyst® 15 (1.00g) was added, and the mixture was stirred at rt for 3 h. The Amberlyst was removed by filtration and the solvent removed under vacuum to give **9b** as a pale yellow solid (169 mg, 97%). R$_f$ 0.60 (Pet. Ether 40-60/EtOAc, 2:1); M.p. 226 °C (Acetone); IR (film, cm^{-1}) 3212 (br, NH), 1773, 1700, 1610; ^{1}H NMR (acetone-d$_6$; 600 MHz) 8.01 (1H, t, *J* = 7.3 Hz, 6-H), 8.13 (1H, d, *J* = 7.3 Hz, 7-H), 8.22 (1H, d, *J* = 7.3 Hz, 5-H), 10.41 (1H, s br, NH), 10.97 (1H, s, CHO); ^{13}C NMR (acetone-d$_6$; 151 MHz) 128.6 (CH), 131.5 (CH), 134.0 (C), 134.7 (C), 135.0 (C), 135.4 (CH), 168.5 (C=O), 169.3 (C=O), 189.3 (CHO); *m/z* HRMS (ESI+) found [MH]$^+$ 176.0344, $C_9H_6NO_3$ requires 176.0348.

6. Transamidation Reactions

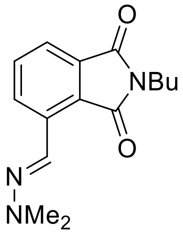
General Boric Acid Transamidation Procedure: To a solution of 4-((2,2-dimethylhydrazono)methyl)isoindoline-1,3-dione **5b** (229 mg, 1.00 mmol) and boric acid (6.2 mg, 0.1 mmol) in toluene (0.2 mL) and 1,4-dioxane (0.2 mL), water (36 μL, 2.0 mmol) and amine (2 or 5 mmol) were added and the mixture was stirred at 100 °C. After 72 h the mixture was cooled to rt and IRA 743 scavenger (approximately 1 g) and water (0.2 mL) were added, and the mixture stirred for a further 1 h. The scavenger resin was removed by filtration and the filtrate collected and the solvent removed under vacuum. The crude product was dry-loaded onto silica and purified by flash column chromatography (Pet. Ether 40-60/EtOAc, 5:95) to give the product.

4-((2,2-Dimethylhydrazono)methyl)-2-(4-methylbenzyl)isoindoline-1,3-dione 5e



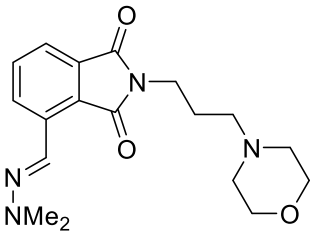
Following the general boric acid procedure with p-tolylmethanamine (255 μL, 2.00 mmol) gave **5e** as a yellow solid (241 mg, 75%). Experimental data as before.

2-Butyl-4-((2,2-dimethylhydrazono)methyl)isoindoline-1,3-dione 5u



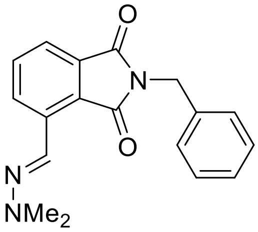
Following the general boric acid procedure with *n*-butylamine (198 μL, 2.00 mmol) gave a **5u** as a yellow solid (252 mg, 92%). R_f 0.41 (Pet. Ether 40-60/EtOAc, 4:1); M.p. 91-92 °C (EtOAc); IR (film, cm^{-1}) 1760, 1696, 1547; ^1H NMR ($CDCl_3$; 600 MHz) 0.92 (3H, t, *J* = 7.3 Hz, CH_3), 1.37 (2H, sx, *J* = 7.3 Hz, CH_2), 1.65 (2H, qn, *J* = 7.3 Hz, CH_2), 3.12 (6H, s, 2 x CH_3), 3.65 (2H, t, *J* = 7.3 Hz, CH_2), 7.55 (1H, t, *J* = 7.6 Hz, 6-H), 7.60 (1H, d, *J* = 7.6 Hz, 7-H), 8.11 (1H, s, N=CH), 8.22 (1H, d, *J* = 7.6 Hz, 5-H); ^{13}C NMR ($CDCl_3$; 151 MHz) 13.8 (CH_3), 20.3 (CH_2), 30.8 (CH_2), 37.8 (CH_2), 42.7 (2 x CH_3), 120.9 (CH), 124.7 (N=CH), 124.8 (C), 128.9 (C), 132.5 (C), 133.3 (CH), 136.3 (C), 168.7 (C=O), 169.7 (C=O); *m/z* HRMS (ESI+) found $[MH]^+$ 274.1551, $C_{15}H_{20}N_3O_2$ requires 274.3382.

4-((2,2-Dimethylhydrazono)methyl)-2-(3-morpholinopropyl)isoindoline-1,3-dione 5v



Following the general boric acid procedure with 3-morpholinopropylamine (292 µL, 2.00 mmol) gave **5v** as a yellow solid (269 mg, 78%). R$_f$ 0.17 (Pet. Ether 40-60/EtOAc, 1:2); M.p. 98-99 °C (Water); IR (film, cm^{-1}) 1759, 1697, 1596, 1547; ^{1}H NMR (CDCl$_3$; 600 MHz) 1.87 (2H, t, J = 6.8 Hz, CH$_2$), 2.42 (6H, m, CH$_2$ and 2 x morpholine CH$_2$), 3.12 (6H, s, 2 x CH$_3$), 3.58 (4H, m, 2 x morpholine CH$_2$), 3.74 (2H, t, J = 6.9 Hz, CH$_2$), 7.56 (1H, t, J = 7.5 Hz, 6-H), 7.60 (1H, d, J = 7.5 Hz, 7-H), 8.10 (1H, s, N=CH), 8.23 (1H, d, J = 7.5 Hz, 5-H); ^{13}C NMR (CDCl$_3$; 151 MHz) 13.9 (CH$_3$), 20.4 (CH$_2$), 30.9 (CH$_2$), 37.9 (CH$_2$), 42.8 (2 x CH$_3$), 121.0 (CH), 124.8 (N=CH), 124.9 (C), 129.0 (C), 132.6 (C), 133.4 (CH), 136.4 (C), 168.8 (C=O), 169.8 (C=O); *m/z* HRMS (ESI+) found [MH]$^+$ 345.1924, C$_{18}$H$_{24}$N$_4$O$_3$ requires 345.1927.

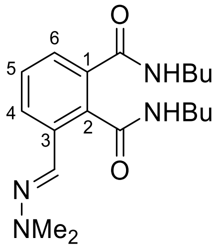
2-Benzyl-4-((2,2-dimethylhydrazono)methyl)isoindoline-1,3-dione 5w



Following the general boric acid procedure with benzylamine (219 µL, 2.00 mmol) gave **5w** as a yellow solid (191 mg, 62%). R$_f$ 0.29 (Pet. Ether 40-60/EtOAc, 4:1); M.p. 136-138 °C (water); IR (film, cm^{-1}) 1754, 1696, 1546; ^{1}H NMR (CDCl$_3$; 600 MHz) 3.12 (6H, s, 2 x CH$_3$), 4.83 (2H, s, CH$_2$), 7.27 (1H, t, J = 7.5 Hz, Ph-4), 7.32 (2H, t, J = 7.5 Hz, Ph-3), 7.43 (2H, d, J = 7.5 Hz, Ph-2-H), 7.56 (1H, t, J = 7.6 Hz, 6-H), 7.63 (1H, d, J = 7.6 Hz, 7-H), 8.09 (1H, s, N=CH), 8.23 (1H, d, J = 7.6 Hz, 5-H); ^{13}C NMR (CDCl$_3$; 151 MHz) 41.5 (CH$_2$), 42.7 (2 x CH$_3$), 121.0, 124.5, 124.7, 127.9, 128.6, 128.8, 129.1, 132.4, 133.5, 136.6, 136.7, 168.3 (C=O), 169.2 (C=O); *m/z* HRMS (ESI+) found [MH]$^+$ 308.0831, C$_{18}$H$_{18}$N$_3$O$_2$ requires 308.1399.

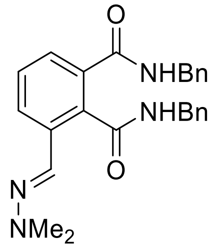
7. Preparation of Diamides 10

***N*,*N*-Dibutyl-3-((2,2-dimethylhydrazono)methyl)phthalamide 10a**



A solution of 4-((2,2-dimethylhydrazono)methyl)-2-ethylisoindoline-1,3-dione **5a** (245 mg, 1.00 mmol) in butylamine (4 mL) was stirred for 3 h at rt and then added to water (40 mL). A yellow precipitate formed, the solution was cooled on ice and the precipitate collected by filtration, washed with cold water (2 x 50 mL) and dried to give **10a** (313 mg, 96%) as yellow needles. R_f 0.47 (Pet. Ether 40-60/EtOAc, 2:1); M.p. 132-133 °C (water); IR (film, cm^{-1}) 3258 (br, NH), 1630, 1554, 1458; ^{1}H NMR ($CDCl_3$; 600 MHz) 0.932 (3H, t, *J* = 7.4 Hz, CH_3), 0.935 (3H, t, *J* = 7.4 Hz, CH_3), 1.379 (2H, sx, *J* = 7.4 Hz, CH_2), 1.383 (2H, sx, *J* = 7.4 Hz, CH_2), 1.53 (2H, qn, *J* = 7.4 Hz, CH_2), 1.55 (2H, qn, *J* = 7.4 Hz, CH_2), 2.98 (6H, s, 2 x CH_3), 3.35 (2H, m, NCH_2), 3.40 (2H, m, NCH_2), 6.07 (1H, br t, *J* = 5.0 Hz, NH), 6.51 (1H, br t, *J* = 5.0 Hz, NH), 7.18 (1H, s, N=CH), 7.34 (1H, t, *J* = 7.6 Hz, 5-H), 7.46 (1H, d, *J* = 7.6 Hz, 6-H), 7.95 (1H, d, *J* = 7.6 Hz, 4-H); ^{13}C NMR ($CDCl_3$; 151 MHz) 13.8 (CH_3), 13.9 (CH_3), 20.2 (CH_2), 20.3 (CH_2), 31.57 (CH_2), 31.61 (CH_2), 40.0 (CH_2), 40.1 (CH_2), 42.7 (2 x CH_3), 126.6 (CH), 126.9 (CH), 127.8 (CH), 129.3 (CH), 132.7 (C), 134.2 (C), 134.5 (C), 168.5 (C=O), 169.8 (C=O); *m/z* HRMS (ESI+) found $[MH]^+$ 347.2442, $C_{19}H_{31}N_4O_2$ requires 347.2447.

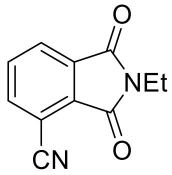
***N*,*N*-Dibenzyl-3-((2,2-dimethylhydrazono)methyl)phthalamide 10b**



A solution of 4-((2,2-dimethylhydrazono)methyl)-2-ethylisoindoline-1,3-dione **5a** (245 mg, 1.00 mmol) in benzylamine (4 mL) was stirred for 3 h at rt and then added to water (40 mL). A yellow precipitate formed, the solution was cooled on ice and the precipitate collected by filtration, washed with cold water (2 x 50 mL), dried, and purified by flash column chromatography (Pet. Ether 40-60/EtOAc, 95:5) to give **10b** (311mg, 75%) as yellow needles. R_f 0.53 (Pet. Ether 40-60/EtOAc, 2:1); M.p. 184-185 °C (EtOAc); IR (film, cm^{-1}) 3254 (br, NH), 1636, 1554, 1496; ^{1}H NMR ($(CD_3)_2SO$; 600 MHz) 2.73 (6H, s, 2 x CH_3), 4.33 (2H, d, *J* = 5.8 Hz, NCH_2), 4.41 (2H, d, *J* = 5.8 Hz, NCH_2), 7.01 (1H, s, N=CH); 7.23 (2H, t, *J* = 6.3 Hz, 2 x Ph-3-H) 7.27-7.40 (9H, m, 8 x Ph-H and 5-H), 7.42 (1H, d, *J* = 7.6 Hz, 6-H), 7.87 (1H, d, *J* = 7.6 Hz, 4-H), 8.61 (1H, br t, *J* = 5.8 Hz, NH), 8.81 (1H, br t, *J* = 5.8 Hz, NH); ^{13}C NMR (($(CD_3)_2SO$; 151 MHz) 42.1 (2 x CH_3), 42.5 (CH_2), 42.6 (CH_2), 125.0 (CH), 125.7 (CH), 126.7 (CH), 126.8 (CH), 127.2 (CH), 127.5 (CH), 127.8 (CH), 128.1 (CH), 128.2 (CH), 133.7 (C), 134.7 (C), 134.8 (C), 139.4 (C), 167.4 (C=O), 167.6 (C=O); *m/z* HRMS (ESI+) found $[MH]^+$ 415.1837, $C_{25}H_{27}N_4O_2$ requires 415.2134.

8. Preparation of Nitrile 11

2-Ethyl-1,3-dioxoisoindoline-4-carbonitrile 11a

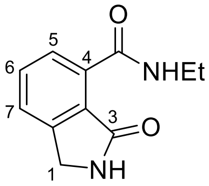


To a solution of 4-((2,2-dimethylhydrazono)methyl)-2-ethylisoindoline-1,3-dione **5a** (245 mg, 1.00 mmol) in methanol (10 mL) on ice, magnesium monoperoxyphthalate hexahydrate (1.23 g, 2.50 mmol) was added and the reaction stirred for 5 min. To the reaction mixture, water (20 mL) was added, and the organic component extracted with ethyl acetate (3 x 100 mL), dried with $MgSO_4$, and the solvent removed under vacuum, giving **11a** as a white solid (194 mg, 97%). R_f 0.34 (Pet. Ether 40-60/EtOAc, 3:2); M.p. 158-159 °C (EtOAc); IR (film, cm^{-1}) 2239 (C≡N), 1777, 1704; ^{1}H NMR ($CDCl_3$; 600 MHz) 1.30 (3H, t, *J* = 7.3 Hz, CH_2CH_3), 3.79 (2H, q, *J* = 7.3 Hz, CH_2CH_3), 7.85 (1H, t, *J* = 7.6 Hz, 6-H), 7.97 (1H, dd, *J* = 7.6, 1.1 Hz, 7-H), 8.07 (1H, dd, *J* = 7.6, 1.1 Hz, 5-H); ^{13}C NMR ($CDCl_3$; 151 MHz) 13.9 (CH_3), 33.7 (CH_2), 107.8 (C), 114.4 (C), 127.2 (CH), 133.4 (C), 133.5 (C), 134.6 (CH), 137.8 (CH) 165.2 (C=O), 166.4 (C=O); *m/z* HRMS (ESI+) found $[MH]^+$ 201.0659, $C_{11}H_9N_2O_2$ requires 201.0664.

9. Preparation of Lactams 12

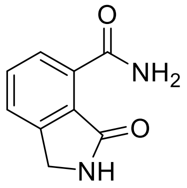
General Lactam Procedure: To a solution of phthalimide hydrazone in water, Pd/C (10%, 50% wet) was added and the reaction vessel evacuated under vacuum and filled with argon. Methanol was added and the reaction vessel evacuated once more and put under hydrogen using a balloon. Formic acid (2 equivalents) was added and the reaction mixture stirred at room temperature for 16 h. The reaction mixture was filtered through Celite and the solution collected. The organic component was extracted with ethyl acetate (3 x 50 mL). H_2SO_4 was added (2 equivalents) and the reaction mixture stirred for 5 min. A white precipitate formed and was collected by filtration, washed with cold ethyl acetate (100 mL), and dried in vacuo, giving the product.

N-Ethyl-3-oxoisoindoline-4-carboxamide 12a



Following the general lactam procedure with 4-((2,2-dimethylhydrazono)methyl)-2-ethylisoindoline-1,3-dione **5a** (245 mg, 1.00 mmol), Pd/C (20 mg), in water (7 mL) and methanol (14 mL) gave **12a** as white crystals (188 mg, 92%). R_f 0.30 (CH_3OH/EtOAc, 4:1); M.p. decomposed at 205-210 °C; IR (film, cm^{-1}) 2879, 1769, 1697; ^1H NMR (CD_3OD; 600 MHz) 1.27 (3H, t, J = 7.3 Hz, CH_2CH_3), 3.74 (2H, q, J = 7.3 Hz, CH_2CH_3), 4.58 (2H, s, CH_2), 7.83 (1H, d, J = 7.5 Hz, 7-H), 7.86 (1H, t, J = 7.5 Hz, 6-H), 7.93 (1H, d, J = 7.5 Hz, 5-H); ^{13}C NMR (CD_3OD; 151 MHz) 14.0 (CH_3), 33.9 (CH_2), 39.8 (CH_2), 125.0 (CH), 131.3 (C), 132.4 (C), 134.2 (C), 135.9 (CH), 136.5 (CH), 168.9 (C=O), 170.0 (C=O); *m/z* HRMS (ESI+) found $[MH]^+$ 205.1094, $C_{11}H_{13}N_3O_2$ requires 205.0977.

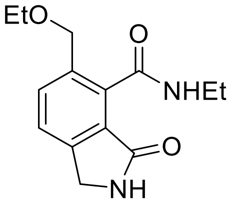
3-Oxoisoindoline-4-carboxamide 12b[6]



Following the general lactam procedure with 4-((2,2-dimethylhydrazono)methyl)isoindoline-1,3-dione **5b** (217 mg, 1.00 mmol), Pd/C (20 mg), in water (7 mL) and methanol (14 mL) gave **12b** as white crystals (173 mg, 98%). R_f 0.28 (CH_3OH/EtOAc, 4:1); M.p. decomposed at 205-210 °C (EtOAc); IR (film, cm^{-1}) 3038 (br), 2925 (br), 1763, 1699, 1600, 1515; ^1H NMR (CD_3OD; 600 MHz) 4.56 (2H, s, CH_2), 7.83 (1H, dd, J = 7.3, 1.7 Hz, 7-H), 7.86 (1H, t, J = 7.3 Hz, 6-H), 7.90 (1H, dd, J = 7.3, 1.7 Hz, 5-H); ^{13}C NMR (CD_3OD; 151 MHz) 39.9 (CH_2), 125.1

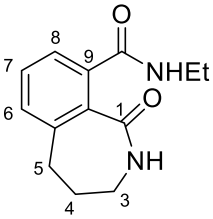
(CH), 132.0 (C), 132.5 (C), 135.1 (C), 136.0 (CH), 136.6 (CH), 170.1 (C=O), 171.3 (C=O); *m/z* HRMS (ESI+) found $[MH]^+$ 177.0657, $C_9H_9N_2O_2$ requires 177.0664.

5-(Ethoxymethyl)-*N*-ethyl-3-oxoisoindoline-4-carboxamide 12c



Following the general lactam procedure with 4-((2,2-dimethylhydrazono)methyl)-7-(ethoxymethyl)-2-ethylisoindoline-1,3-dione **5j** (60.6 mg, 200 µmol), Pd/C (10 mg), in water (3 mL) and methanol (6 mL) gave **12c** as white crystals (33 mg, 62%). R_f 0.35 (CH_3OH/EtOAc, 4:1); M.p. decomposed at 115-120 °C (EtOAc);IR (film, cm^{-1}) 1764, 1697, 1598, 1504; ^1H NMR (CD_3OD; 600 MHz) 1.23-1.29 (6H, m, NCH_2CH_3 and OCH_2CH_3), 3.67 (2H, q, J = 7.2 Hz, NCH_2CH_3), 3.71 (2H, q, J = 7.3 Hz, OCH_2CH_3), 4.55 (2H, s, $ArCH_2N$), 4.99 (2H, s, $ArCH_2O$), 7.78 (1H, d, J = 8.0 Hz, 7-H), 7.92 (1H, d, J = 8.0 Hz, 6-H); ^{13}C NMR (CD_3OD; 151 MHz) 14.0 (CH_3), 15.4 (CH_3), 33.8 (CH_2), 39.8 (CH_2), 67.7 (CH_2), 68.1 (CH_2), 129.8 (C), 131.1 (C), 131.4 (C), 134.5 (CH), 136.5 (CH), 140.9 (C), 169.0 (C=O), 169.9 (C=O); *m/z* HRMS (ESI+) found $[MH]^+$ 263.1389, $C_{14}H_{19}N_2O_3$ requires 263.1396.

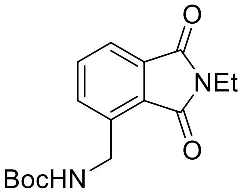
***N*-Ethyl-1-oxo-2,3,4,5-tetrahydro-1H-benzo[c]azepine-9-carboxamide 12d**



Following the general lactam procedure with 4-(3-(2,2-dimethylhydrazono)prop-1-en-1-yl)-2-ethylisoindoline-1,3-dione **5s** (135 mg, 500 µmol), Pd/C (20 mg), in water (3 mL) and methanol (6 mL) gave **12d** as white crystals (52 mg, 45%). R_f 0.11 (CH_3OH/EtOAc, 4:1); M.p. 124-126 °C (EtOAc); IR (film, cm^{-1}) 2942 (w, br), 1767, 1697, 1657, 1556; ^1H NMR (CD_3OD; 600 MHz) 1.23 (3H, t, J = 7.2 Hz, CH_2CH_3), 2.02 (2H, qn, J = 7.7 Hz, 4-H_2), 2.99 (2H, t, J = 7.7 Hz, 5-H_2), 3.17 (2H, t, J = 7.7 Hz, 3-H_2), 3.68 (2H, q, J = 7.2 Hz, CH_2CH_3), 7.61 (1H, dd, J = 6.8, 1.7 Hz, 8-H), 7.67-7.73 (2H, m, 6-H and 7-H), 8.53 (1H, br s, N*H*Et); ^{13}C NMR (CD_3OD; 151 MHz) 14.1 (CH_3), 29.0 (CH_2), 29.9 (CH_2), 33.6 (CH_2), 40.2 (CH_2), 122.5 (CH), 129.9 (C), 134.2 (C), 135.3 (CH), 136.7 (CH), 141.6 (C), 169.4 (C=O), 170.2 (C=O); *m/z* HRMS (ESI+) found $[MH]^+$ 233.1285, $C_{13}H_{17}N_2O_2$ requires 233.1290.

10. Preparation of Boc-Protected Amine 13

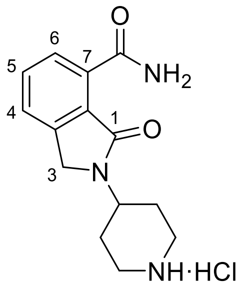
Tert-butyl-((2-ethyl-1,3-dioxoisoindolin-4-yl)methyl)carbamate 13



To a solution of 4-((2,2-dimethylhydrazono)methyl)-2-ethylisoindoline-1,3-dione **5a** (245 mg, 1.00 mmol) in water (7 mL), Pd/C (10%, 50% wet, 20 mg) was added and the reaction vessel evacuated under vacuum and filled with argon. Methanol (14 mL) was added and the reaction vessel evacuated once more and put under hydrogen using a balloon. Formic acid (92.0 mg, 75.4 µL, 2.00 mmol) was added and the reaction mixture stirred at room temperature for 16 h. The reaction mixture was filtered through Celite and the solution collected. Solid $NaHCO_3$ was slowly added until the solution was alkaline, then di-*tert*-butyl dicarbonate (1.09 g, 1.15 mL, 5.00 mmol) added and the reaction stirred at rt for 4 h. The organic component was extracted with ethyl acetate (3 x 100 mL), dried with $MgSO_4$, and the solvent removed under vacuum. The crude product was dry-loaded onto silica and purified by flash column chromatography (Pet. Ether 40-60/EtOAc, 5:95), giving **13a** as a yellow oil (234 mg, 77%). R_f 0.46 (Pet. Ether 40-60/EtOAc, 3:2); IR (film, cm^{-1}) 1807, 1770, 1704, 1508; ^1H NMR ($CDCl_3$; 600 MHz) 1.25 (3H, t, *J* = 7.3 Hz, CH_2CH_3), 1.39 (9H, s, $C(CH_3)_3$), 3.70 (2H, q, *J* = 7.3 Hz, CH_2CH_3), 4.61 (2H, d, *J* = 6.5 Hz, $ArCH_2$), 5.63 (1H, br t, *J* = 6.5 Hz, NH), 7.61 (1H, t, *J* = 7.4 Hz, 6-H), 7.66 (1H, d, *J* = 7.4 Hz, 7-H), 7.71 (1H, d, *J* = 7.4 Hz, 5-H); ^{13}C NMR ($CDCl_3$; 151 MHz) 14.0 (CH_3), 28.5 ($C(CH_3)_3$), 33.0 (CH_2CH_3), 40.9 ($ArCH_2$), 79.7 ($C(CH_3)_3$), 122.3 (CH), 128.9 (C), 132.9 (C), 134.1 (CH), 134.6 (CH), 138.5 (C), 156.0 ($C(O)O^tBu$), 168.2 (C=O), 169.1 (C=O); *m/z* HRMS (ESI+) found $[MH]^+$ 305.1493, $C_{16}H_{21}N_2O_4$ requires 305.1501.

11. Preparation of 14

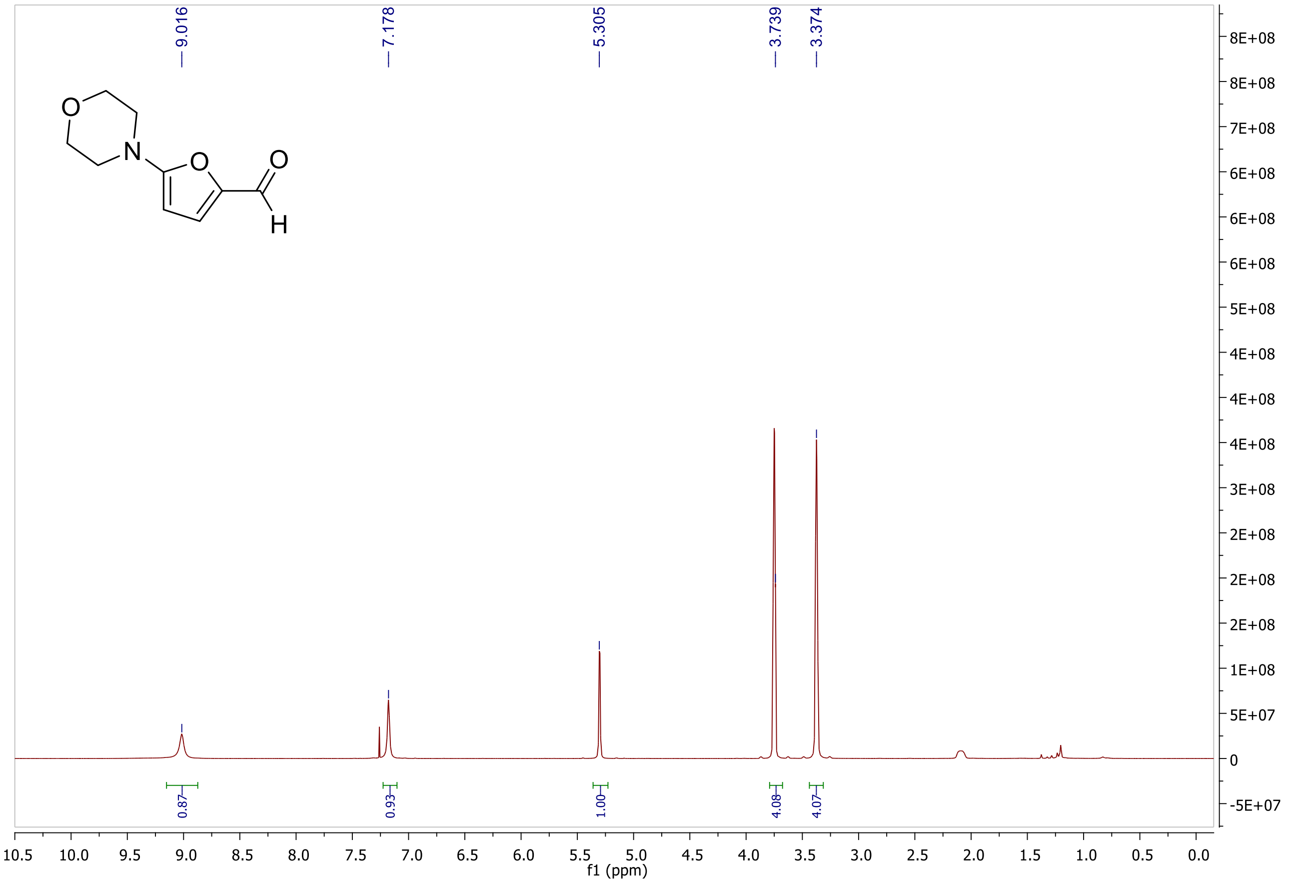
4-(7-carbamoyl-1-oxoisoindolin-2-yl)piperidin-1-ium chloride 14·HCl

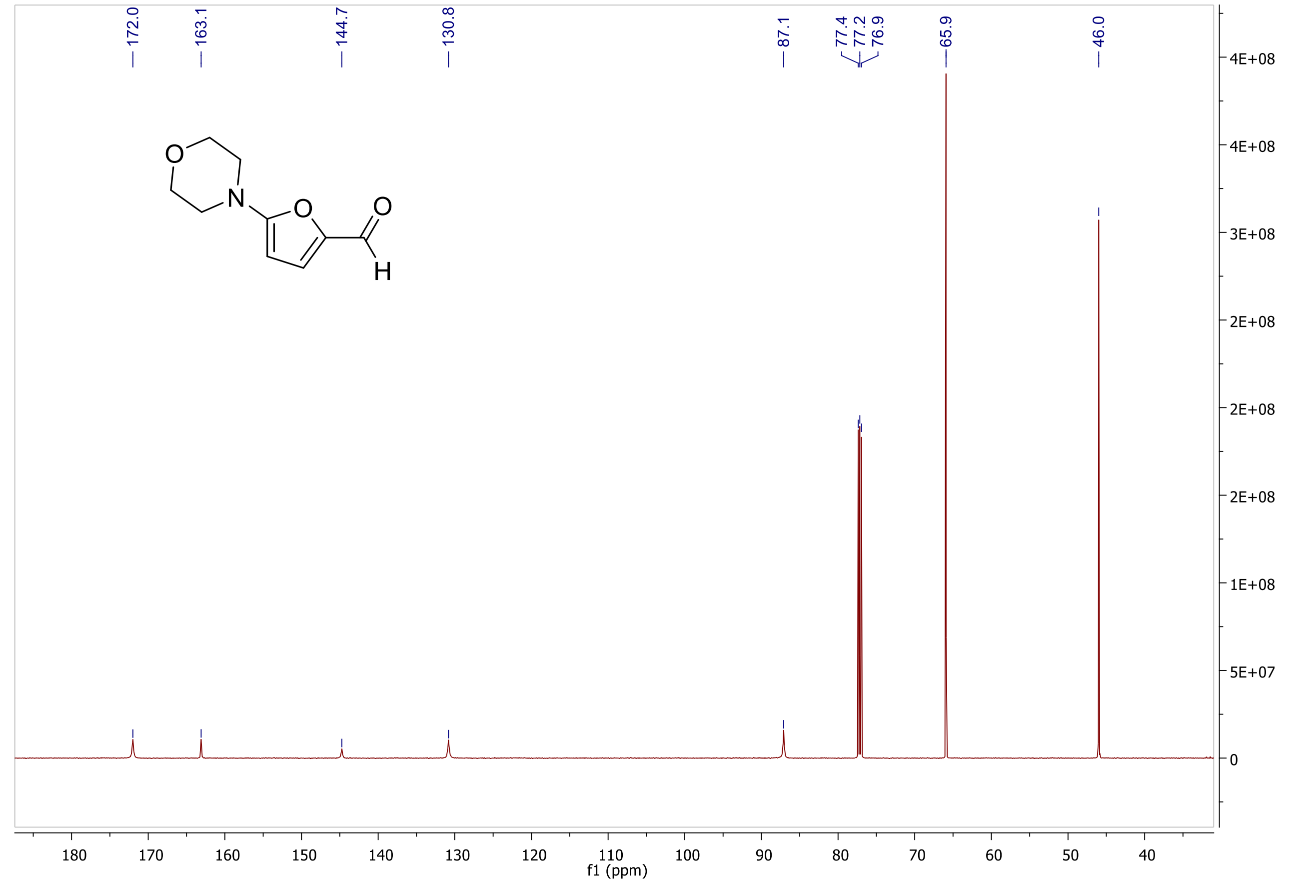


To a dry flask, 1,3-dioxoisoindoline-4-carbaldehyde **9b** (1.05 g, 6.00 mmol), *tert*-butyl 4-aminopiperidine-1-carboxylate **15** (1.20 g, 6.00 mmol), and dry THF (15 mL) were added and the flask sealed, evacuated, filled with nitrogen, and fitted with a nitrogen balloon. The mixture was stirred at rt and tris-(2,2,2-trifluoroethyl) borate (1.85 g, 1.30 mL, 6.00 mmol) added dropwise, then stirred for a further 2 h. Sodium cyanoborohydride (754 mg, 12.0 mmol) was dissolved in THF (5 mL) and added to the reaction mixture, followed by acetic acid (721 mg, 686 µL, 12.0 mmol), and the mixture stirred for a further 2 h. Hydrogen chloride solution (4 M in dioxane, 15 mL) was added slowly and the mixture stirred for 1 h. The precipitate formed was collected by filtration and washed with THF (2 x 50 mL), then recrystallized (EtOH:H_2O, 9:1), giving **14·HCl** as a colourless salt (1.32 g, 74%). M.p. decomposed at 240-250 °C (EtOH/H_2O); IR (film, cm^{-1}) 2960 (br, NH), 2706, 2592, 2517, 1758, 1720, 1701, 1587, 1549, 1455; ^{1}H NMR (D_2O; 600 MHz) 2.06 (2H, d, *J* = 13.2, 4.0 Hz, 2 x $C\mathit{H}_{ax}H_{eq}$), 2.60 (2H, br d, *J* = 13.2 Hz, 2 x $CH_{ax}\mathit{H}_{eq}$), 3.23 (2H, td, *J* = 13.2, 2.2 Hz, 2 x $C\mathit{H}_{ax}H_{eq}NH_2^+$), 3.71 (2H, br d, *J* = 13.2 Hz, 2 x $CH_{ax}\mathit{H}_{eq}NH_2^+$), 3.82 (1H, app tt, *J* = 11.8, 4.0 Hz, CHN), 4.79 (2H, s, $ArCH_2$), 7.92 (1H, dd, *J* = 7.4, 1.2 Hz, 4-H), 7.95 (1H, t, *J* = 7.4 Hz, 5-H), 8.02 (1H, dd, *J* = 7.4, 1.2 Hz, 6-H); ^{13}C NMR (D_2O; 151 MHz) 25.7 (2 x CH_2), 42.8 (2 x CH_2), 44.3 (CH_2), 53.5 (CH), 125.4 (CH), 129.2 (C), 130.9 (C), 133.6 (C), 136.1 (CH), 137.2 (CH), 171.0 (C=O), 171.5 (C=O); *m/z* HRMS (ESI+) found [**14**H]$^+$ 260.1398, $C_{14}H_{18}N_3O_2$ requires 260.1399.

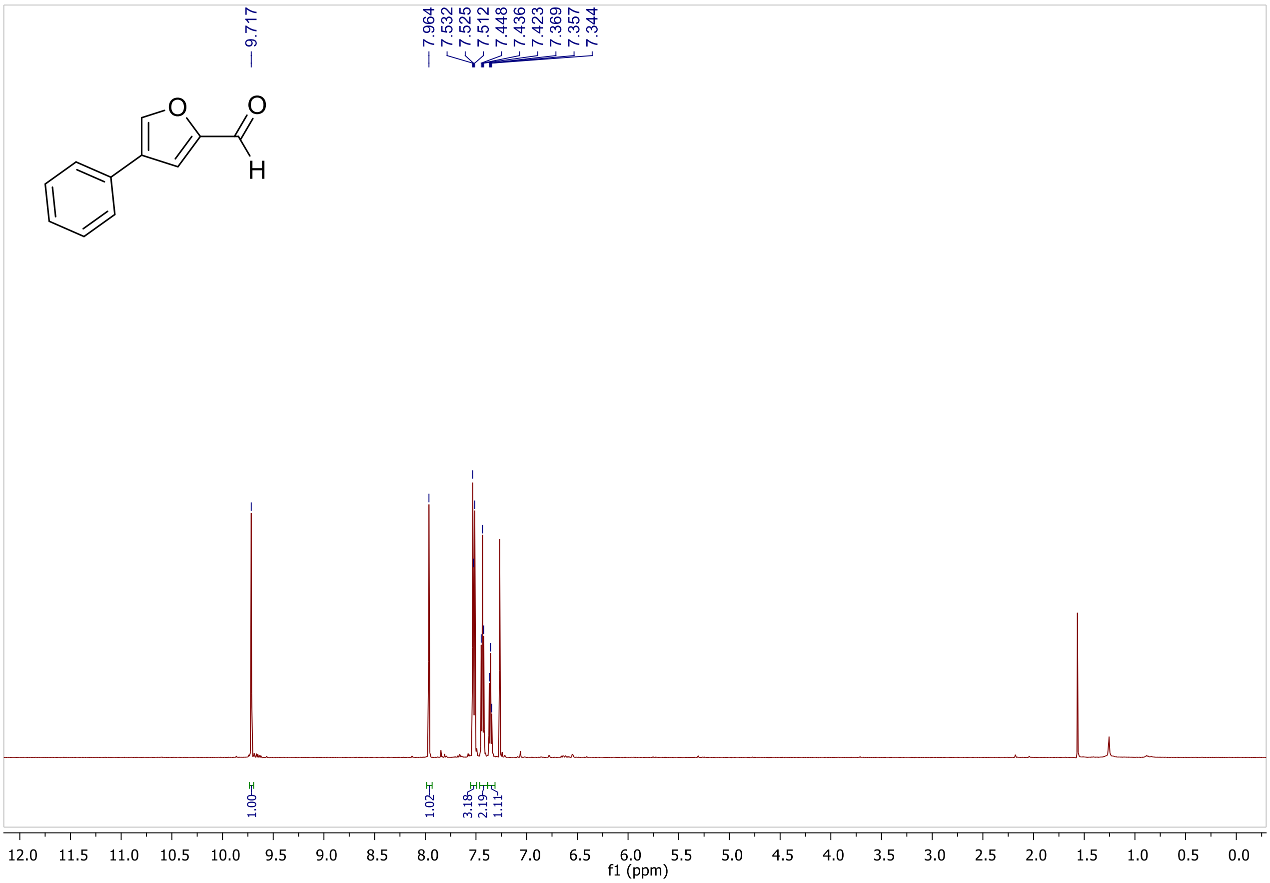
Spectra

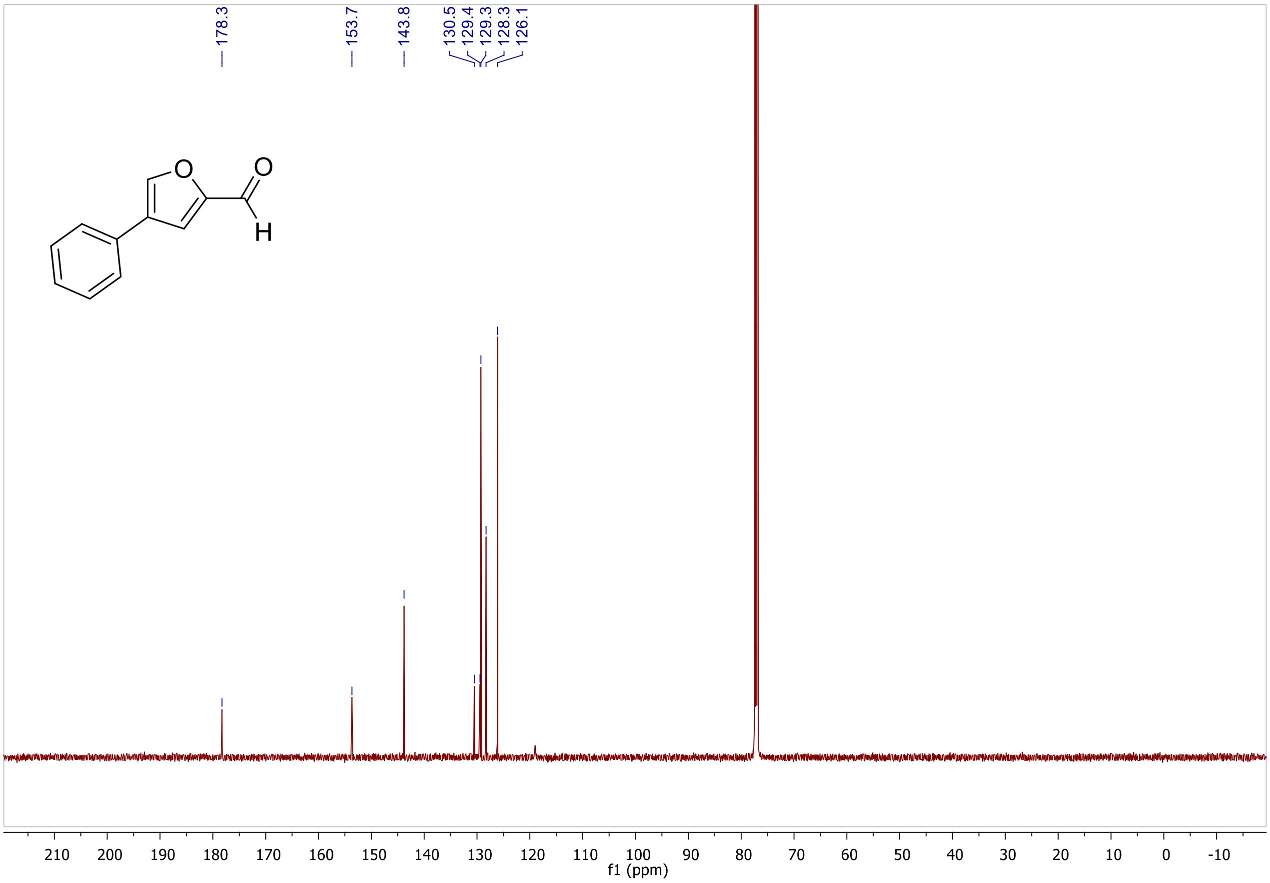
1,1-dimethyl-2-((5-nitrofuran-2-yl)methylene)hydrazine 1l



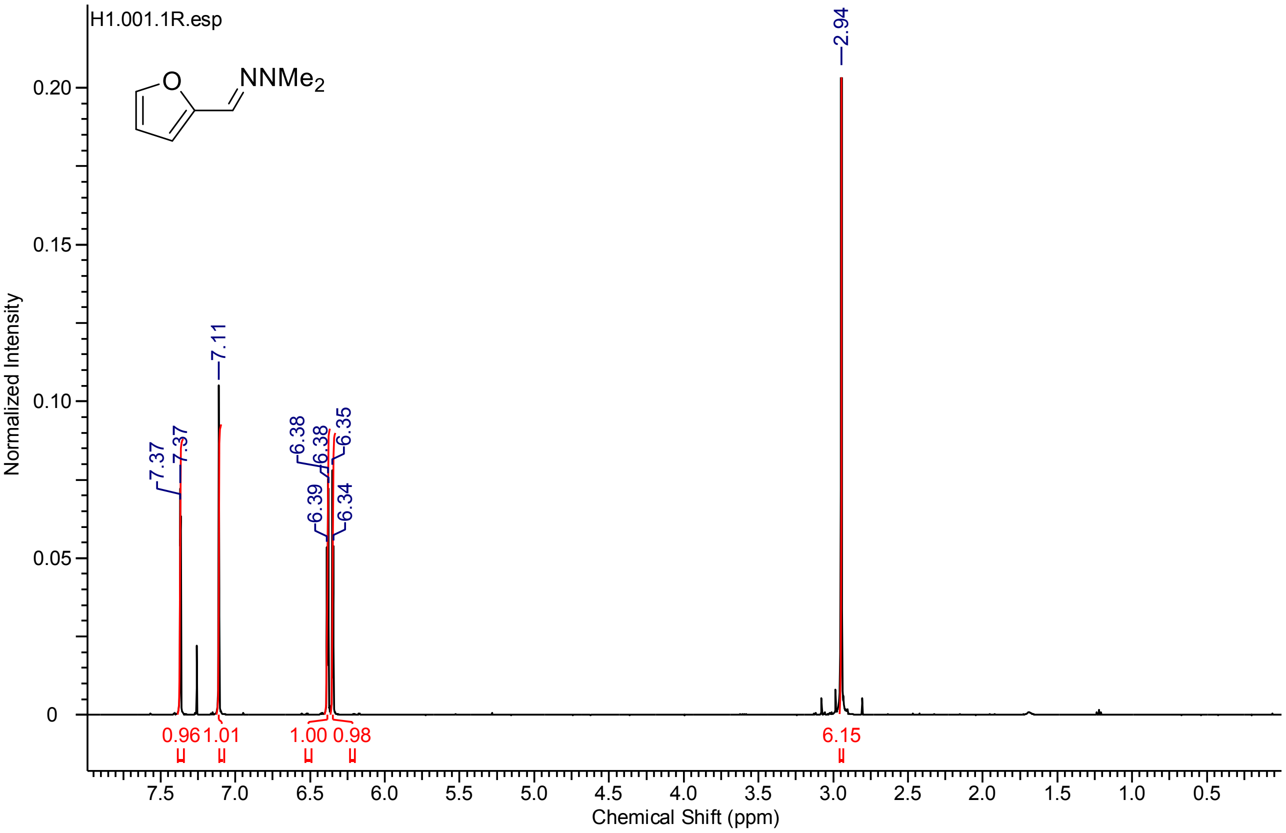


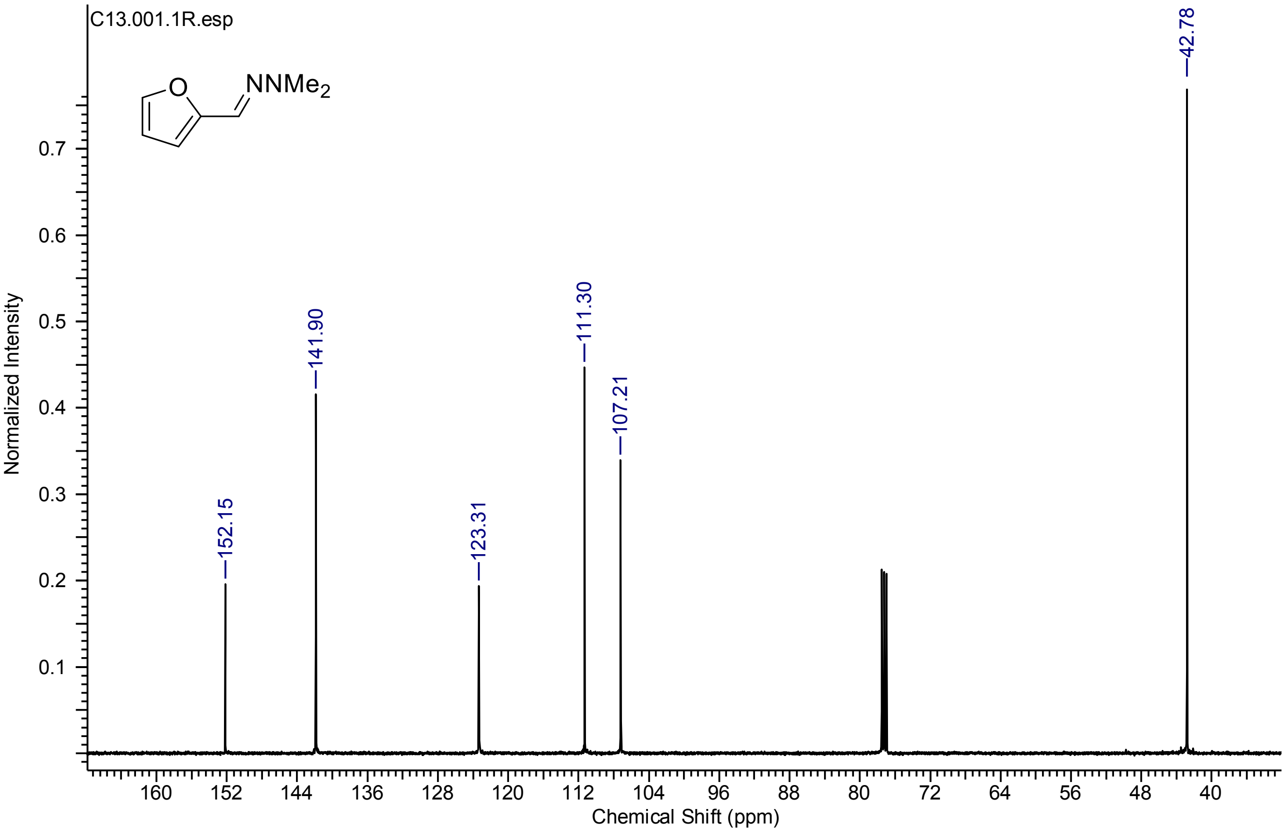
4-Phenylfuran-2-carbaldehyde 1q



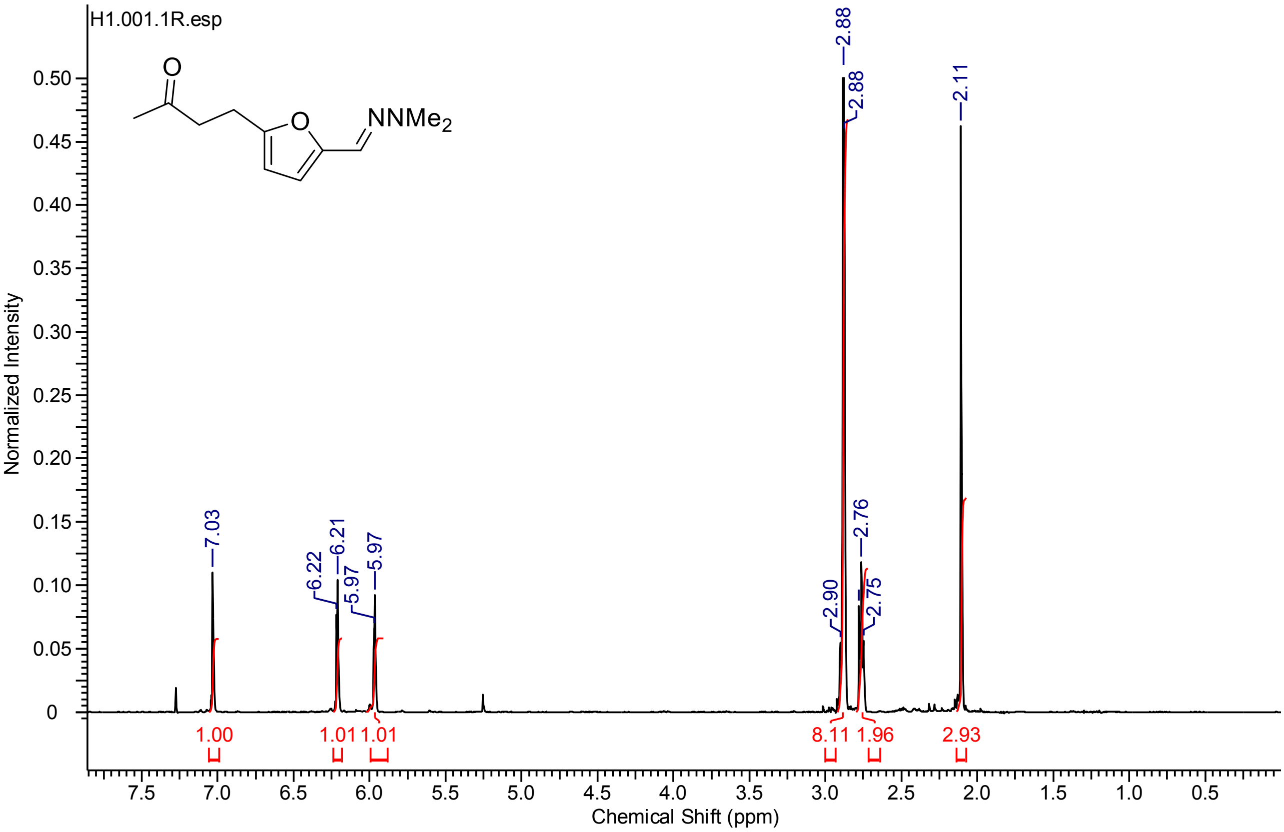


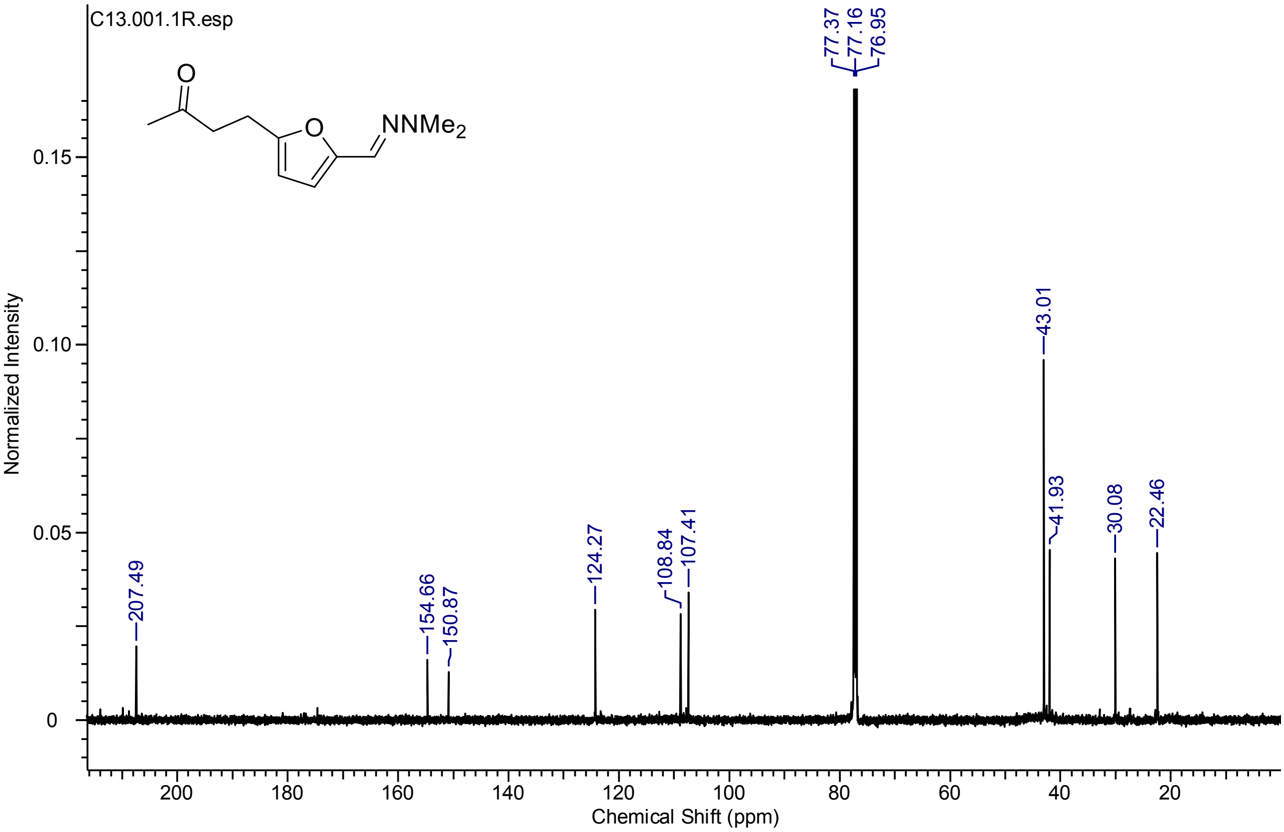
2-Furaldehyde dimethylhydrazone 2a



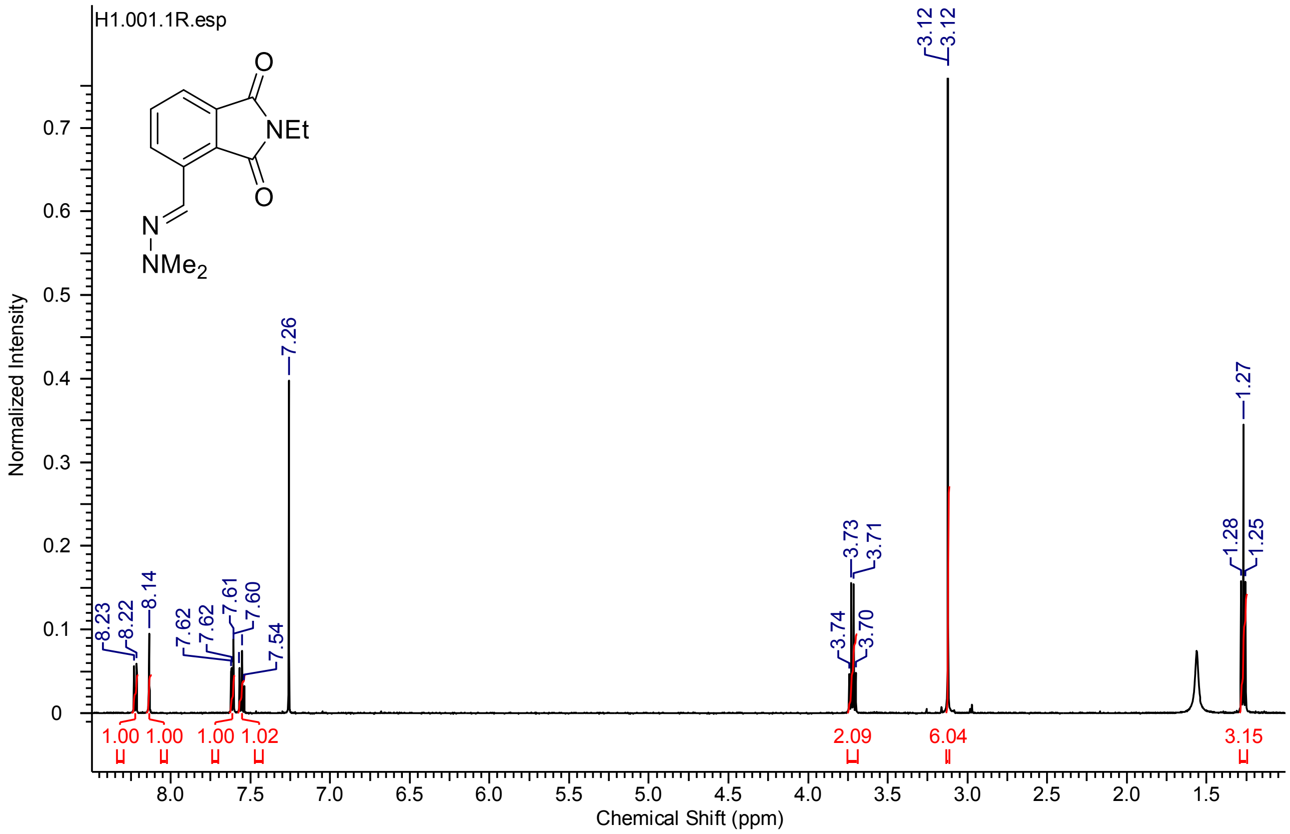


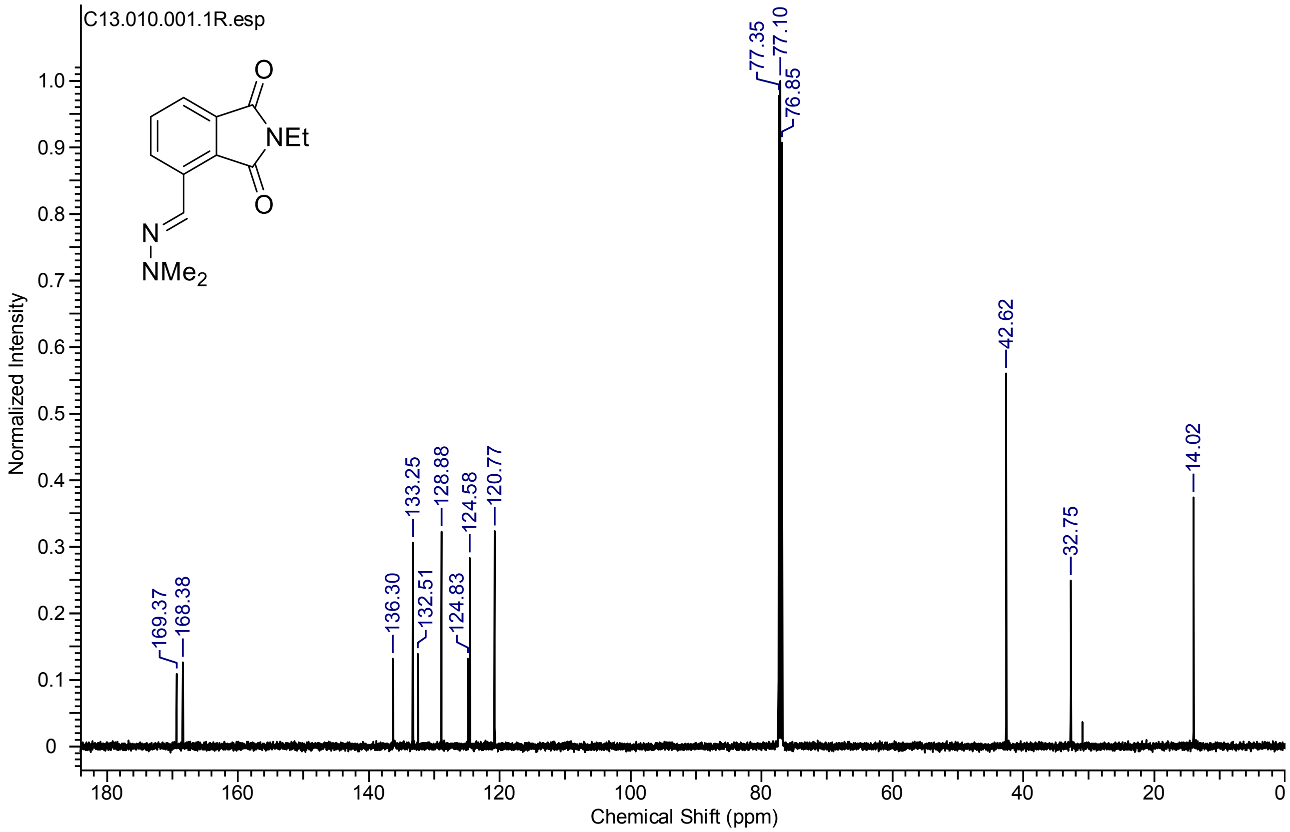
4-(5-((2,2-Dimethylhydrazono)methyl)furan-2-yl)butan-2-one 2t



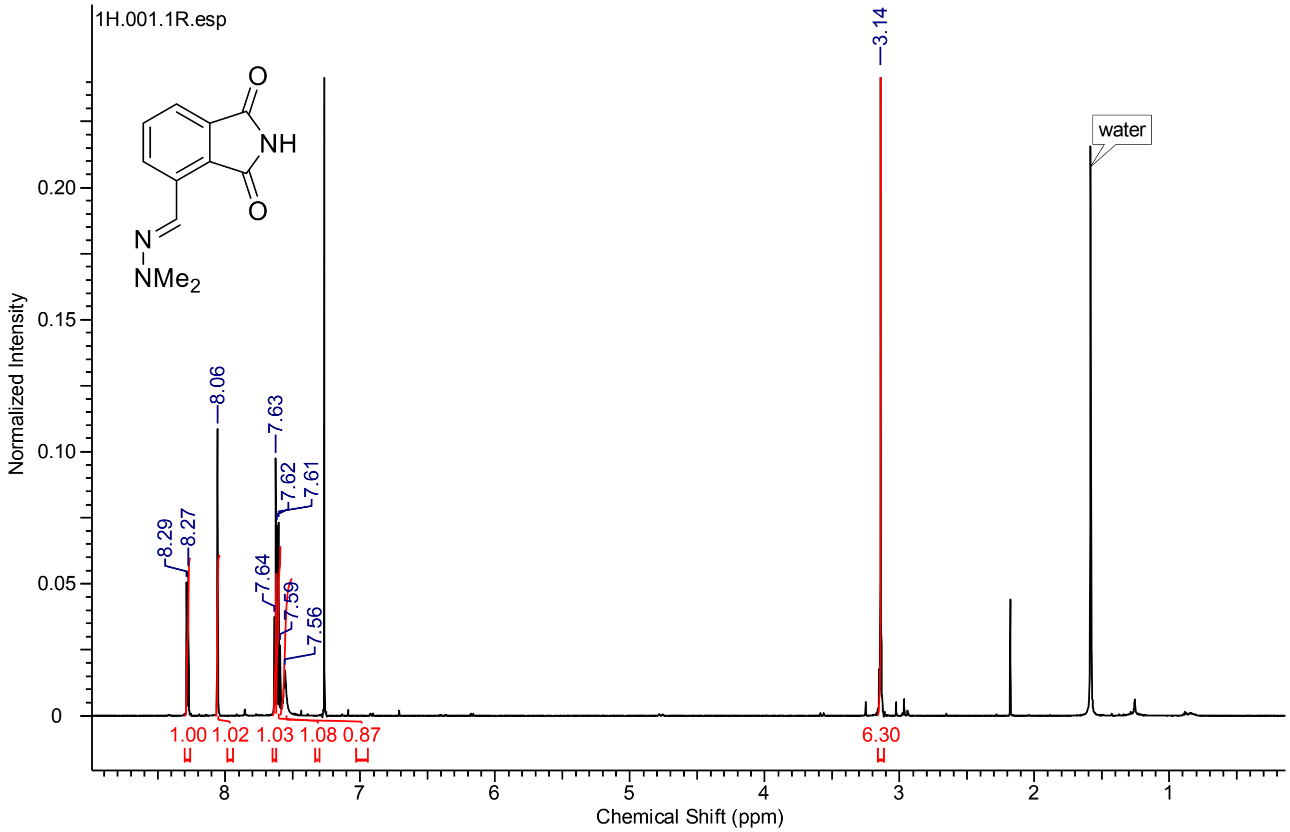


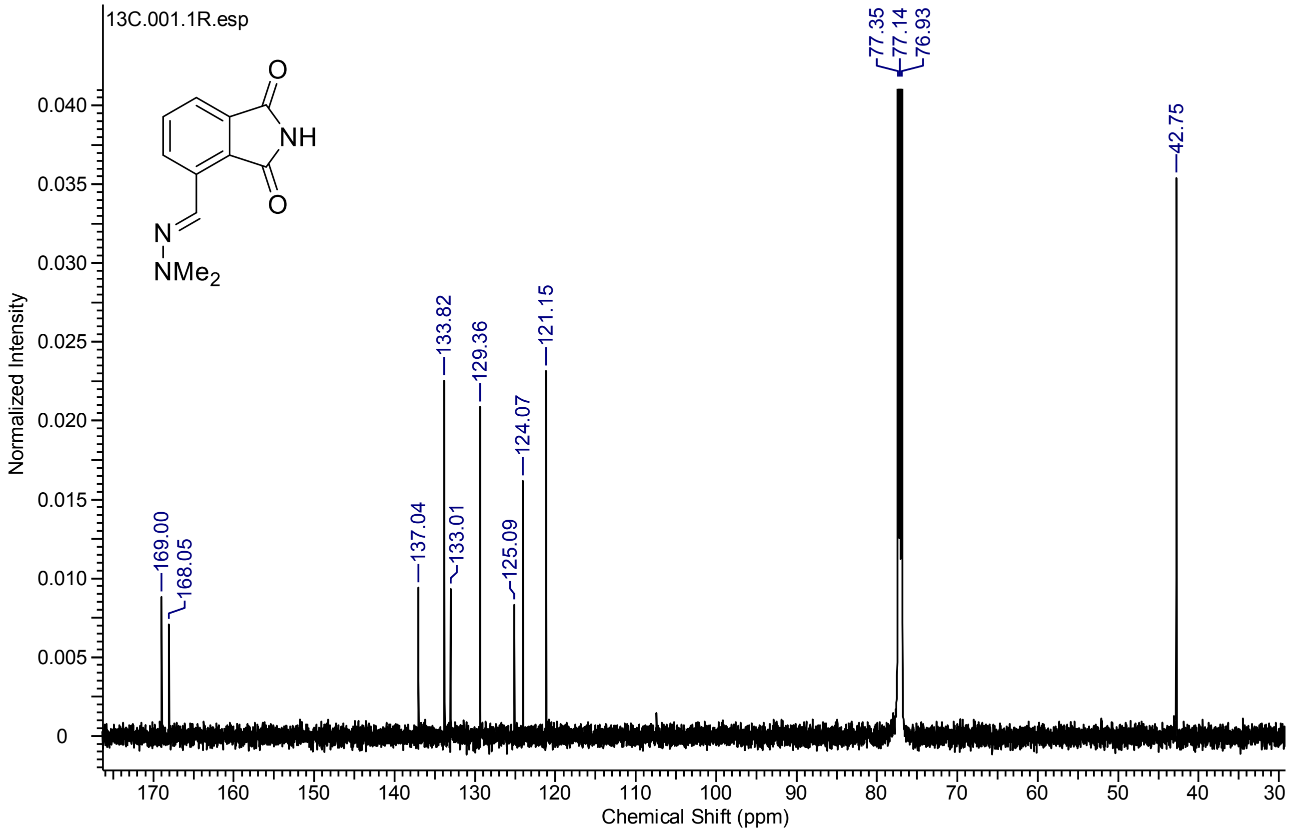
4-((2,2-Dimethylhydrazono)methyl)-2-ethylisoindoline-1,3-dione 5a



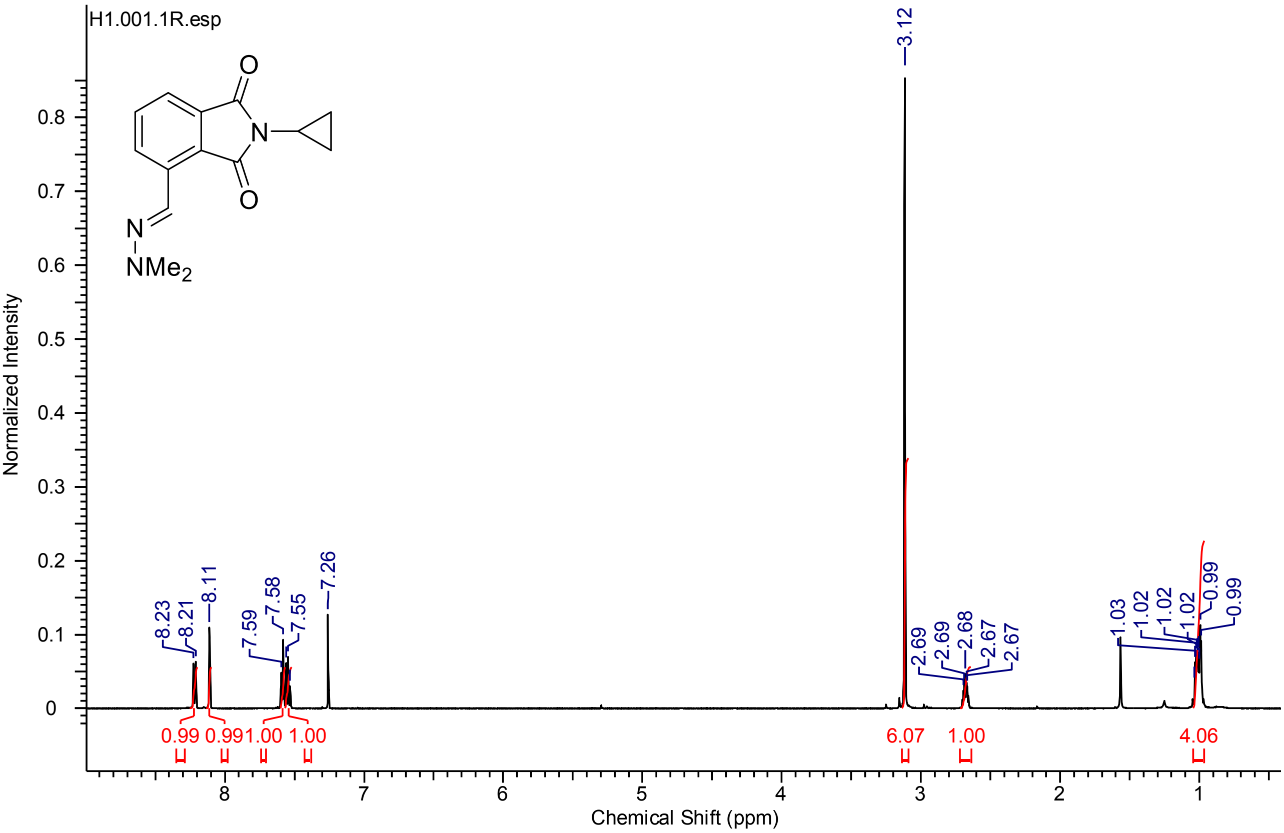


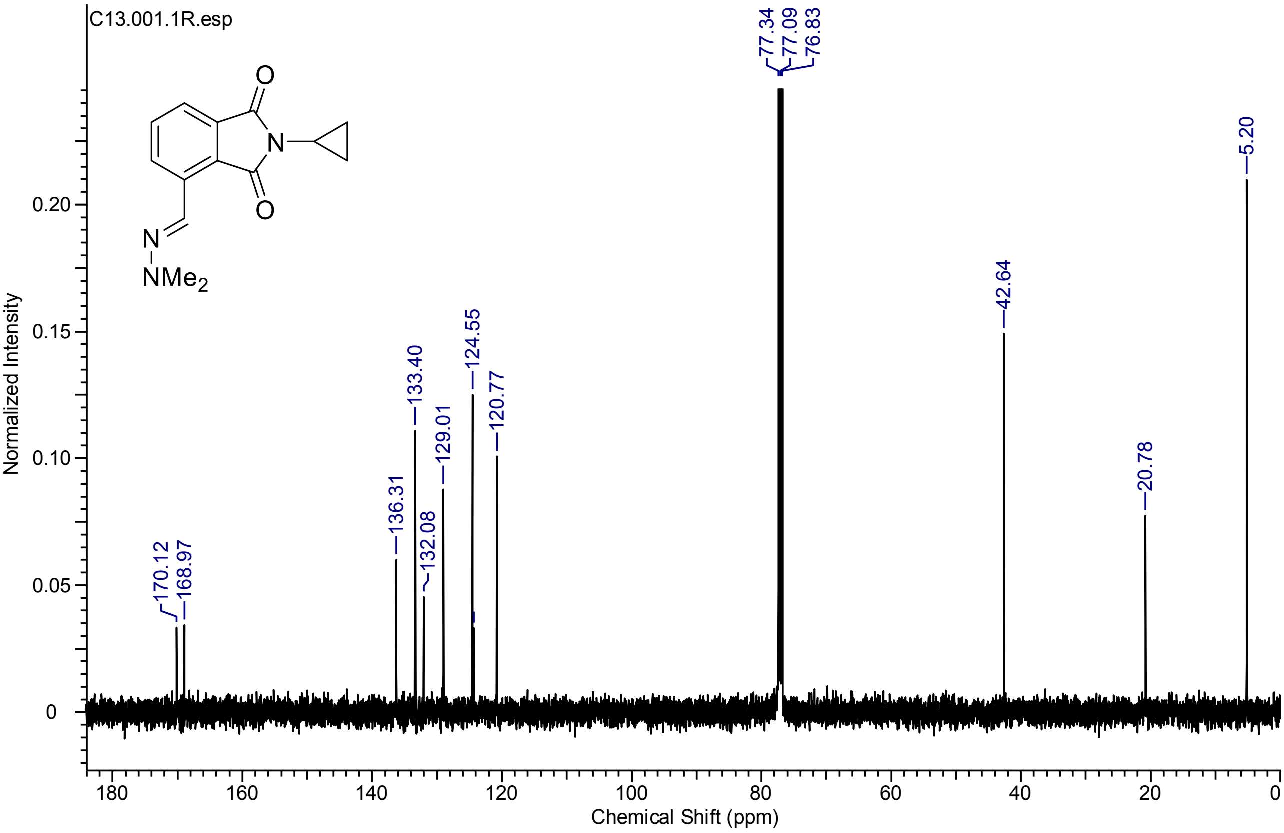
4-((2,2-Dimethylhydrazono)methyl)isoindoline-1,3-dione 5b



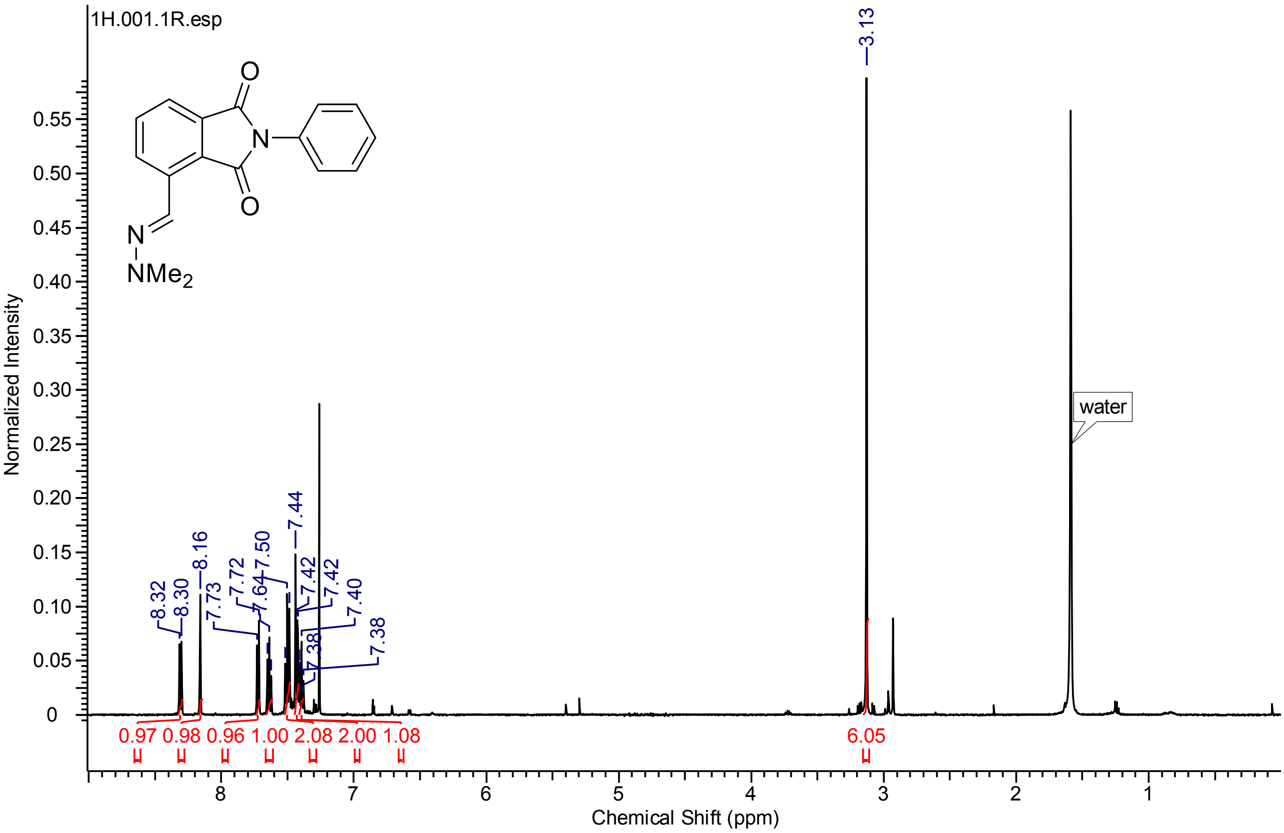


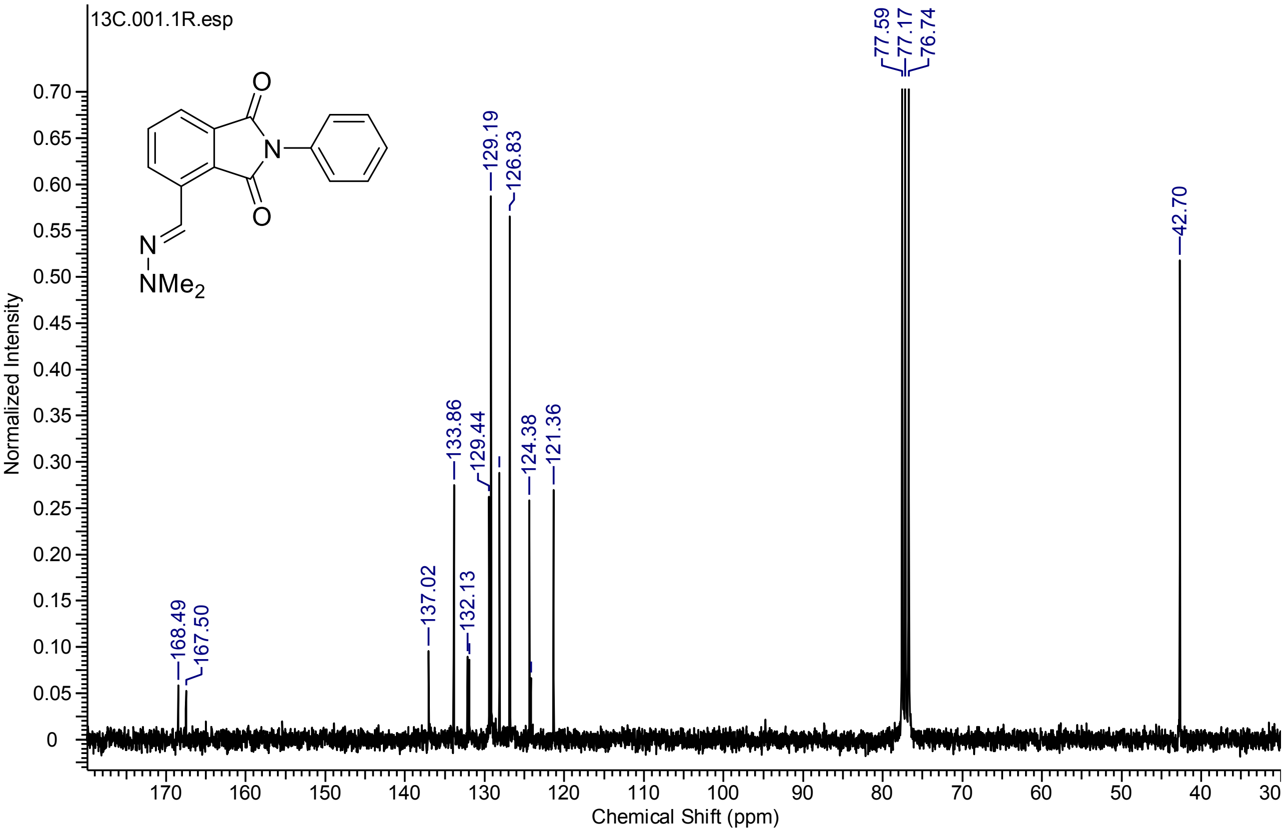
2-Cyclopropyl-4-((2,2-dimethylhydrazono)methyl)isoindoline-1,3-dione 5c



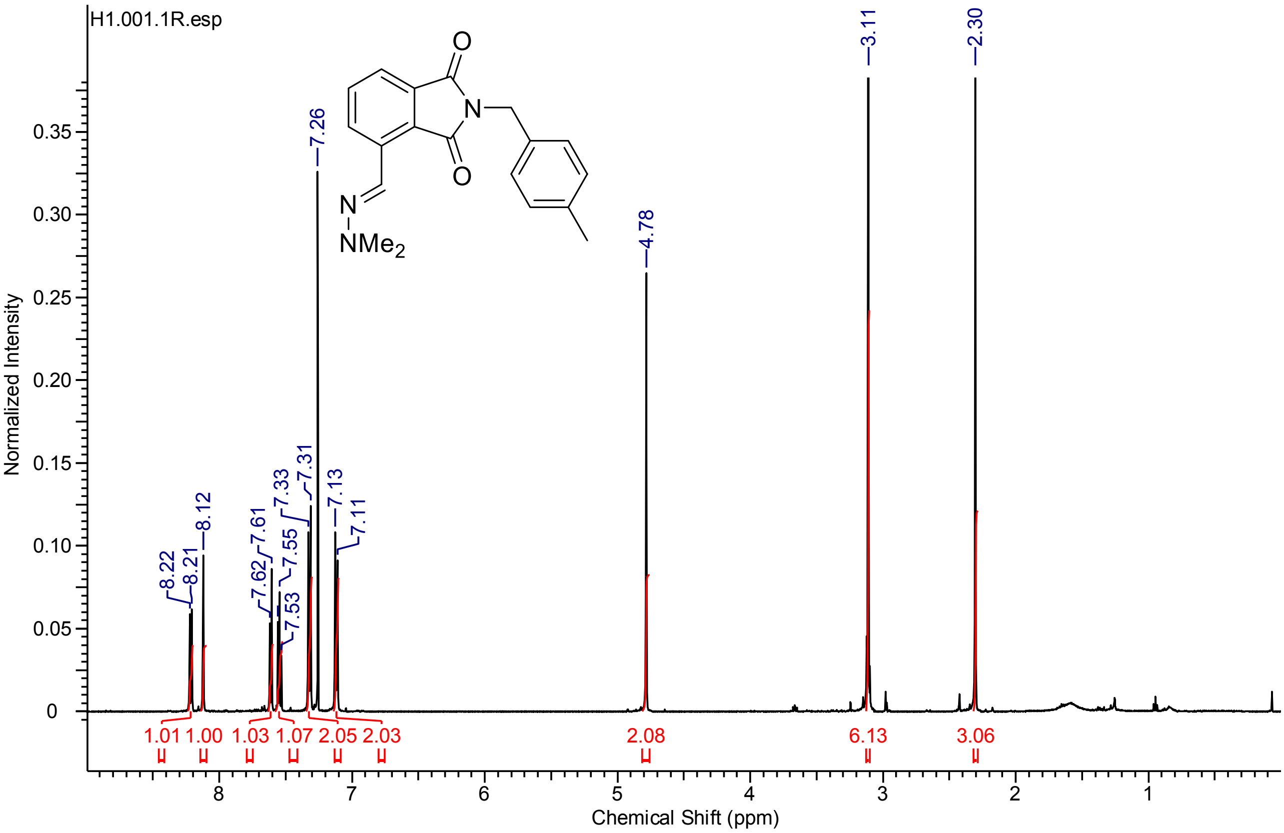


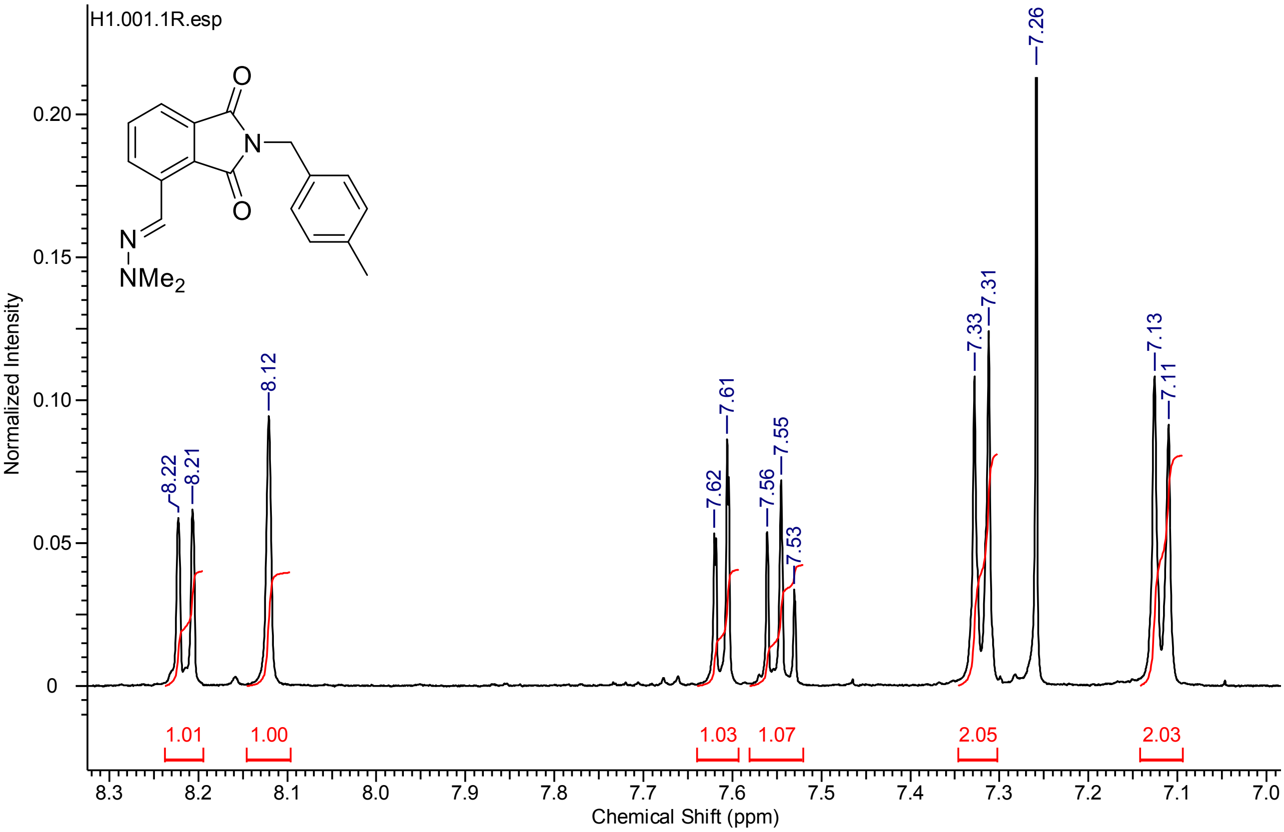
4-((2,2-Dimethylhydrazono)methyl)-2-phenylisoindoline-1,3-dione 5d

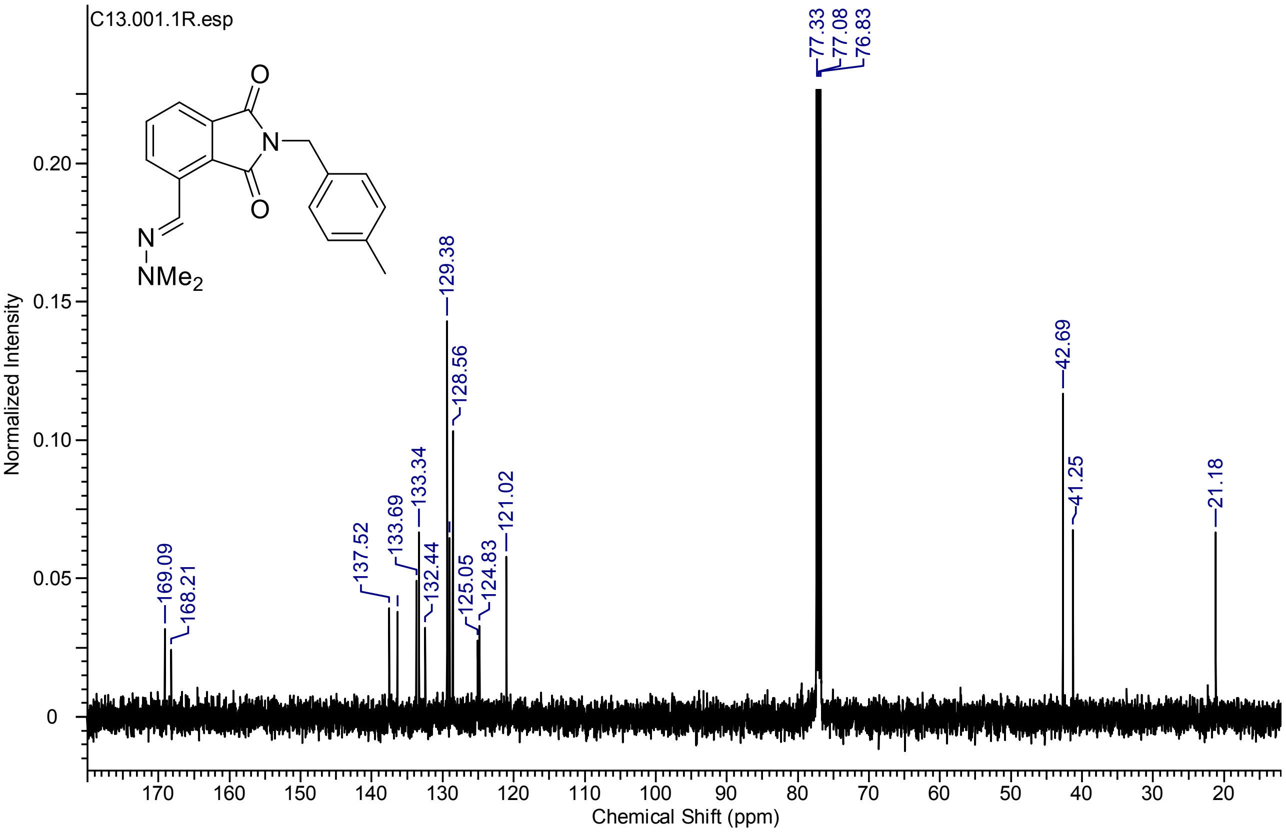




4-((2,2-Dimethylhydrazono)methyl)-2-(4-methylbenzyl)isoindoline-1,3-dione 5e



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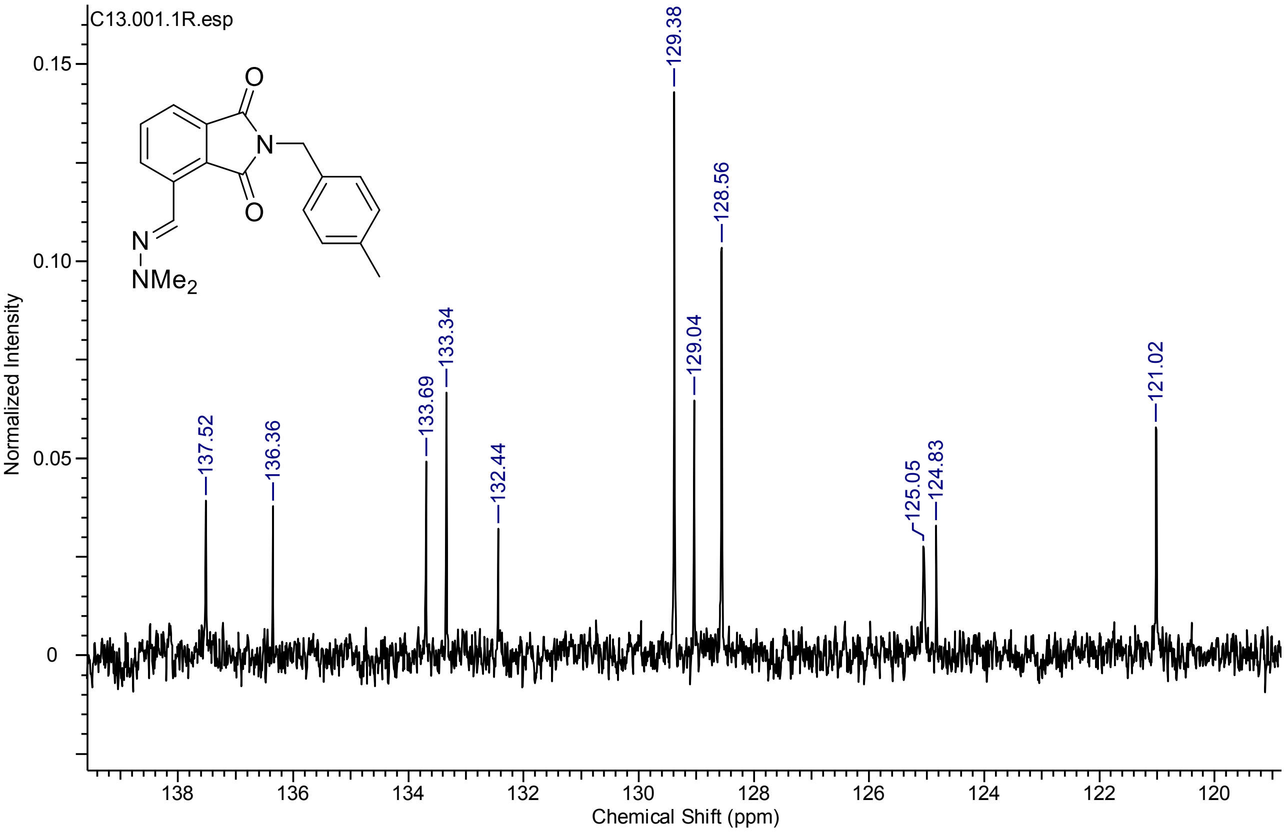
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125.05
124.83
121.02
Normalized Intensity
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0.10
0.05
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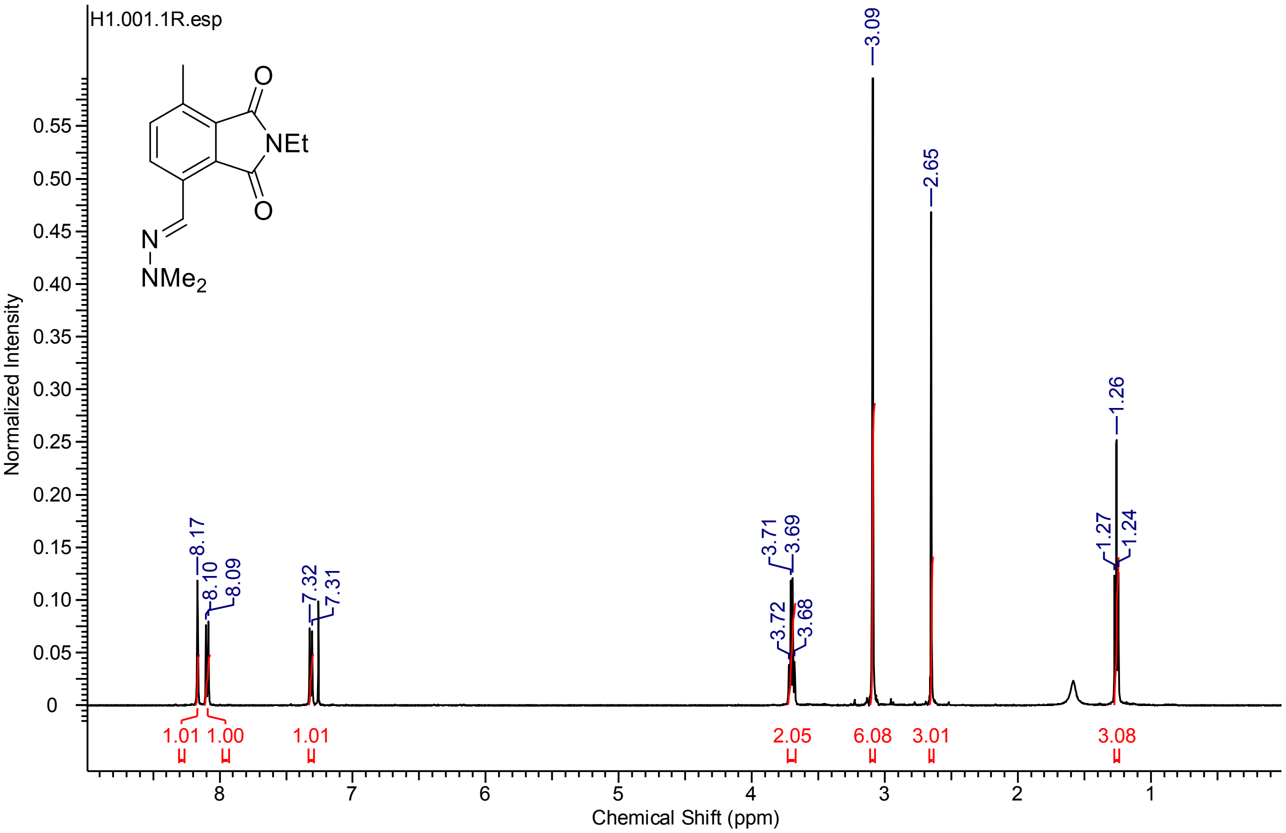
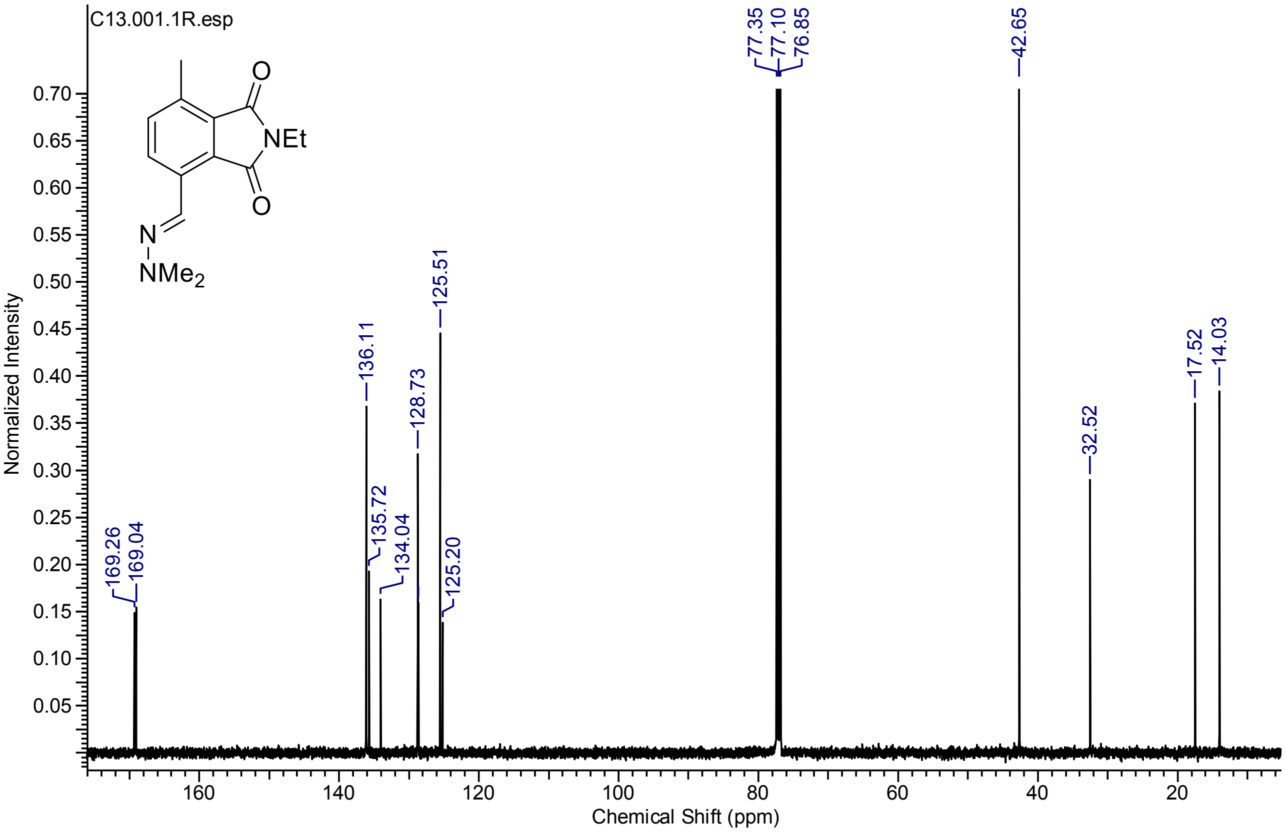
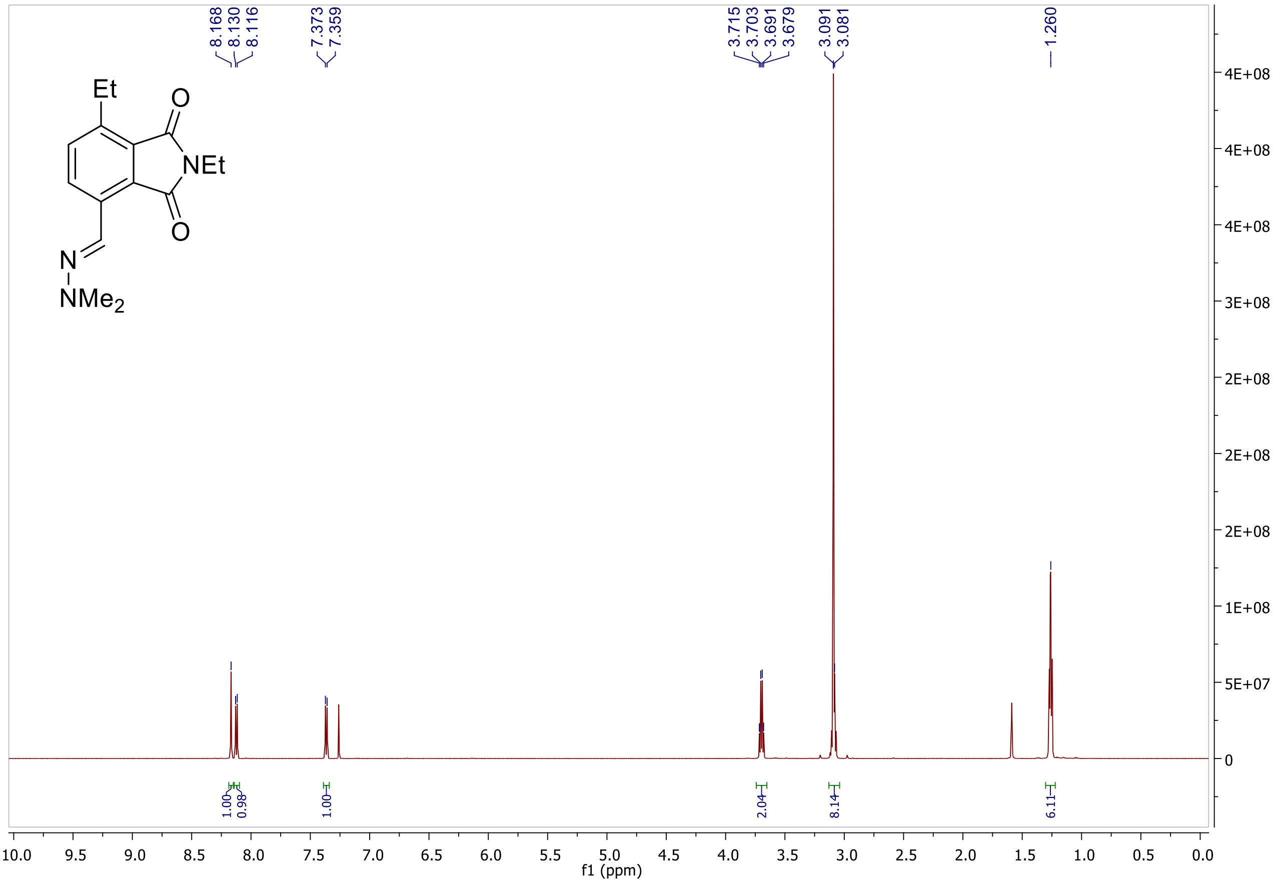
Chemical Shift (ppm)

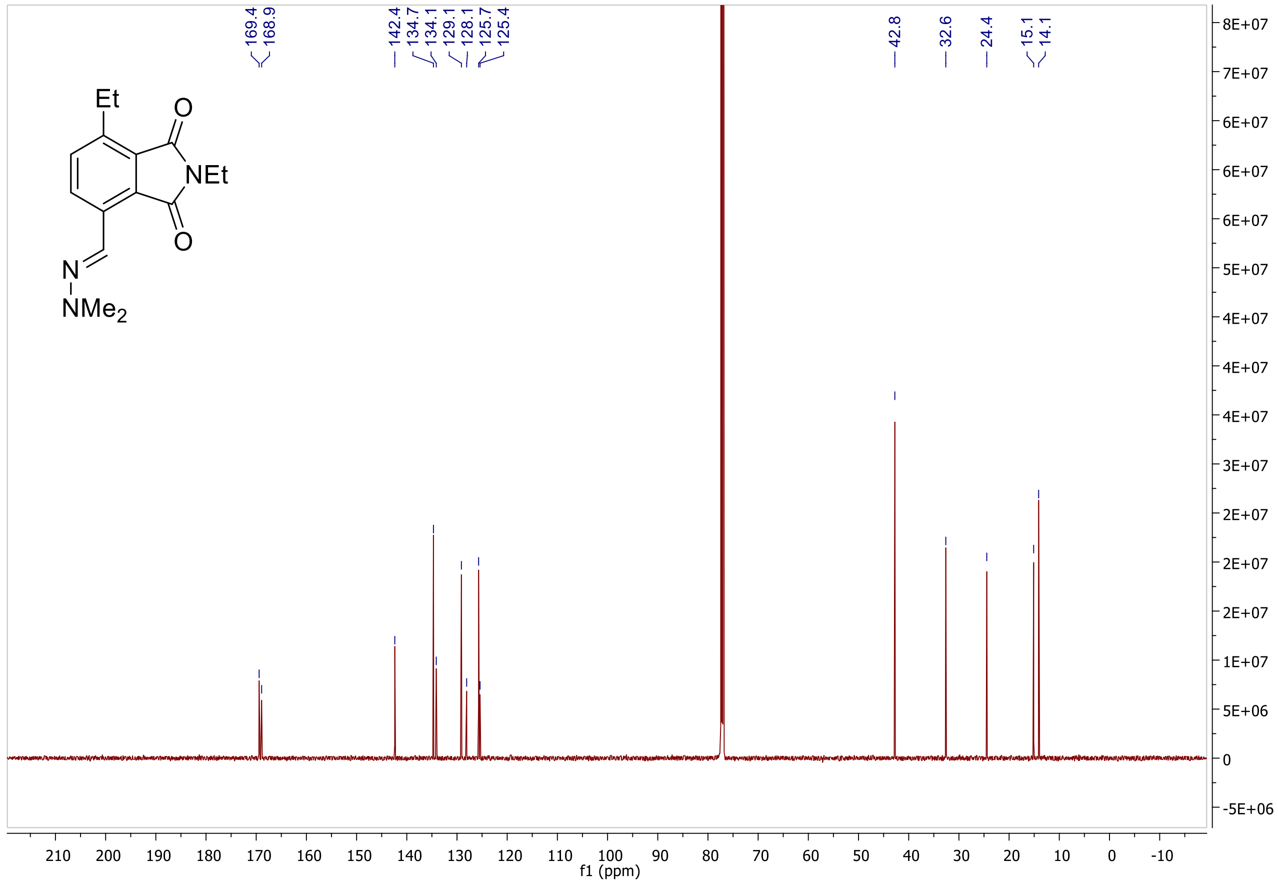
4-((2,2-Dimethylhydrazono)methyl)-2-ethyl-7-methylisoindoline-1,3-dione 5f



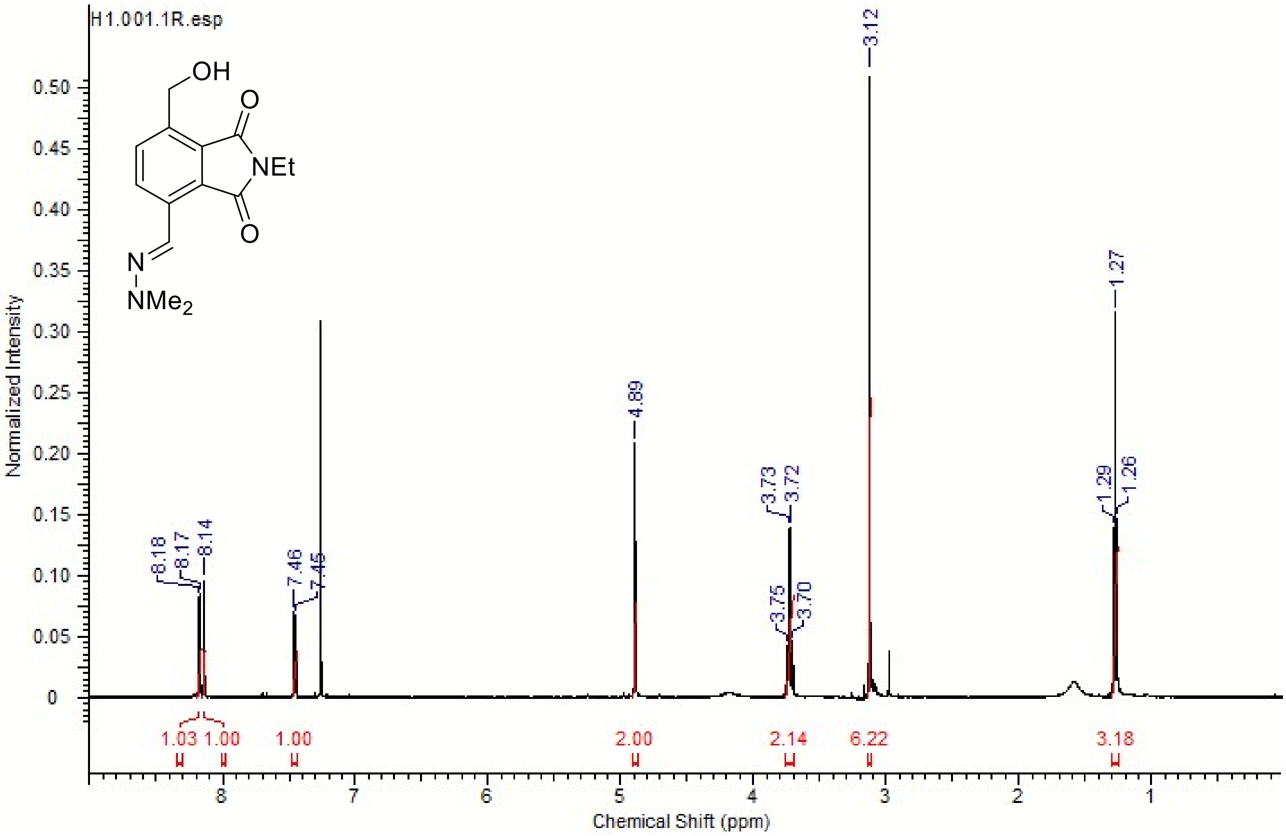


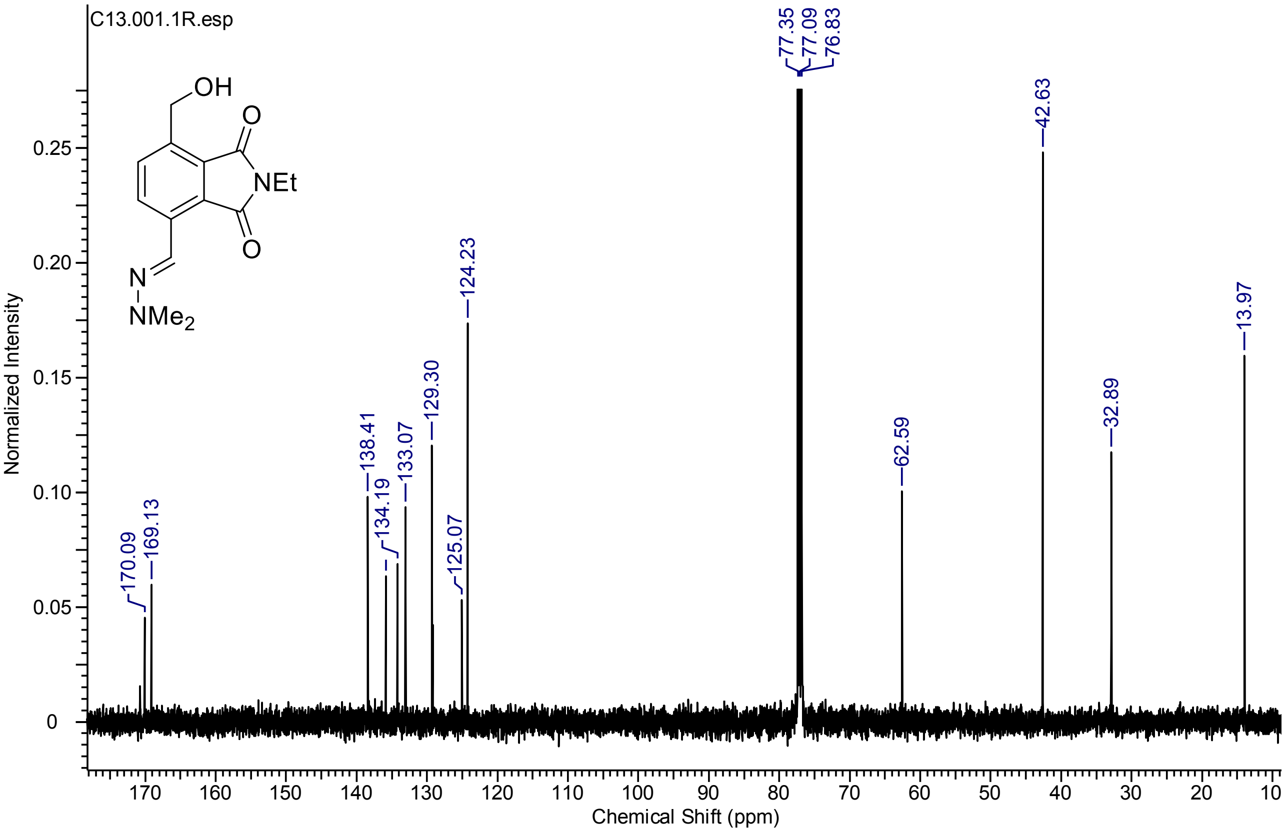
4-((2,2-dimethylhydrazono)methyl)-2,7-diethylisoindoline-1,3-dione 5g



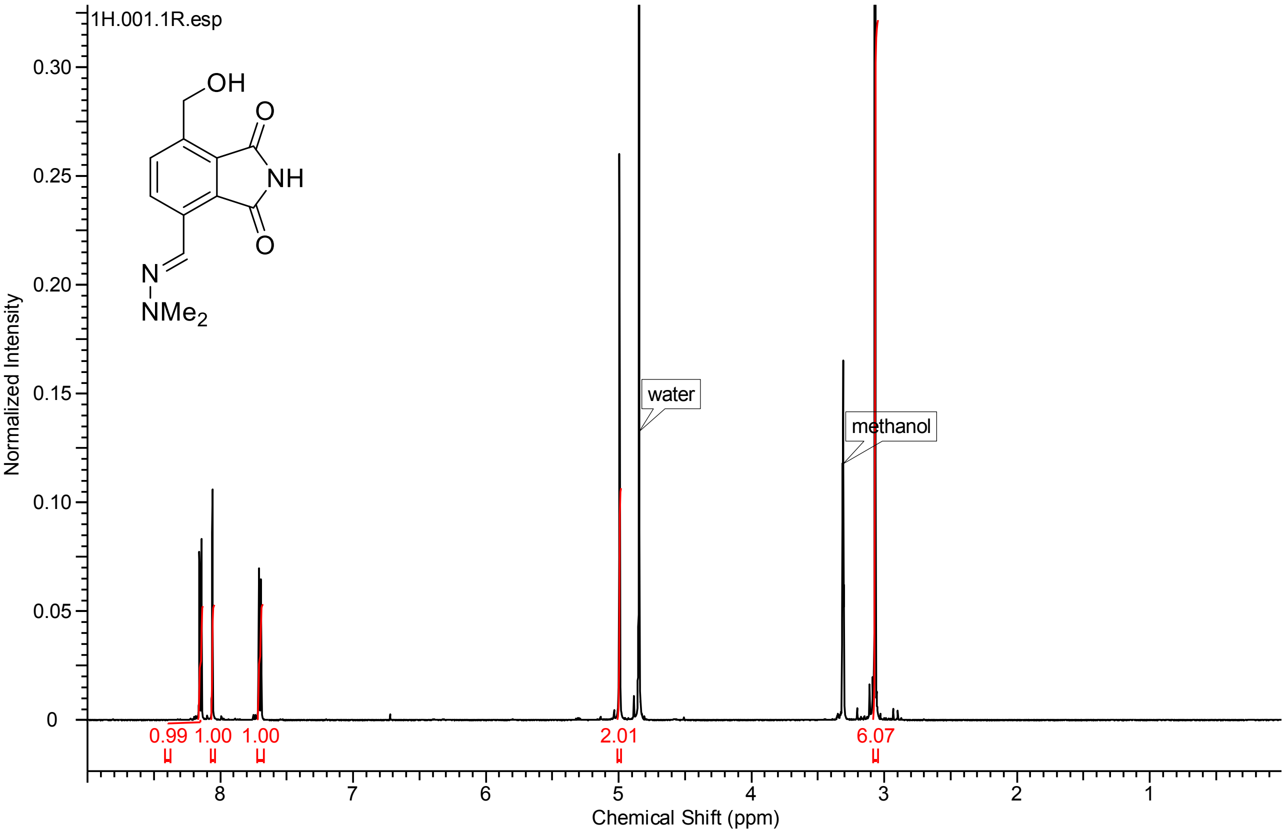


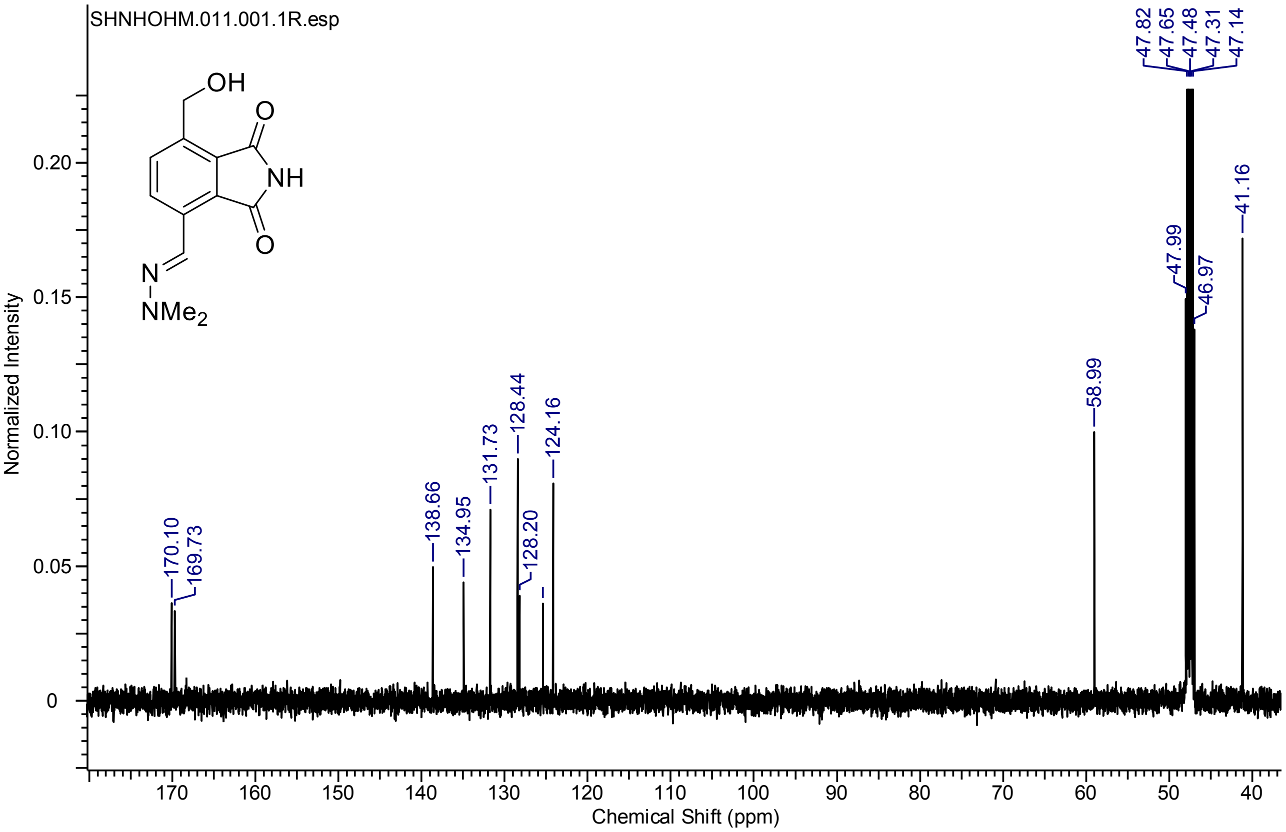
4-((2,2-Dimethylhydrazono)methyl)-2-ethyl-7-(hydroxymethyl)isoindoline-1,3-dione 5h



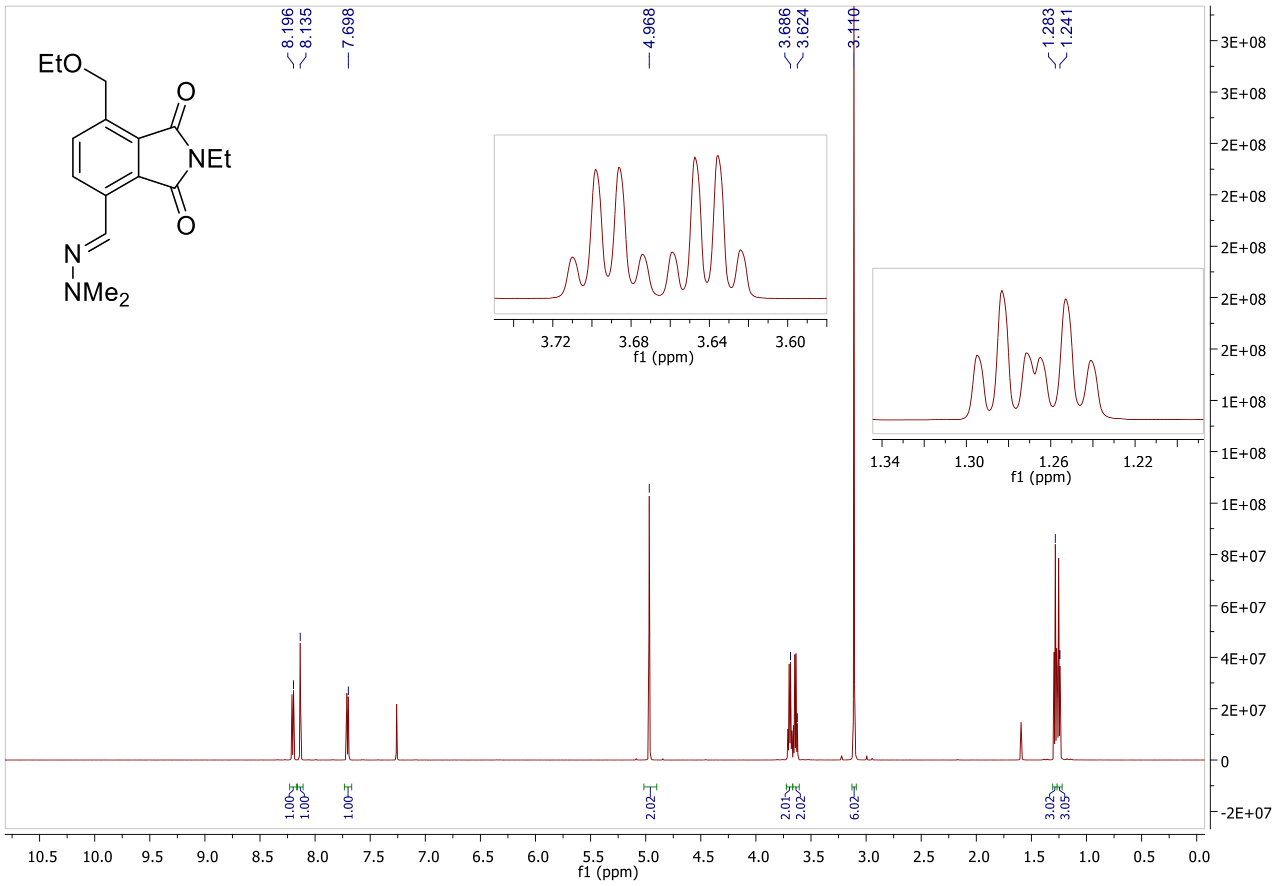


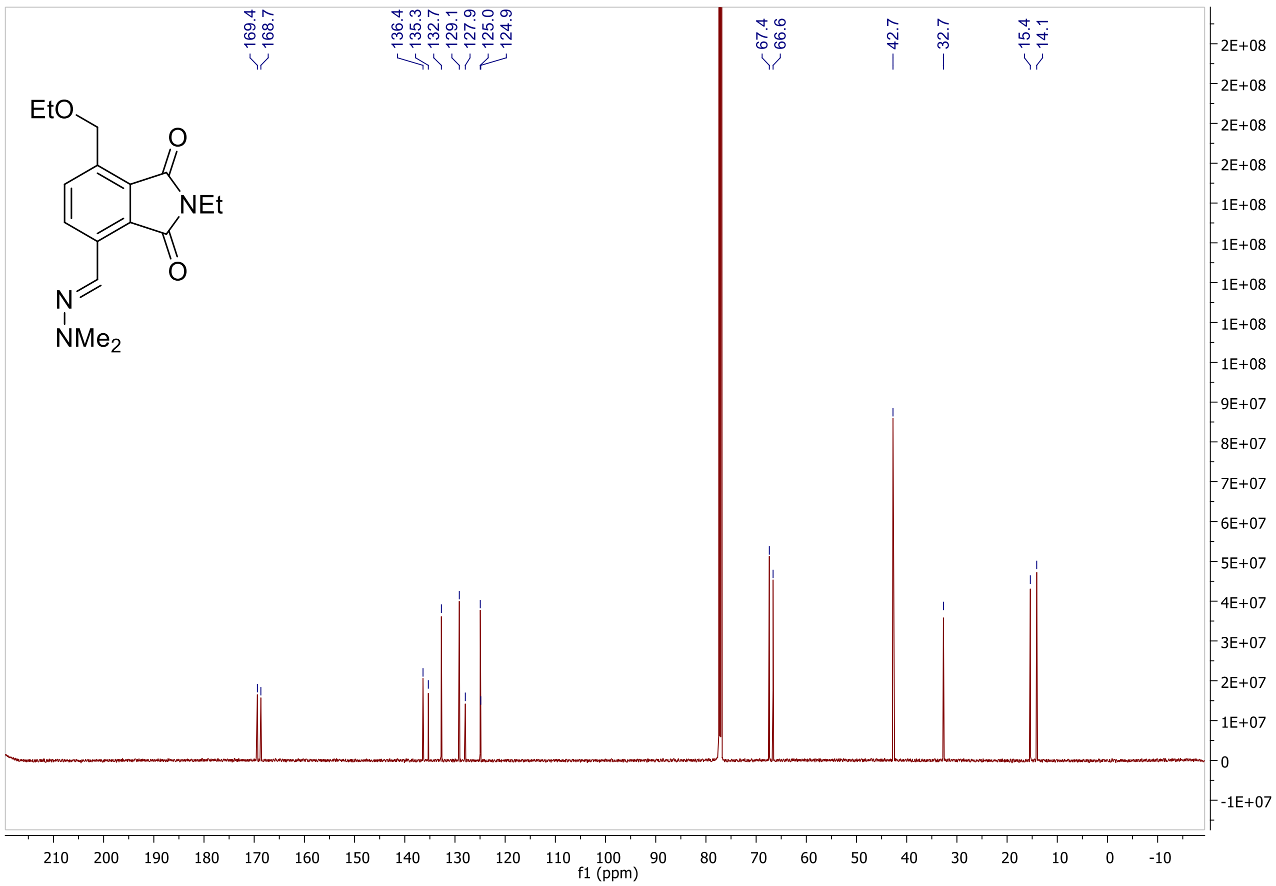
4-((2,2-Dimethylhydrazono)methyl)-7-(hydroxymethyl)isoindoline-1,3-dione 5i



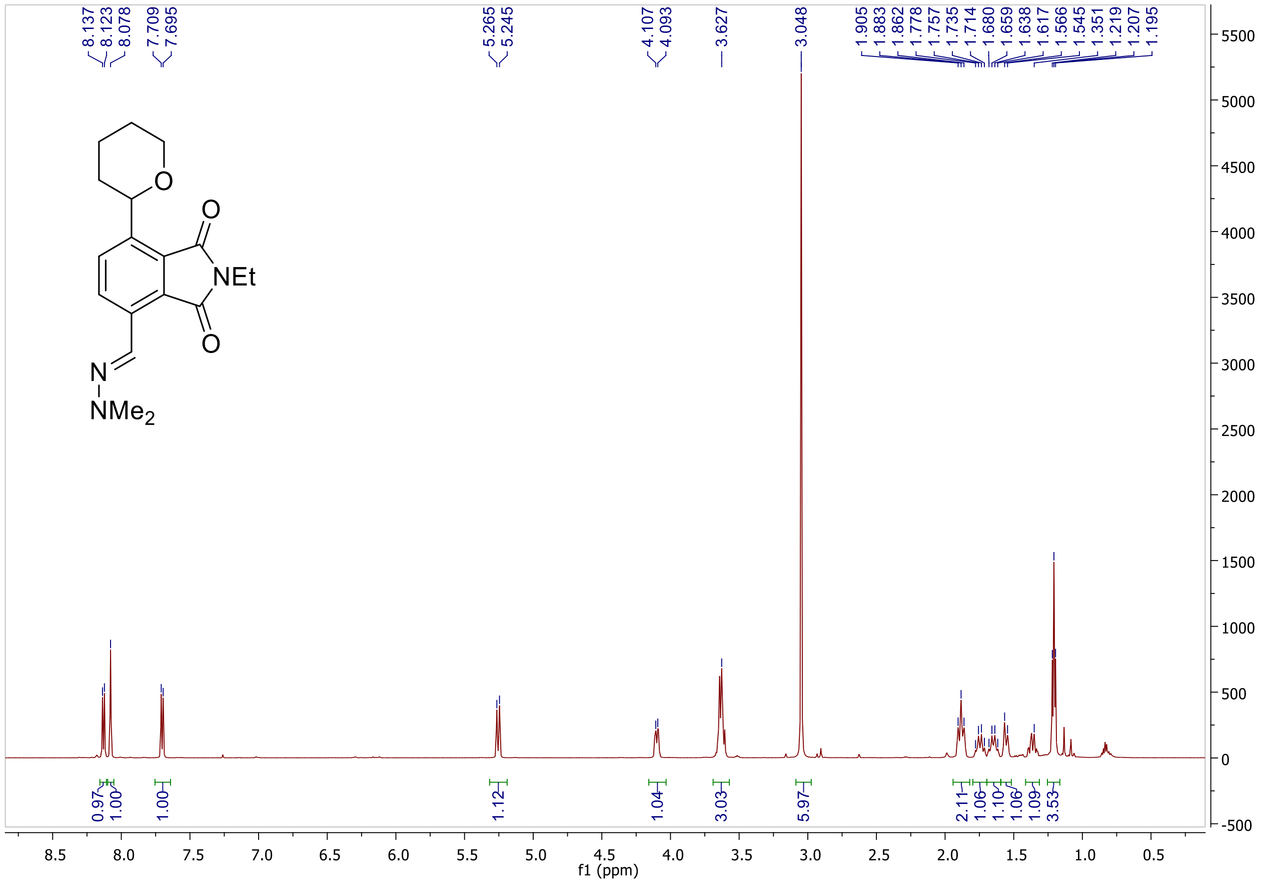


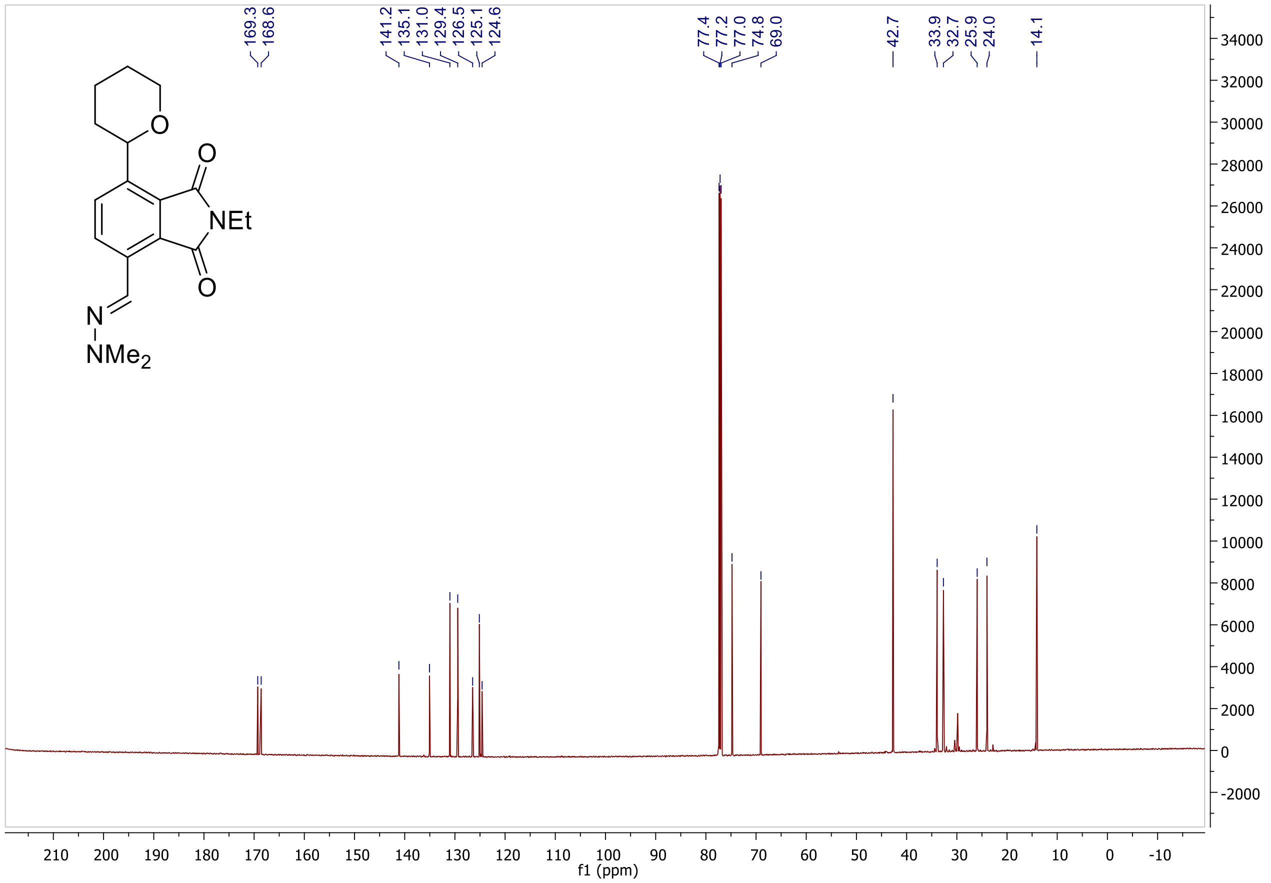
4-((2,2-Dimethylhydrazono)methyl)-7-(ethoxymethyl)-2-ethylisoindoline-1,3-dione 5j



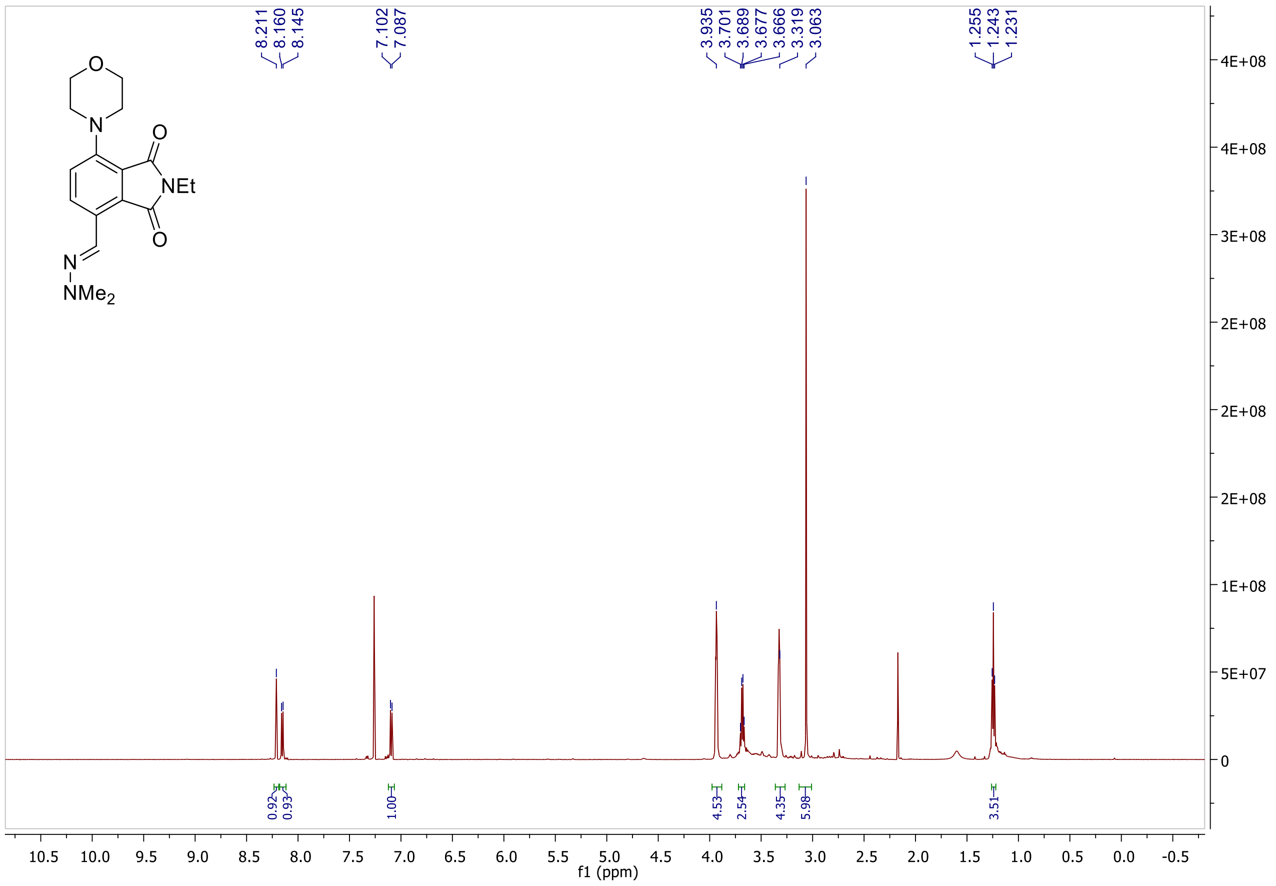


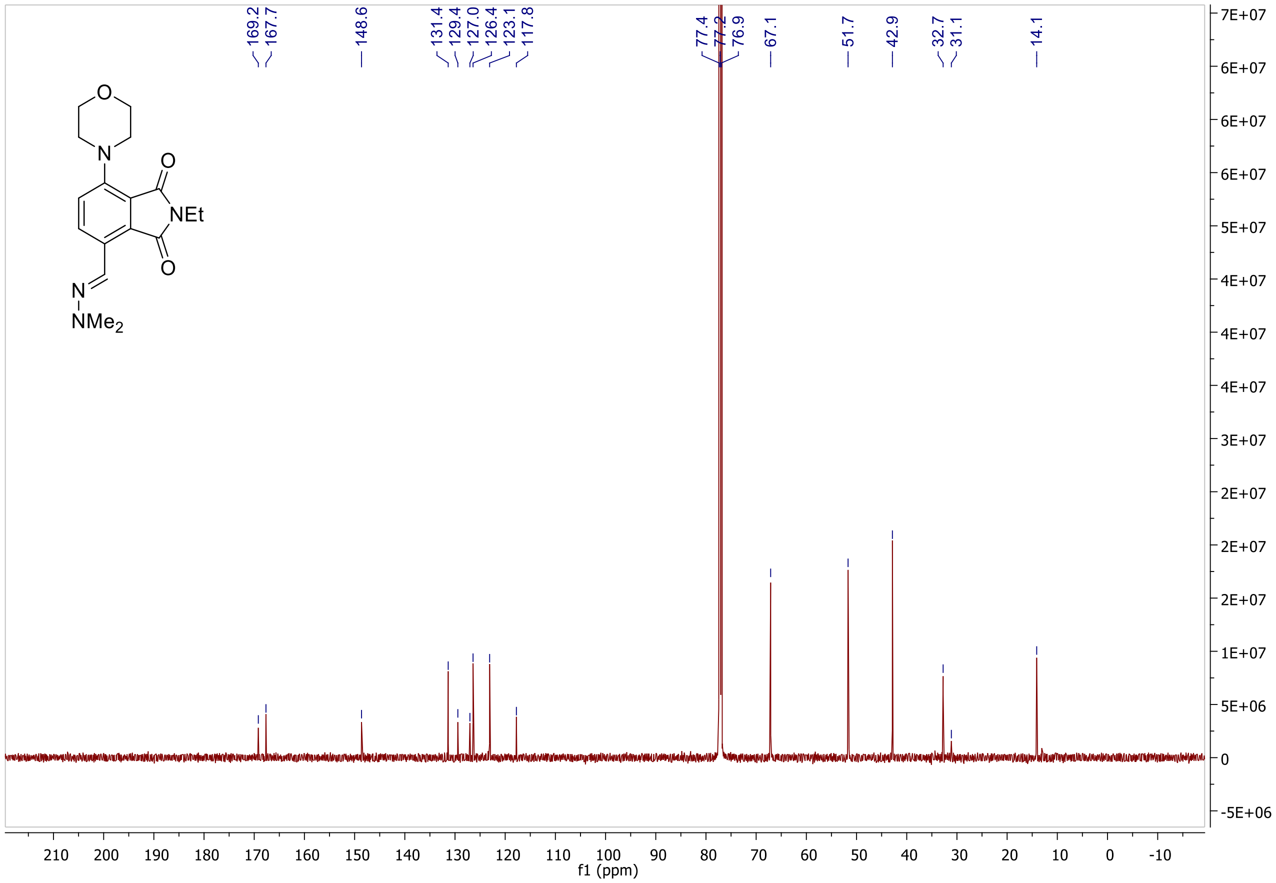
4-((2,2-Dimethylhydrazono)methyl)-2-ethyl-7-(tetrahydro-2H-pyran-2-yl)isoindoline-1,3-dione 5k



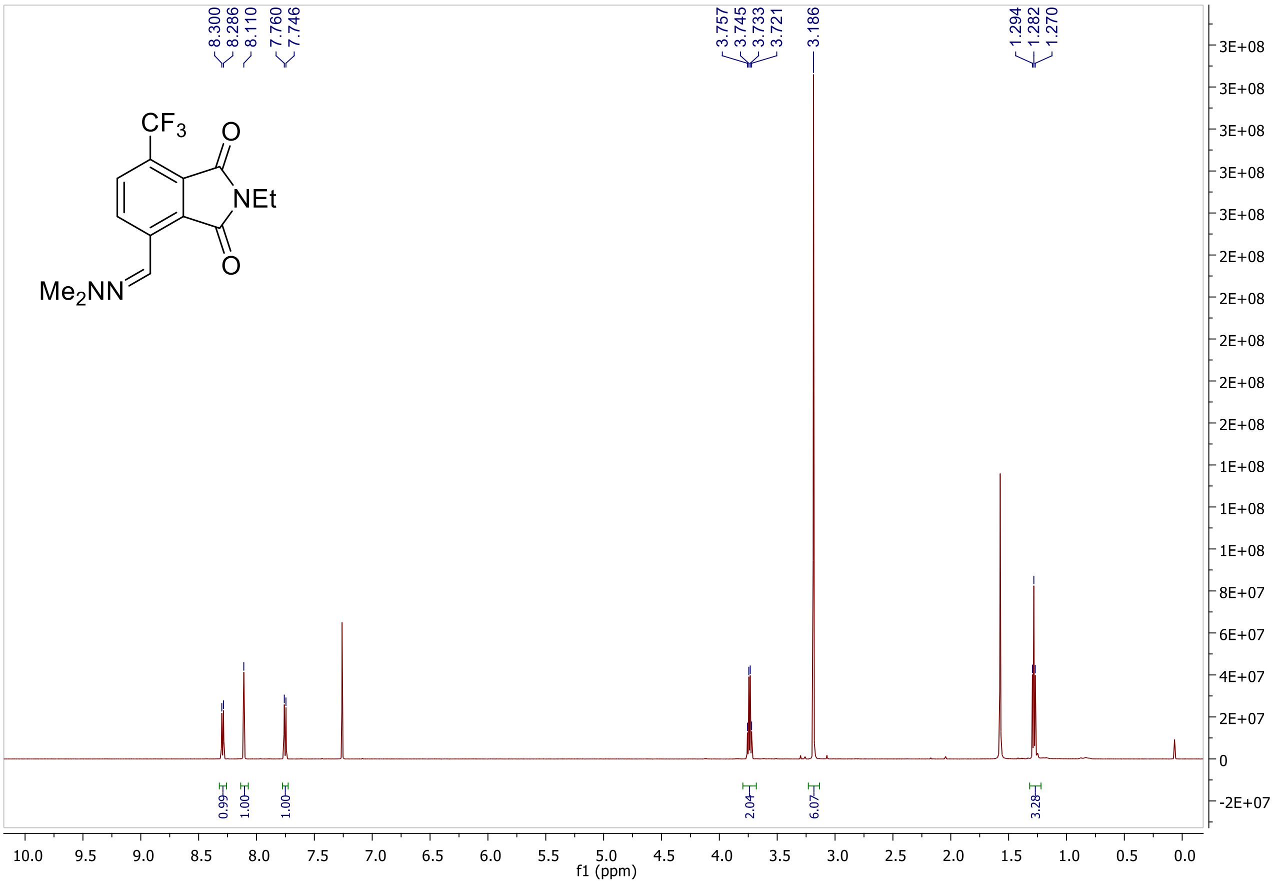


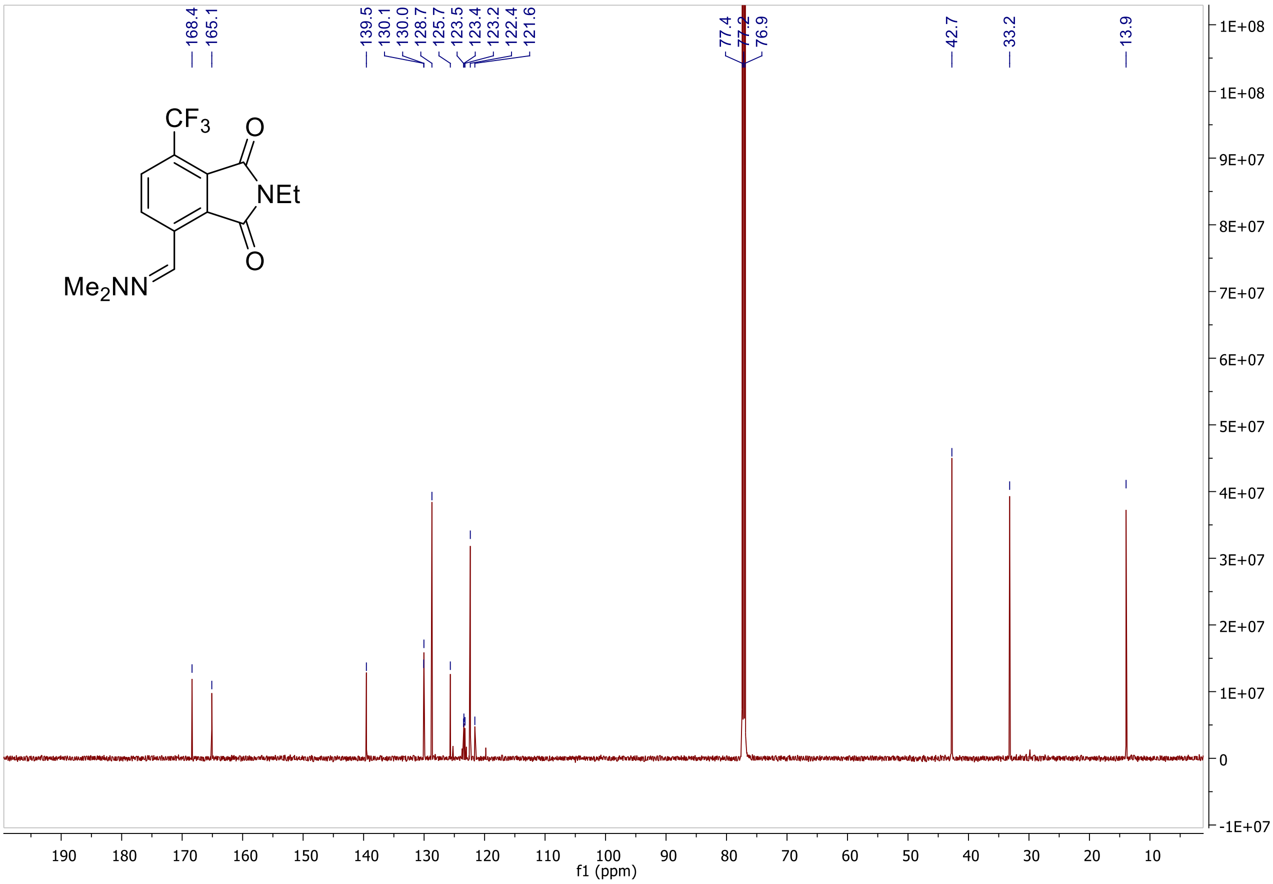
4-((2,2-Dimethylhydrazono)methyl)-2-ethyl-7-morpholinoisoindoline-1,3-dione 5l



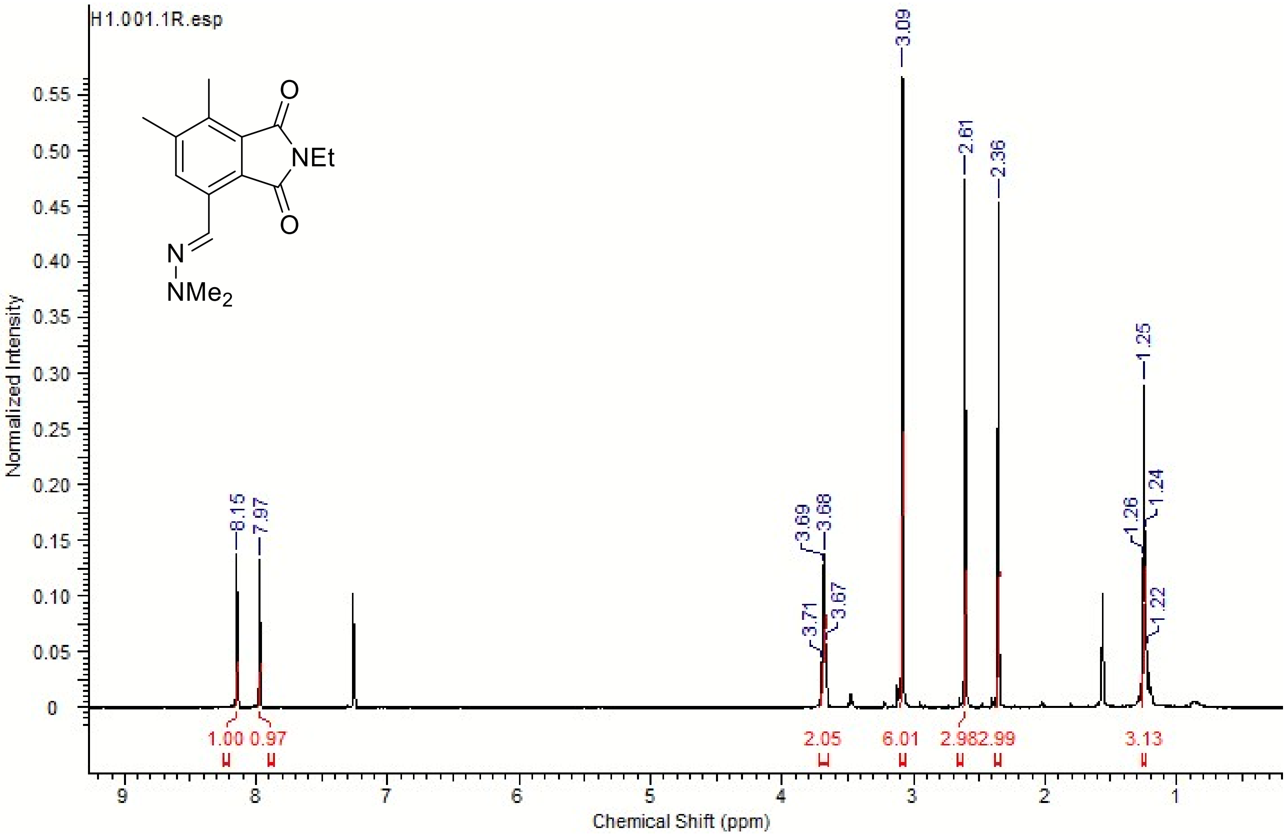


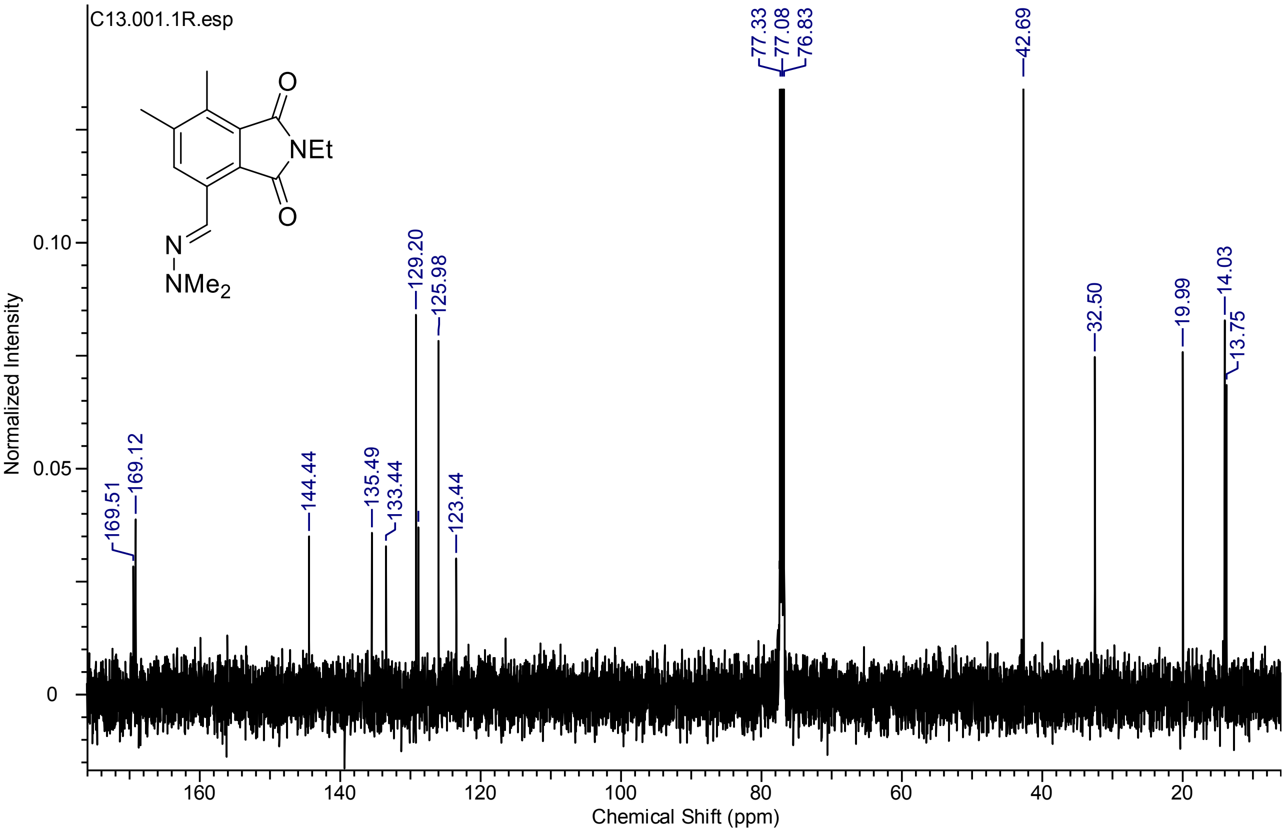
4-((2,2-Dimethylhydrazono)methyl)-2-ethyl-7-(trifluoromethyl)isoindoline-1,3-dione 5m



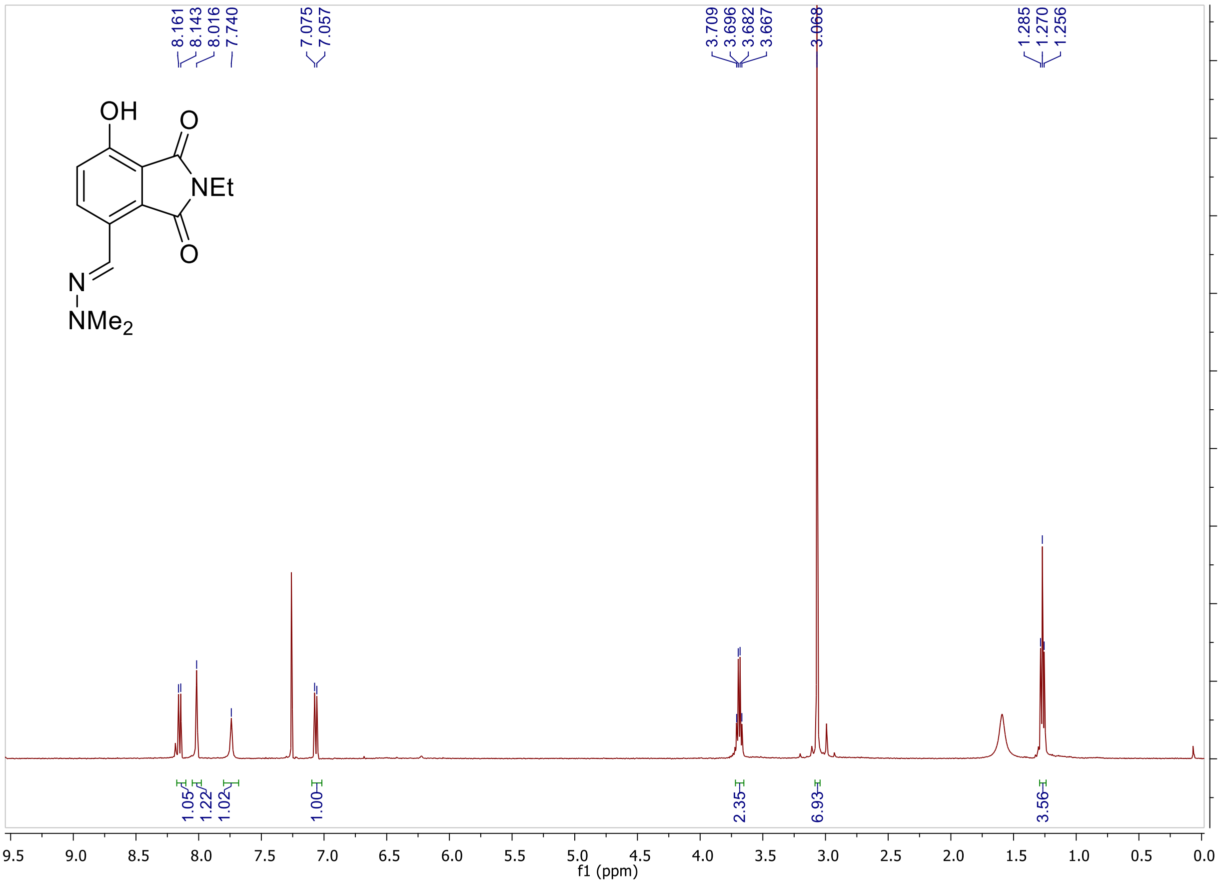


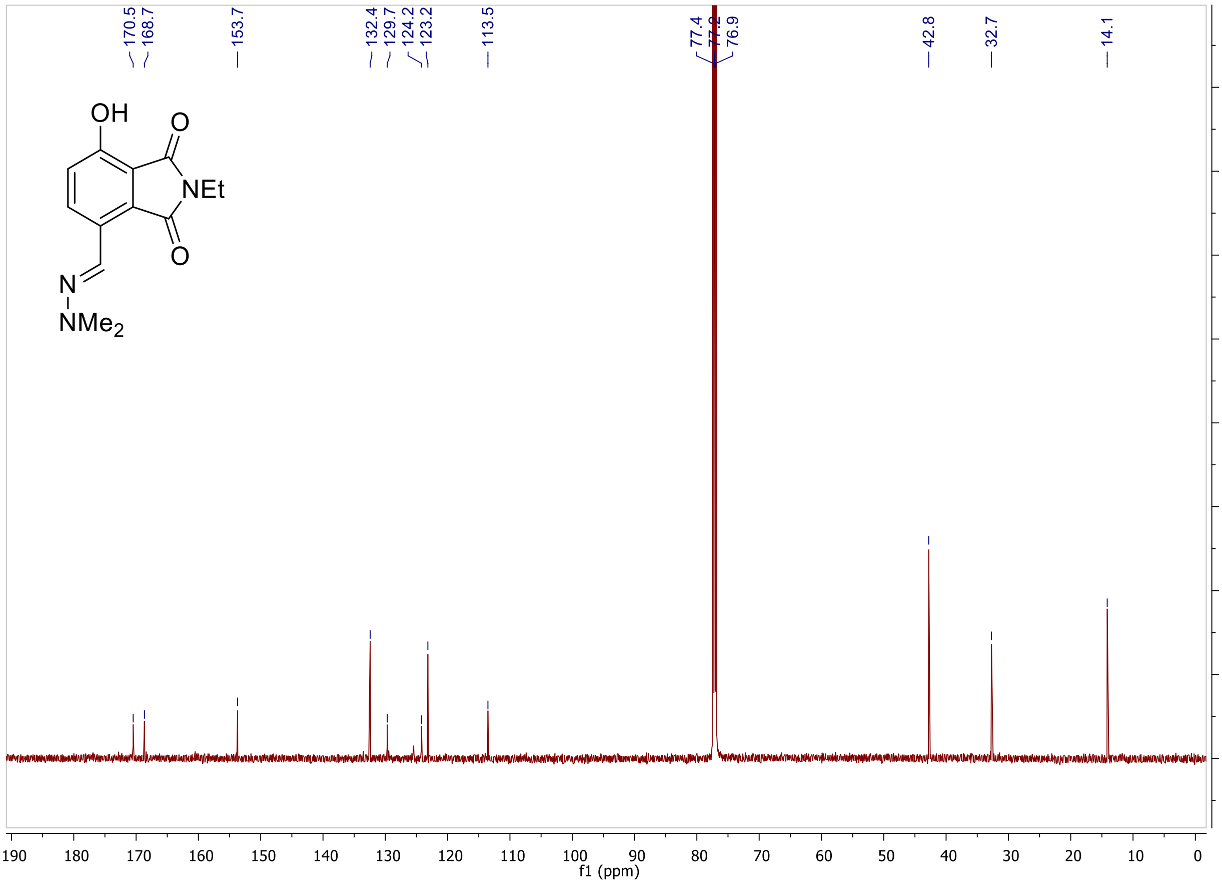
4-((2,2-Dimethylhydrazono)methyl)-2-ethyl-4,5-methylisoindoline-1,3-dione 5n



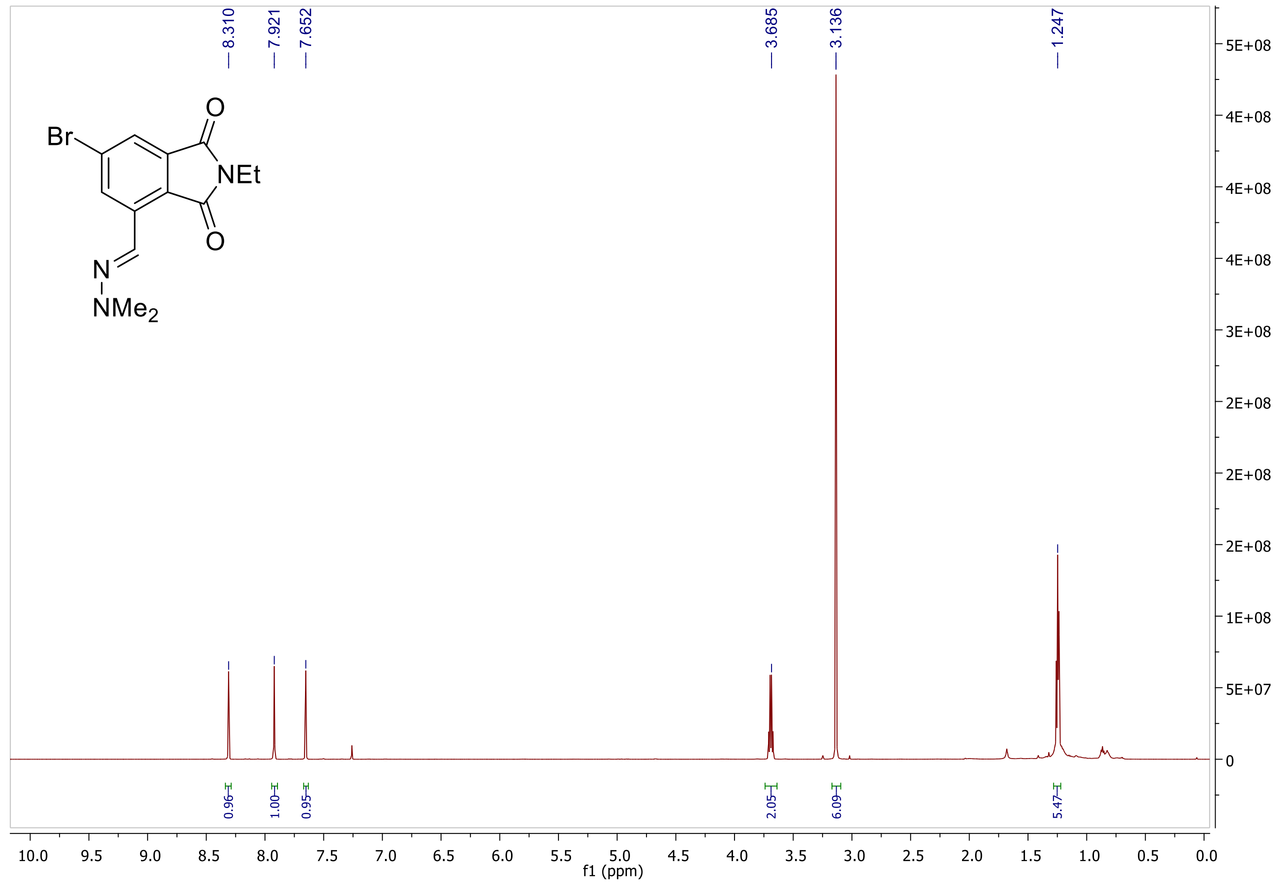


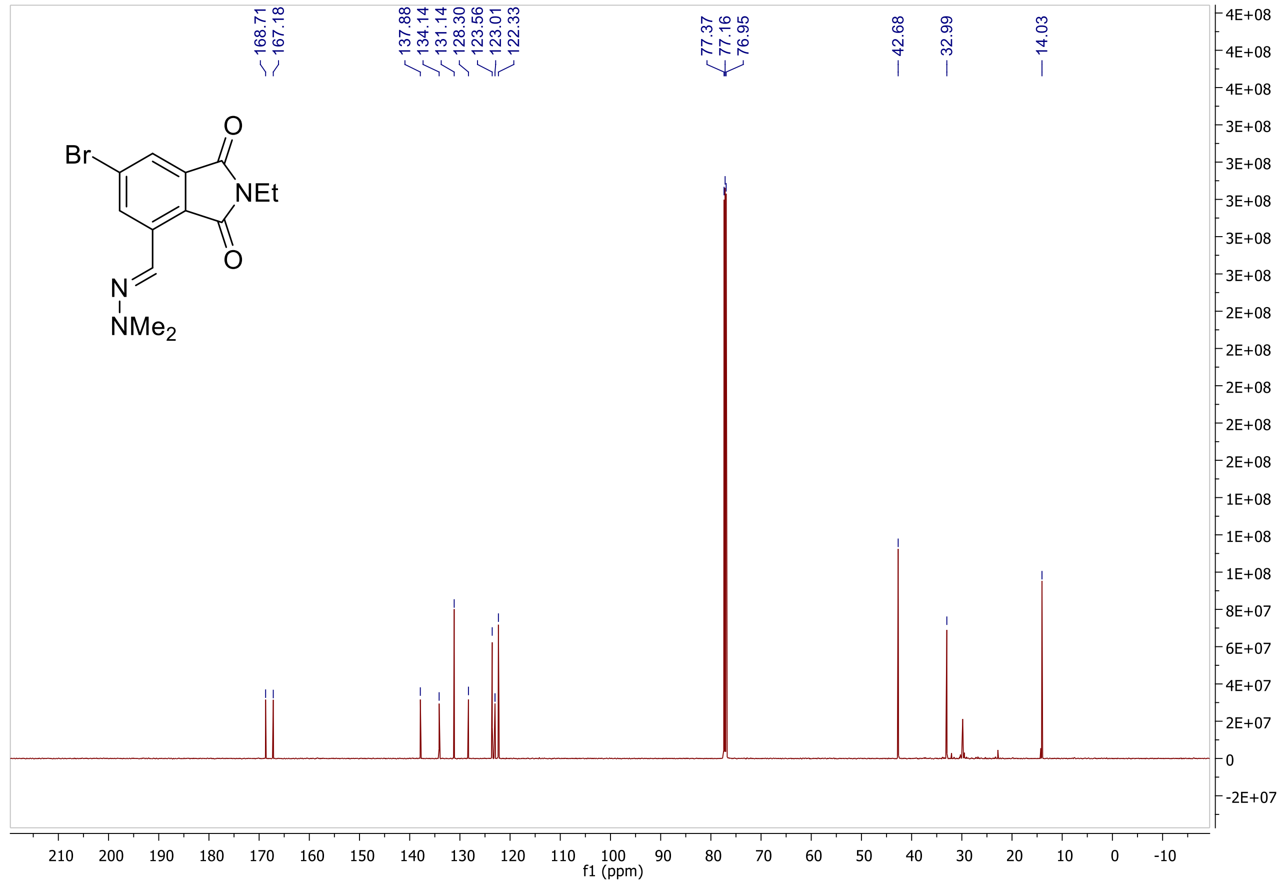
4-((2,2-dimethylhydrazono)methyl)-2-ethyl-7-hydroxyisoindoline-1,3-dione 5o



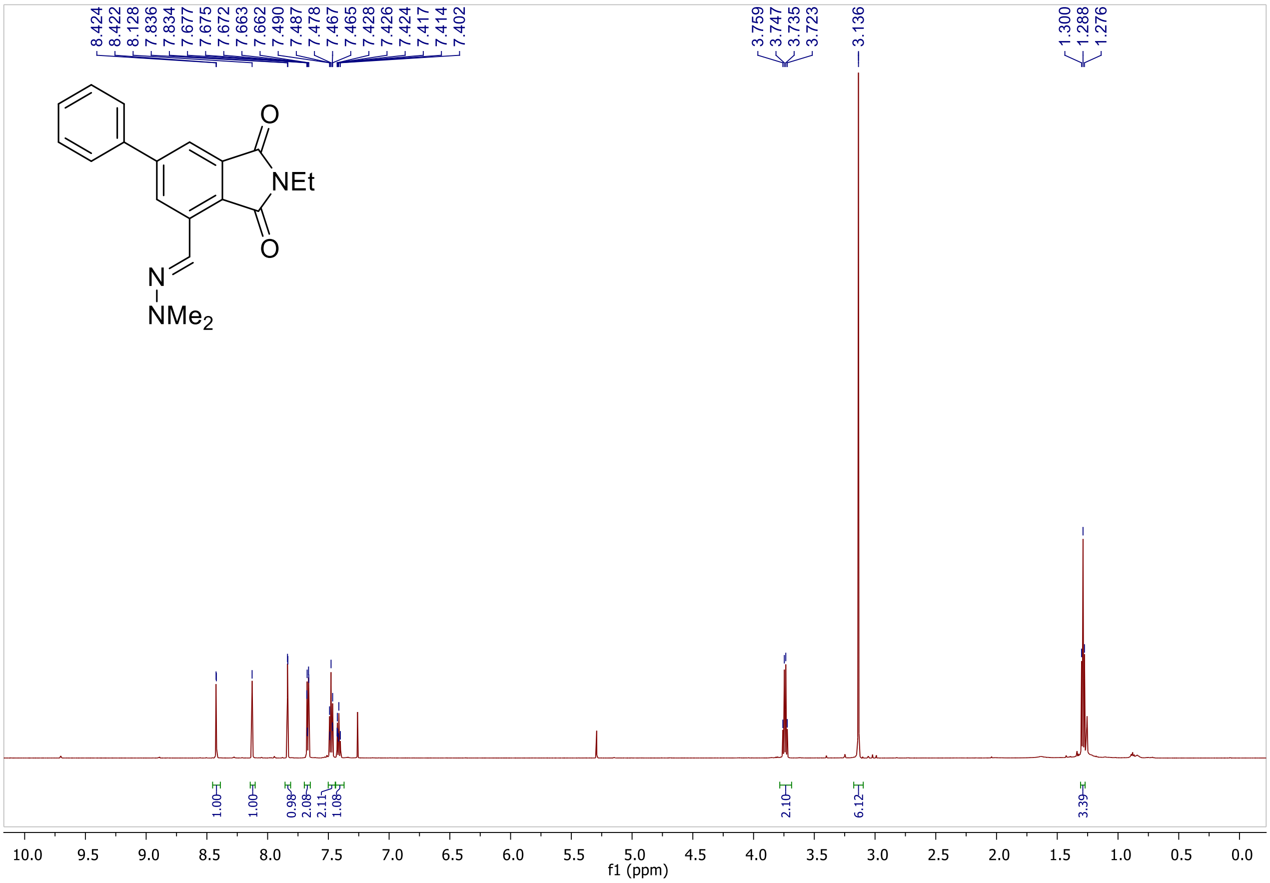


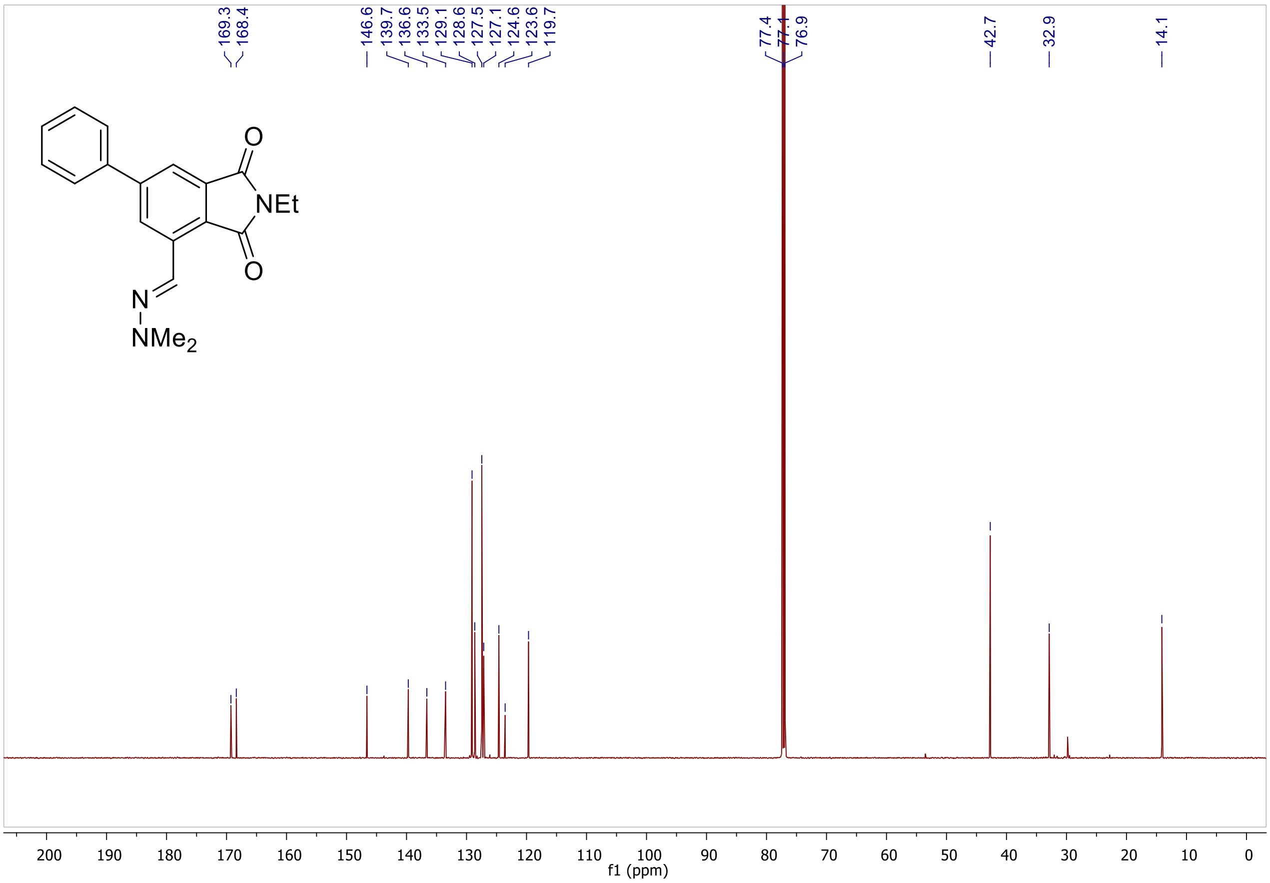
6-Bromo-4-((2,2-dimethylhydrazono)methyl)-2-ethylisoindoline-1,3-dione 5p



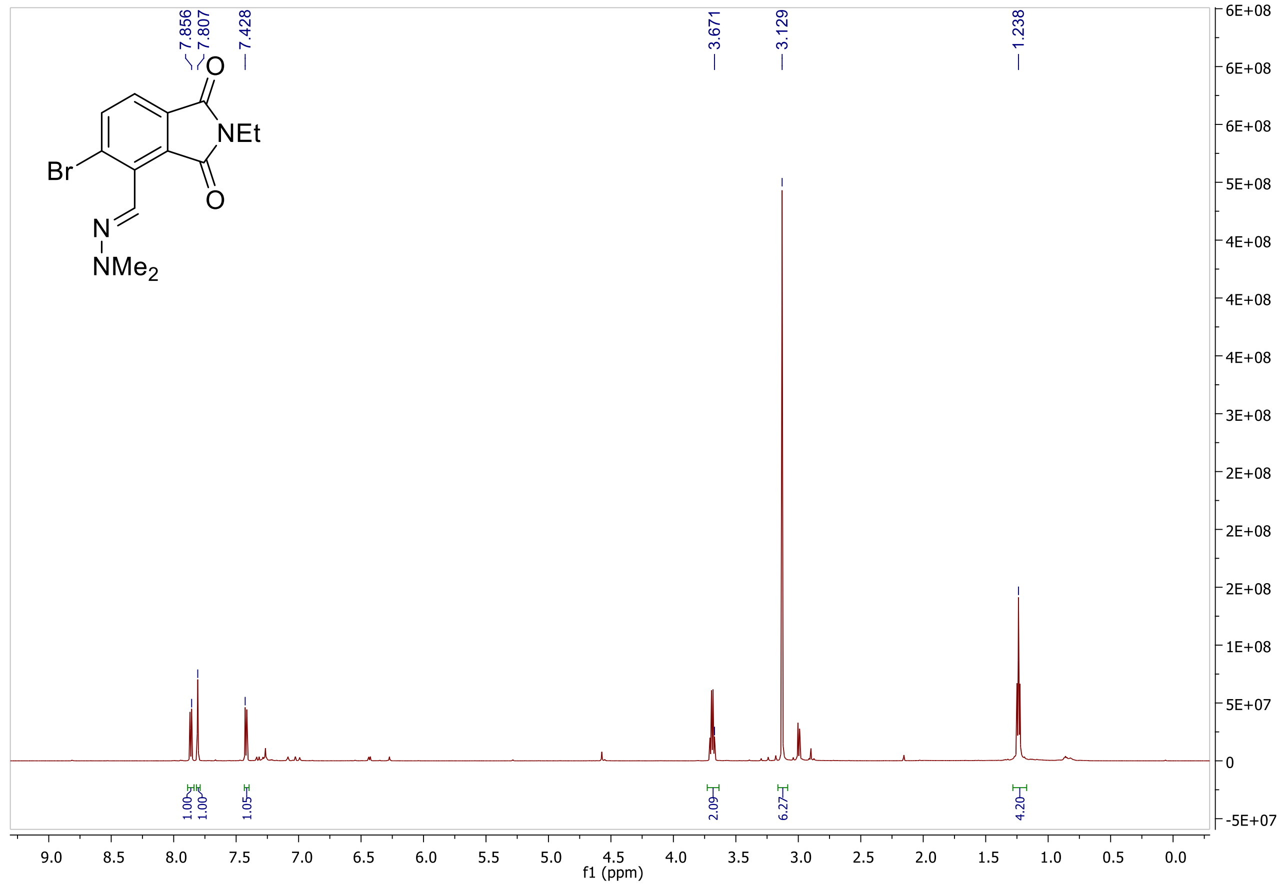


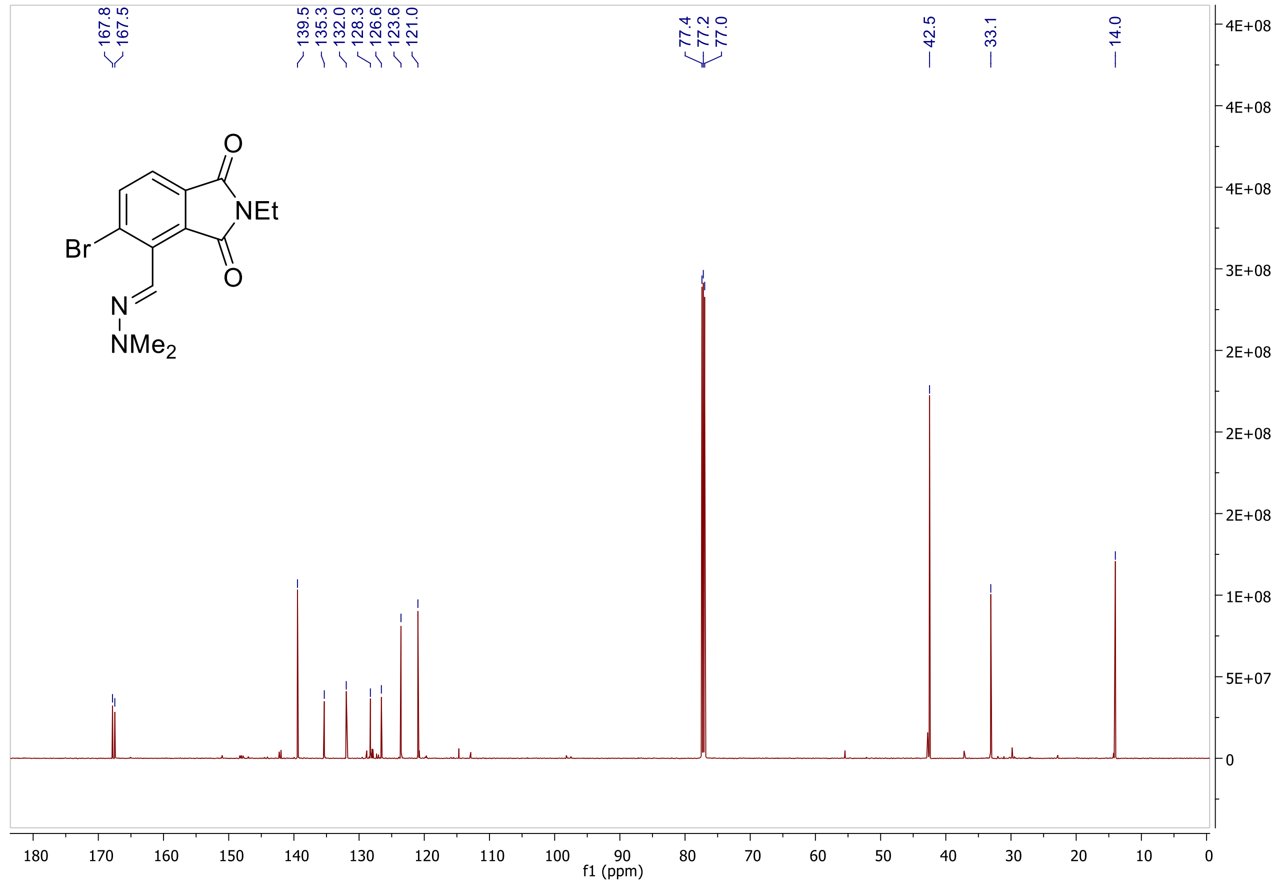
4-((2,2-Dimethylhydrazono)methyl)-2-ethyl-6-phenylisoindoline-1,3-dione 5q



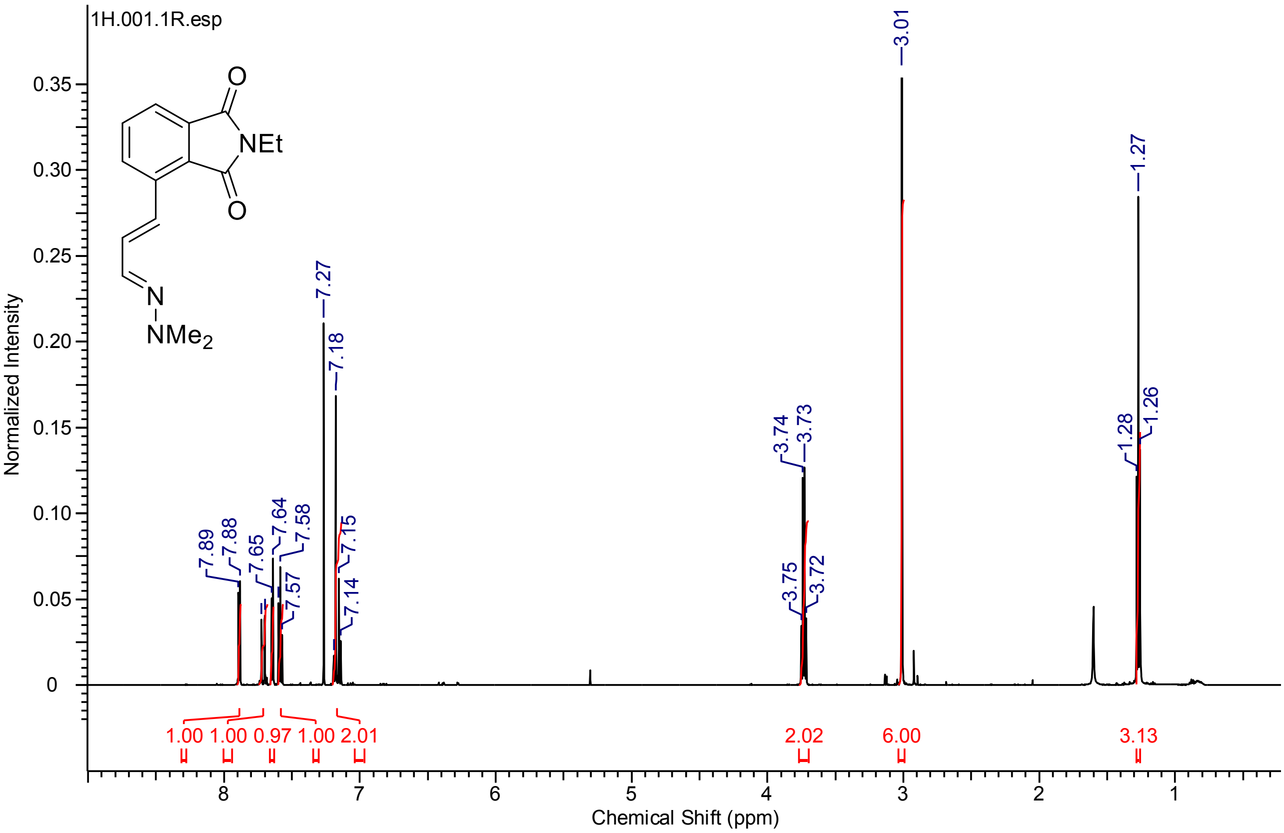


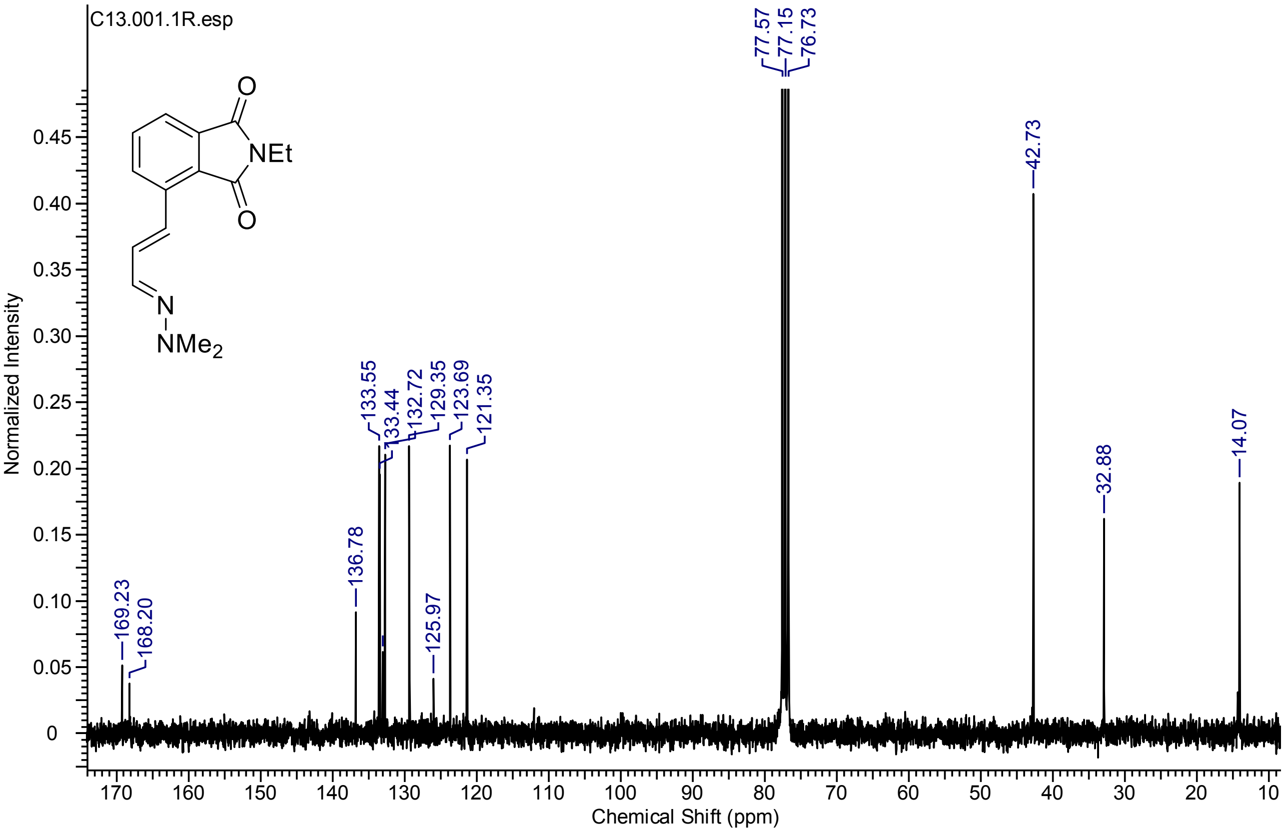
5-Bromo-4-((2,2-dimethylhydrazono)methyl)-2-ethylisoindoline-1,3-dione 5r



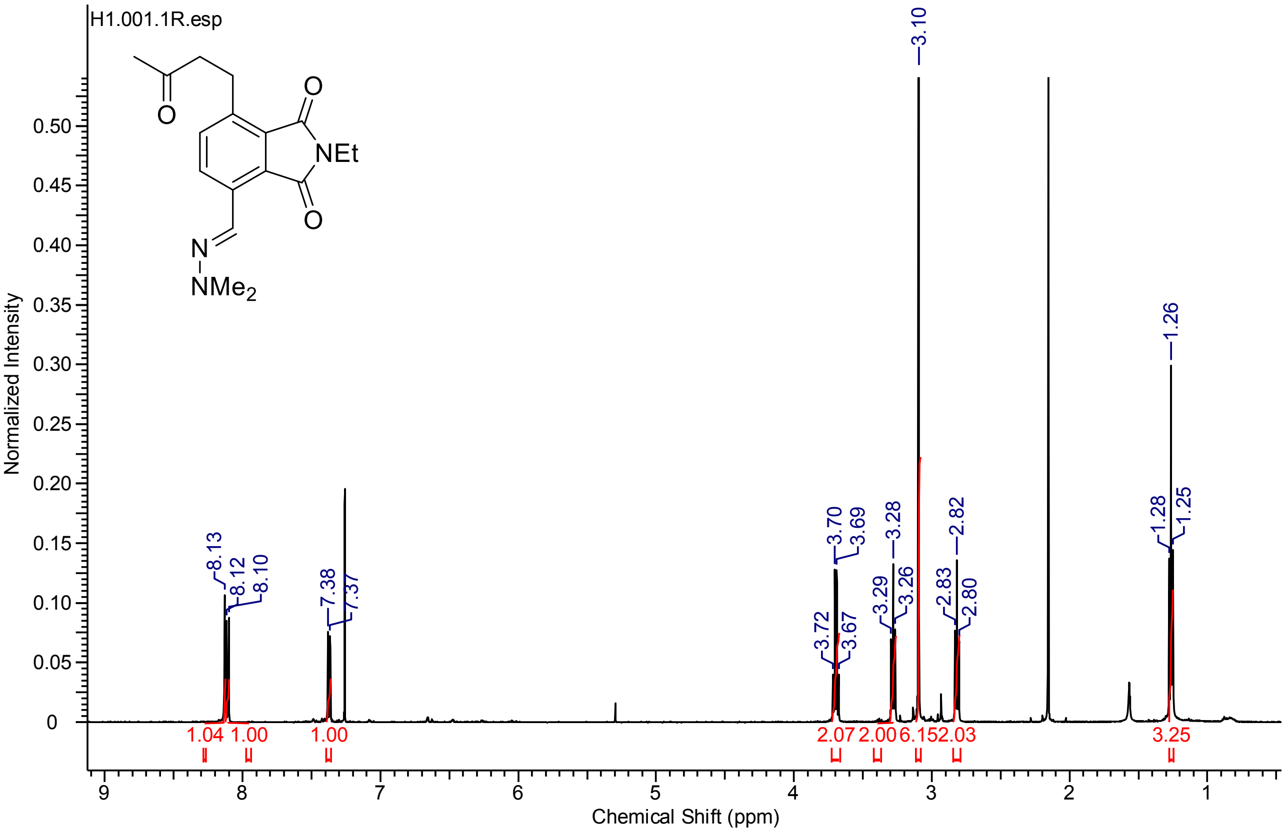


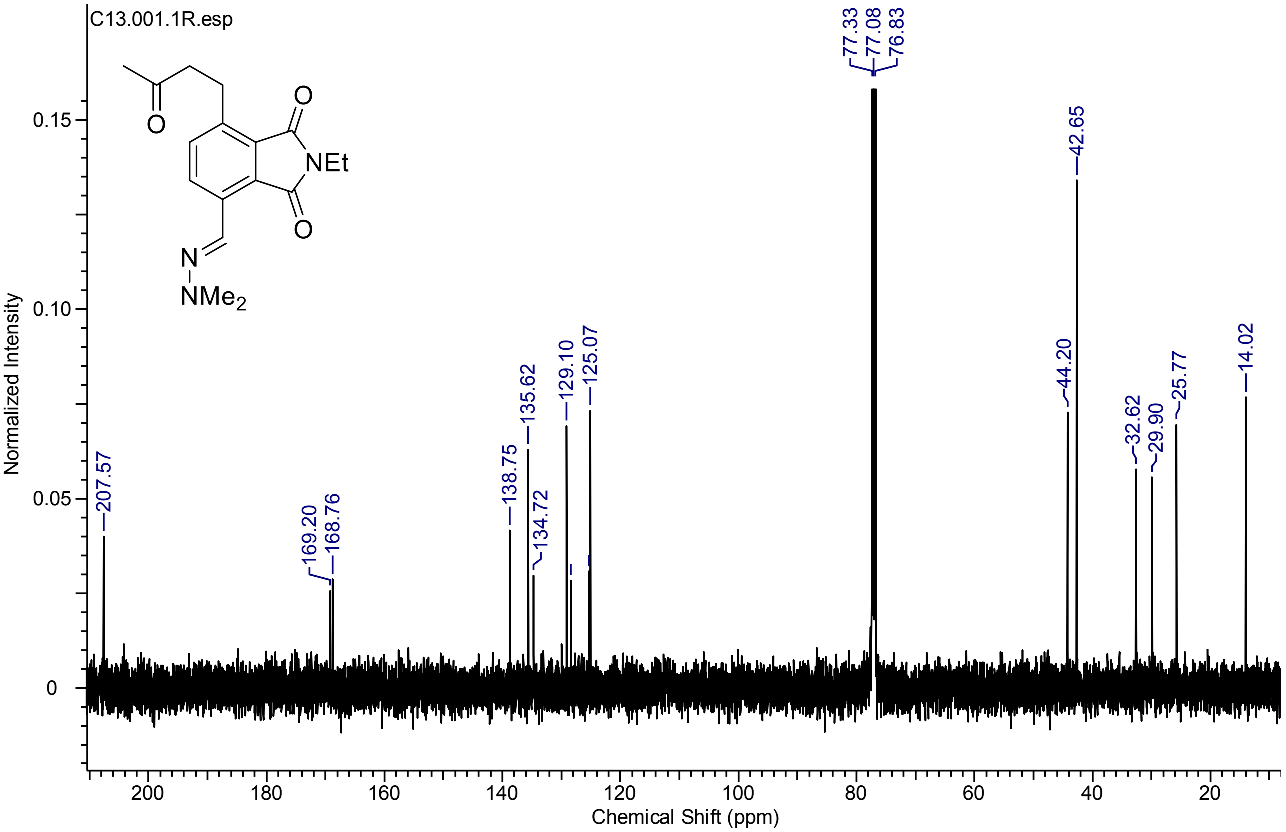
4-(3-(2,2-Dimethylhydrazono)prop-1-en-1-yl)-2-ethylisoindoline-1,3-dione 5s



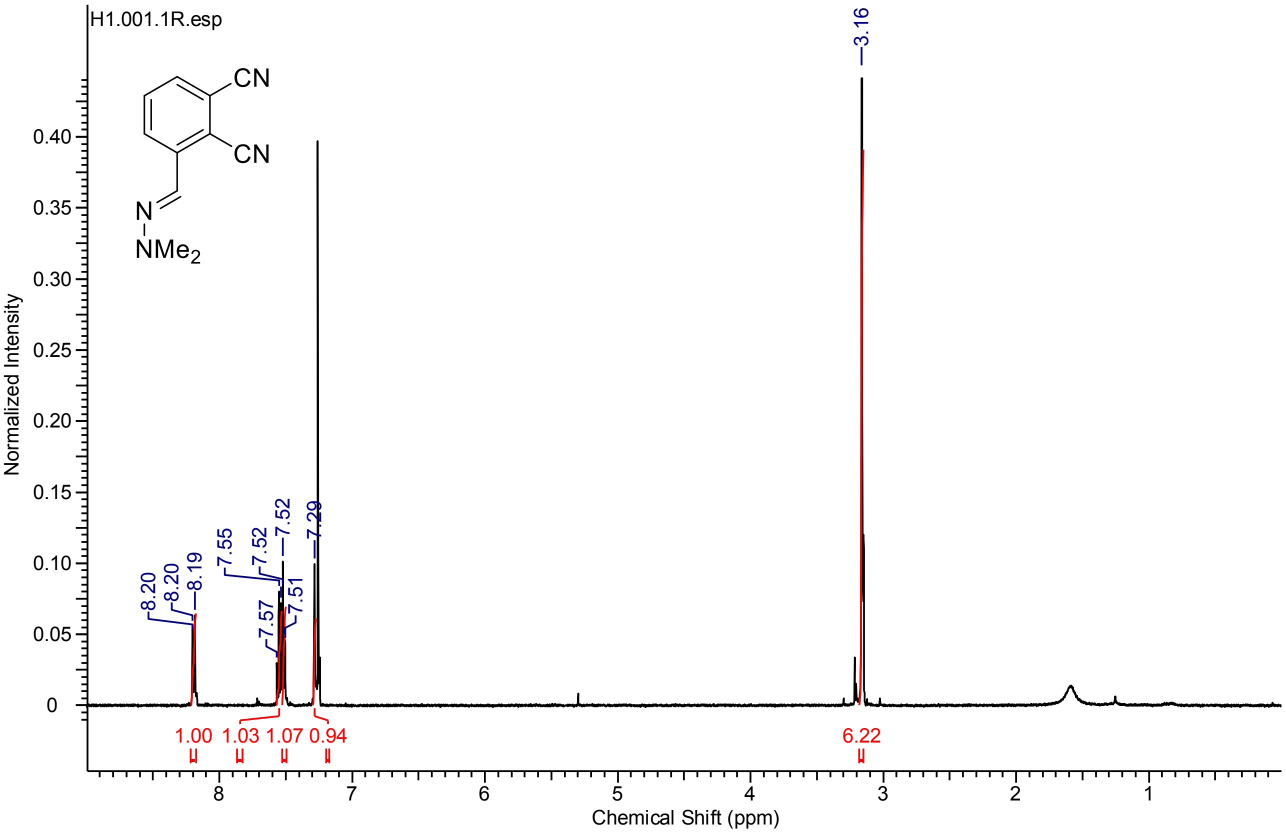


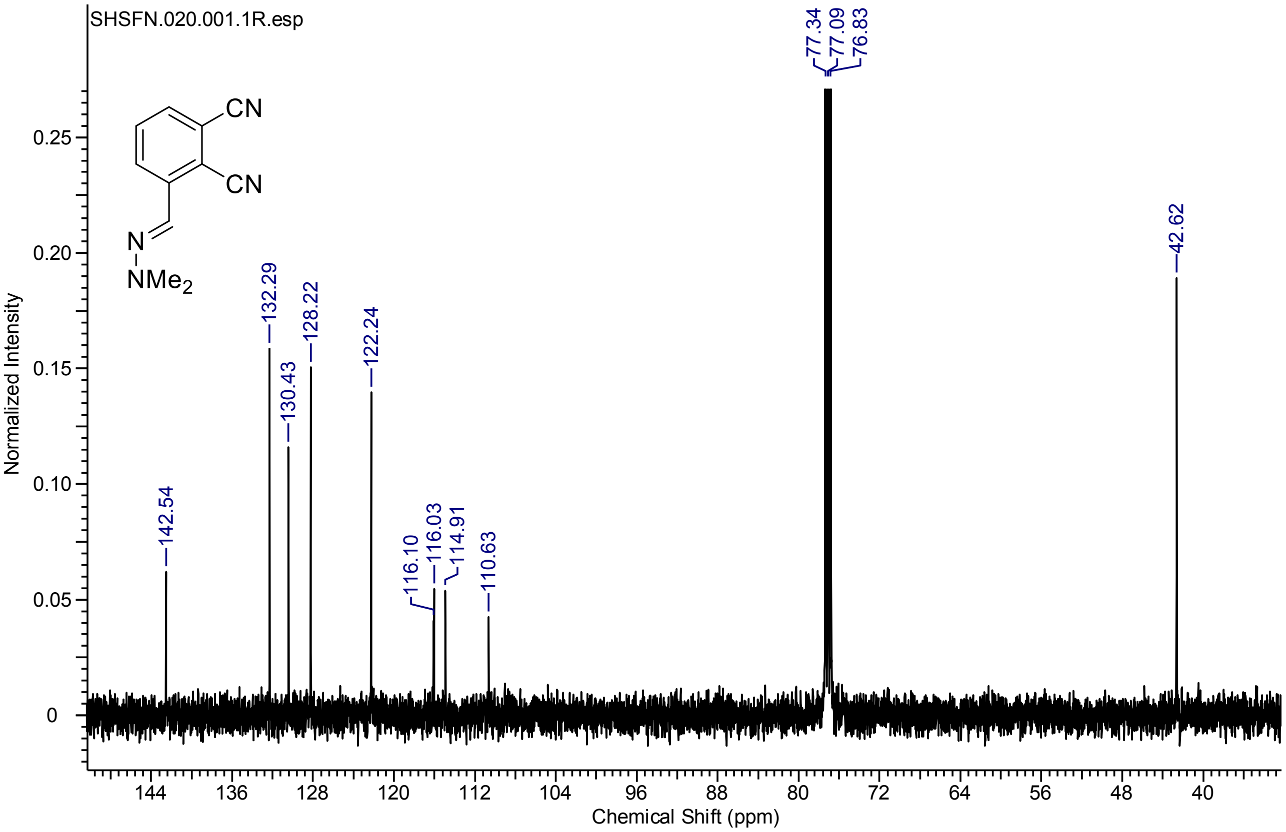
4-((2,2-Dimethylhydrazono)methyl)-2-ethyl-7-(3-oxobutyl)isoindoline-1,3-dione 5t



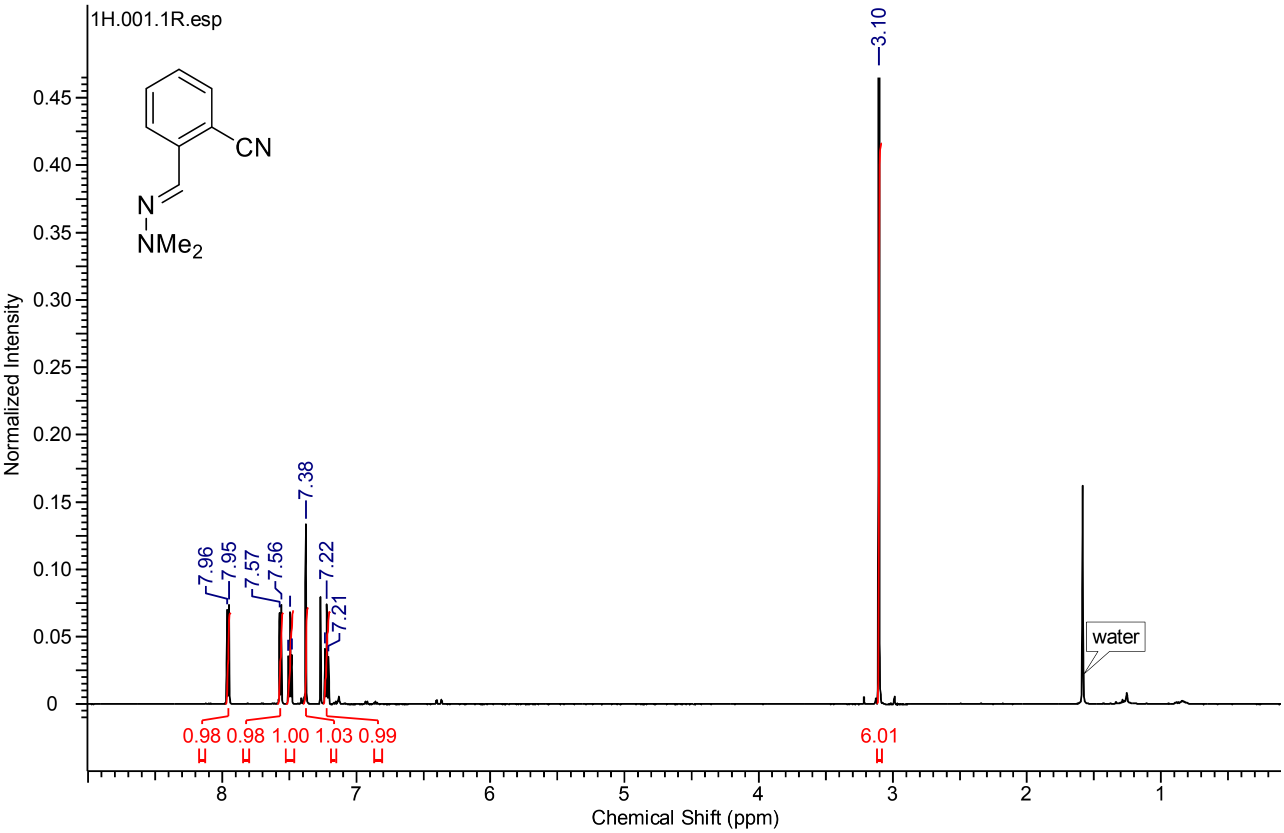


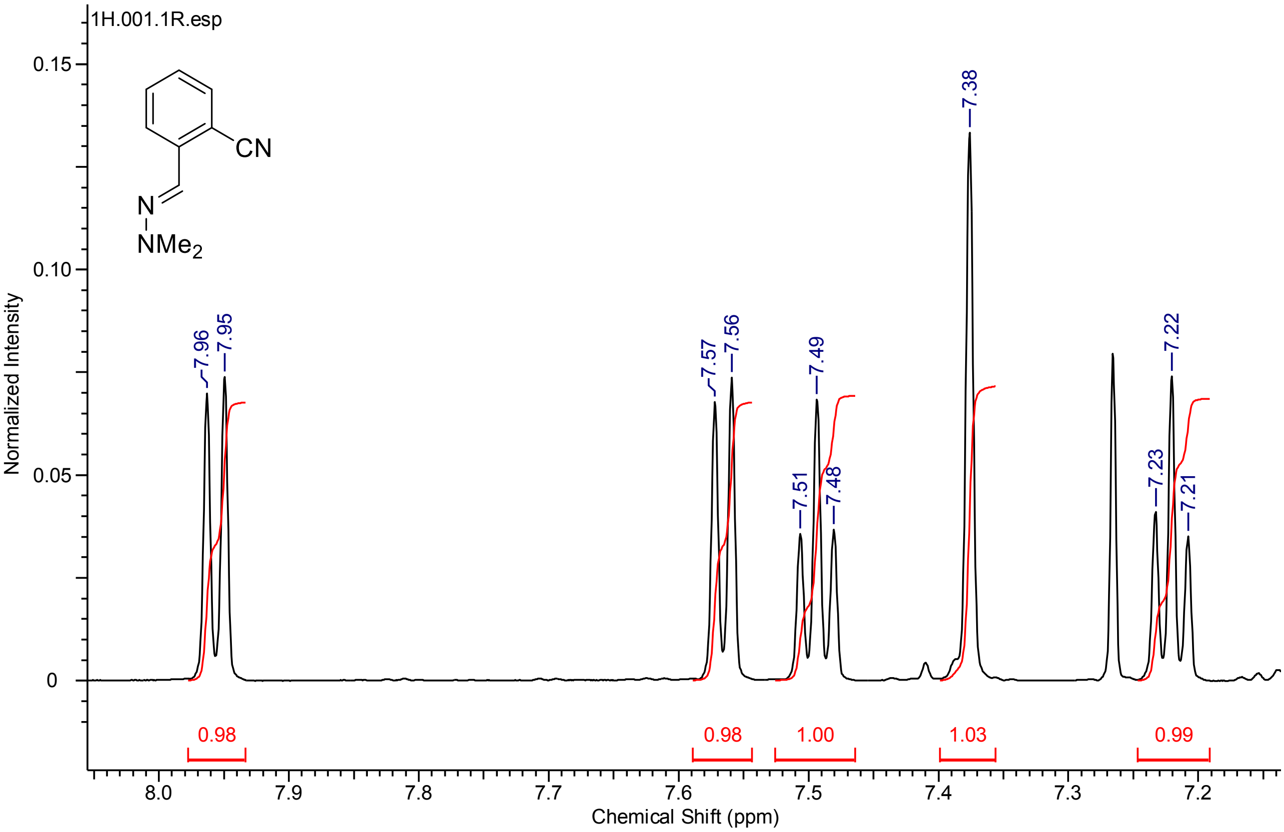
3-((2,2-Dimethylhydrazono)methyl)phthalonitrile 8a

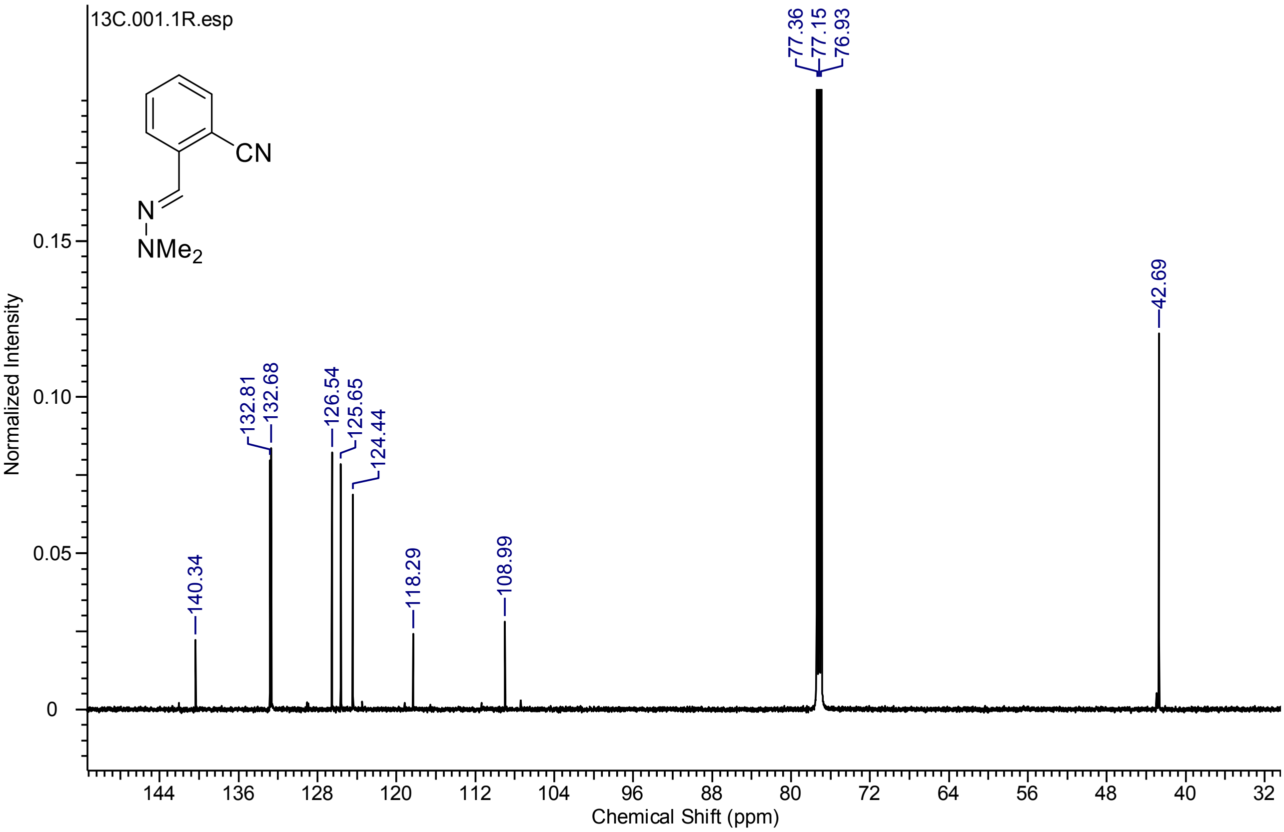




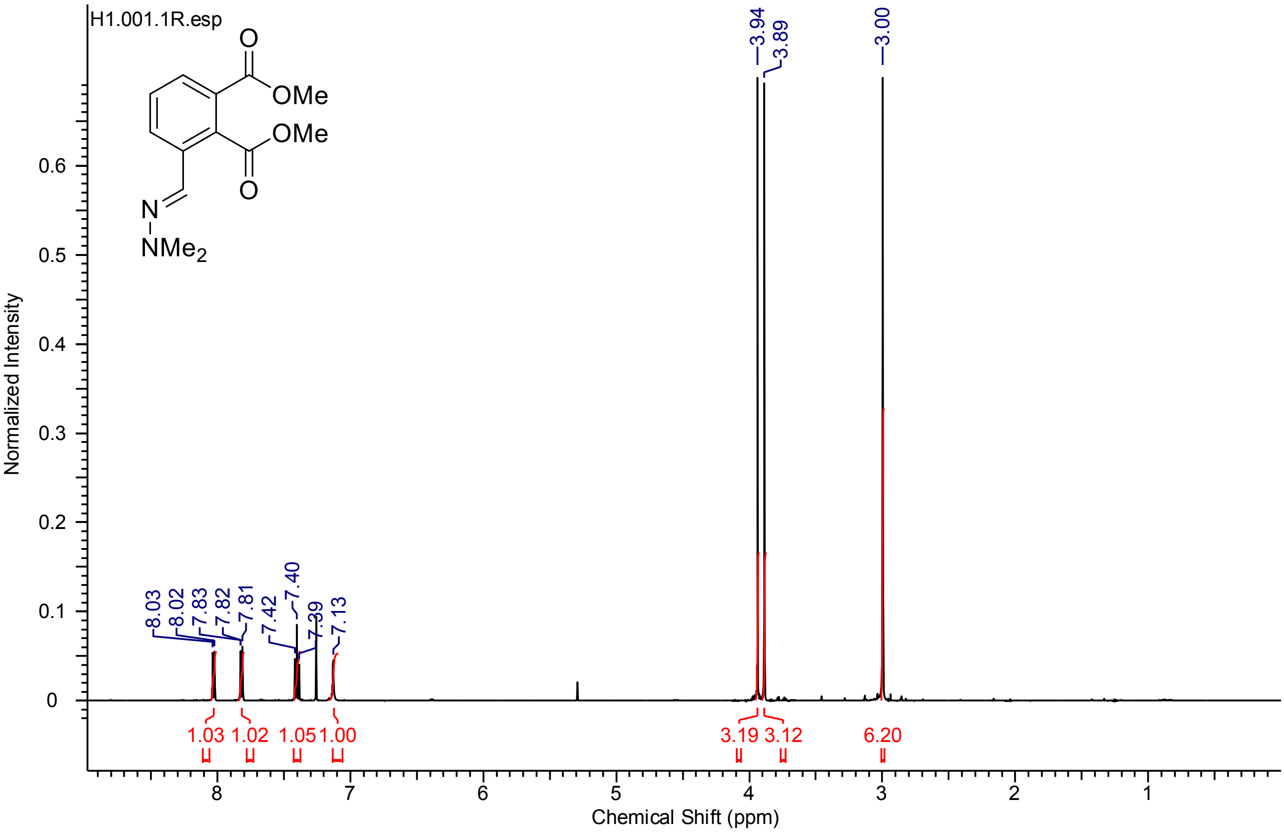
3-((2,2-Dimethylhydrazono)methyl)benzonitrile 8b

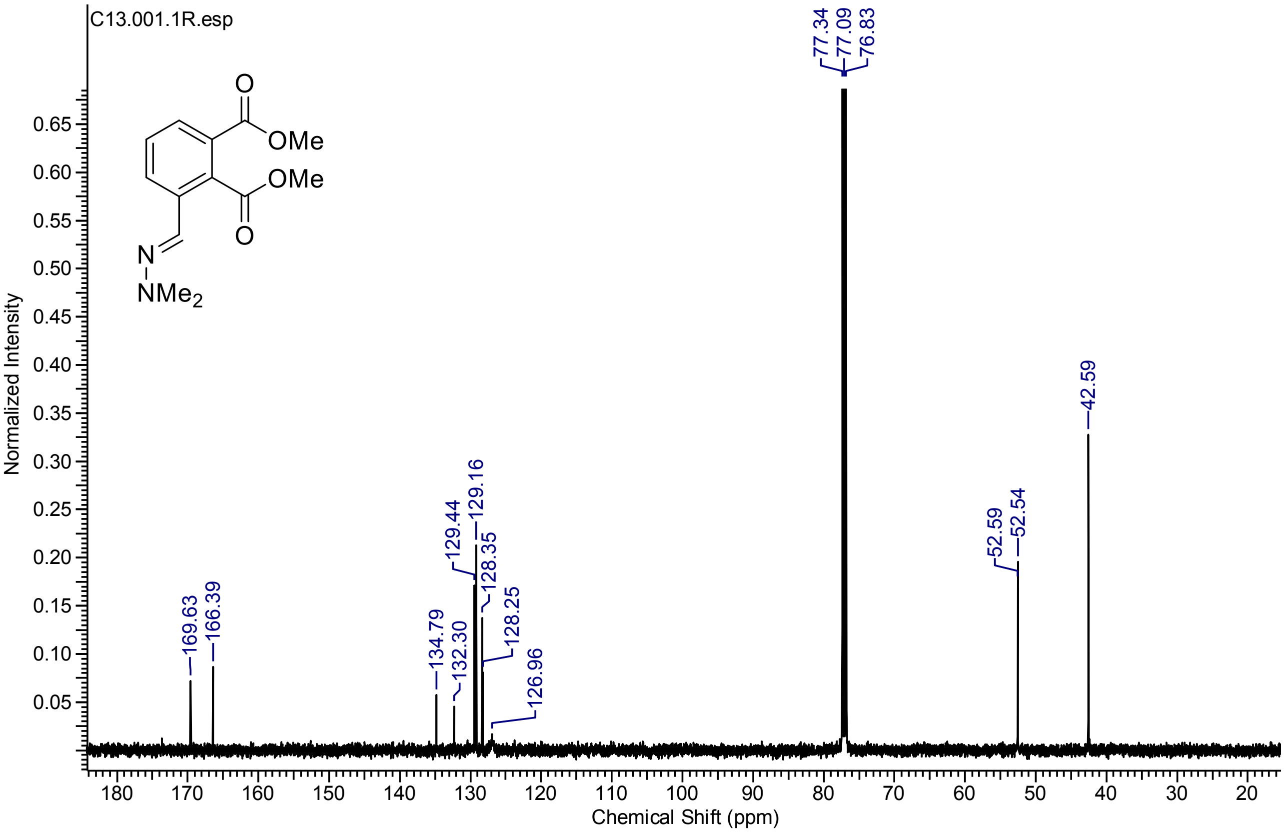




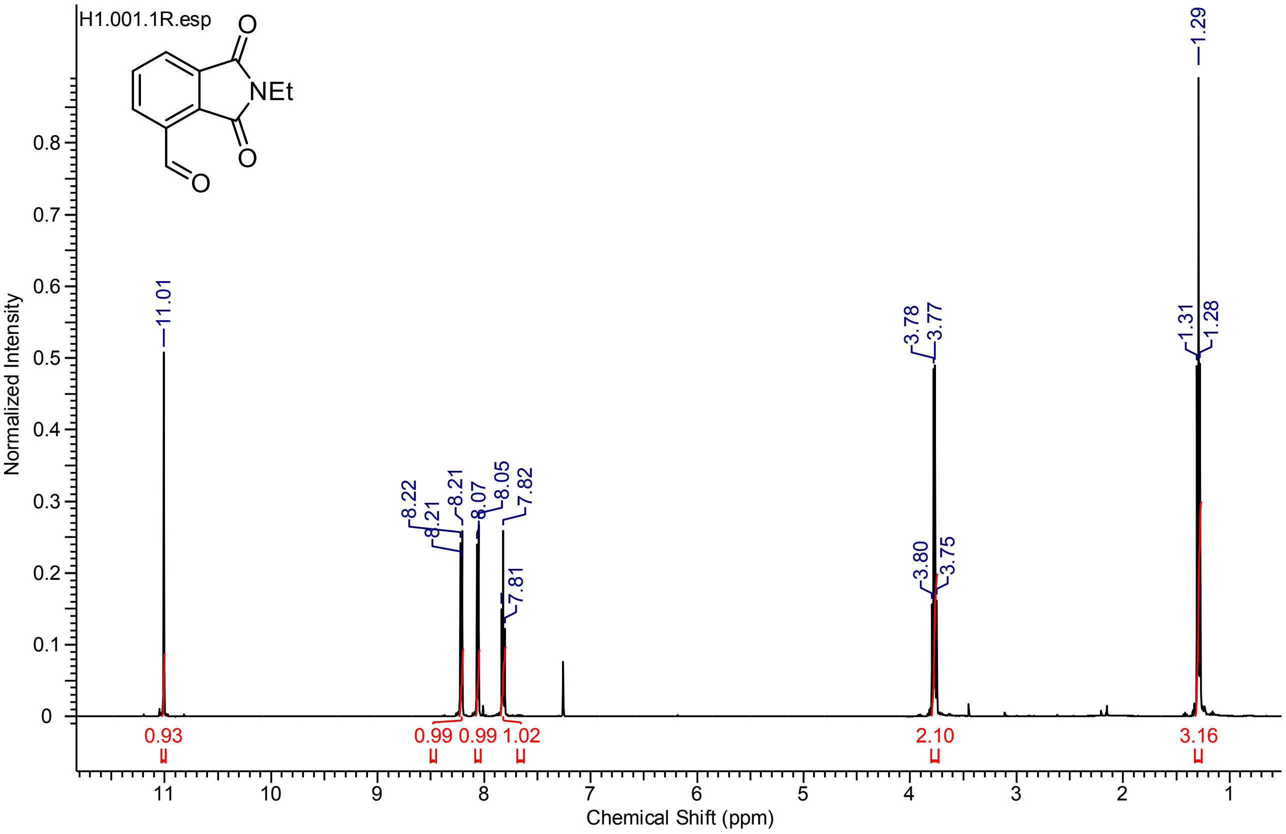

13C.001.1R.esp
CN
N
NMe$_2$
Normalized Intensity
0.15
0.10
0.05
0
140.34
132.81
132.68
126.54
125.65
124.44
118.29
108.99
77.36
77.15
76.93
42.69
144
136
128
120
112
104
96
88
80
72
64
56
48
40
32
Chemical Shift (ppm)

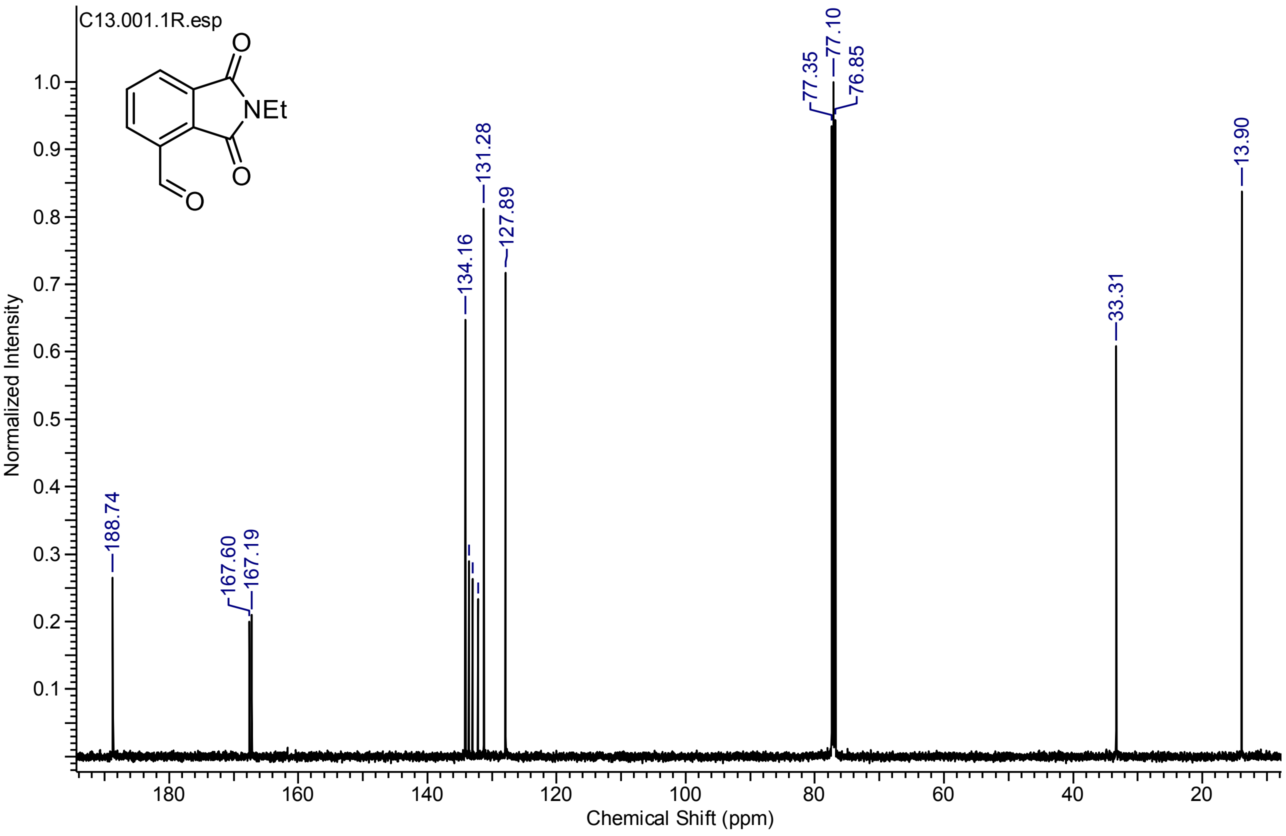
Dimethyl-3-((2,2-dimethylhydrazono)methyl)phthalate 8c



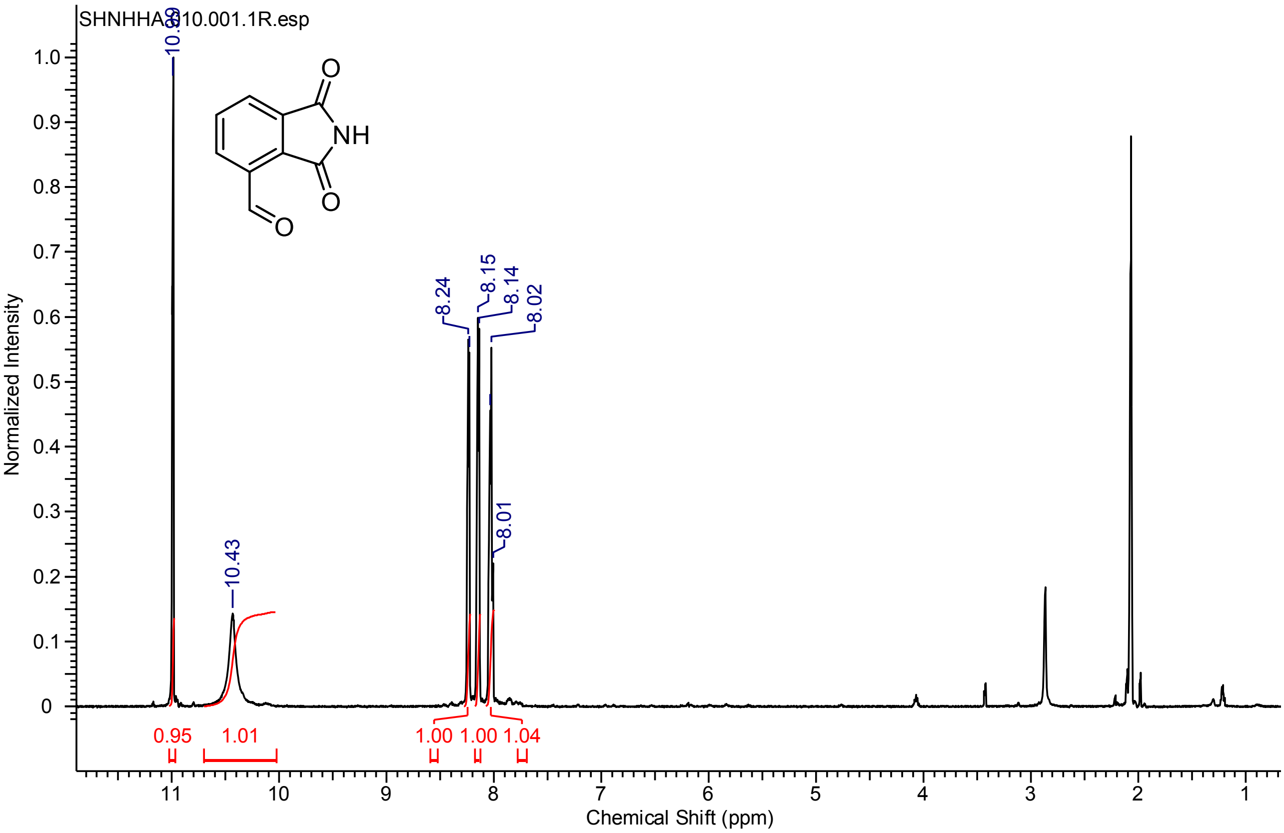


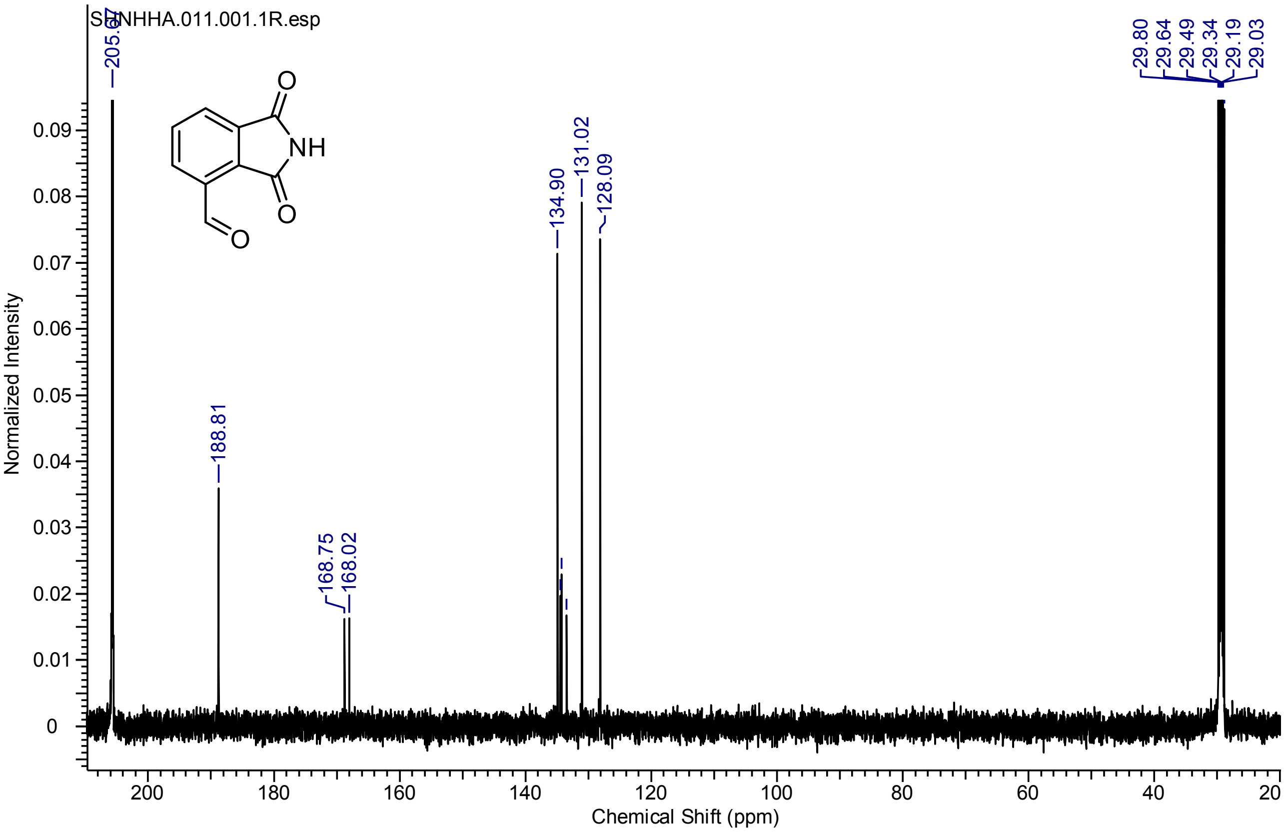
2-Ethyl-1,3-dioxoisoindoline-4-carbaldehyde 9a

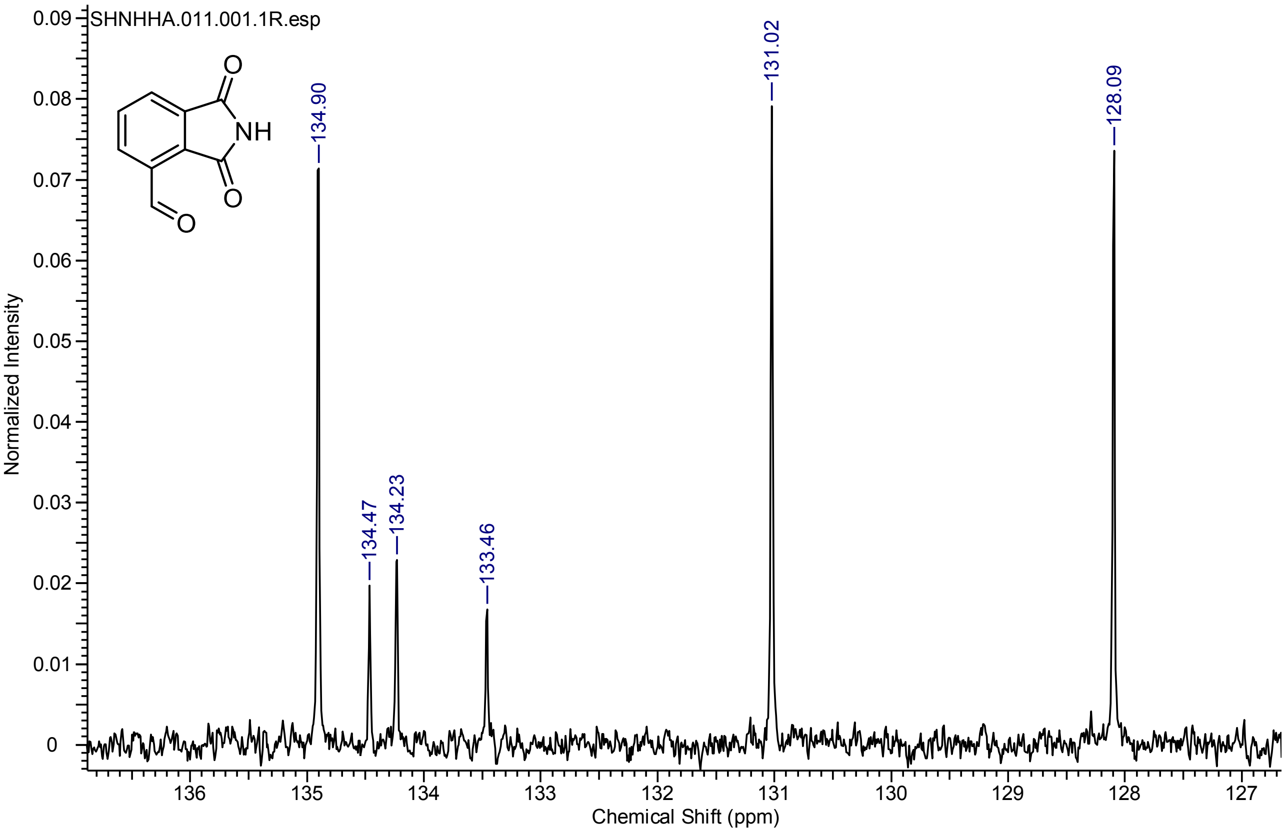




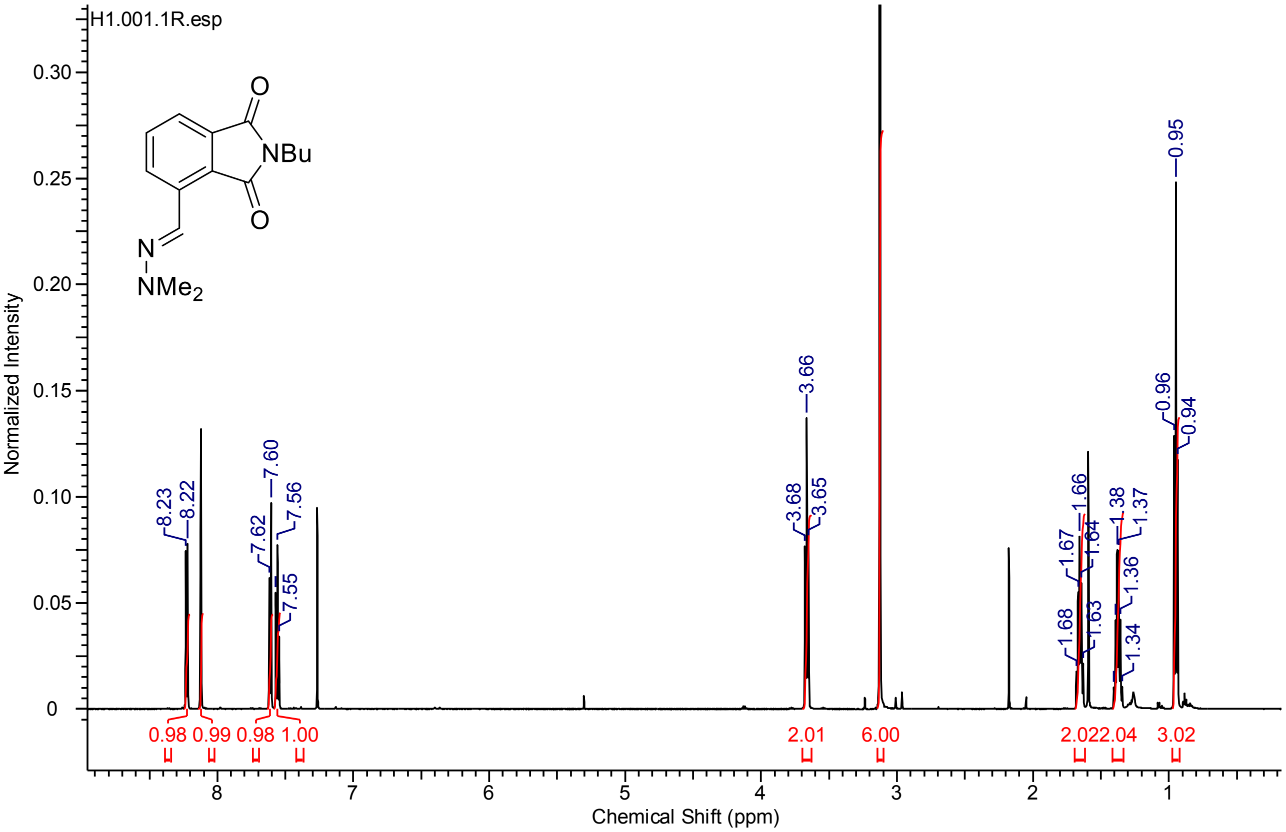
1,3-Dioxoisoindoline-4-carbaldehyde 9b

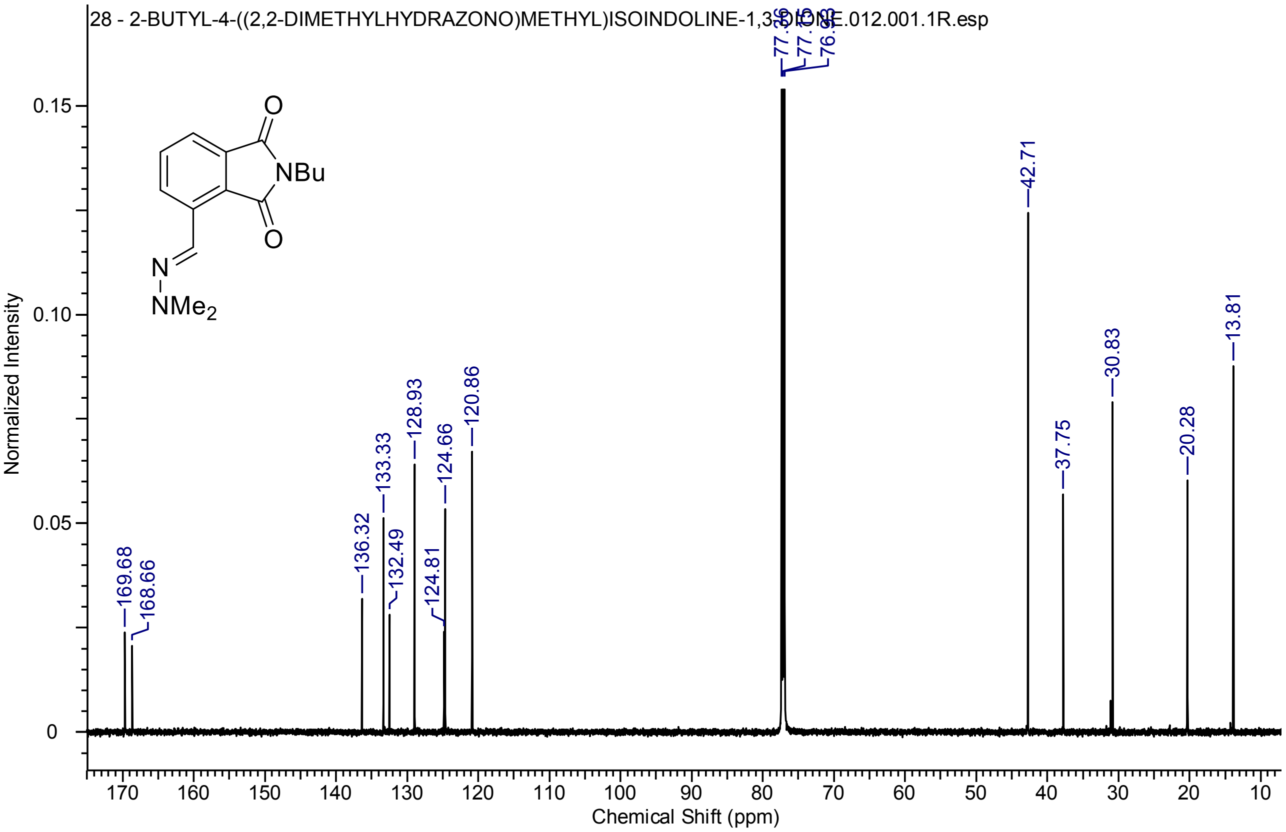




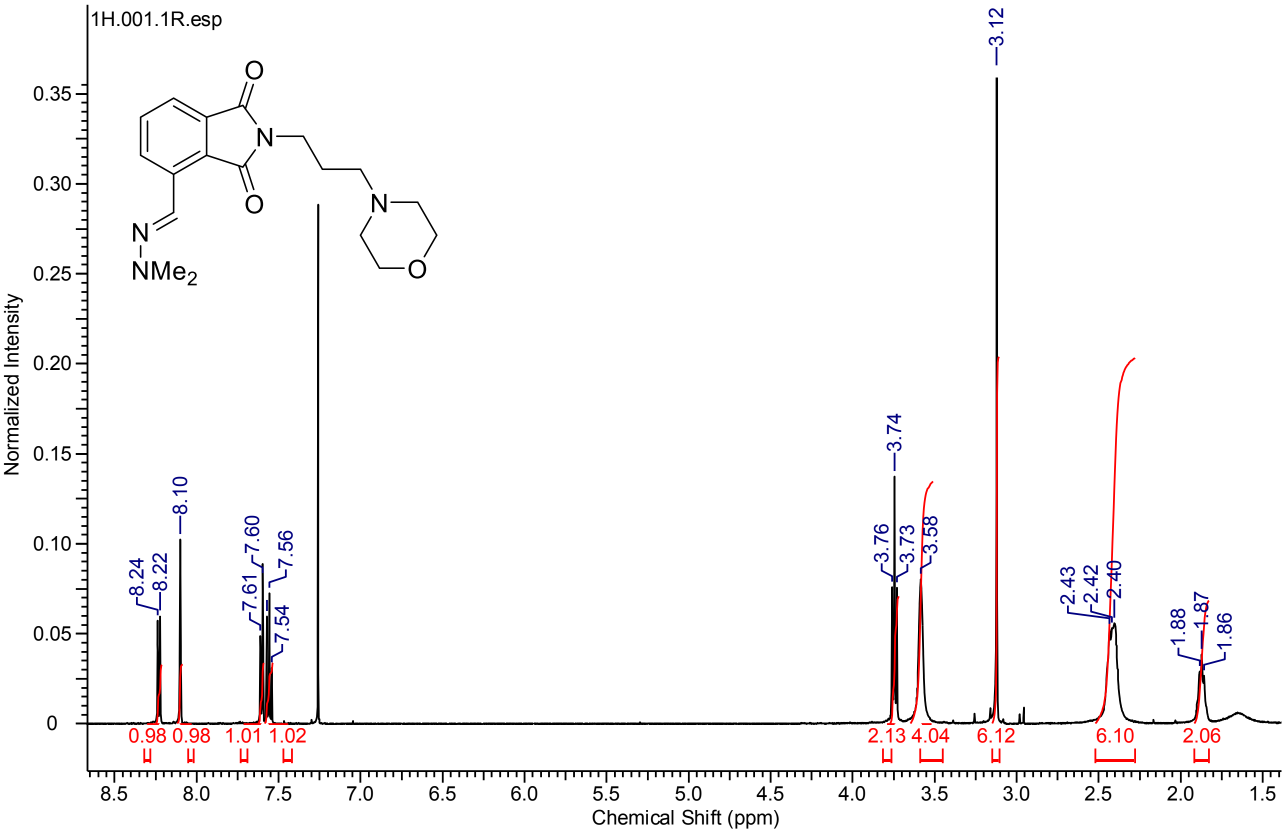

SHNHHA.011.001.1R.esp
O
NH
O
O
134.90
134.47
134.23
133.46
131.02
128.09
Normalized Intensity
0.09
0.08
0.07
0.06
0.05
0.04
0.03
0.02
0.01
0
136
135
134
133
132
131
130
129
128
127
Chemical Shift (ppm)

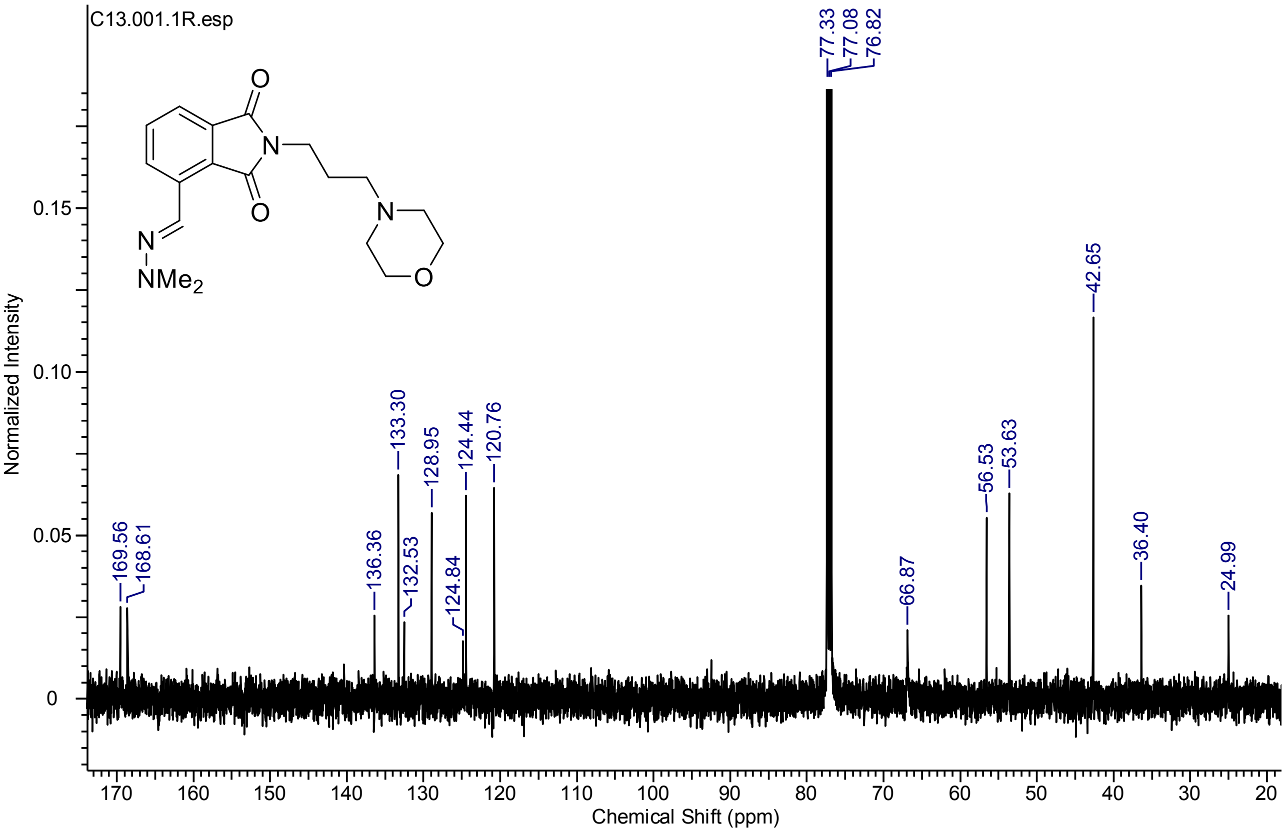
2-Butyl-4-((2,2-dimethylhydrazono)methyl)isoindoline-1,3-dione 5u



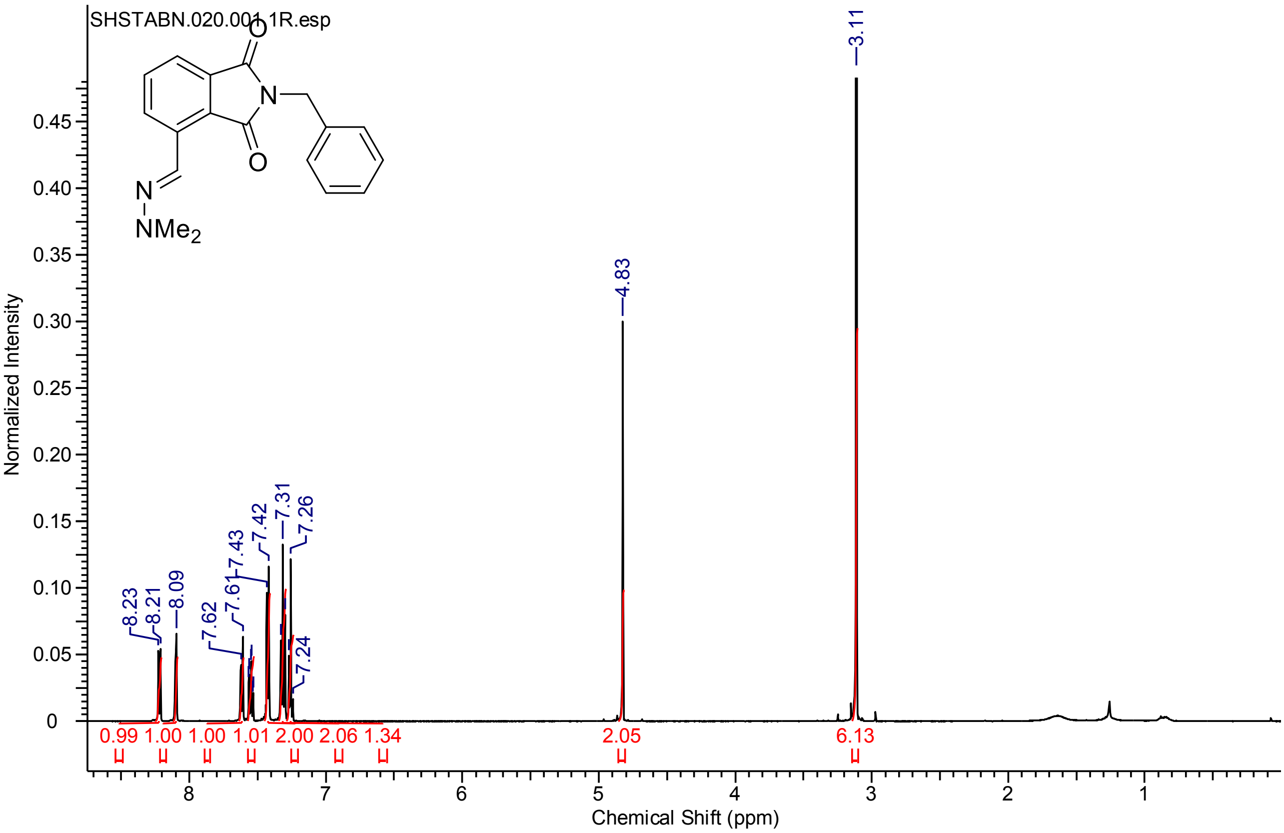


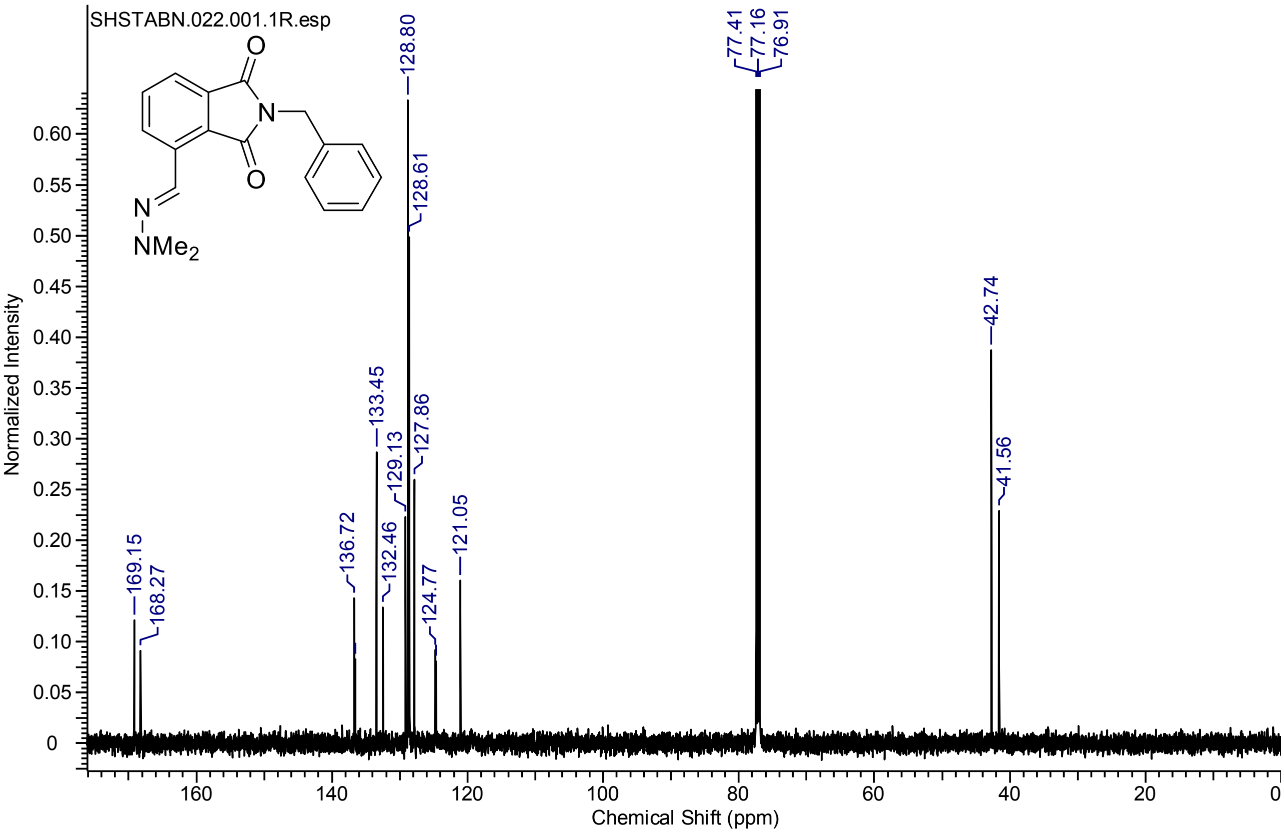
4-((2,2-Dimethylhydrazono)methyl)-2-(3-morpholinopropyl)isoindoline-1,3-dione 5v



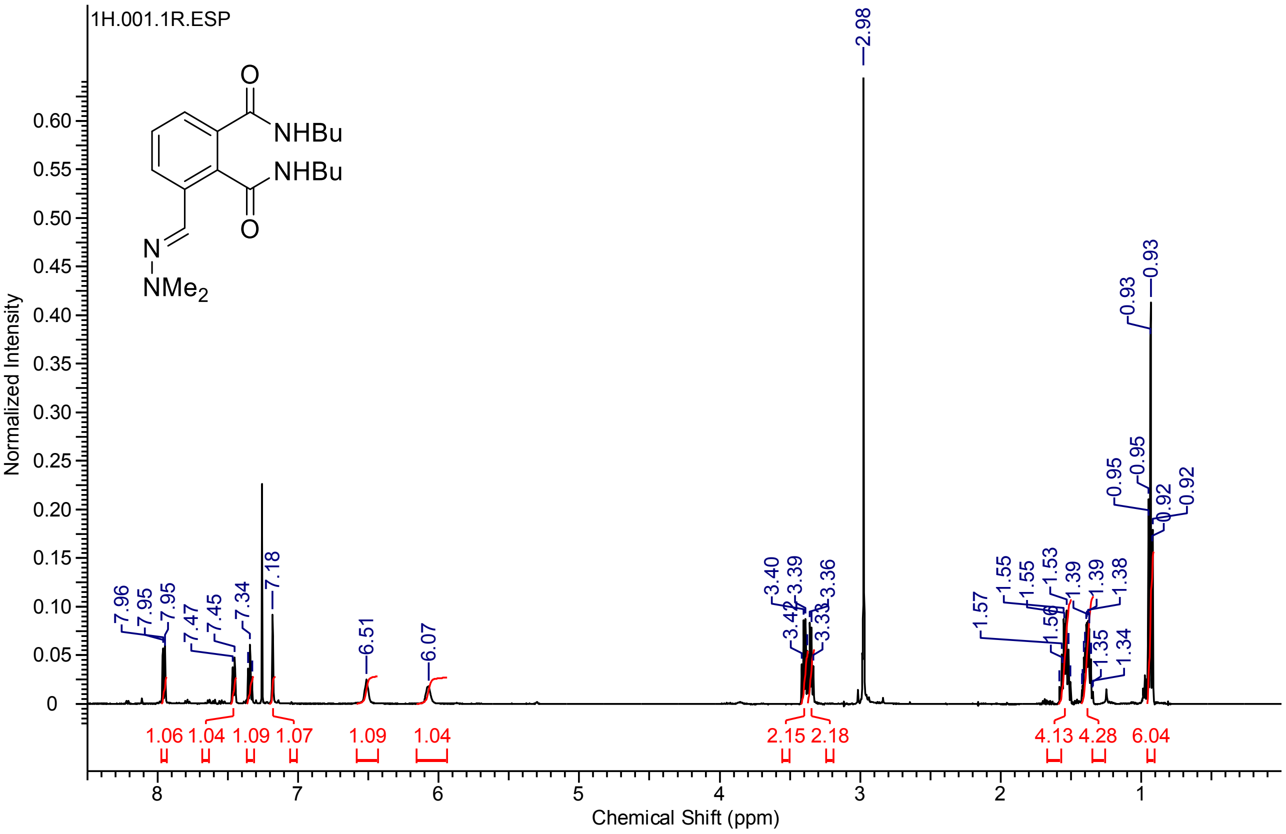


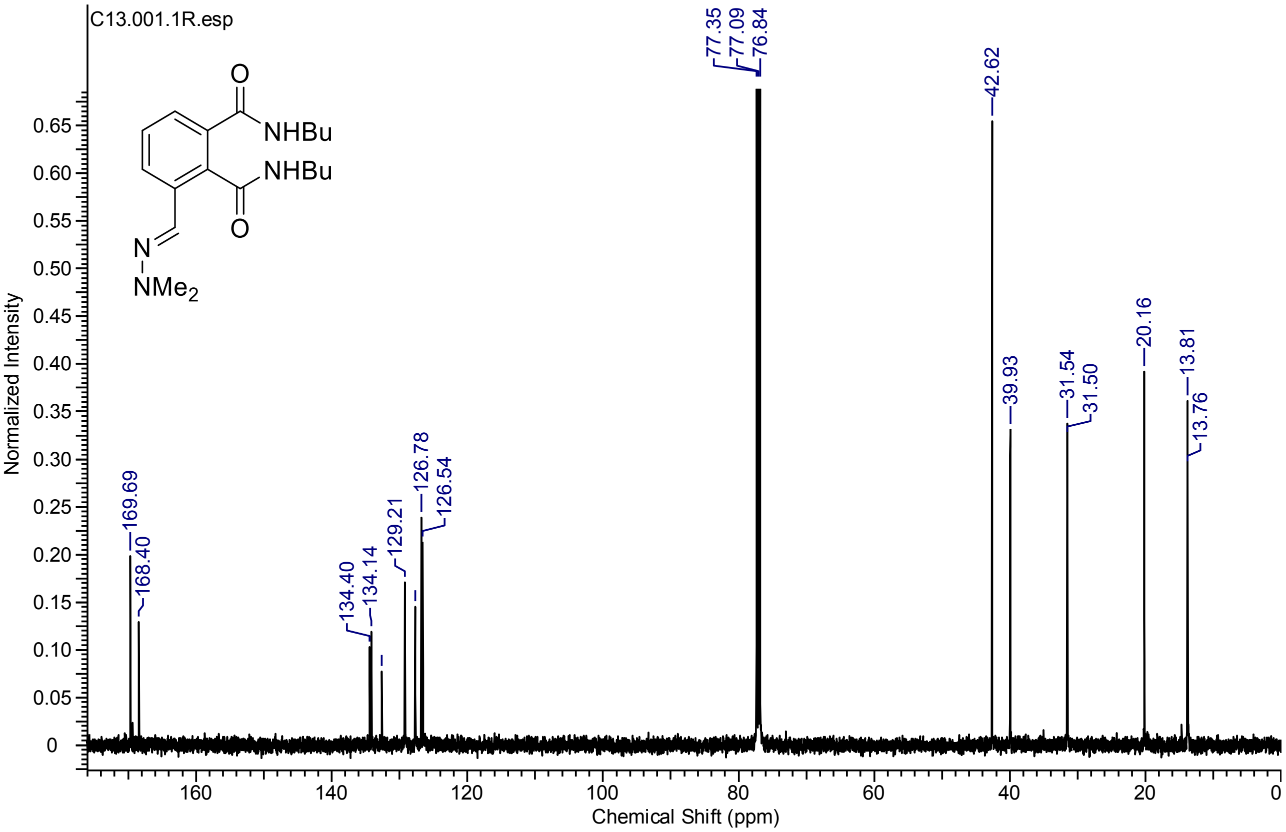
2-Benzyl-4-((2,2-dimethylhydrazono)methyl)isoindoline-1,3-dione 5w

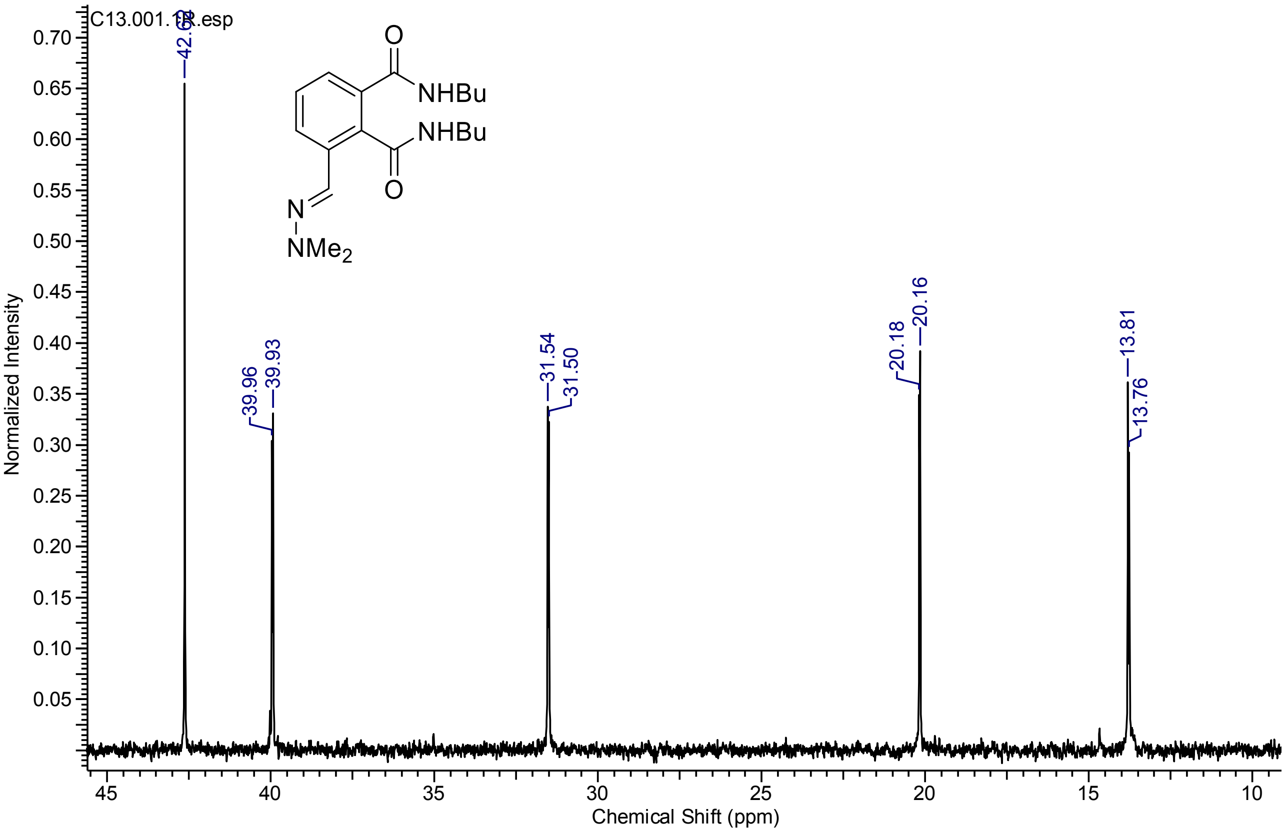




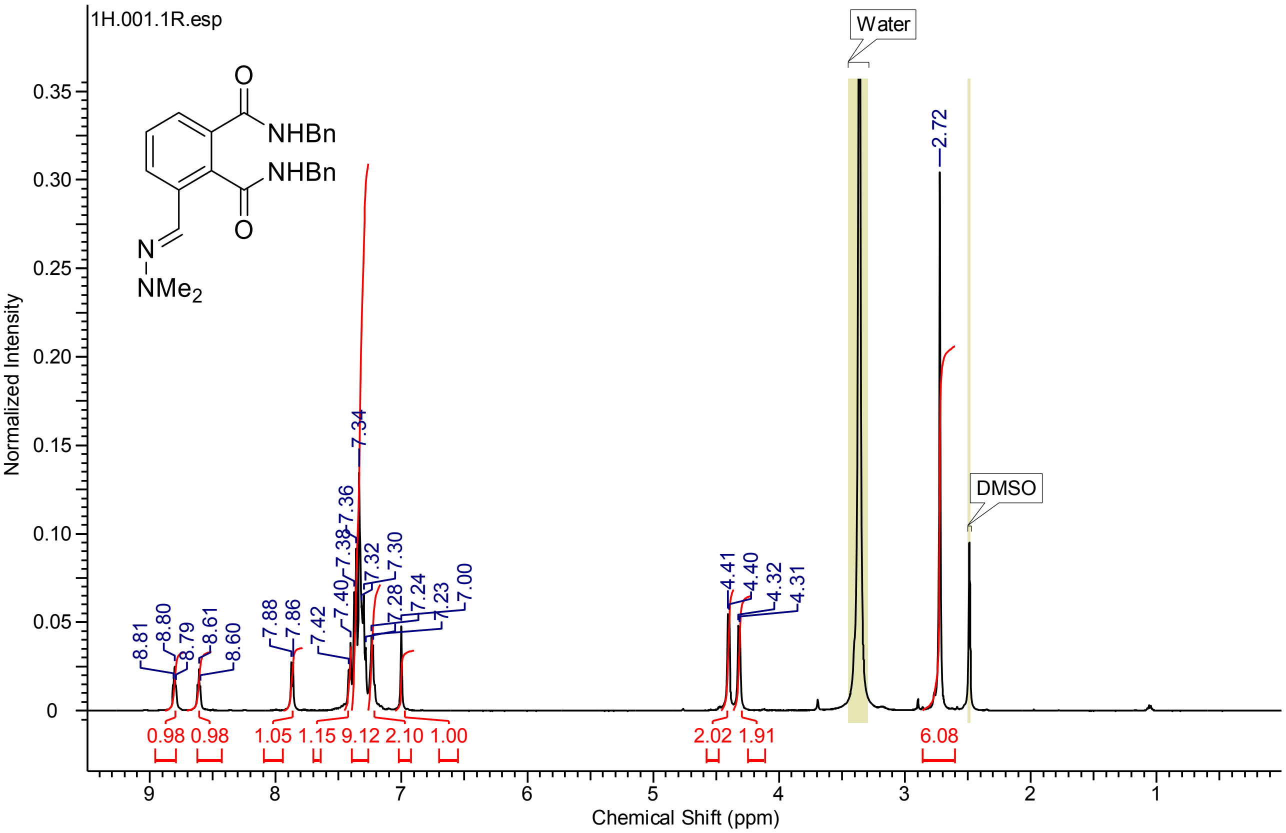
N,N-Dibutyl-3-((2,2-dimethylhydrazono)methyl)phthalamide 10a

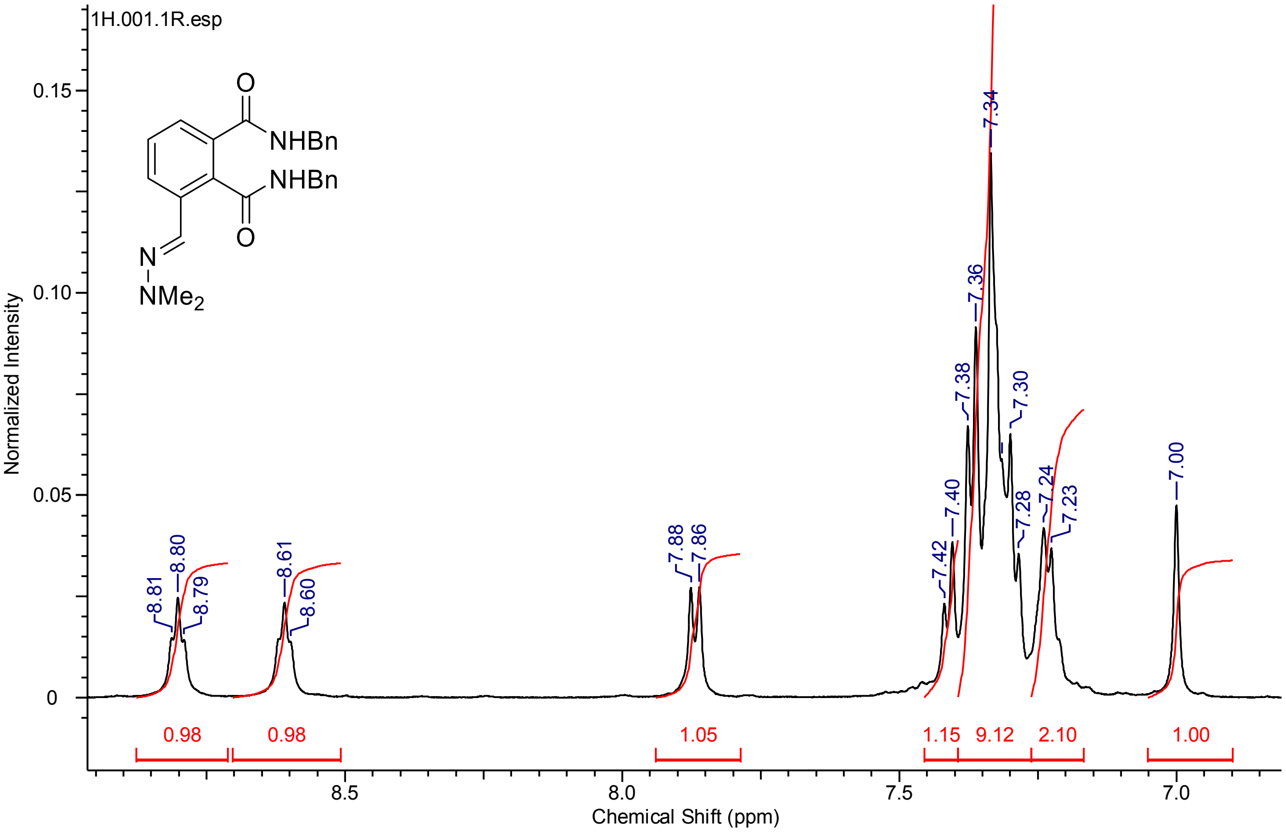


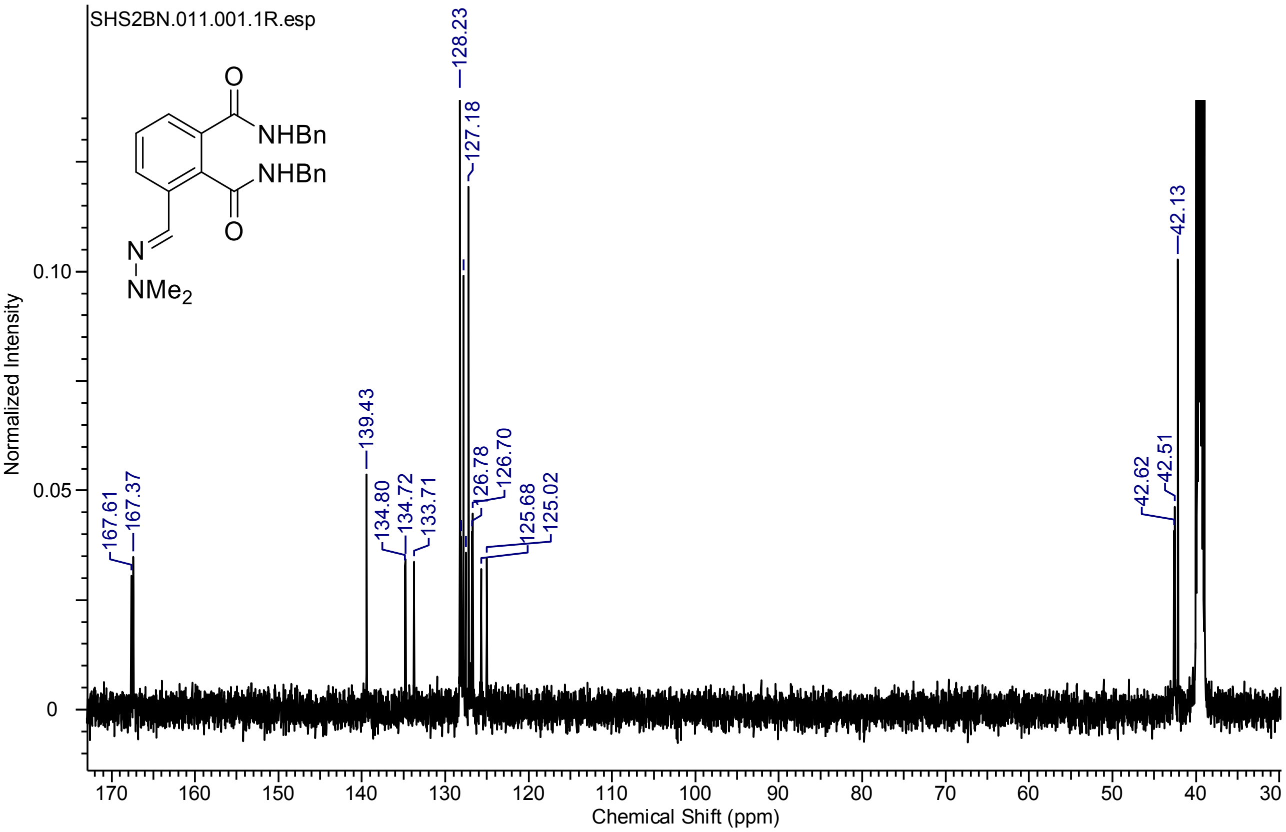


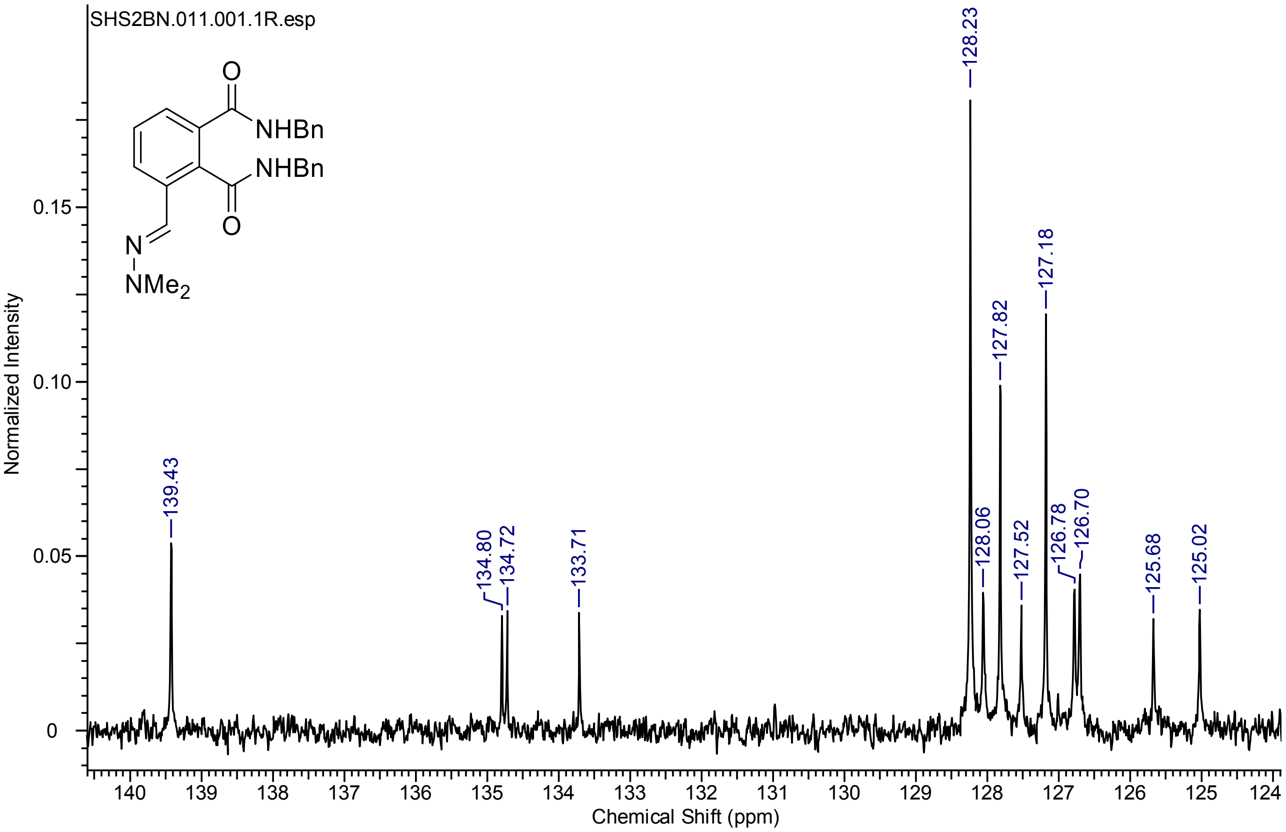

C13.001.1R.esp
42.62
39.96
39.93
31.54
31.50
20.18
20.16
13.81
13.76
O
NHBu
NHBu
O
N
NMe$_2$
Normalized Intensity
0.70
0.65
0.60
0.55
0.50
0.45
0.40
0.35
0.30
0.25
0.20
0.15
0.10
0.05
45
40
35
30
25
20
15
10
Chemical Shift (ppm)

N,N-Dibenzyl-3-((2,2-dimethylhydrazono)methyl)phthalamide 10b

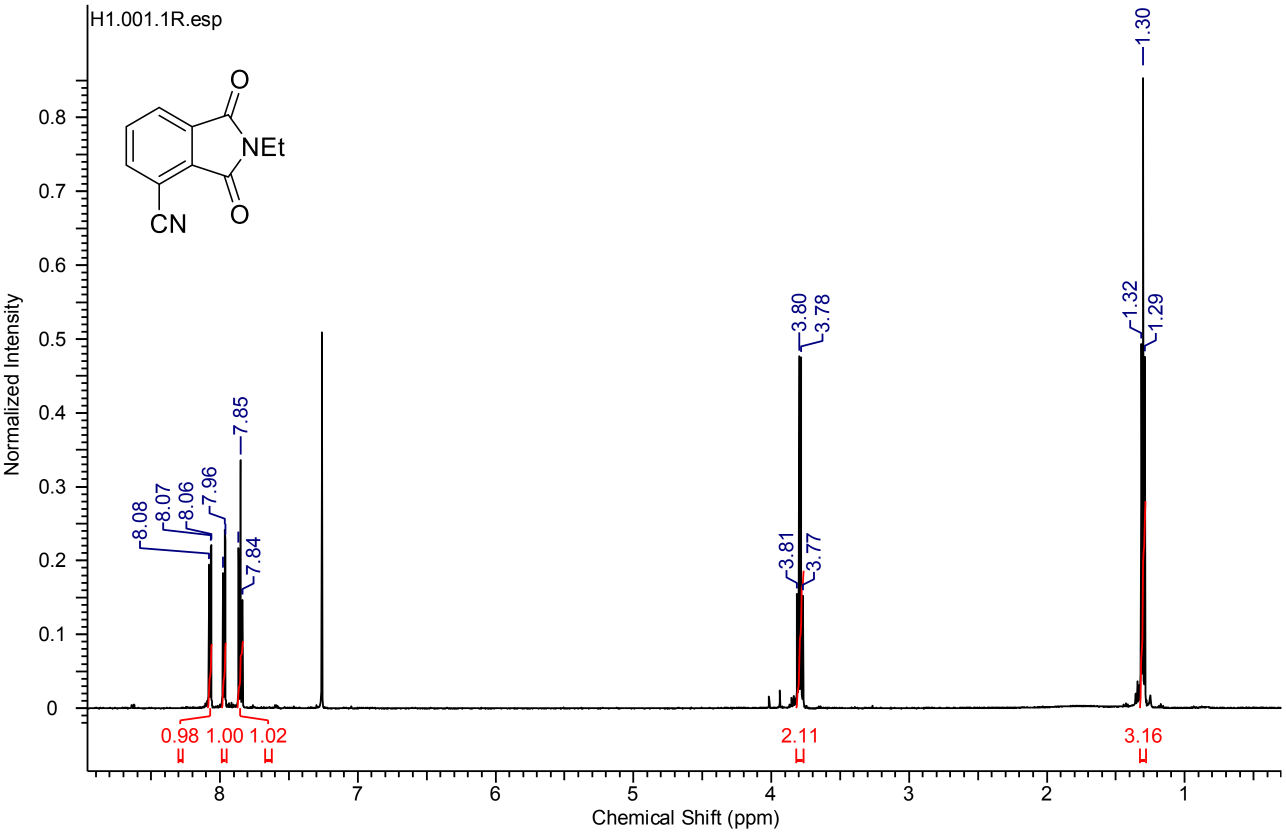


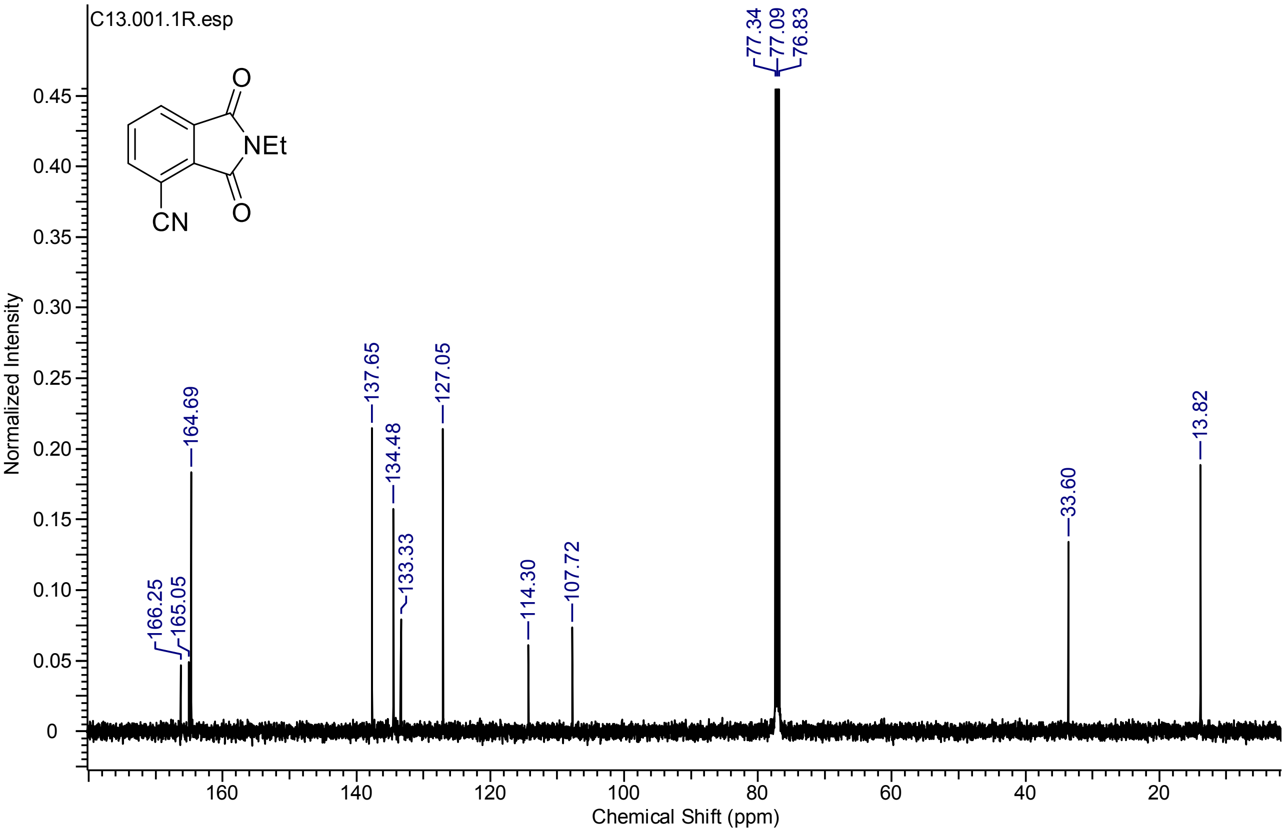



SHS2BN.011.001.1R.esp
O
NHBn
NHBn
O
N
NMe2
Normalized Intensity
0.10
0.05
0
167.61
167.37
139.43
134.80
134.72
133.71
128.23
127.18
126.78
126.70
125.68
125.02
42.62
42.51
42.13
170 160 150 140 130 120 110 100 90 80 70 60 50 40 30
Chemical Shift (ppm)

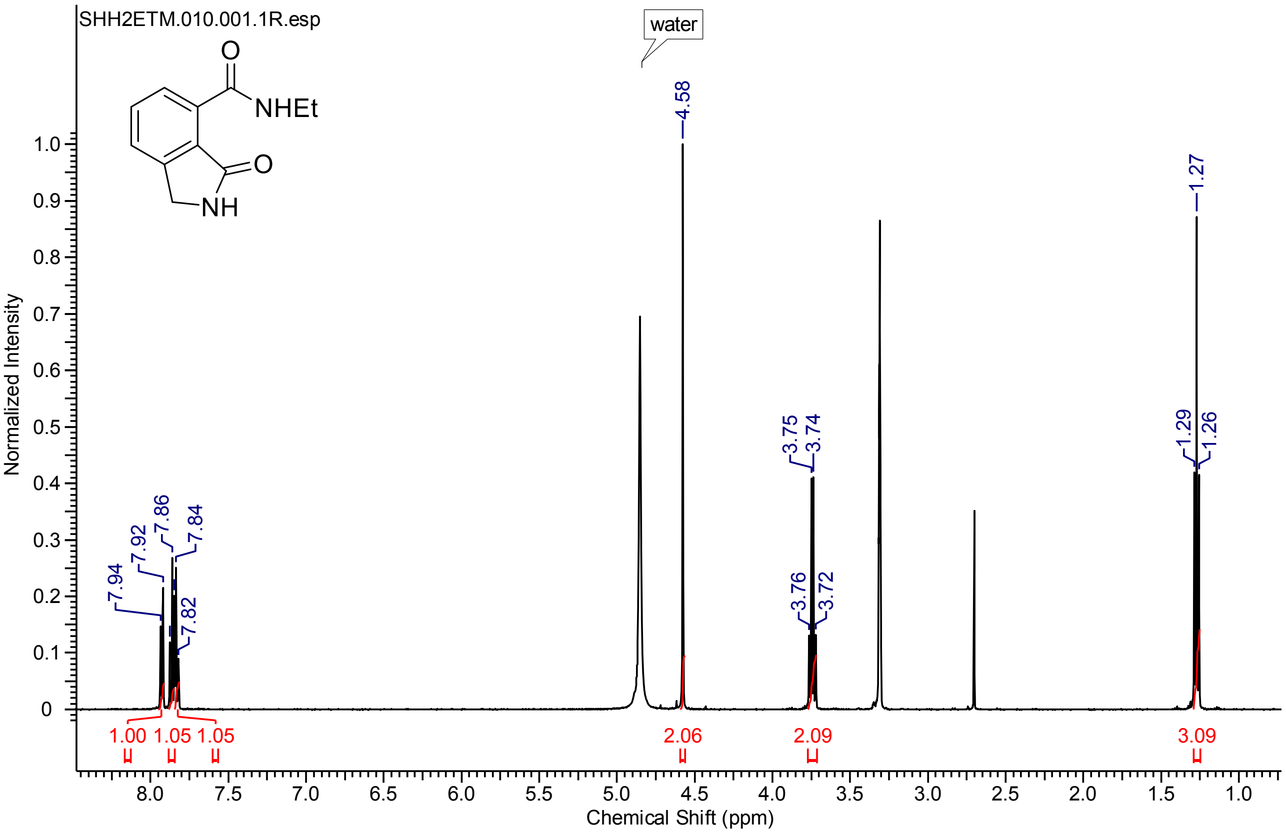

SHS2BN.011.001.1R.esp
O
NHBn
NHBn
O
N
NMe2
Normalized Intensity
0.15
0.10
0.05
0
139.43
134.80
134.72
133.71
128.23
128.06
127.82
127.52
127.18
126.78
126.70
125.68
125.02
140 139 138 137 136 135 134 133 132 131 130 129 128 127 126 125 124
Chemical Shift (ppm)

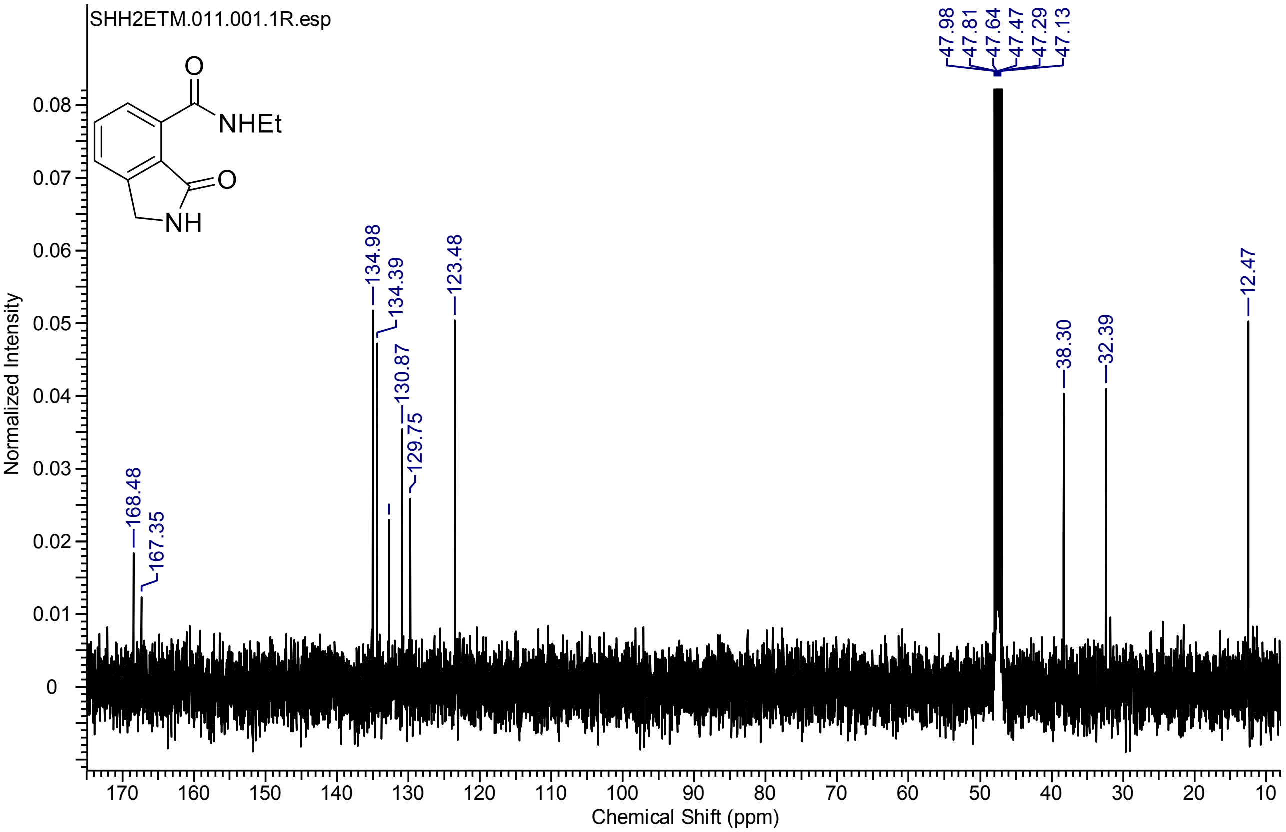
2-Ethyl-1,3-dioxoisoindoline-4-carbonitrile 11



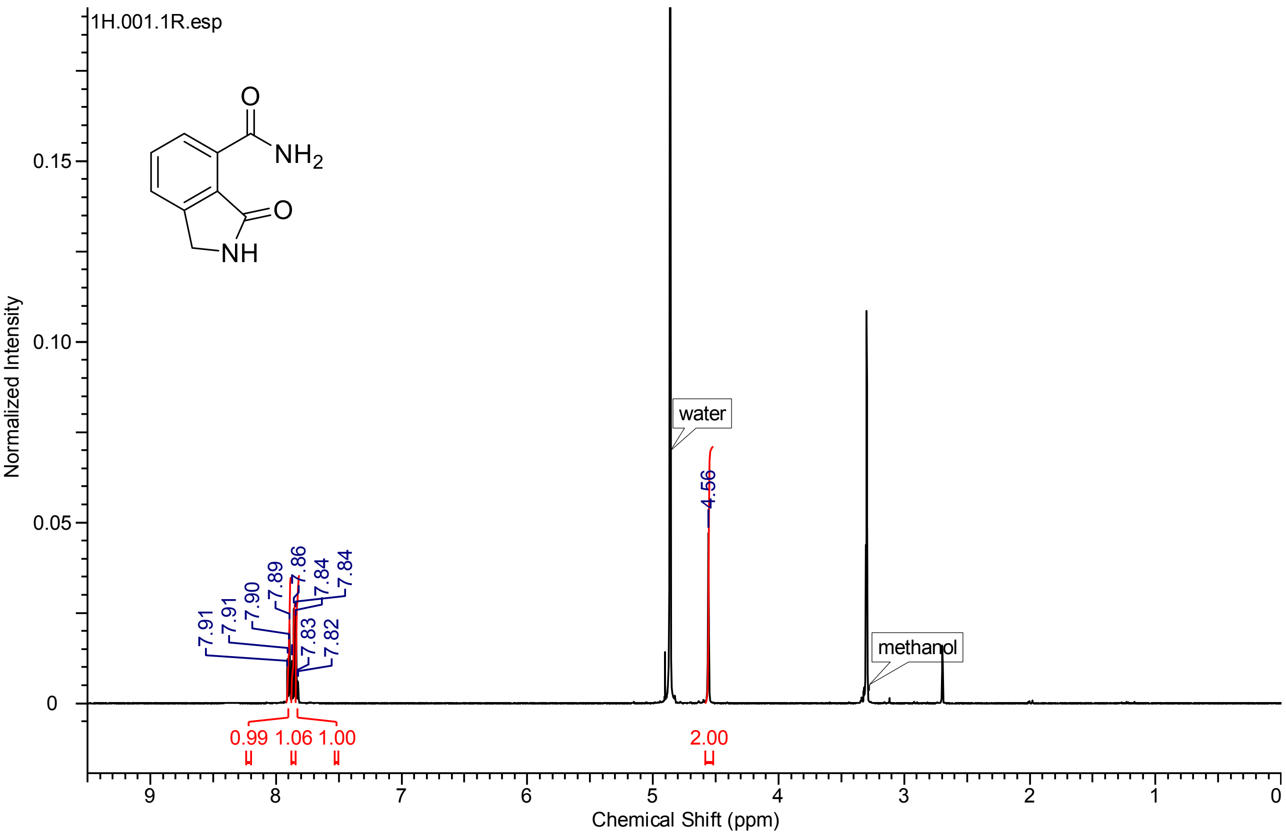


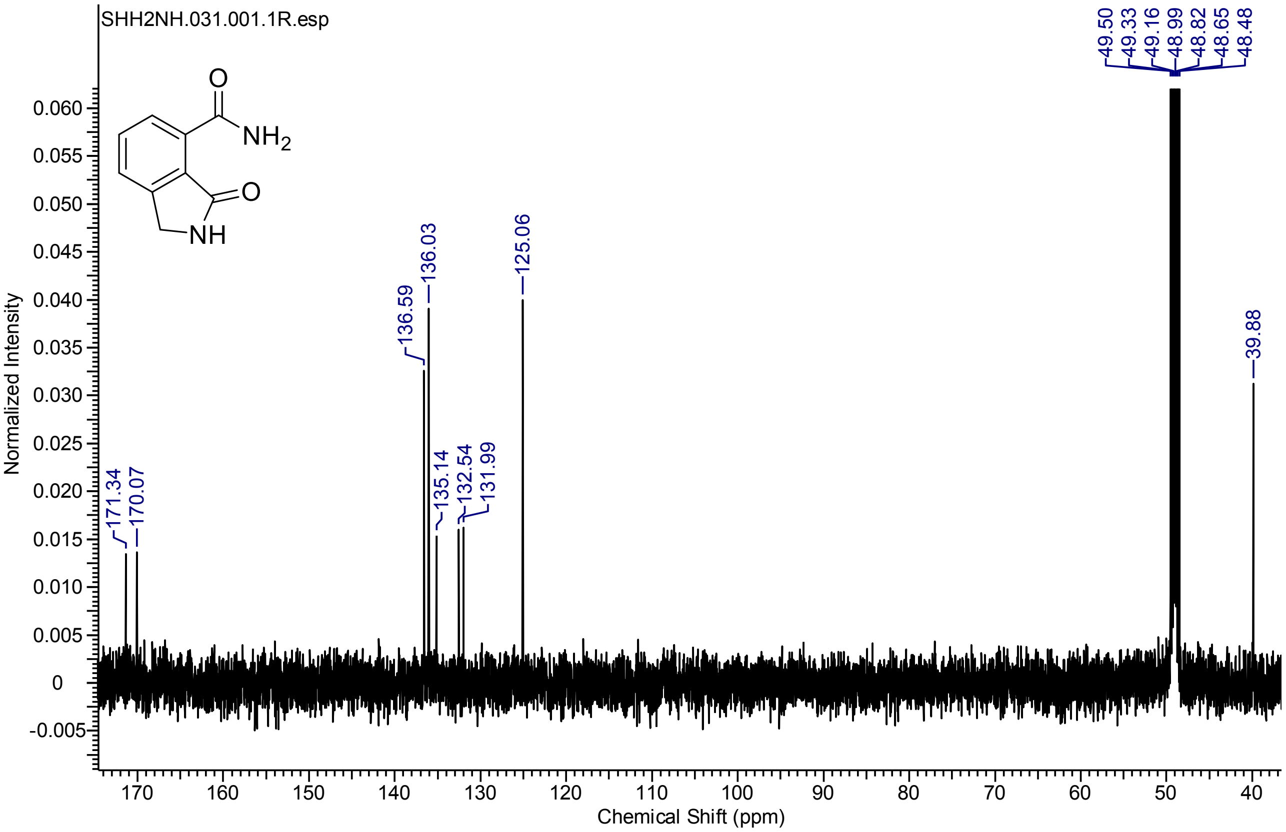
N-Ethyl-3-oxoisoindoline-4-carboxamide 12a



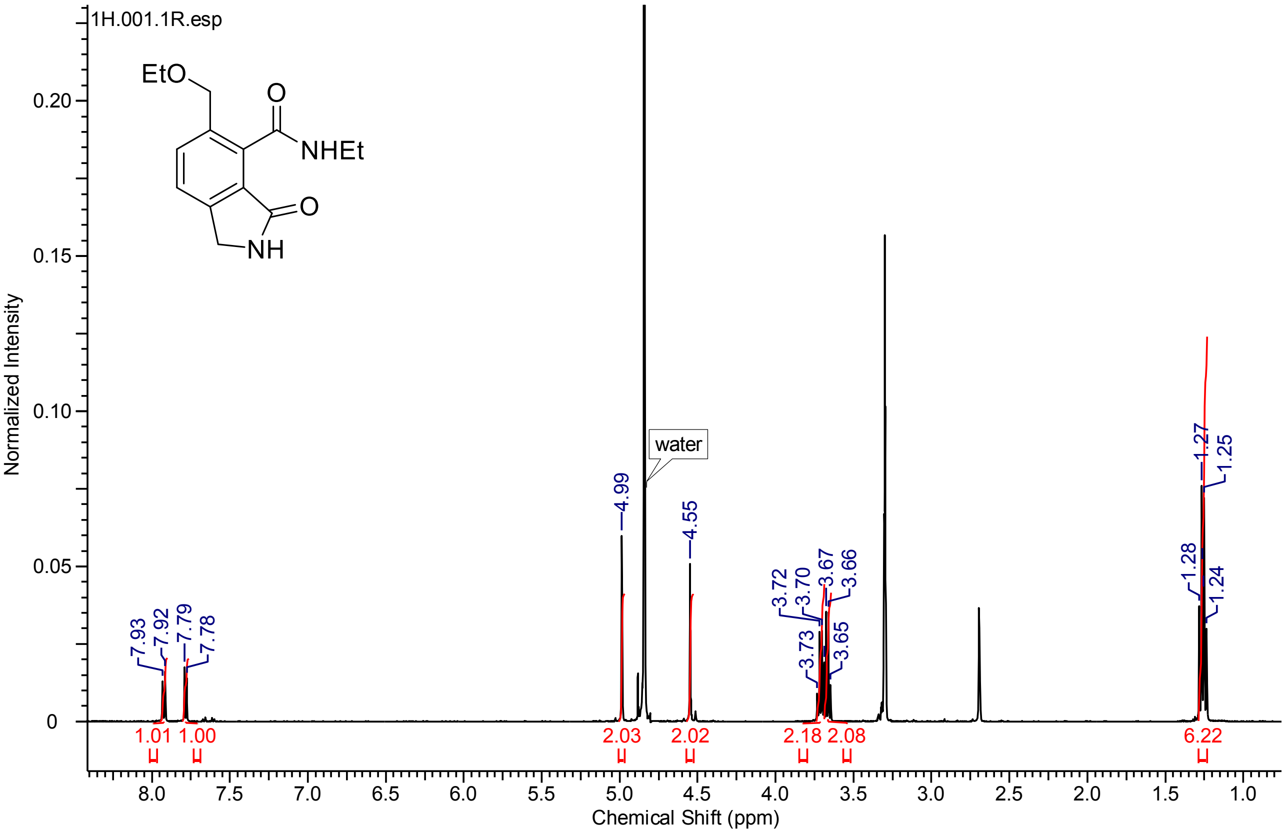


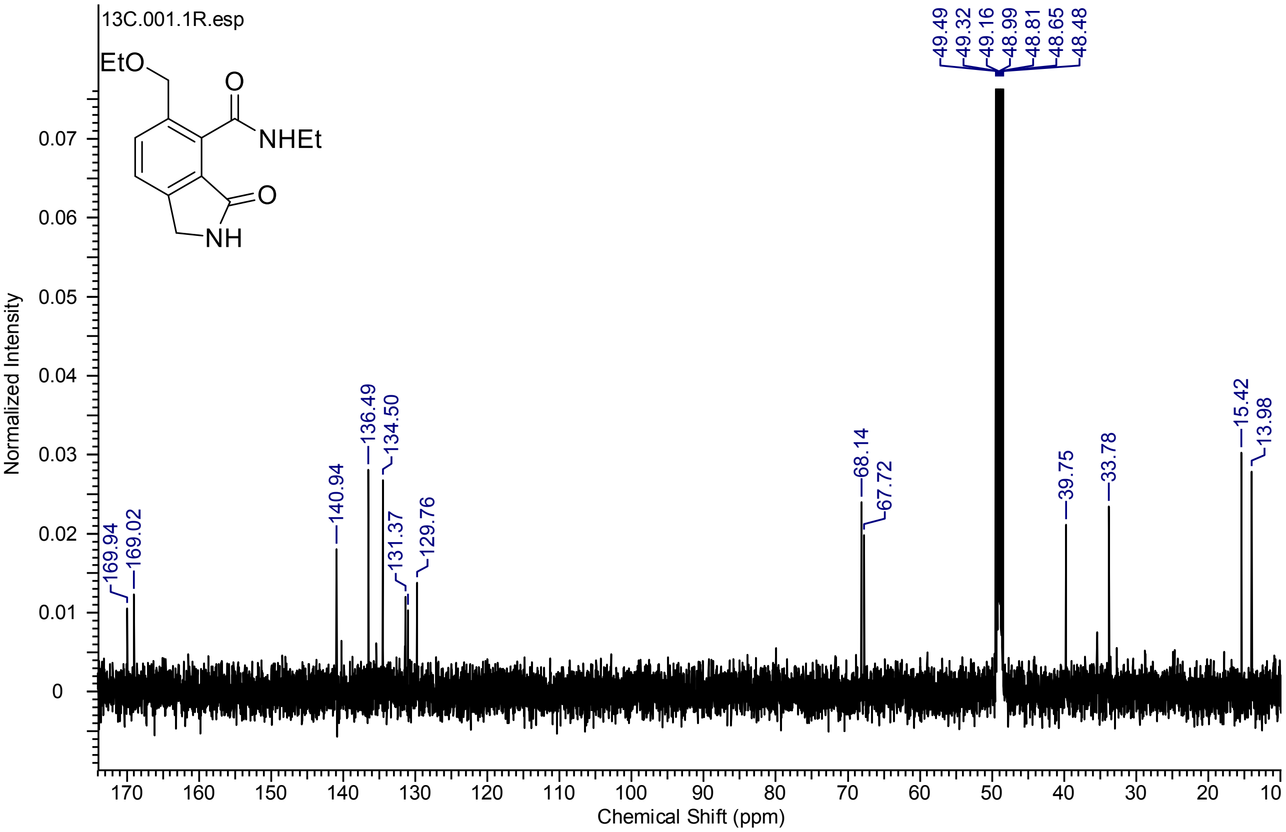
3-Oxoisoindoline-4-carboxamide 12b



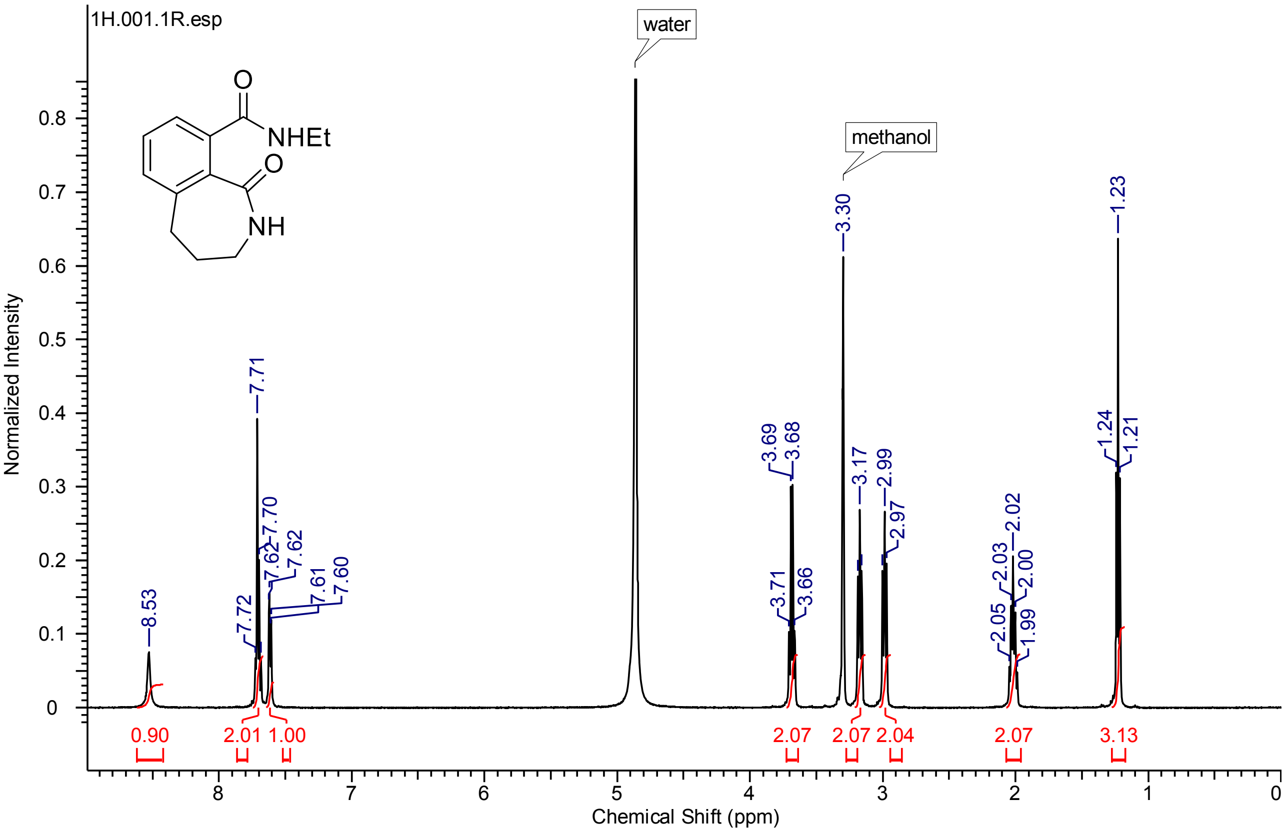


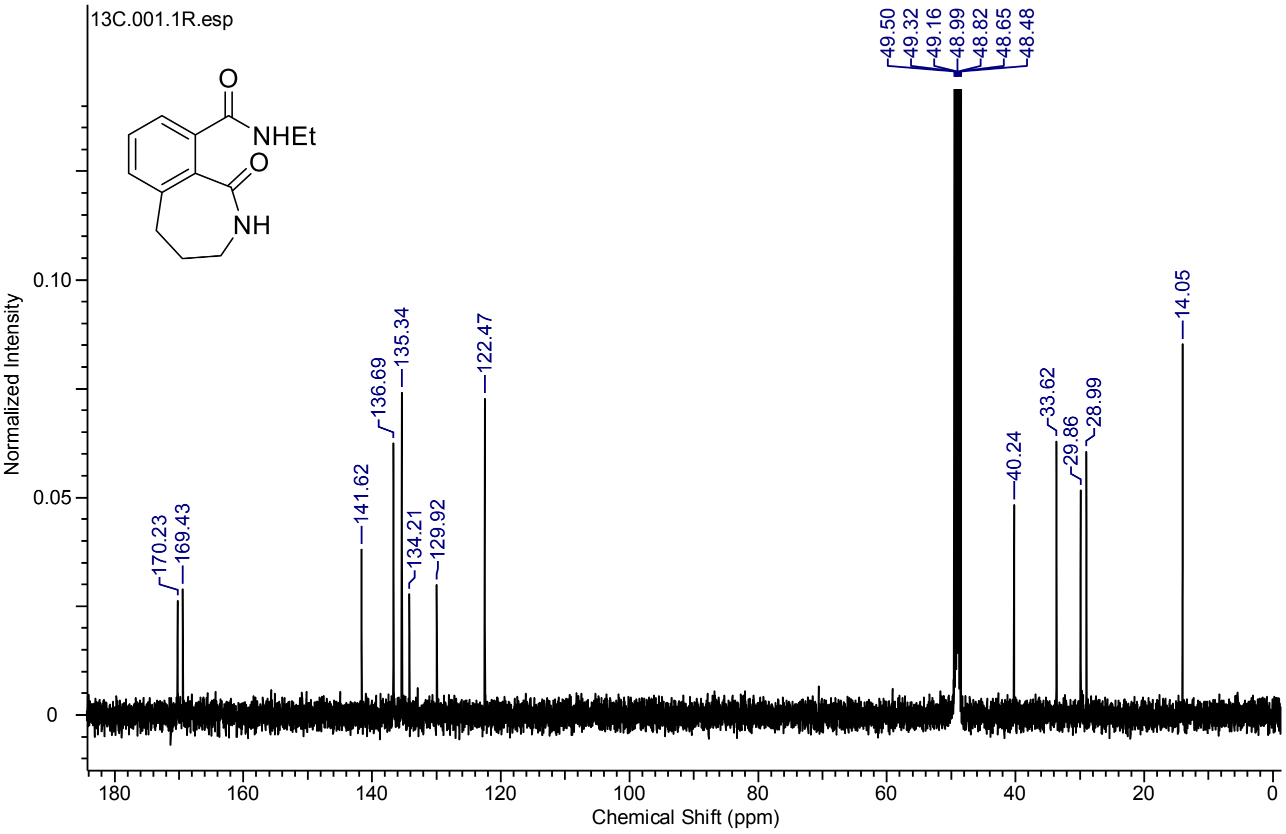
5-(Ethoxymethyl)-N-ethyl-3-oxoisoindoline-4-carboxamide 12c



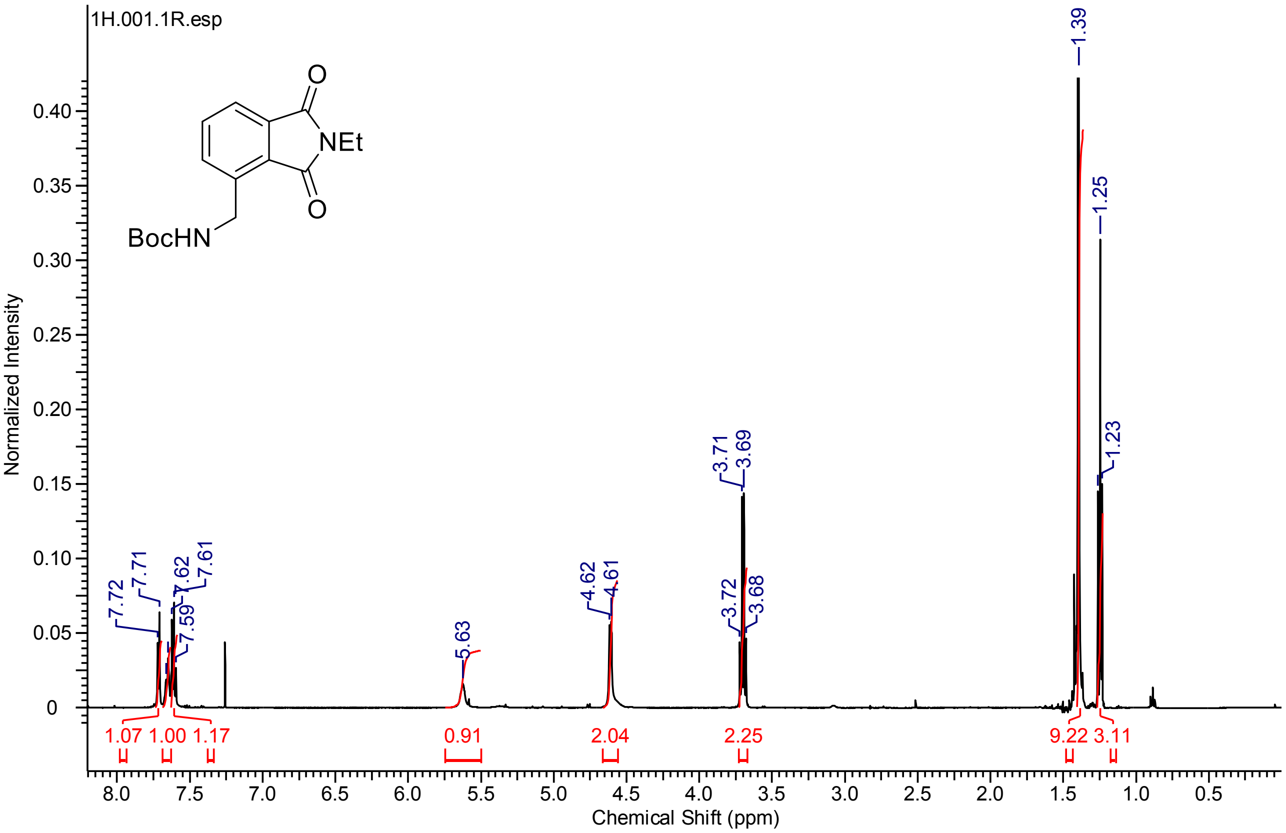


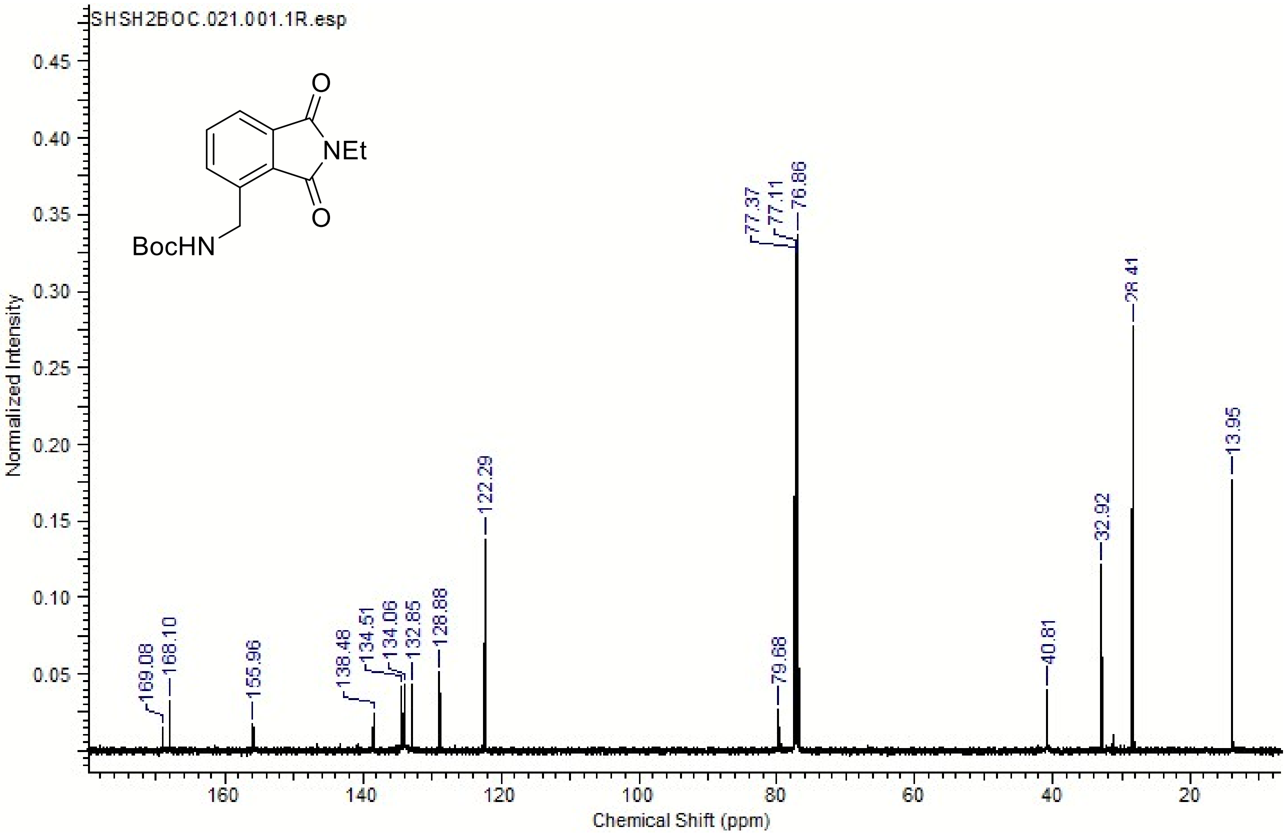
N-Ethyl-1-oxo-2,3,4,5-tetrahydro-1H-benzo[c]azepine-9-carboxamide 12d



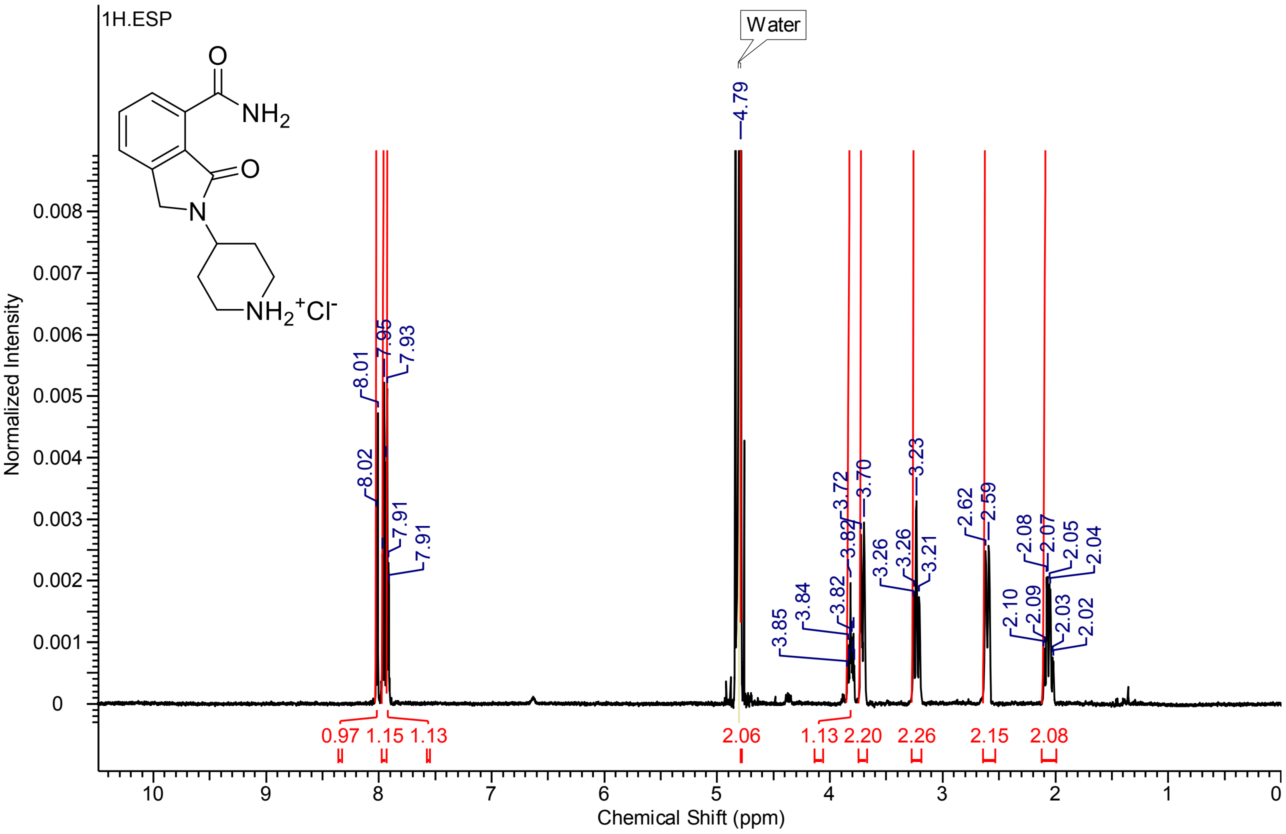


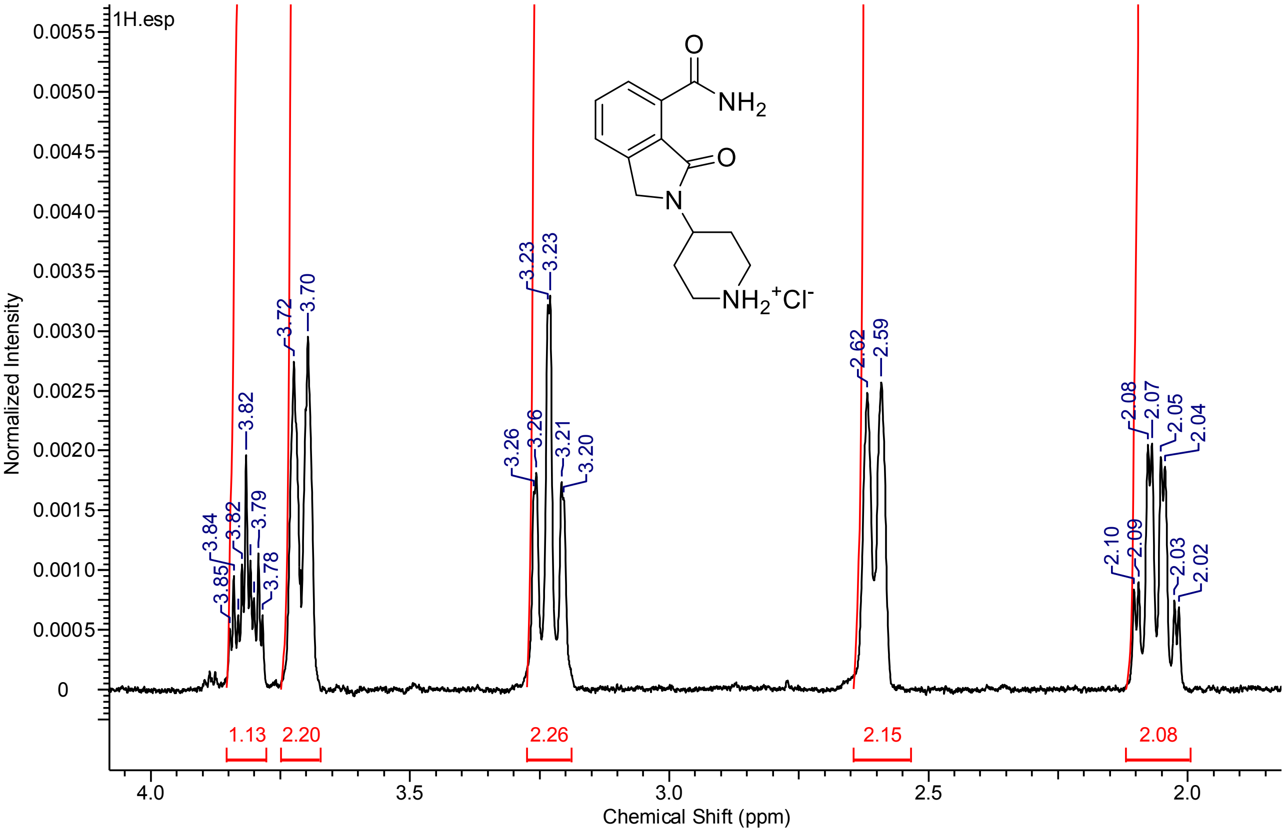
Tert-butyl-((2-ethyl-1,3-dioxoisoindolin-4-yl)methyl)carbamate 13

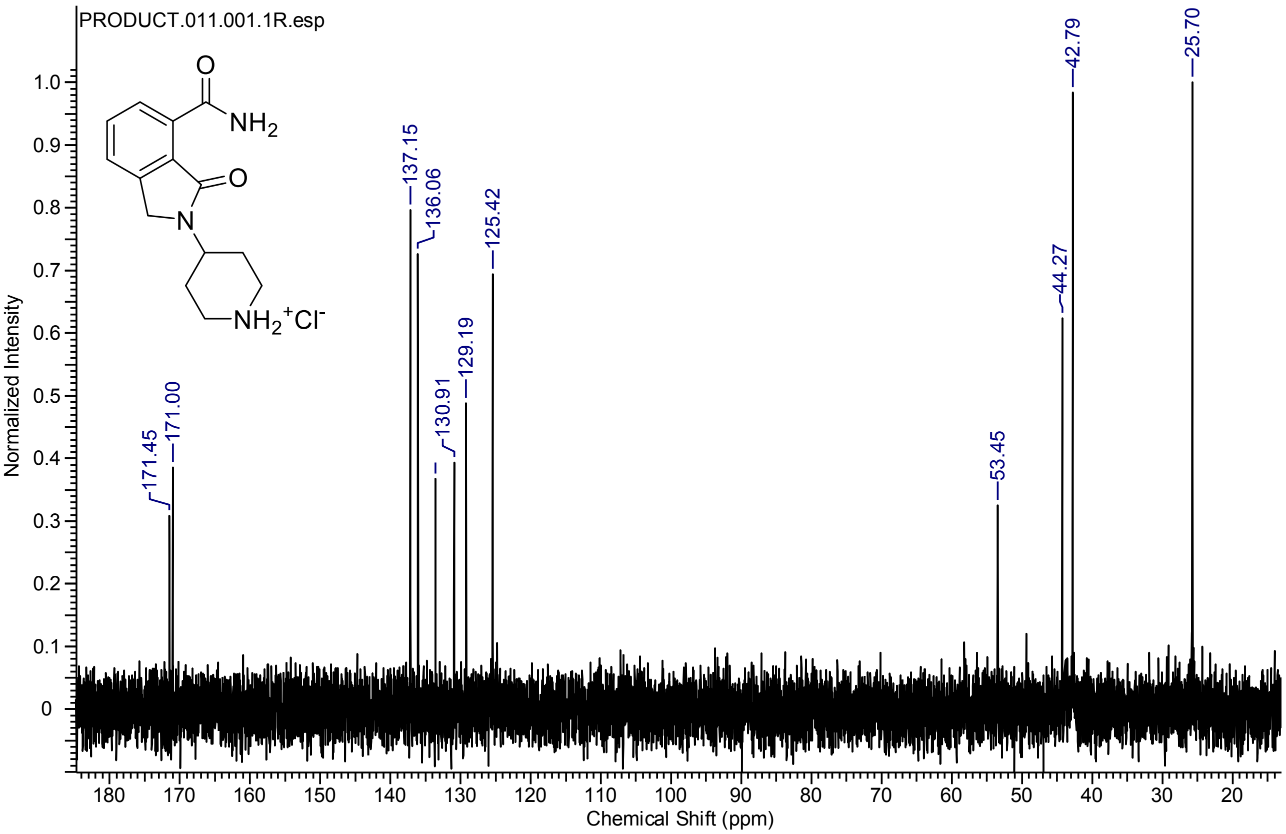




4-(7-carbamoyl-1-oxoisoindolin-2-yl)piperidin-1-ium chloride 14·HCl






PRODUCT.011.001.1R.esp
O
NH2
O
N
NH2+Cl-
171.45
171.00
137.15
136.06
130.91
129.19
125.42
53.45
44.27
42.79
25.70
Normalized Intensity
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20
Chemical Shift (ppm)

References

1. R. Medimagh, S. Marque, D. Prim, S. Chatti and H. Zarrouk, *J. Org. Chem.,* 2008, **73**, 2191.

2. A. Mitsch, P. Wißner, K. Silber, I. Sattler, G. Klebeb and M. Schlitzera, *Bioorg. Med. Chem.,* 2004, **12**, 4585.

3. M. Carmeli, N. Shefer and S. Rozen, *Tett. Lett.,* 2006, **47**, 8969.

4. K. T. Potts and E. B. Walsh, *J. Org. Chem.,* 1984, **49**, 4099.

5. A. B. Koldobskii, *Zh. Org. Khim.* 1992, **28**, 809.

6. T. V. Hughes, S. L. Emanuel, H. R. O'Grady, P. J. Connolly, C. Rugg, A. R. Fuentes-Pesquera, P. Karnachi, R. Alexander and S. A. Middleton, *Bioorg. Med. Chem*., 2008, **18**, 5130.