

## Supporting Information

### Fe-catalyzed Chemoselective Hydrogenation of Maleimide to Succinimide using Water as Hydrogen Source

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#### Table of Contents

[1.1] General experimental details	S2
[1.2] Preparation of starting materials	S3
[1.3] General experimental procedure	S3
[1.4] Optimization studies	S4
[1.5] Mechanistic studies	S8
[1.6] Synthetic utility and list of unsuccessful substrates	S15
[1.7] Crystallographic data for compound <b>2n</b>	S16
[1.8] Analytical data	S18
[1.9] References	S30
[2.0] <sup>1</sup> H NMR, <sup>13</sup> C NMR spectra for selected compounds	S31

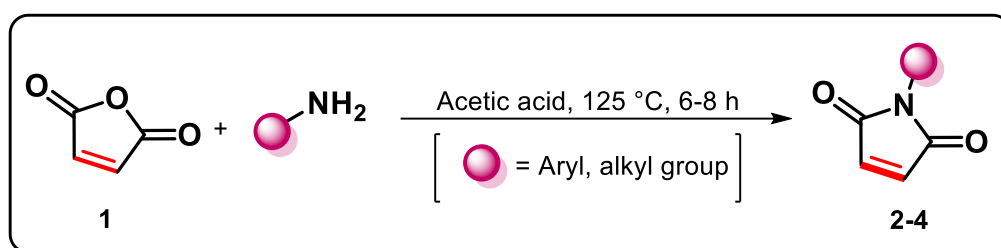
## [1.1] General experimental details

All solvents and reagents were used, as received from the suppliers. TLC was performed on Merck Kiesel gel 60, F<sub>254</sub> plates with the layer thickness of 0.25 mm. Column chromatography was performed on silica gel (100-200 mesh) using a gradient of ethyl acetate and hexane as mobile phase. <sup>1</sup>H-NMR spectral data were collected at 500 MHz (Bruker and JEOL), and <sup>13</sup>C NMR were recorded at 125 MHz (Bruker and JEOL). <sup>1</sup>H-NMR spectral data are given as chemical shifts in ppm followed by multiplicity (*s*- singlet; *d*- doublet; *t*- triplet; *q*- quartet; *m*- multiplet), number of protons and coupling constants. <sup>13</sup>C NMR chemical shifts are expressed in ppm. GC data were recorded using Agilent GC Spectrometer. HRMS (ESI) spectral data were collected using Bruker High Resolution Mass Spectrometer. FT-IR data were recorded on Bruker ALPHA FT-IR Spectrometer using platinum ATR. Single crystal data were collected on Bruker D8 QUEST photon III C7 device with MoK $\alpha$  radiation (0.71073 Å) type micro-focus sealed tube source and ‘ $\phi$  and  $\omega$  scans’ was utilized for the measurement. Bruker APEX4 v2022.1-0' (Bruker AXS Inc., 2022) software was utilized for crystallographic data. All the reactions were performed in a closed system using pressure tube. All iron salts were purchased from Tokyo Chemicals Industry (TCI). Iron(II) Acetate (Assay- 98 %; CAS Number 3094-87-9; Product Number I0765, Pack Size 5G). Zinc Dust was purchased from HIMEDIA, India. (Purity-98 %, CAS No 7440-66-6, EC Number 231-175-3, Pack Size 100g).

## [1.2] Preparation of starting materials

### Preparation of substituted maleimides:

**Procedure:** In a round bottom flask, primary amine (1 mmol, 1 equiv.), and maleic anhydride (2 mmol, 2.0 equiv.) were dissolved in acetic acid (1.5 mL). The reaction mixture was stirred at 125 °C for 6 to 8 h until maleic anhydride dissolved completely. After the stipulated time, the reaction mixture was cooled to room temperature and the whole reaction mixture was transferred to a 500 mL beaker. Saturated sodium bicarbonate aqueous solution was added to the beaker slowly until effervescence stop. The aqueous mixture was extracted with ethyl acetate (3 x 20 mL). The organic layer was further washed with 1(N) HCl (2 x 50 mL) and brine solution (30 mL) respectively. The solvent was *concentrated in vacuo*, and the residue was purified by column chromatography using a gradient of hexane and ethyl acetate (eluent system) to afford the pure maleimide products.<sup>1</sup>



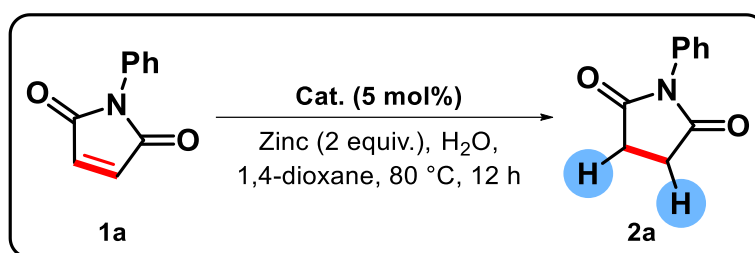
## [1.3] General experimental procedure

### Iron catalyzed hydrogenation of maleimides:

**Procedure:** In a 15 mL oven-dried pressure tube, maleimide **1** (0.25 mmol, 1 equiv.), Fe(OAc)<sub>2</sub> (0.0125 mmol, 0.05 equiv.), zinc (0.25 mmol, 1 equiv.) and H<sub>2</sub>O (0.25 mL), were dissolved in 1.75 mL of 1,4-dioxane and heated at 80 °C in a pre-heated oil bath for 6-12 h in a closed system. After the stipulated time, the reaction mixture was cooled to room temperature and quenched with 1.0 mL of ethyl acetate and passed through a pad of celite. The filtrate was *concentrated in vacuo*, and the residue was purified by column chromatography using a gradient of hexane and ethyl acetate (eluent system) to afford the pure succinimide products.

## [1.4] Optimization studies

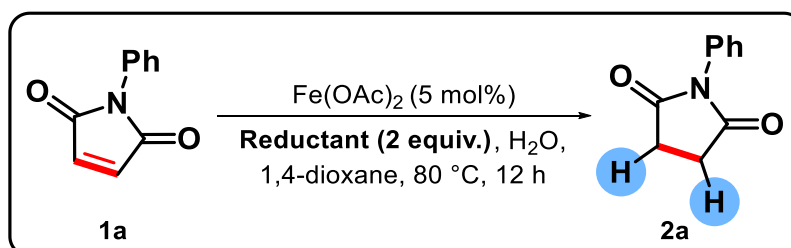
**Table S1:** Screening of catalyst<sup>a</sup>



Entry	Catalyst	GC Yield of 2a (%)
1	<b>Fe(OAc)<sub>2</sub></b>	<b>81(79)<sup>b</sup></b>
2	Fe(acac) <sub>3</sub>	39
3	FeCl <sub>3</sub>	31
4	FeCl <sub>2</sub> ·4H <sub>2</sub> O	29
5	FeSO <sub>4</sub> ·6H <sub>2</sub> O	38

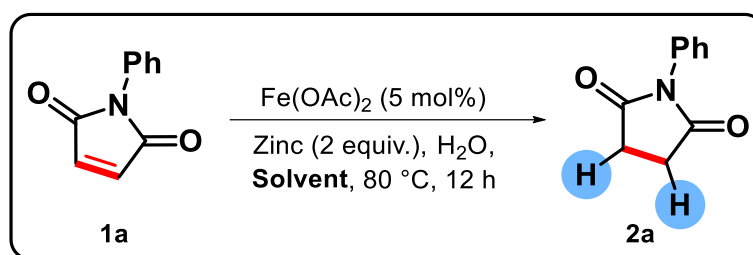
Reaction conditions: <sup>a</sup>**1a** (0.25 mmol), **Catalyst** (5 mol%), Zinc (2 equiv.), H<sub>2</sub>O (0.5 mL), using 1,4-dioxane (1.5 mL) in a pressure tube at 80 °C preheated oil bath for 12 h. GC yield was determined by using mesitylene as internal standard. <sup>b</sup>Isolated yield.

**Table S2:** Screening of reductant<sup>a</sup>



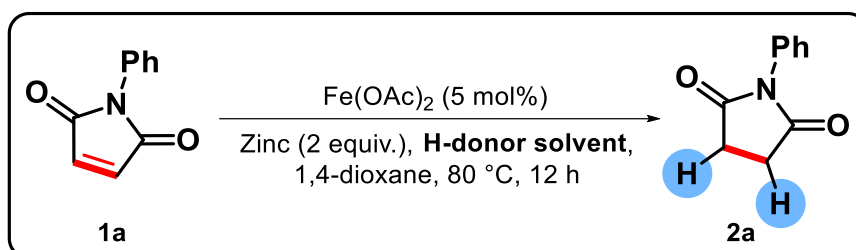
Entry	Catalyst	GC Yield of 2a (%)
1	Manganese	14
2	<b>Zinc</b>	<b>81(79)<sup>b</sup></b>
3	Aluminium foil	9

Reaction conditions: <sup>a</sup>**1a** (0.25 mmol), Fe(OAc)<sub>2</sub> (5 mol%), **Reductant** (2 equiv.), H<sub>2</sub>O (0.5 mL), using 1,4-dioxane (1.5 mL) in a pressure tube at 80 °C preheated oil bath for 12 h. GC yield was determined by using mesitylene as internal standard. <sup>b</sup>Isolated yield.

**Table S3:** Screening of solvent<sup>a</sup>

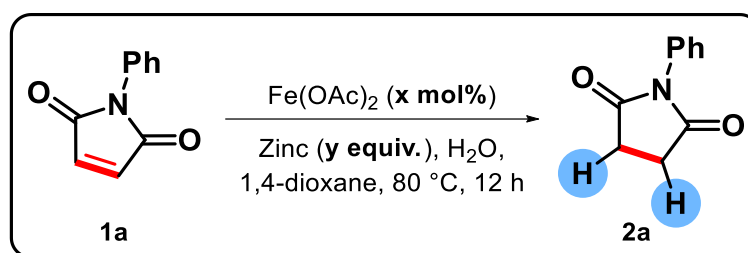
Entry	Solvent	GC Yield of <b>2a</b> (%)
1	Acetonitrile	40
2	DMF	41
<b>3</b>	<b>1,4-Dioxane</b>	<b>81(79)<sup>b</sup></b>
4	THF	20
5	2-Me-THF	7
6	Toluene	31

Reaction conditions: **1a** (0.25 mmol),  $\text{Fe}(\text{OAc})_2$  (5 mol%), Zinc (2 equiv.),  $\text{H}_2\text{O}$  (0.5 mL), using **Solvent** (1.5 mL) in a pressure tube at 80 °C preheated oil bath for 12 h. GC yield was determined by using mesitylene as internal standard. <sup>b</sup>Isolated yield.

**Table S4:** Screening of H-donor solvent<sup>a</sup>

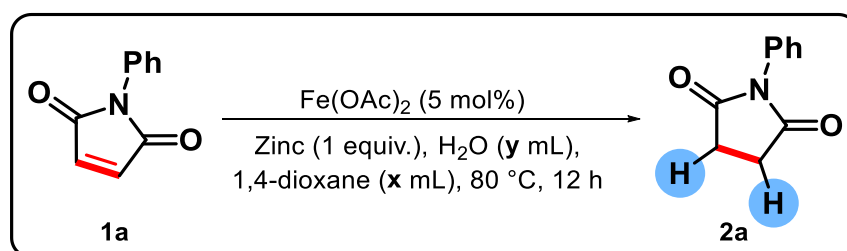
Entry	H-donor solvent	GC Yield of <b>2a</b> (%)
1	MeOH	20
2	<i>i</i> -PrOH	16
3	<i>n</i> -Butanol	11
<b>4</b>	<b>H<sub>2</sub>O</b>	<b>81(79)<sup>b</sup></b>

Reaction conditions: **1a** (0.25 mmol),  $\text{Fe}(\text{OAc})_2$  (5 mol%), Zinc (2 equiv.), **H-donor solvent** (0.5 mL), using 1,4-dioxane (1.5 mL) in a pressure tube at 80 °C preheated oil bath for 12 h. GC yield was determined by using mesitylene as internal standard. <sup>b</sup>Isolated yield.

**Table S5:** Screening of catalyst and reductant loading<sup>a</sup>

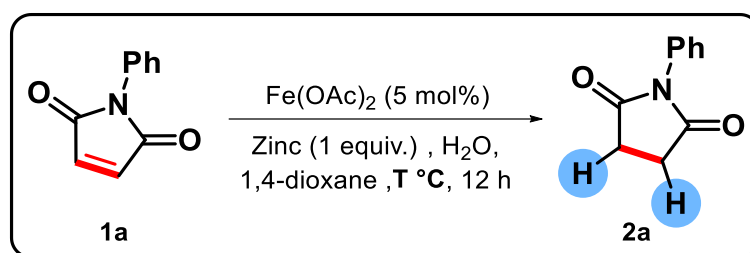
Entry	$\text{Fe}(\text{OAc})_2$ ( $x$ )	Zinc ( $y$ )	GC Yield of <b>2a</b> (%)
1	2.5	2	50
2	5	2	81(79) <sup>b</sup>
<b>3</b>	<b>5</b>	<b>1</b>	<b>82(79)<sup>b</sup></b>
4	5	0.5	65
5	-	1	21
6	5	-	trace

Reaction conditions: **1a** (0.25 mmol),  $\text{Fe}(\text{OAc})_2$  ( $x$  mol%), Zinc ( $y$  equiv.),  $\text{H}_2\text{O}$  (0.5 mL), using 1,4-dioxane (1.5 mL) in a pressure tube at  $80^\circ\text{C}$  preheated oil bath for 12 h. GC yield was determined by using mesitylene as internal standard. <sup>b</sup>Isolated yield.

**Table S6:** Screening of solvent ratio<sup>a</sup>

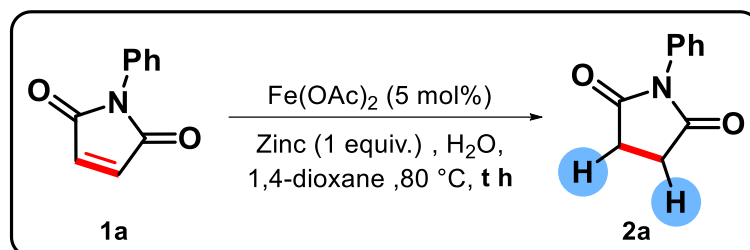
Entry	1,4-dioxane ( $x$ )	$\text{H}_2\text{O}$ ( $y$ )	GC Yield of <b>2a</b> (%)
1	-	2.0	trace
2	0.25	1.75	<5
3	1.0	1.0	25
4	1.5	0.5	82(79) <sup>b</sup>
<b>5</b>	<b>1.75</b>	<b>0.25</b>	<b>94(91)<sup>b</sup></b>
6	2.0	0	trace

Reaction conditions: **1a** (0.25 mmol),  $\text{Fe}(\text{OAc})_2$  (5 mol%), Zinc (1 equiv.),  $\text{H}_2\text{O}$  ( $y$  mL), using 1,4-dioxane ( $x$  mL) in a pressure tube at  $80^\circ\text{C}$  preheated oil bath for 12 h. GC yield was determined by using mesitylene as internal standard. <sup>b</sup>Isolated yield.

**Table S7:** Screening of reaction temperature<sup>a</sup>

Entry	Temperature ( °C)	GC Yield of <b>2a</b> (%)
1	50	64
2	60	75
3	70	82
<b>4</b>	<b>80</b>	<b>94(91)<sup>b</sup></b>

Reaction conditions: <sup>a</sup>**1a** (0.25 mmol),  $\text{Fe}(\text{OAc})_2$  (5 mol%), Zinc (1 equiv.),  $\text{H}_2\text{O}$  (0.25 mL), using 1,4-dioxane (1.75 mL) in a pressure tube at  $T$  °C preheated oil bath for 12 h. GC yield was determined by using mesitylene as internal standard. <sup>b</sup>Isolated yield.

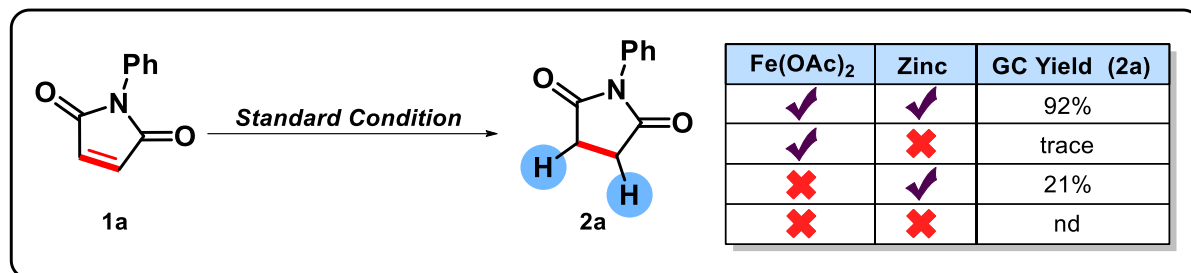
**Table S8:** Screening of reaction time<sup>a</sup>

Entry	Time (t h)	GC Yield of <b>2a</b> (%)
1	3	34
<b>2</b>	<b>6</b>	<b>92(90)<sup>b</sup></b>
3	12	94(91) <sup>b</sup>
4	18	94
5	24	95

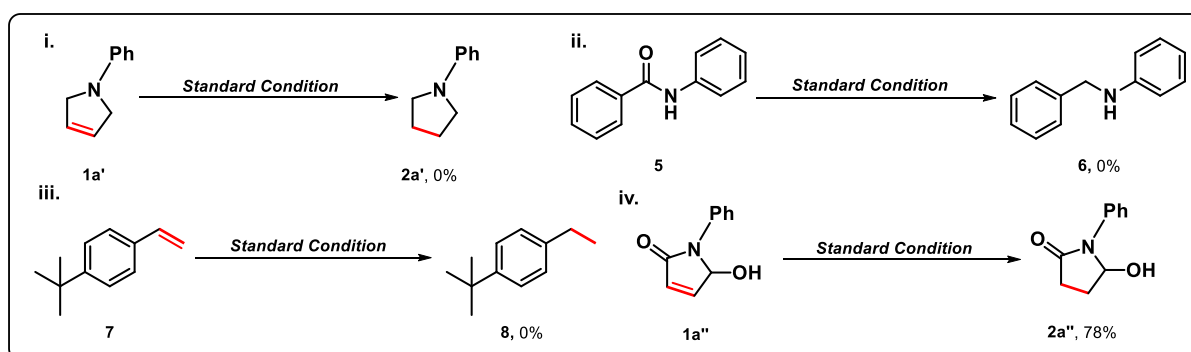
Reaction conditions: <sup>a</sup>**1a** (0.25 mmol),  $\text{Fe}(\text{OAc})_2$  (5 mol%), Zinc (1 equiv.),  $\text{H}_2\text{O}$  (0.25 mL), using 1,4-dioxane (1.75 mL) in a pressure tube at 80 °C preheated oil bath for  $t$  h. GC yield was determined by using mesitylene as internal standard. <sup>b</sup>Isolated yield

## [1.5] Mechanistic studies

### Scheme S1: Control experiments:



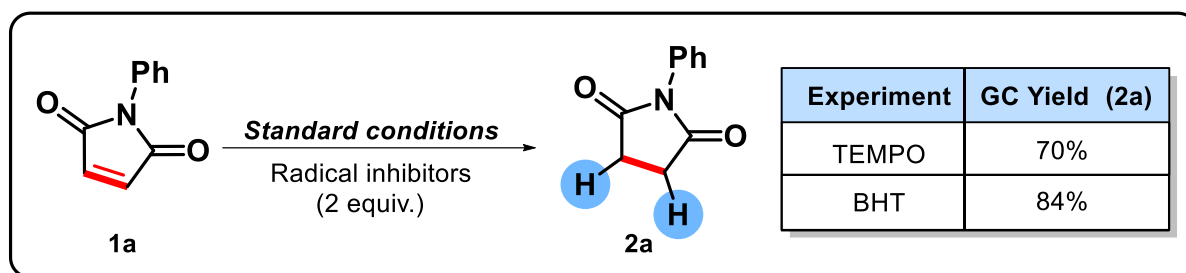
**Procedure:** Control experiments were performed in the absence of catalyst and/or the reductant to comprehend their significance in the reaction mixture (Scheme S1). In a 15 mL oven-dried pressure tube, N-phenylmaleimide **1a** (0.25 mmol, 1 equiv.), Fe(OAc)<sub>2</sub> (0.0125 mmol, 0.05 equiv.), zinc (0.25 mmol, 1 equiv.), and H<sub>2</sub>O (0.25 mL), were dissolved in 1.75 mL of 1,4-dioxane and heated at 80 °C in a pre-heated oil bath for 6 h in a closed system and resulted in 90% isolated yield of **2a**. Next **1a** was treated under standard condition but in absence of the reductant (zinc), wherein we observed negligible product formation in GC yield. Similarly, next reaction was performed using the same reactant under standard reaction conditions but without catalyst (Fe(OAc)<sub>2</sub>), which resulted in 21% product formation (GC yield). Further another reaction employing the same substrate **1a** in the absence of both catalyst and reductant, didn't result in any product formation as expected. Thus, the reductant and the catalyst were pivotal to obtain the desired product **2a**.



**Procedure:** To evaluate the selectivity of our catalytic system, control experiments were conducted using substrates lacking either the carbonyl or alkene moiety. First, 1-phenyl-2,5-dihydro-1H-pyrrole **1a'** was subjected to the standard reaction conditions; however, no reduced product was detected. Similarly, N-phenyl benzamide **5** failed to undergo carbonyl reduction under identical conditions. Thereafter, 4-tert-butylstyrene **7** was employed as substrate, but no hydrogenation of the alkene occurred. These results clearly indicated that

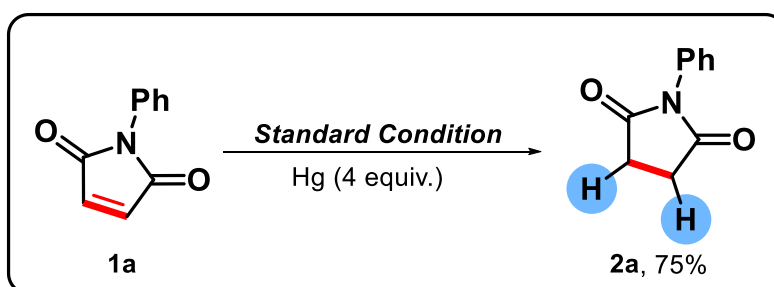
the catalytic protocol is ineffective toward isolated carbonyl groups or alkenes, and is selective only for  $\alpha,\beta$ -unsaturated carbonyl compounds, where both functionalities are present simultaneously. Another experiment was performed wherein one of the carbonyl group was selectively reduced to alcohol to generate substrate **1a''**, which was then subjected to our reaction protocol, affording the desired product in 78% isolated yield. All of the above results highlights the chemo-selectivity of the protocol.

### Scheme S2: Radical trapping experiment:



**Procedure:** In a 15 mL oven-dried pressure tube, N-phenylmaleimide **1a** (0.25 mmol, 1 equiv.),  $\text{Fe}(\text{OAc})_2$  (0.0125 mmol, 0.05 equiv.), zinc (0.25 mmol, 1 equiv.), radical inhibitors (TEMPO and BHT, 0.5 mmol, 2 equiv.) and  $\text{H}_2\text{O}$  (0.25 mL), were dissolved in 1.75 mL of 1,4-dioxane and heated at 80 °C in a pre-heated oil bath for 6 h in a closed system. After the stipulated time, the reaction mixture was cooled to room temperature and quenched with 1.0 mL of ethyl acetate and passed through a pad of celite. Desired product was observe in good yield, thereby ruling out the possibility of any radical pathway reaction.

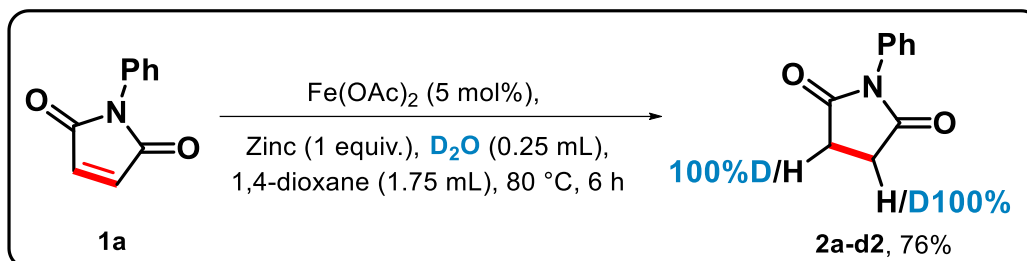
### Scheme S3: Evidence for homogeneity:



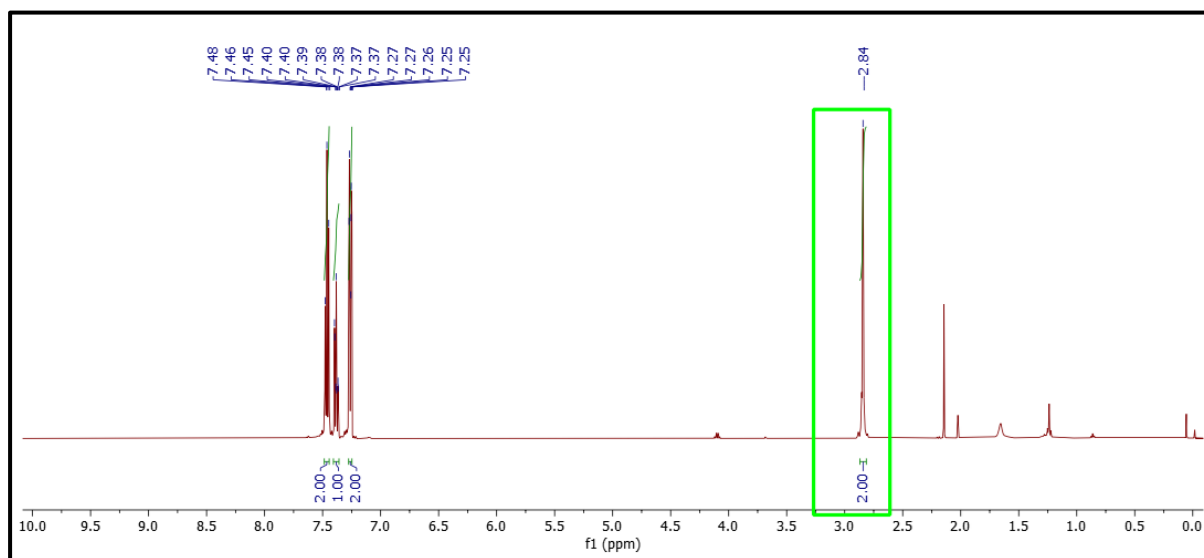
**Procedure:** In a 15 mL oven-dried pressure tube, N-phenylmaleimide **1a** (0.25 mmol, 1 equiv.),  $\text{Fe}(\text{OAc})_2$  (0.0125 mmol, 0.05 equiv.), zinc (0.25 mmol, 1 equiv.), mercury (1.0 mmol, 4 equiv.) and  $\text{H}_2\text{O}$  (0.25 mL), were dissolved in 1.75 mL of 1,4-dioxane and heated at 80 °C in a pre-heated oil bath for 6 h in a closed system. After the stipulated time, the reaction mixture was cooled to room temperature and quenched with 1.0 mL of ethyl acetate and passed through a

pad of celite. Desired product was observed in 75% GC yield, thereby ensuring reaction is homogeneous in nature.

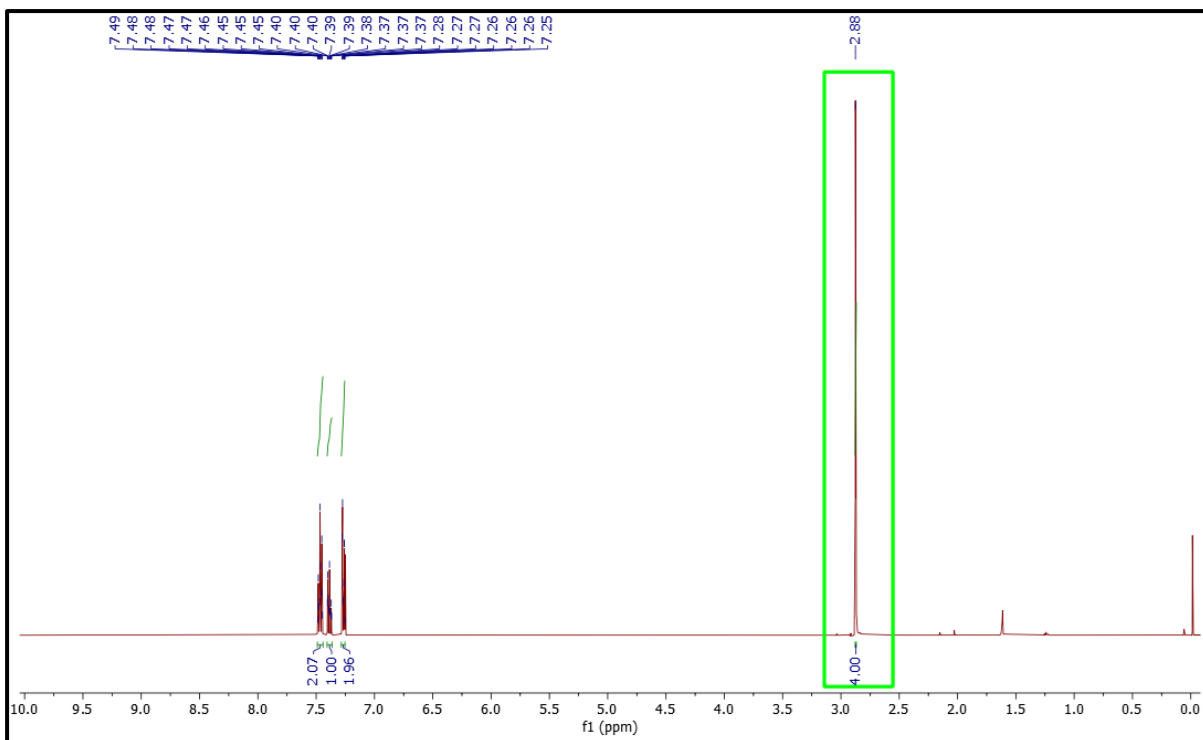
#### Scheme S4: Deuterium labelling experiment:



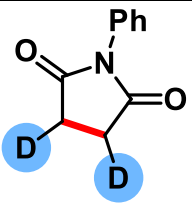
**Procedure:** In a 15 mL oven-dried pressure tube, N-phenylmaleimide **1a** (0.25 mmol, 1 equiv.),  $\text{Fe}(\text{OAc})_2$  (0.0125 mmol, 0.05 equiv.), zinc (0.25 mmol, 1 equiv.), and  $\text{D}_2\text{O}$  (0.25 mL), were dissolved in 1.75 mL of 1,4-dioxane and heated at 80 °C in a pre-heated oil bath for 6 h in a closed system. After the stipulated time, the reaction mixture was cooled to room temperature and quenched with 1.0 mL of ethyl acetate and passed through a pad of celite. The filtrate was *concentrated in vacuo*, and the residue was purified by column chromatography using a gradient of hexane and ethyl acetate (eluent system) to afford the pure deuterated succinimide **2a-d2** product in 76% isolated yield with 100% deuterium incorporation.



$^1\text{H}$  NMR Spectra of Deuterated compound **2a-d2**.



<sup>1</sup>H NMR Spectra of standard compound **2a**.

Position of Deuterium Incorporation	Signal	Integral Value before Deuterium Incorporation	Integral Value after Deuterium Incorporation	Calculated Ratio
 <p><b>2a-d2</b></p>	2.88-2.84	4.00	2.00	$\{(4-2)/2\} \times 100 = 100$ Deuterium incorporation per proton = 100%

#### Scheme S5: Calculation of P<sub>H</sub>/P<sub>D</sub>:

Considering individual reaction for the formation of deuterated and non-deuterated product **2a-d2** and **2a**

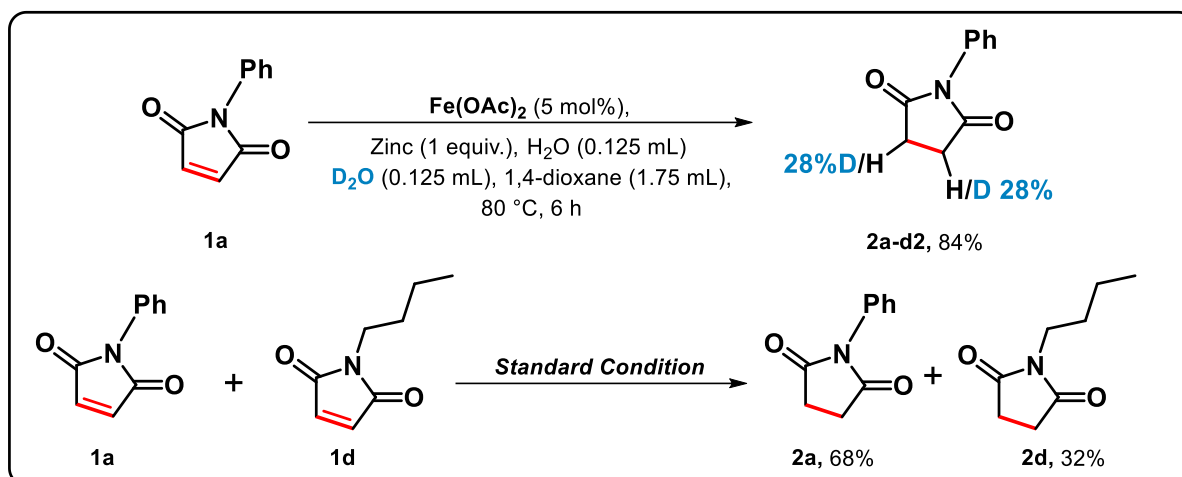
Deuterium incorporation in **2a-d2** by D<sub>2</sub>O = 100% of D

Yield of product (**2a-d2**) for the deuterated reaction = 76%

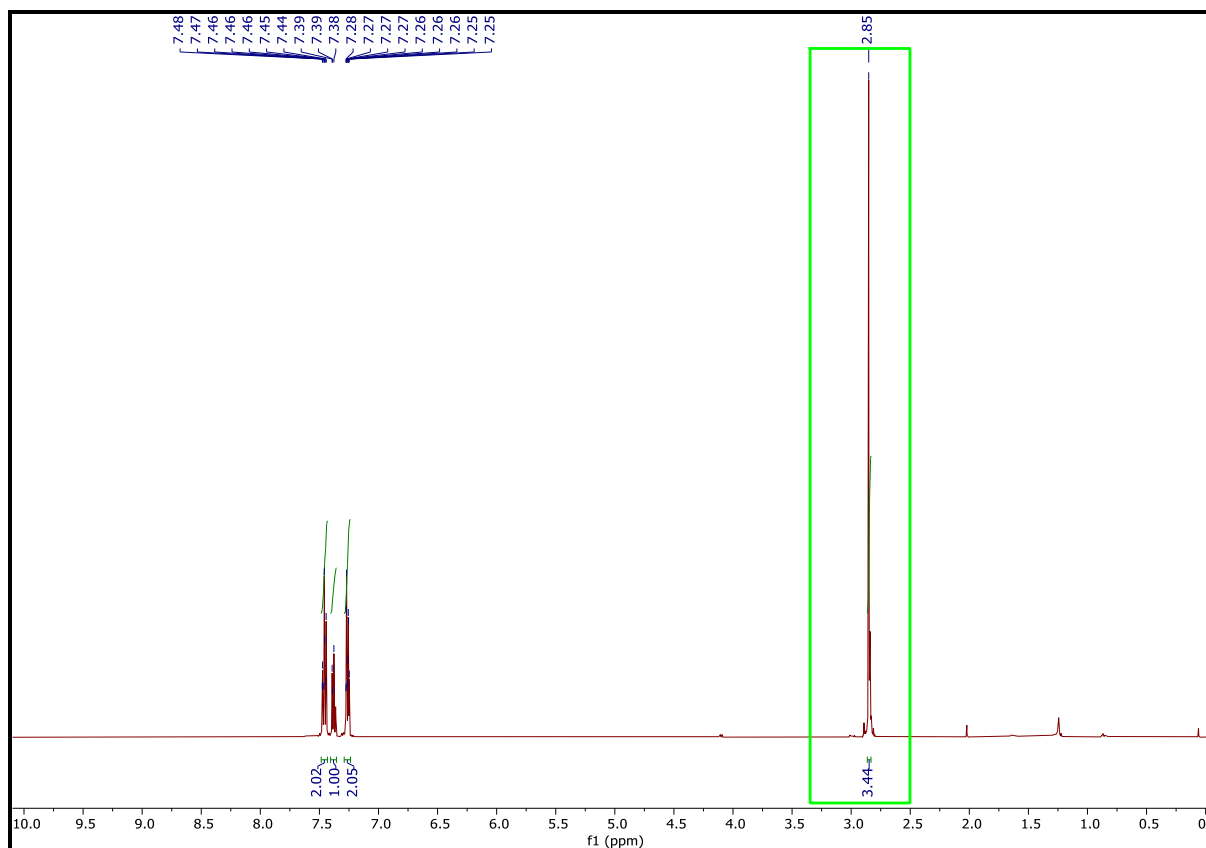
Yield of product (**2a**) for the non-deuterated reaction = 90%

So, P<sub>H</sub>/P<sub>D</sub> = 90/76 = 1.18

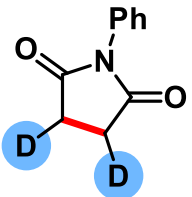
### Scheme S6: One pot intermolecular competitive experiment:



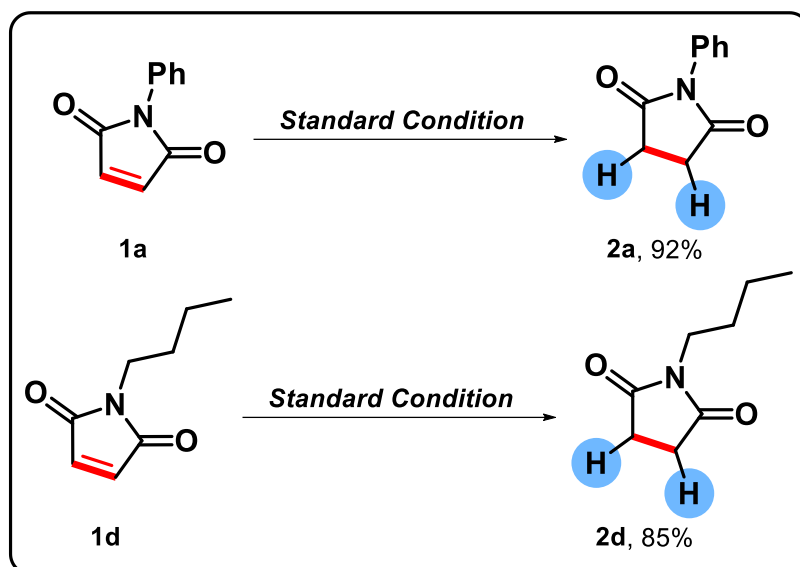
**Procedure:** In a 15 mL oven-dried pressure tube, N-phenylmaleimide **1a** (0.25 mmol, 1 equiv.),  $\text{Fe}(\text{OAc})_2$  (0.0125 mmol, 0.05 equiv.), zinc (0.25 mmol, 1 equiv.),  $\text{D}_2\text{O}$  (0.125 mL), and  $\text{H}_2\text{O}$  (0.125 mL), were dissolved in 1.75 mL of 1,4-dioxane. In another 15 mL oven-dried pressure tube, N-phenylmaleimide **1a** (0.125 mmol, 1 equiv.), N-butylmaleimide **1d** (0.125 mmol, 1 equiv.),  $\text{Fe}(\text{OAc})_2$  (0.0125 mmol, 0.1 equiv.), zinc (0.25 mmol, 2 equiv.), and  $\text{H}_2\text{O}$  (0.25 mL), were dissolved in 1.75 mL of 1,4-dioxane. Both the reaction mixtures were placed in a pre-heated oil bath at 80 °C for 6 h. After the stipulated time, the reaction mixture was cooled to room temperature and quenched with 1.0 mL of ethyl. In the first reaction set, the deuterated product **2a-d2** was obtained in 84% isolated yield with 28% deuterium incorporation. In the second reaction set, GC analysis showed the formation of **2a** in 68% yield and **2d** in 32% yield.



<sup>1</sup>H NMR Spectra of Deuterated compound **2a-d2**.

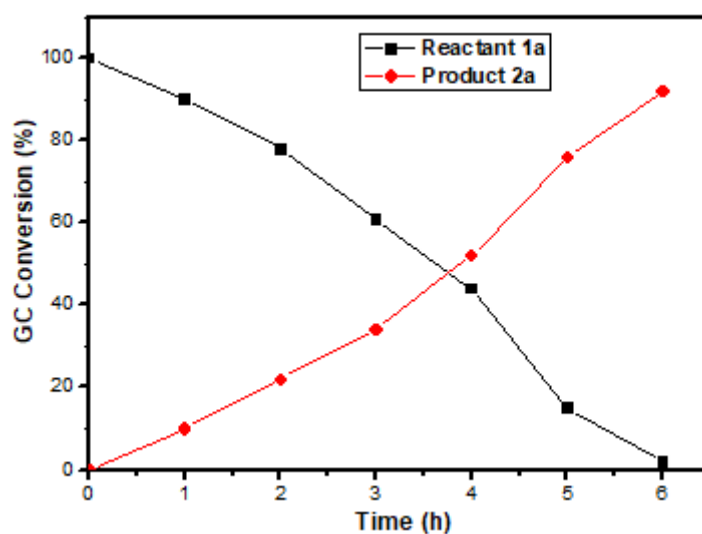
Position of Deuterium Incorporation	Signal	Integral Value before Deuterium Incorporation	Integral Value after Deuterium Incorporation	Calculated Ratio
 <b>2a-d2</b>	2.88-2.84	4.00	3.44	$\{(4-3.44)/2\} \times 100 = 28$ Deuterium incorporation per proton = 28%

### Scheme S7: Parallel competitive experiment:



**Procedure:** In a 15 mL oven-dried pressure tube, N-phenylmaleimide **1a** (0.25 mmol, 1 equiv.), Fe(OAc)<sub>2</sub> (0.0125 mmol, 0.05 equiv.), zinc (0.25 mmol, 1 equiv.), and H<sub>2</sub>O (0.25 mL), were dissolved in 1.75 mL of 1,4-dioxane. In another 15 mL oven-dried pressure tube, N-butylmaleimide **1d** (0.25 mmol, 1 equiv.), Fe(OAc)<sub>2</sub> (0.0125 mmol, 0.05 equiv.), zinc (0.25 mmol, 1 equiv.), and H<sub>2</sub>O (0.25 mL), were dissolved in 1.75 mL of 1,4-dioxane. Both the reaction mixtures were placed in a pre-heated oil bath at 80 °C for 6 h. After the stipulated time, the reaction mixture was cooled to room temperature and quenched with 1.0 mL of ethyl acetate. GC analysis of the reaction mixtures showed the formation of **2a** in 92% yield and **2d** in 85% yield.

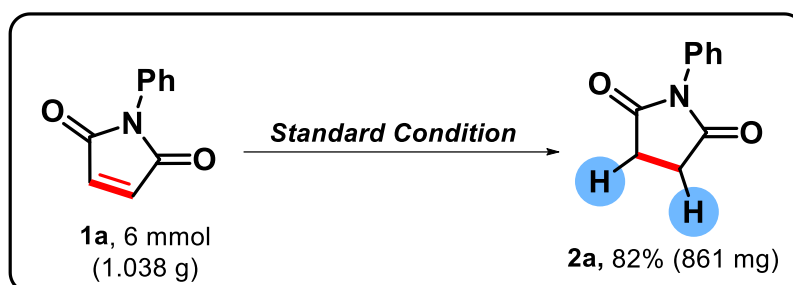
### Scheme S8: Time conversion plot for hydrogenation of **1a** to **2a**:



**Procedure:** In a 15 mL oven-dried pressure tube, N-phenylmaleimide **1a** (0.25 mmol, 1 equiv.), Fe(OAc)<sub>2</sub> (0.0125 mmol, 0.05 equiv.), Zinc (0.25 mmol, 1 equiv.) and H<sub>2</sub>O (0.25 mL), were dissolved in 1.75 mL of 1,4-dioxane and heated at 80 °C in a pre-heated oil bath. The progress of the reaction was monitored using GC with time after every 1 h and injected in GC.

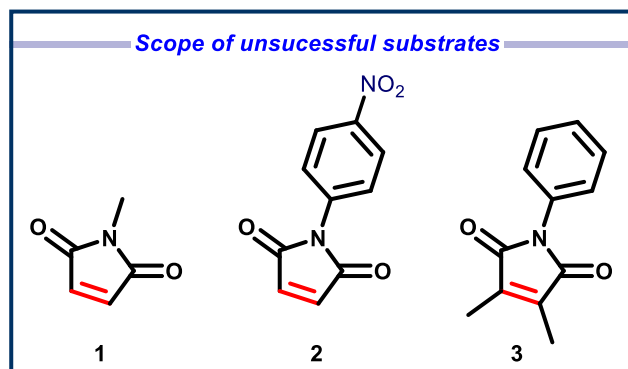
### [1.6] Synthetic Utility

#### Scheme S9: Scale up reaction:



**Procedure:** In a 50 mL oven-dried round bottom flask, N-phenylmaleimide **1a** (6.0 mmol, 1.0 equiv.), Fe(OAc)<sub>2</sub> (0.3 mmol, 0.05 equiv.), zinc (6.0 mmol, 1 equiv.), and H<sub>2</sub>O (3.0 mL), were dissolved in 20.0 mL of 1,4-dioxane and heated at 80 °C in a pre-heated oil bath for 6 h in a closed system. After the stipulated time, the reaction mixture was cooled to room temperature, quenched with 10.0 mL of ethyl acetate, and passed through a pad of celite. The filtrate was *concentrated in vacuo*, and the residue was purified by column chromatography using a gradient of hexane and ethyl acetate (eluent system) to afford the pure white solid N-phenylsuccinimide **2a** product in 861 mg with 82% isolated yield.

#### Scheme S10: Scope of unsuccessful substrates:



### [1.7] XRD analysis for compound 2n

Identification code: DB\_SM\_252B\_2177\_0ma\_a

CCDC: 2483009

Bond precision: C-C = 0.0040 Å Wavelength=0.71073

Cell: a=13.9665(9) b=5.5509(3) c=13.1458(8)

alpha=90 beta=107.595(2) gamma=90

Temperature: 299 K

	<b>Calculated</b>	<b>Reported</b>
Volume	971.47(10)	971.47(10)
Space group	P 21/c	P 21/c
Hall group	-P 2ybc	-P 2ybc
Moiety formula	C11 N O4	?
Sum formula	C11 N O4	C44 N4 O16
Mr	210.12	840.48
Dx, g cm <sup>-3</sup>	1.437	1.437
Z	4	1
Mu (mm <sup>-1</sup> )	0.114	0.114
F000	420.0	420.0
F000'	420.27	
h,k,lmax	18,7,17	18,7,17
Nref	2422	2420
Tmin,Tmax	0.980,0.997	0.890,1.000
Tmin'	0.967	

Correction method= # Reported T Limits: Tmin=0.890 Tmax=1.000

AbsCorr = ?

Data completeness= 0.999

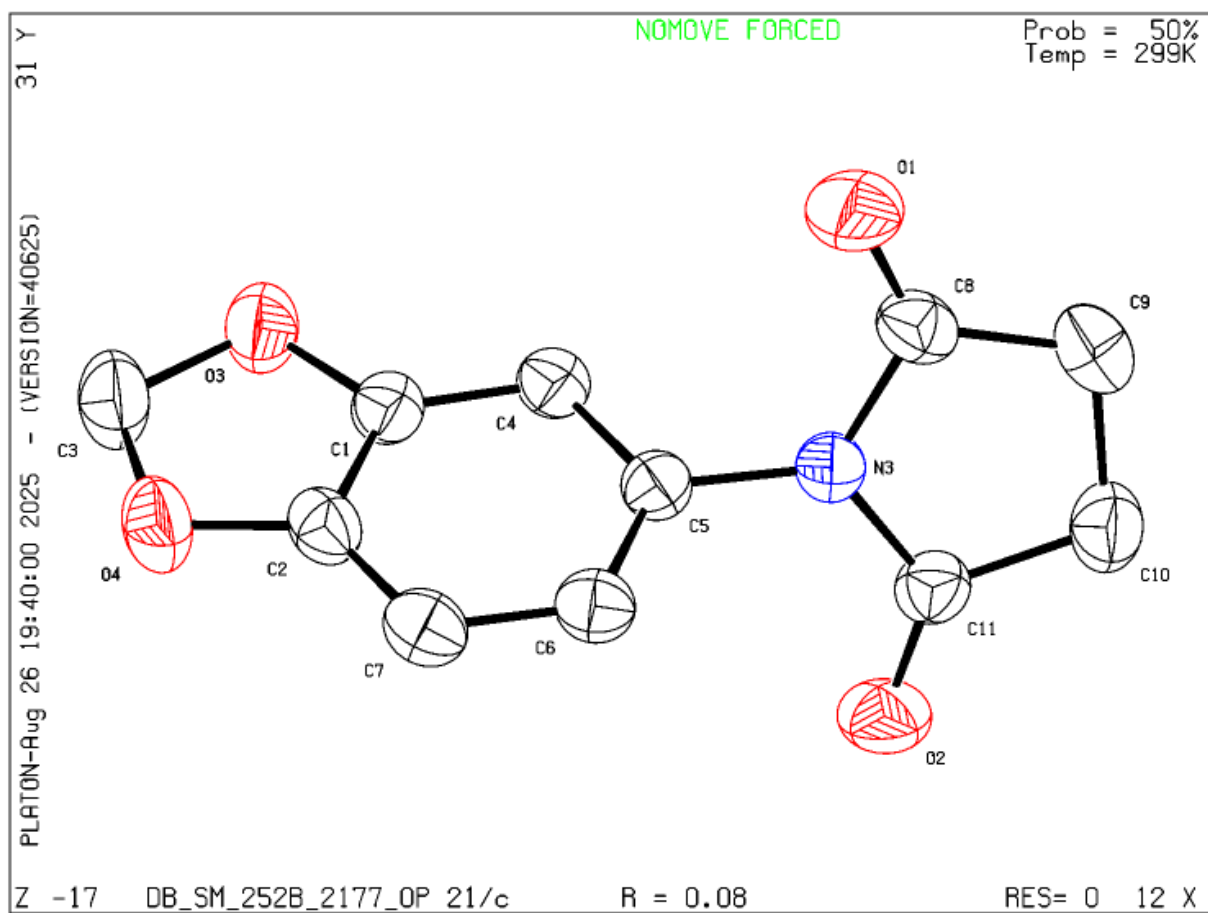
Theta(max)= 28.340

R(reflections)= 0.0795( 1670)

wR2(reflections)= 0.2838(  
2420)

S = 1.066

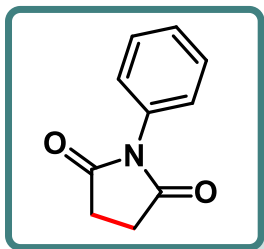
Npar= 145



Platon-ellipsoid plot for compound **2n**

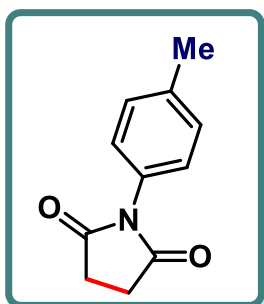
## [1.8] Analytical Data

### 1-Phenylpyrrolidine-2,5-dione (2a):<sup>2</sup>



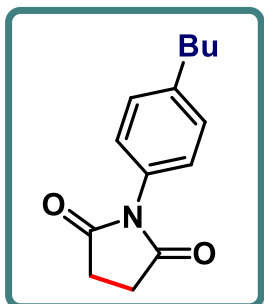
Following the general procedure **1.3**, the title product was obtained as a white solid using silica-gel column chromatography eluting with 40% ethyl acetate in hexane (39 mg, Yield: 90%). <sup>1</sup>H NMR (500 MHz, CDCl<sub>3</sub>) δ 7.49 – 7.45 (m, 2H), 7.40 – 7.37 (m, 1H), 7.28 – 7.25 (m, 2H), 2.88 (s, 4H). <sup>13</sup>C{<sup>1</sup>H} NMR (125 MHz, CDCl<sub>3</sub>) δ 176.3, 131.9, 129.3, 128.7, 126.5, 28.5. FT-IR (ATR): 1699, 1388, 1182 cm<sup>-1</sup>.

### 1-(*p*-Tolyl)pyrrolidine-2,5-dione (2b):<sup>2</sup>



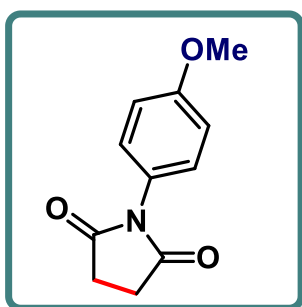
Following the general procedure **1.3**, the title product was obtained as a yellow solid using silica-gel column chromatography eluting with 40% ethyl acetate in hexane (39 mg, Yield: 83%). <sup>1</sup>H NMR (500 MHz, CDCl<sub>3</sub>) δ 7.27 (d, *J* = 8.0 Hz, 2H), 7.14 (d, *J* = 8.3 Hz, 2H), 2.86 (s, 4H), 2.37 (s, 3H). <sup>13</sup>C{<sup>1</sup>H} NMR (125 MHz, CDCl<sub>3</sub>) δ 176.4, 138.8, 129.9, 129.2, 126.3, 28.4, 21.2. FT-IR (ATR): 1702, 1384, 1180 cm<sup>-1</sup>.

### 1-(4-Butylphenyl)pyrrolidine-2,5-dione (2c):



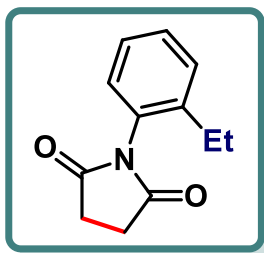
Following the general procedure **1.3**, the title product was obtained as a pale white solid using silica-gel column chromatography eluting with 40% ethyl acetate in hexane (50 mg, Yield: 87%). <sup>1</sup>H NMR (500 MHz, CDCl<sub>3</sub>) δ 7.27 (d, *J* = 8.5 Hz, 2H), 7.15 (d, *J* = 8.4 Hz, 2H), 2.86 (s, 4H), 2.63 – 2.60 (m, 2H), 1.62 – 1.56 (m, 2H), 1.39-1.31 (m, 2H), 0.91 (t, *J* = 7.4 Hz, 3H). <sup>13</sup>C{<sup>1</sup>H} NMR (125 MHz, CDCl<sub>3</sub>) δ 176.5, 143.7, 129.3, 126.2, 35.4, 33.4, 28.4, 22.4, 14.0. FT-IR (ATR): 1702, 1513, 1388, 1184 cm<sup>-1</sup>. HRMS (ESI-TOF) *m/z* [M+H]<sup>+</sup> Calcd. for C<sub>14</sub>H<sub>17</sub>NO<sub>2</sub> 232.1332; Found 232.1333.

### 1-(4-Methoxyphenyl)pyrrolidine-2,5-dione (2d):<sup>2</sup>



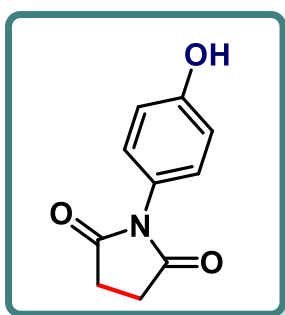
Following the general procedure **1.3**, the title product was obtained as a yellow solid using silica-gel column chromatography eluting with 40% ethyl acetate in hexane (40 mg, Yield: 80%). <sup>1</sup>H NMR (500 MHz, CDCl<sub>3</sub>) δ 7.19 – 7.16 (m, 2H), 6.98 – 6.95 (m, 2H), 3.81 (s, 3H), 2.86 (s, 4H). <sup>13</sup>C{<sup>1</sup>H} NMR (125 MHz, CDCl<sub>3</sub>) δ 176.5, 159.6, 127.7, 124.5, 114.6, 55.5, 28.4. FT-IR (ATR): 1698, 1508, 1384, 1162 cm<sup>-1</sup>.

### 1-(2-Ethylphenyl)pyrrolidine-2,5-dione (2e):



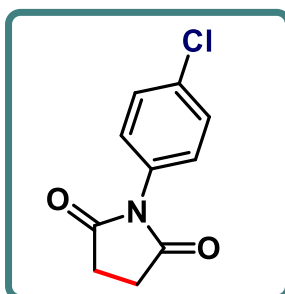
Following the general procedure **1.3**, the title product was obtained as a yellow solid using silica-gel column chromatography eluting with 40% ethyl acetate in hexane (48 mg, Yield: 95%).  $^1\text{H}$  NMR (500 MHz,  $\text{CDCl}_3$ )  $\delta$  7.41 – 7.35 (m, 2H), 7.31 – 7.27 (m, 1H), 7.03 (dd,  $J = 7.7$ , 1.0 Hz, 1H), 2.89 (s, 4H), 2.43 (q,  $J = 7.6$  Hz, 2H), 1.15 (t,  $J = 7.6$  Hz, 3H).  $^{13}\text{C}\{^1\text{H}\}$  NMR (125 MHz,  $\text{CDCl}_3$ )  $\delta$  176.6, 141.4, 130.5, 129.9, 129.4, 128.2, 127.1, 28.7, 24.2, 14.1. FT-IR (ATR): 1702, 1381, 1180  $\text{cm}^{-1}$ . HRMS (ESI-TOF)  $m/z$   $[\text{M}+\text{H}]^+$  Calcd. for  $\text{C}_{12}\text{H}_{13}\text{NO}_2$  204.1019; Found 204.1020.

### 1-(4-Hydroxyphenyl)pyrrolidine-2,5-dione (2f):<sup>3</sup>



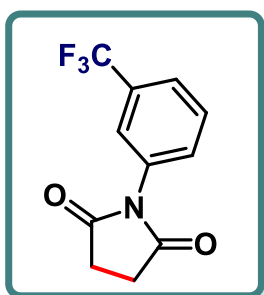
Following the general procedure **1.3**, the title product was obtained as a yellow solid using silica-gel column chromatography eluting with 60% ethyl acetate in hexane (30 mg, Yield: 64%).  $^1\text{H}$  NMR (500 MHz,  $\text{DMSO-d}_6$ )  $\delta$  9.67 (s, 1H), 6.98 (d,  $J = 8.7$  Hz, 2H), 6.79 (d,  $J = 8.7$  Hz, 2H), 2.69 (s, 4H).  $^{13}\text{C}\{^1\text{H}\}$  NMR (125 MHz,  $\text{DMSO-d}_6$ )  $\delta$  177.7, 157.6, 128.8, 124.2, 115.8, 28.8. FT-IR (ATR): 3411, 1743, 1369, 1223  $\text{cm}^{-1}$ .

### 1-(4-Chlorophenyl)pyrrolidine-2,5-dione (2g):<sup>2</sup>



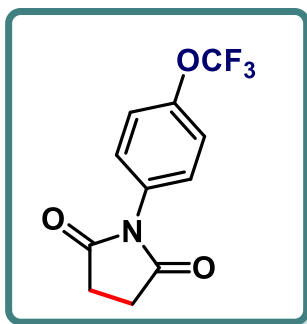
Following the general procedure **1.3**, the title product was obtained as a white solid using silica-gel column chromatography eluting with 40% ethyl acetate in hexane (42 mg, Yield: 81%).  $^1\text{H}$  NMR (500 MHz,  $\text{CDCl}_3$ )  $\delta$  7.43 (d,  $J = 8.9$  Hz, 2H), 7.24 (d,  $J = 8.9$  Hz, 2H), 2.88 (s, 4H).  $^{13}\text{C}\{^1\text{H}\}$  NMR (125 MHz,  $\text{CDCl}_3$ )  $\delta$  175.9, 134.5, 130.3, 129.4, 127.7, 28.4. FT-IR (ATR): 1705, 1387, 1184  $\text{cm}^{-1}$ .

### 1-(3-(Trifluoromethyl)phenyl)pyrrolidine-2,5-dione (2h):<sup>4</sup>



Following the general procedure **1.3**, the title product was obtained as a yellow solid using silica-gel column chromatography eluting with 40% ethyl acetate in hexane (43 mg, Yield: 70%).  $^1\text{H}$  NMR (500 MHz,  $\text{CDCl}_3$ )  $\delta$  7.64 (d,  $J = 7.8$  Hz, 1H), 7.60 – 7.57 (m, 2H), 7.50 (d,  $J = 8.0$  Hz, 1H), 2.89 (d,  $J = 1.3$  Hz, 4H).  $^{13}\text{C}\{^1\text{H}\}$  NMR (125 MHz,  $\text{CDCl}_3$ )  $\delta$  175.7, 132.5, 131.7 (q,  $J = 32.8$  Hz), 129.8, 125.4 (q,  $J = 3.8$  Hz), 123.5 (q,  $J = 273.4$  Hz), 123.5 (q,  $J = 5$  Hz), 28.4.  $^{19}\text{F}$  NMR (470 MHz,  $\text{CDCl}_3$ )  $\delta$  -62.57. FT-IR (ATR): 1711, 1321, 1182, 1065  $\text{cm}^{-1}$ .

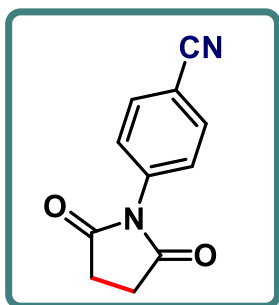
### 1-(4-(Trifluoromethoxy)phenyl)pyrrolidine-2,5-dione (2i):<sup>5</sup>



(ATR):1712, 1182, 1143  $\text{cm}^{-1}$ .

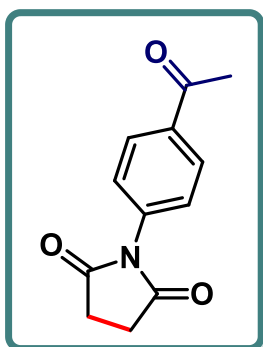
Following the general procedure **1.3**, the title product was obtained as a white solid using silica-gel column chromatography eluting with 40% ethyl acetate in hexane (40 mg, Yield: 61%).  $^1\text{H}$  NMR (500 MHz,  $\text{CDCl}_3$ )  $\delta$  7.35 – 7.29 (m, 4H), 2.88 (s, 4H).  $^{13}\text{C}\{^1\text{H}\}$  NMR (125 MHz,  $\text{CDCl}_3$ )  $\delta$  175.9, 148.8, 130.3, 127.9, 121.7, 120.4 (q,  $J$  = 258 Hz), 28.4.  $^{19}\text{F}$  NMR (470 MHz,  $\text{CDCl}_3$ )  $\delta$  -57.78. FT-IR

### 4-(2,5-Dioxypyrrolidin-1-yl)benzotrile (2j):<sup>6</sup>



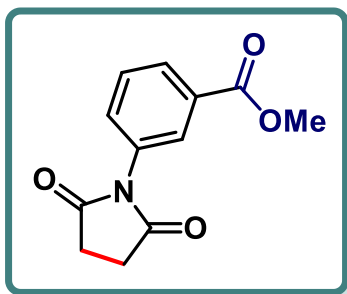
Following the general procedure **1.3**, the title product was obtained as a white solid using silica-gel column chromatography eluting with 40% ethyl acetate in hexane (34 mg, Yield: 67%).  $^1\text{H}$  NMR (500 MHz,  $\text{CDCl}_3$ )  $\delta$  7.76 (d,  $J$  = 9.0 Hz, 2H), 7.50 (d,  $J$  = 9.0 Hz, 2H), 2.93 (s, 4H).  $^{13}\text{C}\{^1\text{H}\}$  NMR (125 MHz,  $\text{CDCl}_3$ )  $\delta$  175.3, 135.8, 133.0, 126.9, 118.1, 112.2, 29.7. FT-IR (ATR): 2236, 1713, 1266, 1012  $\text{cm}^{-1}$ .

### 1-(4-Acetylphenyl)pyrrolidine-2,5-dione (2k):<sup>2</sup>



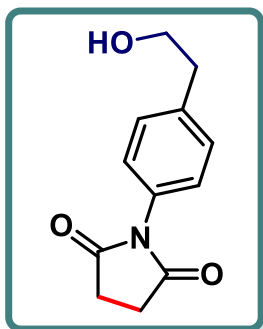
Following the general procedure **1.3**, the title product was obtained as a white solid using silica-gel column chromatography eluting with 40% ethyl acetate in hexane (40 mg, Yield: 74%).  $^1\text{H}$  NMR (500 MHz,  $\text{CDCl}_3$ )  $\delta$  8.05 (d,  $J$  = 8.8 Hz, 2H), 7.43 (d,  $J$  = 8.8 Hz, 2H), 2.91 (s, 4H), 2.60 (s, 3H).  $^{13}\text{C}\{^1\text{H}\}$  NMR (125 MHz,  $\text{CDCl}_3$ )  $\delta$  197.1, 175.7, 136.7, 136.0, 129.2, 126.4, 28.5, 26.7. FT-IR (ATR): 1704, 1682, 1383, 1176  $\text{cm}^{-1}$ .

### Methyl 3-(2,5-dioxypyrrolidin-1-yl)benzoate (2l):



Following the general procedure **1.3**, the title product was obtained as a white solid using silica-gel column chromatography eluting with 40% ethyl acetate in hexane (48 mg, Yield: 82%).  $^1\text{H}$  NMR (500 MHz,  $\text{CDCl}_3$ )  $\delta$  8.05 – 8.03 (m, 1H), 7.96 – 7.95 (m, 1H), 7.52 (t,  $J$  = 7.9 Hz, 1H), 7.47 – 7.45 (m, 1H), 3.88 (s, 3H), 2.86 (s, 4H).  $^{13}\text{C}\{^1\text{H}\}$  NMR (125 MHz,  $\text{CDCl}_3$ )  $\delta$  176.0, 166.0, 132.2, 131.4, 130.9, 129.7, 129.3, 127.7, 52.4, 28.5. FT-IR (ATR): 1702, 1394, 1295, 1180  $\text{cm}^{-1}$ . HRMS (ESI-TOF)  $m/z$   $[\text{M}+\text{H}]^+$  Calcd. for  $\text{C}_{12}\text{H}_{11}\text{NO}_4$  234.0761; Found 234.0761.

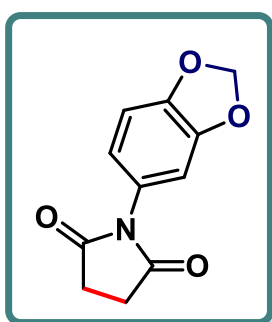
### 1-(4-(2-Hydroxyethyl)phenyl)pyrrolidine-2,5-dione (2m):



Following the general procedure **1.3**, the title product was obtained as a pale yellow solid using silica-gel column chromatography eluting with 40% ethyl acetate in hexane (46 mg, Yield: 84%).  $^1\text{H}$  NMR (500 MHz,  $\text{CDCl}_3$ )  $\delta$  7.30 (d,  $J$  = 8.6 Hz, 2H), 7.19 (d,  $J$  = 8.5 Hz, 2H), 4.25 (s, 2H), 2.93 (s, 2H), 2.84 (s, 4H).  $^{13}\text{C}\{^1\text{H}\}$  NMR (125 MHz,  $\text{CDCl}_3$ )  $\delta$  176.4, 171.0, 138.6, 130.4, 129.7, 126.5, 64.5, 28.4, 21.0. FT-IR (ATR): 1703, 1383, 1236, 1177  $\text{cm}^{-1}$ . HRMS (ESI-TOF)  $m/z$   $[\text{M}+\text{H}]^+$  Calcd.

for  $\text{C}_{12}\text{H}_{13}\text{NO}_3$  220.0968; Found 220.0969.

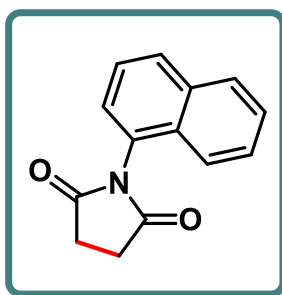
### 1-(Benzo[d][1,3]dioxol-5-yl)pyrrolidine-2,5-dione (2n):



Following the general procedure **1.3**, the title product was obtained as a white solid using silica-gel column chromatography eluting with 40% ethyl acetate in hexane (36 mg, Yield: 66%).  $^1\text{H}$  NMR (500 MHz,  $\text{CDCl}_3$ )  $\delta$  6.87 – 6.85 (m, 1H), 6.71 – 6.69 (m, 2H), 5.99 (s, 2H), 2.85 (s, 4H).  $^{13}\text{C}\{^1\text{H}\}$  NMR (125 MHz,  $\text{CDCl}_3$ )  $\delta$  176.4, 148.2, 147.9, 125.3, 120.4, 108.5, 107.7, 101.9, 28.4. FT-IR (ATR): 1699, 1184  $\text{cm}^{-1}$ .

$^1$ . HRMS (ESI-TOF)  $m/z$   $[\text{M}+\text{H}]^+$  Calcd. for  $\text{C}_{11}\text{H}_9\text{NO}_4$  220.0604; Found 220.0607.

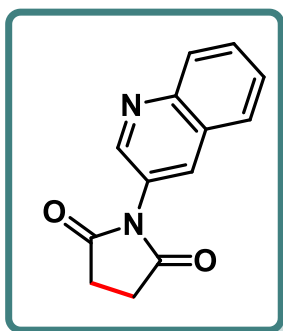
### 1-(Naphthalen-1-yl)pyrrolidine-2,5-dione (2o):<sup>2</sup>



Following the general procedure **1.3**, the title product was obtained as a white solid using silica-gel column chromatography eluting with 40% ethyl acetate in hexane (42 mg, Yield: 75%).  $^1\text{H}$  NMR (500 MHz,  $\text{CDCl}_3$ )  $\delta$  7.96 – 7.91 (m, 2H), 7.57 – 7.51 (m, 4H), 7.33 (dd,  $J$  = 7.3, 1.1 Hz, 1H), 3.01 – 2.88 (m, 4H).  $^{13}\text{C}\{^1\text{H}\}$  NMR (125 MHz,  $\text{CDCl}_3$ )  $\delta$  176.8, 134.5, 130.1, 129.3, 128.8, 128.7, 127.3, 126.7,

126.4, 125.5, 122.0, 28.8. FT-IR (ATR): 1703, 1172  $\text{cm}^{-1}$ .

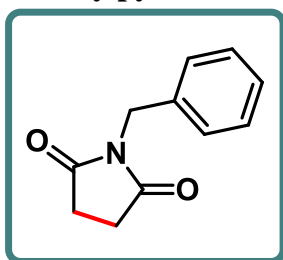
### 1-(Quinolin-3-yl)pyrrolidine-2,5-dione (2p):



Following the general procedure **1.3**, the title product was obtained as a yellow solid using silica-gel column chromatography eluting with 40% ethyl acetate in hexane (15 mg, Yield: 28%).  $^1\text{H}$  NMR (500 MHz,  $\text{CDCl}_3$ )  $\delta$  8.87 (d,  $J = 2.6$  Hz, 1H), 8.18 – 8.13 (m, 2H), 7.87 – 7.85 (m, 1H), 7.79 – 7.75 (m, 1H), 7.61 – 7.58 (m, 1H), 2.99 (s, 4H).  $^{13}\text{C}\{^1\text{H}\}$  NMR (125 MHz,  $\text{CDCl}_3$ )  $\delta$  175.9, 147.7, 147.3, 133.0, 130.4, 129.4, 128.1, 127.5, 127.4, 125.6, 28.6. FT-IR (ATR): 1701, 1179  $\text{cm}^{-1}$ .

<sup>1</sup>. HRMS (ESI-TOF)  $m/z$   $[\text{M}+\text{H}]^+$  Calcd. for  $\text{C}_{13}\text{H}_{10}\text{N}_2\text{O}_2$  227.0815; Found 227.0814.

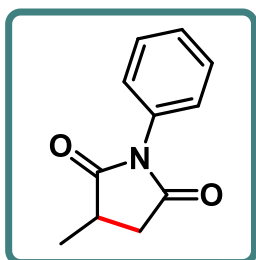
### 1-Benzylpyrrolidine-2,5-dione (2q):<sup>2</sup>



Following the general procedure **1.3**, the title product was obtained as a white solid using silica-gel column chromatography eluting with 20% ethyl acetate in hexane (41 mg, Yield: 87%).  $^1\text{H}$  NMR (500 MHz,  $\text{CDCl}_3$ )  $\delta$  7.38 (dd,  $J = 8.0, 1.5$  Hz, 2H), 7.31 – 7.26 (m, 3H), 4.64 (s, 2H), 2.69 (s, 4H).  $^{13}\text{C}\{^1\text{H}\}$  NMR (125 MHz,  $\text{CDCl}_3$ )  $\delta$  176.9, 135.8, 129.0, 128.7, 128.0, 42.4, 28.2. FT-IR (ATR): 1690, 1164  $\text{cm}^{-1}$ .

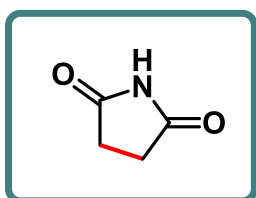
FT-IR (ATR): 1690, 1164  $\text{cm}^{-1}$ .

### (R)-3-Methyl-1-phenylpyrrolidine-2,5-dione (2r):<sup>2</sup>



Following the general procedure **1.3**, the title product was obtained as a yellow solid using silica-gel column chromatography eluting with 40% ethyl acetate in hexane (37 mg, Yield: 79%).  $^1\text{H}$  NMR (500 MHz,  $\text{CDCl}_3$ )  $\delta$  7.47 – 7.44 (m, 2H), 7.39 – 7.35 (m, 1H), 7.28 – 7.26 (m, 2H), 3.05 (dd,  $J = 17.7, 9.2$  Hz, 1H), 3.02 – 2.97 (m, 1H), 2.47 (dd,  $J = 17.5, 4.2$  Hz, 1H), 1.41 (d,  $J = 7.2$  Hz, 3H).  $^{13}\text{C}\{^1\text{H}\}$  NMR (125 MHz,  $\text{CDCl}_3$ )  $\delta$  179.6, 175.5, 132.0, 129.2, 128.6, 126.5, 36.6, 34.9, 16.9. FT-IR (ATR): 1696, 1392, 1175  $\text{cm}^{-1}$ .

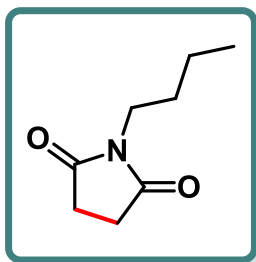
### Pyrrolidine-2,5-dione (2s):<sup>7</sup>



Following the general procedure **1.3**, the title product was obtained as a white solid using silica-gel column chromatography eluting with 60% ethyl acetate in hexane (11 mg, Yield: 44%).  $^1\text{H}$  NMR (500 MHz,  $\text{CDCl}_3$ )  $\delta$  2.78 (d,  $J = 4.3$  Hz, 4H).  $^{13}\text{C}\{^1\text{H}\}$  NMR (125 MHz,  $\text{CDCl}_3$ )  $\delta$

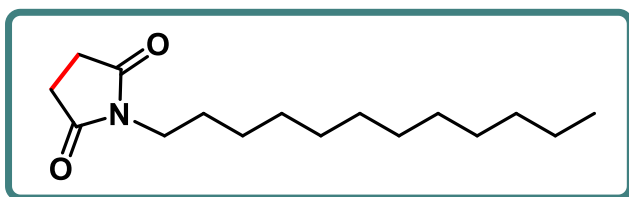
177.3, 29.6. FT-IR (ATR): 1681, 1201  $\text{cm}^{-1}$ .

### 1-Butylpyrrolidine-2,5-dione (2t):<sup>8</sup>



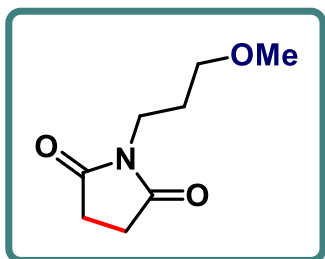
Following the general procedure **1.3**, the title product was obtained as a yellow oil using silica-gel column chromatography eluting with 40% ethyl acetate in hexane (32 mg, Yield: 82%). <sup>1</sup>H NMR (500 MHz, CDCl<sub>3</sub>) δ 3.47 – 3.43 (m, 2H), 2.65 (s, 4H), 1.52 – 1.46 (m, 2H), 1.30 – 1.22 (m, 2H), 0.89 – 0.85 (m, 3H). <sup>13</sup>C{<sup>1</sup>H} NMR (125 MHz, CDCl<sub>3</sub>) δ 177.4, 38.6, 29.7, 28.2, 20.1, 13.6. FT-IR (ATR): 2940, 2872, 1692, 1404, 1128 cm<sup>-1</sup>.

### 1-Dodecylpyrrolidine-2,5-dione (2u):<sup>9</sup>



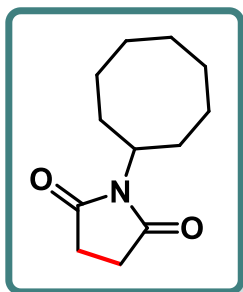
Following the general procedure **1.3**, the title product was obtained as a white solid using silica-gel column chromatography eluting with 40% ethyl acetate in hexane (48 mg, Yield: 72%). <sup>1</sup>H NMR (500 MHz, CDCl<sub>3</sub>) δ 3.45 – 3.42 (m, 2H), 2.64 (s, 4H), 1.50 (d, *J* = 7.1 Hz, 2H), 1.23-1.20 (m, 18H), 0.82 (t, *J* = 6.9 Hz, 3H). <sup>13</sup>C{<sup>1</sup>H} NMR (125 MHz, CDCl<sub>3</sub>) δ 177.3, 38.9, 31.9, 29.6, 29.59, 29.51, 29.3, 29.2, 28.1, 27.7, 26.9, 22.7, 14.1. FT-IR (ATR): 2918, 2850, 1690, 1404, 1133 cm<sup>-1</sup>.

### 1-(3-Methoxypropyl)pyrrolidine-2,5-dione (2v):



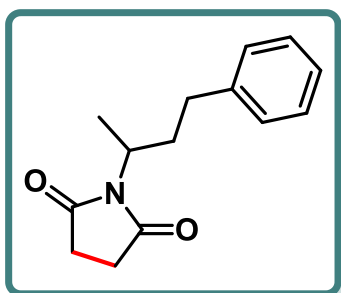
Following the general procedure **1.3**, the title product was obtained as a colourless oil using silica-gel column chromatography eluting with 20% ethyl acetate in hexane (23 mg, Yield: 54%). <sup>1</sup>H NMR (500 MHz, CDCl<sub>3</sub>) δ 3.57 (t, *J* = 7.0 Hz, 2H), 3.36 – 3.34 (m, 2H), 3.26 – 3.25 (m, 3H), 2.65 (s, 4H), 1.82 – 1.77 (m, 2H). <sup>13</sup>C{<sup>1</sup>H} NMR (125 MHz, CDCl<sub>3</sub>) δ 177.3, 70.3, 58.6, 36.5, 28.2, 27.7. FT-IR (ATR): 2945, 1687, 1367 cm<sup>-1</sup>. HRMS (ESI-TOF) *m/z* [M+H]<sup>+</sup> Calcd. for C<sub>8</sub>H<sub>13</sub>NO<sub>3</sub> 172.0968; Found 172.0969.

### 1-Cyclooctylpyrrolidine-2,5-dione (2w):



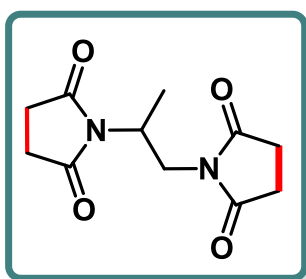
Following the general procedure **1.3**, the title product was obtained as a pale yellow solid using silica-gel column chromatography eluting with 40% ethyl acetate in hexane (40 mg, Yield: 77%). <sup>1</sup>H NMR (500 MHz, CDCl<sub>3</sub>) δ 4.21 – 4.14 (m, 1H), 2.59 (s, 4H), 2.22 – 2.16 (m, 2H), 1.75 – 1.20 (m, 12H). <sup>13</sup>C{<sup>1</sup>H} NMR (125 MHz, CDCl<sub>3</sub>) δ 177.1, 52.3, 31.0, 28.1, 26.2, 25.9, 25.2. FT-IR (ATR): 2928, 1680, 1181 cm<sup>-1</sup>. HRMS (ESI-TOF) *m/z* [M+H]<sup>+</sup> Calcd. for C<sub>12</sub>H<sub>19</sub>NO<sub>2</sub> 210.1489; Found 210.1490.

### 1-(4-Phenylbutan-2-yl)pyrrolidine-2,5-dione (2x):



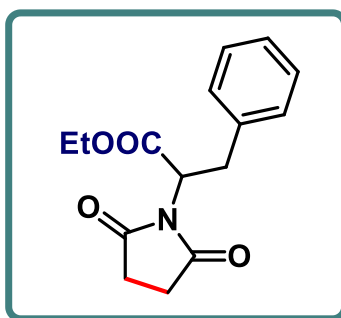
Following the general procedure **1.3**, the title product was obtained as a yellow oil using silica-gel column chromatography eluting with 40% ethyl acetate in hexane (44 mg, Yield: 76%).  $^1\text{H}$  NMR (500 MHz,  $\text{CDCl}_3$ )  $\delta$  7.25 – 7.22 (m, 2H), 7.15 – 7.11 (m, 3H), 4.27 – 4.23 (m, 1H), 2.68 – 2.62 (m, 1H), 2.49 – 2.33 (m, 6H), 1.93 – 1.87 (m, 1H), 1.35 (d,  $J = 7.0$  Hz, 3H).  $^{13}\text{C}\{^1\text{H}\}$  NMR (125 MHz,  $\text{CDCl}_3$ )  $\delta$  177.5, 141.1, 128.4, 128.3, 126.0, 48.3, 33.5, 33.2, 28.0, 18.2. FT-IR (ATR): 1694, 1367  $\text{cm}^{-1}$ . HRMS (ESI-TOF)  $m/z$   $[\text{M}+\text{H}]^+$  Calcd. for  $\text{C}_{14}\text{H}_{17}\text{NO}_2$  232.1332; Found 232.1332.

### 1,1'-(Propane-1,2-diyl)bis(pyrrolidine-2,5-dione) (2y):



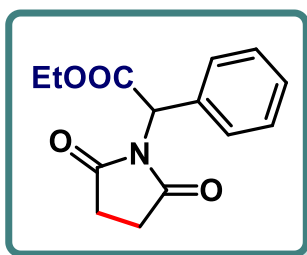
Following the general procedure **1.3**, the title product was obtained as a white solid using silica-gel column chromatography eluting with 40% ethyl acetate in hexane (51 mg, Yield: 85%).  $^1\text{H}$  NMR (500 MHz,  $\text{CDCl}_3$ )  $\delta$  4.35-4.31 (m, 1H), 4.11 – 4.07 (m, 1H), 3.59 – 3.55 (m, 1H), 2.66 – 2.53 (m, 8H), 1.51 (d,  $J = 7.3$  Hz, 3H).  $^{13}\text{C}\{^1\text{H}\}$  NMR (125 MHz,  $\text{CDCl}_3$ )  $\delta$  178.0, 177.5, 47.3, 40.8, 28.1, 28.0, 15.2. FT-IR (ATR): 1694, 1384, 1179  $\text{cm}^{-1}$ . HRMS (ESI-TOF)  $m/z$   $[\text{M}+\text{H}]^+$  Calcd. for  $\text{C}_{11}\text{H}_{14}\text{N}_2\text{O}_4$  239.1026; Found 239.1023.

### Ethyl 2-(2,5-dioxypyrrolidin-1-yl)-3-phenylpropanoate (3a):



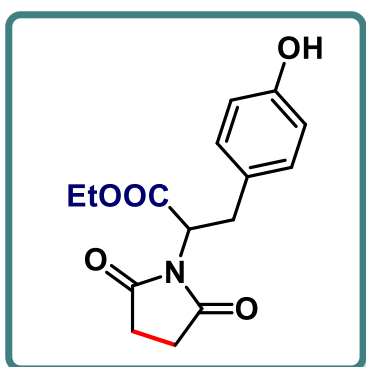
Following the general procedure **1.3**, the title product was obtained as a colourless oil using silica-gel column chromatography eluting with 40% ethyl acetate in hexane (50 mg, Yield: 72%).  $^1\text{H}$  NMR (500 MHz,  $\text{CDCl}_3$ )  $\delta$  7.24 – 7.09 (m, 5H), 4.97 (dd,  $J = 11.5, 5.6$  Hz, 1H), 4.25 – 4.18 (m, 2H), 3.48 – 3.36 (m, 2H), 2.58 – 2.43 (m, 4H), 1.27 – 1.23 (m, 3H).  $^{13}\text{C}\{^1\text{H}\}$  NMR (125 MHz,  $\text{CDCl}_3$ )  $\delta$  176.2, 168.3, 136.6, 128.9, 128.6, 127.0, 62.0, 53.6, 33.7, 27.9, 14.1. FT-IR (ATR): 1739, 1706, 1389  $\text{cm}^{-1}$ . HRMS (ESI-TOF)  $m/z$   $[\text{M}+\text{H}]^+$  Calcd. for  $\text{C}_{15}\text{H}_{17}\text{NO}_4$  276.1230; Found 276.1228.

### Ethyl 2-(2,5-dioxopyrrolidin-1-yl)-2-phenylacetate (3b):



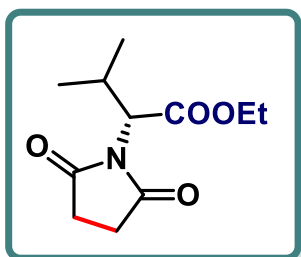
Following the general procedure **1.3**, the title product was obtained as a yellow solid using silica-gel column chromatography eluting with 40% ethyl acetate in hexane (50 mg, Yield: 77%).  $^1\text{H}$  NMR (500 MHz,  $\text{CDCl}_3$ )  $\delta$  7.46 – 7.44 (m, 2H), 7.31 – 7.29 (m, 3H), 5.79 (s, 1H), 4.23 (q,  $J = 6.9$  Hz, 2H), 2.68 (s, 4H), 1.23 (t,  $J = 7.1$  Hz, 3H).  $^{13}\text{C}\{^1\text{H}\}$  NMR (125 MHz,  $\text{CDCl}_3$ )  $\delta$  176.0, 167.5, 134.0, 130.0, 128.7, 128.5, 62.2, 56.4, 28.2, 14.1. FT-IR (ATR): 1743, 1704, 1384, 1173  $\text{cm}^{-1}$ . HRMS (ESI-TOF)  $m/z$   $[\text{M}+\text{H}]^+$  Calcd. for  $\text{C}_{14}\text{H}_{15}\text{NO}_4$  262.1074; Found 262.1074.

### Ethyl 2-(2,5-dioxopyrrolidin-1-yl)-3-(4-hydroxyphenyl)propanoate (3c):



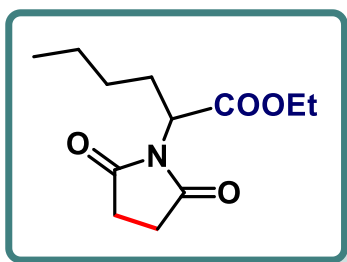
Following the general procedure **1.3**, the title product was obtained as a white solid using silica-gel column chromatography eluting with 40% ethyl acetate in hexane (59 mg, Yield: 81%).  $^1\text{H}$  NMR (500 MHz,  $\text{CDCl}_3$ )  $\delta$  6.94 (d,  $J = 8.5$  Hz, 2H), 6.66 (d,  $J = 8.5$  Hz, 2H), 6.46 (s, 1H), 4.94 (dd,  $J = 11.5, 5.5$  Hz, 1H), 4.26 – 4.19 (m, 2H), 3.40 – 3.28 (m, 2H), 2.58 – 2.48 (m, 4H), 1.26 (t,  $J = 7.1$  Hz, 3H).  $^{13}\text{C}\{^1\text{H}\}$  NMR (125 MHz,  $\text{CDCl}_3$ )  $\delta$  176.9, 168.5, 155.1, 130.0, 127.9, 115.5, 62.2, 54.0, 32.8, 27.9, 14.1. FT-IR (ATR): 3283, 1742, 1683, 1237, 1176  $\text{cm}^{-1}$ . HRMS (ESI-TOF)  $m/z$   $[\text{M}+\text{H}]^+$  Calcd. for  $\text{C}_{15}\text{H}_{17}\text{NO}_5$  292.1179; Found 292.1179.

### Ethyl (R)-2-(2,5-dioxopyrrolidin-1-yl)-3-methylbutanoate (3d):



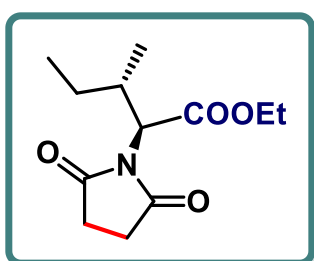
Following the general procedure **1.3**, the title product was obtained as a yellow oil using silica-gel column chromatography eluting with 40% ethyl acetate in hexane (32 mg, Yield: 57%).  $^1\text{H}$  NMR (500 MHz,  $\text{CDCl}_3$ )  $\delta$  4.37 (d,  $J = 8.6$  Hz, 1H), 4.18 – 4.15 (m, 2H), 2.75 (s, 4H), 2.67 – 2.60 (m, 1H), 1.23 – 1.20 (m, 3H), 1.10 (d,  $J = 6.7$  Hz, 3H), 0.81 (d,  $J = 6.9$  Hz, 3H).  $^{13}\text{C}\{^1\text{H}\}$  NMR (125 MHz,  $\text{CDCl}_3$ )  $\delta$  176.6, 168.4, 61.5, 58.2, 28.0, 27.8, 21.1, 19.4, 14.1. FT-IR (ATR): 2968, 1744, 1703, 1384, 1184  $\text{cm}^{-1}$ . HRMS (ESI-TOF)  $m/z$   $[\text{M}+\text{H}]^+$  Calcd. for  $\text{C}_{11}\text{H}_{17}\text{NO}_4$  228.1230; Found 228.1232.

### Ethyl-2-(2,5-dioxopyrrolidin-1-yl)hexanoate (3e):



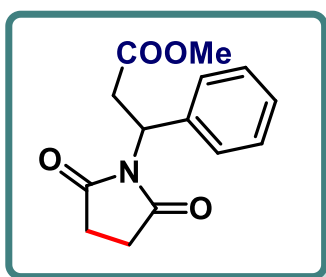
Following the general procedure **1.3**, the title product was obtained as a yellow oil using silica-gel column chromatography eluting with 40% ethyl acetate in hexane (36 mg, Yield: 60%).  $^1\text{H}$  NMR (500 MHz,  $\text{CDCl}_3$ )  $\delta$  4.64 – 4.61 (m, 1H), 4.18 – 4.11 (m, 2H), 2.72 (s, 4H), 2.10 – 2.05 (m, 2H), 1.32 – 1.23 (m, 3H), 1.21 (d,  $J = 7.1$  Hz, 3H), 1.19 – 1.09 (m, 1H), 0.84 (t,  $J = 7.2$  Hz, 3H).  $^{13}\text{C}\{^1\text{H}\}$  NMR (125 MHz,  $\text{CDCl}_3$ )  $\delta$  176.6, 168.9, 61.8, 52.8, 28.4, 28.1, 27.5, 22.1, 14.1, 13.9. FT-IR (ATR): 2970, 1738, 1702, 1389, 1183  $\text{cm}^{-1}$ . HRMS (ESI-TOF)  $m/z$   $[\text{M}+\text{H}]^+$  Calcd. for  $\text{C}_{12}\text{H}_{19}\text{NO}_4$  242.1387; Found 242.1389.

### Ethyl (2S,3S)-2-(2,5-dioxopyrrolidin-1-yl)-3-methylpentanoate (3f):



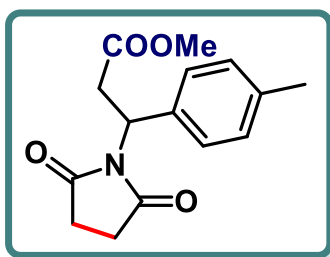
Following the general procedure **1.3**, the title product was obtained as a colourless oil using silica-gel column chromatography eluting with 40% ethyl acetate in hexane (40 mg, Yield: 67%).  $^1\text{H}$  NMR (500 MHz,  $\text{CDCl}_3$ )  $\delta$  4.43 (d,  $J = 8.4$  Hz, 1H), 4.17 – 4.12 (m, 2H), 2.72 (s, 4H), 2.43 – 2.35 (m, 1H), 1.39 – 1.31 (m, 1H), 1.22 – 1.19 (m, 3H), 1.05 (d,  $J = 6.7$  Hz, 3H), 1.01 – 0.92 (m, 1H), 0.83 (t,  $J = 7.4$  Hz, 3H).  $^{13}\text{C}\{^1\text{H}\}$  NMR (125 MHz,  $\text{CDCl}_3$ )  $\delta$  176.6, 168.5, 61.5, 57.6, 33.8, 28.0, 25.7, 16.9, 14.1, 11.0. FT-IR (ATR): 2968, 1742, 1702, 1386, 1185  $\text{cm}^{-1}$ . HRMS (ESI-TOF)  $m/z$   $[\text{M}+\text{H}]^+$  Calcd. for  $\text{C}_{12}\text{H}_{19}\text{NO}_4$  242.1387; Found 242.1388.

### Methyl 3-(2,5-dioxopyrrolidin-1-yl)-3-phenylpropanoate (3g):



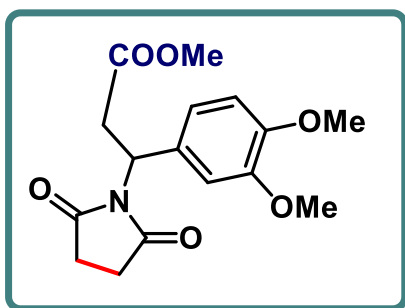
Following the general procedure **1.3**, the title product was obtained as a yellow oil using silica-gel column chromatography eluting with 40% ethyl acetate in hexane (44 mg, Yield: 67%).  $^1\text{H}$  NMR (500 MHz,  $\text{CDCl}_3$ )  $\delta$  7.46 – 7.44 (m, 2H), 7.32 – 7.25 (m, 3H), 5.64 – 5.61 (m, 1H), 3.75 – 3.69 (m, 1H), 3.63 (d,  $J = 2.2$  Hz, 3H), 3.09 (dd,  $J = 16.7, 5.5$  Hz, 1H), 2.62 (d,  $J = 2.9$  Hz, 4H).  $^{13}\text{C}\{^1\text{H}\}$  NMR (125 MHz,  $\text{CDCl}_3$ )  $\delta$  177.1, 171.2, 137.9, 128.7, 128.4, 128.0, 51.9, 51.5, 34.6, 28.0. FT-IR (ATR): 1736, 1695, 1359, 1171  $\text{cm}^{-1}$ . HRMS (ESI-TOF)  $m/z$   $[\text{M}+\text{H}]^+$  Calcd. for  $\text{C}_{14}\text{H}_{15}\text{NO}_4$  262.1074; Found 262.1075.

### Methyl 3-(2,5-dioxopyrrolidin-1-yl)-3-(p-tolyl)propanoate (3h):



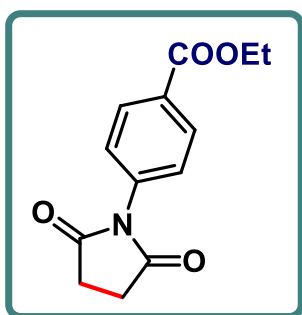
Following the general procedure **1.3**, the title product was obtained as a colourless oil using silica-gel column chromatography eluting with 40% ethyl acetate in hexane (42 mg, Yield: 61%).  $^1\text{H}$  NMR (500 MHz,  $\text{CDCl}_3$ )  $\delta$  7.34 (d,  $J = 8.5$  Hz, 2H), 7.10 (d,  $J = 8.6$  Hz, 2H), 5.60 (dd,  $J = 10.7, 5.8$  Hz, 1H), 3.70 (dd,  $J = 16.7, 10.4$  Hz, 1H), 3.62 (s, 3H), 3.08 (dd,  $J = 16.7, 5.7$  Hz, 1H), 2.61 (s, 4H), 2.29 (s, 3H).  $^{13}\text{C}\{^1\text{H}\}$  NMR (125 MHz,  $\text{CDCl}_3$ )  $\delta$  177.1, 171.2, 138.2, 135.0, 129.4, 127.9, 51.9, 51.2, 34.6, 28.0, 21.1. FT-IR (ATR): 1734, 1698, 1358, 1176  $\text{cm}^{-1}$ . HRMS (ESI-TOF)  $m/z$   $[\text{M}+\text{H}]^+$  Calcd. for  $\text{C}_{15}\text{H}_{17}\text{NO}_4$  276.1230; Found 276.1231.

### Methyl 3-(3,4-dimethoxyphenyl)-3-(2,5-dioxopyrrolidin-1-yl)propanoate (3i):



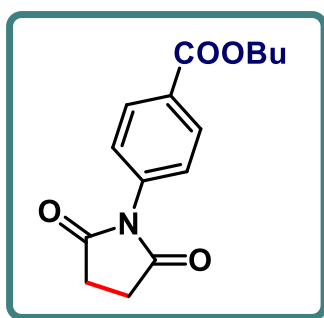
Following the general procedure **1.3**, the title product was obtained as a white solid using silica-gel column chromatography eluting with 40% ethyl acetate in hexane (44 mg, Yield: 55%).  $^1\text{H}$  NMR (500 MHz,  $\text{CDCl}_3$ )  $\delta$  7.01 – 6.99 (m, 2H), 6.74 (d,  $J = 8.1$  Hz, 1H), 5.55 – 5.51 (m, 1H), 3.82 – 3.79 (m, 6H), 3.69 – 3.63 (m, 1H), 3.59 (dd,  $J = 2.1, 1.3$  Hz, 3H), 3.07 (dd,  $J = 16.7, 5.8$  Hz, 1H), 2.59 (s, 4H).  $^{13}\text{C}\{^1\text{H}\}$  NMR (125 MHz,  $\text{CDCl}_3$ )  $\delta$  177.2, 171.1, 149.0, 148.9, 130.6, 120.5, 111.3, 110.9, 55.9, 55.8, 51.9, 51.4, 34.8, 28.0. FT-IR (ATR): 1736, 1695, 1362, 1255, 1141  $\text{cm}^{-1}$ . HRMS (ESI-TOF)  $m/z$   $[\text{M}+\text{H}]^+$  Calcd. for  $\text{C}_{16}\text{H}_{19}\text{NO}_6$  322.1285; Found 322.1286.

### Ethyl 4-(2,5-dioxopyrrolidin-1-yl)benzoate (4a):<sup>10</sup>



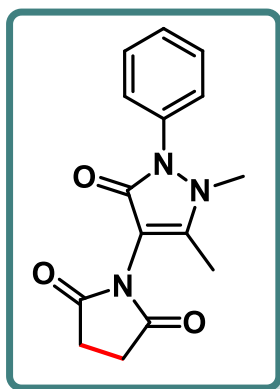
Following the general procedure **1.3**, the title product was obtained as a white solid using silica-gel column chromatography eluting with 40% ethyl acetate in hexane (50 mg, Yield: 81%).  $^1\text{H}$  NMR (500 MHz,  $\text{CDCl}_3$ )  $\delta$  8.11 (d,  $J = 8.9$  Hz, 2H), 7.38 (d,  $J = 8.6$  Hz, 2H), 4.35 (q,  $J = 7.3$  Hz, 2H), 2.86 (s, 4H), 1.36 (t,  $J = 7.3$  Hz, 3H).  $^{13}\text{C}\{^1\text{H}\}$  NMR (125 MHz,  $\text{CDCl}_3$ )  $\delta$  175.8, 165.7, 135.8, 130.45, 130.40, 126.2, 61.3, 28.5, 14.3. FT-IR (ATR): 1700, 1386, 1268, 1178,  $\text{cm}^{-1}$ .

### Butyl 4-(2,5-dioxopyrrolidin-1-yl)benzoate (**4b**):



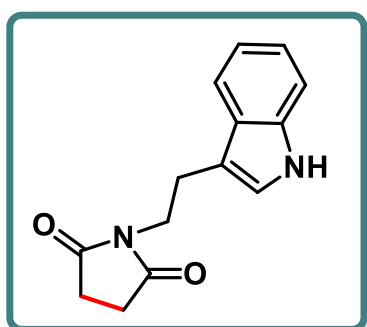
Following the general procedure **1.3**, the title product was obtained as a white solid using silica-gel column chromatography eluting with 40% ethyl acetate in hexane (49 mg, Yield: 72%).  $^1\text{H}$  NMR (500 MHz,  $\text{CDCl}_3$ )  $\delta$  8.11 (d,  $J = 8.9$  Hz, 2H), 7.38 (d,  $J = 8.9$  Hz, 2H), 4.30 (t,  $J = 6.8$  Hz, 2H), 2.87 (s, 4H), 1.75 – 1.69 (m, 2H), 1.48 – 1.40 (m, 2H), 0.95 (t,  $J = 7.6$  Hz, 3H).  $^{13}\text{C}\{^1\text{H}\}$  NMR (125 MHz,  $\text{CDCl}_3$ )  $\delta$  175.8, 165.8, 135.8, 130.5, 130.4, 126.2, 65.1, 30.7, 28.5, 19.3, 13.8. FT-IR (ATR): 1702, 1388, 1282, 1178,  $\text{cm}^{-1}$ . HRMS (ESI-TOF)  $m/z$   $[\text{M}+\text{H}]^+$  Calcd. for  $\text{C}_{15}\text{H}_{17}\text{NO}_4$  276.1230; Found 276.1232.

### 1-(1,5-Dimethyl-3-oxo-2-phenyl-2,3-dihydro-1H-pyrazol-4-yl)pyrrolidine-2,5-dione (**4c**):<sup>11</sup>



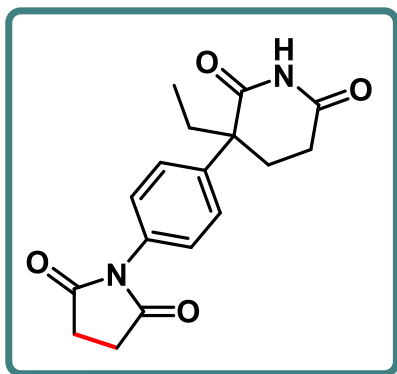
Following the general procedure **1.3**, the title product was obtained as a yellow solid using silica-gel column chromatography eluting with pure ethyl acetate (37 mg, Yield: 52%).  $^1\text{H}$  NMR (500 MHz,  $\text{DMSO-d}_6$ )  $\delta$  7.48 (t,  $J = 7.9$  Hz, 2H), 7.34 – 7.30 (m, 3H), 3.13 (s, 3H), 2.77 (s, 4H), 2.10 (s, 3H).  $^{13}\text{C}\{^1\text{H}\}$  NMR (125 MHz,  $\text{DMSO-d}_6$ )  $\delta$  177.1, 160.8, 154.1, 135.0, 129.7, 127.4, 124.8, 101.4, 35.7, 28.8, 10.8. FT-IR (ATR): 1739, 1651, 1367, 1219,  $\text{cm}^{-1}$ .

### 1-(2-(1H-indol-3-yl)ethyl)pyrrolidine-2,5-dione (**4d**):<sup>12</sup>



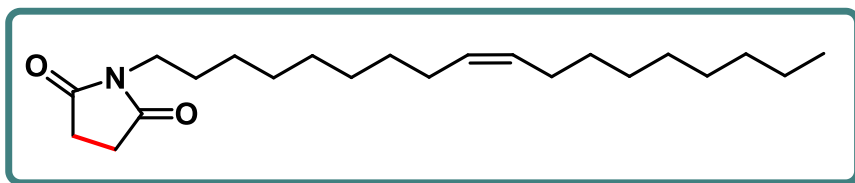
Following the general procedure **1.3**, the title product was obtained as a white solid using silica-gel column chromatography eluting with 40% ethyl acetate in hexane (18 mg, Yield: 76%).  $^1\text{H}$  NMR (500 MHz,  $\text{DMSO-d}_6$ )  $\delta$  10.81 (s, 1H), 7.50 (dd,  $J = 7.4, 4.1$  Hz, 1H), 7.31 (dd,  $J = 7.5, 4.6$  Hz, 1H), 7.15 (s, 1H), 7.05 – 7.02 (m, 1H), 6.98 – 6.95 (m, 1H), 3.59 – 3.56 (m, 2H), 2.86 – 2.84 (m, 2H), 2.57 (s, 4H).  $^{13}\text{C}\{^1\text{H}\}$  NMR (125 MHz,  $\text{DMSO-d}_6$ )  $\delta$  178.1, 136.7, 127.5, 123.4, 121.5, 118.9, 118.4, 112.0, 111.1, 39.1, 28.5, 23.6. FT-IR (ATR): 1709, 1360, 1221, 1055  $\text{cm}^{-1}$ .

### 3-(4-(2,5-Dioxopyrrolidin-1-yl)phenyl)-3-ethylpiperidine-2,6-dione (4e):<sup>2</sup>



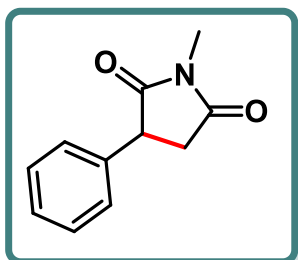
Following the general procedure **1.3**, the title product was obtained as a white solid using silica-gel column chromatography eluting with 60% ethyl acetate in hexane (46 mg, Yield: 59%). <sup>1</sup>H NMR (500 MHz, DMSO-d<sub>6</sub>) δ 8.53 (s, 1H), 7.36 (d, *J* = 8.9 Hz, 2H), 7.29 (d, *J* = 6.6 Hz, 2H), 2.85 (s, 4H), 2.57 (d, *J* = 17.4 Hz, 1H), 2.41 – 2.33 (m, 2H), 2.21 – 2.17 (m, 1H), 2.05 – 2.00 (m, 1H), 1.86 (dd, *J* = 14.2, 7.4 Hz, 1H), 0.87 – 0.75 (m, 3H). <sup>13</sup>C{<sup>1</sup>H} NMR (125 MHz, DMSO-d<sub>6</sub>) δ 176.2, 174.9, 172.4, 139.3, 131.3, 127.1, 126.8, 50.9, 33.0, 29.2, 28.4, 26.8, 9.1. FT-IR (ATR): 2936, 1703, 1678, 1178 cm<sup>-1</sup>.

### (*Z*)-1-(Octadec-9-en-1-yl)pyrrolidine-2,5-dione (4f):



Following the general procedure **1.3**, the title product was obtained as a yellow oil using silica-gel column chromatography eluting with 40% ethyl acetate in hexane (57 mg, Yield: 65%). <sup>1</sup>H NMR (500 MHz, DMSO-d<sub>6</sub>) δ 5.32 – 5.27 (m, 2H), 3.44 – 3.41 (m, 2H), 2.63 (s, 4H), 1.95 – 1.93 (m, 4H), 1.48 (d, *J* = 6.1 Hz, 2H), 1.25-1.21 (m, 22H), 0.83 – 0.80 (m, 3H). <sup>13</sup>C{<sup>1</sup>H} NMR (125 MHz, DMSO-d<sub>6</sub>) δ 177.2, 129.9, 129.8, 38.9, 32.6, 31.9, 29.8, 29.7, 29.5, 29.4, 29.3, 29.2, 29.1, 28.1, 27.7, 27.25, 27.21, 26.8, 22.7, 14.1. FT-IR (ATR): 2925, 2851, 1700 cm<sup>-1</sup>. HRMS (ESI-TOF) *m/z* [M+H]<sup>+</sup> Calcd. for C<sub>22</sub>H<sub>39</sub>NO<sub>2</sub> 350.3054; Found 350.3056.

### 1-Methyl-3-phenylpyrrolidine-2,5-dione (4g):<sup>13</sup>



Following the general procedure **1.3**, the title product was obtained as a pale yellow liquid using silica-gel column chromatography eluting with 40% ethyl acetate in hexane (20 mg, Yield: 71%). <sup>1</sup>H NMR (500 MHz, CDCl<sub>3</sub>) δ 7.35 (t, *J* = 7.2 Hz, 2H), 7.29 (t, *J* = 7.4 Hz, 1H), 7.20 (d, *J* = 6.9 Hz, 2H), 4.01 (dd, *J* = 9.6, 4.8 Hz, 1H), 3.19 (dd, *J* = 18.5, 9.5 Hz, 1H), 3.05 (s, 3H), 2.81 (dd, *J* = 18.4, 4.8 Hz, 1H). <sup>13</sup>C{<sup>1</sup>H} NMR (125 MHz, CDCl<sub>3</sub>) δ 177.9, 176.4, 137.1, 129.3, 128.1, 127.5, 46.0, 37.2, 25.3. FT-IR (ATR): 1684 cm<sup>-1</sup>.

## [1.9] References

1. R. Mandal, B. Emayavaramban, and B. Sundararaju., *Org. Lett.*, 2018, **20**, 2835–2838.
2. S. Lv, Z. Yuan, J. Zheng, Z. Liu, J. Ye, J. Li, S. Xu, F. Xie, D. Ye, B. Li, *Green Chem.*, 2024, **26**, 2592–2598.
3. P. Leowanawat, N. Zhang, A.-M. Resmerita, B. M. Rosen, V. Percec, *J. Org. Chem.*, 2011, **76**, 9946–9955.
4. B. A. Tretyakov, S. Y. Gadomsky, A. A. Terentiev, *Organics*, 2023, **4**, 186–195.
5. G. Zhang, Z. Luo, C. Guan, X. Zhang, C. Ding, *J. Org. Chem.*, 2023, **88**, 9249–9256.
6. B. J. Jelier, P. F. Tripet, E. Pietrasiak, I. Franzoni, G. Jeschke, A. Togni, *Angew. Chem. Int. Ed.*, 2018, **57**, 13784–13789.
7. M. Bayat, J. M. Fox, *J. Heterocycl. Chem.*, 2016, **53**, 1661.
8. S. Puertas, F. Rebolledo, V. Gotor, *Tetrahedron*, 1995, **51**, 1495–1502.
9. P. Szcześniak, B. Furman, *Chem. Commun.*, 2022, **58**, 1898–1901.
10. A. M. Al-Azzawi, A. Sa'adi Hassan, *Int. J. Res. Pharm. Chem.*, 2014, **4**, 755–762.
11. F.; Campos, R.; Corrêa, M.; Souza, R.; Yunes, R.; Nunes, V. Cechinel-Filho, *Arzneimittelforschung*, 2011, **52**, 455–461.
12. B. Pal, P. K.; Pradhan, P. Jaisankar, V. S. Giri, *Synthesis (Stuttg)*. 2003, **10**, 1549–1552.
13. F. Zhang, X. Y. Wu, P. P. Gao, H. Z. Zhang, Li, S. Ai, G. Li, *Chem. Sci.*, 2024, **15**, 6178–6183.

[2.0]  $^1\text{H}$ ,  $^{13}\text{C}$  and  $^{19}\text{F}$  NMR of selected compounds

