Practical Catalytic Cleavage of C(sp³)–C(sp³) Bonds in Amines

Wu Li, Weiping Liu, David K. Leonard, Jabor Rabeah, Kathrin Junge, Angelika Brückner, and Matthias Beller*

anie_201903019_sm_misccellaneous_information.pdf
Supporting Information

Contents

1. General Remarks

2. General Procedure for Substrates Preparation (GR I)

3. General Procedure for Substrates Preparation (GR II)

4. General Procedure for the Oxidation Reaction (GR III)

5. General Procedure for the Oxidation Reaction (GR VI)

6. Catalytic Experiments

7. Mechanistic Studies

8. NMR Experiments for 7b and 37b

9. Characterization Data for the Substrates and Products

10. $^1$H NMR and $^{13}$C NMR and Spectra for Substrates and Products

11. References
1. General Remarks

Deuterated solvents were ordered from Deutero GmbH. NMR spectra were received using Bruker 300 Fourier, Bruker AV 300 and Bruker AV 400 spectrometers. Chemical shifts are reported in ppm relative to the deuterated solvent. Coupling constants are expressed in Hertz (Hz). The following abbreviations are used: s = singlet, d = doublet, t = triplet and m = multiplet. The residual solvent signals were used as references for $^1$H and $^{13}$C NMR spectra (CDCl$_3$: $\delta$H = 7.26 ppm, $\delta$C = 77.12 ppm; DMSO-$d_6$: $\delta$H = 2.50 ppm, $\delta$C = 39.52 ppm). All measurements were carried out at room temperature unless otherwise stated. Mass spectra were in general recorded on an AMD 402/3 or a HP 5989A mass selective detector. Gas chromatography was performed on a HP 7890A chromatography with a HP5 column. High resolution mass spectra (HRMS) were obtained either from a MAT 95 XP from Thermo (EI) or from an HPLC system 1200 and downstream ESI-TOF-MS 6210 from Agilent (ESI). Thin layer chromatography was performed on Merck TLC-plates with fluorescence indication (silica type 60, F$_{254}$), spots were visualized using UV-light or vaniline. Column chromatography was performed using silica with a grain size of 40–63 µm from Macherey-Nagel. Solvents were used directly without further purification. HPLC grade MeCN supplier is Fisher Chemical. Linezolid supplier is Gute Chemie–abcr Services. Substrates 23a, 24a, 33a, 35a, 37a, 38a, 40a, 41a, 42a, 44a, 45a, 46a, 47a, 48a, 49a, 50a, 51a, 52a, 53a, 57a, 58a, 59a, 68a were prepared following the method or modified method published by Ma and co-workers (Ma, D., et al. Org. Lett., 2003, 5, 2453–2455.) Other chemicals were obtained from commercial sources and were used without further purification. Unless otherwise mentioned, all catalytic reactions were carried out in 4 mL or 8 mL glass vials, which were set in an alloy plate and placed inside 300 mL autoclave (PARR Instrument Company).

EPR spectra were recorded on a Bruker EMX-micro cw-EPR spectrometer (X-band, $\nu \approx 9.7$ GHz) at different temperature with a microwave power of 6.9 mW, a modulation frequency of 100 kHz and modulation amplitude up to 5G. The EPR spectrometer is equipped with a variable temperature control unit including a liquid N$_2$ cryostat and a temperature controller. UV-Vis spectra were recorded on an AvaSpec-2048 UV-vis spectrometer (Avantes). To monitor the Cu$^{II}$ signal and detect radical intermediates might be formed upon the catalytic reaction, the reaction was stopped at different time intervals and 50 µL of the reaction mixture were transferred into a glass microcapillary tube (Hirschmann) to record immediately the EPR spectra at room temperature.
2. General Procedure for Substrates Preparation (GR I)

In a 8 mL vial fitted with magnetic stirring bar and septum cap, Pd/C (Palladium on activated charcoal 10% Pd basis (Sigma-Aldrich)) (40 mg) and ketones (2.0 mmol) were added. Then, a needle was inserted in the septum which allows gaseous reagents to enter. EtOH (3.0 mL) was added. The vials (up to seven) were set in an alloy plate and then placed into a 300 mL steel Parr autoclave. The autoclave was flushed with air 3 times at 5 bar and finally pressurized to the desired value (50 bar). Then it was placed into an aluminium block and heated to the desired temperature (130 °C) from room temperature. At the end of the reaction, the autoclave was quickly cooled down at room temperature with an ice bath and vented. Finally, the samples were removed from the autoclave, and diluted with acetone. The reaction mixture was analyzed by GC or as isolated product (column chromatography: n-heptane/ethyl acetate) by NMR, GC-MS and HRMS.
General Procedure for Substrates Preparation (GR I): A mixture of aryl bromide (10 mmol), morpholines (20 mmol), K$_2$CO$_3$ (20 mmol), Cul (1.0 mmol) and L-proline (2.0 mmol) in 10 mL of DMSO was heated at 90 °C and for 24 h. The cooled mixture was partitioned between water and ethyl acetate. The organic layer was separated, and the aqueous layer was extracted with ethyl acetate. The combined organic layers were dried over Na$_2$SO$_4$, and concentrated in vacuo. The desired products were isolated by silica gel column.
chromatography (n-heptane/ethyl acetate mixtures). (Ma, D., et al. Org. Lett., 2003, 5, 2453–2455.)
Substrates Preparation (20a and 72a)

To a 100 mL round bottom flask equipped with magnetic stir bar was added amine (8.0 mmol, 1 equiv.) and methanol (20 mL). Next, aldehyde (10.0 mmol, 1.25 equiv.) was added, followed by NaBH$_3$CN (10.0 mmol, 1.25 equiv.). After completion (monitored by TLC or GC-FID), the reaction was quenched with saturated NaHCO$_3$ (20 mL) and methanol was removed by evaporation under reduced pressure. The mixture was diluted with H$_2$O and extracted with ethyl acetate (50 mL x 3). The extracts were combined and washed with brine and dried over anhydrous Na$_2$SO$_4$ and filtered. Lastly, the solvent was removed by evaporation under reduced pressure.

Substrates Preparation (5a, 8a and 18a)

To a 100 mL round bottom flask equipped with magnetic stir bar was added dimethylformamide (20 mL), bromide (20.0 mmol, 1 equiv.) and amine (30.0 mmol, 2.0 equiv.). The reaction mixture was heated to 100 °C. After completion (monitored by TLC or GC-FID), the reaction mixture was filtered to remove K$_2$CO$_3$. The mixture was diluted with H$_2$O and extracted with ethyl acetate (50 mL x 3). The extracts were combined and washed with brine and dried over anhydrous Na$_2$SO$_4$ and then filtered. Lastly, solvent and amine was removed by evaporation under reduced pressure.
4. General Procedure for the Oxidation Reaction (GR III)

**General Procedure for the Oxidative Cleavage of Carbon–Carbon Single Bonds (GR III)**

In an 8 mL vial fitted with magnetic stirring bar and septum cap, CuCl (2.5 mg, 0.025 mmol) was added. Then, a needle was inserted in the septum which allows gaseous reagents to enter. MeCN (2.0 mL), pyridine (80 mg) and substrates (tertiary amine, 0.5 mmol) were added, independently. The vials (up to seven) were set in an alloy plate and then placed into a 300 mL steel Parr autoclave. The autoclave was flushed with air 2 times at 10 bar and finally pressurized to the desired value (30 bar). Then it was placed into an aluminium block and heated to the desired temperature (100 °C) from room temperature. At the end of the reaction, the autoclave was quickly cooled down at room temperature with an ice bath and vented. Finally, the samples were removed from the autoclave, and diluted with acetone. The reaction mixture was analyzed by GC or as isolated product (column chromatography: n-heptane/ethyl acetate) by NMR, GC-MS and HRMS.

5. General Procedure for the Oxidation Reaction (GR VI)

**General Procedure for the Oxidative Cleavage of Carbon–Carbon Single Bonds (GR II)**

In a 4 mL vial fitted with magnetic stirring bar and septum cap, Cu(CF$_3$SO$_3$)$_2$ (6.0 mg) and N-phenylmorpholine were added. Then, a needle was inserted in the septum which allows gaseous reagents to enter. MeCN (2.0 mL) and pyridine (8.0 mg) were added, independently. The vials (up to eight) were set in an alloy plate and then placed into a 300 mL steel Parr autoclave. The autoclave was flushed with air 2 times at 10 bar and finally pressurized to the desired value (20 bar). Then it was placed into an aluminium block and heated to the desired temperature (80 °C) from room temperature. At the end of the reaction,
the autoclave was quickly cooled down at room temperature with an ice bath and vented. Finally, the samples were removed from the autoclave, and diluted with acetone. The reaction mixture was analyzed by GC or as isolated product (column chromatography: chromatography: n-heptane/ethyl acetate) by NMR, GC-MS and HRMS.

6. Catalytic Experiments

Table S1. Conditions optimisation

| Entry | Catalyst (5 mol%) | Additive | Yield (%) |
|-------|------------------|----------|-----------|
| 1     | Pd(OAc)$_2$     | -        | 20        |
| 2     | RuCl$_3$        | -        | 11        |
| 3     | Ru(acac)$_3$    | -        | trace    |
| 4     | AgCF$_3$SO$_3$  | -        | trace    |
| 5     | Ag$_2$CO$_3$    | -        | 19        |
| 6     | Co(OAc)$_2$·4H$_2$O | -    | 20        |
| 7     | Cu(OAc)$_2$     | -        | 60        |
| 8     | CuCl            | -        | 74        |
| 9     | CuBr$_2$        | -        | 70        |
| 10    | CuBr            | -        | 70        |
| 11    | CuI             | -        | 72        |
| 12    | Cu(CF$_3$SO$_3$)$_2$ | - | 64        |
| 13    | Copper(II) Phthalocyanine | - | trace |
| 14    | CuCl            | L1       | 80        |
| 15    | CuCl            | L2       | 78        |
| 16    | CuCl            | L3       | 48        |
|   |   |   |   |
|---|---|---|---|
| 17 | CuCl | L4 | 0 |
| 18 | CuCl | L5 | 0 |
| 19 | CuCl | L6 | 44 |
| 20 | CuCl | L7 | 90 |
| 21 | CuCl | L8 | 38 |
| 22 | CuCl | L9 | 53 |
| 23 | CuCl | L10 | 67 |
| 24 | CuCl | L11 | 67 |
| 25 | CuCl | L12 | 72 |
| 26 | CuCl | L13 | 60 |
| 27 | CuCl | L14 | 33 |
| 28 | CuCl | L15 | trace |
| 29 | CuCl | L7 (20 mol%) | 74 |
| 30 | CuCl | L7 (40 mol%) | 80 |
| 31 | CuCl | L7 (1.0 eq.) | 84 |
| 32 | CuCl | L7 (2.0 eq.) | 72* |
| 33 | CuCl | L7 (2.0 eq.) | 74* |
| 34 | - | L7 (2.0 eq.) | trace |

Reaction conditions: Tri-n-butylamine 3a (0.5 mmol), catalyst (5 mol%) and additive (y mol%), 30 bar air, MeCN, 100 °C. *Yield determined by GC using n-dodecane as the standard. **20 bar air, 80 °C. *CuCl (3 mol%).

---

![Chemical structure](image)

---

Reaction conditions: Tri-n-butylamine 3a (0.5 mmol), catalyst (5 mol%) and additive (2.0 eq.), 30 bar air, MeCN (2.0 mL), 100 °C, 24 h.
As part of a program to develop new catalysts for the oxidation of amines, recently we investigated the reaction of tributylamine (3a, 0.5 mmol) with molecular oxygen in the presence of different potential metal catalysts (5 mol%). In general, the reactions of the benchmark substrate were performed in aerobic atmosphere (30 bar) at 100 °C using acetonitrile as solvent due to its stability against oxidation. Among the tested catalysts trace or only low activity was observed in the presence of Pd(OAc)$_2$, RuCl$_3$, Ru(acac)$_3$, AgCF$_3$SO$_3$, Ag$_2$CO$_3$, Co(OAc)$_2$:4H$_2$O (Table S1, entries 1-6). Surprisingly, using Cu(OAc)$_2$ N,N-dibutylformamide was obtained in 60% yield (Table S1, entry 7). Apparently, in this case a selective cleavage of the C-C bond took place. Consequently, other copper salts, such as CuCl, CuBr$_2$, CuBr, Cul, Cu(CF$_3$SO$_3$)$_2$ and copper(II) phthalocyanine were examined as the catalyst (Table S1, entries 8-13), and CuCl gave the highest yield. As nitrogen-containing additives are known to improve the efficiency of aerobic oxidation reactions, urea and acetamide were added to the model substrate using CuCl due to the stability (Table S1, entries 14 and 15). Notably, in the presence of urea, the product yield increased to 80% (Table S1, entry 14). Decreased yields or no desired C-C bond cleavage product was observed using DABCO (1,4-diazabicyclo[2.2.2]octane), TMEDA ($N^1,N^1,N^2,N^2$-tetramethylethane-1,2-diamine), L-phenylalanine and morpholine (Table S1, entries 6-19), which have been mostly relied on in aerobic oxidation reactions. To our delight, in the presence of pyridine, the product yield increased to 90% (Table S1, entry 20). More expensive pyridines with electron-rich as well as electron-poor substituents gave no improvement (Table S1 entries 21-26). From a mechanistic point it is interesting that the bidentate ligand 2,2'-bipyridine and 1,10-phenanthroline monohydrate (Table S1 entries 27 and 28) gave much lower yields of product. Decreased amounts of pyridine and catalyst loading as well as lower temperature lead to less N,N-dibutylformamide (Table S1 entries 29-32). Finally, the efficiency and selectivity of the reaction dramatically decreased in the absence of a copper catalyst (Table S1, entry 34). Notably, dehydrogenated product N,N-dibutylbut-1-en-1-amine was observed by GC-MS (Fig. S2 and Scheme S2). Interestingly, N,N-dibutylformamide formed and dehydrogenated intermediate disappeared while CuCl catalyst was added. This dehydrogenated product could be an intermediate of this C-C bond cleavage reaction.
Table S2. Catalytic Experiments: tri-n-butylamine

| Catalyst | Additive (200 mol%) | Temperature (°C) | Yield (%) |
|----------|---------------------|------------------|-----------|
| Cu₂O     | -                   | 80               | trace     |
|          | -                   | 120              | 42        |
|          | Pyridine            | 80               | trace     |
|          |                     | 100              | 34        |
| CuO      | -                   | 80               | trace     |
|          | -                   | 120              | 10        |
|          | Pyridine            | 80               | 0         |
|          |                     | 100              | trace     |

Reaction conditions: Tri-n-butylamine 3a (0.5 mmol), catalyst (5 mol%) and additive (y mol%), 30 bar air, MeCN, T °C. Yield determined by GC using n-dodecane as the standard.

Upscale reactions

- CuCl (5 mol%)
- Cu(CF₃SO₃)₂ (5 mol%)
- CuCl (5 mol%)
Control experiments.

Figure S1. Putative intermediate of C-C bond cleavage reaction.
Scheme S1. GC-MS spectra of control experiments.
Scheme S2. GC-MS spectra of 18b.
Table S3. Conditions optimisation
Selective cleavage C-C single bond of N-phenylmorpholine use different catalysts.

| Entry | Catalyst          | Ligand | Yield (%) |
|-------|-------------------|--------|-----------|
| 1     | CuCl              | pyridine | 63        |
| 2     | Cu(OAc)$_2$       | pyridine | 66        |
| 3     | CuBr$_2$          | pyridine | 43        |
| 4     | CuBr              | pyridine | 55        |
| 5     | Cu(CF$_3$SO$_3$)$_2$ | pyridine | 90        |
| 6     | CuI               | pyridine | 0         |

Reaction conditions: Substrates 21a (0.5 mmol), catalyst (3 mol%) and additive (20 mol%), 20 bar air, MeCN, 80 °C. *Yield determined by GC using $n$-dodecane as the standard.

When N-phenylmorpholine (0.5 mmol) was chosen as the benchmark substrate, only 63% 2-(N-phenylformamido)ethyl formate was obtained using CuCl (3 mol%) as the catalyst under milder conditions (20 bar air at 80 °C) (Table S3, entry 1). Consequently, other copper salts, such as Cu(OAc)$_2$, CuBr$_2$, CuBr, Cu(CF$_3$SO$_3$)$_2$ and CuI were examined as the catalyst (Table S3, entries 2-5). To our delight, using Cu(CF$_3$SO$_3$)$_2$ C-C bond cleavage product was obtained in 90% yield (Table S3, entry 5). Only trace amount of C-C bond cleavage product was detected when the reaction was performed under 1 atmosphere air or O$_2$ (eq. S1).
Table S4. Conditions comparison

![Chemical diagram]

| Catalyst | Additive (20 mol%) | Temperature (°C) | Yield (%) |
|----------|--------------------|------------------|-----------|
| Cu<sub>2</sub>O | Pyridine          | 80               | 52        |
|          |                   | 100              | 28        |
|          |                   | 120              | 48        |
| CuO      | Pyridine          | 80               | 33        |
|          |                   | 100              | 55        |
|          |                   | 120              | trace     |

Reaction conditions: Substrate 21a (0.5 mmol), catalyst (3 mol%) and additive (20 mol%), 20 bar air, MeCN, 80 °C. Yield determined by GC using n-dodecane as the standard.

Table S5. Substrates comparison

![Chemical diagram]

| Substrate | Catalyst | Additive (20 mol%) | Temperature (°C) | Yield (%) |
|-----------|----------|--------------------|------------------|-----------|
| 21a       | Cu<sub>2</sub>O | Pyridine          | 100              | trace     |
|           |          |                   | 120              | 0         |
| 21b       | CuO      | Pyridine          | 100              | trace     |
|           |          |                   | 120              | 0         |
|           | Cu<sub>2</sub>O | Pyridine          | 80               | 27        |
|           |          | Pyridine          | 100              | 32        |
| 21c       | Cu<sub>2</sub>O | Pyridine          | 80               | trace     |
|           |          |                   | 120              | 0         |
| 21d       | CuO      | Pyridine          | 80               | trace     |
|           |          |                   | 120              | 0         |

Reaction conditions: Substrates a (0.5 mmol), catalyst (3 mol%) and additive (20 mol%), 20 bar air, MeCN, T °C. Isolated yields.
1 Atmosphere air or O₂ experiment (eq. S1):

\[ \text{Cu(CF}_3\text{SO}_3)_2 \text{ (3 mol\%)} \]
\[ \text{Pyridine (20 mol\%)} \]
\[ \text{MeCN, 80 °C, 48 h} \]

(1) air balloon
(2) O₂ balloon

![Diagram of reaction](image)

Gram scale reaction (eq. S2):

\[ \text{Cu(CF}_3\text{SO}_3)_2 \text{ (3 mol\%)} \]
\[ \text{Pyridine (20 mol\%)} \]
\[ \text{MeCN, 80 °C, 48 h} \]

68% conversion

![Diagram of reaction](image)

7. Mechanistic Studies

Pyridine-\text{d}_5\text{ experiment (eq. S3)}:

\[ \text{Cu(CF}_3\text{SO}_3)_2 \text{ (3 mol\%)} \]
\[ \text{MeCN, 20 bar air} \]
\[ 80 °C, 24 h \]

Pyridine-\text{d}_5\text{ (20 mol\%)}

GC-MS: 193

Detected by GC-MS: 84

![Diagram of reaction](image)

Radical-trapping Experiments and GC-MS Results

In a 4 mL vial fitted with magnetic stirring bar and septum cap, Cu(CF₃SO₃)₂ (6.0 mg), 4-phenylmorpholine, TEMPO (or BHT) were added. Then, a needle was inserted in the septum which allows gaseous reagents to enter. Solvent MeCN (2.0 mL) and pyridine (8.0 mg) were added, independently. The vial (up to eight) was set in an alloy plate and then placed into a
300 mL steel Parr autoclave. The autoclave was flushed with air 2 times at 10 bar and finally pressurized to the desired value (20 bar). Then it was placed into an aluminium block and heated to the desired temperature (80 °C) from room temperature. At the end of the reaction, the autoclave was quickly cooled down at room temperature with an ice bath and vented. Finally, the sample was removed from the autoclave, and diluted with acetone. \( \text{n-Dodecane} \) 90 mg was added for GC and GC-MS measurement (eq. S6).

![Scheme S3. GC-MS spectra of radical-trapping experiment.](image)

**Scheme S3. GC-MS spectra of radical-trapping experiment.**

**Stoichiometric amounts of Cu(OTf)₂ (eq. S8)**

![Scheme S4. Stoichiometric amounts of Cu(OTf)₂.](image)
Figure S2. Kinetic data of the C-C bonds cleavage reaction

\[\text{Yield of } 21\text{b} (\%)\]

**EPR and UV-Vis Investigation**

To get deeper insight into the catalytic process, the interaction of the different components in the reaction mixture was investigated in a consecutive manner by EPR and UV-vis spectroscopy. A solution of 0.016 mmol Cu(OTf)\(_2\) in 2.0 mL acetonitrile shows an EPR signal at \(g = 2.165\) with a poorly resolved hyperfine structure (hfs) (Figure S3) arising from the coupling of the unpaired electron of Cu\(^{\text{II}}\) with its nuclear spin \((d^9, S = 1/2, I = 3/2)\). The reason for unresolved hfs is due to the fast exchange between the CH\(_3\)CN and Cu-coordinated solvent molecules\(^2\). Upon addition of pyridine, the four hfs lines become more resolved at \(g_{\text{iso}} = 2.123\) with a coupling constant of \(A = 80\) G, indicating that the pyridine ligand is coordinated to the Cu\(^{\text{II}}\) site. However, addition of N-phenylmorpholine (21a) to Cu(OTf)\(_2\) at 20 °C and ambient pressure caused a quick vanish of the Cu\(^{\text{II}}\) signal and a rise of a temporary radical signal with unresolved hfs at \(g = 2.004\) which disappeared within less than one minute, pointing to its high reactivity. We attribute these changes to the reduction of Cu\(^{\text{II}}\) by 21a to Cu\(^{\text{I}}\) which is accompanied by the formation of an EPR-active radical intermediate.
(Figure S3e). Samples taken from the catalytic reactor after 30 and 80 min (Figure S3c and d) showed only a very weak Cu\textsuperscript{II} signal, indicating that oxidation of Cu\textsuperscript{I} by O\textsubscript{2} under these conditions is very slow in comparison to fast reduction of Cu\textsuperscript{II} by 21a.

The in situ-UV-vis spectrum of Cu(OTf)\textsubscript{2} in CH\textsubscript{3}CN shows bands below 300 nm and around 750 nm arising from a ligand-to-metal charge transfer (LMCT) and a d-d transition of Cu\textsuperscript{II}. When pyridine is added, the LMCT band increases and the d-d band shifts to lower wavelength (565 nm), indicating the coordination of pyridine to Cu\textsuperscript{II}, yet without any change of its divalent valence state as evident, too, from the EPR spectrum in Figure S3. When 21a is added to Cu(OTf)\textsubscript{2} in CH\textsubscript{3}CN without pyridine, the LMCT and d-d bands of Cu\textsuperscript{II} disappear and new metal-to-ligand (MLCT) bands of Cu\textsuperscript{I} appear around 320 and 466 nm (Figure S4c), indicating fast reduction of Cu\textsuperscript{II} to Cu\textsuperscript{I}, in agreement with EPR results. Subsequent addition of pyridine to this solution changes the spectrum only slightly, probably due to coordination of pyridine to Cu\textsuperscript{I} (Figure S4d).

Figure S3. EPR spectra of a) Cu(OTf)\textsubscript{2}; b) Cu(OTf)\textsubscript{2} + pyridine; and after catalytic test under standard conditions for c) 30 min; d) 180 min; e) Cu(OTf)\textsubscript{2} + 21a; recorded at 20 °C.
The EPR and UV-vis experiments in the above were conducted under argon atmosphere. We did some in situ EPR investigation with a frozen solution under Ar, too. Firstly, we measured EPR spectra of \( \text{Cu(OTf)}_2 \) in MeCN at 200 K, then we added \( N \)-phenylmorpholine at 293 K to Cu(II) solution and frozen again rapidly. The drop of the Cu(II) signal was attributed to its reduction to Cu(I). Heating the sample at 293 for different periods decreased the Cu(II) signal again (see below) suggesting that reaction of \( N \)-phenylmorpholine with Cu(II) is very fast. Additionally, we conducted some EPR investigations at 90 K, which did not provide any evidence for the formation of Cu(II) antiferromagnetic species. Such dimer, if they formed, should have a d-d transition band in the Vis region (see for example, Solomon, E. I.; Sundaram, U. M.; Machonkin, T. E., Multicopper Oxidases and Oxygenases. *Chem. Rev.* 1996, 96, 2563-2605 and Mirica, L. M.; Ottenwaelder, X.; Stack, T. D. P., Structure and Spectroscopy of Copper-Dioxygen Complexes. *Chem. Rev.* 2004, 104, 1013-1045.) Of course, we aware that solvents with a high dielectric constant will lower signal sensitivity or eliminate the signals completely when conducted at room temperature. Therefore, all the EPR investigations at RT were conducted using EPR capillary tubes (ID 0.5 mm) to prevent absorption of the microwave energy by the solvents. Clearly, the lack of the EPR signal seen in some of the EPR spectra cannot be due to this effect.
Scheme S4. The formation of α-amino radical was detected by LC-MS

When 2 equivalents of TEMPO (2,2,6,6-Tetramethyl-1-piperidinyloxy) was added into the reaction system, the reaction was totally shut down, along with the dehydrogenation product 4-phenyl-3,4-dihydro-2H-1,4-oxazine detected by GC-MS. A colorless liquid mixture was isolated by silica gel column chromatography.
8. NMR Experiments for 7b and 37b.

Original spectra for 7b:
Original spectra for 7b (The CDCl₃ was filtered through K₂CO₃.)
Those peaks marked in the spectra are from the same product. When we increased the temperature for \textbf{37b} during NMR experiment, the lower peaks disappeared regularly. As you can see, in the spectra in DMSO-d$_6$, two lower peaks at chemical shift 8.2 and 8.4 are disappeared regularly. The lower peak at 8.4 is from formamide which coalesces to peak at 8.5. And the peak at about 8.2 is from formate which coalesces to peak at 8.1.
9. Characterization Data for the Substrates and Products

3-(Dibutylamino)propanenitrile (5a)

\[
\begin{align*}
&\text{Me} & & \text{N} & & \text{NC} \\
& & & \text{Me} & & \\
\end{align*}
\]

$^1$H NMR (300 MHz, CDCl$_3$) $\delta$ (ppm) 2.85–2.69 (m, 2H), 2.51–2.30 (m, 6H), 1.54–1.22 (m, 9H), 0.91 (t, $J = 7.1$ Hz, 6H).

$^{13}$C NMR (75 MHz, CDCl$_3$) $\delta$ (ppm) 119.34, 53.69, 49.73, 29.63, 20.63, 16.29, 14.17.

$N,N$-Dibutyldecan-1-amine (6a)

\[
\begin{align*}
&\text{Me} & & \text{N} & & \text{C}_{10}\text{H}_{21} \\
& & & \text{Me} & & \\
\end{align*}
\]

$^1$H NMR (400 MHz, CDCl$_3$) $\delta$ (ppm) 2.46–2.33 (m, 6H), 1.48–1.35 (m, 6H), 1.33–1.21 (m, 18H), 0.96–0.82 (m, 9H).

$^{13}$C NMR (101 MHz, CDCl$_3$) $\delta$ (ppm) 54.36, 54.05, 32.06, 29.82, 29.79, 29.77, 29.69, 29.49, 29.25, 27.81, 27.07, 22.84, 20.96, 14.26.

2-Methoxy-$N$-(2-methoxyethyl)-$N$-phenethylethan-1-amine (8a)

\[
\begin{align*}
&\text{OMe} & & \text{N} & & \text{OMe} \\
& & & \text{Me} & & \\
\end{align*}
\]

$^1$H NMR (400 MHz, CDCl$_3$) $\delta$ (ppm) 7.28–7.17 (m, 2H), 7.15–7.08 (m, 3H), 3.42 (t, $J = 6.0$ Hz, 4H), 3.28 (s, 6H), 2.73 (t, $J = 6.0$ Hz, 8H).

$^{13}$C NMR (101 MHz, CDCl$_3$) $\delta$ (ppm) 140.58, 128.85, 128.44, 126.02, 71.21, 58.98, 57.38, 53.97, 33.41.
$N,N$-Bis(2-methoxyethyl)cyclohexanamine (9a)

$N,N$-Bis(2-methoxyethyl)cycloheptanamine (10a)

$N$-Butyl-$N$-(3-methylbutan-2-yl)butan-1-amine (11a)

$\text{H NMR (300 MHz, CDCl}_3\text{)} \delta (\text{ppm}) 3.34 (s, 10H), 2.71 (s, 4H), 2.45 (s, 1H), 1.77 (d, $J$ = 9.0 Hz, 4H), 1.61 (d, $J$ = 12.2 Hz, 1H), 1.17 (d, $J$ = 10.0 Hz, 5H).

$\text{H NMR (300 MHz, CDCl}_3\text{)} \delta (\text{ppm}) 3.40 (t, J = 6.5 Hz, 4H), 3.34 (s, 6H), 2.74–2.55 (m, 5H), 1.82 (s, 2H), 1.66 (dd, $J$ = 6.9, 4.1 Hz, 2H), 1.55–1.35 (m, 8H).

$\text{H NMR (300 MHz, CDCl}_3\text{)} \delta (\text{ppm}) 2.75–2.70 (m, 1H), 2.51–2.34 (m, 4H), 1.70–1.57 (m, 1H), 1.42–1.28 (m, 8H), 1.00–0.93 (m, 3H), 0.90 (td, $J$ = 7.3, 3.3 Hz, 12H).

$\text{H NMR (300 MHz, CDCl}_3\text{)} \delta (\text{ppm}) 2.75–2.70 (m, 1H), 2.51–2.34 (m, 4H), 1.70–1.57 (m, 1H), 1.42–1.28 (m, 8H), 1.00–0.93 (m, 3H), 0.90 (td, $J$ = 7.3, 3.3 Hz, 12H).

$\text{HR-MS (ESI) m/z calcd for } [\text{C}_{12}\text{H}_{26}\text{N}_{0}^{+}]^{+} ([\text{M+H}]^{+}): 216.1958$, found: 216.1966.

$\text{HR-MS (ESI) m/z calcd for } [\text{C}_{13}\text{H}_{30}\text{N}^{+}]^{+} ([\text{M+H}]^{+}): 230.2115$, found: 230.2123.

$\text{HR-MS (ESI) m/z calcd for } [\text{C}_{13}\text{H}_{30}\text{N}^{+}]^{+} ([\text{M+H}]^{+}): 200.2373$, found: 200.2380.
**N,N-Dibutyl-4-methylpentan-2-amine (12a)**

![Chemical structure of N,N-Dibutyl-4-methylpentan-2-amine (12a)](image)

$^1$H NMR (400 MHz, CDCl$_3$) $\delta$ (ppm) 2.68–2.64 (m, 1H), 2.48–2.20 (m, 4H), 1.56 (dddd, $J = 7.7, 6.7, 2.5, 0.9$ Hz, 1H), 1.42–1.23 (m, 10H), 0.91–0.84 (m, 15H).

$^{13}$C NMR (101 MHz, CDCl$_3$) $\delta$ (ppm) 52.66, 49.90, 49.47, 35.85, 31.41, 25.04, 23.25, 20.81, 14.27.

**HR-MS (ESI)** m/z calcd for [C$_{14}$H$_{32}$N]$^+$ ([M+H]$^+$): 214.2529, found: 214.2531.

**N,N-Dibutylheptan-2-amine (13a)**

![Chemical structure of N,N-Dibutylheptan-2-amine (13a)](image)

$^1$H NMR (400 MHz, CDCl$_3$) $\delta$ (ppm) 2.73–2.66 (m, 1H), 2.50–2.28 (m, 4H), 1.48–1.38 (m, 4H), 1.37–1.18 (m, 12H), 0.95–0.85 (m, 12H).

$^{13}$C NMR (101 MHz, CDCl$_3$) $\delta$ (ppm) 55.47, 50.03, 32.17, 30.96, 26.90, 22.82, 20.81, 20.55, 14.22, 14.15, 14.01.

**HR-MS (ESI)** m/z calcd for [C$_{15}$H$_{34}$N]$^+$ ([M+H]$^+$): 228.2686, found: 228.2691.

**N-Butyl-N-(1-cyclobutylethyl)butan-1-amine (14a)**

![Chemical structure of N-Butyl-N-(1-cyclobutylethyl)butan-1-amine (14a)](image)

$^1$H NMR (400 MHz, CDCl$_3$) $\delta$ (ppm) 2.67–2.52 (m, 1H), 2.46–2.15 (m, 5H), 1.99–1.88 (m, 2H), 1.85–1.48 (m, 4H), 1.46–1.13 (m, 8H), 0.97–0.84 (m, 6H), 0.77 (d, $J = 6.5$ Hz, 3H).

$^{13}$C NMR (101 MHz, CDCl$_3$) $\delta$ (ppm) 60.96, 50.18, 39.80, 31.50, 27.67, 27.00, 20.72, 18.17, 14.28, 9.76.

**HR-MS (ESI)** m/z calcd for [C$_{14}$H$_{30}$N]$^+$ ([M+H]$^+$): 212.2373, found: 212.2377.
**N,N-Dibutylcyclohexanamine (15a)**

![Structure of N,N-Dibutylcyclohexanamine (15a)](image)

$^1$H NMR (400 MHz, CDCl$_3$) δ (ppm) 2.43 (t, $J = 7.6$ Hz, 5H), 1.87–1.69 (m, 4H), 1.40 (td, $J = 8.4$, 4.1 Hz, 4H), 1.35–1.25 (m, 4H), 1.25–1.14 (m, 4H), 0.90 (t, $J = 7.3$ Hz, 6H).

$^{13}$C NMR (101 MHz, CDCl$_3$) δ (ppm) 60.33, 50.61, 31.39, 29.18, 26.62, 26.42, 20.89, 14.28.

**N,N-Dibutylcycloheptanamine (16a)**

![Structure of N,N-Dibutylcycloheptanamine (16a)](image)

$^1$H NMR (300 MHz, CDCl$_3$) δ (ppm) 2.66 (s, 1H), 2.36 (t, $J = 7.4$ Hz, 4H), 1.85–1.60 (m, 4H), 1.57–1.22 (m, 16H), 0.90 (t, $J = 7.2$ Hz, 6H).

$^{13}$C NMR (75 MHz, CDCl$_3$) δ (ppm) 61.55, 50.78, 31.73, 30.33, 28.11, 26.30, 20.93, 14.30.

HR-MS (ESI) m/z calcd for [C$_{15}$H$_{32}$N]$^+$ ([M+H]$^+$): 226.2529, found: 226.2532.

**N,N-Dibutylcyclooctanamine (17a)**

![Structure of N,N-Dibutylcyclooctanamine (17a)](image)

$^1$H NMR (300 MHz, CDCl$_3$) δ (ppm) 2.76 (s, 1H), 2.33 (dd, $J = 8.5$, 6.3 Hz, 4H), 1.75–1.22 (m, 22H), 0.90 (t, $J = 7.2$ Hz, 6H).

$^{13}$C NMR (75 MHz, CDCl$_3$) δ (ppm) 59.63, 50.78, 31.75, 30.18, 28.60, 26.75, 26.14, 20.93, 14.30.

HR-MS (ESI) m/z calcd for [C$_{16}$H$_{34}$N]$^+$ ([M+H]$^+$): 240.2686, found: 240.2687.
**N-Butyl-N-phenethylbutan-1-amine (18a)**

\[
\text{Me} \quad \text{N} \quad \text{Me} \\
\begin{array}{c}
\text{Ph} \\
\end{array}
\]

\(^1\)H NMR (400 MHz, CDCl\(_3\)) \(\delta\) (ppm) 7.38–7.26 (m, 2H), 7.25–7.18 (m, 3H), 2.85–2.67 (m, 4H), 2.58–2.44 (m, 4H), 1.55–1.42 (m, 4H), 1.39–1.27 (m, 4H), 0.95 (t, \(J = 7.3\) Hz, 6H).

\(^{13}\)C NMR (101 MHz, CDCl\(_3\)) \(\delta\) (ppm) 141.04, 128.85, 128.44, 125.97, 56.28, 53.97, 33.59, 29.45, 20.92, 14.27.

**N-Butyl-N-(1-phenylpropan-2-yl)butan-1-amine (19a)**

\[
\text{Me} \quad \text{N} \quad \text{Me} \\
\begin{array}{c}
\text{Ph} \\
\end{array}
\]

\(^1\)H NMR (400 MHz, CDCl\(_3\)) \(\delta\) (ppm) 7.35–7.15 (m, 2H), 7.09 (td, \(J = 6.6, 1.7\) Hz, 3H), 3.02–2.75 (m, 2H), 2.49–2.14 (m, 5H), 1.33 (ddt, \(J = 13.8, 8.8, 4.3\) Hz, 4H), 1.27–1.17 (m, 4H), 0.96–0.70 (m, 9H).

\(^{13}\)C NMR (101 MHz, CDCl\(_3\)) \(\delta\) (ppm) 141.35, 129.38, 128.25, 125.74, 57.61, 50.17, 39.67, 31.55, 20.81, 14.77, 14.30.

**HR-MS (ESI)** m/z calcd for [C\(_{17}\)H\(_{30}\)N]\(^+\) ([M+H]\(^+\)): 348.2373, found: 348.2380.

**N,N-Dibutylaniline (20a)**

\[
\begin{array}{c}
\text{Me} \\
\text{N} \\
\text{Me} \\
\end{array}
\begin{array}{c}
\text{Ph} \\
\end{array}
\]

\(^1\)H NMR (400 MHz, CDCl\(_3\)) \(\delta\) (ppm) 7.25–7.16 (m, 2H), 6.73–6.49 (m, 3H), 3.35–3.13 (m, 4H), 1.63–1.52 (m, 4H), 1.36 (dq, \(J = 14.7, 7.4\) Hz, 4H), 0.96 (t, \(J = 7.3\) Hz, 6H).

\(^{13}\)C NMR (101 MHz, CDCl\(_3\)) \(\delta\) (ppm) 148.31, 129.31, 115.17, 111.80, 50.91, 29.55, 20.52, 14.18.
4-(4-Methoxyphenyl)morpholine (23a)

![Chemical Structure]

$^1$H NMR (300 MHz, CDCl$_3$): δ (ppm) 6.99–6.71 (m, 4H), 3.91–3.82 (m, 4H), 3.77 (s, 3H), 3.11–2.99 (m, 4H).

$^{13}$C NMR (75 MHz, CDCl$_3$): δ (ppm) 154.20, 145.57, 118.02, 114.64, 67.12, 55.70, 51.03.

4-(4-Fluorophenyl)morpholine (24a)

![Chemical Structure]

$^1$H NMR (300 MHz, CDCl$_3$): δ (ppm) 7.05–6.91 (m, 2H), 6.91–6.76 (m, 2H), 3.90–3.74 (m, 4H), 3.14–2.99 (m, 4H).

$^{13}$C NMR (75 MHz, CDCl$_3$): δ (ppm) 157.32 (d, $J = 239.0$ Hz), 147.94 (d, $J = 2.3$ Hz), 117.49 (d, $J = 7.6$ Hz), 115.63 (d, $J = 22.0$ Hz), 66.93, 50.34.

$^{19}$F-NMR (282 MHz, CDCl$_3$): δ (ppm) 124.18.

N-(4-Morpholinophenyl)acetamide (33a)

![Chemical Structure]

$^1$H NMR (300 MHz, DMSO-$d_6$): δ (ppm) 9.71 (s, 1H), 7.44 (d, $J = 9.0$ Hz, 2H), 6.86 (d, $J = 9.0$ Hz, 2H), 3.82–3.61 (m, 4H), 3.12–2.91 (m, 4H), 2.00 (s, 3H).

$^{13}$C NMR (75 MHz, DMSO-$d_6$): δ (ppm) 167.61, 147.03, 131.75, 120.12, 115.44, 66.14, 49.00, 23.82.

4-(3-Chlorophenyl)morpholine (35a)

![Chemical Structure]


\textsuperscript{1}H NMR (300 MHz, CDCl\textsubscript{3}): $\delta$ (ppm) 7.22–7.11 (m, 1H), 6.91–6.70 (m, 3H), 3.90–3.77 (m, 4H), 3.24–3.07 (m, 4H).

\textsuperscript{13}C NMR (75 MHz, CDCl\textsubscript{3}): $\delta$ (ppm) 152.41, 135.10, 130.17, 119.74, 115.56, 113.66, 66.80, 48.93.

3-Morpholinobenzonitrile (37a)

\begin{center}
\textsuperscript{1}H NMR (300 MHz, CDCl\textsubscript{3}): $\delta$ (ppm) 7.33 (dd, $J = 9.2, 7.4$ Hz, 1H), 7.17–7.03 (m, 3H), 3.94–3.74 (m, 4H), 3.26–3.09 (m, 4H).

\textsuperscript{13}C NMR (75 MHz, CDCl\textsubscript{3}): $\delta$ (ppm) 151.41, 130.05, 123.02, 119.70, 119.35, 118.23, 113.12, 66.67, 48.52.
\end{center}

1-(3-Morpholinophenyl)ethan-1-one (38a)

\begin{center}
\textsuperscript{1}H NMR (400 MHz, CDCl\textsubscript{3}): $\delta$ (ppm) 7.48–7.45 (m, 1H), 7.40 (ddd, $J = 7.6, 1.6, 1.0$ Hz, 1H), 7.31 (ddd, $J = 8.1, 7.6, 0.5$ Hz, 1H), 7.07 (ddd, $J = 8.2, 2.7, 1.0$ Hz, 1H), 3.86–3.75 (m, 4H), 3.23–3.10 (m, 4H), 2.54 (s, 3H).

\textsuperscript{13}C NMR (101 MHz, CDCl\textsubscript{3}): $\delta$ (ppm) 198.31, 151.41, 137.93, 129.27, 120.19 (d, $J = 1.3$ Hz), 114.32, 66.71, 48.97, 26.71.
\end{center}

4-(o-Tolyl)morpholine (40a)

\begin{center}
\textsuperscript{1}H NMR (300 MHz, CDCl\textsubscript{3}): $\delta$ (ppm) 7.19 (m, 2H), 7.07–6.90 (m, 2H), 3.90–3.79 (m, 4H), 3.02–2.83 (m, 4H), 2.33 (s, 3H).

\textsuperscript{13}C NMR (75 MHz, CDCl\textsubscript{3}): $\delta$ (ppm) 151.38, 132.76, 131.31, 126.79, 123.55, 119.08, 67.59, 52.39, 18.02.
\end{center}
4-(2-Methoxyphenyl)morpholine (41a)

\[
\text{O} \quad \text{N} \quad \text{O} \quad \text{OMe}
\]

\[^1\text{H NMR (300 MHz, CDCl}_3\):} \; \delta \text{ (ppm)} \; 7.08–6.77 \text{ (m, 4H), 3.87 (m, 7H), 3.08 (t, } J = 4.6 \text{ Hz, 4H).}
\]
\[^{13}\text{C NMR (75 MHz, CDCl}_3\):} \; \delta \text{ (ppm)} \; 152.37, 123.32, 121.18, 118.16, 111.44, 67.30, 55.50, 51.31.

4-(2-Chlorophenyl)morpholine (42a)

\[
\text{Cl} \quad \text{N} \quad \text{O}
\]

\[^1\text{H NMR (400 MHz, CDCl}_3\):} \; \delta \text{ (ppm)} \; 7.37 \text{ (dd, } J = 7.9, 1.5 \text{ Hz, 1H),} \; 7.26–7.21 \text{ (m, 1H),} \; 7.12–7.03 \text{ (m, 1H),} \; 7.00 \text{ (ddd, } J = 7.9, 7.3, 1.6 \text{ Hz, 1H),} \; 3.94–3.80 \text{ (m, 4H),} \; 3.14–2.99 \text{ (m, 4H).}
\]
\[^{13}\text{C NMR (101 MHz, CDCl}_3\):} \; \delta \text{ (ppm)} \; 148.98, 130.92, 128.89, 127.82, 124.19, 120.50, 67.26, 51.82.

4-(3,4-Dimethylphenyl)morpholine (44a)

\[
\text{Me} \quad \text{N} \quad \text{O} \quad \text{Me}
\]

\[^1\text{H NMR (300 MHz, CDCl}_3\):} \; \delta \text{ (ppm)} \; 7.12–7.00 \text{ (m, 1H),} \; 6.81–6.74 \text{ (m, 1H),} \; 6.71 \text{ (dd, } J = 8.2, 2.7 \text{ Hz, 1H),} \; 3.98–3.83 \text{ (m, 4H),} \; 3.22–3.06 \text{ (m, 4H),} \; 2.31–2.26 \text{ (s, 3H),} \; 2.25–2.19 \text{ (s, 3H).}
\]
\[^{13}\text{C NMR (75 MHz, CDCl}_3\):} \; \delta \text{ (ppm)} \; 149.70, 137.27, 130.31, 128.43, 117.76, 113.53, 67.10, 50.08, 20.32, 18.88.

4-(3,5-Dimethylphenyl)morpholine (45a)

\[
\text{Me} \quad \text{N} \quad \text{O} \quad \text{Me}
\]
1H NMR (400 MHz, CDCl₃): δ (ppm) 6.60 (s, 3H), 4.00–3.77 (m, 4H), 3.31–3.06 (m, 4H), 2.33 (s, 6H).

13C NMR (101 MHz, CDCl₃): δ (ppm) 151.49, 138.75, 122.08, 113.79, 67.06, 49.64, 21.73.

4-(3,5-Dichlorophenyl)morpholine (46a)

1H NMR (300 MHz, CDCl₃): δ (ppm) 6.82 (t, J = 1.7 Hz, 1H), 6.73 (d, J = 1.8 Hz, 2H), 3.90–3.73 (m, 4H), 3.21–3.03 (m, 4H).

13C NMR (75 MHz, CDCl₃): δ (ppm) 152.74, 135.59, 119.32, 113.62, 66.61, 48.46.

HR-MS (EI) m/z calcd for [C₁₀H₁₁NOF₂⁺][M⁺]: 199.0803, found: 199.0801.

19F NMR (282 MHz, CDCl₃) δ (ppm) -125.98–-139.29 (m), -142.50–-153.86 (m).

4-(3,4-Difluorophenyl)morpholine (47a)

1H NMR (300 MHz, CDCl₃): δ (ppm) 7.08–7.01 (m, 1H), 6.72–6.65 (m, 1H), 6.60–6.54 (m, 1H), 3.87–3.78 (m, 4H), 3.11–3.01 (m, 4H).

13C NMR (75 MHz, CDCl₃): δ (ppm) 152.27 (d, J = 13.3 Hz), 149.02 (d, J = 13.3 Hz), 148.51 (dd, J = 7.5, 2.4 Hz), 146.06 (d, J = 12.9 Hz), 142.88 (d, J = 13.0 Hz), 117.33 (dd, J = 17.7, 1.8 Hz), 111.15 (dd, J = 5.6, 3.1 Hz), 105.01 (d, J = 20.3 Hz), 66.77, 49.65.

4-(4-Chloro-2-fluorophenyl)morpholine (48a)

1H NMR (400 MHz, CDCl₃): δ (ppm) 7.14–6.99 (m, 2H), 6.90–6.75 (m, 1H), 3.96–3.76 (m, 4H), 3.10–2.95 (m, 4H).
$^{13}$C NMR (101 MHz, CDCl$_3$): $\delta$ (ppm) 155.45 (d, $J = 249.8$ Hz), 138.92 (d, $J = 8.4$ Hz), 127.21 (d, $J = 10.0$ Hz), 124.69 (d, $J = 3.6$ Hz), 119.48 (d, $J = 3.8$ Hz), 117.08 (d, $J = 24.3$ Hz), 67.02, 50.98 (d, $J = 3.3$ Hz).

$^{19}$F NMR (282 MHz, CDCl$_3$) $\delta$ (ppm) 120.00.

HR-MS (EI) m/z calcd for [C$_{10}$H$_{11}$NOClF$^+$] $[M^+]$: 215.0508, found: 215.0504.

4-(Naphthalen-1-yl)morpholine (49a)

$^1$H NMR (300 MHz, CDCl$_3$): $\delta$ (ppm) 8.33–8.05 (m, 1H), 7.90–7.73 (m, 1H), 7.58 (dt, $J = 8.6$, 1.0 Hz, 1H), 7.54–7.32 (m, 3H), 7.18–6.97 (m, 1H), 4.06–3.89 (m, 4H), 3.20–2.96 (m, 4H).

$^{13}$C NMR (75 MHz, CDCl$_3$): $\delta$ (ppm) 134.93, 128.61, 126.05, 125.98, 124.01, 123.52, 114.84, 67.60, 53.65.

4-(6-Methoxynaphthalen-2-yl)morpholine (50a)

$^1$H NMR (400 MHz, CDCl$_3$): $\delta$ (ppm) 7.73–7.59 (m, 2H), 7.32–7.22 (m, 1H), 7.20–7.07 (m, 3H), 4.01–3.88 (m, 7H), 3.33–3.14 (m, 4H).

$^{13}$C NMR (101 MHz, CDCl$_3$): $\delta$ (ppm) 156.30, 147.70, 129.86, 129.69, 128.41, 127.75, 119.75, 119.01, 110.82, 105.90, 67.08, 55.38, 50.33.

4-(Pyridin-2-yl)morpholine (51a)

$^1$H NMR (400 MHz, CDCl$_3$): $\delta$ (ppm) 8.19 (ddd, $J = 5.0$, 2.0, 0.9 Hz, 1H), 7.49 (ddd, $J = 8.6$, 7.2, 2.0 Hz, 1H), 6.73–6.51 (m, 2H), 3.92–3.70 (m, 4H), 3.54–3.41 (m, 4H).

$^{13}$C NMR (101 MHz, CDCl$_3$): $\delta$ (ppm) 159.65, 147.98, 147.70, 129.86, 129.69, 128.41, 127.75, 119.75, 119.01, 110.82, 105.90, 67.08, 55.38, 50.33.

HR-MS (ESI): m/z calculated for [C$_9$H$_{13}$N$_2$O$^+$] $[(M+H)^+]$: 165.1022, found: 165.1023.
4-(9-Phenyl-9H-carbazol-3-yl)morpholine (52a)

\[
\begin{align*}
\text{1H NMR (400 MHz, CDCl}_3\text{): } & \delta \text{ (ppm) 8.02 (dt, } J = 7.8, 1.0 \text{ Hz, 1H), 7.66–7.58 (m, 1H), 7.54–7.43 \text{ (m, 4H), 7.40–7.24 (m, 4H), 7.21–7.14 (m, 1H), 7.07 (dd, } J = 9.0, 2.4 \text{ Hz, 1H), 4.01–3.74 (m, 4H), 3.26–3.08 \text{ (m, 4H).} \\
\text{13C NMR (101 MHz, CDCl}_3\text{): } & \delta \text{ (ppm) 141.37, 138.00, 136.52, 129.95, 127.32, 127.00, 126.04, 123.95, 123.40, 120.30, 119.75, 117.94, 110.51, 109.96, 107.92, 67.25, 52.07.} \\
\text{HR-MS (ESI): m/z calculated for } [\text{C}_{22}\text{H}_{21}\text{N}_2\text{O}]^+ ([M+H]^+) : 329.1648, \text{ found: 329.1648.}
\end{align*}
\]

4-(Dibenzo[b,d]furan-2-yl)morpholine (53a)

\[
\begin{align*}
\text{1H NMR (400 MHz, CDCl}_3\text{): } & \delta \text{ (ppm) 7.83 (ddd, } J = 7.7, 1.4, 0.7 \text{ Hz, 1H), 7.46 (dt, } J = 8.3, 0.9 \text{ Hz, 1H), 7.43–7.32 \text{ (m, 3H), 7.29–7.20 (m, 1H), 7.04 (dd, } J = 9.0, 2.5 \text{ Hz, 1H), 4.07–3.73 (m, 4H), 3.28–3.01 \text{ (m, 4H).} \\
\text{13C NMR (101 MHz, CDCl}_3\text{): } & \delta \text{ (ppm) 156.92, 151.44, 127.18, 124.80, 124.57, 122.57, 120.60, 117.98, 112.06, 111.84, 107.92, 67.18, 51.51.} \\
\text{HR-MS (ESI): m/z calculated for } [\text{C}_{16}\text{H}_{16}\text{NO}_2]^+ ([M+H]^+) : 254.1176, \text{ found: 254.1176.}
\end{align*}
\]

4-Decylmorpholine (56a)

\[
\begin{align*}
\text{1H NMR (300 MHz, CDCl}_3\text{): } & \delta \text{ (ppm) 3.79–3.62 (m, 4H), 2.42 (dd, } J = 5.7, 3.7 \text{ Hz, 4H), 2.36–2.24 \text{ (m, 2H), 1.56–1.39 (m, 2H), 1.26 (q, } J = 3.1 \text{ Hz, 14H), 0.92–0.78 \text{ (m, 3H).} \\
\text{13C NMR (75 MHz, CDCl}_3\text{): } & \delta \text{ (ppm) 67.12, 59.40, 53.93, 32.03, 29.71, 29.46, 27.67, 26.69, 22.82, 14.25.}
\end{align*}
\]
(R)-3-Methyl-4-phenylmorpholine (57a)

![Chemical structure](image)

$^1$H NMR (400 MHz, CDCl$_3$) δ (ppm): 7.33–7.22 (m, 2H), 6.95–6.76 (m, 3H), 3.97 (dtd, $J = 11.2$, 3.4, 0.9 Hz, 1H), 3.91–3.78 (m, 1H), 3.80–3.58 (m, 3H), 3.23–3.05 (m, 2H), 1.07 (dd, $J = 6.5$, 0.6 Hz, 3H).

$^{13}$C NMR (101 MHz, CDCl$_3$): δ (ppm) 150.10, 129.34, 119.97, 116.87, 72.20, 67.36, 51.16, 44.59, 11.81.

HR-MS (EI) m/z calcd for [C$_{11}$H$_{15}$NO$^+$] [M$^+$]: 177.1148, found: 177.1146.

4-Phenyl-3-propylmorpholine (58a)

![Chemical structure](image)

$^1$H NMR (300 MHz, CDCl$_3$): δ (ppm) 7.30–7.22 (m, 2H), 6.91–6.75 (m, 3H), 4.03–3.84 (m, 2H), 3.80–3.65 (m, 2H), 3.54 (dd, $J = 10.2$, 2.7 Hz, 1H), 3.23–3.10 (m, 2H), 1.90–1.68 (m, 1H), 1.44–1.12 (m, 3H), 0.91–0.83 (m, 3H).

$^{13}$C NMR (75 MHz, CDCl$_3$): δ (ppm) 150.00, 129.38, 119.11, 115.71, 68.82, 67.14, 55.56, 44.67, 27.42, 20.26, 14.22.

HR-MS (EI) m/z calcd for [C$_{13}$H$_{19}$NO$^+$] [M$^+$]: 205.1461, found: 205.1460.

2,6-Dimethyl-4-phenylmorpholine (59a)

![Chemical structure](image)

$^1$H NMR (300 MHz, CDCl$_3$): δ (ppm) 7.37–7.26 (m, 2.67H), 7.05–6.74 (m, 3.54H), 4.19 (td, $J = 6.3$, 3.3 Hz, 0.43H), 3.84 (dqd, $J = 10.4$, 6.3, 2.4 Hz, 2H), 3.48 (ddd, $J = 11.1$, 2.3, 1.2 Hz, 2H), 3.33–3.12 (m, 0.42H), 2.91 (ddd, $J = 11.8$, 6.1, 1.0 Hz, 0.40H), 2.60–2.25 (m, 2H), 1.29 (d, $J = 6.3$ Hz, 6H).
$^{13}$C NMR (75 MHz, CDCl$_3$): δ (ppm) 150.69, 128.89, 119.49, 115.59, 115.49, 71.38, 66.20, 54.58, 54.04, 18.81, 17.79.

2-Methyl-4-phenylmorpholine (60a)

$^1$H NMR (300 MHz, CDCl$_3$): δ (ppm) 7.40–7.23 (m, 2H), 7.05–6.87 (m, 3H), 4.05 (ddd, $J = 11.4$, 3.5, 1.6 Hz, 1H), 3.89–3.68 (m, 2H), 3.56–3.30 (m, 2H), 2.86 (td, $J = 11.8$, 3.5 Hz, 1H), 2.52 (dd, $J = 11.8$, 10.2 Hz, 1H), 1.29 (d, $J = 6.3$ Hz, 3H).

$^{13}$C NMR (75 MHz, CDCl$_3$): δ (ppm) 151.24, 129.29, 120.05, 115.89, 71.90, 66.85, 55.73, 48.71, 19.19.

HR-MS (EI) m/z calcd for [C$_{11}$H$_{15}$NO$^+$] [M$^+$]: 177.1148, found: 177.1149.

1,4-Diphenylpiperazine (62a)

$^1$H NMR (300 MHz, CDCl$_3$): δ (ppm) 7.41–7.27 (m, 4H), 7.07–6.97 (m, 4H), 6.97–6.83 (m, 2H), 3.37 (s, 8H).

$^{13}$C NMR (75 MHz, CDCl$_3$): δ (ppm) 151.34, 129.32, 120.22, 116.48, 49.56.

1-(4-Methoxyphenyl)-4-phenylpiperazine (63a)

$^1$H NMR (300 MHz, CDCl$_3$): δ (ppm) 7.26–7.15 (m, 2H), 6.93–6.87 (m, 3H), 6.84–6.75 (m, 3H), 6.65–6.50 (m, 1H), 3.70 (s, 3H), 3.37–3.23 (m, 4H), 3.20–3.06 (m, 4H).

$^{13}$C NMR (75 MHz, CDCl$_3$): δ (ppm) 154.18, 151.38, 145.71, 129.28, 120.10, 118.62, 116.42, 114.60, 55.69, 51.04, 49.62.
1-(2,4-Dimethylphenyl)-4-(4-methoxyphenyl)piperazine (64a)

\[
\begin{align*}
\text{Me} & \quad \text{N} & \quad \text{Me} \\
\text{Me} & \quad \text{N} & \quad \text{Me} \\
\text{Me} & \quad \text{OMe} & \\
\end{align*}
\]

$^1$H NMR (300 MHz, CDCl$_3$): $\delta$ (ppm) 7.10–6.96 (m, 5H), 6.90 (d, $J = 9.1$ Hz, 2H), 3.81 (s, 3H), 3.36–3.19 (m, 4H), 3.14–2.94 (m, 4H), 2.40–2.26 (m, 6H).

$^{13}$C NMR (75 MHz, CDCl$_3$): $\delta$ (ppm) 153.92, 149.07, 145.98, 132.82, 132.67, 131.95, 127.17, 119.05, 118.34, 114.55, 55.67, 52.23, 51.35, 20.84, 17.85.

HR-MS (EI) m/z calcd for [C$_{19}$H$_{24}$N$_2$O$^+$] [M$^+$]: 296.1883, found: 296.1882.

$N,N$-Dibutyl-3,3,5-trimethylcyclohexan-1-amine (65a)

\[
\begin{align*}
\text{Me} & \quad \text{N} & \quad \text{Me} \\
\text{Me} & \quad \text{N} & \quad \text{Me} \\
\end{align*}
\]

$^1$H NMR (400 MHz, CDCl$_3$) $\delta$ (ppm) 2.76–2.58 (m, 1H), 2.53–2.41 (m, 4H), 1.58–1.54 (m, 1H), 1.47–1.23 (m, 14H), 0.98–0.89 (m, 15H).

$^{13}$C NMR (101 MHz, CDCl$_3$) $\delta$ (ppm) 53.40, 50.31, 45.97, 40.32, 35.10, 32.57, 31.65, 30.40, 26.73, 22.05, 20.91, 14.25.

HR-MS (ESI) m/z calcd for [C$_{17}$H$_{36}$N$^+$] ([M+H$^+$]): 254.2842, found: 254.2854.

$N$-Butyl-$N$-(4-(2,2,6-trimethylcyclohexyl)butan-2-yl)butan-1-amine (66a)

\[
\begin{align*}
\text{Me} & \quad \text{N} & \quad \text{Me} \\
\text{Me} & \quad \text{N} & \quad \text{Me} \\
\end{align*}
\]
$^1$H NMR (400 MHz, CDCl$_3$) $\delta$ (ppm) 2.64 (d, $J = 7.0$ Hz, 1H), 2.48–2.16 (m, 4H), 1.94–1.80 (m, 1H), 1.55–1.22 (m, 14H), 1.21–1.01 (m, 4H), 1.02–0.75 (m, 19H).

$^{13}$C NMR (101 MHz, CDCl$_3$) $\delta$ (ppm) 55.75, 53.95, 50.08, 42.45, 36.84, 35.29, 31.51, 30.58, 28.68, 27.70, 23.08, 22.34, 21.35, 20.90, 14.49, 14.32.

HR-MS (ESI) m/z calcd for [C$_{21}$H$_{44}$N]$: [M+H]$: 310.3468, found: 310.3474.

$^N$-(4-(Benzo[d][1,3]dioxol-5-yl)butan-2-yl)-$N$-butylbutan-1-amine (67a)

$^1$H NMR (300 MHz, CDCl$_3$) $\delta$ (ppm) 6.78–6.53 (m, 3H), 5.91 (s, 2H), 2.84–2.20 (m, 7H), 1.71 (s, 2H), 1.44–1.22 (m, 8H), 1.01–0.81 (m, 9H).

$^{13}$C NMR (101 MHz, CDCl$_3$) $\delta$ (ppm) 147.56, 145.47, 137.09, 121.13, 109.01, 108.16, 100.79, 54.48, 49.86, 33.27, 31.53, 20.84, 14.30, 13.96.

HR-MS (ESI) m/z calcd for [C$_{19}$H$_{32}$NO]$: [M+H]$: 306.2428, found: 306.2429.

4-(Benzo[d][1,3]dioxol-5-yl)-$N$,$N$-bis(2-methoxyethyl)butan-2-amine (68a)

$^1$H NMR (400 MHz, CDCl$_3$) $\delta$ (ppm) 6.74–6.66 (m, 2H), 6.65–6.55 (m, 1H), 5.89 (s, 2H), 3.38 (td, $J = 6.8$, 1.9 Hz, 4H), 3.33 (s, 6H), 2.68 (dt, $J = 13.5$, 6.8 Hz, 3H), 2.62–2.47 (m, 4H), 1.71 (dddd, $J = 13.3$, 9.8, 5.7, 3.6 Hz, 1H), 1.47 (ddt, $J = 13.5$, 9.7, 6.5 Hz, 1H), 0.96 (d, $J = 6.5$ Hz, 3H).

$^{13}$C NMR (101 MHz, CDCl$_3$) $\delta$ (ppm) 147.51, 145.45, 136.75, 121.09, 108.98, 108.09, 100.73, 72.74, 58.86, 56.31, 50.42, 36.50, 32.96, 14.37.

HR-MS (ESI) m/z calcd for [C$_{17}$H$_{28}$NO$_4$]$: [M+H]$: 310.2013, found: 310.2021.
1-(5-(Dibutylamino)hexyl)-3,7-dimethyl-3,7-dihydro-1H-purine-2,6-dione (69a)

\[
\begin{align*}
\text{Me} & \quad \text{N} & \quad \text{O} & \quad \text{Me} \\
\text{Me} & \quad \text{N} & \quad \text{O} & \quad \text{Me}
\end{align*}
\]

\[\begin{align*}
^1H \text{ NMR (300 MHz, CDCl}_3\text{)} & \quad \delta (ppm) \quad 7.49 (d, J = 0.7 Hz, 1H), \quad 4.05–3.91 (m, 5H), \quad 3.56 (s, 3H), \\
& \quad 2.74–2.53 (m, 1H), \quad 2.44–2.18 (m, 4H), \quad 1.70–1.57 (m, 2H), \quad 1.45–1.18 (m, 12H), \quad 0.88 (t, J = 7.2 Hz, 9H).
\end{align*}\]

\[\begin{align*}
^{13}C \text{ NMR (75 MHz, CDCl}_3\text{)} & \quad \delta (ppm) \quad 155.30, \quad 151.47, \quad 148.70, \quad 141.29, \quad 107.69, \quad 54.87, \quad 49.75, \\
& \quad 41.47, \quad 33.58, \quad 29.66, \quad 28.24, \quad 24.62, \quad 20.67, \quad 14.14.
\end{align*}\]

HR-MS (ESI) m/z calcd for [C\textsubscript{21}H\textsubscript{38}N\textsubscript{5}O\textsubscript{2}]\textsuperscript+ ([M+H]\textsuperscript+): 392.3020, found: 392.3018.

1-(5-(Bis(2-methoxyethyl)amino)hexyl)-3,7-dimethyl-3,7-dihydro-1H-purine-2,6-dione (70a)

\[
\begin{align*}
\text{Me} & \quad \text{O} & \quad \text{Me} & \quad \text{Me}
\end{align*}
\]

\[\begin{align*}
^1H \text{ NMR (400 MHz, CDCl}_3\text{)} & \quad \delta (ppm) \quad 7.49 (q, J = 0.6 Hz, 1H), \quad 4.04–3.93 (m, 5H), \quad 3.56 (s, 3H), \\
& \quad 3.32 (s, 9H), \quad 2.77–2.52 (m, 5H), \quad 1.76 (s, 1H), \quad 1.62 (q, J = 7.6 Hz, 2H), \quad 1.50 (s, 1H), \quad 1.41– 1.33 (m, 2H), \quad 1.25 (d, J = 6.9 Hz, 1H), \quad 0.93 (d, J = 6.5 Hz, 3H).
\end{align*}\]

\[\begin{align*}
^{13}C \text{ NMR (101 MHz, CDCl}_3\text{)} & \quad \delta (ppm) \quad 155.28, \quad 151.46, \quad 148.71, \quad 141.33, \quad 107.68, \quad 72.71, \quad 58.82, \\
& \quad 56.93, \quad 50.34, \quad 41.40, \quad 33.58, \quad 29.67, \quad 28.12, \quad 24.49, \quad 14.64.
\end{align*}\]

HR-MS (ESI) m/z calcd for [C\textsubscript{19}H\textsubscript{33}N\textsubscript{5}O\textsubscript{4}]\textsuperscript+ ([M+H]\textsuperscript+): 396.2605, found: 396.2604.

HR-MS (ESI): m/z calculated for [C\textsubscript{19}H\textsubscript{33}N\textsubscript{5}O\textsubscript{4}Na]\textsuperscript+ ([M+Na]\textsuperscript+): 418.2425, found: 418.2426.
(8R,9S,10S,13R,14S,17R)-N,N-Dibutyl-10,13-dimethyl-17-((R)-6-methylheptan-2-yl)hexadecahydro-1H-cyclopenta[a]phenanthren-3-amine (71a)

\[
\begin{align*}
\text{Me} & \quad \text{Me} \\
\text{N} & \quad \text{Me}
\end{align*}
\]

\(^1\text{H} \text{NMR (400 MHz, CDCl}_3\text{)} \ \delta \text{ (ppm)} \ 2.46 \text{ (m, 5H), } 1.91-0.82 \text{ (m, 57H), 0.64 (d, } J = 2.0 \text{ Hz, 3H).}
\]

\(^{13}\text{C} \text{ NMR (101 MHz, CDCl}_3\text{)} \ \delta \text{ (ppm)} \ 61.04, 56.67, 56.45, 54.66, 50.64, 46.32, 43.35, 42.85, 40.83, 40.38, 39.68, 36.88, 36.33, 36.04, 35.95, 35.23, 32.33, 31.00, 29.62, 28.49, 28.17, 27.77, 26.77, 24.42, 23.96, 23.88, 22.98, 22.72, 20.93, 18.84, 14.32, 12.20.
\]

\text{HR-MS (ESI)} m/z \text{ calcd for [C}_{35}\text{H}_{66}\text{N}^+ ([M+H]^+): 500.5190, found: 500.5198.}

\text{N,N-Dibutyl-3,7-dimethyloct-6-en-1-amine (72a)}

\[
\begin{align*}
\text{Me} & \quad \text{Me} \\
\text{N} & \quad \text{Me}
\end{align*}
\]

\(^1\text{H} \text{NMR (400 MHz, CDCl}_3\text{)} \ \delta \text{ (ppm)} \ 5.09 \text{ (ddt, } J = 8.6, 5.7, 1.4 \text{ Hz, 1H), 2.51–2.30 \text{ (m, 6H), 2.10–1.90 \text{ (m, 2H), 1.68 (q, } J = 1.3 \text{ Hz, 3H), 1.61–1.58 \text{ (m, 3H), 1.52–1.36 \text{ (m, 6H), 1.35–1.22 \text{ (m, 6H), 1.19–1.11 \text{ (m, 1H), 0.94–0.86 \text{ (m, 9H).}}
\]

\(^{13}\text{C} \text{ NMR (101 MHz, CDCl}_3\text{)} \ \delta \text{ (ppm)} \ 131.20, 125.05, 54.01, 52.15, 37.40, 33.92, 31.17, 29.24, 25.87, 25.66, 20.96, 19.89, 17.77, 14.26.
\]

\text{HR-MS (ESI)} m/z \text{ calcd for [C}_{18}\text{H}_{38}\text{N}^+ ([M+H]^+): 268.2999, found: 268.3004.}

S43
**N,N-diethylformamide (1b)**

\[
\begin{align*}
\text{Me} & \quad \text{N} \quad \text{O} \\
\text{Me} & 
\end{align*}
\]

**10 mmol scale**

In a 300 mL steel Parr autoclave, Cu(OTf)\(_2\) (180 mg, 0.5 mmol) was added, MeCN (30.0 mL), pyridine (1.60 g) and tertiary amine (1.01 g, 10 mmol) were added, independently. The autoclave was flushed with air 2 times at 10 bar and finally pressurized to the desired value (30 bar). Then it was placed into an aluminium block and heat to the desired temperature (130 °C) from room temperature. At the end of the reaction, the autoclave was quickly cooled down at room temperature with an ice bath and vented. Finally, the yield of 1b was determined by GC using n-dodecan as the standard. Safety statement: The scaling up reactions performed with a flammable solvent (MeCN) under high pressures of air (40 bar) with a substrate capable of autoxidation (n-tributylamine), so the explosion hazard should be taken in consideration.

**N,N-Dipropylformamide (2b)**

\[
\begin{align*}
\text{Me} & \quad \text{N} \quad \text{O} \\
\text{Me} & 
\end{align*}
\]

According to GP III, CuCl (2.5 mg), acetonitrile (2.0 mL), pyridine (80 mg), tripropylamine 2a (66 mg, 0.46 mmol), air (30 bar), room temperature to 130 °C and then at 130 °C for 24 h. The product 2b (44 mg, 0.34 mmol, 73%) was obtained by column chromatography (n-Heptane/EtOAc: 4:1) as a light yellow liquid.

\(^1\)H NMR (400 MHz, CDCl\(_3\)) \(\delta\) (ppm) 8.12 (s, 1H), 3.25–3.18 (m, 2H), 3.13 (dd, \(J = 7.7, 6.6\) Hz, 2H), 1.62–1.44 (m, 4H), 0.85 (td, \(J = 7.4, 2.0\) Hz, 6H).

\(^{13}\)C NMR (101 MHz, CDCl\(_3\)) \(\delta\) (ppm) 163.03, 49.32, 43.87, 21.85, 20.56, 11.36, 10.97.

**N,N-Dibutylformamide (3b)**

\[
\begin{align*}
\text{Me} & \quad \text{N} \quad \text{O} \\
\text{Me} & 
\end{align*}
\]
According to GP III, CuCl (2.5 mg), acetonitrile (2.0 mL), pyridine (80 mg), tributylamine 3a (92 mg, 0.50 mmol), air (30 bar), room temperature to 100 °C and then at 100 °C for 24 h. The yield of 3b was determined by GC using n-dodecan as the standard.

10 mmol scale
In a 300 mL steel Parr autoclave, CuCl (55 mg, 0.56 mmol) was added, MeCN (30.0 mL), pyridine (1.60 g) and tributylamine 3a (1.85 g, 10 mmol) were added, independently. The autoclave was flushed with air 2 times at 10 bar and finally pressurized to the desired value (40 bar). Then it was placed into an aluminium block and heat to the desired temperature (100 °C) from room temperature. At the end of the reaction, the autoclave was quickly cooled down at room temperature with an ice bath and vented. Finally, the yield of 3b was determined by GC using n-dodecan as the standard (90%). Safety statement: The scaling up reactions performed with a flammable solvent (MeCN) under high pressures of air (40 bar) with a substrate capable of autoxidation (n-tributylamine), so the explosion hazard should be taken in consideration.

N,N-Diisopropylformamide (4b)

According to GP III, CuCl (2.6 mg), acetonitrile (2.0 mL), pyridine (80 mg), N-ethyl-N-isopropylpropan-2-amine 4a (74 mg, 0.57 mmol), air (40 bar), room temperature to 130 °C and then at 130 °C for 24 h. The the yield of 4b was determined by GC using n-dodecan as the standard.

N-Butyl-N-(2-cyanoethyl)formamide (5b)

According to GP III, CuCl (2.6 mg), acetonitrile (2.0 mL), pyridine (80 mg), 3-(dibutylamino)propanenitrile 5a (100 mg, 0.55 mmol), air (30 bar), room temperature to 100 °C and then at 100 °C for 24 h. The product 5b (65 mg, 0.42 mmol, 76%) was obtained by column chromatography (n-Heptane/ EtOAc: 3:1) as a light yellow liquid.

\(^1\)H NMR (400 MHz, CDCl\(_3\)) \(\delta\) (ppm) 8.19 (s, 1H), 3.85–3.01 (m, 4H), 2.89–2.28 (m, 2H), 1.42 (dtd, \(J = 92.8, 14.9, 7.3\) Hz, 4H), 0.94 (h, \(J = 10.0, 8.0\) Hz, 3H).
\(^{13}\text{C}\) NMR (75 MHz, DMSO-\(d_6\)) \(\delta\) (ppm) 163.70, 163.38, 119.52, 119.43, 46.75, 42.85, 37.97, 30.71, 29.42, 20.05, 19.60, 18.01, 16.02, 14.19, 14.05.

HR-MS (EI) m/z calcd for [C\(_8\)H\(_{14}\)N\(_2\)O\(^+\)] [M\(^+\)]: 154.1101, found: 154.1104.

\(N\)-Butyl-\(N\)-decylformamide (6b)

According to GP III, CuCl (2.5 mg), acetonitrile (2.0 mL), pyridine (80 mg), \(N, N\)-dibutyldecan-1-amine \(6a\) (136 mg, 0.51 mmol), air (30 bar), room temperature to 100 °C and then at 100 °C for 24 h. The product \(6b\) (119 mg, 0.49 mmol, 96%) was by column chromatography (n-Heptane/EtOAc: 3:1) obtained as a light yellow liquid.

\(^1\)H NMR (400 MHz, CDCl\(_3\)) \(\delta\) (ppm) 8.38 (s, 1H), 3.41–3.10 (m, 4H), 1.47 (q, \(J = 7.6\) Hz, 5H), 1.39–1.08 (m, 15H), 0.90–0.81 (m, 6H).

\(^{13}\text{C}\) NMR (101 MHz, CDCl\(_3\)) \(\delta\) (ppm) 162.44, 47.43, 42.07, 31.86, 30.72, 29.49, 29.37, 29.19, 26.48, 22.66, 20.14, 19.65, 14.09, 13.78, 13.62.

HR-MS (EI) m/z calcd for [C\(_{15}\)H\(_{31}\)NO\(^+\)] [M\(^+\)]: 241.2400, found: 241.2400.

\(N, N\)-Bis(2-(2-methoxyethoxy)ethyl)formamide (7b)

According to GP III, CuCl (2.5 mg), acetonitrile (2.0 mL), pyridine (80 mg), tris(2-(2-methoxyethoxy)ethyl)amine \(7a\) (170 mg, 0.53 mmol), air (30 bar), room temperature to 100 °C and then at 100 °C for 24 h. The product \(7b\) (99 mg, 0.40 mmol, 75%) was obtained by column chromatography (n-Heptane/EtOAc: 3:1) as a light yellow liquid.

\(^1\)H NMR (400 MHz, CDCl\(_3\)) \(\delta\) (ppm) 8.45 (s, 1H), 3.61–3.41 (m, 16H), 3.31 (s, 6H).

\(^{13}\text{C}\) NMR (101 MHz, CDCl\(_3\)) \(\delta\) (ppm) 163.46, 71.87, 71.77, 70.55, 70.19, 69.24, 68.86, 59.06, 58.94, 48.76, 43.03.

HR-MS (EI) m/z calcd for [C\(_{11}\)H\(_{23}\)NO\(^+\)] [M\(^+\)]: 249.1571, found: 249.1570.
**N-(2-Methoxyethyl)-N-phenethylformamide (8b)**

![Chemical Structure of N-(2-Methoxyethyl)-N-phenethylformamide (8b)](image)

According to GP III, CuCl (2.7 mg), acetonitrile (2.0 mL), pyridine (80 mg), 2-methoxy-N-(2-methoxyethyl)-N-phenethylthene-1-amine 8a (132 mg, 0.56 mmol), air (30 bar), room temperature to 100 °C and then at 100 °C for 24 h. The product 8b (91 mg, 0.44 mmol, 79%) was obtained by column chromatography (n-Heptane/EtOAc: 5:1) as a light yellow liquid.

$^1$H NMR (400 MHz, CDCl$_3$) δ 9.29–8.17 (m, 1H), 7.39–7.04 (m, 5H), 3.54 (dd, $J = 20.8$, 12.7 Hz, 5H), 3.38–3.28 (m, 4H), 2.85 (t, $J = 6.8$ Hz, 2H).

$^{13}$C NMR (101 MHz, DMSO-$d_6$) δ (ppm) 163.25, 139.02, 129.09, 128.82, 126.65, 69.78, 58.49, 49.12, 44.02, 34.90.

HR-MS (EI) m/z calcd for [C$_{12}$H$_{17}$NO$_2$]$^+$/[M$^+$]: 207.1254, found: 207.1257.

**N-Cyclohexyl-N-(2-methoxyethyl)formamide (9b)**

![Chemical Structure of N-Cyclohexyl-N-(2-methoxyethyl)formamide (9b)](image)

According to GP III, CuCl (2.6 mg), acetonitrile (2.0 mL), pyridine (80 mg), N,N-bis(2-methoxyethyl)cyclohexanamine 9a (104 mg, 0.48 mmol), air (30 bar), room temperature to 100 °C and then at 100 °C for 24 h. The product 9b (89 mg, 0.48 mmol, 99%) was obtained by column chromatography (n-Heptane/EtOAc: 3:1) as a light yellow liquid.

$^1$H NMR (400 MHz, CDCl$_3$) δ (ppm) 8.38 (s, 1H), 3.47–3.10 (m, 8H), 1.87–1.68 (m, 3H), 1.68–1.52 (m, 2H), 1.49–1.33 (m, 2H), 1.32–1.17 (m, 2H), 1.12–0.94 (m, 1H).

$^{13}$C NMR (101 MHz, CDCl$_3$) δ (ppm) 163.16, 72.26, 70.44, 58.69, 41.73, 32.76, 25.80, 25.36.

HR-MS (EI) m/z calcd for [C$_{10}$H$_{16}$NO$_2$]$^+$/[M$^+$]: 185.1410, found: 185.1412.

**N-Cycloheptyl-N-(2-methoxyethyl)formamide (10b)**

![Chemical Structure of N-Cycloheptyl-N-(2-methoxyethyl)formamide (10b)](image)


According to GP III, CuCl (2.8 mg), acetonitrile (2.0 mL), pyridine (80 mg), N,N-bis(2-methoxyethyl)cycloheptanamine 10a (146 mg, 0.64 mmol), air (30 bar), room temperature to 100 °C and then at 100 °C for 24 h. The product 10b (123 mg, 0.62 mmol, 97%) was obtained by column chromatography (n-Heptane/EtOAc: 3:1) as a light yellow liquid.

$^1$H NMR (400 MHz, CDCl$_3$) δ (ppm) 8.48 (s, 1H), 3.52–3.20 (m, 8H), 1.86–1.33 (m, 12H).

$^{13}$C NMR (101 MHz, CDCl$_3$) δ (ppm) 161.90, 71.89, 70.36, 58.61, 42.28, 34.96, 27.13, 24.87.

HR-MS (EI) m/z calcd for [C$_{11}$H$_{21}$NO$_2$]$^+$/[M$^+$]: 199.1567, found: 199.1574.

$N$-Butyl-$N$-(3-methylbutan-2-yl)formamide (11b)

According to GP III, CuCl (2.6 mg), acetonitrile (2.0 mL), pyridine (80 mg), $N$-butyl-$N$-(3-methylbutan-2-yl)butan-1-amine 11a (80 mg, 0.40 mmol), air (30 bar), room temperature to 100 °C and then at 100 °C for 24 h. The product 11b (66 mg, 0.39 mmol, 98%) was obtained by column chromatography (n-Heptane/EtOAc: 3:1) as a light yellow liquid.

$^1$H NMR (400 MHz, CDCl$_3$) δ (ppm) 8.15 (s, 1H), 3.56–3.37 (m, 1H), 3.22–2.92 (m, 2H), 1.62–1.37 (m, 4H), 1.35–1.12 (m, 7H), 0.93–0.86 (m, 6H).

$^{13}$C NMR (101 MHz, CDCl$_3$) δ (ppm) 162.62, 54.51, 41.00, 37.54, 31.06, 20.79, 20.65, 19.71, 14.02, 13.87.

HR-MS (EI) m/z calcd for [C$_{10}$H$_{21}$NO]$^+$/[M$^+$]: 171.1617, found: 171.1609.

$N$-Butyl-$N$-(4-methylpentan-2-yl)formamide (12b)

According to GP III, CuCl (2.5 mg), acetonitrile (2.0 mL), pyridine (80 mg), $N$,$N$-dibutyl-4-methylpentan-2-amine 12a (68 mg, 0.32 mmol), air (30 bar), room temperature to 100 °C and then at 100 °C for 24 h. The product 12b (56 mg, 0.30 mmol, 94%) was obtained by column chromatography (n-Heptane/EtOAc: 3:1) as a light yellow liquid.
\(^1\)H NMR (300 MHz, CDCl\(_3\)) \(\delta\) (ppm) 8.61 (s, 1H), 3.68–3.41 (m, 1H), 3.16 (ddt, \(J = 34.6, 15.0, 7.3\) Hz, 2H), 1.66–1.39 (m, 4H), 1.36–1.08 (m, 6H), 0.98–0.78 (m, 9H).

\(^{13}\)C NMR (75 MHz, CDCl\(_3\)) \(\delta\) (ppm) 161.92, 52.72, 44.41, 41.07, 31.14, 24.63, 22.92, 22.09, 21.05, 20.65, 13.87.

HR-MS (ESI) m/z calcd for [C\(_{11}\)H\(_{24}\)N\(_2\)O\(_2\)]\(^+\) ([M+H]\(^+\)) : 186.1852, found: 186.1860.

\(N\)-Butyl-\(N\)-(heptan-2-yl)formamide (13b)

According to GP III, CuCl (2.5 mg), acetonitrile (2.0 mL), pyridine (80 mg), \(N,N\)-dibutylheptan-2-amine 13a (95 mg, 0.42 mmol), air (30 bar), room temperature to 100 °C and then at 100 °C for 24 h. The product 13b (81 mg, 0.40 mmol, 95%) was obtained by column chromatography (n-Heptane/EtOAc: 3:1) as a light yellow liquid.

\(^1\)H NMR (400 MHz, CDCl\(_3\)) \(\delta\) (ppm) 8.41 (s, 1H), 3.42 (dt, \(J = 8.6, 6.6\) Hz, 1H), 3.25–2.97 (m, 2H), 1.58–1.39 (m, 4H), 1.31–1.13 (m, 11H), 0.92–0.82 (m, 6H).

\(^{13}\)C NMR (101 MHz, CDCl\(_3\)) \(\delta\) (ppm) 162.26, 54.92, 41.07, 35.36, 31.55, 31.05, 26.21, 22.56, 20.73, 14.03, 13.85, 13.74.

HR-MS (EI) m/z calcd for [C\(_{12}\)H\(_{25}\)NO\(_2\)]\(^+\) [M\(^+\)]: 199.1931, found: 199.1927.

\(N\)-Butyl-\(N\)-(1-cyclobutylethyl)formamide (14b)

According to GP III, CuCl (2.5 mg), acetonitrile (2.0 mL), pyridine (80 mg), \(N\)-butyl-\(N\)-(1-cyclobutylethyl)butan-1-amine 14a (94 mg, 0.45 mmol), air (30 bar), room temperature to 100 °C and then at 100 °C for 24 h. The product 14b (76 mg, 0.42 mmol, 93%) was obtained by column chromatography (n-Heptane/EtOAc: 3:1) as a light yellow liquid.

\(^1\)H NMR (400 MHz, CDCl\(_3\)) \(\delta\) (ppm) 8.55 (s, 1H), 3.30 (dq, \(J = 10.0, 6.5\) Hz, 1H), 3.25–2.97 (m, 2H), 1.58–1.39 (m, 4H), 1.31–1.13 (m, 11H), 0.92–0.82 (m, 6H).

HR-MS (EI) m/z calcd for [C\(_{12}\)H\(_{23}\)NO\(_2\)]\(^+\) [M\(^+\)]: 199.1931, found: 199.1927.
$^{13}$C NMR (101 MHz, CDCl$_3$) $\delta$ (ppm) 161.95, 60.64, 41.31, 30.98, 26.28, 26.09, 20.56, 17.16, 17.04, 15.74, 13.84.

HR-MS (EI) m/z calcd for [C$_{11}$H$_{21}$NO$^+$] [M$^+$]: 183.1618, found: 183.1614.

$N$-Butyl-$N$-cyclohexylformamide (15b)

According to GP III, CuCl (2.5 mg), acetonitrile (2.0 mL), pyridine (80 mg), $N,N$-dibutylcyclohexanamine 15a (90 mg, 0.43 mmol), air (30 bar), room temperature to 100 °C and then at 100 °C for 24 h. The product 15b (75 mg, 0.41 mmol, 95%) was obtained by column chromatography (n-Heptane/EtOAc: 3:1) as a light yellow liquid.

$^1$H NMR (400 MHz, CDCl$_3$) $\delta$ (ppm) 8.90 (s, 1H), 3.33–3.01 (m, 3H), 1.79 (ddd, $J = 27.4, 9.5, 3.5$ Hz, 3H), 1.71–1.58 (m, 2H), 1.56–1.39 (m, 4H), 1.35–1.20 (m, 4H), 1.16–1.02 (m, 1H), 0.89 (td, $J = 7.3, 4.8$ Hz, 3H).

$^{13}$C NMR (101 MHz, CDCl$_3$) $\delta$ (ppm) 161.39, 59.00, 42.14, 32.92, 30.72, 25.97, 25.24, 20.47, 13.85.

HR-MS (EI) m/z calcd for [C$_{11}$H$_{21}$NO$^+$] [M$^+$]: 183.1618, found: 183.1612.

$N$-Butyl-$N$-cycloheptylformamide (16b)

According to GP III, CuCl (2.5 mg), acetonitrile (2.0 mL), pyridine (80 mg), $N,N$-dibutylcycloheptanamine 16a (117 mg, 0.52 mmol), air (30 bar), room temperature to 100 °C and then at 100 °C for 24 h. The product 16b (100 mg, 0.51 mmol, 98%) was obtained by column chromatography (n-Heptane/EtOAc: 2:1) as a light yellow liquid.

$^1$H NMR (400 MHz, CDCl$_3$) $\delta$ (ppm) 8.73 (s, 1H), 3.29 (dd, $J = 9.7, 4.2$ Hz, 1H), 3.21–3.02 (m, 2H), 1.82–1.24 (m, 16H), 0.88 (td, $J = 7.2, 4.7$ Hz, 3H).

$^{13}$C NMR (101 MHz, CDCl$_3$) $\delta$ (ppm) 161.30, 61.18, 42.42, 35.06, 30.93, 27.13, 24.90, 20.36, 13.68.

HR-MS (EI) m/z calcd for [C$_{12}$H$_{23}$NO$^+$] [M$^+$]: 197.1774, found: 197.1780.

S50
N-Butyl-N-cyclooctylformamide (17b)

\[
\begin{align*}
\text{Me} & \quad \text{N} \quad \text{O} \\
\text{Cyclooctyl} & 
\end{align*}
\]

According to GP III, CuCl (2.5 mg), acetonitrile (2.0 mL), pyridine (80 mg), N,N-dibutylcyclooctanamine 17a (129 mg, 0.54 mmol), air (30 bar), room temperature to 100 °C and then at 100 °C for 24 h. The product 17b (112 mg, 0.53 mmol, 98%) was obtained by column chromatography (n-Heptane/EtOAc: 2:1) as a light yellow liquid.

\(^1\)H NMR (400 MHz, DMSO-\(d_6\)) \(\delta\) (ppm) 8.04 (d, \(J = 75.4\) Hz, 1H), 3.90–3.40 (m, 1H), 3.23–2.99 (m, 2H), 1.93–1.14 (m, 18H), 0.93–0.82 (m, 3H).

\(^{13}\)C NMR (101 MHz, DMSO-\(d_6\)) \(\delta\) (ppm) 162.41, 58.48, 41.71, 33.63, 33.32, 31.85, 26.40, 25.91, 20.42, 14.14.

HR-MS (EI) m/z calcd for [C\(_{13}\)H\(_{25}\)NO\(^+\)] [M\(^+\)]: 211.1931, found: 211.1929.

N-Butyl-N-phenethylformamide (18b)

\[
\begin{align*}
\text{Ph} & \quad \text{N} \quad \text{O} \\
\text{Butyl} & 
\end{align*}
\]

According to GP III, CuCl (1.7 mg), acetonitrile (2.0 mL), pyridine (80 mg), N-butyl-N-phenethylbutan-1-amine 18a (75 mg, 0.32 mmol), air (30 bar), room temperature to 100 °C and then at 100 °C for 24 h. The product 18b (37 mg, 0.18 mmol, 56%) was obtained by column chromatography (n-Heptane/EtOAc: 2:1) as a light yellow liquid.

\(^1\)H NMR (300 MHz, CDCl\(_3\)) \(\delta\) (ppm) 7.88 (s, 1H), 7.41–6.85 (m, 5H), 3.51–3.32 (m, 2H), 3.31–3.17 (m, 1H), 3.04 (t, \(J = 7.1\) Hz, 1H), 2.88–2.68 (m, 2H), 1.52–1.35 (m, 2H), 1.30–1.14 (m, 2H), 0.86 (dd, \(J = 8.5, 7.1\) Hz, 3H).

\(^{13}\)C NMR (75 MHz, CDCl\(_3\)) \(\delta\) (ppm) 162.97, 138.89, 133.11, 129.01, 126.93, 49.18, 44.36, 35.60, 30.84, 20.28, 13.93.

HR-MS (EI) m/z calcd for [C\(_{13}\)H\(_{19}\)NO\(^+\)] [M\(^+\)]: 205.1461, found: 205.1460.
**N-Butyl-N-(1-phenylpropan-2-yl)formamide (19b)**

![Chemical structure of N-Butyl-N-(1-phenylpropan-2-yl)formamide (19b)](attachment:image)

According to **GP III**, CuCl (2.6 mg), acetonitrile (2.0 mL), pyridine (80 mg), N-butyl-N-(1-phenylpropan-2-yl)butan-1-amine 19a (113 mg, 0.46 mmol), air (30 bar), room temperature to 100 °C and then at 100 °C for 24 h. The product 19b (100 mg, 0.46 mmol, 99%) was obtained by column chromatography (n-Heptane/EtOAc: 2:1) as a light yellow liquid.

$^1$H NMR (400 MHz, DMSO-$d_6$) δ (ppm) 7.83 (s, 1H), 7.31–7.24 (m, 2H), 7.23–7.13 (m, 3H), 3.83 (q, $J = 7.1$ Hz, 1H), 3.21–2.95 (m, 2H), 2.80 (d, $J = 7.4$ Hz, 2H), 1.50–1.31 (m, 2H), 1.27–1.13 (m, 5H), 0.89–0.82 (m, 3H).

$^{13}$C NMR (101 MHz, DMSO-$d_6$) δ (ppm) 162.69, 139.33, 129.51, 128.70, 126.67, 55.51, 46.47, 41.24, 32.80, 19.72, 18.22, 14.03.

**N-Butyl-N-phenylformamide (20b)**

![Chemical structure of N-Butyl-N-phenylformamide (20b)](attachment:image)

According to **GP III**, CuCl (2.7 mg), acetonitrile (2.0 mL), pyridine (80 mg), N,N-dibutylaniline 20a (106 mg, 0.52 mmol), air (30 bar), room temperature to 100 °C and then at 100 °C for 24 h. The product 20b (65 mg, 0.37 mmol, 71%) was obtained by column chromatography (n-Heptane/EtOAc: 2:1) as a yellow liquid.

$^1$H NMR (400 MHz, DMSO-$d_6$) δ (ppm) 8.39 (s, 1H), 7.42 (t, $J = 7.7$ Hz, 2H), 7.35–7.22 (m, 3H), 3.77 (t, $J = 7.1$ Hz, 2H), 1.38 (ddd, $J = 8.7$, 6.3, 2.1 Hz, 2H), 1.22 (td, $J = 9.3$, 8.3, 6.0 Hz, 2H), 0.82 (td, $J = 7.3$, 3.3 Hz, 3H).

$^{13}$C NMR (101 MHz, DMSO-$d_6$) δ (ppm) 162.43, 141.19, 129.99, 126.58, 123.80, 43.38, 29.56, 19.77, 14.00.

**HR-MS (El)** m/z calcd for [C$_{11}$H$_{15}$NO$^+$] [M$^+$]: 177.1148, found: 177.1154.
2-(N-Phenylformamido)ethyl formate (21b)

According to GR VI, Cu(CF₃SO₃)₂ (5.8 mg), 4-phenylmorpholine 21a (80 mg, 0.49 mmol), acetonitrile (2.0 mL), pyridine (8.0 mg), air (20 bar), room temperature to 80 °C and then at 80 °C for 24 h. The product 21b (84 mg, 0.44 mmol, 90%) was obtained by column chromatography (n-Heptane/EtOAc: 5:1) as a light yellow liquid.

$^1$H NMR (300 MHz, CDCl₃): $\delta$ (ppm) 8.40 (s, 1H), 8.02–7.92 (m, 1H), 7.47–7.38 (m, 2H), 7.36–7.24 (m, 1H), 7.27–7.14 (m, 2H), 4.34 (t, $J$ = 5.5 Hz, 2H), 4.11 (t, $J$ = 5.6 Hz, 2H).

$^{13}$C NMR (75 MHz, CDCl₃): $\delta$ (ppm) 162.73, 160.61, 140.65, 129.86, 127.36, 124.49, 60.65, 44.22.

HR-MS (EI) m/z calcd for [C₁₀H₁₁NO₃⁺] [M⁺]: 193.0733, found: 193.0738.

2-(N-p-Tolylformamido)ethyl formate (22b)

According to GR VI, Cu(CF₃SO₃)₂ (6.0 mg), 4-(p-tolyl)morpholine 22a (86 mg, 0.49 mmol), acetonitrile (2.0 mL), air (20 bar), pyridine (8.0 mg), room temperature to 80 °C and then at 80 °C for 24 h. The product 22b (86 mg, 0.42 mmol, 86%) was obtained by column chromatography (n-Heptane/EtOAc: 5:1) as a light yellow liquid.

$^1$H NMR (300 MHz, CDCl₃): $\delta$ (ppm) 8.33 (s, 1H), 7.95 (p, $J$ = 0.7 Hz, 1H), 7.25–7.15 (m, 2H), 7.10–7.01 (m, 2H), 4.30 (td, $J$ = 5.7, 0.9 Hz, 2H), 4.05 (dd, $J$ = 6.0, 5.3 Hz, 2H), 2.41–2.28 (m, 3H).

$^{13}$C NMR (75 MHz, CDCl₃): $\delta$ (ppm) 162.77, 160.65, 138.04, 137.43, 130.42, 124.65, 60.65, 44.25, 21.00.

HR-MS (EI) m/z calcd for [C₁₁H₁₃NO₃⁺] [M⁺]: 207.0890, found: 207.0894.

2-(N-(4-Methoxyphenyl)formamido)ethyl formate (23b)
According to GR VI, Cu(CF₃SO₃)₂ (6.0 mg), 4-(4-methoxyphenyl)morpholine 23a (97 mg, 0.41 mmol), acetonitrile (2.0 mL), pyridine (8.0 mg), air (30 bar), room temperature to 100 °C and then at 100 °C for 24 h. The product 23b (91 mg, 0.41 mmol, 82%) was obtained by column chromatography (n-Heptane/EtOAc: 4:1) as yellow liquid.

1H NMR (400 MHz, CDCl₃): δ (ppm) 8.26 (s, 1H), 7.96 (t, J = 0.7 Hz, 1H), 7.16–7.03 (m, 2H), 6.96–6.81 (m, 2H), 4.28 (td, J = 5.7, 0.9 Hz, 2H), 4.01 (td, J = 5.6, 0.6 Hz, 2H), 3.80 (s, 3H).

13C NMR (101 MHz, CDCl₃): δ (ppm) 162.87, 160.65, 158.91, 133.37, 126.72, 114.94, 60.63, 55.59, 44.54.

HR-MS (EI) m/z calcd for [C₁₁H₁₃NO₄⁺] [M⁺]: 223.0839, found: 223.0836.

2-(N-(4-Fluorophenyl)formamido)ethyl formate (24b)

According to GR VI, Cu(CF₃SO₃)₂ (6.2 mg), 4-(4-fluorophenyl)morpholine 24a (95 mg, 0.52 mmol), acetonitrile (2.0 mL), pyridine (8.0 mg), air (30 bar), room temperature to 100 °C and then at 100 °C for 24 h. The product 24b (94 mg, 0.45 mmol, 87%) was obtained by column chromatography (n-Heptane/EtOAc: 5:1) as a light yellow liquid.

1H NMR (400 MHz, CDCl₃): δ (ppm) 8.30 (s, 1H), 7.95 (t, J = 0.7 Hz, 1H), 7.22–7.14 (m, 2H), 7.13–7.04 (m, 2H), 4.31 (td, J = 5.6, 0.8 Hz, 2H), 4.04 (ddd, J = 6.0, 5.2, 0.6 Hz, 2H).

13C NMR (101 MHz, CDCl₃): δ (ppm) 162.87, 160.65, 158.91, 133.37, 126.72, 114.94, 60.63, 55.59, 44.64.

19F NMR (282 MHz, CDCl₃): δ (ppm) -113.98.

HR-MS (EI) m/z calcd for [C₁₁H₁₀FNO₃⁺] [M⁺]: 211.0639, found: 211.0639.
2-(N-(4-Chlorophenyl)formamido)ethyl formate (25b)

According to GR VI, Cu(CF₃SO₃)₂ (5.8 mg), 4-(4-chlorophenyl)morpholine 25a (99 mg, 0.50 mmol), acetonitrile (2.0 mL), pyridine (8.0 mg), air (20 bar), room temperature to 80 °C and then at 80 °C for 24 h. The product 25b (85 mg, 0.37 mmol, 74%) was obtained by column chromatography (n-Heptane/EtOAc: 5:1) as a light yellow liquid.

1H NMR (300 MHz, CDCl₃): δ (ppm) 8.35 (s, 1H), 7.95 (t, J = 0.7 Hz, 1H), 7.43–7.31 (m, 2H), 7.19–7.05 (m, 2H), 4.36–4.26 (m, 2H), 4.05 (m, 2H).

13C NMR (75 MHz, CDCl₃): δ (ppm) 162.38, 160.57, 139.33, 133.13, 130.05, 125.76, 60.67, 44.40.

HR-MS (EI) m/z calcd for [C₁₀H₁₀ClNO₃⁺][M⁺]: 227.0344, found: 227.0340.

2-(N-(4-Bromophenyl)formamido)ethyl formate (26b)

According to GR VI, Cu(CF₃SO₃)₂ (6.0 mg), 4-(4-bromophenyl)morpholine 26a (124 mg, 0.51 mmol), acetonitrile (2.0 mL), pyridine (8.0 mg), air (30 bar), room temperature to 100 °C and then at 100 °C for 24 h. The product 26b (51 mg, 0.19 mmol, 37%) was obtained by column chromatography (n-Heptane/EtOAc: 5:1) as a yellow liquid.

1H NMR (300 MHz, CDCl₃): δ (ppm) 8.37 (s, 1H), 7.96 (t, J = 0.7 Hz, 1H), 7.58–7.51 (m, 2H), 7.09 (d, J = 8.8 Hz, 2H), 4.33 (m, 2H), 4.12–4.02 (m, 2H).

13C NMR (75 MHz, CDCl₃): δ (ppm) 162.36, 160.57, 139.33, 133.13, 130.05, 125.76, 60.67, 44.40.

HR-MS (EI) m/z calcd for [C₁₀H₁₀BrNO₃⁺][M⁺]: 270.9839, found: 270.9841.
2-(N-(4-(4,4,5,5-Tetramethyl-1,3,2-dioxaborolan-2-yl)phenyl)formamido)ethyl formate (27b)

According to GR VI, Cu(CF$_3$SO$_3$)$_2$ (6.3 mg), 4-(4-(4,4,5,5-tetramethyl-1,3,2-dioxaborolan-2-yl)phenyl)morpholine 27a (145 mg, 0.50 mmol), acetonitrile (2.0 mL), pyridine (8.0 mg), air (20 bar), room temperature to 80 °C and then at 80 °C for 24 h. The product 27b (92 mg, 0.29 mmol, 58%) was obtained by column chromatography (n-Heptane/EtOAc: 5:1) as a light yellow liquid.

$^1$H NMR (300 MHz, CDCl$_3$): $\delta$ (ppm) 8.43 (s, 1H), 7.92 (t, $J = 0.7$ Hz, 1H), 7.89–7.73 (m, 2H), 7.22–7.10 (m, 2H), 4.42–4.24 (m, 2H), 4.11 (dd, $J = 5.9$, 5.3 Hz, 2H), 1.33 (s, 12H).

$^{13}$C NMR (75 MHz, CDCl$_3$): $\delta$ (ppm) 162.57, 160.61, 143.17, 136.45, 122.96, 84.17, 60.74, 43.92, 24.94.

HR-MS (EI) m/z calcd for [C$_{16}$H$_{22}$BNO$_5$]$^+$ [M$^+$]: 319.1586, found: 319.1590.

2-(N-(4-Formylphenyl)formamido)ethyl formate (28b)

According to GR VI, Cu(CF$_3$SO$_3$)$_2$ (6.0 mg), 4-morpholinobenzaldehyde 28a (96 mg, 0.50 mmol), acetonitrile (2.0 mL), pyridine (8.0 mg), air (30 bar), room temperature to 100 °C and then at 100 °C for 24 h. The product 28b (71 mg, 0.32 mmol, 64%) was obtained by column chromatography (n-Heptane/EtOAc: 8:1) as a colorless liquid.

$^1$H NMR (300 MHz, CDCl$_3$): $\delta$ (ppm) 9.99 (s, 1H), 8.56 (s, 1H), 7.99–7.85 (m, 3H), 7.45–7.32 (m, 2H), 4.44–4.31 (m, 2H), 4.16 (tt, $J = 5.8$, 0.5 Hz, 2H).

$^{13}$C NMR (75 MHz, CDCl$_3$): $\delta$ (ppm) 190.77, 162.14, 160.54, 146.06, 134.49, 131.47, 123.11, 60.70, 43.99.

HR-MS (EI) m/z calcd for [C$_{11}$H$_{11}$NO$_4$]$^+$ [M$^+$]: 221.0683, found: 221.0678.
4-(3-Oxomorpholino)benzaldehyde (28c)

According to **GR VI**, Cu(CF$_3$SO$_3$)$_2$ (6.0 mg), 4-morpholinobenzaldehyde 28a (96 mg, 0.50 mmol), acetonitrile (2.0 mL), pyridine (8.0 mg), air (30 bar), room temperature to 100 °C and then at 100 °C for 24 h. The product 28c (15 mg, 0.07 mmol, 14%) was obtained by column chromatography (n-Heptane/EtOAc: 8:1) as a yellow solid.

$^1$H NMR (300 MHz, CDCl$_3$): δ (ppm) 10.00 (s, 1H), 8.01–7.84 (m, 2H), 7.69–7.50 (m, 2H), 4.37 (s, 2H), 4.12–4.02 (m, 2H), 3.94–3.76 (m, 2H).

$^{13}$C NMR (75 MHz, CDCl$_3$): δ (ppm) 191.19, 166.86, 146.62, 134.42, 130.75, 125.10, 68.77, 64.15, 49.12.

HR-MS (EI) m/z calcd for [C$_{11}$H$_{11}$NO$_3$]$^+$ [M$^+$]: 205.0733, found: 205.0738.

2-(N-(4-Cyanophenyl)formamido)ethyl formate (29b)

According to **GR VI**, Cu(CF$_3$SO$_3$)$_2$ (6.0 mg), 4-morpholinobenonitrile 29a (95 mg, 0.50 mmol), acetonitrile (2.0 mL), pyridine (8.0 mg), air (30 bar), room temperature to 100 °C and then at 100 °C for 24 h. The product 29b (52 mg, 0.24 mmol, 48%) was obtained by column chromatography (n-Heptane/EtOAc: 8:1) as a white solid.

$^1$H NMR (300 MHz, CDCl$_3$): δ (ppm) 8.52 (s, 1H), 8.00–7.88 (m, 1H), 7.78–7.66 (m, 2H), 7.39–7.29 (m, 2H), 4.37 (td, $J = 5.5$, 0.9 Hz, 2H), 4.13 (dd, $J = 5.8$, 5.2 Hz, 2H).

$^{13}$C NMR (75 MHz, CDCl$_3$): δ (ppm) 161.90, 160.49, 144.85, 133.98, 123.34, 118.03, 110.47, 60.68, 44.08.

HR-MS (EI) m/z calcd for [C$_{11}$H$_{10}$N$_2$O$_3$]$^+$ [M$^+$]: 218.0686, found: 218.0685.
4-(3-Oxomorpholino)benzonitrile (29c)

According to GR VI, Cu(CF₃SO₃)₂ (6.0 mg), 4-morpholinobenzonitrile 29a (95 mg, 0.50 mmol), acetonitrile (2.0 mL), pyridine (8.0 mg), air (30 bar), room temperature to 100 °C and then at 100 °C for 24 h. The product 29c (13 mg, 0.06 mmol, 12%) was obtained by column chromatography (n-Heptane/EtOAc: 8:1) as a white solid.

₁H NMR (300 MHz, CDCl₃): δ (ppm) 7.76–7.67 (m, 2H), 7.60–7.47 (m, 2H), 4.36 (s, 2H), 4.10–4.00 (m, 2H), 3.88–3.75 (m, 2H).

₁³C NMR (75 MHz, CDCl₃): δ (ppm) 166.85, 145.21, 133.20, 125.18, 118.44, 110.24, 68.75, 64.09, 48.96.

HR-MS (EI) m/z calcd for [C₁₁H₁₀N₂O₂⁺] [M⁺]: 202.0737, found: 202.0734.

2-(N-(4-Acetylphenyl)formamido)ethyl formate (30b)

According to GR VI, Cu(CF₃SO₃)₂ (6.0 mg), 1-(4-morpholinophenyl)ethan-1-one 30a (101 mg, 0.49 mmol), acetonitrile (2.0 mL), pyridine (8.0 mg), air (30 bar), room temperature to 120 °C and then at 120 °C for 24 h. The product 30b (90 mg, 038 mmol, 78%) was obtained by column chromatography (n-Heptane/EtOAc: 8:1) as a yellow liquid.

₁H NMR (300 MHz, CDCl₃): δ (ppm) 8.45 (s, 1H), 8.00–7.89 (m, 2H), 7.87 (t, J = 0.7 Hz, 1H), 7.28–7.09 (m, 2H), 4.36–4.22 (m, 2H), 4.07 (dd, J = 5.9, 5.2 Hz, 2H), 2.52 (s, 3H).

₁³C NMR (75 MHz, CDCl₃): δ (ppm) 196.67, 162.16, 160.52, 144.81, 135.26, 130.14, 122.83, 60.64, 43.87, 26.62.

HR-MS (EI) m/z calcd for [C₁₂H₁₃NO₄⁺] [M⁺]: 235.0839, found: 235.0838.
2-(N-(4-(2-Phenylacetyl)phenyl)formamido)ethyl formate (31b)

According to GR VI, Cu(CF₃SO₃)₂ (6.5 mg), 1-(4-morpholinophenyl)-2-phenylethan-1-one 31a (143 mg, 0.54 mmol), acetonitrile (2.0 mL), pyridine (8.0 mg), air (30 bar), room temperature to 100 °C and then at 100 °C for 24 h. The product 31b (73 mg, 0.25 mmol, 46%) was obtained by column chromatography (n-Heptane/EtOAc: 5:1) as a light yellow liquid.

¹H NMR (300 MHz, CDCl₃): δ (ppm) 8.45 (s, 1H), 8.04–7.95 (m, 2H), 7.87 (t, J = 0.7 Hz, 1H), 7.33–7.07 (m, 7H), 4.33–4.25 (m, 2H), 4.20 (s, 2H), 4.06 (dd, J = 5.9, 5.3 Hz, 2H).

¹³C NMR (75 MHz, CDCl₃): δ (ppm) 196.27, 162.18, 160.56, 144.89, 134.72, 134.25, 130.54, 129.45, 128.87, 127.15, 122.86, 60.69, 45.66, 43.93.

HR-MS (EI) m/z calcd for [C₁₈H₁₇NO₄⁺] [M⁺]: 311.1152, found: 311.1154.

4-(N-(2-(Formyloxy)ethyl)formamido)benzoic acid (32b)

According to GR VI, Cu(CF₃SO₃)₂ (6.3 mg), 4-morpholinobenzoic acid 32a (104 mg, 0.50 mmol), acetonitrile (2.0 mL), pyridine (8.0 mg), air (30 bar), room temperature to 120 °C and at 120 °C for 24 h. The product 32b (71 mg, 0.30 mmol, 60%) was obtained by column chromatography (n-Heptane/EtOAc: 3:1) as a white solid.

¹H NMR (300 MHz, DMSO-d₆): δ (ppm) 12.99 (s, 1H), 8.62 (s, 1H), 8.17–8.07 (m, 1H), 8.08–7.87 (m, 2H), 7.54–7.41 (m, 2H), 4.28–4.18 (m, 2H), 4.14–4.05 (m, 2H).

¹³C NMR (75 MHz, DMSO-d₆): δ (ppm) 166.71, 162.18, 161.87, 144.52, 130.73, 128.06, 22.15, 60.17, 42.48.

HR-MS (EI) m/z calcd for [C₁₁H₁₁NO₅⁺] [M⁺]: 237.0631, found: 237.0632.
2-(N-(4-Acetamidophenyl)formamido)ethyl formate (33b)

According to GR VI, Cu(CF$_3$SO$_3$)$_2$ (6.5 mg), N-(4-morpholinophenyl)acetamide 33a (111 mg, 0.50 mmol), acetonitrile (2.0 mL), pyridine (8.0 mg), air (30 bar), room temperature to 100 °C and then at 100 °C for 24 h. The product 33b (89 mg, 0.36 mmol, 72%) was obtained by column chromatography (n-Heptane/EtOAc: 4:1) as a light brown liquid.

$^1$H NMR (300 MHz, DMSO-d$_6$): δ (ppm) 10.03 (s, 1H), 8.34 (s, 1H), 8.14 (t, $J = 0.7$ Hz, 1H), 7.73–7.55 (m, 2H), 7.32–7.19 (m, 2H), 4.17 (dd, $J = 5.9, 5.0$ Hz, 2H), 4.03–3.94 (m, 2H), 2.05 (s, 3H).

$^{13}$C NMR (75 MHz, DMSO-d$_6$): δ (ppm) 168.37, 162.46, 161.87, 137.88, 135.29, 124.50, 119.78, 60.10, 43.11, 23.98.

HR-MS (EI) m/z calcd for [C$_{12}$H$_{14}$N$_2$O$_4$]$^+$: 250.0948, found: 250.0947.

2-(N-(4-Nitrophenyl)formamido)ethyl formate (34b)$^{[4]}$

According to GR VI, Cu(CF$_3$SO$_3$)$_2$ (5.8 mg), 4-(4-nitrophenyl)morpholine 34a (105 mg, 0.50 mmol), acetonitrile (2.0 mL), pyridine (8.0 mg), air (30 bar), room temperature to 100 °C and then at 100 °C for 24 h. The product 34b (51 mg, 0.21 mmol, 42%) was obtained by column chromatography (n-Heptane/EtOAc: 4:1) as a yellow liquid.

$^1$H NMR (300 MHz, CDCl$_3$): δ (ppm) 8.59 (s, 1H), 8.35–8.21 (m, 2H), 7.95 (q, $J = 0.7$ Hz, 1H), 7.44–7.31 (m, 2H), 4.44–4.33 (m, 2H), 4.17 (dd, $J = 5.9, 5.2$ Hz, 2H).

$^{13}$C NMR (75 MHz, CDCl$_3$): δ (ppm) 161.84, 160.49, 146.57, 145.81, 125.60, 122.84, 60.71, 44.18.
2-(N-(3-Chlorophenyl)formamido)ethyl formate (35b)

According to GR VI, Cu(CF$_3$SO$_3$)$_2$ (6.5 mg), 4-(3-chlorophenyl)morpholine 35a (125 mg, 0.64 mmol), acetonitrile (2.0 mL), pyridine (8.0 mg), air (30 bar), room temperature to 100 °C and then at 100 °C for 24 h. The product 35b (47 mg, 0.21 mmol, 33%) was obtained by column chromatography (n-Heptane/EtOAc: 5:1) as a light yellow liquid.

$^1$H NMR (300 MHz, CDCl$_3$): $\delta$ (ppm) 8.40 (s, 1H), 7.98 (p, $J = 0.7$ Hz, 1H), 7.41–7.27 (m, 2H), 7.23 (td, $J = 2.0$, 0.5 Hz, 1H), 7.10 (ddd, $J = 7.7$, 2.2, 1.3 Hz, 1H), 4.35 (td, $J = 5.6$, 0.9 Hz, 2H), 4.09 (dd, $J = 5.9$, 5.2 Hz, 2H).

$^{13}$C NMR (75 MHz, CDCl$_3$): $\delta$ (ppm) 162.38, 160.61, 142.07, 135.58, 130.95, 127.55, 124.54, 122.43, 60.72, 44.39.

HR-MS (EI) m/z calcd for [C$_{10}$H$_{10}$ClNO$_3$]+ [M$^+$]: 227.0344, found: 227.0343.

2-(N-(3-Bromophenyl)formamido)ethyl formate (36b)

According to GR VI, Cu(CF$_3$SO$_3$)$_2$ (6.1 mg), 4-(3-bromophenyl)morpholine 36a (117 mg, 0.49 mmol), acetonitrile (2.0 mL), pyridine (8.0 mg), air (30 bar), room temperature to 100 °C and then at 100 °C for 24 h. The product 36b (59 mg, 0.22 mmol, 45%) was obtained by column chromatography (n-Heptane/EtOAc: 8:1) as a yellow liquid.

$^1$H NMR (300 MHz, CDCl$_3$): $\delta$ (ppm) 8.33 (s, 1H), 7.91 (p, $J = 0.7$ Hz, 1H), 7.39 (ddd, $J = 8.0$, 1.8, 1.0 Hz, 1H), 7.34–7.29 (m, 1H), 7.24–7.19 (m, 1H), 7.08 (ddd, $J = 8.0$, 2.2, 1.0 Hz, 1H), 4.34–4.19 (m, 2H), 4.06–3.98 (m, 2H).

$^{13}$C NMR (75 MHz, CDCl$_3$): $\delta$ (ppm) 162.35, 160.61, 142.07, 135.58, 130.95, 127.55, 124.54, 122.92, 60.72, 44.38.

HR-MS (EI) m/z calcd for [C$_{10}$H$_{10}$BrNO$_3$]+ [M$^+$]: 270.9839, found: 270.9841.
2-(N-(3-Cyanophenyl)formamido)ethyl formate (37b)

According to GR VI, Cu(CF₃SO₃)₂ (5.8 mg), 3-morpholinobenzonitrile 37a (85 mg, 0.45 mmol), acetonitrile (2.0 mL), pyridine (8.0 mg), air (30 bar), room temperature to 100 °C and then at 100 °C for 24 h. The product 37b (59 mg, 0.27 mmol, 60%) was obtained by column chromatography (n-Heptane/EtOAc: 5:1) as a light yellow liquid.

1H NMR (400 MHz, CDCl₃): δ (ppm) 8.43 (s, 1H), 7.97 (t, J = 0.8 Hz, 1H), 7.65–7.52 (m, 3H), 7.47 (ddd, J = 7.9, 2.3, 1.3 Hz, 1H), 4.36 (ddd, J = 5.7, 5.1, 0.8 Hz, 2H), 4.11 (td, J = 5.4, 0.6 Hz, 2H).

13C NMR (101 MHz, CDCl₃): δ (ppm) 162.01, 160.49, 141.91, 131.01, 130.67, 128.37, 127.26, 117.71, 114.24, 60.72, 44.53.

HR-MS (EI) m/z calcd for [C₁₁H₁₀N₂O₃]+ [M⁺]: 218.0686, found: 218.0686.

2-(N-(3-Acetylphenyl)formamido)ethyl formate (38b)

According to GR VI, Cu(CF₃SO₃)₂ (6.0 mg), 1-(3-morpholinophenyl)ethan-1-one 38a (100 mg, 0.49 mmol), acetonitrile (2.0 mL), pyridine (8.0 mg), air (30 bar), room temperature to 100 °C and then at 100 °C for 24 h. The product 38b (82 mg, 0.35 mmol, 71%) was obtained by column chromatography (n-Heptane/EtOAc: 5:1) as a light yellow liquid.

1H NMR (300 MHz, CDCl₃): δ (ppm) 8.41 (s, 1H), 7.94 (m, 1H), 7.87 (ddd, J = 7.7, 1.6, 1.0 Hz, 1H), 7.80 (ddd, J = 2.2, 1.7, 0.5 Hz, 1H), 7.53 (td, J = 7.8, 0.5 Hz, 1H), 7.40 (ddd, J = 8.0, 2.3, 1.1 Hz, 1H), 4.37–4.26 (m, 2H), 4.12 (dd, J = 5.8, 5.2 Hz, 2H), 2.61 (s, 3H).

13C NMR (75 MHz, CDCl₃): δ (ppm) 196.96, 162.41, 160.56, 141.35, 138.71, 130.26, 128.58, 127.19, 123.55, 60.69, 44.28, 26.79.

HR-MS (EI) m/z calcd for [C₁₂H₁₃NO₄]⁺ [M⁺]: 235.0839, found: 235.0838.
2-(N-(3-(4,4,5,5-Tetramethyl-1,3,2-dioxaborolan-2-yl)phenyl)formamido)ethyl formate (39b)

According to GR VI, Cu(CF$_3$SO$_3$)$_2$ (6.0 mg), 4-(3-(4,4,5,5-tetramethyl-1,3,2-dioxaborolan-2-yl)phenyl)morpholine 39a (150 mg, 0.52 mmol), acetonitrile (2.0 mL), pyridine (8.0 mg), air (20 bar), room temperature to 80 °C and then at 80 °C for 24 h. The product 39b (94 mg, 0.30 mmol, 58%) was obtained by column chromatography (n-Heptane/EtOAc: 8:1) as a colorless liquid.

$^1$H NMR (300 MHz, CDCl$_3$): δ (ppm) 8.30 (s, 1H), 7.88 (q, $J = 0.7$ Hz, 1H), 7.66 (dt, $J = 7.3, 1.2$ Hz, 1H), 7.52 (ddd, $J = 2.5, 1.1, 0.5$ Hz, 1H), 7.34 (ddd, $J = 7.9, 7.4, 0.5$ Hz, 1H), 7.25–7.15 (m, 1H), 4.30–4.15 (m, 2H), 4.03 (ddd, $J = 5.9, 5.2, 0.6$ Hz, 2H), 1.26 (s, 12H).

$^{13}$C NMR (75 MHz, CDCl$_3$): δ (ppm) 162.82, 160.67, 140.16, 133.73, 130.57, 129.34, 127.42, 84.33, 60.73, 44.14, 24.96.

HR-MS (EI) m/z calcd for [C$_{16}$H$_{22}$BNO$_5$]$^+$ [M$^+$]: 319.1586, found: 319.1591.

2-(N-o-Tolyiformamido)ethyl formate (40b)

According to GR VI, Cu(CF$_3$SO$_3$)$_2$ (6.2 mg), 4-(o-tolyl)morpholine 40a (95 mg, 0.54 mmol), acetonitrile (2.0 mL), pyridine (8.0 mg), air (30 bar), room temperature to 100 °C and then at 100 °C for 24 h. The product 40b (53 mg, 0.26 mmol, 48%) was obtained by column chromatography (n-Heptane/EtOAc: 10:1) as a light yellow liquid.

$^1$H NMR (300 MHz, CDCl$_3$): δ (ppm) 8.15 (s, 1H), 7.98 (t, $J = 0.8$ Hz, 1H), 7.33–7.27 (m, 2H), 7.26 (s, 1H), 7.20–7.11 (m, 1H), 4.30 (td, $J = 5.6, 0.9$ Hz, 2H), 3.98 (t, $J = 5.6$ Hz, 2H), 2.27 (s, 3H).

$^{13}$C NMR (75 MHz, CDCl$_3$): δ (ppm) 163.48, 160.67, 138.97, 135.94, 131.76, 128.90, 127.42, 60.77, 44.26, 17.87.

HR-MS (EI) m/z calcd for [C$_{11}$H$_{13}$NO$_3$]$^+$ [M$^+$]: 207.0890, found: 207.0890.
2-(N-(2-Methoxyphenyl)formamido)ethyl formate (41b)

According to GR VI, Cu(CF₃SO₃)₂ (6.0 mg), 4-(2-methoxyphenyl)morpholine 41a (95 mg, 0.49 mmol), acetonitrile (2.0 mL), pyridine (8.0 mg), air (30 bar), room temperature to 100 °C and then at 100 °C for 24 h. The product 41b (76 mg, 0.34 mmol, 69%) was obtained by column chromatography (n-Heptane/EtOAc: 8:1) as a yellow liquid.

1H NMR (400 MHz, CDCl₃): δ (ppm) 8.13 (s, 1H), 7.94 (p, J = 0.7 Hz, 1H), 7.33 (ddd, J = 8.3, 7.5, 1.7 Hz, 1H), 7.14 (dd, J = 8.0, 1.7 Hz, 1H), 7.02–6.90 (m, 2H), 4.32–4.16 (m, 2H), 3.99 (td, J = 5.7, 0.6 Hz, 2H), 3.82 (s, 3H).

13C NMR (101 MHz, CDCl₃): δ (ppm) 163.78, 160.72, 155.36, 129.72, 129.13, 128.80, 121.03, 111.99, 60.98, 55.67, 43.69.

HR-MS (EI) m/z calcd for [C₁₁H₁₃NO₄⁺] [M⁺]: 223.0839, found: 223.0834.

2-(N-(2-Chlorophenyl)formamido)ethyl formate (42b)

According to GR VI, Cu(CF₃SO₃)₂ (6.0 mg), 4-(2-chlorophenyl)morpholine 42a (76 mg, 0.39 mmol), acetonitrile (2.0 mL), pyridine (8.0 mg), air (30 bar), room temperature to 100 °C and then at 100 °C for 24 h. The product 42b (42 mg, 0.19 mmol, 49%) was obtained by column chromatography (n-Heptane/EtOAc: 8:1) as a colorless liquid.

1H NMR (300 MHz, CDCl₃): δ (ppm) 8.10 (s, 1H), 7.90 (t, J = 0.7 Hz, 1H), 7.51–7.42 (m, 1H), 7.33–7.22 (m, 3H), 4.25 (td, J = 5.6, 0.9 Hz, 2H), 3.98 (t, J = 5.5 Hz, 2H).

13C NMR (75 MHz, CDCl₃): δ (ppm) 163.20, 160.72, 155.36, 129.72, 129.13, 128.80, 121.03, 111.99, 60.98, 44.29.

HR-MS (EI) m/z calcd for [C₁₀H₁₀ClNO₃⁺] [M⁺]: 227.0344, found: 227.0343.
Ethyl 2-(N-(2-(Formyloxy)ethyl)formamido)benzoate (43b)

According to GR VI, Cu(CF₃SO₃)₂ (6.9 mg), ethyl 2-morpholinobenzoate 43a (116 mg, 0.49 mmol), acetonitrile (2.0 mL), pyridine (8.0 mg), air (30 bar), room temperature to 100 °C and then at 100 °C for 24 h. The product 43b (41 mg, 0.15 mmol, 31%) was obtained by column chromatography (n-Heptane/EtOAc: 8:1) as a yellow liquid.

¹H NMR (400 MHz, CDCl₃): δ (ppm) 8.14 (s, 1H), 8.02 (ddd, J = 7.8, 1.7, 0.4 Hz, 1H), 7.94 (p, J = 0.7 Hz, 1H), 7.60 (ddd, J = 7.9, 7.5, 1.6 Hz, 1H), 7.49–7.44 (m, 1H), 7.31 (ddd, J = 8.0, 1.2, 0.4 Hz, 1H), 4.39–4.23 (m, 4H), 4.00 (t, J = 5.6 Hz, 2H), 1.36 (t, J = 7.1 Hz, 3H).

¹³C NMR (101 MHz, CDCl₃): δ (ppm) 165.59, 162.96, 160.67, 140.48, 133.43, 132.22, 129.94, 129.31, 128.68, 61.95, 61.29, 45.69, 14.29.

GC-MS (EI) (70 eV): m/z (%) = 265 (M⁺).

2-(N-(3,4-Dimethylphenyl)formamido)ethyl formate (44b)

According to GR VI, Cu(CF₃SO₃)₂ (6.4 mg), 4-(3,4-dimethylphenyl)morpholine 44a (96 mg, 0.50 mmol), acetonitrile (2.0 mL), pyridine (8.0 mg), air (30 bar), room temperature to 100 °C and then at 100 °C for 24 h. The product 44b (82 mg, 0.37 mmol, 74%) was obtained by column chromatography (n-Heptane/EtOAc: 8:1) as a light yellow liquid.

¹H NMR (300 MHz, CDCl₃): δ (ppm) 8.33 (s, 1H), 7.97 (t, J = 0.7 Hz, 1H), 7.15 (dq, J = 7.9, 0.6 Hz, 1H), 6.99–6.82 (m, 2H), 4.37–4.24 (m, 2H), 4.05 (dd, J = 6.0, 5.4 Hz, 2H), 2.26 (m, 6H).

¹³C NMR (75 MHz, CDCl₃): δ (ppm) 162.82, 160.69, 138.38, 138.25, 136.12, 130.82, 125.91, 122.12, 60.65, 44.18, 19.98, 19.36.

HR-MS (EI) m/z calcd for [C₁₂H₁₅NO₃⁺] [M⁺]: 221.1046, found: 221.1043.
2-(N-(3,5-Dimethylphenyl)formamido)ethyl formate (45b)

![Chemical structure of 45b](image)

According to GR VI, Cu(CF₃SO₃)₂ (6.5 mg), 4-(3,5-dimethylphenyl)morpholine 45a (95 mg, 0.50 mmol), acetonitrile (2.0 mL), pyridine (8.0 mg), air (30 bar), room temperature to 100 °C and then at 100 °C for 24 h. The product 45b (72 mg, 0.33 mmol, 66%) was obtained by column chromatography (n-Heptane/EtOAc: 8:1) as a light yellow liquid.

1H NMR (300 MHz, CDCl₃): δ (ppm) 8.35 (s, 1H), 7.97 (t, J = 0.7 Hz, 1H), 6.94 (dt, J = 1.5, 0.7 Hz, 1H), 6.79 (tt, J = 1.3, 0.6 Hz, 2H), 4.38–4.24 (m, 2H), 4.06 (t, J = 5.7 Hz, 2H), 2.33 (m, 6H).

13C NMR (75 MHz, CDCl₃): δ (ppm) 162.79, 160.70, 140.48, 139.72, 129.08, 122.30, 60.67, 44.08, 21.36.

HR-MS (EI) m/z calcd for [C₁₂H₁₅NO₃⁺] [M⁺]: 221.1046, found: 221.1042.

2-(N-(3,5-Dichlorophenyl)formamido)ethyl formate (46b)

![Chemical structure of 46b](image)

According to GR VI, Cu(CF₃SO₃)₂ (6.2 mg), 4-(3,5-dichlorophenyl)morpholine 46a (115 mg, 0.50 mmol), acetonitrile (2.0 mL), pyridine (8.0 mg), air (30 bar), room temperature to 100 °C and then at 100 °C for 24 h. The product 46b (57 mg, 0.22 mmol, 44%) was obtained by column chromatography (n-Heptane/EtOAc: 5:1) as a white solid.

1H NMR (300 MHz, CDCl₃): δ (ppm) 8.41 (s, 1H), 7.98 (p, J = 0.7 Hz, 1H), 7.31 (t, J = 1.8 Hz, 1H), 7.13 (d, J = 1.8 Hz, 2H), 4.34 (td, J = 5.5, 0.9 Hz, 2H), 4.06 (ddd, J = 6.0, 5.1, 0.6 Hz, 2H).

13C NMR (75 MHz, CDCl₃): δ (ppm) 161.95, 160.52, 142.88, 136.21, 127.37, 123.30, 60.65, 44.43.

HR-MS (EI) m/z calcd for [C₁₀H₉Cl₂NO₃⁺] [M⁺]: 260.9954, found: 260.9958.
2-(N-(3,4-Difluorophenyl)formamido)ethyl formate (47b)

According to GR VI, Cu(CF$_3$SO$_3$)$_2$ (5.8 mg), 4-(3,4-difluorophenyl)morpholine 47a (100 mg, 0.50 mmol), acetonitrile (2.0 mL), pyridine (8.0 mg), air (30 bar), room temperature to 100 °C and then at 100 °C for 24 h. The product 47b (78 mg, 0.34 mmol, 68%) was obtained by column chromatography (n-Heptane/EtOAc: 8:1) as a brown liquid.

$^1$H NMR (300 MHz, CDCl$_3$): δ (ppm) 8.43 (s, 1H), 8.06 (t, J = 0.7 Hz, 1H), 7.37–7.28 (m, 1H), 7.18 (ddd, J = 10.8, 6.8, 2.7 Hz, 1H), 7.04 (dddd, J = 8.8, 3.7, 2.7, 1.7 Hz, 1H), 4.42 (ddd, J = 5.7, 5.1, 0.8 Hz, 2H), 4.12 (ddd, J = 6.0, 5.1, 0.6 Hz, 2H).

$^{13}$C NMR (75 MHz, CDCl$_3$): δ (ppm) 162.21, 160.45, 150.61 (dd, J = 252.1, 14.1 Hz), 149.50 (dd, J = 250.1, 12.5 Hz), 137.23 (dd, J = 7.5, 3.6 Hz), 120.83 (dd, J = 6.4, 3.6 Hz), 118.26 (dd, J = 18.4, 1.4 Hz), 114.23 (dd, J = 19.0, 0.9 Hz), 60.68, 44.76.

$^{19}$F NMR (282 MHz, CDCl$_3$): δ (ppm) -132.93– -134.53 (m), -138.20 (d, J = 21.3 Hz).

HR-MS (EI) m/z calcd for [C$_{10}$H$_9$F$_2$NO$_3$]$^+$ [M$^+$]: 229.0545, found: 229.0544.

2-(N-(4-Chloro-2-fluorophenyl)formamido)ethyl formate (48b)

According to GR VI, Cu(CF$_3$SO$_3$)$_2$ (6.3 mg), 4-(4-chloro-2-fluorophenyl)morpholine 48a (109 mg, 0.51 mmol), acetonitrile (2.0 mL), pyridine (8.0 mg), air (30 bar), room temperature to 100 °C and then at 100 °C for 24 h. The product 48b (72 mg, 0.29 mmol, 57%) was obtained by column chromatography (n-Heptane/EtOAc: 8:1) as a light yellow liquid.

$^1$H NMR (300 MHz, CDCl$_3$): δ (ppm) 8.29 (d, J = 1.9 Hz, 1H), 8.03 (t, J = 0.7 Hz, 1H), 7.37–7.27 (m, 3H), 4.40 (td, J = 5.4, 0.7 Hz, 2H), 4.16 – 4.07 (m, 2H).

$^{13}$C NMR (75 MHz, CDCl$_3$): δ (ppm) 162.73 (d, J = 1.9 Hz), 160.53, 159.42, 156.06, 134.89 (d, J = 9.7 Hz), 130.78 (d, J = 2.2 Hz), 129.59 (d, J = 1.6 Hz), 127.10 (d, J = 12.0 Hz), 125.65 (d, J = 3.9 Hz), 118.09, 117.78, 60.89, 44.35 (d, J = 2.3 Hz).

$^{19}$F NMR (282 MHz, CDCl$_3$) δ (ppm) -118.98.
2-\((N-(N\text{-naphthalen-1-yl})\text{formamido})\)ethyl formate (49b)

According to GR VI, Cu\((\text{CF}_3\text{SO}_3\))\(_2\) (6.2 mg), 4-(naphthalen-1-yl)morpholine 49a (106 mg, 0.50 mmol), acetonitrile (2.0 mL), pyridine (8.0 mg), air (30 bar), room temperature to 100 °C and then at 100 °C for 24 h. The product 49b (68 mg, 0.28 mmol, 56%) was obtained by column chromatography (n-Heptane/EtOAc: 8:1) as a light yellow liquid.

\(^1\)H NMR (400 MHz, CDCl\(_3\)): \(\delta\) (ppm) 8.30 (s, 1H), 7.98–7.89 (m, 3H), 7.84–7.77 (m, 1H), 7.61–7.48 (m, 3H), 7.41 (dd, \(J = 7.2, 1.2\) Hz, 1H), 4.59–4.42 (m, 1H), 4.32 (td, \(J = 5.5, 0.8\) Hz, 2H), 3.90–3.73 (m, 1H).

\(^{13}\)C NMR (101 MHz, CDCl\(_3\)): \(\delta\) (ppm) 163.80, 160.67, 136.31, 134.74, 130.79, 129.50, 128.83, 127.69, 126.98, 126.52, 125.58, 122.19, 60.85, 45.01.

HR-MS (EI) m/z calcd for \([C_{14}H_{13}NO_3]^+\) [M\(^+\)]: 243.0890, found: 243.0890.

2-\((N-(6\text{-methoxynaphthalen-2-yl})\text{formamido})\)ethyl formate (50b)

According to GR VI, Cu\((\text{CF}_3\text{SO}_3\))\(_2\) (6.0 mg), 4-(6-methoxynaphthalen-2-yl)morpholine 50a (111 mg, 0.46 mmol), acetonitrile (2.0 mL), pyridine (8.0 mg), air (30 bar), room temperature to 100 °C and then at 100 °C for 24 h. The product 50b (79 mg, 0.29 mmol, 63%) was obtained by column chromatography (n-Heptane/EtOAc: 5:1) as a light yellow liquid.

\(^1\)H NMR (300 MHz, CDCl\(_3\)): \(\delta\) (ppm) 8.37 (s, 1H), 7.88 (t, \(J = 0.7\) Hz, 1H), 7.73–7.61 (m, 2H), 7.47 (dd, \(J = 2.3, 0.7\) Hz, 1H), 7.24–7.18 (m, 1H), 7.13 (dd, \(J = 8.9, 2.5\) Hz, 1H), 7.07 (d, \(J = 2.6\) Hz, 1H), 4.35–4.22 (m, 2H), 4.08 (dd, \(J = 5.9, 5.3\) Hz, 2H), 3.84 (s, 3H).

\(^{13}\)C NMR (75 MHz, CDCl\(_3\)): \(\delta\) (ppm) 162.95, 160.67, 158.28, 135.95, 133.49, 129.25, 128.92, 128.70, 123.46, 123.09, 120.17, 105.75, 60.76, 55.46, 44.35.

HR-MS (EI) m/z calcd for \([C_{15}H_{15}NO_4]^+\) [M\(^+\)]: 273.0996, found: 273.0998.
2-(N-(Pyridin-2-yl)formamido)ethyl formate (51b) and 4-(pyridin-2-yl)morpholin-3-one (51c)

According to GR VI, Cu(CF$_3$SO$_3$)$_2$ (6.0 mg), 4-(pyridin-2-yl)morpholine 51a (82 mg, 0.50 mmol), acetonitrile (2.0 mL), pyridine (8.0 mg), air (30 bar), room temperature to 100 °C and then at 100 °C for 24 h. The product 51b and 51c (32 mg) were obtained by column chromatography (n-Heptane/EtOAc: 5:1) as a colorless liquid.

$^1$H NMR (400 MHz, CDCl$_3$): δ (ppm) 9.05 (s, 1H), 8.40–8.33 (m, 1H), 8.05–7.96 (m, 0.64H), 7.91 (t, $J = 0.8$ Hz, 1H), 7.66 (dddd, $J = 9.8, 8.4, 7.4, 1.9$ Hz, 1.66H), 7.14–6.99 (m, 2.62H), 4.35 (tt, $J = 5.7, 0.8$ Hz, 2H), 4.29 (s, 1H), 4.28–4.21 (m, 2H), 4.07–4.01 (m, 1H), 4.01–3.94 (m, 1H).

$^{13}$C NMR (101 MHz, CDCl$_3$): δ (ppm) 162.35, 160.86, 148.98, 147.76, 138.80, 137.63, 120.83, 119.39, 112.88, 68.73, 64.49, 61.15, 45.78, 40.80.

HR-MS (ESI): m/z calculated for 51b [C$_9$H$_{11}$N$_2$O$_3$]$^+$ ([M+H]$^+$): 195.0764, found: 195.0762.

HR-MS (ESI): m/z calculated for 51c [C$_9$H$_{11}$N$_2$O$_2$]$^+$ ([M+H]$^+$): 179.0815, found: 179.0811.

2-(N-(9-Phenyl-9H-carbazol-3-yl)formamido)ethyl formate (52b)

According to GR VI, Cu(CF$_3$SO$_3$)$_2$ (6.2 mg), 4-(9-phenyl-9H-carbazol-3-yl)morpholine 52a (149 mg, 0.45 mmol), acetonitrile (2.0 mL), pyridine (8.0 mg), air (30 bar), room temperature to 100 °C and then at 100 °C for 24 h. The product 52b (122 mg, 0.34 mmol, 76%) was obtained by column chromatography (n-Heptane/EtOAc: 5:1) as a light yellow liquid.

$^1$H NMR (400 MHz, CDCl$_3$): δ (ppm) 8.52 (s, 1H), 8.16 (dd, $J = 7.8, 1.1$ Hz, 1H), 8.03 (s, 1H), 7.99 (d, $J = 2.1$ Hz, 1H), 7.66 (t, $J = 7.7$ Hz, 2H), 7.59–7.42 (m, 6H), 7.39–7.32 (m, 1H), 7.30–7.21 (m, 1H), 4.42 (t, $J = 5.6$ Hz, 2H), 4.22 (t, $J = 5.6$ Hz, 2H).
$^{13}$C NMR (101 MHz, CDCl$_3$): $\delta$ (ppm) 163.39, 160.76, 141.74, 139.95, 137.23, 133.09, 130.15, 128.03, 127.16, 126.97, 124.11, 123.76, 122.66, 120.58, 120.54, 120.54, 117.80, 60.79, 45.10.

HR-MS (ESI): m/z calculated for [C$_{22}$H$_{19}$N$_2$O$_3$]$^+$ ([M+H]$^+$): 359.1390, found: 359.1389.

2-(N-(Dibenzo[b,d]furan-2-yl)formamido)ethyl formate (53b)

According to GR VI, Cu(CF$_3$SO$_3$)$_2$ (6.0 mg), 4-(dibenzo[b,d]furan-2-yl)morpholine 53a (98 mg, 0.51 mmol), acetonitrile (2.0 mL), pyridine (8.0 mg), air (30 bar), room temperature to 100 °C and then at 100 °C for 24 h. The product 53b (98 mg, 0.35 mmol, 74%) was obtained by column chromatography (n-Heptane/EtOAc: 5:1) as a light yellow liquid.

$^1$H NMR (400 MHz, CDCl$_3$): $\delta$ (ppm) 8.45 (s, 1H), 8.01 (t, $J = 0.7$ Hz, 1H), 7.96 (ddd, $J = 7.7$, 1.4, 0.7 Hz, 1H), 7.79 (dd, $J = 2.3$, 0.6 Hz, 1H), 7.60 (dt, $J = 8.3$, 0.7 Hz, 2H), 7.52 (ddd, $J = 8.4$, 7.2, 1.3 Hz, 1H), 7.43–7.35 (m, 1H), 7.30 (dd, $J = 8.7$, 2.3 Hz, 1H), 4.39 (ddd, $J = 5.8$, 5.3, 0.8 Hz, 2H), 4.24–4.13 (m, 2H).

$^{13}$C NMR (101 MHz, CDCl$_3$): $\delta$ (ppm) 163.07, 160.67, 157.02, 154.94, 135.79, 128.19, 125.50, 124.56, 123.46, 123.23, 120.95, 117.83, 112.76, 112.03, 60.72, 45.01.

HR-MS (ESI): m/z calculated for [C$_{16}$H$_{14}$NO$_4$]$^+$ ([M+H]$^+$): 284.0917, found: 284.0919.

2-(N-methylformamido)ethyl formate (54b)

According to GR VI, Cu(CF$_3$SO$_3$)$_2$ (6.0 mg), 4-methylmorpholine 54a (100 mg, 1.0 mmol), acetonitrile (2.0 mL), pyridine (40 mg), air (30 bar), room temperature to 100 °C and then at 100 °C for 24 h. The product 54b (44 mg, 0.34 mmol, 34%) was obtained by column chromatography (n-Heptane/EtOAc: 5:1) as a colorless yellow liquid.

$^1$H NMR (400 MHz, CDCl$_3$): $\delta$ (ppm) 8.12–7.94 (m, 2H), 4.28 (dtd, $J = 13.8$, 5.3, 0.8 Hz, 2H), [3.63–3.57 (m), 3.50 (t, $J = 5.3$ Hz), 2H], [3.01 (s)–2.89 (d), (3H)].

$^{13}$C NMR (101 MHz, CDCl$_3$): $\delta$ (ppm) 163.03, 162.99, 160.72, 160.48, 60.96, 60.04, 48.19, 43.29, 35.54, 29.86.

S70
HR-MS (ESI): m/z calculated for [C₅H₉NO₃Na]⁺ ([M+Na]⁺): 154.0475, found: 154.0473.

2-(N-Ethylformamido)ethyl formate (55b)

According to GP III, CuCl (2.5 mg), acetonitrile (2.0 mL), pyridine (80 mg), N-ethylmorpholine 55a (91 mg, 0.79 mmol), air (30 bar), room temperature to 100 °C and then at 100 °C for 24 h. The product 55b (63 mg, 0.43 mmol, 54%) was obtained by column chromatography (n-Heptane/EtOAc: 5:1) as a light yellow liquid.

¹H NMR (300 MHz, CDCl₃) δ 8.29–7.92 (m, 2H), 4.25 (dtd, J = 13.8, 5.6, 0.8 Hz, 2H), 3.60–3.27 (m, 4H), 1.15 (dt, J = 20.1, 7.2 Hz, 3H).

¹³C NMR (75 MHz, CDCl₃) δ 162.98, 160.50, 61.15, 43.12, 40.93, 14.86.

HR-MS (EI) m/z calcd for [C₆H₁₁NO₃⁺][M⁺]: 145.0733, found: 145.0733.

2-(N-Decylformamido)ethyl formate (56b)

According to GR VI, Cu(CF₃SO₃)₂ (6.0 mg), 4-decylmorpholine 56a (130 mg, 0.57 mmol), acetonitrile (2.0 mL), pyridine (40 mg), air (40 bar), room temperature to 130 °C and then at 130 °C for 24 h. The product 56b (120 mg, 0.47 mmol, 82%) was obtained by column chromatography (n-Heptane/EtOAc: 5:1) as a yellow liquid.

¹H NMR (400 MHz, CDCl₃) δ 8.27–7.85 (m, 2H), 4.25 (dtd, J = 20.3, 5.5 Hz, 2H), 3.55 (t, J = 5.7 Hz, 1H), 3.47 (t, J = 5.4 Hz, 1H), 3.35–3.19 (m, 2H), 1.51 (dt, J = 13.1, 4.3 Hz, 2H), 1.35–1.14 (m, 14H), 0.87–0.82 (m, 3H).

¹³C NMR (101 MHz, CDCl₃) δ 163.34, 160.72, 61.09, 48.43, 41.26, 31.89, 29.53, 29.30, 29.21, 28.75, 27.35, 26.89, 26.44, 22.71, 14.15.

HR-MS (EI) m/z calcd for [C₁₄H₂₇NO₃⁺][M⁺]: 257.1986, found: 257.1985.
(R)-2-(N-Phenylformamido)propyl formate (57b)

![Chemical structure](image)

According to GR VI, Cu(CF₃SO₃)₂ (6.2 mg), (R)-3-methyl-4-phenylmorpholine 57a (75 mg, 0.38 mmol), acetonitrile (2.0 mL), pyridine (8.0 mg), air (30 bar), room temperature to 100 °C and then at 100 °C for 24 h. The product 57b (52 mg, 0.25 mmol, 66%) was obtained by column chromatography (n-Heptane/EtOAc: 8:1) as a yellow liquid.

¹H NMR (300 MHz, CDCl₃): δ (ppm) 8.23 (s, 1H), 8.06 (t, J = 0.8 Hz, 1H), 7.46–7.36 (m, 3H), 7.22–7.15 (m, 2H), 4.85 (ddd, J = 8.8, 7.0, 5.1 Hz, 1H), 4.30 (dddd, J = 11.5, 5.2, 1.0, 0.5 Hz, 1H), 1.25 (d, J = 7.1 Hz, 3H).

¹³C NMR (75 MHz, CDCl₃): δ (ppm) 163.22, 160.62, 138.30, 129.69, 128.55, 128.49, 64.20, 49.54, 15.58.

HR-MS (EI) m/z calcd for [C₁₁H₁₃NO₃⁺][M⁺]: 207.0890, found: 207.0889.

2-(N-Phenylformamido)pentyl formate (58b)

![Chemical structure](image)

According to GR VI, Cu(CF₃SO₃)₂ (1.2 mg), 4-phenyl-3-propylmorpholine 58a (13 mg, 0.06 mmol), acetonitrile (1.0 mL), pyridine (4.0 mg), air (30 bar), room temperature to 100 °C and then at 100 °C for 24 h. The product 58b (9.0 mg, 0.04 mmol, 67%) was obtained by column chromatography (n-Heptane/EtOAc: 8:1) as a yellow liquid.

¹H NMR (300 MHz, CDCl₃): δ (ppm) 8.31 (s, 1H), 8.09–8.05 (m, 1H), 7.46–7.34 (m, 3H), 7.23–7.17 (m, 2H), 4.78–4.62 (m, 1H), 4.40–4.30 (m, 1H), 4.25–4.12 (m, 1H), 1.72–1.30 (m, 4H), 1.09–0.91 (m, 3H).

¹³C NMR (75 MHz, CDCl₃): δ (ppm) 163.65, 160.69, 139.01, 129.76, 128.38, 128.09, 63.43, 54.46, 31.65, 19.69, 14.00.

HR-MS (EI) m/z calcd for [C₁₃H₁₇NO₃⁺][M⁺]: 235.1203, found: 235.1201.
1-(N-Phenylformamido)propan-2-yl acetate (59b)

According to GR VI, Cu(CF₃SO₃)₂ (6.2 mg), 2,6-dimethyl-4-phenylmorpholine 59a (98 mg, 0.51 mmol), acetonitrile (2.0 mL), pyridine (8.0 mg), air (30 bar), room temperature to 100 °C and then at 100 °C for 24 h. The product 59b (61 mg, 0.28 mmol, 55%) was obtained by column chromatography (n-Heptane/EtOAc: 8:1) as a colorless liquid.

³H NMR (300 MHz, CDCl₃): δ (ppm) 8.38 (s, 1H), 7.50–7.37 (m, 2H), 7.33–7.23 (m, 1H), 7.23–7.11 (m, 2H), 5.21–5.04 (m, 1H), 4.07–3.88 (m, 2H), 1.77 (s, 3H), 1.24 (d, J = 6.4 Hz, 3H).

¹³C NMR (75 MHz, CDCl₃): δ (ppm) 170.40, 162.83, 141.32, 129.76, 127.03, 124.33, 68.85, 48.88, 20.97, 17.88.

HR-MS (EI) m/z calcd for [C₁₂H₁₅NO₃⁺] [M⁺]: 221.1046, found: 221.1044.

1-(N-Phenylformamido)propan-2-yl formate (60b) 2-(N-phenylformamido)ethyl acetate (60c)

According to GR VI, Cu(CF₃SO₃)₂ (5.8 mg), 2-methyl-4-phenylmorpholine 60a (82 mg, 0.46 mmol), acetonitrile (2.0 mL), pyridine (8.0 mg), air (20 bar), room temperature to 80 °C and then at 80 °C for 24 h. The product 60b and 60c (66 mg, 0.32 mmol, 70%) was obtained by column chromatography (n-Heptane/EtOAc: 5:1) as a colorless liquid.

³H NMR (300 MHz, CDCl₃): δ (ppm) 8.40 (d, J = 3.8 Hz, 1H), 7.89 (dq, J = 1.0, 0.5 Hz, 1H), 7.49–7.36 (m, 3H), 7.36–7.25 (m, 2H), 7.25–7.13 (m, 3H), 5.27 (dddd, J = 7.5, 6.5, 4.4, 1.0 Hz, 1H), 4.32–4.20 (m, 0.72H), 4.12–4.05 (m, 0.93H), 4.04–3.96 (m, 1.67H), 1.91 (s, 1H), 1.29 (dd, J = 6.4, 0.5 Hz, 3H).

¹³C NMR (75 MHz, CDCl₃): δ (ppm) 170.79, 162.91, 160.41, 140.98, 129.86, 127.27, 124.37, 68.41, 61.44, 9.11, 44.35, 20.73, 17.90.

HR-MS (EI) m/z calcd for [C₁₁H₁₃NO₃⁺] [M⁺]: 207.0890, found: 207.0890.
**N-Formyl-N-(2-(N-phenylformamido)ethyl)acetamide (61b)**

![Chemical Structure of N-Formyl-N-(2-(N-phenylformamido)ethyl)acetamide (61b)]

According to GR VI, Cu(CF₃SO₃)₂ (6.5 mg), 1-(4-phenylpiperazin-1-yl)ethan-1-one 61a (80 mg, 0.50 mmol), acetonitrile (2.0 mL), pyridine (8.0 mg), air (30 bar), room temperature to 100 °C and then at 100 °C for 24 h. The product 61b (43 mg, 0.18 mmol, 36%) was obtained as a light yellow liquid.

¹H NMR (300 MHz, CDCl₃): δ (ppm) 9.04 (s, 1H), 8.33 (s, 1H), 7.49–7.38 (m, 2H), 7.36–7.27 (m, 1H), 7.25–7.19 (m, 2H), 4.10–3.89 (m, 4H), 2.32 (s, 3H).

¹³C NMR (75 MHz, CDCl₃): δ (ppm) 171.44, 163.02, 162.93, 141.02, 129.84, 127.13, 124.06, 43.45, 8.23, 22.83.

HR-MS (El) m/z calcd for [C₁₂H₁₄N₂O₃⁺] [M⁺]: 234.0999, found: 234.0997.

**N,N’-(Ethane-1,2-diyl)bis(N-phenylformamide) (62b)**

![Chemical Structure of N,N’-(Ethane-1,2-diyl)bis(N-phenylformamide) (62b)]

According to GR VI, Cu(CF₃SO₃)₂ (5.8 mg), 1,4-diphenylpiperazine 62a (119 mg, 0.50 mmol), acetonitrile (2.0 mL), pyridine (160 mg), air (30 bar), room temperature to 100 °C and at 100 °C for 24 h. The product 62b (53 mg, 0.20 mmol, 40%) was obtained by column chromatography (n-Heptane/EtOAc: 8:1) as a yellow solid.

¹H NMR (300 MHz, CDCl₃): δ (ppm) 8.35 (s, 2H), 7.44–7.37 (m, 4H), 7.35–7.29 (m, 2H), 7.11–7.05 (m, 4H), 4.07 (s, 4H).

¹³C NMR (75 MHz, CDCl₃): δ (ppm) 162.74, 140.80, 129.81, 126.96, 123.60, 43.39.

HR-MS (El) m/z calcd for [C₁₆H₁₆N₂O₂⁺] [M⁺]: 268.1206, found: 268.1202.
**N-(4-Methoxyphenyl)-N-(2-(N-phenylformamido)ethyl)formamide (63b)**

According to GR VI, Cu(CF₃SO₃)₂ (12 mg), 1-(4-methoxyphenyl)-4-phenylpiperazine 63a (144 mg, 0.54 mmol), acetonitrile (2.0 mL), pyridine (160 mg), air (30 bar), room temperature to 100 °C and then at 100 °C for 24 h. The product 63b (42 mg, 0.14 mmol, 26%) was obtained by column chromatography (n-Heptane/EtOAc: 5:1) as a yellow solid.

**1H NMR** (300 MHz, CDCl₃): δ (ppm) 8.33 (s, 1H), 8.21 (s, 1H), 7.45–7.33 (m, 3H), 7.13–7.07 (m, 2H), 7.00–6.93 (m, 2H), 6.92–6.85 (m, 2H), 4.06–3.94 (m, 4H), 3.82 (s, 3H).

**13C NMR** (75 MHz, CDCl₃): δ (ppm) 162.88, 162.73, 158.69, 140.88, 133.67, 129.83, 127.02, 125.87, 123.82, 114.91, 55.69, 43.77, 43.35.

**HR-MS (EI) m/z calcd for [C₁₇H₁₈N₂O₃]+ [M⁺]: 298.1312, found: 298.1309.

**N-(2,4-Dimethylphenyl)-N-(2-(N-(4-methoxyphenyl)formamido)ethyl)formamide (64b)**

According to GR VI, Cu(CF₃SO₃)₂ (12 mg), 1-(3,4-dimethylphenyl)-4-(4-methoxyphenyl)piperazine 64a (147 mg, 0.50 mmol), acetonitrile (2.0 mL), pyridine (160 mg), air (30 bar), room temperature to 100 °C and then at 100 °C for 24 h. The product 64b (39 mg, 0.12 mmol, 24%) was obtained by column chromatography (n-Heptane/EtOAc: 5:1) as a yellow solid.

**1H NMR** (300 MHz, CDCl₃): δ (ppm) 8.22 (s, 1H), 8.05 (s, 1H), 7.12–7.06 (m, 3H), 7.02–6.95 (m, 2H), 6.91 (d, J = 8.9 Hz, 2H), 3.92 (d, J = 6.5 Hz, 2H), 3.83–3.77 (m, 5H), 2.34 (s, 3H), 2.14 (s, 3H).

**13C NMR** (75 MHz, CDCl₃): δ (ppm) 163.52, 162.81, 158.75, 138.71, 136.60, 135.33, 133.57, 132.29, 128.74, 127.85, 126.12, 114.94, 55.67, 43.44, 43.23, 21.11, 17.82.

**HR-MS (EI) m/z calcd for [C₁₉H₂₂N₂O₅]⁺ [M⁺]: 326.1625, found: 326.1625.
**N-Butyl-N-(3,3,5-trimethylcyclohexyl)formamide (65b)**

According to **GP III**, CuCl (2.5 mg), acetonitrile (2.0 mL), pyridine (80 mg), N,N-dibutyl-3,3,5-trimethylcyclohexan-1-amine 65a (138 mg, 0.55 mmol), air (30 bar), room temperature to 100 °C and then at 100 °C for 24 h. The product 65b (115 mg, 0.51 mmol, 93%) was obtained by column chromatography (n-Heptane/EtOAc: 2:1) as a light yellow liquid.

\[ \text{H NMR (400 MHz, DMSO-}d_6\text{) } \delta \text{ (ppm) 8.28–7.90 (m, 1H), 3.26–3.04 (m, 3H), 1.73 (s, 1H), 1.47–1.18 (m, 10H), 1.07–1.00 (m, 5H), 0.91–0.86 (m, 7H).} \]

\[ \text{13C NMR (101 MHz, DMSO-}d_6\text{) } \delta \text{ (ppm) 162.76, 50.55, 44.42, 43.88, 42.66, 37.27, 33.87, 32.08, 31.27, 28.99, 27.65, 21.51, 20.34, 14.18.} \]

\[ \text{HR-MS (EI) m/z calcd for } [\text{C}_{14}\text{H}_{27}\text{NO}]^{+}[\text{M}^+] : 225.2093, \text{ found: } 225.2089. \]

**N-Butyl-N-(4-(2,2,6-trimethylcyclohexyl)butan-2-yl)formamide (66b)**

According to **GP III**, CuCl (2.8 mg), acetonitrile (2.0 mL), pyridine (80 mg), N-butyl-N-(4-(2,2,6-trimethylcyclohexyl)butan-2-yl)butan-1-amine 66a (80 mg, 0.26 mmol), air (30 bar), room temperature to 100 °C and then at 100 °C for 24 h. The product 66b (74 mg, 0.26 mmol, 99%) was obtained by column chromatography (n-Heptane/EtOAc: 1:1) as a light yellow liquid.

\[ \text{H NMR (400 MHz, CDCl}_3\text{) } \delta \text{ (ppm) 9.86–8.22 (m, 1H), 4.23–2.68 (m, 3H), 1.59–0.74 (m, 31H).} \]

\[ \text{13C NMR (101 MHz, CDCl}_3\text{) } \delta \text{ (ppm) 161.46, 55.76, 53.47, 49.74, 42.14, 36.53, 36.07, 34.29, 31.18, 30.34, 28.56, 27.77, 22.31, 20.92, 20.62, 20.61, 18.53, 13.85.} \]

\[ \text{HR-MS (EI) m/z calcd for } [\text{C}_{18}\text{H}_{35}\text{NO}]^{+}[\text{M}^+] : 281.2713, \text{ found: } 281.2716. \]
\[N-(4-(\text{Benzo}[d][1,3]dioxol-5-yl)butan-2-yl)-N\text{-butylformamide (67b)}\]

According to **GP III**, CuCl (2.7 mg), acetonitrile (2.0 mL), pyridine (80 mg), \(N-(4-\text{(benzo}[d][1,3]dioxol-5-yl)butan-2-yl)-N\text{-butylbutan-1-amine 67a}\) (130 mg, 0.43 mmol), air (30 bar), room temperature to 100 °C and then at 100 °C for 24 h. The product \(67b\) (109 mg, 0.39 mmol, 91%) was obtained by column chromatography (n-Heptane/EtOAc: 1:1) as a yellow liquid.

\(^1\)H NMR (400 MHz, CDCl\textsubscript{3}) \(\delta\) (ppm) 8.02 (s, 1H), 6.69–6.40 (m, 3H), 5.83 (s, 2H), 3.39 (ddd, \(J = 9.1, 6.9, 5.4\) Hz, 1H), 3.24–2.95 (m, 2H), 2.67–1.67 (m, 2H), 1.88–1.64 (m, 2H), 1.57–1.13 (m, 5H), 0.86 (td, \(J = 7.4, 2.0\) Hz, 3H).

\(^{13}\)C NMR (101 MHz, CDCl\textsubscript{3}) \(\delta\) (ppm) 162.86, 147.74, 145.85, 135.41, 121.03, 108.71, 108.24, 100.84, 53.64, 40.73, 36.79, 33.48, 32.21, 31.05, 20.73, 18.73.

**HR-MS** (EI) m/z calcd for [\(\text{C}_{16}\text{H}_{23}\text{NO}_3\)]\(^+\) [\(M^+\)]: 277.1673, found: 277.1672.

\[N-(4-(\text{Benzo}[d][1,3]dioxol-5-yl)butan-2-yl)-N-(2\text{-methoxyethyl})formamide (68b)\]

According to **GP III**, CuCl (2.5 mg), acetonitrile (2.0 mL), pyridine (80 mg), 4-\(\text{(benzo}[d][1,3]dioxol-5-yl)-N,N\text{-bis(2-methoxyethyl)butan-2-amine 68a}\) (172 mg, 0.56 mmol), air (30 bar), room temperature to 100 °C and then at 100 °C for 24 h. The product \(68b\) (149 mg, 0.53 mmol, 95%) was obtained by column chromatography (n-Heptane/EtOAc: 1:1) as a light yellow liquid.

\(^1\)H NMR (400 MHz, CDCl\textsubscript{3}) \(\delta\) (ppm) 8.40 (s, 1H), 6.75–6.51 (m, 3H), 5.89 (s, 2H), 3.65–3.19 (m, 8H), 2.69–2.26 (m, 2H), 1.96–1.67 (m, 2H), 1.23 (dd, \(J = 13.8, 6.4\) Hz, 3H).

\(^{13}\)C NMR (101 MHz, CDCl\textsubscript{3}) \(\delta\) (ppm) 162.86, 147.73, 145.64, 134.63, 121.04, 108.57, 108.23, 100.85, 70.25, 58.74, 54.02, 40.96, 36.80, 32.22, 20.65.

**HR-MS** (EI) m/z calcd for [\(\text{C}_{15}\text{H}_{21}\text{NO}_4\)]\(^+\) [\(M^+\)]: 279.1465, found: 279.1465.
**N-Butyl-N-(6-(3,7-dimethyl-2,6-dioxo-2,3,6,7-tetrahydro-1H-purin-1-yl)hexan-2-yl)formamide (69b)**

According to **GP III**, CuCl (2.8 mg), acetonitrile (2.0 mL), pyridine (80 mg), 1-(5-(dibutylamino)hexyl)-3,7-dimethyl-3,7-dihydro-1H-purine-2,6-dione 69a (130 mg, 0.33 mmol), air (30 bar), room temperature to 100 °C and then at 100 °C for 24 h. The product 69b (115 mg, 0.32 mmol, 97%) was obtained by column chromatography (n-Heptane/EtOAc: 1:1) as a light yellow liquid.

1H NMR (400 MHz, CDCl₃) δ (ppm) 8.14 (s, 1H), 7.77–7.41 (s, 1H), 3.93 (s, 5H), 3.48 (d, J = 37.7 Hz, 4H), 3.07 (ddt, J = 38.2, 17.6, 11.9 Hz, 2H), 1.75–1.40 (m, 6H), 1.35–1.10 (m, 7H), 0.92–0.82 (m, 3H).

13C NMR (101 MHz, CDCl₃) δ (ppm) 162.52, 155.31, 151.32, 141.52, 54.49, 48.92, 44.79, 40.83, 34.79, 34.04, 30.89, 29.54, 27.74, 23.83, 20.64, 19.96, 18.68, 13.66.

**HR-MS** (ESI) m/z calcd for [C₁₈H₃₀N₅O₃]⁺ ([M+H]⁺): 364.2343, found: 364.2351.

**N-(6-(3,7-Dimethyl-2,6-dioxo-2,3,6,7-tetrahydro-1H-purin-1-yl)hexan-2-yl)-N-(2-methoxyethyl)formamide (70b)**

According to **GP III**, CuCl (2.8 mg), acetonitrile (2.0 mL), pyridine (80 mg), 1-(5-(bis(2-methoxyethyl)amino)hexyl)-3,7-dimethyl-3,7-dihydro-1H-purine-2,6-dione 70a (102 mg, 0.26 mmol), air (30 bar), room temperature to 100 °C and then at 100 °C for 24 h. The product 70b (69 mg, 0.19 mmol, 73%) was obtained by column chromatography (n-Heptane/EtOAc: 1:1) as a colorless liquid.

1H NMR (400 MHz, CDCl₃) δ (ppm) 8.31 (s, 1H), 7.78 (s, 1H), 3.96 (d, J = 7.1 Hz, 5H), 3.68–3.25 (m, 11H), 1.70–1.45 (m, 4H), 1.38–1.07 (m, 5H).

13C NMR (101 MHz, DMSO-d₆) δ (ppm) 164.10, 163.33, 154.85, 151.23, 143.40, 71.78, 69.96, 58.44, 53.77, 48.44, 44.11, 33.64, 29.81, 27.54, 23.65, 20.69, 18.88.
HR-MS (ESI) m/z calcd for [C_{17}H_{28}N_{5}O_{4}]^{+} ([M+H]^{+}): 366.2136, found: 366.2144.

**N-Butyl-N-((8R,9S,10S,13R,14S,17R)-10,13-dimethyl-17-((R)-6-methylheptan-2-yl)hexadecahydro-1H-cyclopenta[a]phenanthren-3-yl)formamide (71b)**

According to GP III, CuCl (2.5 mg), acetonitrile (2.0 mL) and DMF (2.0 mL), pyridine (80 mg), (8R,9S,10S,13R,14S,17R)-N,N-dibutyl-10,13-dimethyl-17-((R)-6-methylheptan-2-yl)hexadecahydro-1H-cyclopenta[a]phenanthren-3-amine 71a (90 mg, 0.18 mmol), air (30 bar), room temperature to 100 °C and then at 100 °C for 24 h. The product 71b (82 mg, 0.17 mmol, 94%) was obtained by column chromatography (n-Heptane/EtOAc: 2:1 to 1:5) as a colorless solid.

1H NMR (400 MHz, CDCl₃) δ (ppm) 3.24 (m, 3H), 2.44–0.29 (m, 53H).

13C NMR (101 MHz, CDCl₃) δ (ppm) 156.46, 60.51, 56.54, 56.35, 54.21, 46.18, 43.21, 42.84, 40.82, 39.44, 37.83, 36.49, 35.70, 34.51, 33.71, 32.89, 31.88, 30.37, 28.61, 27.94, 27.04, 26.40, 24.88, 23.55, 22.76, 21.08, 20.75, 19.93, 18.61, 13.81, 12.31, 12.01.

HR-MS (EI) m/z calcd for [C_{32}H_{57}NO]^{+} [M]^{+}: 471.4435, found: 471.4435.

**N-Butyl-N-(3,7-dimethyloct-6-en-1-yl)formamide (72b)**

According to GP III, CuCl (2.8 mg), acetonitrile (2.0 mL), pyridine (80 mg), N,N-dibutyl-3,7-dimethyloct-6-en-1-amine 72a (131 mg, 0.49 mmol), air (30 bar), room temperature to 100 °C
and then at 100 °C for 24 h. The product 72b (72 mg, 0.30 mmol, 72%) was obtained by
column chromatography (n-Heptane/EtOAc: 4:1) as a light yellow liquid.

\(^1\)H NMR (400 MHz, DMSO-\(d_6\)) \(\delta\) (ppm) 8.00 (s, 1H), 5.19–4.98 (m, 1H), 3.27–3.09 (m, 4H),
2.04–1.86 (m, 2H), 1.69–1.62 (m, 3H), 1.60–1.54 (m, 3H), 1.48–1.19 (m, 8H), 1.18–1.07 (m, 1H), 0.93–0.85 (m, 6H).

\(^{13}\)C NMR (101 MHz, DMSO-\(d_6\)) \(\delta\) (ppm) 162.85, 131.00, 124.97, 46.42, 44.81, 41.16, 36.87,
35.72, 34.10, 30.69, 29.62, 25.95, 20.04, 19.74, 17.93, 13.98.

HR-MS (ESI) m/z calcd for \([\text{C}_{15}\text{H}_{30}\text{NO}]^+\) ([M+H]+): 240.2322, found: 240.2331.

Linezolid (73a) (Supplier: Gute Chemie–abcr Services)

\(^1\)H NMR (400 MHz, DMSO-\(d_6\)): \(\delta\) (ppm) 8.24 (t, \(J = 5.9\) Hz, 1H), 7.49 (dd, \(J = 15.0, 2.5\) Hz,
1H), 7.18 (ddd, \(J = 8.8, 2.6, 0.9\) Hz, 1H), 7.06 (dd, \(J = 9.8, 8.8\) Hz, 1H), 4.79–4.58 (m, 1H),
4.08 (t, \(J = 9.0\) Hz, 1H), 3.79–3.63 (m, 5H), 3.40 (t, \(J = 5.5\) Hz, 2H), 3.03–2.89 (m, 4H), 1.83
(s, 3H).

\(^{13}\)C NMR (101 MHz, DMSO-\(d_6\)): \(\delta\) (ppm) 170.43, 156.24, 154.51, 153.82, 135.98 (d, \(J = 8.8\)
Hz), 133.90 (d, \(J = 10.5\) Hz), 119.71 (d, \(J = 4.2\) Hz), 114.53 (d, \(J = 3.3\) Hz), 107.08 (d, \(J =
26.2\) Hz), 72.01, 66.62, 51.17 (d, \(J = 2.8\) Hz), 47.75, 41.87, 22.91.

\(^{19}\)F NMR (282 MHz, CDCl\(_3\)): \(\delta\) (ppm) -119.93.

(S)-2-(N-(4-(Acetamidomethyl)-2-oxooxazolidin-3-yl)-2-fluorophenyl)formamido)ethyl
formate (73b)

According to GP II, Cu(CF\(_3\)SO\(_3\))\(_2\) (6.0 mg), Linezolid 73a (174 mg, 0.52 mmol), acetonitrile
(2.0 mL), pyridine (8.0 mg), air (30 bar), room temperature to 100 °C and then at 100 °C for
24 h. The product 73b (160 mg, 0.44 mmol, 85%) was obtained by column chromatography
(n-Heptane/EtOAc: 2:1 to 1:5) as yellow solid.
$^1$H NMR (300 MHz, DMSO-$d_6$): $\delta$ (ppm) 8.43–8.00 (m, 3H), 7.77–7.30 (m, 3H), 4.86–4.68 (m, 1H), 4.25–4.03 (m, 3H), 3.95 (t, $J = 5.4$ Hz, 2H), 3.78 (dd, $J = 9.4, 6.4, 1.1$ Hz, 1H), 3.44 (t, $J = 5.5$ Hz, 2H).

$^{13}$C NMR (75 MHz, DMSO-$d_6$): $\delta$ (ppm) 170.08, 166.60–162.15 (m), 161.80, 158.89, 155.63, 154.01, 139.23 (d, $J = 10.7$ Hz), 131.42–127.22 (m), 122.73 (d, $J = 12.2$ Hz), 120.71 (d, $J = 13.3$ Hz), 114.10 (d, $J = 3.1$ Hz), 105.90 (dd, $J = 26.1, 13.0$ Hz), 71.78 (d, $J = 3.3$ Hz), 60.59, 60.35, 47.73, 47.23, 43.50, 41.37, 22.45.

$^{19}$F NMR (282 MHz, DMSO-$d_6$): $\delta$ (ppm) -118.13 (dt, $J = 12.8, 6.7$ Hz), -121.61 (dd, $J = 12.7, 8.9$ Hz).

HR-MS (EI) m/z calcd for [C$_{16}$H$_{18}$FN$_3$O$_6$]$^+$ [M$^+$]: 367.1174, found: 367.1173.

2-(N-(5-Ethoxy-1-methyl-6-oxo-1,6-dihydropyridazin-4-yl)formamido)ethyl formate (74b)

According to GP II, Cu(CF$_3$SO$_3$)$_2$ (3.6 mg), Emofazone 74a (41 mg, 0.17 mmol), acetonitrile (2.0 mL), pyridine (32 mg), air (30 bar), room temperature to 100 °C and then at 100 °C for 24 h. The product 74b (31 mg, 0.12 mmol, 71%) was obtained by column chromatography (n-Heptane/EtOAc: 2:1 to 5:1) as colorless liquid.

$^1$H NMR (400 MHz, CDCl$_3$) $\delta$ (ppm) 8.22 (s, 1H), 8.01 (s, 1H), 7.63 (d, $J = 6.9$ Hz, 1H), 4.63 (t, $J = 7.1$ Hz, 2H), 4.32 (td, $J = 5.5, 0.9$ Hz, 2H), 3.98 (td, $J = 5.4, 0.6$ Hz, 2H), 3.77 (d, $J = 8.3$ Hz, 3H), 1.34 (t, $J = 7.1$ Hz, 3H).

$^{13}$C NMR (101 MHz, CDCl$_3$) $\delta$ (ppm) 162.45, 160.33, 158.14, 148.41, 135.44, 128.87, 69.18, 61.09, 43.62, 40.33, 15.84.

HR-MS (ESI) m/z calcd for [C$_{11}$H$_{16}$N$_3$O$_5$]$^+$ ([M+H]$^+$): 270.1084, found: 270.1088.
10. \(^1\)H NMR and \(^{13}\)C NMR and Spectra for Substrates and Products

Original spectra for 5a:
Original spectra for 6a:
Original spectra for 8a:
Original spectra for 9a:

MeO
N
OMe

CH3
Data File C:\CHERK\DATA\201005\2010-05-02 09-48-05\WJ-6-1850.D
Sample Name: WJ-6-1850

Acq. Operator : Lab 2.112  Seq. line : 4
Acq. Instrument : GC Lab.133  Location : Vial 4
Injection Date : 5/3/2010 11:26:41 AM
Inj Volume : 1 µl
Method : C:\CHERK\DATA\201005\2010-05-02 09-48-05\STANDARDTH 29.M (Sequence Method)
Last changed : 5/28/2010 4:06:15 PM by Lab 2.112
Method Info : HP5 (38m,0.25x8.25); 50B/128/8/15-200/8/25-300/10; 3ml/min; 208.132bd

Area Percent Report

Sorted By : Signal
Multiplier : 1.0000
Dilution : 1.0000
Use Multiplier & Dilution Factor with ISTDs

Signal 1: FID1 A, Front Signal

| # | Min. | Width | Area | Height | Area % | µS | % |
|---|------|-------|------|--------|--------|----|---|
| 1 | 2.333 | 0.0170 | 6.90126 | 7.26250 | 0.81887 | |
| 2 | 2.280 | 0.0195 | 8.56239 | 7.51857 | 0.81290 | |
| 3 | 2.256 | 0.0179 | 7.3368884 | 6.841584 | 98.58112 | |
| 4 | 13.873 | 0.0164 | 1038.95966 | 523.36466 | 1.29599 | |

Totals : 7.44248e4 6.89531e4

*** End of Report ***

GC Lab.133 5/3/2010 8:12:26 AM Lab 2.112
Original spectra for 10a:
Data File C:\\VEMSIT11\DATA\20090528\2003-05-02 09-48-35\14-10-58.D
Sample Name: M1-4-2108

================================================================================================

Acq. Operator : Lab 2.112
Seq. Line : 7
Acq. Instrument : GC Lab.133
Injection Date : 5/2/2013 12:48:37 PM
Inj : 1
Injection Volume : 1 pL
Method : C:\\VEMSIT11\DATA\20090528\2003-05-02 09-48-35\STANDARDABNTH 10.M (Sequence Method)
Last changed : 5/2/2013 12:48:35 PM by Lab 2.113
Method Info : MPS [30:25,25:25]; 50/8-12/0,15-200/9-25-599/28; 1ml/min; 200612md

Area Percent Report

Sort By : Signal
Multiplier : 1.0000
Dilution : 1.0000
Use Multiplier & Dilution Factor with IS/THs

Signal 1: FID2 A, Front Signal

Peak Ret Time Type Width Area % Height Area %
[sec] [mm] [µm²] [µm] % [sec] [mm] [µm²] [µm] %
1 2.132 VI 0.0562 7.9842 7.5447 0.0079
2 1.171 VI 0.0129 2.9363 2.4916 0.0079
3 2.208 VI 0.0105 5.7375 4.9791 0.0079
4 2.256 VI S 0.0173 7.2616 6.7404 0.0079
5 3.064 88 0.0900 3.3129 1.1843 0.0043
6 1.327 88 0.0528 3.8135 3.9427 0.0451
7 1.403 88 0.0396 4.83287 2.4914 0.0397

Totals : 7.313164 6.831526

*** End of Report ***

GC Lab.133 5/3/2013 8:16:15 AM lab 2.113
Original spectra for 11a:
Original spectra for 12a:
Original spectra for 13a:
Data File C:\CHENG\DATA\2013\05\2013-05-22 09-48-05\W-4-982.D
Sample Name: W-4-982

------------------------------------------------------------------------------------------------------------------------
Acq. Operator : Lab 2.112  
Inj. Line : R  
Acq. Instrument : GC Lab.133  
Location : Vial II  
Injection Date : 5/3/2013 1:13:15 PM  
Injection Size : 1  
 inj Volume : 3 µl
Method : C:\CHENG\DATA\2013\05\2013-05-22 09-48-05\STANDARDS_FINAL.M (Sequence method)
Last changed : 9/28/2010 4:06:15 PM by Lab 2.112
Method Info : MPS (24mX.25mm.0.25): 56/6-120/6/15-200/6/25-300/6/6; 50g/LH; 200g/H60

---

Area Percent Report

--------------------
Sorted By : Signal
Multiplier : 1.0000  
Dilution : 1.0000
Use Multiplier & Dilution Factor with ESTBs

Signal 1: FIDU A, Front Signal

Peak Retention Type Width Area Height Area %
# [min] [µm] [µm²] [µm] [%]
---[---]--------[----------]--------[----------]
1 2.333 BB 0.013 7.1838 6.52689 9.40089
2 2.201 BB 0.013 4.47632 4.20043 9.0357
3 2.225 VB 5 0.017 7.497264 6.925704 99.7606
4 13.304 BB 0.043 5.991645 43.03989 9.31869

Totals : 7.631664 6.925704

*** End of Report ***

GC Lab.133 5/3/2013 8:15:45 AM Lab 2.112  Page 3 of 1
Original spectra for 14a:
Area Percent Report

Sorted By: Signal
Multiplier: 3.0000
Dilution: 3.0000
Use Multiplier & Dilution Factor with ISUBs

Signal 1: FID1 A, Front Signal

| Peak | Retention Type | Width | Area | Height | Area % |
|------|----------------|-------|------|--------|--------|
| 1    | 2.133 min      | 0.4556 | 7.7953 | 6.57988 | 0.0106 |
| 2    | 2.082 min      | 0.4198 | 6.62243 | 3.78133 | 0.00959 |
| 3    | 2.257 min      | 0.4876 | 7.48383 | 7.05896 | 0.09752 |
| 4    | 2.739 min      | 0.4388 | 228.6276 | 82.77813 | 0.2856 |

Totals: 7.766546 | 7.068346

*** End of Report ***
Original spectra for 15a:
Data file C:\CHEM32\DATA\201805\2018-05-02 09-49-05\AU-4-003.D
Sample Name: AU-4-003

-------------------------------------------------------------------------------------------------
Acq. Operator : Lab 2.112  Seq. line : 1
Acq. Instrument : GC lab.133  Location : Vial 3
Injection Date : 5/2/2018 11:00:05 AM  Inj. : 1
Inj. Volume : 1 µl
Method : C:\CHEM32\DATA\201805\2018-05-02 09-49-05\STANDARDITH 20.P (Sequence Method)
Last changed : 8/28/2018 4:06:15 PM by Lab 2.112
Method Info : HPS (3040.2280.25) 500/1-228/11-228/112-228/11/12-228/11/23-300/30; 3m/min; 2601528d

-------------------------------------------------------------------------------------------------

Area Percent Report

-------------------------------------------------------------------------------------------------

Sorted by : Signal
Multiplier : 1.0000
Dilution : 1.0000
Use Multiplier & Dilution Factor with IS78s

Signal 1: FID 4, Front Signal

| Ret Time | Type | Width | Area  | Height | Area |
|----------|------|-------|-------|--------|------|
|          |      | [min] | [µm²] | [µl]   | %    |
| 1        | 2,133 | 0.0514| 7.973640 | 7.15873 | 0.9566 |
| 2        | 2,202 | 0.0413| 5.102836 | 4.42283 | 0.8027 |
| 3        | 2,256 | 0.0473| 7.4616404| 6.937804 | 99.1197 |
| 4        | 13,139 | 0.0186| 7.860373 | 2.82916 | 0.8194 |
| 5        | 13,261 | 0.0510| 641.78119 | 15.45086 | 0.8517 |

Totals : 7.127604 6.9599404

-------------------------------------------------------------------------------------------------

*** End of Report ***

GC lab.133 5/3/2018 8:11:50 AM Lab 2.112
Original spectra for 16a:
Original spectra for 17a:
Data File C:\CHM313\DATA\201905\2019-05-02 09-48-05\WJ-4-1875-1.D
Sample Name: WJ-4-1875-1

Acq. Operator : Lab 2.112
Seq. Line : 19
Acq. Instrument : GC Lab.133
Injection Date : 5/2/2019 6:06:18 PM
Inj. Vol : 1
Inj Volume : 1 µL
Method : C:\CHM313\DATA\201905\2019-05-02 09-48-05\STANDARDs 20.m (Sequence Method)
Last changed : 8/28/2018 4:06:15 PM by Lab 2.112
Method Info : HPS (5µm, 25cm, 25): 30/T/3/120/12/21-25/100/15/5/32/300/50; 32/30m; 210/32m

**GRAPH: Area Percent Report**

**Sorted By :** Signal
**Multiplier :** 1.0000
**Dilution :** 1.0000
Use Multiplier & Dilution Factor with IS70s

**Signal 1: FID1 A, Front Signal**

| Peak RetTime Type Width Area Height Area % |
| --- | --- | --- | --- | --- | --- |
| | 2 | 1.33 | 0.8157 | 7.39447 | 6.74833 0.63616 |
| 2 | 3.281 | 0.0158 | 7.17886 | 5.96452 0.0000 |
| 3 | 2.256 | 0.8172 | 2.426169 | 0.795816 0.00103 |
| 4 | 15.191 | 0.8151 | 131.450549 | 53.76757 0.37893 |

**Totals :** 7.17175e+6 5.98835e+6

**End of Report**
Original spectra for 18a:
Original spectra for 19a:
Original spectra for 20a:
Original spectra for 23a:
Original spectra for 24a:
Original spectra for 33a:
Original spectra for 35a:
Original spectra for 37a:
Original spectra for 38a:
Original spectra for 40a:
Original spectra for 41a:
Original spectra for 42a:
Original spectra for 44a:
Original spectra for 45a:

![Spectra Image]

1H NMR in CDCl3 (Bruker Topspin 3.5p) 1802 13

13C NMR in CDCl3 (Bruker Topspin 4.0) 1802 13
Original spectra for 46a:
Original spectra for 47a:
Original spectra for 48a:
Original spectra for 49a:
Original spectra for 50a:
Original spectra for 51a:
Original spectra for 52a:
Original spectra for 53a:
Original spectra for 56a:
Original spectra for 57a:
Original spectra for 58a:
Original spectra for 59a:
Original spectra for 60a:
Original spectra for 62a:
Original spectra for 63a:
Original spectra for 64a:
Original spectra for 65a:
Data File C:\CHEM31\DATA\201305\2013-05-02 09-48-05\W4-4-992-1.D
Sample Name: W4-4-992-1

Acq. Operator : Lab 2.312
Seq. Line : 22
Acq. Instrument : GC Lab.133
Location : Vial 12
Injection Date : 5/2/2019 7:25:52 PM
Inj. : 1
Try Volume : 1 µl
Method : C:\CHEM31\DATA\201305\2013-05-02 09-48-05\STANDARD 28.N (Sequence)
Last changed : 8/28/2018 4:08:15 PM by Lab 2.312
Method Info : HPS (366.25cm.25): 50/0.125/59/58/59/58/58/58/58/58/10/10/10/10/10

Area Percent Report

Sorted By : Signal
Multiplier : 1.0000
Dilution : 1.0000
Use Multiplier & Dilution Factor with ISTDs

Signal 1: FID A, front signal

| #   | Width | Area   | Height | Area   |
|-----|-------|--------|--------|--------|
|     | [min] | [µl²]  | [µl]   | [µl]   |
|     |       |        |        |        |
| 1   | 2.123 | 0.0009 | 7.78996| 6.54556| 0.098941|
| 2   | 2.380 | 0.0001 | 4.32313| 3.47774| 0.09596 |
| 3   | 2.357 | 0.0001 | 7.588764| 6.08964| 0.098242|
| 4   | 2.599 | 0.0004 | 10.99812| 10.32158| 0.05772 |
| 5   | 3.343 | 0.0001 | 35.8954 | 30.2629| 0.17629 |

Totals : 7.7757964 7.616704

*** End of Report ***
Original spectra for 66a:
## Data File

File Location: C:\chris\L1\DATA\2013R1\2013-10-31 07-41-42-0801\6-988-COL-25.D
Sample Name: W-4-988-col2-25

---

### Acquisition Information
- **Acq. Operator:** Lab 2.112
- **Acq. Instrument:** GC Lab.133
- **Location:** Vial 28
- **Injection Date:** 18/12/2018 7:47:02 AM
- **Inj:** 1
- **Inj Volume:** 1 µl
- **Method:** C://CHP32\L1\DATA\2013R1\2013-10-31 07-41-42-0801\STANDARD09 20.M (Sequence Method)
- **Last Changed:** 8/28/2019 4:00:15 PM by Lab 2.112
- **Method Info:** FFS 080925.25: 50/9-126/8/25-200/9/25-300/10; 1atm; 200130m

### Additional Info
- Peak(s) manually integrated

---

### Area Percent Report

| Sorted By | Area Percent Report |
|-----------|---------------------|
| Signal    |                     |
| Multiplier| 1.0000              |
| Dilution  | 1.0000              |

**Use Multiplier & Dilution Factor with ISTDs**

### Signal 1: FID1 A, Front Signal

| Peak RetTime Type | Width | Area | Height | Area |
|-------------------|-------|------|--------|------|
|                  | [min] | [nA] | [pA]   | %    |
| 1                 | 2.235 | 0.0153 | 2.22059 | 0.00157 |
| 2                 | 2.298 | 0.0140 | 19.83987 | 0.01399 |
| 3                 | 2.626 | 0.0138 | 462.55990 | 0.01398 |
| 4                 | 2.012 | 0.0349 | 9.59006 | 2.74335 |
| 5                 | 2.070 | 0.0372 | 10.84992 | 0.03772 |
| 6                 | 3.063 | 0.0560 | 163.16457 | 0.05600 |
| 7                 | 3.150 | 0.0462 | 1.7099465 | 3.759606 |
| 8                 | 3.387 | 0.0618 | 3885.51308 | 90.53544 |
| 9                 | 3.465 | 0.0617 | 0.24082 | 7.57981 |
| 10                | 2.130 | 0.0294 | 225.70047 | 0.02772 |

**Totals:** 1.41856e5 4.06777e6

GC Lab.133 5/2/2019 4:46:33 PM Lab 2.112

Page 1 of 2
Original spectra for 67a:
Original spectra for 68a:
Original spectra for 69a:
Original spectra for 70a:
Original spectra for 71a:
Original spectra for 72a:
Original spectra for 2b:
Original spectra for 5b:
Original spectra for 6b:
Original spectra for 7b:
Original spectra for 7b (The CDCl₃ was filtered through K₂CO₃.)
Original spectra for 8b (in DMSO-\textit{d6}):
Original spectra for 8b (in CDCl₃):

\[
\begin{align*}
\text{N} & \quad \text{OMe} \\
\end{align*}
\]
Original spectra for 9b:
Original spectra for 10b:
Original spectra for 11b:
Original spectra for 12b:
Original spectra for 13b:
Original spectra for 14b:
Original spectra for 15b:
Original spectra for 16b:
Original spectra for 17b:
Original spectra for 18b:
Original spectra for 19b:
Original spectra for 20b:
Original spectra for 21b:
Original spectra for 22b:
Original spectra for 23b:
Original spectra for 24b:
Original spectra for 25b:
Original spectra for 26b:
Original spectra for 27b:
Original spectra for 28b:
Original spectra for 28c:
Original spectra for 29b:
Original spectra for 29c:
Original spectra for 30b:
Original spectra for 31b:
Original spectra for 32b:
Original spectra for 33b:
Original spectra for 34b:
Original spectra for 35b:
Original spectra for 36b:

[Chemical structure of 36b]

[Spectroscopic data and analysis]
Original spectra for 37b:
Original spectra for **38b**:

![Spectra Image]

- **1H** (ppm)
- **13C** (ppm)

---

**1H** spectrum details:

- **13C** spectrum details:

---

S187
Original spectra for 39b:
Original spectra for 40b:
Original spectra for 41b:
Original spectra for 42b:
Original spectra for 43b:
Original spectra for 44b:
Original spectra for 45b:
Original spectra for 46b:
Original spectra for 47b:
Original spectra for 48b:
Original spectra for 49b:
Original spectra for 50b:
Original spectra for 51b and 51c:
Original spectra for 52b:
Original spectra for 53b:
Original spectra for 54b:
Original spectra for 55b:
Original spectra for 56b:
Original spectra for 57b:
Original spectra for 58b:
Original spectra for 59b:
Original spectra for 60b and 60c:
Original spectra for 61b:
Original spectra for 62b:
Original spectra for 63b:
Original spectra for 64b:
Original spectra for 65b:

![Chemical Structure](image)

![NMR Spectra](image)
Original spectra for 66b:
Original spectra for 67b:
Original spectra for 68b:
Original spectra for 69b:
Original spectra for 70b (in CDCl₃):

(in DMSO-d6)
Original spectra for 71b:

DMSO-\textit{d}6
Original spectra for 72b (in DMSO-$d_6$):
Original spectra for 72b (in CDCl₃):
Original spectra for 73a:
Original spectra for 73b:
Original spectra for 74b:
11. References

[1] D. Wang, A. B. Weinstein, P. B. White, S. S. Stahl, *Chem. Rev.* **2018**, *118*, 2636-2679.

[2] R. Stößer, G. Scholz, K. Möckel, E. Backhaus, *J. Mol. Struct.* **1994**, *319*, 203-210.

[3] R. Suarez-Bertoa, F. Saliu, M. Bruschi, B. Rindone, *Tetrahedron* **2012**, *68*, 8267-8275.

[4] F. Saliu, M. Orlandi, M. Bruschi, *ISRN Org. Chem.* **2012**, *2012*, 281642.