Synthesis of α-Ketoamides from Aryl Methyl Ketones and *N*,*N*-Dimethylformamide via Copper-Catalyzed Aerobic Oxidative Coupling

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Abstract: A copper-catalyzed aerobic oxidative coupling of aryl methyl ketones with *N*,*N*-dimethylformamide was developed, which afforded α-ketoamides by a sequence of dioxygen activation, C–H bond functionalization, and amide formation with *N*,*N*-dimethylformamide as the nitrogen source. Molecular oxygen was found to play a crucial role in this transformation.

Key words: aryl methyl ketones, DMF, copper, oxygen, α-ketoamides

α-Ketoamides, as a kind of important organic compounds, are widely found in natural products and bioactive compounds,[1] and they also show broad applications in various functionality transformations.[2] Many methods have been reported for the synthesis of α-ketoamides,[3] such as the traditional condensation of α-keto acids or α-keto acyl halides with amines,[3a,b] many interesting oxidative approaches,[3c,g,4] and palladium-catalyzed double carbonylation of diaryliodonium salts or aryl halides.[5] Among the oxidative reactions, copper-catalyzed oxidative amidation/diketonization of terminal alkynes with anilines,[4a] oxidative coupling of arylacetaldehydes and secondary amines,[4b] and oxidative coupling of aryl methyl ketones and amines[4c] are the most attractive ones. Yet in most cases, expensive substrates (α-keto acids, α-keto acyl halides, terminal alkynes, and arylacetaldehydes) and special reaction conditions were still required. *N*,*N*-Dimethylformamide as a ubiquitous solvent, is very cheap and has been widely used in all kinds of reactions, and recently, many methods have been developed using *N*,*N*-dimethylformamide as a reactant, acting as CHO, amide, CN, or amino group surrogates.[6] Aryl methyl ketones as cheap and commercially available starting materials, have attracted significant attention in organic and pharmaceutical synthesis. And lately functionalization of sp^3 C–H bond in aryl methyl ketones became a hot topic and many efficient methods have been developed based on catalytic functionalization of sp^3 C–H bond adjacent to carbonyl group in aryl methyl ketones.[4c,7] Very recently, Wang et al. reported an α-ketoamide formation reaction by treating an aryl methyl ketone with *N*,*N*-dimethylformamide;[8] this reaction needs both peroxide and iodine as oxidants. Compared to peroxides and iodine, molecular oxygen is an ideal oxidant because of its low toxicity, easy availability, and abundance. Recently we have been interested in copper-catalyzed aerobic oxidation/oxygenation with cheap, commercially available starting materials to construct new carbon–carbon and carbon–heteroatom bonds.[9] As continuation of our interest in this area, herein we report a copper-catalyzed aerobic oxidation to synthesize α-ketoamides from aryl methyl ketones and *N*,*N*-dimethylformamide.

On the basis of our own current research and the above reported literature, it is rational that the reaction between aryl methyl ketones and *N*,*N*-dimethylformamide could afford α-ketoamides in the presence of copper catalyst under an oxygen atmosphere. There are three known methods to convert *N*,*N*-dimethylformamide into amino group: acid, imidazole, and the TBAI/TBHP system.[6b] Because peroxide was needed in the TBAI/TBHP system, we decided to focus on the first two methods. In our initial study, acetophenone was chosen as the model substrate and an added acid to promote the formation of amino group from *N*,*N*-dimethylformamide in the presence of $Cu(OAc)_2$ at 130 °C under oxygen atmosphere. To our delight, 50% of α-ketoamide **3a** was detected when PivOH was added. After screening, it turned out that acetic acid gave the best result among TFA, $PhCO_2H$, and imidazole. Catalysts screening showed that Cu_2O gave the highest yield of desired product (Table 1, entries 2, 6–13). Further investigation indicated that temperature is very important for this transformation. When the temperature was increased to 150 °C, the yield of the desired product was dropped to 30%, yet when the temperature was lowered to 120 °C, 75% of desired product was obtained in GC yield with 65% isolated yield (Table 1, entries 14, 15). When catalyst loading was reduced to 10 mol%, the yield dropped to 62% (Table 1, entry 16), and addition of other solvent such as toluene to *N*,*N*-dimethylformamide caused notorious effect and only trace amount of the desired product was detected (Table 1, entry 17). No desired product was formed in the absence of oxygen or copper catalyst (Table 1, entries 18, 19), which demonstrated that both oxygen and copper catalyst played crucial roles in the reaction. Eventually, the optimized reaction conditions emerged as: aryl methyl ketone (0.5 mmol), Cu_2O (20 mol%), and acetic acid (2 equiv) in *N*,*N*-dimethylformamide (1 mL) under oxygen atmosphere at 120 °C.

With the optimized conditions in hand, we examined the scope of substituted acetophenones (Scheme 1). Both electron-rich and electron-poor aryl methyl ketones were

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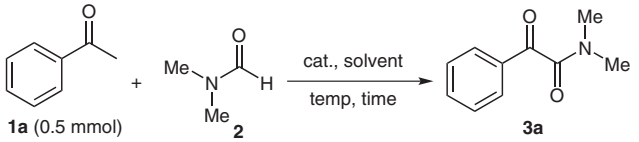
readily converted into the desired products (Scheme 1, **3a**–**q**, **t**). Furthermore, substituents at different positions of the arene group (*p*-, *m*-, and *o*-position) did affect the efficiency (Scheme 1, **3b**–**d**, **3e**–**g**, **3h**,**i**, **3j**,**k**, **3m**–**o**), with *ortho*-position giving lower yields probably due to the steric hindrance (Scheme 1, **3d**, **3f**, **3i**, **3j**, and **3m**). Halo-substituted aryl methyl ketones survived well leading to halo-substituted products (Scheme 1, **3b**–**i**), which could be further transformed into other functionalities. Apart from the halo-substituted aryl methyl ketones, 4-trifluoromethyl, methyl, ethyl, isopropyl, methoxy, nitro, and 1- and 2-naphthyl methyl ketones were all well tolerated under the standard conditions and gave the corresponding products in moderate to good yields (Scheme 1, **3j**–**t**). Thiophene methyl ketone also gave a decent yield of the desired product (Scheme 1, **3u**). When other formamides were used, only reasonable to low yields of the desired products were obtained (Scheme 1, **3v**–**x**).

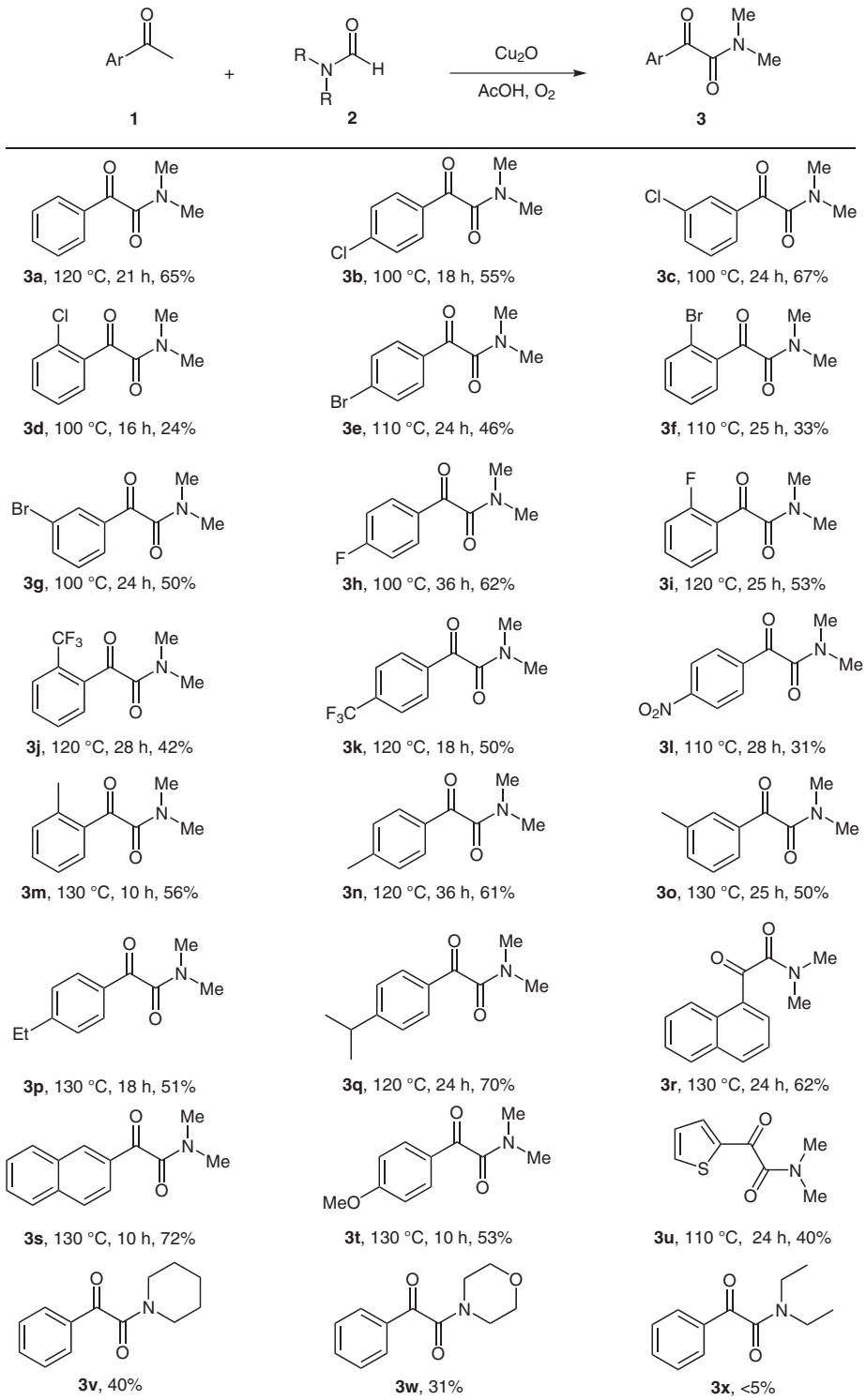
To gain the preliminary insight into the mechanism of the reaction, several control experiments were conducted (Scheme 2). Thus, acetophenone was reacted with *N*,*N*-dimethylformamide in the presence of $^{18}O_2$ (1 atm) under standard conditions. The product obtained was characterized as ^{18}O-**3a** by GCMS, which indicated that the new carbonyl group should come from O_2. When the reaction was carried out under a nitrogen atmosphere, no product **3a** was obtained (Table 1, entry 16), which demonstrated that molecular oxygen acted both as an oxidant and initiator for this reaction. Reactions carried out with α-hydroxyacetophenone and α-carbonyl aldehyde in the standard conditions afforded the desired product **3a** in 45% and 56% yield, respectively.

Table 1 Optimization of the Reaction Conditions[a]



Entry	Catalyst	Atmosphere	Acid (2 equiv, 1 mmol)	Solvent	Temp (°C)	Time (h)	Yield (%)[b]
1	$Cu(OAc)_2$ (20 mol%)	O_2	PivOH	DMF (1 mL)	130	24	50
2	$Cu(OAc)_2$ (20 mol%)	O_2	AcOH	DMF (1 mL)	130	24	60
3	$Cu(OAc)_2$ (20 mol%)	O_2	TFA	DMF (1 mL)	130	24	51
4	$Cu(OAc)_2$ (20 mol%)	O_2	$PhCO_2H$	DMF (1 mL)	130	24	trace
5	$Cu(OAc)_2$ (20 mol%)	O_2	imidazole	DMF (1 mL)	130	24	trace
6	$Cu(OTf)_2$ (20 mol%)	O_2	AcOH	DMF (1 mL)	130	24	27
7	$Cu(TFA)_2$ (20 mol%)	O_2	AcOH	DMF (1 mL)	130	24	52
8	$CuBr_2$ (20 mol%)	O_2	AcOH	DMF (1 mL)	130	24	7
9	$CuSO_4$ (20 mol%)	O_2	AcOH	DMF (1 mL)	130	24	34
10	Cu_2O (20 mol%)	O_2	AcOH	DMF (1 mL)	130	24	70
11	CuO (20 mol%)	O_2	AcOH	DMF (1 mL)	130	24	34
12	CuBr (20 mol%)	O_2	AcOH	DMF (1 mL)	130	24	40
13	CuI (20 mol%)	O_2	AcOH	DMF (1 mL)	130	24	41
14	Cu_2O (20 mol%)	O_2	AcOH	DMF (1 mL)	150	24	30
15	Cu_2O (20 mol%)	O_2	AcOH	DMF (1 mL)	120	24	75 (65)c
16	Cu_2O (10 mol%)	O_2	AcOH	DMF (1 mL)	130	24	62
17	Cu_2O (20 mol%)	O_2	AcOH	DMF (5 equiv) + 1.5 mL toluene	130	24	trace
18	Cu_2O (20 mol%)	N_2	AcOH	DMF (1 mL)	130	24	0
19	–	O_2	AcOH	DMF (1 mL)	130	24	0

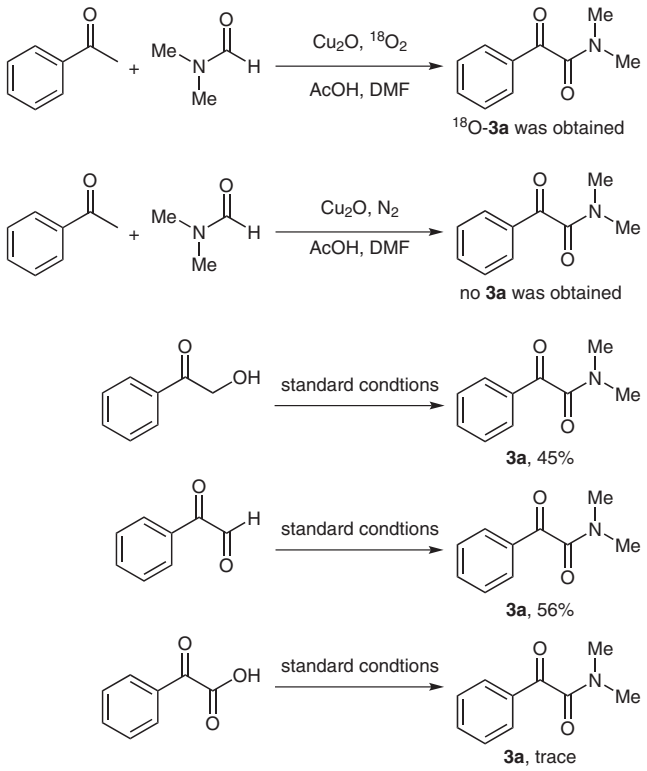
[a] Reaction conditions: acetophenone (**1**; 0.5 mmol), acid (2 equiv, 1 mmol), catalyst, DMF (1 mL) in a sealed tube under corresponding atmosphere.
[b] GC yields using dodecane as internal standard.
[c] Isolated yield.



Scheme 1 Reaction of DMF with various aryl methyl ketones. *Reaction conditions*: acetophenone derivative (0.5 mmol), Cu_2O (20 mol%), AcOH (1 mmol, 2 equiv), formamide (1 mL), at the corresponding temperature under O_2 atmosphere in a sealed tube, isolated yield.

On the basis of these results and the previous reports, a mechanism was postulated as depicted in Scheme 3: acetophenone was first oxidized into α-carbonyl aldehyde **4** in the presence of copper salt and oxygen, the aldehyde then reacted with the amino group, which was generated in situ from *N*,*N*-dimethylformamide and acid, to give the hemiaminal intermediate **5**. Eventually α-ketoamide **3a** was obtained by oxidation of intermediate **5** by copper salt and oxygen.

To summarize, a copper-catalyzed aerobic oxidative synthesis of α-ketoamides from aryl methyl ketones and *N*,*N*-dimethylformamide was developed. This reaction proceeds smoothly by a sequence of dioxygen activation, C–



Scheme 2 Control experiments

H bond functionalization, and amide formation with *N*,*N*-dimethylformamide as the nitrogen source. Molecular oxygen was found to play a crucial role in this transformation.

All experiments were conducted in a Schlenk tube. Flash column chromatography was performed over silica gel (200–300 mesh). ^{1}H NMR spectra were recorded on a Bruker AVIII 400 M spectrometer. Chemical shifts (in ppm) were referenced to the residual solvent peak ($CDCl_3$ at 7.26 ppm or DMSO-d_6 at 2.50 ppm). ^{13}C NMR spectra were obtained by using the same NMR spectrometers and were calibrated against the control line of the solvent signal ($CDCl_3$ at 77.00 ppm or DMSO-d_6 at 39.6 ppm). Unless otherwise noted, materials obtained from commercial suppliers were used without further purification. Petroleum ether (PE) used was the fraction boiling in the range of 60–90 °C.

α-Ketoamides from Aryl Methyl Ketones and DMF; Phenyl-*N*,*N*-dimethyl-2-oxoacetamide (3a);[10] Typical Procedure

A Schlenk tube was charged with acetophenone (**1a**; 60 mg, 0.5 mmol), AcOH (60 mg, 1 mmol), and Cu_2O (14.3 mg, 0.1 mmol, 20 mol%) in DMF (1 mL). The resulting solution was stirred at 120 °C under O_2. Upon completion of the reaction [monitored by TLC (eluent: PE–EtOAc, 6:1) and GC], EtOAc (20 mL) was added. The organic layer was washed with sat. aq $NaHCO_3$ (2 × 15 mL) and brine (20 mL). The combined aqueous layers were extracted with EtOAc (2 × 15 mL) and the combined organic layers were dried (Na_2SO_4). The solvents were removed via rotary evaporator and the residue was purified with flash chromatography [silica gel 200–300 mesh, petroleum ether–EtOAc, 5:1] to give **3a**; yield: 57.5 mg (65%); yellow oil.

[CAS Reg. No. 51579-87-4]

^{1}H NMR (400 MHz, $CDCl_3$): δ = 7.93 (d, *J* = 4 Hz, 2 H) 7.62 (t, *J* = 8 Hz, 1 H) 7.49 (t, *J* = 2 Hz, 2 H), 3.10 (s, 3 H), 2.94 (s, 3 H).

^{13}C NMR (100 MHz, $CDCl_3$): δ = 191.7, 166.7, 134.7, 133.1, 129.7, 129.0, 37.1, 34.0.

2-(4-Chlorophenyl)-*N*,*N*-dimethyl-2-oxoacetamide (3b)[10]
[CAS Reg. No. 74491-48-8]

Yield: 58 mg (55%); yellow oil.

^{1}H NMR (400 MHz, $CDCl_3$): δ = 7.88 (d, *J* = 8.4 Hz, 2 H), 7.46 (d, *J* = 8.5 Hz, 2 H), 3.09 (s, 3 H), 2.94 (s, 3 H).

^{13}C NMR (100 MHz, $CDCl_3$): δ = 190.3, 166.5, 141.3, 131.5, 131.0, 129.4, 37.0, 34.1.

2-(3-Chlorophenyl)-*N*,*N*-dimethyl-2-oxoacetamide (3c)[10]
Yield: 70.7 mg (67%); yellow oil.

^{1}H NMR (400 MHz, $CDCl_3$): δ = 7.91 (t, *J* = 2 Hz, 1 H), 7.82 (m, 1 H), 7.59 (m, 1 H), 7.44 (t, *J* = 7.6 Hz, 1 H), 3.11 (s, 3 H), 2.95 (s, 3 H).

^{13}C NMR (100 MHz, $CDCl_3$): δ = 190.2, 166.3, 135.4, 134.7, 134.6, 130.5, 130.3, 129.4, 127.8, 37.0, 34.1.

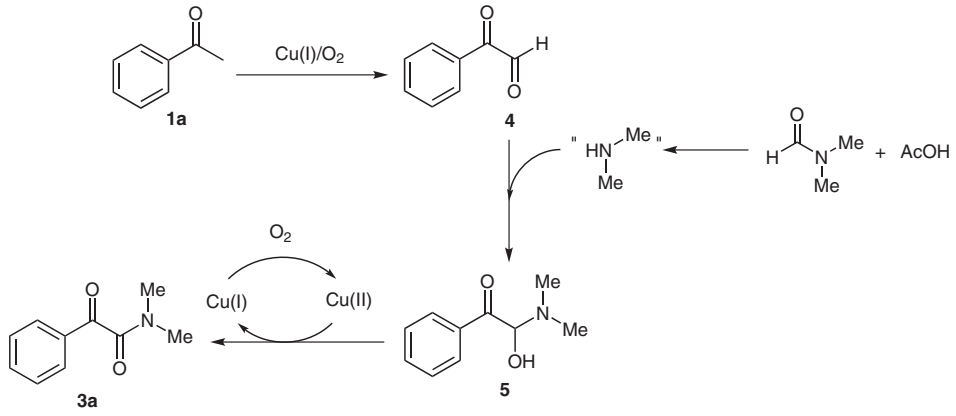
2-(2-Chlorophenyl)-*N*,*N*-dimethyl-2-oxoacetamide (3d)[10]
[CAS Reg. No. 668992-53-8]

Yield: 25.3 mg (24%); yellow oil.

^{1}H NMR (400 MHz, $CDCl_3$): δ = 7.88 (d, *J* = 7.2 Hz, 1 H), 7.49 (t, *J* = 5.6 Hz, 1 H), 7.41 (m, 2 H), 3.08 (s, 6 H).

^{13}C NMR (100 MHz, $CDCl_3$): δ = 190.2, 166.9, 134.3, 133.7, 133.5, 132.2, 130.8, 127.3, 37.1, 34.5.

2-(4-Bromophenyl)-*N*,*N*-dimethyl-2-oxoacetamide (3e)[10]
[CAS Reg. No. 1267453-29-1]



Scheme 3 Plausible mechanism

Yield: 58.7 mg (46%); yellow oil.

^{1}H NMR (400 MHz, $CDCl_3$): δ = 7.79 (d, *J* = 8.6 Hz, 2 H), 7.63 (d, *J* = 8.6 Hz, 2 H), 3.09 (s, 3 H), 2.94 (s, 3 H).

^{13}C NMR (100 MHz, $CDCl_3$): δ = 190.5, 166.4, 132.4, 131.9, 131.1, 130.2, 37.0, 34.1.

2-(2-Bromophenyl)-*N*,*N*-dimethyl-2-oxoacetamide (3f)[11]
[CAS Reg. No. 1115951-84-2]

Yield: 42.1 mg (33%); yellow oil.

^{1}H NMR (400 MHz, $CDCl_3$): δ = 7.82 (dd, J_1 = 7.5 Hz, J_2 = 2 Hz, 1 H), 7.63 (dd, J_1 = 7.6 Hz, J_2 = 1 Hz, 1 H), 7.42 (m, 2 H), 3.09 (s, 3 H), 3.07 (s, 3 H).

^{13}C NMR (100 MHz, $CDCl_3$): δ = 190.9, 166.3, 135.5, 134.1, 134.1, 132.7, 127.8, 121.6, 37.3, 34.7.

2-(3-Bromophenyl)-*N*,*N*-dimethyl-2-oxoacetamide (3g)[11]
[CAS Reg. No. 1426249-30-0]

Yield: 63.8 mg (50%); yellow oil.

^{1}H NMR (400 MHz, $CDCl_3$): δ = 8.09 (s, 1 H), 7.88 (d, *J* = 7.7 Hz, 1 H), 7.76 (d, *J* = 7.3 Hz, 1 H), 7.39 (m, 1 H), 3.12 (s, 3 H), 2.97 (s, 3 H).

^{13}C NMR (100 MHz, $CDCl_3$): δ = 190.1, 166.2, 137.5, 134.9, 132.4, 130.6, 128.3, 123.3, 37.0, 34.1.

2-(4-Fluorophenyl)-*N*,*N*-dimethyl-2-oxoacetamide (3h)[10]
[CAS Reg. No. 126086-37-1]

Yield: 60.5 mg (62%); yellow oil.

^{1}H NMR (400 MHz, $CDCl_3$): δ = 7.97 (m, 2 H), 7.17 (t, *J* = 8.6 Hz, 2 H), 3.10 (s, 3 H), 2.95 (s, 3 H).

^{13}C NMR (100 MHz, $CDCl_3$): δ = 190.0, 168.0, 166.7, 165.4, 132.5, 132.4, 129.7, 116.4, 116.2, 37.0, 34.1.

2-(2-Fluorophenyl)-*N*,*N*-dimethyl-2-oxoacetamide (3i)[10]
[CAS Reg. No. 1426249-31-1]

Yield: 51.7 mg (53%); yellow oil.

^{1}H NMR (400 MHz, $CDCl_3$): δ = 7.97 (m, 1 H), 7.6 (m, 1 H), 7.31 (d, *J* = 8 Hz, 1 H), 7.15 (m, 1 H), 3.09 (s, 3 H), 3.01 (s, 3 H).

^{13}C NMR (100 MHz, $CDCl_3$): δ = 188.2, 167.4, 163.9, 161.4, 136.5, 131.0, 124.9, 116.7, 36.8, 34.1.

***N*,*N*-Dimethyl-2-oxo-2-[2-(trifluoromethyl)phenyl]acetamide (3j)**
Yield: 51.5 mg (42%); yellow oil.

^{1}H NMR (400 MHz, $CDCl_3$): δ = 7.80 (m, 2 H), 7.66 (m, 2 H), 3.10 (s, 3 H), 3.08 (s, 3 H).

^{13}C NMR (100 MHz, $CDCl_3$): δ = 190.4, 165.6, 134.5, 132.4, 132.0, 131.6, 127.2, 127.2, 37.1, 34.8.

***N*,*N*-Dimethyl-2-oxo-2-[4-(trifluoromethyl)phenyl]acetamide (3k)**
[CAS Reg. No. 1456807-74-1]

Yield: 61.3 mg (50%); yellow oil.

^{1}H NMR (400 MHz, $CDCl_3$): δ = 8.07 (d, *J* = 8 Hz, 2 H), 7.77 (d, *J* = 8.4 Hz, 2 H), 3.1 (s, 3 H), 2.98 (s, 3 H).

^{13}C NMR (100 MHz, $CDCl_3$): δ = 190.3, 166.1, 135.8, 135.5, 130.0, 126.03, 125.99, 37.0, 34.2.

***N*,*N*-Dimethyl-2-(4-nitrophenyl)-2-oxoacetamide (3l)**[10]
[CAS Reg. No. 431059-81-3]

Yield: 34.4 mg (31%); yellow solid; mp 132–134 °C (Lit.[10] mp 136–138 °C).

^{1}H NMR (400 MHz, $CDCl_3$): δ = 8.33 (d, *J* = 8.8 Hz, 2 H), 8.13 (d, *J* = 8.8 Hz, 2 H), 3.14 (s, 3 H), 3.00 (s, 3 H).

^{13}C NMR (100 MHz, $CDCl_3$): δ = 189.2, 165.6, 151.1, 137.6, 130.8, 126.4, 124.1, 123.9, 37.1, 34.3.

***N*,*N*-Dimethyl-2-oxo-2-(*o*-tolyl)acetamide (3m)**[10]
[CAS Reg. No. 1403603-11-1]

Yield: 53.5 mg (56%); yellow oil.

^{1}H NMR (400 MHz, $CDCl_3$): δ = 7.69 (d, *J* = 7 Hz, 1 H), 7.48 (t, *J* = 6.6 Hz, 1 H), 7.31 (t, *J* = 6.8 Hz, 2 H), 3.11 (s, 3 H), 2.97 (s, 3 H), 2.66 (s, 3 H).

^{13}C NMR (100 MHz, $CDCl_3$): δ = 193.8, 167.8, 141.4, 133.7, 132.6, 132.6, 131.6, 126.2, 37.0, 34.0, 21.7.

***N*,*N*-Dimethyl-2-oxo-2-(*p*-tolyl)acetamide (3n)**
[CAS Reg. No. 51579-89-6]

Yield: 58.3 mg (61%); yellow oil.

^{1}H NMR (400 MHz, $CDCl_3$): δ = 7.82 (d, *J* = 8.0 Hz, 2 H), 7.33 (d, *J* = 8.0 Hz, 2 H), 3.10 (s, 3 H), 2.94 (s, 3 H), 2.43 (s, 3 H).

^{13}C NMR (100 MHz, $CDCl_3$): δ = 191.6, 167.2, 146.0, 131.0, 130.6, 129.7, 129.7, 37.0, 33.9, 21.8.

***N*,*N*-Dimethyl-2-oxo-2-(*m*-tolyl)acetamide (3o)**
[CAS Reg. No. 51579-90-9]

Yield: 47.8 mg (50%); yellow oil.

^{1}H NMR (400 MHz, $CDCl_3$): δ = 7.72 (d, *J* = 3.2 Hz, 2 H), 7.44 (d, *J* = 7.5 Hz, 1 H), 7.38 (t, *J* = 7.6 Hz, 1 H), 3.10 (s, 3 H), 2.94 (s, 3 H), 2.40 (s, 3 H).

^{13}C NMR (100 MHz, $CDCl_3$): δ = 192.0, 167.2, 139.0, 135.6, 133.1, 130.0, 128.9, 126.9, 37.0, 34.0, 21.2.

2-(4-Ethylphenyl)-*N*,*N*-dimethyl-2-oxoacetamide (3p)
[CAS Reg. No. 1267457-91-9]

Yield: 52.3 mg (51%); yellow oil.

^{1}H NMR (400 MHz, $CDCl_3$): δ = 7.85 (d, *J* = 8.2 Hz, 2 H), 7.31 (d, *J* = 8.2 Hz, 2 H), 3.10 (s, 3 H), 2.94 (s, 3 H), 2.71 (q, *J* = 7.6 Hz, 2 H), 1.25 (t, *J* = 7.6 Hz, 3 H).

^{13}C NMR (100 MHz, $CDCl_3$): δ = 191.6, 167.3, 152.1, 130.9, 129.9, 128.6, 37.1, 34.0, 29.1.

2-(4-Isopropylphenyl)-*N*,*N*-dimethyl-2-oxoacetamide (3q)
[CAS Reg. No. 1268109-94-9]

Yield: 76.6 mg (70%); yellow oil.

^{1}H NMR (400 MHz, $CDCl_3$): δ = 7.85 (d, *J* = 8.4 Hz, 2 H), 7.34 (d, *J* = 8.3 Hz, 2 H), 3.09 (s, 3 H), 2.94 (s, 3 H), 1.25 (d, *J* = 6.9 Hz, 6 H).

^{13}C NMR (100 MHz, $CDCl_3$): δ = 191.5, 167.3, 156.6, 131.0, 129.9, 127.2, 37.1, 34.5, 34.0, 23.5.

***N*,*N*-Dimethyl-2-(naphthalen-1-yl)-2-oxoacetamide (3r)**
[CAS Reg. No. 51579-92-1]

Yield: 70.4 mg (62%); yellow oil.

^{1}H NMR (400 MHz, $CDCl_3$): δ = 9.25 (d, *J* = 8.8 Hz, 1 H), 8.11 (d, *J* = 8.4 Hz, 1 H), 7.99 (d, *J* = 6.2 Hz, 1 H), 7.91 (d, *J* = 8.0 Hz, 1 H), 7.70 (m, 1 H), 7.56 (m, 2 H).

^{13}C NMR (100 MHz, $CDCl_3$): δ = 194.2, 167.7, 136.3, 135.9, 134.3, 134.1, 131.0, 129.9, 129.3, 128.7, 128.5, 127.0, 125.8, 124.6, 37.2, 34.2.

***N*,*N*-Dimethyl-2-(naphthalen-2-yl)-2-oxoacetamide (3s)**[10]
[CAS Reg. No. 51579-91-0]

Yield: 81.7 mg (72%); yellow oil.

^{1}H NMR (400 MHz, $CDCl_3$): δ = 8.44 (s, 1 H), 8.03 (dd, J_1 = 8.4 Hz, J_2 = 1.6 Hz, 1 H), 7.96 (m, 2 H), 7.89 (d, *J* = 8.2 Hz, 1 H), 7.64 (t, *J* = 7.0 Hz, 1 H), 7.57 (t, *J* = 7.0 Hz, 1 H), 3.18 (s, 3 H), 3.00 (s, 3 H)

^{13}C NMR (100 MHz, $CDCl_3$): δ = 191.9, 167.2, 136.4, 133.0, 132.5, 130.5, 129.9, 129.4, 129.1, 128.0, 127.1, 123.7, 37.2, 34.1.

2-(4-Methoxyphenyl)-*N*,*N*-dimethyl-2-oxoacetamide (3t)[10]
[CAS Reg. No. 51579-95-4]

Yield: 54.8 mg (53%); yellow oil.

^{1}H NMR (400 MHz, $CDCl_3$): δ = 7.97 (d, *J* = 3.6 Hz, 2 H), 6.93 (d, *J* = 7.2 Hz, 2 H), 3.84 (s, 3 H), 3.06 (s, 3 H), 2.91 (s, 3 H).

***N*,*N*-Dimethyl-2-oxo-2-(thiophen-2-yl)acetamide (3u)**[10]
[CAS Reg. No. 26878-17-1]

Yield: 36.6 mg (40%); yellow oil.

^{1}H NMR (400 MHz, $CDCl_3$): δ = 7.79 (m, 2 H), 7.16 (m, 1 H), 3.08 (s, 3 H), 3.02 (s, 3 H).

^{13}C NMR (100 MHz, $CDCl_3$): δ = 183.5, 165.9, 140.1, 136.4, 136.1, 128.6, 37.3, 34.4.

1-Phenyl-2-(piperidin-1-yl)ethane-1,2-dione (3v)[10]
[CAS Reg. No. 14377-63-0]

Yield: 43.5 mg (40%); yellow oil.

^{1}H NMR (400 MHz, $CDCl_3$): δ = 7.95 (dd, J_1 = 8.8 Hz, J_2 = 0.8 Hz, 2 H), 7.64 (m, 1 H), 7.51 (t, *J* = 7.2 Hz, 2 H), 3.71 (m, 2 H), 3.29 (m, 2 H), 1.70 (m, 4 H), 1.55 (m, 2 H).

1-Morpholino-2-phenylethane-1,2-dione (3w)[10]
[CAS Reg. No. 40991-78-4]

Yield: 33.9 mg (31%); yellow oil.

^{1}H NMR (400 MHz, $CDCl_3$): δ = 7.97 (m, 2 H), 7.67 (m, 1 H), 7.53 (t, *J* = 7.6 Hz, 2 H), 3.80 (s, 4 H), 3.66 (m, 2 H), 3.39 (t, *J* = 4.8 Hz, 2 H).

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