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Copper(II) Triflate Catalyzed Amination of 1,3-Dicarbonyl Compounds

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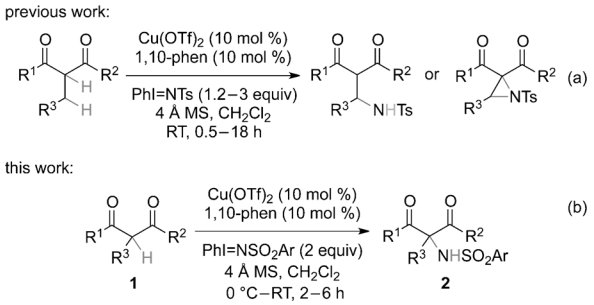
Abstract: A method to prepare α,α-acyl amino acid derivatives efficiently by $Cu(OTf)_2$+1,10-phenanthroline (1,10-phen)-catalyzed amination of 1,3-dicarbonyl compounds with PhI=NSO_2Ar is described. The mechanism is thought to initially involve aziridination of the enolic form of the substrate, formed in situ through coordination to the Lewis acidic metal catalyst, by the putative copper–nitrene/imido species generated from the reaction of the metal catalyst with the iminoiodane source. Subsequent ring opening of the resultant aziridinol adduct under the Lewis acidic conditions then provided the α-aminated product. The utility of this method was exemplified by the enantioselective synthesis of a precursor of 3-styryl-2-benzoyl-L-alanine.

Keywords: amination · copper · dicarbonyl compounds · homogenous catalysis · iminoiodanes

Introduction

An ongoing challenge in medicinal chemistry is the design of new compounds containing unnatural α-amino acids, those outside the set of 20 used by nature, which can exhibit novel modes of therapeutic activity.[1] For this reason, the development of novel routes to new members of this immensely important class of biomolecules from readily available and inexpensive substrates and catalytic systems continues to be actively pursued in organic synthesis.[2]

Transition-metal-catalyzed nitrogen-atom and -group transfer reactions have become one of the most powerful and convenient synthetic routes to amines and amine derivatives over the years.[3–8] Recently, this included renewed interest in the development of this approach by using copper catalysis, owing to its low cost and better biocompatibility when compared to other metal complexes.[3–6] For example, we reported a method for the synthesis of α-acyl β-amino acid derivatives that relied on nitrene/imido insertion into the β-methylene C–H bond of 2-alkyl-substituted 1,3-dicarbonyl compounds with PhI=NTs as the nitrogen source and a $Cu(OTf)_2$+1,10-phen catalyst system (Scheme 1a).[4a] By increasing the amount of the iminoiodane, preferential formal aziridination of the C–C bond of the 2-alkyl substituent of the starting material to give 2,2-diacyl aziridines could be realized. Further exploration of this field led us to investigate the potential chemical reactivity at the α-position of 1,3-dicarbonyl compounds (Scheme 1b). We reasoned that insertion of a putative metal–nitrene/imido species into the α-C–H bond of the substrate would represent an attractive synthetic approach to ketone-substituted α-amino acid derivatives, a new of class of biomolecules that would be of interest in drug discovery.[1] Herein, we disclose details of this efficient synthetic method to this novel class of α-amino acid derivatives that relies on the copper(II)-catalyzed chemoselective amination of 1,3-dicarbonyl compounds with PhI=NSO_2Ar. The application of this catalytic C–N bond-formation process to the enantioselective synthesis of a precursor of 3-styryl-2-benzoyl-L-alanine in two steps is also presented.



Scheme 1. Copper(II)-catalyzed reactivities of β-dicarbonyl compounds with PhI=NSO_2Ar.

Results and Discussion

Following our success by using $Cu(OTf)_2$+1,10-phen to effect amination and aziridination of 2-alkyl-substituted 1,3-dicarbonyl compounds with PhI=NTs, we chose this catalytic system and ethyl 3-oxo-3-phenylpropanoate (**1a**) as a model substrate to test the feasibility of our hypothesis (Table 1). Subjecting **1a** and 2 equivalents of PhI=NTs to 10 mol% of $Cu(OTf)_2$, 10 mol% of 1,10-phen, and 4 Å molecular sieves

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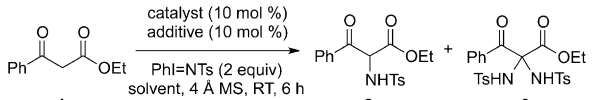
Table 1. Optimization of the reaction conditions.[a]



Entry	Catalyst	Additive	Solvent	Yield [%][b]	
				2a	**3a**
1	$Cu(OTf)_2$	1,10-phen	CH_2Cl_2	99	–
2	$Cu(OTf)_2$	terpy	CH_2Cl_2	58	8
3	$Cu(OTf)_2$	pyridine	CH_2Cl_2	12	42
4	$Cu(OTf)_2$	picolinic acid	CH_2Cl_2	76	–
5[c]	$Cu(OTf)_2$	1,10-phen	CH_2Cl_2	47	10
6[d]	$Cu(OTf)_2$	1,10-phen	CH_2Cl_2	74	–
7[e]	$Cu(OTf)_2$	1,10-phen	CH_2Cl_2	51	–
8[f]	$Cu(OTf)_2$	1,10-phen	CH_2Cl_2	42	–
9	$Cu(OTf)_2$	1,10-phen	THF	73[g]	–
10	$Cu(OTf)_2$	1,10-phen	CH_3CN	24	20
11	$Cu(OTf)_2$	1,10-phen	$PhCH_3$	37	–
12	$Cu(OTf)_2$	–	CH_2Cl_2	60	16
13	CuO	–	CH_2Cl_2	69	16
14	$CuCl_2$	–	CH_2Cl_2	3	20
15	$CuBr_2$	–	CH_2Cl_2	–	10
16	CuOTf	–	CH_2Cl_2	68	16
17	Cu_2O	–	CH_2Cl_2	12	8
18	CuCN	–	CH_2Cl_2	–	23
19	CuCl	–	CH_2Cl_2	–	31
20	CuBr	–	CH_2Cl_2	30	9
21	CuI	–	CH_2Cl_2	–	–
22	CuO	1,10-phen	CH_2Cl_2	76	11
23	CuOTf	1,10-phen	CH_2Cl_2	24	12
24	$[Rh_2(oct)_4]$	–	CH_2Cl_2	34	–
25	[Ru(TTP)(CO)]	–	CH_2Cl_2	68	10

[a] All reactions were carried out at room temperature in CH_2Cl_2 for 6 h in the presence of powdered 4 Å MS (400 mg) with catalyst/ligand/**1a**/PhI=NTs at a molar ratio of 1:1:10:20. [b] Isolated yield. [c] Reaction conducted with 5 mol% of $Cu(OTf)_2$. [d] Reaction conducted with 1.5 equivalents of PhI=NTs. [e] PhI=NTs was replaced by $PhI(OAc)_2$ and $TsNH_2$. [f] PhI=NTs was replaced by PhI=O and $TsNH_2$. [g] Tetrahydro-*N*-tosylfuran-2-amine (**4**) was additionally obtained in 26% yield.

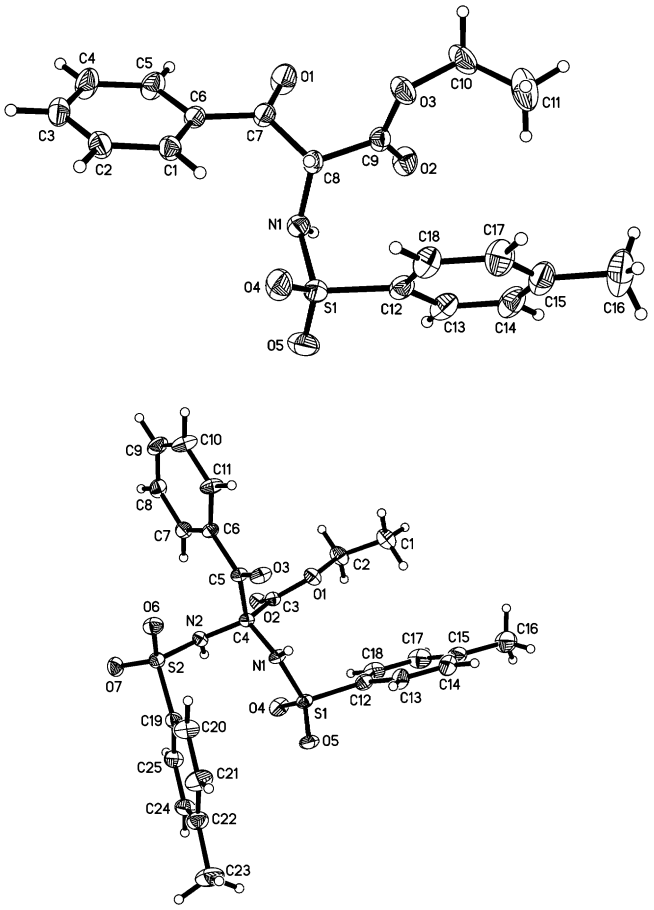
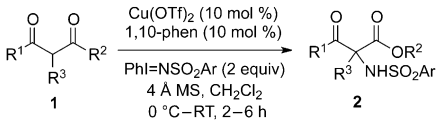


Figure 1. ORTEP drawings of a) **2a** and b) **3a** with thermal ellipsoids at the 50% probability level.[9]

(MS) in dichloromethane at room temperature for 6 h gave the best result (Table 1, entry 1). Under these conditions, ethyl 3-oxo-3-phenyl-2-(tosylamino)propanoate (**2a**) was obtained in near quantitative yield. On the other hand, lower product yields were found when terpyridine (terpy), pyridine, or picolinic acid were used in place of 1,10-phen as ligand (Table 1, entries 2–4). The reactions with terpy or pyridine as ligand also afforded ethyl 3-oxo-3-phenyl-2,2-bis(tosylamino)propanoate (**3a**) in 8 and 42% yield, respectively (Table 1, entries 2 and 3). The structure of both the α,α-acyl amino acid derivative and the diaminated by-product were determined by ^1H NMR measurements and X-ray crystallography (Figure 1).[9] A similar outcome was obtained on lowering the catalyst loading from 10 to 5 mol% or lowering the amount of PhI=NTs from 2 to 1.5 equivalents, changing the nitrogen source from PhI=NTs to $TsNH_2$ and either $PhI(OAc)_2$ or PhI=O, or changing the solvent from dichloromethane to THF, CH_3CN, or toluene (Table 1, entries 5–11). The reaction with THF in place of dichloromethane as solvent was found to give tetrahydro-*N*-tosylfuran-2-amine (**4**) as an additional by-product in 26% yield (Table 1, entry 9).[4c] Likewise, control experiments with $Cu(OTf)_2$ and other Cu^I and Cu^{II} salts in the absence of a ligand or $[Rh_2(oct)_4]$ (Hoct = octanoic acid) or [Ru(TTP)CO] (H_2(TTP) = *meso*-tetrakis(*p*-tolyl)porphyrin) as catalyst did not lead to any improvements (Table 1, entries 12–21, 24 and 25). A survey of all these latter metal catalysts showed that either the mono- or the diaminated adduct or both were obtained in low yields of 9–69%, or no reaction was observed and the starting material was recovered in near quantitative yield. Interestingly, while reactions mediated by either CuO or CuOTf gave a slightly higher product yield than that with $Cu(OTf)_2$ as catalyst, their activity in analogous experiments in the presence of the 1,10-phen ligand were found to be less effective (Table 1, entries 22 and 23).

The generality of our catalytic system was next investigated by using a series of β-ketoesters and iminoiodane sources, and the results are summarized in Table 2. In general, these reactions proceeded well and a variety of α,α-acyl amino acid derivatives could be afforded in good to excellent yields of 81–99%. With the exception of **1h**, which gave recovery of the substrate in near quantitative yield, β-ketoesters containing benzoyl groups bearing an electron-donating or electron-withdrawing group were well tolerated, giving **2c–g** in 93–97% yield (Table 2, entries 2–7). A com-

Table 2. $Cu(OTf)_2$-catalyzed amination of β-ketoesters **1a–r**.[a]



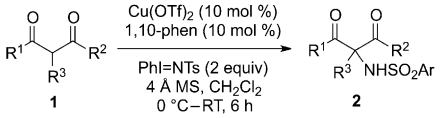
Entry	Product		Yield [%][b]
1		**2b**, R^1 = H, R^2 = Ns	94
2		**2c**, R^1 = OMe, R^2 = Ts	97
3		**2d**, R^1 = Me, R^2 = Ts	93
4[c]		**2e**, R^1 = F, R^2 = Ts	96
5[c]		**2f**, R^1 = Cl, R^2 = Ts	94
6[c]		**2g**, R^1 = Br, R^2 = Ts	95
7[c]		**2h**, R^1 = NO_2, R^2 = Ts	–[d]
8[c]		**2i**	99
9		**2j**, R = *t*Bu	81
10[c]		**2k**, R = *i*Pr	83
11[c]		**2l**	93
12		**2m**	88
13		**2n**, X = O	93
14		**2o**, X = S	95
15		**2p**, X = NMe	92
16		**2q**	94
17		**2r**	–[e]

[a] All reactions were carried out at room temperature in CH_2Cl_2 in the presence of powdered 4 Å MS (400 mg) with $Cu(OTf)_2$/1,10-phen/**1**/PhI=NSO_2Ar at a molar ratio of 1:1:10:20 for 2–6 h; refer to the Experimental Section for individual reaction times. [b] Isolated yield. [c] Reaction carried out at 0 °C. [d] Trace amount of product detected on the basis of ^{1}H NMR analysis of the crude mixture, along with recovery of the starting material in near quantitative yield. [e] Mixture of unknown side products formed, based on ^{1}H NMR analysis of the crude mixture.

parable outcome was found when the reactivity of β-ketoesters with a pendant alkane or cycloalkane moiety was examined, as in **1j–m** (Table 2, entries 9–12). These reactions proceeded well and gave the corresponding α-aminated adducts **2j–m** in excellent yields. Substrates containing a furan (**1n** and **1q**), thiophene (**1o**), or *N*-methyl-substituted pyrrole (**1p**) moiety were well tolerated under the reaction conditions, providing the corresponding α-aminated products **2n–q** in 92–95% yield (Table 2, entries 13–16). Changing the nitrogen source from PhI=NTs to PhI=NNs was also found to have no effect, with the analogous reaction of **1a** with the last nitrogen source giving **2b** in a comparable yield of 94% (Table 2, entry 1). In our hands, the reaction of the cyclic β-ketoester **1r** was the only example that gave a mixture of decomposition products that could not be identified by ^{1}H NMR analysis of the crude mixture (Table 2, entry 17).

We next turned our attention to define the scope of this methodology with respect to other types of 1,3-dicarbonyl compounds (Table 3). With this in mind, the amination of dimethyl malonate (**1s**) with PhI=NTs was first tested in the

Table 3. $Cu(OTf)_2$-catalyzed amination of malonic esters and 1,3-diones **1s–γ**.[a]



Entry	Product		Yield [%][b]
1		**2s**, R = Me	87
2		**2t**, R = Et	99
3[c]		**2u**, R = *i*Pr	99
4		**2v**, R = *t*Bu	98
5[c]		**2w**, R = Ph	53
6[c]		**2x**, R = allyl	88
7		**2y**, R = Ph	70
8		**2z**, R = *t*Bu	–[d]
9		**2α**, R = Me	98
10		**2ß**, R = *t*Bu	66
11		**2?**, R = Ph	62

[a] All reactions were carried out at room temperature in CH_2Cl_2 in the presence of powdered 4 Å MS (400 mg) with $Cu(OTf)_2$/1,10-phen/**1**/PhI=NTs at a molar ratio of 1:1:10:20 for 6 h. [b] Isolated yield. [c] Reaction carried out at 0 °C. [d] Recovery of the starting material in near quantitative yield.

presence of 10 mol% of $Cu(OTf)_2$ and 10 mol% of 1,10-phen under the standard conditions, and dimethyl 2-(tosylamino)malonate (**2s**) could be afforded in 87% yield (Table 3, entry 1). Under similar conditions, repetition of the reaction with other malonic esters **1t–y** gave the corresponding dialkyl and diphenyl 2-(tosylamino)malonates **2t–y** in 53–99% yield (Table 3, entries 2–7). This included one example that tolerated the introduction of a phenyl substituent (**2y**) at the α-position of the substrate (Table 3, entry 7). However, replacing the phenyl substituent at this position with a presumably more bulky *tert*-butyl group (**2z**) was found to result in recovery of the substrate in near quantitative yield (Table 3, entry 8). On the other hand, the reaction could be extended to the 1,3-diones **1α–γ** to give the corresponding 3-(tosylamino)pentane-2,4-diones **2α–γ** in 62–98% yield (Table 3, entries 9–11).

To gain an insight into the possible mechanism, we performed competition experiments on the Cu^{II}-catalyzed amination reactions of **1c–h**. This gave $\log(k_X/k_H)$ values of 0.06 (**1c**), 0.01 (**1d**), −0.03 (**1e**), −0.11 (**1f**), −0.12 (**1g**), and −0.35 (**1h**), suggesting that electron-donating substituents accelerate whereas electron-withdrawing substituents retard the amination process. Fitting (by least squares method) the $\log(k_X/k_H)$ data with the σ_p scale gave rise to good linearity (R^2 = 0.975) with a ρ value of −0.39 (Figure 2).[10] The small and negative ρ value indicates that only a moderate positive charge is built up in the transition state.[11] This value was

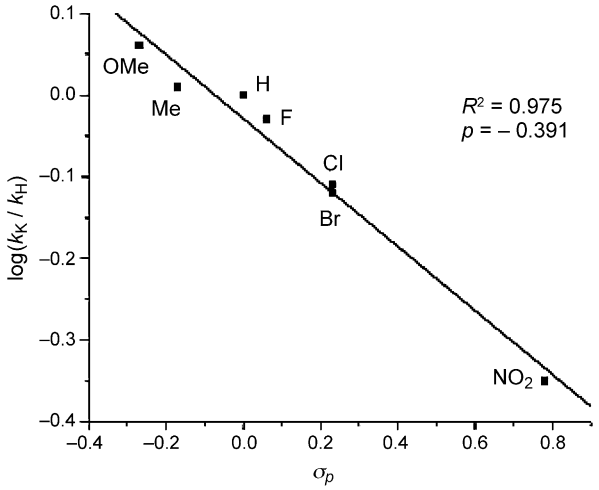
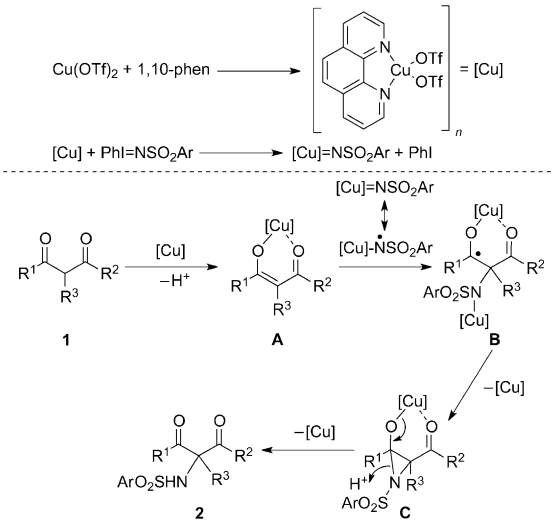


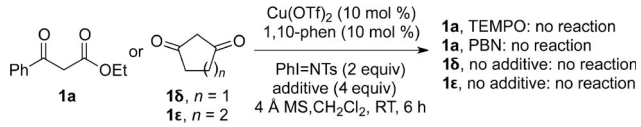
Figure 2. Linear free-energy correlation of $\log(k_X/k_H)$ versus σ_p for the copper(II)-catalyzed amination of 1,3-dicarbonyl compounds **1c–h** with PhI=NTs.



Scheme 3. Tentative proposed mechanism for the copper(II)-catalyzed amination of 1,3-dicarbonyl compounds with PhI=SO_2Ar.

found to be similar to that reported for Cu^{II}-catalyzed alkene aziridinations (−0.6), in which an asynchronous transition state was proposed.[5g]

While isolation of tetrahydro-*N*-tosylfuran-2-amine (**4**), obtained from the reaction of **1a** with PhI=NTs in THF catalyzed by $Cu(OTf)_2$+1,10-phen (Table 1, entry 9), was fortuitous, the result argues in favor of a mechanistic pathway involving a Cu^{II}-mediated nitrene/imido transfer process.[4e] The radical nature of this step was implied by our results showing decomposition of **1a** to a variety of unknown side products when the substrate was treated with PhI=NTs and the Cu^{II} catalyst in the presence of 2,2,6,6-tetramethylpiperidin-1-yl)oxyl (TEMPO) or *N*-tert-butyl-α-phenylnitrone (PBN) under the conditions described in Scheme 2. These

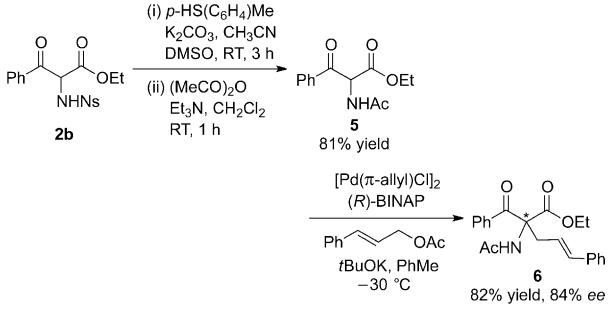


Scheme 2. Control experiments with **1a**, **1δ** and **1ε** catalyzed by Cu-$(OTf)_2$+1,10-phen.

latter results are also in good agreement with previous works using radical inhibitors to implicate the possible involvement of radical species in the respective Ag^{I}- and Cu^{II}-catalyzed amination of C−H bonds of alkanes and 2-alkyl-substituted 1,3-dicarbonyl compounds with PhI=NTs.[4a,7] Additionally, coordination of the metal catalyst to the substrate was shown to be important, based on our observations for the Cu^{II}-mediated control experiments of cyclopentane-1,3-dione (**1δ**) or cyclohexane-1,3-dione (**1ε**) with PhI=NTs (Scheme 2). These tests only afforded the recovery of the substrate in near quantitative yield and led us to surmise that the present Cu^{II}-catalyzed amination process occurs via a copper-enolate species.

A plausible mechanism for the present Cu^{II}-catalyzed amination reaction is outlined in Scheme 3. This involves the initial formation of a Cu–1,10-phen species from the reaction of $Cu(OTf)_2$ and the 1,10-phen additive in either the monomeric or polymeric form.[12] Further reaction of this Cu–1,10-phen complex with PhI=NSO_2Ar generates the putative highly reactive [Cu]=NSO_2Ar species.[13] At the same time, coordination of the Cu–1,10-phen complex to **1** would occur to give the copper-enolate species **A**. In a manner similar to the analogous aminations of silyl enol ethers and β-enamino esters,[8,14] subsequent addition of the nitrene/imido group in [Cu]=NSO_2Ar to the C=C bond of this newly formed copper-enolate via the carboradical **B** would give intermediate **C**. Presumably, the acid-labile nature of the aziridin-2-ol intermediate formed results in ring opening of the cyclic moiety to provide the product **2**.

Having established an efficient route to α,α-acyl amino acid derivatives, we applied this new methodology to the synthesis of the chiral *N*-acyl-protected quaternary α-amino ethyl ester **6** (Scheme 4). At room temperature, nosyl deprotection of **2b** in CH_3CN/DMSO (49:1 *v*/*v*) was achieved with *p*-methoxyphenylthiol in the presence of K_2CO_3 base.



Scheme 4. Synthesis of chiral 3-styryl-2-benzoyl-L-alanine derivative **6** from **2b**.

This was then followed by protection of the resultant free amine with acetic anhydride and Et_3N in dichloromethane to give the *N*-acyl-protected intermediate **5** in 81% yield over two steps. Subsequent treatment of this newly formed adduct with a toluene solution containing cinnamyl acetate, $[Pd(\pi\text{-allyl})Cl]_2$, (*R*)-BINAP (BINAP = 2,2′-bis(diphenylphosphino)-1,1′-binaphthyl), and *t*BuOK afforded the allylated product **6** in 82% yield and 84% *ee*.[15]

Conclusion

In summary, we have developed a mild and highly efficient copper(II)-catalyzed methodology for the amination of 1,3-dicarbonyl compounds with $PhI{=}NSO_2Ar$ as nitrogen source. The catalytic system is inexpensive and extremely simply formed in situ from $Cu(OTf)_2$ and 1,10-phen. The reaction was shown to tolerate a wide variety of substrates to give the corresponding α-aminated products for applications in natural product synthesis and medicinal chemistry, as exemplified by the preparation of a chiral quaternary α-amino acid derivative. Further exploration of the scope and synthetic utility of the present reaction are currently underway and will be reported in due course.

Experimental Section

General remarks: All reactions were performed under a nitrogen atmosphere at ambient temperature unless otherwise stated. PhI=NTs,[16] PhI=O[17] and [Ru(TTP)(CO)][18] were prepared according to known literature procedures. Unless specified, all reagents and starting materials were purchased from commercial sources and used as received. Solvents were purified prior to use following literature procedures; CH_2Cl_2 and CH_3CN were purified prior to use by distilling over CaH_2, pyridine was distilled over KOH, and benzaldehyde was distilled under reduced pressure. Analytical thin layer chromatography (TLC) was performed by using precoated silica gel plates. Visualization was achieved by UV/Vis light (254 nm), followed by treatment with ninhydrin stain and heating. Flash chromatography was performed using silica gel with a gradient solvent system (eluent: EtOAc/*n*-hexane). Unless otherwise stated, ^1H and ^{13}C NMR spectra were measured on a Bruker AV 300 MHz spectrometer. Unless otherwise stated, chemical shifts (ppm) were recorded in $CDCl_3$ solution with tetramethylsilane (TMS) as the internal reference standard. Multiplicities are given as: s (singlet), brs (broad singlet), d (doublet), t (triplet), q (quartet), dd (doublet of doublets) or m (multiplet). The number of protons (*n*) for a given resonance is indicated by *n*H and coupling constants are reported as *J* values in Hz. Low resolution mass spectra were determined by using a Finnigan LCQ Deca XP Max mass spectrometer and reported as a ratio of mass to charge (*m*/*z*). High resolution mass spectra (HRMS) were obtained by using a Waters Q-TOF mass spectrometer. Enantiomeric excess (*ee*) values were determined by Shimadzu high performance liquid chromatography (HPLC) analysis using a CHIRALCEL OJ-H column. Optical rotations were measured in $CHCl_3$ on a Schmidt–Haensch polarimeter with a sodium vapor lamp at 589 nm and a 1 cm cell (*c* given in g/100 mL).

General procedure for $Cu(OTf)_2$ + 1,10-phen-catalyzed amination of 1,3-dicarbonyl compounds 1 to α,α-acyl amino acid derivatives 2: CH_2Cl_2 (2 mL) was added to a mixture of $Cu(OTf)_2$ (0.05 mmol), 1,10-phen (0.05 mmol), and powdered 4 Å MS (400 mg) at 0 °C or room temperature. After stirring for 1 h at the same temperature, PhI=NTs or PhI=NNs (1 mmol) was added, followed by the 1,3-dicarbonyl compound **1** (0.5 mmol). The reaction was monitored by TLC. On complete consumption of the starting material **1**, the crude mixture was filtered through Celite, washed with EtOAc (50 mL), evaporated to dryness, and purified by silica gel flash column chromatography (eluent: *n*-hexane/EtOAc 4:1) to give the α-aminated product **2**.

Ethyl 2-(4-methylphenylsulfonamido)-3-oxo-3-phenylpropanoate (2a): Reaction time = 6 h, white solid; mp 109–110 °C; ^1H NMR (400 MHz): δ = 7.98 (d, J = 7.3 Hz, 2H), 7.73 (d, J = 8.3 Hz, 2H), 7.62 (t, J = 7.4 Hz, 1H), 7.47 (t, J = 7.7 Hz, 2H), 7.24 (d, J = 8.1 Hz, 2H), 5.97 (d, J = 9.2 Hz, 1H), 5.58 (d, J = 8.7 Hz, 1H), 3.97 (m, 2H), 2.38 (s, 3H), 1.05 ppm (t, J = 7.1 Hz, 3H); ^{13}C NMR (100 MHz): δ = 190.3, 167.0, 144.0, 136.5, 134.6, 133.5, 130.2, 129.7, 129.4, 128.8, 128.4, 127.3, 62.6, 60.9, 21.5, 13.7 ppm; IR (neat): $\tilde{\nu}$ = 3356, 1748, 1692, 1344, 1163, 1020 cm^{-1}; HRMS: *m*/*z* calcd for $C_{18}H_{20}NSO_5$: 362.1062 $[M+H]^+$; found: 362.1057.

Ethyl 2-(4-nitrophenylsulfonamido)-3-oxo-3-phenylpropanoate (2b): Reaction time = 6 h, white solid; mp 97–100 °C; ^1H NMR: δ = 8.29 (d, J = 8.4 Hz, 2H), 8.05 (d, J = 8.7 Hz, 2H), 8.02 (d, J = 7.8 Hz, 2H), 7.67 (t, J = 7.2 Hz, 1H), 7.52 (t, J = 7.5 Hz, 2H), 6.44 (d, J = 8.1 Hz, 1H), 5.73 (d, J = 8.7 Hz, 1H), 4.01 (q, J = 6.9 Hz, 2H), 1.05 ppm (t, J = 7.2 Hz, 3H); ^{13}C NMR: δ = 189.7, 165.5, 150.3, 145.6, 135.0, 133.3, 129.4, 129.0, 128.6, 124.3, 63.0, 60.8, 13.7 ppm; IR (neat): $\tilde{\nu}$ = 1748, 1682, 1643, 1531, 1350, 1169, 1092 cm^{-1}; HRMS: *m*/*z* calcd for $C_{17}H_{17}N_2SO_7$: 393.0756 $[M+H]^+$; found: 393.0771.

Ethyl 3-(4-methoxyphenyl)-2-(4-methylphenylsulfonamido)-3-oxopropanoate (2c): Reaction time = 6 h, white solid; mp 135–138 °C; ^1H NMR (400 MHz): δ = 7.99 (d, J = 7.6 Hz, 2H), 7.73 (d, J = 6.8 Hz, 2H), 7.24 (d, J = 6.8 Hz, 2H), 6.94 (d, J = 7.6 Hz, 2H), 6.10 (d, J = 8.4 Hz, 1H), 5.55 (d, J = 8.4 Hz, 1H), 3.96 (m, 2H), 3.88 (s, 3H), 2.38 (s, 3H), 1.05 ppm (t, J = 7.1 Hz, 3H); ^{13}C NMR (100 MHz): δ = 188.3, 166.4, 164.9, 144.0, 136.7, 132.0, 129.8, 127.4, 126.4, 114.2, 62.7, 60.7, 55.8, 21.6, 13.8 ppm; IR (neat): $\tilde{\nu}$ = 3385, 1748, 1682, 1344, 1163, 1094 cm^{-1}; HRMS: *m*/*z* calcd for $C_{19}H_{22}NSO_6$: 392.1168 $[M+H]^+$; found: 392.1173.

Ethyl 3-(4-methylphenyl)-2-(4-methylphenylsulfonamido)-3-oxopropanoate (2d): Reaction time = 6 h, white solid; mp 110–113 °C; ^1H NMR: δ = 7.88 (d, J = 8.4 Hz, 2H), 7.72 (d, J = 8.4 Hz, 2H), 7.28–7.23 (m, 4H), 5.97 (d, J = 8.7 Hz, 1H), 5.55 (d, J = 8.7 Hz, 1H), 3.96 (m, 2H), 2.42 (s, 3H), 2.38 (s, 3H), 1.05 ppm (t, J = 7.2 Hz, 3H); ^{13}C NMR: δ = 189.7, 166.2, 145.9, 143.9, 136.7, 132.0, 129.6, 129.5, 127.3, 62.6, 60.8, 21.8, 21.4, 13.5 ppm; IR (neat): $\tilde{\nu}$ = 3325, 1751, 1690, 1344, 1163, 1092, 1070 cm^{-1}; HRMS: *m*/*z* calcd for $C_{19}H_{22}NSO_5$: 376.1219 $[M+H]^+$; found: 376.1216.

Ethyl 3-(4-fluorophenyl)-2-(4-methylphenylsulfonamido)-3-oxopropanoate (2e): Reaction time = 6 h, white solid; mp 115–118 °C; ^1H NMR (400 MHz): δ = 8.05 (m, 2H), 7.73 (d, J = 8.2 Hz, 2H), 7.25 (d, J = 8.2 Hz, 2H), 7.16 (d, J = 8.2 Hz, 2H), 6.01 (d, J = 8.7 Hz, 1H), 5.55 (d, J = 8.7 Hz, 1H), 3.97 (m, 2H), 2.39 (s, 3H), 1.05 ppm (t, J = 7.3 Hz, 3H); ^{13}C NMR (100 MHz): δ = 188.9, 166.1, 144.2, 136.5, 132.5, 132.4, 129.9, 127.5, 116.4, 116.2, 62.9, 61.0, 21.7, 13.7 ppm; IR (neat): $\tilde{\nu}$ = 3356, 1747, 1681, 1337, 1234, 1161, 1090 cm^{-1}; HRMS: *m*/*z* calcd for $C_{18}H_{19}NSO_5$: 380.0968 $[M+H]^+$; found: 380.0972.

Ethyl 3-(4-chlorophenyl)-2-(4-methylphenylsulfonamido)-3-oxopropanoate (2f): Reaction time = 6 h, white solid; mp 118–120 °C; ^1H NMR (400 MHz): δ = 7.95 (d, J = 8.2 Hz, 2H), 7.72 (d, J = 8.2 Hz, 2H), 7.46 (d, J = 8.7 Hz, 2H), 7.25 (d, J = 8.2 Hz, 2H), 5.94 (d, J = 8.7, 1H), 5.53 (d, J = 8.5 Hz, 1H), 3.98 (m, 2H), 2.39 (s, 3H), 1.06 ppm (t, J = 7.1 Hz, 3H); ^{13}C NMR (100 MHz): δ = 189.3, 166.4, 144.3, 144.2, 141.4, 136.5, 130.9, 129.8, 129.3, 127.4, 63.0, 61.0, 21.6, 13.8 ppm; IR (neat): $\tilde{\nu}$ = 3300, 1734, 1687, 1342, 1165, 1109, 1088 cm^{-1}; HRMS: *m*/*z* calcd for $C_{18}H_{19}NSO_5Cl$: 396.0672 $[M+H]^+$; found: 396.0671.

Ethyl 3-(4-bromophenyl)-2-(4-methylphenylsulfonamido)-3-oxopropanoate (2g): Reaction time = 6 h, white solid; mp 130–133 °C; ^1H NMR (400 MHz): δ = 7.88 (d, J = 8.8 Hz, 2H), 7.67 (d, J = 8.4 Hz, 2H), 7.60 (d, J = 8.4 Hz, 2H), 7.23 (d, J = 8.4 Hz, 2H), 5.91 (d, J = 9.2 Hz, 1H), 5.49 (d, J = 8.8 Hz, 1H), 3.94 (m, 2H), 2.37 (s, 3H), 1.04 ppm (t, J = 7.2 Hz, 3H); ^{13}C NMR (100 MHz): δ = 189.5, 165.8, 144.1, 136.4, 132.2, 130.8, 130.1, 129.7, 129.3, 127.3, 62.8, 60.9, 21.5, 13.7 ppm; IR (neat): $\tilde{\nu}$ = 3325, 1751, 1690, 1344, 1163, 1092, 1070 cm^{-1}; HRMS: *m*/*z* calcd for $C_{18}H_{19}NSO_5Br$: 440.0167 $[M+H]^+$; found: 440.0146.

Ethyl 2-(4-methylphenylsulfonamido)-3-oxo-3m-tolylpropanoate (2i): Reaction time = 6 h, white solid; mp 95–98 °C; ^{1}H NMR (400 MHz): δ = 7.80–7.77 (m, 2H), 7.73 (d, J = 8.3 Hz, 2H), 7.43–7.41 (m, 1H), 7.35 (dd, J = 7.7 Hz, J = 7.5 Hz, 1H), 7.23 (d, J = 8.1 Hz, 2H), 6.06 (d, J = 9.2 Hz, 1H), 5.58 (d, J = 8.8 Hz, 1H), 3.96 (m, 2H), 2.39 (s, 3H), 2.37 (s, 3H), 1.04 ppm (t, J = 7.2 Hz, 3H); ^{13}C NMR (100 MHz): δ = 190.3, 166.1, 143.9, 138.8, 136.6, 135.4, 133.5, 129.8, 129.7, 128.7, 127.3, 126.6, 126.5, 62.6, 60.9, 21.5, 21.3, 13.7 ppm; IR (neat): $\tilde{\nu}$ = 3328, 1755, 1682, 1598, 1454, 1337, 1164 cm^{-1}; HRMS: m/z calcd for $C_{18}H_{19}NSO_5Cl$: 376.1219 $[M+H]^+$; found: 376.1215.

Ethyl 4,4-dimethyl-2-(4-methylphenylsulfonamido)-3-oxopentanoate (2j): Reaction time = 3 h, pale yellow solid; mp 85–87 °C; ^{1}H NMR: δ = 7.73 (d, J = 8.1 Hz, 2H), 7.29 (d, J = 8.1 Hz, 2H), 5.84 (d, J = 9.6 Hz, 1H), 5.08 (d, J = 9.6 Hz, 1H), 3.98 (dq, J = 2.1, J = 7.2 Hz, 2H), 2.41 (s, 3H), 1.15 (s, 9H), 1.13 ppm (t, J = 7.2 Hz, 3H); ^{13}C NMR: δ = 205.0, 166.2, 143.9, 136.5, 129.6, 127.3, 62.4, 58.6, 44.9, 26.1, 21.5, 13.7 ppm. IR (neat): $\tilde{\nu}$ = 3340, 3019, 2960, 1749, 1715, 1599, 1344, 1163 cm^{-1}; HRMS: m/z calcd for $C_{16}H_{24}NSO_5$: 342.1375 $[M+H]^+$; found: 342.1386.

Ethyl 4-methyl-2-(4-methylphenylsulfonamido)-3-oxopentanoate (2k): Reaction time = 3 h, yellow oil; obtained as two ketone/enol tautomers in a ratio of 0.9:1; ^{1}H NMR: δ = 12.62 (s, 1H), 7.73 (d, J = 8.2 Hz, 1.8H), 7.68 (d, J = 8.2 Hz, 2H), 7.31–7.26 (m, 3.8H), 6.05 (d, J = 8.4 Hz, 0.9H), 5.92 (s, 1H), 4.82 (d, J = 8.4 Hz, 0.9H), 4.38–4.20 (m, 1.8H), 4.05 (q, J = 7.1 Hz, 2H), 3.48–3.43 (m, 0.9H), 3.04–2.95 (m, 1H), 2.41 (s, 5.7H), 1.20–0.86 ppm (m, 17.1H); ^{13}C NMR: δ = 204.3, 186.1, 170.3, 166.1, 144.0, 143.4, 136.8, 136.4, 129.5, 129.4, 129.3, 127.6, 127.2, 97.8, 62.8, 62.6, 60.9, 38.2, 29.5, 21.44, 21.37, 19.2, 18.3, 17.6, 13.8, 13.5 ppm; IR (neat): $\tilde{\nu}$ = 3280, 3024, 2984, 2940, 1732, 1599, 1339, 1215, 1094 cm^{-1}; HRMS: m/z calcd for $C_{15}H_{22}NSO_5$: 328.1219 $[M+H]^+$; found: 328.1210.

Ethyl 3-(cyclopropyl)-2-(4-methylphenylsulfonamido)-3-oxopropanoate (2l): Reaction time = 3 h, colorless oil; obtained as two ketone/enol tautomers in a ratio of 2:1; ^{1}H NMR: δ = 12.66 (s, 0.5H), 7.73 (d, J = 8.2 Hz, 3H), 7.30 (d, J = 8.2 Hz, 3H), 5.92 (d, J = 7.9 Hz, 1H), 5.75 (s, 0.5H), 4.87 (d, J = 7.9 Hz, 1H), 4.33 (q, J = 7.1, 1H), 4.09 (q, J = 7.1 Hz, 2H), 2.42 (s, 4.5H), 2.27–2.14 (m, 1.5H), 1.39–0.85 ppm (m, 10.5H); ^{13}C NMR: δ = 200.1, 166.0, 143.9, 136.5, 129.7, 129.3, 127.7, 127.3, 92.7, 65.3, 63.2, 62.6, 21.5, 18.6, 15.9, 13.9, 13.8, 13.3, 13.0, 12.8, 9.2 ppm; IR (neat): $\tilde{\nu}$ = 3281, 2982, 2938, 1748, 1713, 1078 cm^{-1}; HRMS: m/z calcd for $C_{15}H_{21}NSO_5$: 326.1062 $[M+H]^+$; found: 326.1069.

Ethyl 3-(1-adamantyl)-3-oxo-2-(tosylamino)propanoate (2m): Reaction time = 4 h, pale yellow solid; mp 110–113 °C; ^{1}H NMR: δ = 7.73 (d, J = 8.4 Hz, 2H), 7.29 (d, J = 8.4 Hz, 2H), 5.85 (d, J = 9.6 Hz, 1H), 5.08 (d, J = 9.6 Hz, 1H), 3.98 (m, 2H), 2.41 (s, 3H), 2.02 (m, 3H), 1.77–1.67 (m, 12H), 1.12 ppm (t, J = 7.2 Hz, 3H); ^{13}C NMR: δ = 205.1, 166.3, 143.9, 136.6, 129.6, 127.4, 62.3, 58.0, 47.1, 38.6, 37.6, 36.4, 36.2, 27.8, 27.6, 21.5, 13.8 ppm; IR (neat): $\tilde{\nu}$ = 3317, 3019, 2911, 2853, 1748, 1707, 1599 cm^{-1}; HRMS: m/z calcd for $C_{22}H_{30}NSO_5$: 420.1845 $[M+H]^+$; found: 420.1847.

Ethyl 3-(furan-2-yl)-2-(4-methylphenylsulfonamido)-3-oxopropanoate (2n): Reaction time = 2 h, white solid; mp 102–104 °C; ^{1}H NMR (400 MHz): δ = 7.72 (d, J = 8.4 Hz, 2H), 7,66 (s, 1H), 7.41 (d, J = 3.6 Hz, 1H), 7.25 (d, J = 8.4 Hz, 2H), 6.60 (dd, J = 1.6 Hz, J = 2.0 Hz, 1H), 5.94 (d, J = 8.8 Hz, 1H), 5.35 (d, J = 8.8 Hz, 1H), 4.03 (q, J = 4.0 Hz, 2H), 2.39 (s, 3H), 1.10 ppm (t, J = 7.2 Hz, 3H); ^{13}C NMR (100 MHz): δ = 178.4, 165.8, 149.8, 148.3, 144.0, 136.5, 129.7, 127.3, 121.1, 113.0, 62.8, 60.7, 21.5, 13.8 ppm; IR (neat): $\tilde{\nu}$ = 3302, 3019, 1751, 1685, 1599, 1463, 1221, 1163 cm^{-1}; HRMS: m/z calcd for $C_{16}H_{18}NSO_6$: 352.0855 $[M+H]^+$; found: 352.0852.

Ethyl 3-(thiophen-2-yl)-2-(4-methylphenylsulfonamido)-3-oxopropanoate (2o): Reaction time = 2 h, pale yellow solid; mp 118–121 °C; ^{1}H NMR (400 MHz): δ = 7.98 (d, J = 4.0 Hz, 1H), 7.76 (d, J = 5.2 Hz, 1H), 7.71 (d, J = 8.4 Hz, 2H), 7.24 (d, J = 8.4 Hz, 2H), 7.17 (dd, J = 5.2 Hz, J = 4.0 Hz, 1H), 5.93 (d, J = 8.8 Hz, 1H), 5.40 (d, J = 8.8 Hz, 1H), 3.97–4.06 (m, 2H), 2.39 (s, 3H), 1.10 ppm (t, J = 7.2 Hz, 3H); ^{13}C NMR(100 MHz): δ = 182.7, 165.9, 144.1, 140.2, 136.5, 136.4, 135.3, 129.7, 128.7, 127.3, 62.8, 61.6, 21.5, 13.7 ppm; IR (neat): $\tilde{\nu}$ = 3424, 3020, 1750, 1675, 1520, 1411, 1357, 1217, 1165 cm^{-1}; HRMS: m/z calcd for $C_{16}H_{18}NS_2O_5$: 368.0626 $[M+H]^+$; found: 368.0635.

Ethyl 3-(1-methyl-1*H*-pyrrol-2-yl)-2-(4-methylphenylsulfonamido)-3-oxopropanoate (2p): Reaction time = 2 h, white solid; mp 100–103 °C; ^{1}H NMR (400 MHz): δ = 7.70 (d, J = 8.0 Hz, 2H), 7.22–7.27 (m, 3H), 6.89 (s, 1H), 6.18 (dd, J = 2.4, J = 4.0 Hz, 1H), 6.02 (d, J = 8.8 Hz, 1H), 5.29 (d, J = 8.8 Hz, 1H), 3.95–4.04 (m, 2H), 3.79 (s, 3H), 2.38 (s, 3H), 1.11 ppm (t, J = 7.2 Hz, 3H); ^{13}C NMR(100 MHz): δ = 178.5, 166.7, 143.7, 136.8, 133.5, 129.7, 127.8, 122.6, 109.4, 62.4, 60.8, 37.6, 21.5, 13.8 ppm; IR (neat): $\tilde{\nu}$ = 3305, 2981, 1750, 1645, 1337, 1265 cm^{-1}; HRMS: m/z calcd for $C_{17}H_{21}N_2SO_5$: 365.1171 $[M+H]^+$; found: 365.1166.

Ethyl 3-(furan-3-yl)-3-oxo-2-(tosylamino)propanoate (2q): Reaction time = 2 h, yellow solid; obtained as two ketone/enol tautomers in a ratio of 2:1; mp 116–119 °C; ^{1}H NMR: δ = 12.74 (s, 0.5H), 8.33 (s, 1H), 8.29 (s, 0.5H), 7.73 (d, J = 8.3 Hz, 2H), 7.69 (d, J = 8.3 Hz, 1H), 7.44 (s, 1H), 7.40 (s, 0.5H), 7.29–7.25 (m, 3H), 7.02 (d, J = 1.3 Hz, 0.5H), 6.77 (d, J = 1.3 Hz, 1H), 6.16 (d, J = 9.0 Hz, 1H), 6.06 (s, 0.5H), 5.17 (d, J = 9.0 Hz, 1H), 3.90–4.04 (m, 2H), 3.71–3.68 (m, 1H), 2.40 (s, 1.5H), 2.38 (s, 3H), 1.07 (t, J = 7.1 Hz, 3H), 0.87 ppm (t, J = 7.1 Hz, 1.5H); ^{13}C NMR: δ = 184.4, 170.7, 168.2, 166.1, 149.9, 147.5, 144.4, 144.1, 143.6, 142.8, 137.1, 136.3, 129.7, 129.4, 127.5, 127.3, 124.4, 120.0, 110.2, 108.8, 98.4, 62.8, 62.7, 61.2, 21.5, 21.4, 13.7, 13.5 ppm; IR (neat): $\tilde{\nu}$ = 3348, 3021, 1748, 1688, 1647, 1622, 1599, 1287, 1215, 1163 cm^{-1}; HRMS: m/z calcd for $C_{16}H_{18}NSO_6$: 352.0855 $[M+H]^+$; found: 352.0850.

Dimethyl 2-(4-methylphenylsulfonamido)malonate (2s):[19] Reaction time = 6 h, pale yellow solid; obtained as a mixture with $TsNH_2$; mp 117–118 °C; ^{1}H NMR (400 MHz, CD_3COCD_3): δ = 7.80 (d, J = 8.4 Hz, 2H), 7.49 (d, J = 9.2 Hz, 2H), 4.79 (d, J = 9.2 Hz, 1H), 3.61 (s, 6H), 2.43 ppm (s, 3H); ^{13}C NMR(100 MHz): δ = 166.0, 143.5, 141.5, 129.5, 126.1, 59.0, 52.6, 20.5 ppm; HRMS: m/z calcd for $C_{12}H_{16}NSO_6$: 302.0698 $[M+H]^+$; found: 302.0706.

Diethyl 2-(4-methylphenylsulfonamido)malonate (2t): Reaction time = 6 h, yellow oil; ^{1}H NMR: δ = 7.73 (d, J = 8.4 Hz, 2H), 7.28 (d, J = 8.4 Hz, 2H), 5.64 (d, J = 8.4 Hz, 1H), 4.66 (d, J = 8.7 Hz, 1H), 4.12 (q, J = 7.2, 4H), 2.41 (s, 3H), 1.19 ppm (t, J = 6.9 Hz, 6H) ^{13}C NMR: δ = 165.6, 144.0, 136.5, 129.7, 127.3, 62.8, 58.8, 21.5, 13.8 ppm; IR (neat): $\tilde{\nu}$ = 3362, 3096, 1746, 1645, 1344, 1302, 1288, 1163, 1094 cm^{-1}; HRMS: m/z calcd for $C_{14}H_{20}NSO_6$: 330.1011 $[M+H]^+$; found: 330.1024.

Diisopropyl 2-(tosylamino)malonate (2u): Reaction time = 6 h, pale yellow oil; ^{1}H NMR: δ = 7.74 (d, J = 8.1 Hz, 2H), 7.28 (d, J = 8.1 Hz, 2H), 5.68 (d, J = 8.4 Hz, 1H), 4.99–4.90 (m, 2H), 4.57 (d, J = 8.4 Hz, 1H), 2.41 (s, 3H), 1.12–1.06 ppm (m, 12H); ^{13}C NMR: δ = 165.2, 143.9, 136.6, 129.7, 127.3, 70.8, 59.0, 21.5, 21.4, 21.3 ppm; IR (neat): $\tilde{\nu}$ = 3497, 3237, 1742, 1599, 1283, 1156, 1101 cm^{-1}; HRMS: m/z calcd for $C_{16}H_{24}NSO_6$: 358.1324 $[M+H]^+$; found: 357.1323.

Di-*tert*-butyl 2-(tosylamino)malonate (2v): Reaction time = 6 h, pale yellow solid; mp 113–115 °C; ^{1}H NMR (400 MHz): δ = 7.71 (d, J = 8.4 Hz, 2H), 7.27 (d, J = 8.4 Hz, 2H), 5.72 (d, J = 8.8 Hz, 1H), 4.39 (d, J = 8.4 Hz, 1H), 2.36 (s, 3H), 1.33 ppm (s, 18H); ^{13}C NMR (100 MHz): δ = 164.7, 143.8, 136.7, 129.6, 127.3, 83.6, 60.0, 27.6, 21.4 ppm. IR (neat): $\tilde{\nu}$ = 3362, 3020, 2982, 2934, 1738, 1599, 1371, 1348, 1163, 1144 cm^{-1}; HRMS: m/z calcd for $C_{18}H_{28}NSO_6$: 386.1637 $[M+H]^+$; found: 386.1620.

Diphenyl 2-(4-methylphenylsulfonylamido)malonate (2w): Reaction time = 6 h, white solid; mp 166–169 °C; ^{1}H NMR: δ = 7.69 (d, J = 8.20 Hz, 2H), 7.43–7.17 (m, 10H), 7.00 (d, J = 7.80 Hz, 2H), 6.70 (s, 1H), 2.36 ppm (s, 3H); ^{13}C NMR: δ = 162.9, 150.2, 144.2, 137.2, 129.8, 129.7, 129.6, 127.4, 126.9, 120.8, 120.5, 90.6, 72.7, 21.6 ppm; IR (neat): $\tilde{\nu}$ = 3404, 3021, 1767, 1090 cm^{-1}; HRMS: m/z calcd for $C_{22}H_{20}NSO_6$: 3426.1062 $[M+H]^+$; found: 426.1069.

Diallyl 2-(4-methylphenylsulfonamido)malonate (2x): Reaction time = 6 h, white solid; mp 84–86 °C; ^{1}H NMR (400 MHz): δ = 7.74 (d, J = 8.2 Hz, 2H), 7.30 (d, J = 8.1 Hz, 2H), 5.82–5.73 (m, 2H) 5.67 (d, J = 8.5 Hz, 1H), 5.30–5.22 (m, 4H), 4.73 (d, J = 8.60 Hz, 1H), 4.55 (dd, J = 5.70 Hz, J = 1.02 Hz, 4H), 2.42 ppm (s, 3H); ^{13}C NMR (100 MHz): δ = 165.2, 144.1, 136.4, 130.6, 129.7, 127.3, 119.5, 67.1, 58.7, 21.6 ppm; IR (neat): $\tilde{\nu}$ = 3019, 1744, 1634, 1163, 1092, 988, 930 cm^{-1}; HRMS: m/z calcd for $C_{16}H_{20}NSO_6$: 354.1011 $[M+H]^+$; found: 354.1000.

Diethyl 2-(4-methylphenylsulfonamido)-2-phenylmalonate (2y): Reaction time = 6 h, white solid; mp 110–115 °C; ^{1}H NMR (400 MHz): δ = 7.53 (d,

J=7.4 Hz, 2H), 7.38 (d, J=8.1 Hz, 2H), 7.21–7.14 (m, 3H), 7.07 (d, J=8.1 Hz, 2H), 6.30 (s, 1H), 4.23–4.17 (m, 4H), 2.34 (s, 3H), 1.23 ppm (t, J=7.2 Hz, 6H); ^{13}C NMR (100 MHz): δ=166.9, 142.9, 138.5, 133.6, 129.0, 128.7, 128.6, 128.4, 128.0, 127.8, 126.9, 63.1, 21.4, 13.8 ppm; IR (neat): $\tilde{\nu}$=3435, 2957, 2926, 2853, 1740, 1456, 1094, 1016 cm^{-1}; HRMS: m/z calcd. for $C_{20}H_{24}SNO_6$: 406.1324 $[M+H]^+$; found: 406.1310.

***N*-(2,4-dioxopentan-3-yl)-4-methylbenzenesulfonamide (2α)**: Reaction time=6 h, white solid; mp 166–169 °C; ^{1}H NMR: δ=7.71 (d, J=8.2 Hz, 2H), 7.33 (d, J=8.2 Hz, 2H) 6.22 (s, 1H), 2.44 (s, 3H), 1.88 ppm (s, 6H); ^{13}C NMR: δ=194.2, 144.4, 136.7, 130.2, 127.5, 110.2, 22.3, 21.8 ppm; IR (neat): $\tilde{\nu}$=3374, 1745, 1599, 1159, 1093 cm^{-1}; HRMS: m/z calcd for $C_{12}H_{16}NO_4S$: 270.0800 $[M+H]^+$; found: 270.0808.

4-Methyl-*N*-(2,2,6,6-tetramethyl-3,5-dioxoheptan-4-yl)benzenesulfonamide (2β): Reaction time=6 h, white solid; mp 146–148 °C; ^{1}H NMR (400 MHz): δ=7.68 (d, J=8.4 Hz, 2H), 7.26 (d, J=8.4 Hz, 2H), 5.81 (d, J=10.0 Hz, 1H), 5.36 (d, J=10.0 Hz, 1H), 2.39 (s, 3H), 1.08 ppm (s, 18H); ^{13}C NMR (100 MHz): δ=208.0, 144.2, 135.5, 129.7, 127.8, 59.8, 44.3, 27.1, 21.5 ppm; IR (neat): $\tilde{\nu}$=1719, 1697, 1643, 1342, 1165, 1092 cm^{-1}; HRMS: m/z calcd for $C_{18}H_{28}NSO_4$: 354.1739 $[M+H]^+$; found: 354.1740.

***N*-(1,3-dioxo-1,3-diphenylpropan-2-yl)-4-methylbenzenesulfonamide (2γ)**: Reaction time=6 h, white solid; mp 166–169 °C; ^{1}H NMR (400 MHz): δ=7.90 (d, J=8.8 Hz, 4H), 7.65 (d, J=8.4 Hz, 2H), 7.59 (t, J=7.2 Hz, 2H) 7.42 (t, J=8.0 Hz, 4H), 7.14 (d, J=8.0 Hz, 2H), 6.26 (s, 2H), 2.33 ppm (s, 3H); ^{13}C NMR (100 MHz): δ=191.9, 144.0, 136.0, 134.4, 134.0, 129.7, 129.1, 128.9, 63.8, 21.5 ppm; IR (neat): $\tilde{\nu}$=1697, 1674, 1639, 1597, 1335, 1161, 1090 cm^{-1}; HRMS: m/z calcd for $C_{22}H_{20}NSO_4$: 394.1113 $[M+H]^+$; found: 394.1132.

Ethyl 3-oxo-3-phenyl-2,2-bis(tosylamino)propanoate (3a): Reaction time=6 h, white solid; mp 155–159 °C; ^{1}H NMR (400 MHz): δ=8.07 (d, J=8.0 Hz, 2H), 7.62 (d, J=8.0 Hz, 4H), 7.53 (t, J=7.6 Hz, 1H), 7.37 (t, J=7.6 Hz, 2H), 7.23 (d, J=8.0 Hz, 4H), 6.83 (bs, 2H), 3.42 (m, 2H), 2.38 (s, 6H), 0.57 ppm (t, J=7.2 Hz, 3H); ^{13}C (100 MHz) NMR: δ=185.7, 164.0, 143.9, 137.2, 134.1, 132.4, 129.7, 129.4, 128.7, 127.6, 74.1, 63.6, 21.6, 12.8 ppm; IR (neat): $\tilde{\nu}$=3018, 2954, 2922, 2852, 1751, 1691, 1452, 1377, 1167 cm^{-1}; HRMS: m/z calcd for $C_{25}H_{26}S_2N_2O_7Na$: 553.1079 $[M+Na]^+$; found: 553.1077.

Tetrahydro-*N*-tosylfuran-2-amine (4):[4e] ^{1}H NMR (400 MHz): δ=7.80 (d, J=8.1 Hz, 2H), 7.28 (d, J=8.1 Hz, 2H), 5.93 (d, J=8.7 Hz, 1H), 5.31–5.37 (m, 1H), 3.66–3.70 (m, 2H), 2.42 (s, 3H), 2.05–2.16 (m, 1H), 1.78–1.95 ppm (m, 3H); ^{13}C NMR (100 MHz): δ=143.2, 138.6, 129.5, 127.0, 84.9, 67.2, 32.5, 23.9, 21.5 ppm; MS (ESI): m/z: 242 $[M+H]^+$.

Ethyl 2-acetamido-3-oxo-3-phenylpropanoate (5):[20] Yellow solid; ^{1}H NMR (400 MHz): δ=8.08 (d, J=8.4 Hz, 2H), 7.58 (t, J=7.4 Hz, 1H), 7.46 (t, J=8.0 Hz, 2H), 7.18 (d, J=7.2 Hz, 1H), 6.22 (d, J=7.6 Hz, 1H), 4.12 (q, J=7.2 Hz, 2H), 2.07 (s, 3H), 1.10 ppm (t, J=7.2 Hz, 3H); ^{13}C NMR (100 MHz): δ=191.7, 170.0, 166.6, 134.2, 134.0, 129.4, 128.5, 62.2, 58.0, 22.6, 13.6 ppm; MS (ESI): m/z: 250 $[M+H]^+$.

Ethyl 2-(N-acetylamino)-3-oxo-3-phenyl-2-{(*E*)-3-phenyl-2-propenyl}propionate (6): The enantiomeric excess of **6** was determined to be 84% *ee* by HPLC analysis (CHIRALCEL OJ-H, *n*-hexane/2-propanol 9:1). Pale yellow solid; mp 124–127 °C; $[\alpha]_D^{21}$=+31.8 (c=0.5, $CHCl_3$); ^{1}H NMR (400 MHz): δ=7.88 (d, J=7.2 Hz, 2H), 7.51 (t, J=7.6 Hz, 1H), 7.39 (t, J=7.6 Hz, 2H), 7.28–7.20 (m, 5H), 7.16 (s, 1H), 6.40 (d, J=16.0 Hz, 1H), 5.99–5.91 (m, 1H), 4.31–4.18 (m, 2H), 3.37 (d, J=7.6 Hz, 2H), 1.89 (s, 3H), 1.18 ppm (t, J=7.2 Hz, 3H); ^{13}C NMR (100 MHz): δ=191.4, 169.5, 168.6, 136.9, 135.0, 133.0, 128.5, 128.3, 127.6, 126.2, 122.6, 70.1, 63.2, 37.2, 22.9, 14.0 ppm; IR (neat): $\tilde{\nu}$=3435, 1765, 1740, 1327, 1260, 1157, 1094, 1016 cm^{-1}; HRMS: m/z calcd for $C_{22}H_{24}NO_4$: 366.1705 $[M+H]^+$; found: 366.1711.

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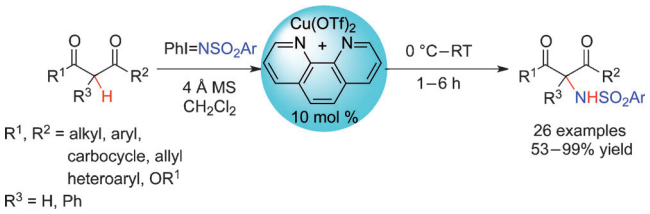

Iminoiodanes aminate: A method to prepare α,α-acyl amino acid derivatives efficiently by $Cu(OTf)_2$+1,10-phenanthroline-catalyzed amination of 1,3-dicarbonyl compounds with PhI=NSO_2Ar is described (see scheme). The utility of the method was exemplified by the enantioselective synthesis of a precursor of 3-styryl-2-benzoyl-L-alanine.

Homogeneous Catalysis

*T. M. U. Ton, F. Himawan, J. W. W. Chang, P. W. H. Chan** ..... ▮▮▮▮–▮▮▮▮

Copper(II) Triflate Catalyzed Amination of 1,3-Dicarbonyl Compounds

