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Received 19th April 2019, Accepted 5th July 2019 DOI: 10.1039/c9ob00901a A facile copper(I)-catalyzed homo-coupling of indanone derivatives using diaziridinone under mild conditions[†]

Wenyong Han, 🝺 Yihui Yang, Yingguang Zhu and Yian Shi*

A novel and efficient Cu(i)-catalyzed homo-coupling of indanone derivatives using diaziridinone as an oxidant is described. A variety of 1,4-dicarbonyl compounds bearing two adjacent quaternary stereocenters were obtained in high yields with high diastereoselectivities *via* a base-free and operationally simple process under mild reaction conditions.

Oxidative coupling of enolates and relative derivatives provides a straightforward approach to 1,4-dicarbonyl functional moieties, which are contained in many biologically and chemically important molecules.¹ Thus far, a variety of effective methods with various oxidants have been developed.²⁻¹¹ In our earlier studies, we have shown that di-t-butyldiaziridinone (1) can efficiently diaminate olefins in the presence of Pd(0) and Cu(1) catalysts.¹² Recently, we found that di-t-butyldiaziridinone (1) can also act as an effective oxidant for homo-coupling of anilines to azo compounds and hydrazines,13 and homo-coupling of terminal alkynes to symmetrical 1,3-diynes¹⁴ in the presence of a Cu catalyst (Scheme 1). In our further exploration of its reactivity, we discovered that di-t-butyldiaziridinone can effectively promote the oxidative coupling of indanone derivatives to form 1,4-dicarbonyl compounds bearing two adjacent quaternary stereocenters in the presence of Cu catalysts. Herein we wish to report our preliminary studies on this subject.

Our initial studies were carried out with methyl 1-oxo-2indane-carboxylate **2a** as a test substrate. Treating **2a** with 5 mol% CuCl-P(^{*n*}Bu)₃ and di-*t*-butyldiaziridinone (1) in CHCl₃ at room temperature for 24 h led to the formation of 1,4-dicarbonyl compound **3a** in 92% yield (Table 1, entry 1). Interestingly, the reaction proceeded with high diastereoselectivity (12:1 dr). The selectivity was further improved to 20:1 with toluene as solvent (Table 1, entry 3). No oxidative coupling occurred with other metal catalysts, such as FeCl₂, CoCl₂, NiBr₂, and Pd(OAc)₂ (Table 1, entries 7–10). The best diastereoselectivity was obtained with $P(^{n}Bu)_{3}$ as ligand (Table 1, entries 3, 11–14). No reaction occurred without metal catalyst (Table 1, entry 15) or di-*t*-butyldiaziridinone (Table 1, entry 16).

The oxidative coupling process can be extended to various substituted methyl 1-oxo-2-indane-carboxylates in 75–98% yields with 8:1 to 20:1 dr (Table 2, entries 1–9). The diasteroselectivity slightly varied with the substituent on the phenyl group. Similar diasteroselectivity was obtained with the corresponding isopropyl ester (Table 2, entry 1 *vs.* entry 10). The structures of **3a** and **3b** were determined by X-ray (see ESI†).¹⁵ 2-Phenyl-1*H*-indene-1,3(2*H*)-dione (**2k**) was also effective for the coupling process, affording the corresponding product **3k**^{10*a*} in 65% yield (Table 2, entry 11). However, indanones with acyl group at α-position (2-acetyl-2,3-dihydro-1*H*-inden-1-one) and tetralone with α-methyl ester (methyl 1-oxo-1,2,3,4-tetrahydronaphthalene-2-carboxylate) were found to be poor substrates under the current reaction conditions.

While a precise understanding of the reaction mechanism awaits further study, a plausible catalytic pathway for the oxidative homo-coupling is proposed in Scheme 2. The CuCl first reductively cleaved the N–N bond of di-*t*-butyldiaziridinone (1) to form Cu(π) nitrogen radical **A** and/or four-membered Cu(π)





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Department of Chemistry, Colorado State University, Fort Collins, Colorado 80523, USA. E-mail: Yian.Shi@colostate.edu; Fax: +(1)-970-4911801; Tel: +(1)-970-4917424 †Electronic supplementary information (ESI) available: Experimental procedures, characterization data, crystallographic data, and NMR spectra. CCDC 1904252 (**3a**) and 1904257 (**3b**). For ESI and crystallographic data in CIF or other electronic format see DOI: 10.1039/c9ob00901a



^{*a*} The reaction was carried out with **2a** (0.50 mmol), di-*t*-butyldiaziridinone (**1**) (0.60 mmol), catalyst (0.025 mmol), and ligand (0.025 mmol) in solvent (0.8 mL) at room temperature for 24 h unless otherwise stated. ^{*b*} Isolated yield of both diastereomers. ^{*c*} The dr value was determined by ¹H NMR analysis of the crude reaction mixture. ^{*d*} In the absence of di-*t*-butyldiaziridinone (**1**). phen = 1,10phenanthroline.

species **B**, which reacted with methyl 1-oxo-2-indane-carboxylate 2**a** to form radical intermediate **C**. Dimerization of **C** gave coupling product 3**a**. When the reaction was carried out in the presence TEMPO, compound 4 was isolated in 74% yield, which supports the involvement of radical intermediate **C** (Scheme 3).¹⁶

When ethyl 3-oxo-3-phenylpropanoate (5) was treated with 10 mol% CuCl, 20 mol% $P(^{n}Bu)_{3}$, and 4.0 equiv. di-*t*-butyldiaziridinone in CDCl₃ at 65 °C for 24 h, tetrasubstituted olefin **6** was obtained in 74% yield as two isomers with a ratio of 4.6 : 1 (Scheme 4). Compound **6** was likely formed by the dehydrogenation of intermediate 7,¹⁷ which resulted from the dimerization of radical **D**. Compound **6** was also formed in good yield when the preformed 7^{9c} was subjected to the reaction conditions, which is consistent with the proposed reaction mechanism (Scheme 5).¹⁸

In summary, we have developed a mild and efficient method for the oxidative coupling of indanone derivatives with CuCl catalyst and di-*t*-butyldiaziridinone (1) as an oxidant, giving the corresponding 1,4-dicarbonyl compounds containing vicinal quaternary carbons in 65–98% yields with high diastereoselectivities (8:1 to 20:1 dr). The reaction is base-free and operationally simple. Further development of other oxidative coupling processes with diaziridinones and related compounds are currently underway.

Table 2 Substrate scope^a



^{*a*} The reaction was carried out with **2** (0.50 mmol), di-*t*-butyldiaziridinone (1) (1.00 mmol), CuCl (0.025 mmol), and $P(n-Bu)_3$ (0.025 mmol) in toluene (0.8–1.0 mL) at room temperature for 48 h unless otherwise stated. ^{*b*} Isolated yield. ^{*c*} The dr value was determined by ¹H NMR analysis of the crude reaction mixture. ^{*d*} With di-*t*-butyldiaziridinone (1) (0.60 mmol) for 24 h. ^{*e*} For 72 h.



Scheme 2 Proposed catalytic cycle.



Scheme 3 Trapping of radical intermediate with TEMPO.



Scheme 4 The formation of tetrasubstituted olefin 6.



Scheme 5 The dehydrogenation of compound 7.

Conflicts of interest

There are no conflicts to declare.

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