Copper(II) and 2,2'-Biimidazole-promoted Novel Reaction of 4,4,4-Trifluoro-1-phenylbutane-1,3-diones with Iodobenzene Diacetate

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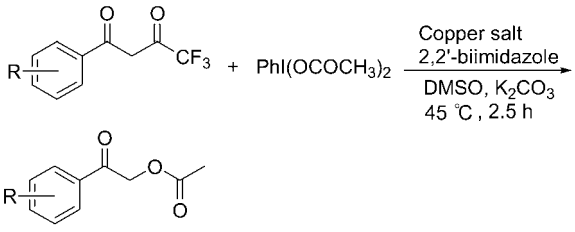
A new and efficient way was developed to carry out the reaction of 4,4,4-trifluoro-1-phenylbutane-1,3-dione with iodobenzene diacetate under the assistance of Cu(II) and 2,2'-biimidazole at a low temperature in excellent yield. 2-Acetoxyacetophenone was obtained unexpectedly.

Keywords 1,3-diketone, iodobenzene diacetate, Cu(II), 2,2'-biimidazole, 2-acetoxyacetophenone

Introduction

Over the past decade great progress has been made in improving the efficiency and applicability of cross-coupling reactions. Copper salt was excellent catalyst in various transformations, including formation of carbon-oxygen,[1] carbon-carbon[2] and carbon-nitrogen bonds.[3] Ma *et al.*[2] reported that CuI/*L*-proline (or *N*-methylglycine) was an efficient catalytic system to make Ullmann-type reaction at a low temperature. In 2005, he also found that both aryl iodides and aryl bromides could couple with excess amounts of *β*-keto esters and diethyl malonate to provide the corresponding arylation products under the catalysis of CuI/*L*-proline.[4] Cu(II)-catalyzed Ullmann reaction is rare. As an extension of this work, we studied the 2,2'-biimidazole, Cu(II)-catalyzed coupling reaction of aryl iodides and phenols in 2006.[5] The catalyst system was applied to the reaction of *β*-keto esters and diethyl malonate. However, the desired results were not attained, which thus helped us to focus on the iodobenzene diacetate that has a higher activity than aryl iodides. To our surprise, no coupling product was obtained. When the fluorine-substituted diketones were used in a further research, the products were not acetoxylated compound as reported in the literature,[6] while 2-acetoxyacetophenone was obtained unexpectedly (Eq. 1).



(1)

Experimental

In general, ^{1}H NMR at 400 MHz and ^{13}C NMR at 100 MHz spectra were recorded on a Varian Inova-400 spectrometer with TMS as an internal standard and $CDCl_3$ as solvent. HRMS was recorded on a Micromass OA-TOF instrument. For preparative column chromatography, silica gel H60 was used with the solvent system displayed in the text.

General procedure

A mixture of 1 mmol of 4,4,4-trifluoro-1-phenylbutane-1,3-dione, 1 mmol of iodobenzene diacetate, 2 mmol of K_2CO_3, 0.15 mmol of copper(II) salt, 0.15 mmol of 2,2'-biimidazole and 1 mL of the solvent were heated at 45 ℃. After the reaction was completed as monitored by TLC, the cooled mixture was partitioned between CH_2Cl_2 and water. The organic layer was separated, and the aqueous layer was extracted with CH_2Cl_2. The combined organic layer was dried over Na_2SO_4, and concentrated *in vacuo*. The residual was loaded on a silica gel column and eluted with ethyl acetate/petroleum ether (*V*/*V*＝1/8) to afford the product.

1,3-Dioxo-1-phenylbutan-2-yl acetate (1) Yellow liquid; ^{1}H NMR *δ*: 2.23 (s, 3H, CH_3), 2.30 (s, 3H, CH_3), 6.27 (s, 1H, CH), 7.50 (t, *J*＝7.7 Hz, 2H), 7.63 (t, *J*＝7.3 Hz, 1H), 8.01 (d, *J*＝7.7 Hz, 2H); ^{13}C NMR *δ*: 20.90, 27.26, 66.40, 82.48, 129.12, 134.57, 134.65, 169.68, 191.23, 199.89; HRMS calcd for $C_{12}H_{12}O_4^+$ 220.0736, found 220.0785.

Benzoylmethyl acetate (2)[7] Yellow solid, m.p. 48—50 ℃; ^{1}H NMR *δ*: 2.19 (s, 3H, CH_3), 5.31 (s, 2H,

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CH_2), 7.45 (t, J=7.7 Hz, 2H), 7.57 (t, J=7.4 Hz, 1H), 7.88 (d, J=7.1 Hz, 2H); ^{13}C NMR δ: 20.95, 66.42, 128.12, 129.24, 134.29, 170.81, 192.53; IR (KBr) v: 1750 (C=O), 1704 (C=O) cm^{-1}; HRMS calcd for $C_{10}H_{10}O_3^+$ 178.0630, found 178.0656.

***o*-Fluorophenacyl acetate (3)** Yellow liquid; ^{1}H NMR δ: 2.21 (s, 3H, CH_3), 5.21 (d, J=3.7 Hz, 2H, CH_2), 7.13—7.18 (m, 1H), 7.26 (t, J=7.6 Hz, 1H), 7.54—7.60 (m, 1H), 7.94—7.98 (m, 1H); ^{13}C NMR δ: 20.90, 69.45—69.59, 116.85, 117.08, 125.29, 131.18, 136.02, 136.11, 170.79, 190.89; IR (KBr) v: 1755 (C=O), 1705 (C=O) cm^{-1}; HRMS calcd for $C_{10}H_9FO_3^+$ 196.0536, found 196.0537.

***p*-Methylphenacyl acetate (4)**[8] Green solid, m.p. 84 ℃; ^{1}H NMR δ: 2.22 (s, 3H, CH_3), 2.41 (s, 3H, CH_3), 5.31 (s, 2H, CH_2), 7.27 (d, J=7.1 Hz, 2H), 7.80 (d, J=8.0 Hz, 2H); ^{13}C NMR δ: 21.02, 22.17, 66.37, 128.24, 129.93, 132.06, 145.29, 170.89, 192.15; IR (KBr) v: 1749 (C=O), 1696 (C=O) cm^{-1}; HRMS calcd for $C_{11}H_{12}O_3^+$ 192.0786, found 192.0792.

***p*-Fluorophenacyl acetate (5)**[8] Yellow solid, m.p. 50 ℃; ^{1}H NMR δ: 2.18 (s, 3H, CH_3), 5.27 (s, 2H, CH_2), 7.12 (t, J=8.6 Hz, 2H), 7.90—7.93 (m, 2H); ^{13}C NMR δ: 20.84, 66.19, 116.32—116.54, 130.79—130.89, 165.16, 167.71, 170.74, 191.07; IR (KBr) v: 1749 (C=O), 1696 (C=O) cm^{-1}; HRMS calcd for $C_{10}H_9FO_3^+$ 196.0536, found 196.0541.

***p*-Methoxyphenacyl acetate (6)**[8] Green solid, m.p. 58—59 ℃; ^{1}H NMR δ: 2.11 (s, 3H, CH_3), 3.74 (s, 3H, OCH_3), 5.19 (s, 2H, CH_2), 6.83 (d, J=7.3 Hz, 2H), 7.78 (d, J=7.4 Hz, 2H); ^{13}C NMR δ: 20.81, 55.77, 66.11, 114.34, 127.46, 130.33, 164.35, 170.74, 190.98; IR (KBr) v: 1754 (C=O), 1704 (C=O) cm^{-1}; HRMS calcd for $C_{11}H_{12}O_4^+$ 208.0736, found 208.0744.

3-Bromophenacyl acetate (8) Green solid, m.p. 70 ℃; ^{1}H NMR δ: 2.17 (s, 3H, CH_3), 5.25 (s, 2H, CH_2), 7.32 (t, J=7.9 Hz, 1H), 7.67 (d, J=7.9 Hz, 1H), 7.77 (d, J=7.8 Hz, 1H), 7.98 (s, 1H); ^{13}C NMR δ: 20.84, 66.24, 123.48, 126.59, 130.79, 131.11, 137.04, 170.64, 191.36; IR (KBr) v: 1743 (C=O), 1696 (C=O) cm^{-1}; HRMS calcd for $C_{10}H_9BrO_3^+$ 255.9735, found 255.9732.

3-Methoxyphenacyl acetate (9) Green liquid; ^{1}H NMR δ: 2.11 (s, 3H, CH_3), 3.72 (s, 3H, OCH_3), 5.22 (s, 2H, CH_2), 7.01—7.04 (m, 1H), 7.24 (t, J=7.9 Hz, 1H), 7.32—7.37 (m, 2H); ^{13}C NMR δ: 20.86, 55.77, 66.52, 112.50, 120.51—120.60, 130.26, 135.81, 160.30, 170.73, 192.44; IR (KBr) v: 1751 (C=O), 1695 (C=O) cm^{-1}; HRMS calcd for $C_{11}H_{12}O_4^+$ 208.0736, found 208.0736.

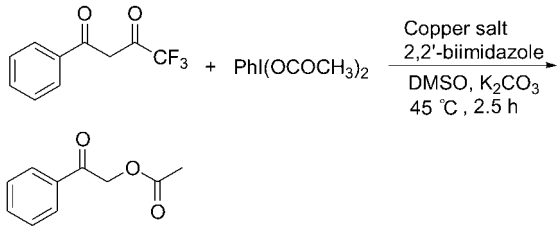
2-(*β*-Naphthyl)-2-oxoethyl acetate (10) Yellow solid, m.p. 79—80 ℃; ^{1}H NMR δ: 2.23 (s, 3H, CH_3), 5.44 (s, 2H, CH_2), 7.49—7.59 (m, 2H), 7.80—7.92 (m, 4H), 8.34 (s, 1H); ^{13}C NMR δ: 20.93, 66.45, 123.52, 127.33, 129.08—129.17, 129.78—129.86, 131.77, 132.63, 136.14, 170.81, 192.43; IR (KBr) v: 1752 (C=O), 1708 (C=O) cm^{-1}; HRMS calcd for $C_{14}H_{12}O_3^+$ 228.0786, found 228.0793.

2-Oxo-2-(*α*-thienyl)ethyl acetate (11) Yellow liquid; ^{1}H NMR δ: 2.20 (s, 3H, CH_3), 5.21 (s, 2H, CH_2), 7.15 (t, J=4.3 Hz, 1H), 7.69 (d, J=4.9 Hz, 1H), 7.74 (d, J=3.7 Hz, 1H); ^{13}C NMR δ: 20.99, 66.14, 128.72, 132.41, 134.83, 140.70, 170.79, 185.83; IR (KBr) v: 1748 (C=O), 1679 (C=O) cm^{-1}; HRMS calcd for $C_8H_8O_3S^+$ 184.0194, found 184.0198.

Results and discussion

Effect of copper salt

In order to find the best copper salt, the reaction of trifluoromethyl dione with iodobenzene diacetate was chosen as the model (Eq. 2). According to the results in Table 1, $Cu(OAc)_2$•H_2O was found to be the best copper salt.



(2)

As indicated in the Table 1, the yield of the reaction promoted by the copper salt with crystal water was much higher than that without crystal water, which possibly proved that water participated in the reaction.

Table 1 Reaction of 4,4,4-trifluoro-1-phenylbutane-1,3-dione with iodobenzene diacetate under the catalysis of copper salts and 2,2'-biimidazole[a]

Entry	Copper salt	Isolated yield/%
1	$Cu(OAc)_2$•H_2O	93
2	$CuSO_4$•$5H_2O$	56
3	$CuCl_2$•$2H_2O$	45
4	CuO	28
5	$CuBr_2$	22
6	CuI	39
7	—	40[b]

[a] Reaction conditions: [Cu] (0.15 mmol), 2,2'-biimidazole (0.15 mmol), 4,4,4-trifluoro-1-phenylbutane-1,3-dione (1 mmol), iodobenzene diacetate (1 mmol), K_2CO_3 (2 mmol), DMSO (1 mL), 45 ℃. [b] Neither copper salt nor ligand.

Effect of base

To find the suitable base, the model reaction with different bases was carried out at 45 ℃. Based on the results in Table 2, K_2CO_3 was found to be the best base.

Effect of solvent

In order to find the best solvent, the model reaction was carried out in several kinds of normal solvent. According to the results in Table 3, DMSO was found to be the suitable reaction solvent.

Table 2 Reaction of 4,4,4-trifluoro-1-phenylbutane-1,3-dione with iodobenzene diacetate under different bases

Entry	Base	Isolated yield/%
1	K_2CO_3	93
2	$CsCO_3$	72
3	K_3PO_4	23
4	NEt_3	trace

Table 3 Reaction of 4,4,4-trifluoro-1-phenylbutane-1,3-dione with iodobenzene diacetate under the common organic solvent

Entry	Solvent	Isolated yield/%
1	DMSO	93
2	DMF	39
3	THF	34
4	Dioxane	17
5	Toluene	11

Synthesis

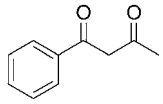
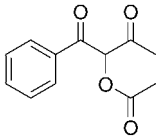
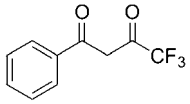
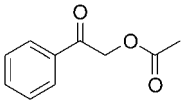
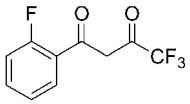
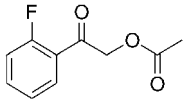
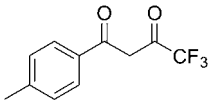
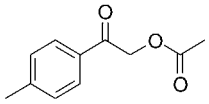
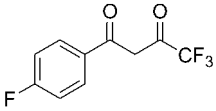
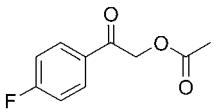
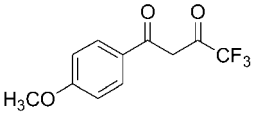
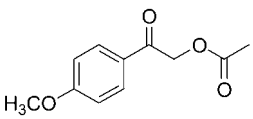
With the optimized condition in hand, the reaction catalyzed by $Cu(OAc)_2•H_2O$ (15 mol%), 2,2'-bi-imidazole (15 mol%) was tested with several different 4,4,4-trifluoro-1-arylbutane-1,3-diones, and the results were summarized in Table 4.

This reaction was sensitive to the electronic properties of the phenyl ring. 4-Methyl, 4-methoxy- and 3-methoxy-1,3-diketones all gave excellent yields of the desired 2-acetoxyacetophenones, and the substrates with electron-withdrawing groups (such as F) led to lower yields.

A mechanism shown in Scheme 1 was proposed for the reaction.

Iodobenzene diacetate could dissociate into ions. The solubility of copper acetate cooperated with 2,2'-biimidazole would be increased. The acetoxylation of the methylene group seemed to proceed much more easily when intermediate **I** reacted with the enolized

Table 4 Reaction of 4,4,4-trifluoro-1-arylbutane-1,3-diones with iodobenzene diacetate under the catalysis of $Cu(OAc)_2•H_2O$ and 2,2'-biimidazole

Entry	Trifluoromethyl diketone	Time/h	Product	Yield [a]/%
1		2.5	 (**1**)	86
2		2.5	 (**2**)	93
3		5	 (**3**)	46
4		2	 (**4**)	97
5		5	 (**5**)	56
6		3	 (**6**)	94

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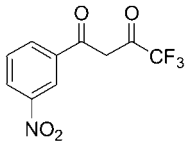
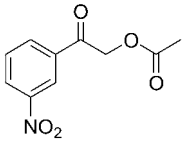
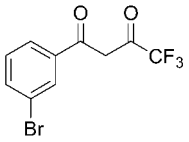
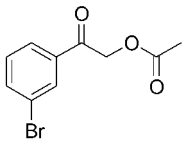
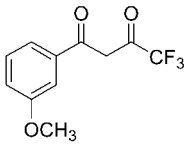
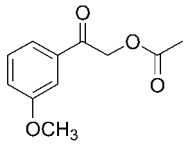
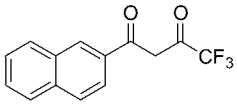
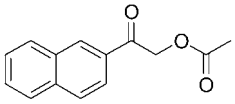
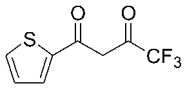
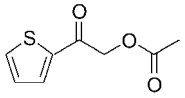
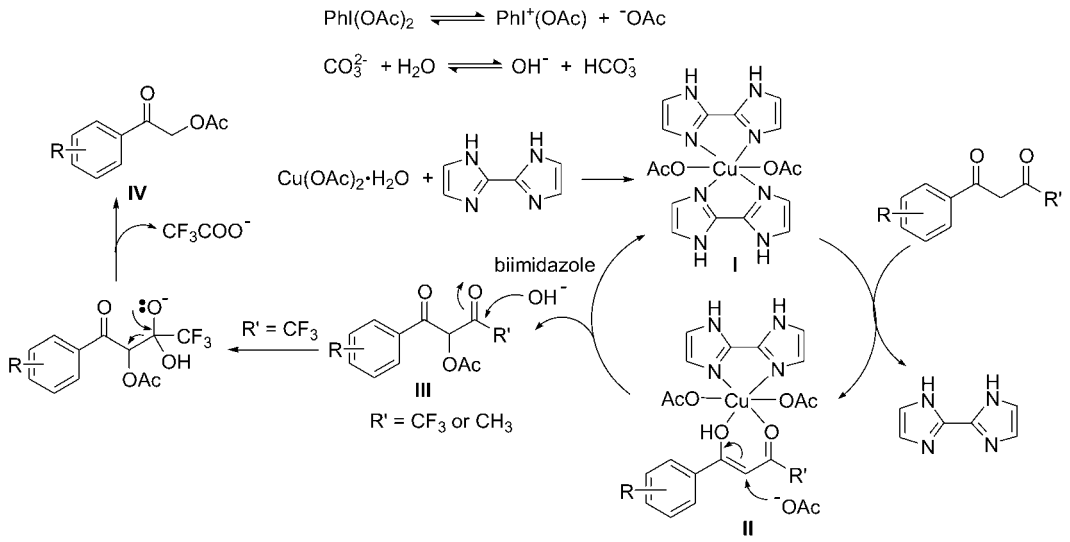
Continued

Entry	Trifluoromethyl diketone	Time/h	Product	Yield [a]/%
7		10	 (**7**)	trace
8		5	 (**8**)	66
9		1.5	 (**9**)	92
10		3	 (**10**)	88
11		2	 (**11**)	95

[a] Isolated yield.

Scheme 1



form of a 1,3-diketone to generate intermediate **II**. As reported in literature,[6] 1,3-diketones were acetoxylated with $PhI(OAc)_2$ in a mixed solvent of acetic acid and acetic anhydride, using sulfulic acid as the catalyst. However, the yield was much lower.

Only when R' was a strong electron withdrawing

group such as CF_3, the CF_3COO^- would be easily removed in an alkaline medium.

Conclusion

In summary, a new and efficient way was developed to carry out the reaction of 4,4,4-trifluoro-1-arylbutane-1,3-diketone with iodobenzene diacetate, which was promoted by Cu(II) and 2,2'-biimidazole. It was applicable to a large variety of substrates with a trifluoromethyl group.

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References

1 (a) Altman, R. A.; Shafir, A.; Choi, A.; Lichtor, P. A.; Buchwald, S. L. *J. Org. Chem*. **2008**, *73*, 284.
(b) Evindar, G.; Batey, R. A. *J. Org. Chem*. **2006**, *71*, 1802.
(c) Cristau, H. J.; Cellier, P. P.; Hamada, S.; Spindler, J. F.; Taillefer, M. *Org. Lett*. **2004**, *6*, 913.
(d) Ma, D.; Cai, Q. *Org. Lett*. **2003**, *5*, 3799.
(e) Nordmann, G.; Buchwald, S. L. *J. Am. Chem. Soc.* **2003**, *125*, 4978.

2 (a) Chen, Y.; Wang, Y.; Sun, Z.; Ma, D. *Org. Lett*. **2008**, *10*, 625.
(b) Liu, Y.; Song, Z.; Yan, B. *Org. Lett*. **2007**, *9*, 409.
(c) Chen, Y.; Xie, X.; Sun, Z.; Ma, D. *J. Org. Chem*. **2007**, *72*, 9329.
(d) Bates, C. G.; Saejueng, P.; Venkataraman, D. *Org. Lett*. **2004**, *6*, 1441.
(e) Zanon, J.; Klapars, A.; Buchwald, S. L. *J. Am. Chem. Soc*. **2003**, *125*, 2890.
(f) Zhang, S.; Zhang, D.; Liebeskind, L. S. *J. Org. Chem*. **1997**, *62*, 2312.

3 (a) Altman, R. A.; Koval, E. D.; Buchwald, S. L. *J. Org. Chem*. **2007**, *72*, 6190.
(b) Zhang, H.; Cai, Q.; Ma, D. *J. Org. Chem*. **2005**, *70*, 5164.
(c) Deng, W.; Wang, Y.; Zhou, W.; Liu, L.; Guo, Q. *Tetrahedron Lett*. **2004**, *45*, 2311.
(d) Shen, R.; Lin, C. T.; Bowman, E. J.; Bowman, B. J.; Porco, J. A., Jr. *J. Am. Chem. Soc*. **2003**, *125*, 7889.

4 Xie, X.; Cai, G.; Ma, D. *Org. Lett*. **2005**, *7*, 4693.

5 Wang, B. A.; Zeng, R. S.; Wei, H. Q.; Jia, A. Q.; Zou, J. P. *Chin. J. Chem*. **2006**, *24*, 1062.

6 Fujio, M.; Moriyasu, A.; Tatsuo, T.; Juichi, I. *Bull. Chem. Soc. Jpn*. **1978**, *51*, 335.

7 Sunil, K.; Ashmar, K.; Rakesh, K. G.; Devinder, K. *Synth. Commun*. **2008**, *38*, 338.

8 Kaila, N.; Janz, K.; DeBernardo, S.; Bedard, P. W.; Camphausen, R. T. *J. Med. Chem*. **2007**, *50*, 21.

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