Preparation of Cyclopropanediol: Novel [2 + 1] Cycloaddition Reaction of Bis(iodozincio)methane with 1,2-Diketones

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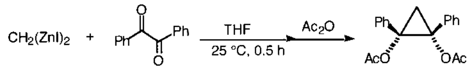
gem-Dizinc reagents which possess a couple of nucleophilic sites on a carbon have been used for a variety of characteristic transformations;[1] the reagents can form two C−C bonds on one carbon atom. The zinc reagents are relatively stable and have moderate reactivity compared to corresponding other dimetal compounds such as dilithium and dimagnesium compounds.[2] These features point to the possibility of the selective reaction combining an appropriate mediator, activator, or catalyst. We have reported the selective alkylidenation of carbonyl compounds with *gem*-dizinc compounds mediated by titanium(II) chloride[3] and the sequential coupling with a pair of organic halides catalyzed with a palladium complex.[4]

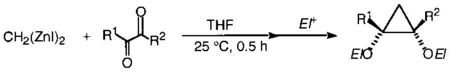
Activation by a ligand as well as a solvent was also examined, and it was shown that coordination of a heteroatom to zinc enhanced the nucleophilicity of bis(iodozincio)methane (**1**).[5] In the case of a heteroatom-containing substrate, such as α-alkoxy ketone, the same type of activation can be expected. For example, in the reaction of organomagnesium reagents, the key to the well-known Cram chelation control with α-alkoxy ketones[6] is considered to be an activation of the reagent with coordination of the α-substituted heteroatom to magnesium.[7] A reaction of a simple ketone with **1** resulted in the complete recovery of the starting substrate,[3] and thus we tried to react the dizinc **1** with an α-heteroatom-substituted ketone. 1,2-Diketone, which has a Lewis basic heteroatom at the α-position of a carbonyl group, seems to be an attractive substrate for the reaction with bis(iodozincio)methane (**1**).[8] The coordination or chelation will activate the zinc reagent and permit a nucleophilic reaction with the carbonyl. The reaction may result in the methylenation of a single carbonyl group under activation with the neighboring carbonyl group to afford an enone. We examined the reaction of **1** with benzil (**2a**) as shown in Scheme 1. Contrary to our expectation, the product was a derivative of [2 + 1] cycloaddition product **3a**.[9] Here we wish to report the efficient [2 + 1] cycloaddition reactions.[10]

Scheme 1



1 **2a** **3a** 69%

Table 1. [2 + 1] Reaction of Bis(iodozincio)Methane with 1,2-Dicarbonyl Compounds[a]



1 **2** **3**

entry	R^1	R^2	El^+	yield of **3**[b] (%)	
1	Ph	Ph	Me_3SiCl	78	**3b**
2	Ph	Me	H_3O^+	80	**3c**
3	Ph	Me	Ac_2O	98	**3d**
4	Ph	Me	Me_3SiCl	97	**3e**
5	CH_3CH_2	CH_3CH_2	Ac_2O	59	**3f**
6	Ph	H	Ac_2O	58[c]	**3g**
7	$-C(Me)_2-(CH_2)_3-C(Me)_2-$		H_3O^+	20[d]	**3h**
8	$-(CH_2)_6-$		H_3O^+	69[d,e]	**3i**
9	$-(CH_2)_6-$		Ac_2O	66	**3j**

[a] 1,2-diketone (**2**, 1.0 mmol), *gem*-dizinc **1** (1.2 mmol) and El^+ (2.4 mmol) were used. [b] Isolated yields. In each entry, only *cis*-isomer was formed diastereoselectively. [c] The methylenated product (1-phenyl-2-propenone) was also isolated in 17% yield. 1-phenyl-2-propenol was isolated in 17% yield. [d] The product was converted into cyclic1,3-diketone during the exposure to air. **3h** was converted into 4,4,8,8-tetramethyl-1,3-cyclooctadienone in 55% yield after exposing in air for 3 days. **3i** was converted into 1,3-cyclononadione in 44% yield after exposing in air for 3 days. [e] The methylenated product (2-methylenecyclooctanone) was isolated in 10% yield.

Benzil (**2a**) was treated with bis(iodozincio)methane (**1**) at 25 °C in THF for 0.5 h. Acetic anhydride was added to the reaction mixture, and the whole was stirred for another 30 min at 25 °C. After aqueous workup followed by purification with silica gel column chromatography, *cis*-1,2-diphenylcyclopropanediol diacetate was obtained in 69% yield diastereoselectively. An X-ray analysis confirmed the structure and stereochemistry.[11] Other examples are summarized in Table 1.

Instead of acylation, an addition of chlorotrimethylsilane to the [2 + 1] reaction mixture gave a silyl ether (entries 1 and 4). Depending on the substrate, the formed 1,2-cyclopropanediol possesses reasonable stability that enable isolation by a silica gel column chromatography (entry 2), but in some cases the product was isomerized into 1,3-diketone gradually under exposure to air during the isolation procedure (entries 7 and 8). In all cases, the [2 + 1] reaction proceeded stereoselectively to give *cis*-diol

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(11) For the X-ray diffraction, a crystal was mounted on a glass fiber coated with epoxy resin. Measurements were made on a Rigaku Mercury charge-coupled device (CCD) system with graphite monochromated Mo Kα radiation. Crystal data: **3a**, $M = 310.35$, monoclinic, $a = 43.816(9)$ Å, $b = 5.922(2)$ Å, $c = 38.178(8)$ Å, $\beta = 100.53°$, $V = 9739(3)$ Å^3, $Z = 24$, $\rho_{cacl} = 1.270$ g/cm^3, λ (Mo Kα) = 0.71069 Å, $F(000) = 3936.00$, μ (Mo Kα) = 0.88 cm^{-1}, $T = 296$ K, $2\theta_{max} = 54.0°$, $R = 0.130$ for 4583 reflections ($I > 2\sigma(I)$). **3j**, $M = 240.30$, orthorhombic, $a = 12.965(1)$ Å, $b = 17.957(2)$ Å, $c = 5.691(1)$ Å, V = 1308.1(6) Å^3, $Z = 4$, $\rho_{cacl} = 1.220$ g/cm^3, λ (Mo Kα) = 0.71069 Å, $F(000) = 520.00$, μ (Mo Kα) = 0.89 cm^{-1}, $T = 296$ K, $2\theta_{max} = 54.2°$, $R = 0.054$ for 1164 reflections ($I > 2\sigma(I)$).

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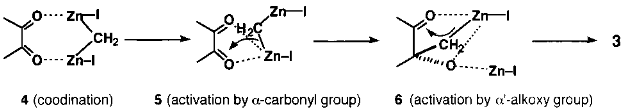
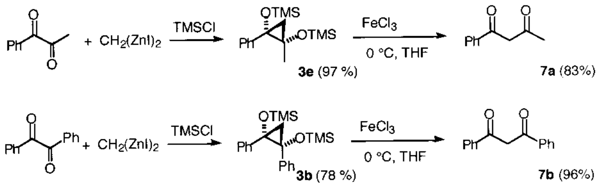
Scheme 2



Scheme 3



derivatives. In entry 6, α-keto aldehyde and bis(iodozincio)methane also gave cyclopropanediol although methylenation of aldehyde proceeded to some extent.[3]

We propose that the following explanation is plausible for the [2 + 1] cycloaddition. As shown in Scheme 2, 1,2-diketone would coodinate with dizinc **1** in *s*-cis form (**4**). Coordination of one zinc atom to one carbonyl which enhances the nucleophilicity of another Zn−C bond (**5**), results in zinc methylation to form the intermediate **6**. In the intermediate **6**, the Zn−C bond is activated by the coordination of the α′-alkoxy group and leads to [2 + 1] cyclization to form **3**.

Although a few synthetic transformations of cyclopropanediol were already reported,[12] we tried to perform a ring-opening reaction using a Lewis acid having oxidizing ability. As shown in Scheme 3, trimethylsilyl ether of cyclopentanediol **3b**,**e** was converted into 1,3-diketone in reasonable yields under the influence of iron(III) chloride in THF.[13] The net transformation can be recognized as methylene insertion to 1,2-diketone compounds.[8]

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Supporting Information Available: Experimental details for the preparation of **1**, **3a**−**j**, and **7a**, and ^{1}H NMR and ^{13}C NMR data of **1**, **3a**−**j**, and **7a**; ORTEP and CIF file of **3a**, **j**. This material is available free of charge via Internet at http://pubs.acs.org.

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[13] The following results transforming **3e** into **7a** were also obtained using the other metal salts: $TiCl_4$ (68%), $SnCl_4$ (32%).