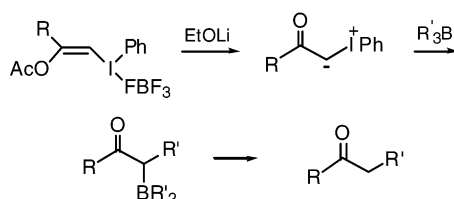


Reaction of Unstabilized Iodonium
Ylides with OrganoboranesMasahito Ochiai,^{*} Yoshimi Tuchimoto, and Nobuyuki HigashiuraFaculty of Pharmaceutical Sciences, University of Tokushima, 1-78 Shomachi,
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ABSTRACT



Exposure of monoketone iodonium ylides, generated by the ester exchange of (*Z*)-(2-acetoxyvinyl)- λ^3 -iodanes with EtOLi, to organoboranes results in a 1,2-shift of a carbon ligand from boron to the ylide carbons, which probably generates hitherto uncharacterized α -boryl ketones.

Onium ylides react with organoboranes and transfer a carbon ligand on boron to ylide carbanions via the intermediate formation of zwitterionic organoborane–ylide complexes. Group 15 (N, P, As) and 16 (S) onium methylides react with organoboranes to afford the corresponding homologated boranes.¹ Reaction of ethyl (dimethylsulfuranylidene)acetate with triphenylborane gives, after alkaline hydrolysis, ethyl phenylacetate in high yields.^{1b} Recently, Shea and co-workers developed an efficient boron-catalyzed polymerization of dimethylsulfoxonium methylide yielding α -hydroxy polymethylene and block copolymers through living polyhomologations.²

On the other hand, reactions of group 17 onium ylides, especially iodonium ylides, with organoboranes are virtually unexplored, despite their extensive synthetic use in organic synthesis.³ Dai and Yang reported an interesting alkyl group

shift from boron to nitrogen in the reaction of [(*N*-tosylimino)iodo]benzene $\text{PhI}=\text{NTs}$ with trialkylboranes.⁴ We are pleased to report herein the reaction of iodonium ylides with organoboranes, in which unstabilized monoketone iodonium ylides **5** smoothly undergo a 1,2-shift of an alkyl or an aryl group from boron to ylide carbons under mild conditions. In marked contrast, no reaction was observed between stabilized iodonium ylides **1** and organoboranes.

β -Dicarbonyl and β -disulfonyl iodonium ylides, relatively stable species, enjoy rich chemistry in modern organic synthesis and serve as useful progenitors for the generation of carbenes.^{3,5} The attempted reaction of the stable ylides **1** with triorganoboranes such as Ph_3B and Et_3B (THF/rt) did not show any evidence for formation of carbon ligand transfer product **3** but instead gave a small amount of O-phenylated ether **2** (Scheme 1). Formation of the enol ether **2** involves the well-known thermal 1,4-rearrangement with phenyl migration from iodine(III) to oxygen atom, which proceeds via the intermediacy of a spiro-Meisenheimer complex.⁶ The stable β -dicarbonyl ylides **1** possess a highly delocalized

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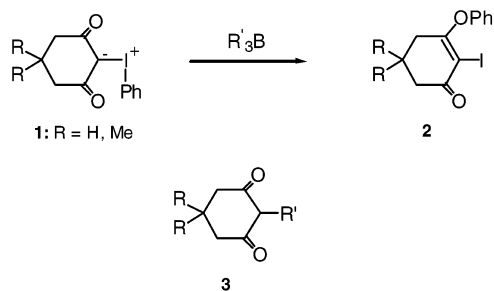
(3) (a) Koser, G. F. In *The Chemistry of Functional Groups, Supplement D*; Wiley: New York, 1983; Chapter 18. (b) Varvoglis, A. *Synthesis* **1984**, 709. (c) Moriarty, R. M.; Vaid, R. K. *Synthesis* **1990**, 431. (d) Varvoglis, A. *The Organic Chemistry of Polycordinated Iodine*; VCH: New York, 1992. (e) Zhdankin, V. V.; Stang, P. J. *Chem. Rev.* **2002**, *102*, 2523.

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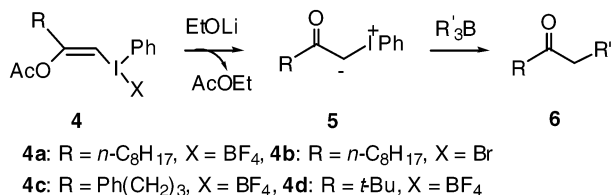
Scheme 1



ylidic carbanion directly bound to the strongly electron-withdrawing phenyliodonio group.⁷ Consequently, they exhibit relatively low nucleophilicity, which in turn renders these ylides inactive toward organoboranes.

Recently, we found that the ester exchange reaction between (Z)-(2-acetoxyvinyl)- λ^3 -iodanes **4** and EtOLi resulted in quantitative generation of the unstable monocarbonyl iodonium ylides **5** in THF at -78°C , with the liberation of ethyl acetate (Scheme 2).⁸ In contrast to the

Scheme 2



stabilized iodonium ylides **1**, the monocarbonyl iodonium ylides **5** are moderately nucleophilic in nature and act as alkylidene transfer agents to carbonyl compounds and activated imines to yield α,β -epoxy ketones and 2-acylaziridines stereoselectively in good yields.⁹ The ylides **5** undergo transfer of a carbon ligand from boron to ylide carbons by the reaction with triorganoboranes. Thus, exposure of the monocarbonyl iodonium ylide **5a** ($\text{R} = n\text{-C}_8\text{H}_{17}$), derived in situ from (Z)-(2-acetoxyvinyl)- λ^3 -iodane **4a** by ester exchange with EtOLi (1.3 equiv) in THF at -78°C for 10–20 min, to Et_3B (1.3 equiv) at -78°C for 1 h and then at room temperature for 0.5 h under argon afforded ethylated ketone **6a** in 86% yield (Table 1, entry 1).¹⁰ Secondary alkyl and aryl groups are also transferred from boron to ylide carbons. Comparison of the results of entries 4 and 5 in Table 1 indicates that only one alkyl group in the trialkylborane is active in the reaction. With use of triethylaluminum instead of Et_3B , ketone **6a** was obtained in 46% yield.

(7) For the Hammett substituent constant ($\sigma_p = 1.37$) of $\text{Ph}(\text{BF}_4)\text{I}^-$, see: Mironova, A. A.; Maletina, I. I.; Iksanova, S. V.; Orda, V. V.; Yagupolskii, L. M. *Zh. Org. Khim.* **1989**, 25, 306.

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Table 1. Reaction of Monocarbonyl Iodonium Ylides **5** with Organoboranes^a

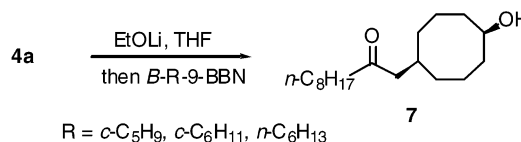
entry	λ^3 -iodane 4	borane	ketone 6	yield (%) ^b
1	4a	Et_3B	6a	86 ^c
2	4a	$n\text{-Bu}_3\text{B}$	6b	68 (72) ^c
3	4a	$s\text{-Bu}_3\text{B}$	6c	76
4	4a	$(c\text{-C}_5\text{H}_9)_3\text{B}$	6d	96
5	4a	$(c\text{-C}_5\text{H}_9)_3\text{B}$	6d	15 ^d
6	4a	$(c\text{-C}_6\text{H}_{11})_3\text{B}$	6e	74
7	4a	$[\text{Ph}(\text{CH}_2)_2]_3\text{B}$	6f	67
8	4a	Ph_3B	6g	67
9	4a	$(p\text{-MeC}_6\text{H}_4)_3\text{B}$	6h	50
10	4b	Ph_3B	6g	73
11	4c	$n\text{-Bu}_3\text{B}$	6i	73
12	4c	$(c\text{-C}_5\text{H}_9)_3\text{B}$	6j	69
13	4d	$n\text{-Bu}_3\text{B}$	6k	62 ^c

^a Reaction was carried out using 1.3 equiv of an organoborane in THF at -78°C for 1 h and then at room temperature for 0.5 h under argon.

^b Isolated yields. ^c GC yields. ^d With use of organoborane (0.33 equiv).

In the Brown group, 9-borabicyclo[3.3.1]nonane (9-BBN) is used as a nonmigrating blocking group on tetrasubstituted borate complexes, for instance, in the α -alkylation of α -bromo ketones and esters.¹¹ The reaction of monocarbonyl iodonium ylide **5a** with *B*-cyclopentyl-9-BBN, however, resulted in an exclusive migration of the cyclooctyl–boron bond rather than the desired cyclopentyl–boron bond to give the hydroxy ketone **7** in 51% yield (Scheme 3). With

Scheme 3



B-cyclohexyl- and *B*-*n*-hexyl-9-BBN, selective formation of **7** was also observed in 37 and 46% yields, respectively.¹²

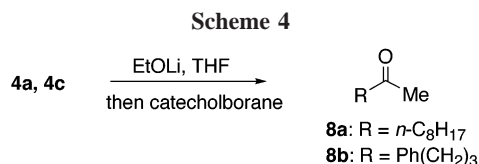
Reaction of iodonium ylides **5** with catecholborane undergoes the boron-to-carbon 1,2-shift of hydrogen to give methyl ketones **8**;^{1d} thus, exposure of **5a** to catecholborane

(10) **Experimental Procedure.** **6a** (Table 1, entry 1): To a stirred solution of (Z)-(2-acetoxy-1-decenyl)(phenyl)(tetrafluoroborate)- λ^3 -iodane (**4a**)⁸ (37 mg, 0.075 mmol) in THF (3.7 mL) was added a 0.58 M THF solution of EtOLi (0.167 mL, 0.097 mmol) at -78°C under argon, and the mixture was stirred for 20 min. After addition of a 1.06 M hexane solution of Et_3B (0.92 mL, 0.097 mmol), the mixture was stirred for 1 h at -78°C and 0.5 h at room temperature. The reaction mixture was quenched with water and extracted with dichloromethane. The organic phase was washed with brine and dried over anhydrous Na_2SO_4 . The yield of **6a** was determined by GC analysis using an FFS ULBON HR-1 capillary column (0.25 mm \times 50 m).

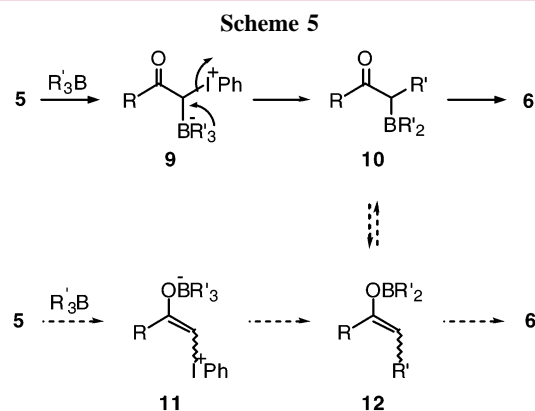
(11) (a) Brown, H. C.; Rogic, M. M.; Nambu, H.; Rathke, M. W. *J. Am. Chem. Soc.* **1969**, 91, 2147. (b) Brown, H. C.; Nambu, H.; Rogic, M. M. *J. Am. Chem. Soc.* **1969**, 91, 6855. (c) Hara, S.; Kishimura, K.; Suzuki, A. *Tetrahedron Lett.* **1978**, 2891.

(12) Reaction of *B*-*n*-hexyl-9-BBN with ethyl diazoacetate gives products derived from exclusive *B*-cyclooctyl bond migration. See: Hooz, J.; Gunn, D. M. *Tetrahedron Lett.* **1969**, 3455.

(1.3 equiv) in THF afforded 2-decanone **8a** in 66% yield (Scheme 4). Similarly, ylide **5c** gave 5-phenyl-2-pentanone **8b** (61%).



The mechanism for the reaction of iodonium ylides **5** with organoboranes, which involves formation of α -boryl ketones **10**, is shown in Scheme 5. Initial formation of zwitterionic



ylide–borane complexes **9**, followed by a rapid boron-to-carbon 1,2-shift of an alkyl group with concomitant reductive elimination of the hypernucleofuge, phenyliodonio group,¹³ produces α -boryl ketones **10**. Subsequent hydrolysis affords ketones **6**. As an alternative process, formation of *O*-boron zwitterions **11** and the further intramolecular nucleophilic vinylic substitution¹⁴ yielding *O*-boron enolates **12** should be considered; however, this pathway is not compatible with our results (See below).

α -Boryl ketones have been proposed as intermediates in some reactions but have never been characterized.¹⁵ Attempted synthesis of α -boryl ketones by the reaction of α -diazo ketones with tripropylborane resulted in exclusive formation of *O*-boron enolates.¹⁶ Ab initio molecular orbital calculation shows that α -boryl ketone ($\text{Me}_2\text{BCH}_2\text{CHO}$) is more unstable than the isomeric boron enolate ($\text{CH}_2=$

CHOBMe_2) by ca. 19 kcal/mol.¹⁷ Interestingly, Abiko and Masamune reported the characterization of the intermediate α -boryl esters in the double aldol reaction of acetate esters.¹⁸

Importantly, deuterium experiments showed that when the reaction mixture of iodonium ylide **5a** with $n\text{-Bu}_3\text{B}$ ($-78^\circ\text{C}/1\text{ h/THF}$) was quenched with MeOD at -78°C , α -deuterated ketone **6b-ad** (59% D) was produced in 71% yield; however, quenching with MeOD after warming the reaction mixture to room temperature showed no deuterium incorporation in **6b** (87% yield). Similar results were obtained in the reaction with $s\text{-Bu}_3\text{B}$. These results probably suggest the involvement of the intermediate α -boryl ketone **10a** (R = $n\text{-C}_8\text{H}_{17}$, R' = $n\text{-Bu}$) under our conditions, which is thermally unstable and easily decomposes to ketone **6b** below room temperature.¹⁹ Formation of *O*-boron enolates **12** via intramolecular vinylic substitution of the zwitterions **11** or through a 1,3-boron shift of **10** does not seem to occur, because enolates **12** are known to be stable even at room temperature.^{16,20}

The temperature effects in the aldol condensations shown in Table 2 further support the thermally unstable nature of

Table 2. Temperature Effects in One-Pot Aldol Condensation^a

		$4a \xrightarrow[\text{THF, } -78^\circ\text{C, 20 min}]{1) \text{ EtOLi}} \xrightarrow[\text{-78}^\circ\text{C, 3 h, then } 25^\circ\text{C, 12 h}]{2) R'_3B, \text{ conditions A; } 3) \text{ ArCHO}}$			
entry	borane	conditions A $T(^{\circ}\text{C})/t(\text{h})$	ArCHO (equiv)	yield (%) ^b	13 6
1	$n\text{-Bu}_3\text{B}$	$-78/1$	PhCHO (2)	56 (30:70) ^c	38
2	$n\text{-Bu}_3\text{B}$	$-78/1, -30$	PhCHO (2)	12 (51:49) ^c	26
3	$n\text{-Bu}_3\text{B}$	$-78/1, 25$	PhCHO (2)	0	68
4	$n\text{-Bu}_3\text{B}$	$-78/1$	$m\text{-ClC}_6\text{H}_4\text{CHO}$ (2)	74 (50:50) ^c	38
5	$n\text{-Bu}_3\text{B}$	$-78/1, 25$	$m\text{-ClC}_6\text{H}_4\text{CHO}$ (2)	0	93
6	$s\text{-Bu}_3\text{B}$	$-78/2$	PhCHO (1.3)	73 (50:50) ^{c,d}	16
7	$(\text{c-C}_5\text{H}_9)_3\text{B}$	$-78/2$	PhCHO (1.3)	62 (72:28) ^c	24

^a Reaction was carried out using 1.3 equiv of EtOLi and organoborane in THF under argon. ^b Isolated yields. ^c Ratios of syn:anti. ^d Syn and anti aldols are 65:35 and 50:50 mixtures of diastereoisomers, respectively.

α -boryl ketones **10**. Treatment of a solution of α -boryl ketone **10a**, generated by the reaction of ylide **5a** with $n\text{-Bu}_3\text{B}$ at -78°C in THF, with benzaldehyde afforded a mixture of aldol products **13** in 56% yields, while aldol condensation after warming a solution of **10a** to -30°C dramatically decreased the yield of **13** to 12% (Table 2, entry 2).²¹ Furthermore, no aldols **13** were produced when a solution

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of **10a** was warmed to room temperature prior to the aldol condensations (Table 2, entries 3 and 5): in these cases, the ketone **6b** was obtained selectively in good yields.

In conclusion, we have shown that, in contrast to the stabilized iodonium ylides, the moderately nucleophilic monocarbonyl iodonium ylides undergo transfer of a carbon ligand from boron to ylide carbons by reaction with trior-

ganoboranes. Most importantly, the reaction probably involves in situ generation of hitherto uncharacterized α -boryl ketones.

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Supporting Information Available: Detailed experimental procedures and spectroscopic data. This material is available free of charge via the Internet at <http://pubs.acs.org>.

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