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LETTERS

Preparation of 2-Iodo-1,3-butadienes from 1-Trimethylsilyl-2,3-butadienes and their Functionalizations

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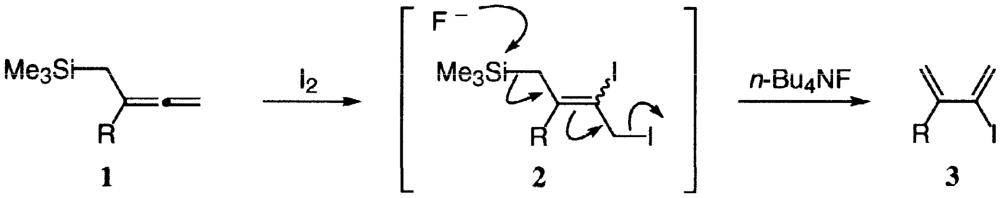
Abstract: Successive treatment of 1-trimethylsilyl-2,3-butadienes with iodine and tetra-*n*-butylammonium fluoride in the same flask affords 2-iodo-1,3-butadienes in good yields and their palladium-catalyzed carbonylation and alkynylation allows introduction of ester and alkynyl groups to the 2-position bearing an iodine atom leading to various 2,3-disubstituted 1,3-butadienes.

In the course of search for the synthetic utility of 1-trimethylsilyl-2,3-butadienes,[1] we have recently found that addition of iodine to 1-trimethylsilyl-2,3-butadienes **1** took place at –78 °C at the terminal double bond to give *vic*-diiodoallylsilanes **2** quantitatively.[2] Interestingly, it was also found that *vic*-diiodoallylsilanes **2** thus formed decomposed gradually to 2-iodo-1,3-butadienes **3** above –30 °C.[3] These findings allowed us to envisage that successive treatment of **1** with iodine and tetra-*n*-butylammonium fluoride (TBAF) in the same flask would produce 2-iodo-1,3-butadienes **3** effectively as depicted in Scheme 1. Exploitation of a general practical method for the preparation of substituted 2-halo-1,3-butadienes such as **3** is important because few methods are available for this purpose.[4] We now report an efficient method with broad applicability for the preparation of 2-iodo-1,3-butadienes **3** from 1-trimethylsilyl-2,3-butadienes **1** and their conversions to various 2,3-disubstituted 1,3-butadienes.



Scheme 1

Experimentation was undertook as shown in Scheme 2 and the results were summarized in Table 1. Nine 2-substituted 1-trimethylsilyl-2,3-butadienes **1**[5] were synthesized in good yields by the reaction of bromides or tosylates **5**, freshly prepared from **4**, with Me_3SiCH_2MgCl in the presence of CuCN and LiCl. It is important to note that use of CuCN and LiCl turned out to be crucial for effecting γ-attack of Grignard reagent leading to exclusive formation of **1**.[6] The precedent method[7] using $LiCuBr_2$ or CuBr often gave a mixture of **1** and the corresponding alkyne produced by competitive α-attack of the Grignard reagent. 1-Trimethylsilyl-2,3-butadienes **1** thus obtained were then allowed to react with iodine followed by TBAF at –78 °C in CH_2Cl_2. It was found that initially formed *vic*-diiodoallylsilanes **2** smoothly underwent F^- mediated elimination reaction

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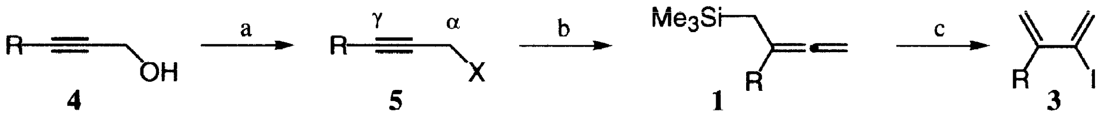
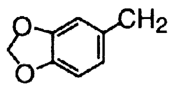
giving 2-iodo-1,3-butadienes **3** in good to excellent yields except two examples shown in entries 6 and 8. A typical procedure is described for the synthesis of 2-iodo-3-phenyl-1,3-butadiene **3** (R = Ph). To an ice-cooled suspension of CuCN (6.9 g, 77 mmol) and LiCl (6.5 g, 153 mmol) in THF (100 ml) was added Me_3SiCH_2MgCl (1 M in Et_2O, 77 ml, 77 mmol). After being stirred at 0 °C for 30 min, the mixture was cooled to –78 °C and a solution of freshly prepared 3-bromo-1-phenylpropyne (5.0 g, 26 mmol) in THF (20 ml) was added. After 1 h at –78 °C, the reaction was quenched by the addition of sat. NH_4Cl. The reaction mixture was diluted with AcOEt, washed with water, dried over $MgSO_4$, and concentrated *in vacuo*. The residue was purified by silica gel column chromatography (*n*-hexane) to give 1-trimethylsilyl-2-phenyl-2,3-butadiene **1** (R = Ph) (4.8 g, 92%). To a stirred mixture of **1** (R = Ph) (4.8 g, 24 mmol) and $NaHCO_3$ (2.9 g, 35 mmol) in CH_2Cl_2 (50 ml) at –78 °C was added a solution of I_2 (9.0 g, 35 mmol) in CH_2Cl_2 (150 ml). After 10 min, TBAF (1 M in THF, 35 ml, 35 mmol) was added and the mixture was stirred at –78 °C for 1 h. The reaction mixture was diluted with AcOEt, washed with 5% $Na_2S_2O_3$ and water, dried over $MgSO_4$, and concentrated *in vacuo*. The residue was purified by silica gel column chromatography (*n*-hexane) to give 2-iodo-3-phenyl-1,3-butadiene **3** (R = Ph) (5.7 g, 93%).



Scheme 2. (a) CBr_4, Ph_3P, CH_2Cl_2, 0 °C or *n*-BuLi, TsCl, THF, –78 °C; (b) Me_3SiCH_2MgCl (3 equiv.), CuCN (3 equiv.), LiCl (6 equiv.), THF, –78 °C; (c) I_2 (1.5 equiv.), $NaHCO_3$, (1.5 equiv.), CH_2Cl_2, –78 °C, then 1 M *n*-Bu_4NF in THF (1.5 equiv.), –78 °C.

Table 1 Preparation of 2-substituted 1-trimethylsilyl-2,3-butadienes and 3-substituted 2-Iodo-1,3-butadienes

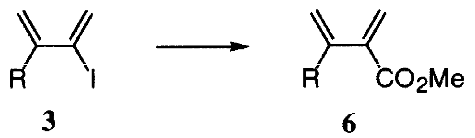
entry	R	X	Yield[a] (%)	
			1 from 4	3 from 1
1	Ph	Br	92	93
2	$BnOCH_2$	Br	87	98
3	Bu	Br	89	87
4	Ph(OBn)CH	Br	94	95
5	C_5H_{11}(OBn)CH	Br	87	91
6	Me_2(OMe)C	Br	77	0
7		TsO	84	88
8	Me_3Si	TsO	75	0[c]
9	Me	TsO	65[b]	60[b]

a) isolated yield. b) the isolated yield decreased because of its volatility. c) 4-iodo-1-trimethylsilyl-2-butyne was produced in variable yield (~50%).

Having developed a new practical method for the preparation of 2-iodo-1,3-butadienes **3**, we then examined functionalization of the 2-position bearing an iodine atom leading to various 2,3-disubstituted 1,3-

butadienes. Table 2, Table 3, and Table 4 show the results of palladium-catalyzed[8] carbonylation, alkynylation, and cross-coupling reactions of **3**. It can been seen that both carbonylation and alkynylation reactions worked well. However, introduction of an substituent by cross-coupling reaction gave unsatisfactory results and the dimeric tetraene **10** was mostly obtained in moderate yield.

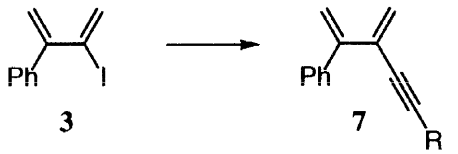
Table 2 Preparation of 3-substituted 2-methoxycarbonyl-1,3-butadienes[a]



entry	R	Yield[b] (%) of **6**
1	Ph	78
2	$BnOCH_2$	76
3	Bu	72
4	Ph(OBn)CH	84
5	C_5H_{11}(OBn)CH	96

a) the reaction was conducted using $(Ph_3P)_4Pd$ (0.03 equiv.), Et_3N (2 equiv.) in MeOH at room temperature under CO (1 atm). b) isolated yield.

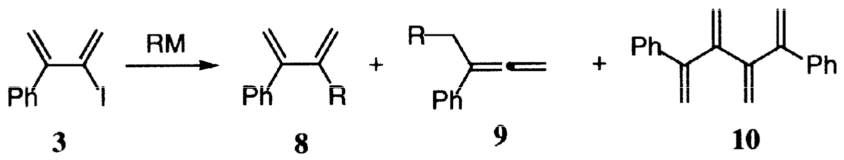
Table 3 Preparation of 2-alkynyl-3-phenyl-1,3-butadienes[a]



entry	R	Yield[b] (%) of **7**
1	Me_3Si	96
2	CH_2OH	80
3	Bu	96
4	Ph	95

a) the reaction was conducted using alkyne (1.1 equiv.), $(Ph_3P)_2PdCl_2$ (0.03 equiv.), CuI (0.06 equiv.), Et_3N (2 equiv.) in THF at room temperature. b) isolated yield.

Table 4 Cross-coupling reactions of 2-iodo-3-phenyl-1,3-butadiene

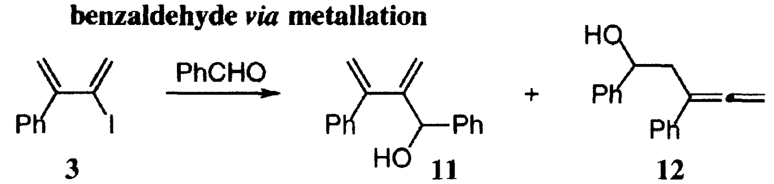


entry	RM (1.5 equiv.)	Method[a]	Yield[b] (%)		
			8	**9**	**10**
1	MeMgBr	A	36	36	0
2	MeLi	B	0	0	63
3	*n*-BuLi	B	0	0	57
4	*n*-$Bu_3SnCH=CH_2$	C	0	0	52

a) A: $(Ph_3P)_4Pd$ (0.03 equiv.), THF, room temperature; B: $(Ph_3P)_4Pd$ (0.03 equiv.), benzene, reflux; C: $Pd_2(dba)_3 \cdot CHCl_3$ (0.03 equiv.), THF, 50 °C. b) isolated yield..

Furthermore, we examined reactions of 2-iodo-3-phenyl-1,3-butadiene **3** (R = Ph) with benzaldehyde *via* metallation. As can be seen from Table 5, **3** (R = Ph) reacted with bezaldehyde in good yields although the regioselectivity of the reaction was dependent on the reaction conditions. In this particular case, dienylmagnesium[9] and chromium[10] species turned out to produce the allene **12** exclusively.

Table 5 Reaction of 2-iodo-3-phenylbuta-1,3-dienes with benzaldehyde *via* metallation



3 11 12

entry	Conditions[a]	11 : 12[b]	Total Yield (%)[c]
1	*t*-BuLi (2 equiv.), Et_2O, –78 °C	36 : 64	83
2	*t*-BuLi (2 equiv.), Et_2O, –78 °C CuCN (0.1 equiv.)	26 : 74	90
3	Mg (1.5 equiv.), $ZnCl_2$ (0.03 equiv.), $(CH_2)_2Br_2$,THF, reflux, then , –40 °C	0 : 100	87
4	$CrCl_2$ (2 equiv.), $NiCl_2$ (0.01 equiv.) DMSO, room temperature	0 : 100	75

a) PhCHO (1.0 equiv.). b) determined by ^{1}H NMR analysis of the mixture. c) inseparable mixture.

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References and Notes

(1) For the chemistry of 1-trimthylsilyl-2,3-butadienes, see: Hatakeyama, S.; Kawamura, M.; Takano, S. *J. Am. Chem. Soc.* **1994**, *116*, 4081-4082 and earlier papers.

(2) Hatakeyama, S.; Sugawara, K.; Takano, S. *J. Chem. Soc. Chem. Commun.* **1993**, 125-127.

(3) For example, when 1-trimethylsilyl-2-phenyl-2,3-butadiene **1** (R = Ph) was allowed to react with iodine in $CDCl_3$ at –20 °C in a NMR tube, the ^{1}H NMR spectrum of the reaction mixture showed the existence of the corresponding *vic*-diiodoallylsilane **2** and 2-iodobuta-1,3-diene **3** in a ratio of 11:1.

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(5) All new compounds reported herein exhibited satisfactory spectral data (^{1}H and ^{13}C NMR, IR, MS).

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