Solvent Effects on Ipso versus Ortho Selectivity in the Reductive Iodonio-Claisen Rearrangement of Allenyl(*p*-methoxyphenyl)iodane

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[3,3]-Sigmatropic rearrangements involving heteroatoms of groups 15 and 16 such as nitrogen, phosphorus, oxygen, sulfur, selenium, and tellurium have been well precedented.[1] Recently, an aromatic Claisen rearrangement involving a hypervalent iodine atom of group 17 was reported; allenyl(aryl)iodanes, generated by S_E2' reaction of aryliodanes with propargylsilanes, -germanes, or -stannanes in the presence of BF_3-Et_2O, undergo reductive [3,3]-sigmatropic rearrangement at −20 °C and afford *o*-propargyliodoarenes regioselectively.[2] The lack of crossover products in the reaction argues for the intramolecularity of this reductive iodonio-Claisen rearrangement.

The presence of *p*-methoxy and *o,o'*-dialkyl groups on aryliodanes, however, leads to deiodinative ipso iodonio-Claisen rearrangement in a highly regioselective manner;[3] thus, reaction of 2,6-dimethyl-4-methoxy(diacetoxyiodo)benzene (**1b**) with 1-(trimethylsilyl)-2-propyne (**2**) in the presence of BF_3-Et_2O in dichloromethane afforded the ipso-substituted alkyne **3b** in more than 98% selectivity (Scheme 1). Competition between deiodinative ipso substitution and the normal ortho rearrangement of allenyliodanes was observed in the reaction of 4-methoxy-(diacetoxyiodo)benzene (**1a**) with **2**, yielding a mixture of the ipso **3a** and the ortho alkynes **4**. We investigated the solvent dependence of ipso versus ortho selectivity in this reductive iodonio-Claisen rearrangement and report that the role of solvent can be interpreted in terms of intrinsic basicities.

Reaction of **1a** with 2 equiv of propargylsilane **2** in the presence of BF_3-Et_2O and $MgSO_4$ in dichloromethane at −20 °C for 1 h afforded the ipso alkyne **3a** as a major product, and the ratio of **3a** to **4** was found to be 55:45 (Table 1, entry 1).[4] Use of chloroform as a solvent showed

Scheme 1

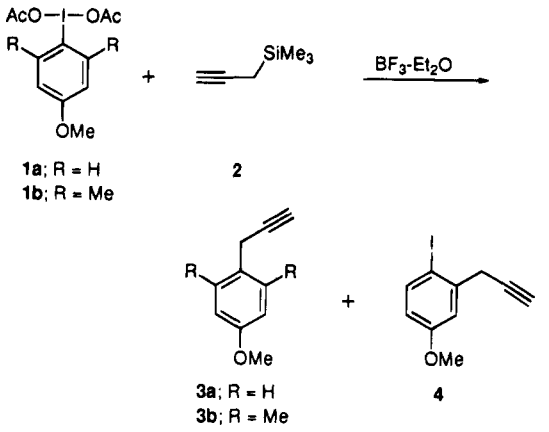

Table 1. Solvent Effects on Ipso versus Ortho Iodonio-Claisen Rearrangement[a]

entry	solvent	**3a**:**4** ratio[b]	% yield[c]
1	CH_2Cl_2	55:45	75
2	$CHCl_3$	53:47	59
3	hexane	47:53	18
4	benzene[d]	46:54	71
5	CCl_4	44:56	54
6	MeCN	42:58	88
7	Et_2O	30:70	80
8	MeOH	20:80	59

[a] Unless otherwise stated, the reaction was carried out at −20 °C for 1 h. [b] Determined by GC analysis of the crude reaction mixture. [c] Total yields of **3a** and **4**. [d] The reaction was carried out at 10 °C for 1 h.

a similar ipso selectivity, whereas a slight preference of the ortho rearrangement over the ipso substitution was observed in hexane, benzene, carbon, tetrachloride, and acetonitrile. This tendency toward ortho selectivity was much increased in diethyl ether and methanol (Table 1, entries 7 and 8).

Changing the Lewis acid catalyst from BF_3-Et_2O to titanium tetrachloride or tin tetrachloride showed no appreciable effects on the product ratios; however, the yield of the rearranged products markedly dropped, and *p*-methoxyiodobenzene of more than 70% yield was obtained. No rearranged products was obtained using aluminum chloride or methylaluminum bis(2,6-di-*tert*-butyl-4-methylphenoxide)[6] as a Lewis acid.

The observed solvent dependency of ipso versus ortho rearrangement does not seem to correlate with solvent parameters such as π^*, E_T, and dielectric constants that measure the intrinsic polarity and/or polarizability.[7] The ortho selectivity for the reductive iodonio-Claisen rearrangement of **1a**, shown in Table 1, seems to increase with the increase of the solvent basicity. Attempts to fit the percent ortho selectivity using Gutmann's donor number (DN) which is defined as the molar enthalpy value for the reaction of the donor with $SbCl_5$ as a reference acceptor failed;[8] however, the percent ortho selectivity correlates well with Taft's β scale of hydrogen-bond acceptor basicities[9] with a correlation coefficient r of 0.966 (Figure 1).

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(4) Use of a 2-fold excess of propargylsilane **2** will be required for the ipso iodonio-Claisen rearrangement.[3] As shown in Scheme 2, the deiodinative ipso rearrangement yielding **3a** will involve generation of an I^+ species, presumably acetyl hypoiodite, which is highly electrophilic[5] and would react rapidly with **2** via an S_E2' process yielding iodoallene. In some experiments, the formation of iodoallene was observed.

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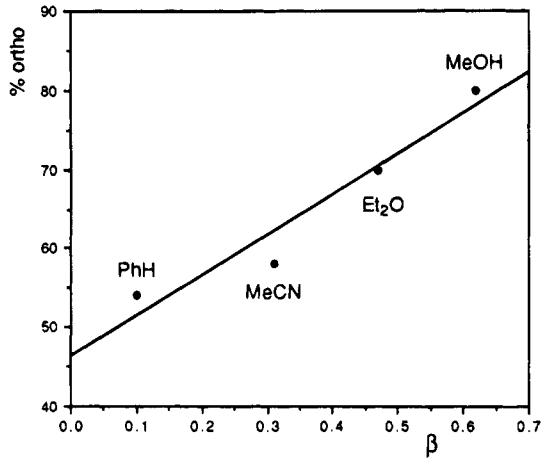
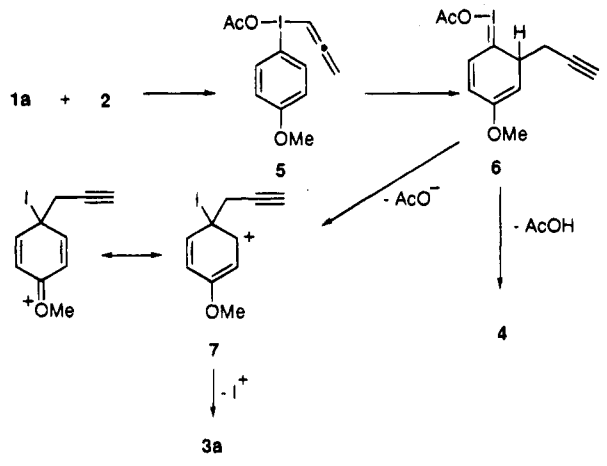


Figure 1. Plots of percent ortho selectivity vs β.

Scheme 2



The reaction course leading to competition between the deiodinative ipso substitution and the normal ortho rearrangement is shown in Scheme 2, which involves an intermediate formation of the *o*-propargyliodane **6**, generated by [3,3]-sigmatropic rearrangement of allenyl(*p*-methoxyphenyl)iodane **5**. Elimination of acetic acid from the intermediate **6** with concomitant energetically preferable reduction of trivalent iodine to univalent iodine will give the normal ortho product **4**. On the other hand, 1,2-rearrangement of the propargyl group of **6** to the ipso site, which also involves a reduction of trivalent iodine, followed by deiodination[4,10] of the resulting cation **7**, will afford the ipso-substituted product **3a**. The tendency toward 1,2-rearrangement of **6** to **7** is enhanced by the presence of a π-donor *p*-methoxy group. The observed solvent effect that the extent of ortho selectivity increases with the increased solvent basicities will be interpreted by considering the difference between the two product-determining steps, that is, deprotonation involved in the concerted or stepwise reductive elimination of acetic acid from **6** and 1,2-rearrangement of the propargyl group of **6**; the rate of the former process will be increased in a solvent with higher basicity, while the solvent basicities will show little effect on the rate of the latter process.

Experimental Section

IR spectra were recorded on a JASCO IRA-1 spectrometer. ^{1}H NMR spectra were recorded in $CDCl_3$ on a JEOL JNM-GX 270 spectrometer. Chemical shifts were reported in parts per million (ppm) downfield from internal Me_4Si. Mass spectra (MS) were obtained on a JMS-D300 spectrometer. Analytical gas chromatography (GC) was conducted on a Shimadzu GC-8A gas chromatograph with 20% silicone GE SF-96 on a Chromosorb W-AWDMCS column (3 m). Thin-layer chromatography (TLC) was carried out on Kieselgel 60 F254 (Merck).

Reactions were performed under a nitrogen atmosphere. THF and diethyl ether was distilled from sodium benzophenone ketyl under nitrogen. Dichloromethane, chloroform, carbon tetrachloride, benzene, and hexane were dried over CaH_2 and distilled. BF_3–Et_2O was distilled from CaH_2 under nitrogen.

4-Methoxy(diacetoxyiodo)benzene (**1a**) was prepared by sodium perborate oxidation of 4-methoxyiodobenzene according to the method developed by McKillop and Kemp.[11] 1-(Trimethylsilyl)-2-propyne (**2**) was prepared according to literature procedure.[12]

General Procedure for the Reductive Propargylation of Aryliodane 1a. In a 20-mL oven-dried two-necked round-bottomed flask fitted with a nitrogen balloon, a rubber septum, and a magnetic stirring bar were placed 4-methoxy(diacetoxyiodo)benzene (**1a**) (0.3 mmol), anhydrous $MgSO_4$ (100 mg), which was dried at 100 °C for 3 h under vacuum, and 2 mL of a freshly distilled solvent. The reaction flask was cooled to −20 °C (dry ice/carbon tetrachloride bath), and 0.037 mL (0.3 mmol) of freshly distilled BF_3-Et_2O was added dropwise. The reaction mixture was stirred for 1 h at −20 °C. The mixture was quenched by addition of water and extracted with dichloromethane. The combined organic extracts were washed with brine, dried over anhydrous Na_2SO_4, and filtered. The yields of the products were determined by analytical GC using tetradecane as internal standard. Pure rearranged products were isolated by preparative TLC [hexane–dichloromethane–diethyl ether (97:1.5:1.5)].

1-(4-Methoxyphenyl)-2-propyne (3a):[13] IR ($CHCl_3$) 3290, 2995, 2820, 1605, 1595, 1505, 1460, 1235, 1165, 1025, 1005 cm^{-1}; ^{1}H NMR ($CDCl_3$) δ 7.28 (d, J = 8.6 Hz, 1 H), 6.88 (d, J = 8.6 Hz, 1 H), 3.80 (s, 3 H), 3.56 (d, J = 2.9 Hz, 2 H), 2.17 (t, J = 2.9 Hz, 1 H); MS *m/z* (relative intensity) 146 (100, M$^+$), 131 (47), 115 (30), 103 (40); HRMS calcd for $C_{10}H_{10}O$ (M$^+$) 146.0731, found 146.0725.

1-(2-Iodo-5-methoxyphenyl)-2-propyne (4): IR ($CHCl_3$) 3290, 2995, 2820, 1585, 1565, 1460, 1410, 1280, 1200–1225, 1150, 1045, 1000, 840 cm^{-1}; ^{1}H NMR ($CDCl_3$) δ 7.69 (d, J = 8.8 Hz, 1 H), 7.23 (d, J = 2.9 Hz, 1 H), 6.57 (dd, J = 8.8, 2.9 Hz, 1 H), 3.81 (s, 3 H), 3.61 (d, J = 2.9 Hz, 2 H), 2.29 (t, J = 2.9 Hz, 1 H); MS *m/z* (relative intensity) 272 (100, M$^+$), 145 (49), 130 (16), 115 (18), 102 (36); HRMS calcd for $C_{10}H_9IO$ (M$^+$) 271.9699, found 271.9689.

Supplementary Material Available: A copy of the ^{1}H NMR spectrum of **4** (1 page). This material is contained in libraries on microfiche, immediately follows this article in the microfilm version of the journal, and can be ordered from the ACS; see any current masthead page for ordering information.

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