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Nucleophilic Reactivities of Tributylstannyl-Substituted Furans and Thiophenes

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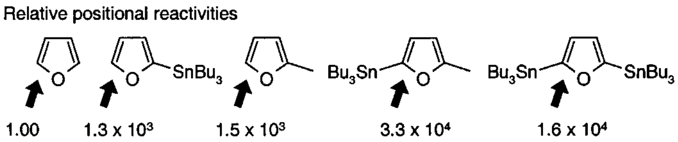
ABSTRACT



Kinetic investigations of the reactions of benzhydryl cations with stannylated furans and thiophenes suggest that 2-(tributylstannyl)furan and -thiophene are preferentially attacked at the 5-position (k_{rel}, $FcPhCH^+$, 20 °C, CH_2Cl_2).

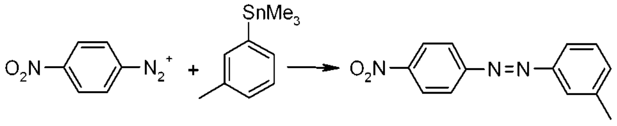
Trialkylarylstannanes have been reported to provide a simple way to introduce electrophiles into an aromatic ring by substitution of the trialkylstannyl group. Friedel−Crafts acylations,[1] formylations,[2] aminocarbonylations,[3] and sulfonation reactions[4] proceed by *ipso*-substitution of the stannyl groups and allow the introduction of groups into positions that are inaccessible by substitution of hydrogen. Furthermore, arylstannanes have been reported to react with weak electrophiles (e.g., diazonium ions) which may not be reactive enough to displace hydrogen (Scheme 1).[5]

In the preceding Letter[6] we have shown that a trimethylsilyl group in the 2-position of furans or thiophenes activates the 5-position for electrophilic attack of benzhydryl cations by a factor of 4−55 whereas the nucleophilic reactivity of the 2-position remains almost constant (factor of 0.35−0.78).

As a consequence, electrophilic alkylations of 2-(trimethylsilyl)furans and -thiophenes proceed with initial attack at the 5-position followed by protodesilylation of position 2. We now report that electrophilic alkylations of 2-(tributylstannyl)furans and -thiophenes proceed analogously and rationalize this behavior by kinetic investigations.

Treatment of 2-(tributylstannyl)furan (**1a**) or -thiophene (**1b**) with a mixture of dianisylmethyl chloride (**2a**)[7] or ferrocenylphenylmethyl acetate (**2b**)[8] and trimethylsilyl tri-

Scheme 1. Reaction of *p*-Nitrobenzene Diazonium Ion with 3-Methyl-1-(trimethylstannyl)benzene[5]



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(1) Neumann, W. P.; Hillgärtner, H.; Baines, K. M.; Dicke, R.; Vorspohl, K.; Kobs, U.; Nussbeutel, U. *Tetrahedron* **1989**, *45*, 951−960.

(2) Niestroj, M.; Neumann, W. P. *Chem. Ber.* **1996**, *129*, 45−51.

(3) Kobs, U.; Neumann, W. P. *Chem. Ber.* **1990**, *123*, 2191−2194. Arnswald, M.; Neumann, W. P. *Chem. Ber.* **1991**, *124*, 1997−2000. Neumann, W. P. *J. Organomet. Chem.* **1992**, *437*, 23−39.

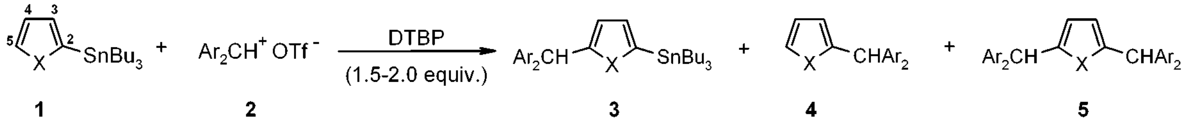
(4) Arnswald, M.; Neumann, W. P. *J. Org. Chem.* **1993**, *58*, 7022−7028.

(5) Neumann, W. P. In *Chemistry and Technology of Silver and Tin*; Kumar Das, V. G., Ng, S. W., Gielen, M., Eds.; Oxford University Press: 1991; pp 151−164, quoted in Davies, A. G. In *Comprehensive Organometallic Chemistry II*; Abel, E. W., Stone, F. G., Wilkinson, G., Eds.; Pergamon: Oxford, 1995; p 236.

(6) Herrlich, M.; Hampel, N.; Mayr, H. *Org. Lett.* **2001**, *3*, 1629.

10.1021/ol0158112 CCC: $20.00

Table 1. Reactions of 2-(Tributylstannyl)furan (**1a**) and -thiophene (**1b**) with Benzhydryl Cations **2** (CH_2Cl_2)[a–c]



	X	Ar_2CH^+				ratio[d]			Yield, %[e]
						3	**4**	**5**	
1a	O	$FcPhCH^+$	(**2b**)	−78 °C	3.5 h	20	59	21	89
1b	S	$FcPhCH^+$	(**2b**)	r. t.	18 h	30	61	9	45
1b	S	An_2CH^+	(**2a**)	0 °C	3.5 h	34	43	23	97

[a] An = p-$CH_3OC_6H_4$-, Fc = ferrocenyl. [b] DTBP = 2,6-di-*tert*-butylpyridine. [c] The reactions were performed as described in ref 12, but the workup was modified. It involved quenching with 15 mL of concentrated ammonia, separation of the two layers and extraction of the aqueous layers with CH_2Cl_2 (3 × 30 mL), washing of the combined organic layers with water, and, finally, drying over $MgSO_4$. [d] The ratios were determined from the ^1H NMR spectra of the crude products. [e] The yields with respect to **2** were determined from the ^1H NMR spectra of the crude products using mesitylene as an internal standard. For calculation it was considered that 2 equiv of **2** is needed for the formation of **5**.

flate in the presence of 2,6-di-*tert*-butylpyridine (DTBP) yields mixtures of **3**−**5** as indicated in Table 1. While **3** must be formed through electrophilic attack of **2** at C-5 of **1**, compound **4** may either be produced via substitution of the tributylstannyl group in **1a** and **1b** or by protodestannylation of **3**. Analogously, **5** may either be formed by electrophilic substitution of **3** or of **4**. Though variable ratios **3**:**4**:**5** obtained under different conditions suggested the formation of **4** through protodestannylation of **3**, we have not (yet) been able to isolate **3** as the main product. Despite that failure, let us first assume that the benzhydryl cations attack only the 5-position of **1**.

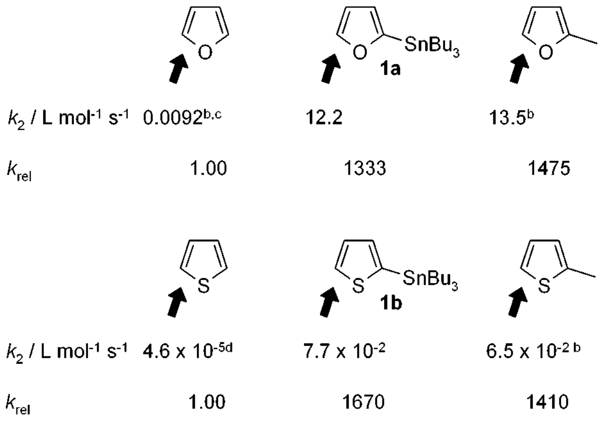
With this hypothesis, we can derive that a tributylstannyl group in the 2-position increases the reactivity of the 5-position of furan and thiophene by roughly 1500 ("*para*"-effect), comparable to the effect of a methyl group (Scheme 2). The magnitude of this effect is quite remarkable since Hammett parameters suggest CH_3 ($\sigma_p^+ = -0.31$)[9] to be a much stronger donor than $SnBu_3$ ($\sigma_p^+ = -0.12$).[10] It shall be noted that the corresponding effect of $SiMe_3$ resembles that of H more closely than that of CH_3.[6]

The relative reactivities shown in Scheme 3 indicate an *ipso*-effect of 5−22 for a tributylstannyl group.

Even if the *ipso*-effect may somewhat be attenuated in these compounds because of the presence of a second electron-releasing group, it is evident from the comparison of Schemes 2 and 3 that the tributylstannyl group in 2-(tributylstannyl)furan and -thiophene activates the 5-position considerably more than the 2-position (Scheme 4) and suggests the exclusive initial formation of **3** instead of **4**.

One may argue that we have been using a self-fulfilling cycle of arguments to arrive at this statement, since the interpretation of our kinetic data was based on the assumption that compounds **1a** and **1b** react exclusively at C-5. However, even in the worst case, i.e., when only the 20% of **3a** and the 30% of **3b** described in Table 1 were produced via electrophilic attack at C-5 of compounds **1a** and **1b**, one would calculate partial rate constants of 0.2 × 12.2 = 2.44 and 0.3 × 0.077 = 0.023 for position 5 of these heteroarenes. From these numbers one can derive "*para*"-effects of >270 in furan and >500 in thiophene, which is still considerably larger than the *ipso*-effect, which can unambiguously be

Scheme 2. Rate Constants for the Electrophilic Attack of the Ferrocenylphenylcarbenium Ion **2b** at the Heteroarenes **1a** and **1b** (20 °C, CH_2Cl_2)[a]



[a] The rate constants were determined photometrically as described in ref 11. [b] From ref 12. [c] Partial rate constant. The actually measured rate constant is 0.0183 L mol^{-1} s^{-1}. [d] Partial rate constant. The actual rate constant (9.2×10^{-5} L mol^{-1} s^{-1}) is calculated from $k_2 = 0.0767$ L mol^{-1} s^{-1} for An_2CH^+ + thiophene (ref 6) using eq 2 in ref 12 ($s = 1$).

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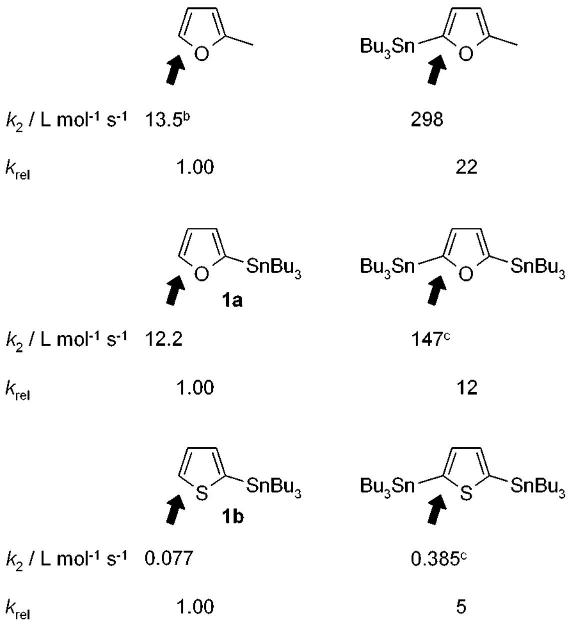
(7) Schneider, R.; Mayr, H.; Plesch, P. H. *Ber. Bunsen-Ges. Phys. Chem.* **1987**, *91*, 1369−1374.

(8) Mayr, H.; Rau, D. *Chem. Ber.* **1994**, *127*, 2493−2498.

(9) Exner, O. *Correlation Analysis of Chemical Data*; Plenum Press: New York, 1988.

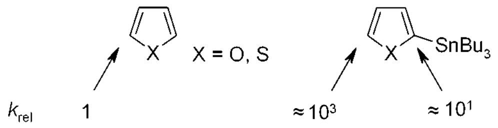
(10) Buchman, O.; Grosjean, M.; Nasielski, J. *Helv. Chim. Acta* **1964**, *47*, 2037−2041.

Scheme 3. Rate Constants for the Electrophilic Attack of the Ferrocenylphenylcarbenium Ion **2b** at the Heteroarenes **1a** and **1b** (20 °C, CH_2Cl_2)[a]



[a] The rate constants were determined photometrically as described in ref 11. [b] From ref 12. [c] Partial rate constant. The actually measured rate constants are 294 L mol^{-1} s^{-1} and 0.769 L mol^{-1} s^{-1}, respectively.

Scheme 4. Relative Reactivities of C-2 and C-5 in 2-(Tributylstannyl)furan and -thiophene



derived from the comparison in the first line of Scheme 3.[13] Even if a small percentage of *ipso*-attack at **1a** and **1b** cannot rigorously be excluded, it is evident from these considerations that as for the corresponding silyl compounds there is a high preference for electrophilic attack at C-5 over C-2 in 2-(tributylstannyl)furan (**1a**) and -thiophene (**1b**). Because of the good accessibility of compounds **1** and the utility of organotin compounds in organic synthesis,[14] efforts to find conditions under which the primary products **3** are isolable in higher yield should continue.

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Supporting Information Available: Spectroscopic data for compounds **3**. This material is available free of charge via the Internet at http://pubs.acs.org.

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[11] Mayr, H.; Schneider, R.; Schade, C.; Bartl, J.; Bederke, R. *J. Am. Chem. Soc.* **1990**, *112*, 4446−4454.

[12] Gotta, M. F.; Mayr, H. *J. Org. Chem.* **1998**, *63*, 9769−9775.

[13] k_{rel} in lines 2 and 3 of Scheme 3 increase by at most factors of 5 and 3 change if attack of $FcPhCH^+$ would also occur at C-2.

[14] Rahm, A.; Quintard, J. P.; Pereyre, M. In *Tin in Organic Synthesis*; Butterworth: Stoneham, MA, 1986.