Alkylation and Allylation of Lithium Arylborates. Factors Affecting the Di / Mono Substitution Ratio†

Ei-ichi Negishi*‡, Ronald E. Merrill, Akiva Abramovitch, and Daniel P. Campbell

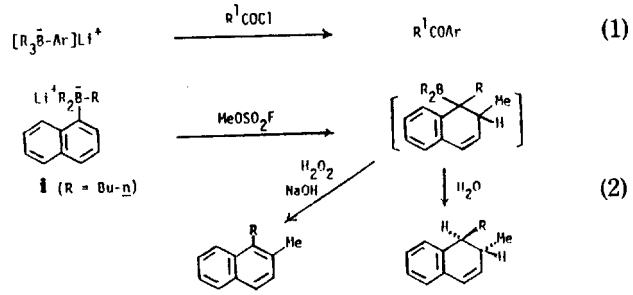
Department of Chemistry, Syracuse University, Syracuse, New York 13210 and Department of Chemistry, Purdue University, W. Lafayette, Indiana 47907. *Received August 10, 1987*

Alkylation and allylation of arylborates give mono(ipso) and/or di(ortho and ipso) substitution products. Those factors which promote polarization or ionization of alkylating agents favor di substitution. The σ-type(ipso) substitution reaction of arylborates involves direct interaction of the carbon-boron bonds rather than predissociation of arylborates into aryllithiums and boranes.

Introduction

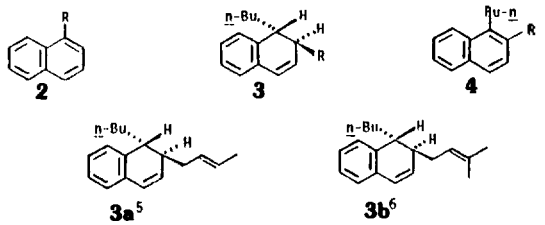
The carbon-boron σ bonds of organoborates are relatively nonnucleophilic in part due to the large steric hindrance around them.[1] However, the intrinsic nucleophilicity associated with the negatively charged tetrahedral boron center can be transmitted through bonds to α, β-unsaturated bonds and other proximal atoms, such as α hydrogen.[2] Indeed, alkenylborates are highly reactive towards various electrophiles, and their reactions are dominated by those involving the alkenyl π bonds (*π reactivity*), whereas the corresponding reactions of alkynylborates involve, more often than not, the carbon-boron σ bonds (*σ reactivity*).[1]

We and others have found that arylborates exhibit this dichotomous behavior in a more intricate manner.[1,3,4] For example, whereas their reaction with acyl halides[3] is dominated by the σ reactivity (eq 1), that with certain alkylating agents[4] predominantly involves π reactivity (eq 2).



We wish to report that those factors which promote polarization or ionization of alkylating agents favor the π-type double(ortho and ipso) substitution reaction of arylborates. We also wish to suggest that the σ-type(ipso) substitution reaction of arylborates involves direct interaction of the carbon-boron σ bonds rather than predissociation of arylborates into aryllithiums and boranes.

In order to probe the effect of the structure of alkylating and allylating agents on the di/mono substitution ratio, we prepared lithium 1-naphthyltri-*n*-butylborate by the reaction of 1-naphthyllithium with *n*-Bu_3B and allowed it to react with Me and Et derivatives containing I, OTs, SO_4, OSO_2F, as well as allyl, crotyl, isoprenyl, and propargyl bromides in THF at room temperature. The reaction mixture was treated with aqueous NaOH to promote the formation of dihydronaphthalenes and then oxidized with NaOH and 30% H_2O_2. The experimental results summarized in Table I indicate the following. First, ethylating agents exhibit considerably higher di/mono substitution ratios than the corresponding methylating agents. Second, the di/mono substitution ratio increases in the order I<OTs<SO_4<OSO_2F. Third, whereas allyl and propargyl bromides give only mono (ipso) substitution products, isoprenyl bromide gives predominantly di (ortho and ipso) substitution products, and crotyl bromide gives both in comparable yields. In summary, the easier the polarization or ionization of alkylating agents is, the higher is the di/mono substitution ratio.



Whereas the mono substitution products in the reactions with crotyl and propargyl bromides are ca. 70:30 mixtures of the two possible regioisomers, that in the reaction with isoprenyl bromide is regiochemically pure 1-isoprenylnaphthalene. Interestingly, the di substitution products (**3** and **4**) were all regiochemically pure (*E*)-crotyl and isoprenyl derivatives. The small J values (≤2 Hz) corresponding to the coupling between the benzylic and allylic ring protons of **3** strongly support their *trans* relationship.

Regardless of the precise mechanism, the di substitution reactions must involve direct interaction of arylborates themselves with alkylating and allylating agents. On the other hand, the mono(ipso) substitution reaction can involve either direct reaction of arylborates or their predissociation into aryllithiums and trialkylboranes. To probe this point, one equivalent each of allyl bromide and cyclohexanone were allowed to react with lithium 1-naphthyltri-*n*-butylborate and 1-naphthyllithium in two separate flasks. The reagents were mixed in THF at -78°C, and the reaction mixtures were gradually warmed to room temperature over 1-2 h. The reaction of 1-naphthyllithium produced 1-(1-naphthyl) cyclohexanol in 70% yield and 1-allylnaphthalene only in 2% yield (eq 3). On the other hand, the reaction of the 1-naphthylborate gave almost exclusively 1-allylnaphthalene (75% yield) along with only a trace of 1-(1-naphthyl)cyclohexanol (eq 4).

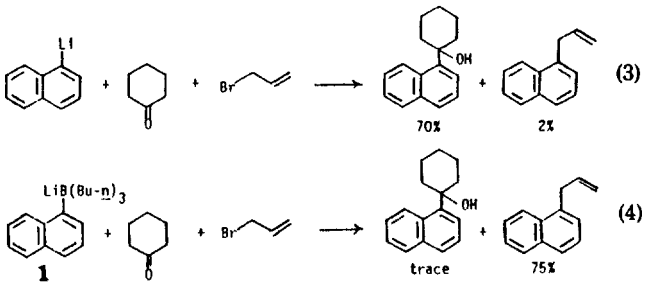
† This paper is dedicated to Professor Nung M. Yoon on the occasion of his 60th birthday.

‡ John Simon Guggenheim Memorial Foundation Fellow (1987).

Table 1. alkylation and Allylation of Lithium 1-Naphthyltri-*n*-butylborate[a]

Alkylating agent	Reaction time, h	Product yield, %				Di(3+4) Mono (2)
		Naphthalene	2	3	4	
MeI	1	98	trace	trace	trace	—
	8	88	11	1	trace	0.09
	48	20	79	1.5	0.5	0.03
MeOTs	24	19	60	12	5	0.28
Me_2SO_4	1	4	53	24	9	0.62
	4	2	65	20	7	0.42
$MeOSO_2F$	1	9	5	56	22	15.6
EtI	48	88	1	2	1	3.0
EtOTs	48	40	6	24	12	6.0
Et_2SO_4	24	20	5	45	23	13.6
$EtOSO_2F$	1	6	3	51	28	26.3
$CH_2=CHCH_2Br$	1	8	92	—	—	—
$CH_3CH=CHCH_2Br$	12	5	40[b]	32[c]	24[c]	1.4
$(CH_3)_2C=CHCH_2Br$	12	7	7	61[c]	25[c]	12.3
$HC\equiv CCH_2Br$	12	10	90[d]	—	—	—

[a] The reaction was carried out in THF at room temperature. [b] A 30:70 mixture of 1-crotylnaphthalene and 1-(1-methyl-2-propenyl) naphthalene. [c] Satisfactory spectral and elemental analytical data were obtained. [d] A 70:30 mixture of 1-(2-propynyl) naphthalene and 1-allenylnaphthalene.



The diametrically opposed chemoselectivity patterns observed in the two reactions strongly disfavor the dissociation mechanism for the reaction shown in eq 4. We therefore conclude that **1** directly reacts with allyl bromide.

Acknowledgements. We thank Research Corporation and the National Science Foundation for support of this work.

References and Notes

1. (a) H. C. Brown, "Organic Synthesis via Boranes", Wiley-Interscience, New York, 1975; (b) E. Negishi, "Organometallics in Organic Synthesis", Vol. 1, Chap. 5, Wiley-Interscience, New York, 1980.
2. (a) R. Damico, *J. Org. Chem.* **29**, 1971 (1964); (b) G. Wittig, *Angew. Chem.*, **70**, 64 (1958).
3. E. Negishi, A. Abramovitch, and R. E. Merrill, *J. Chem. Soc., Chem. Commun.*, 138 (1975).
4. E. Negishi and R. E. Merrill, *J. Chem. Soc., Chem. Commun.*, 860 (1974).
5. **3a:** ^{1}H NMR ($CDCl_3$, Me_4Si) 0.90 (t, J=6 Hz, 3 H), 1.15-1.4 (m, 4 H), 1.4-1.6 (m, 2 H), 1.74 (d, J=6 Hz, 3 H), 1.85-2.0 (m, 1 H), 2.0-2.15 (m, 1 H), 2.41 (dd, J=7.5 and 7.5 Hz, 1 H), 2.78 (t, J=7.5 Hz, 1 H), 5.7-5.8 (m, 2 H), 6.33 (dd, J=7.5 and 10 Hz, 1 H), 6.83 (d, J=10 Hz, 1 H), 7.45-7.5 (m, 2 H), 7.55-7.6 (m, 2 H).
6. **3b:** ^{1}H NMR ($CDCl_3$, Me_4Si) 0.83 (t, J=7 Hz, 3 H), 1.0-1.3 (m, 4 H), 1.43 (dt with a peak at 1.44, J=7 and 7 Hz, 5 H), 1.66 (s, 3 H), 1.89 (m, 2 H), 2.21 (dt, J=2 and 7 Hz, 1 H), 2.52 (dt, J=2 and 7 Hz, 1 H), 5.11 (t, J=6.5 Hz, 1 H), 5.92 (ddd, J=9.5, 6.5, and 1 Hz, 1 H), 6.36 (d, J=9.5 Hz, 1 H), 6.95-7.2 (m, 4 H).