Regiospecific Bromination of Condensed Tetralones *via* Aryloxydifluoroboron Chelates

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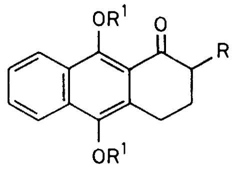
Bromination (Br_2, CCl_4) of the anthracenone derivative (**1b**) under thermal or photochemical conditions gives the expected bromo-compound (**1d**) whereas photochemical bromination of the aryloxydifluoroboron complexes (**2a,b**) gives products (**2c,d**) of benzylic substitution; conversion of (**2c**) and (**3a,b**) into anthraquinone derivatives including madeirin (**4**) is described and extension of the regiospecific bromination procedure to the bicyclic difluoroboron complex (**5a**) is illustrated.

It is difficult to effect free radical allylic or benzylic bromination (Br_2, u.v. light) in compounds possessing an enolisable carbonyl function because of an efficient competing process of electrophilic addition.[†] We describe a procedure whereby appropriately functionalised condensed tetralones can be regioselectively brominated at the benzylic position *via* aryloxydifluoroboron chelates.

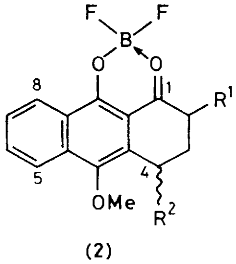
The anthracenone derivative (**1a**)[2] was converted (p-$MeC_6H_4SO_3Me$, Na_2CO_3, o-$Cl_2C_6H_4$) into (**1b**), m.p. 117—119 °C (lit.[3] 115 °C) (82%) and the latter was transformed [Pr^i_2NLi, $B(OCH_2CH_2)_3N$, MeI, 0 °C] into (**1c**),[‡] m.p. 86—88 °C (79%). Treatment of (**1b**) and (**1c**) with $BF_3.Et_2O$ (2 equiv., CH_2Cl_2, room temp., 3 days) gave yellow crystalline aryloxydifluoroboron complexes[3][§] (**2a**), m.p. 211—212.5 °C (79%), and (**2b**), m.p. 160—161 °C (83%), respectively. Bromination of (**1b**) (1.0 equiv. of Br_2, CCl_4, 0 °C) either in the dark or light (150 W sunlamp, CCl_4, azobisisobutyronitrile) gave the expected bromo-derivative (**1d**), m.p. 91—93 °C (92%), whereas photochemical bromination (sunlamp, C_6H_6-CCl_4, room temp.) of (**2a**) and (**2b**) gave the derivatives (**2c,d**)[‡] of benzylic substitution; treatment of the latter with methanol (−20 °C, 72 h) gave the uncomplexed anthracenones (**3a**), m.p. 92—93 °C (85%), and (**3b**) (55%) respectively.

The positional selectivity in the initial bromination was confirmed by converting (**2c**) (Me_2SO, Ac_2O, room temp., 1 min) into 4-bromo-1-hydroxyanthraquinone (m.p. 198 °C, lit.[4] 197—198 °C, 12%) and also by transforming (**3a**) (2,3-dichloro-5,6-dicyanobenzoquinone, PhMe, reflux, 4 h) into 1-hydroxy-4-methoxyanthraquinone (m.p. 167—169 °C, lit.[5] 167—168 °C, 46%); (**3b**) was converted by the latter method into madeirin (**4**), m.p. 187—189 °C (lit.[5] 188—190 °C) (18%).[¶]



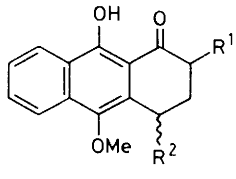
(1)

a, $R^1 = R^2 = H$
b, $R^1 = Me$; $R^2 = H$
c, $R^1 = R^2 = Me$
d, $R^1 = Me$; $R^2 = Br$



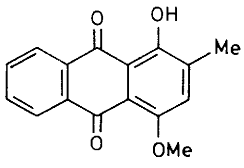
(2)

a, $R^1 = R^2 = H$
b, $R^1 = Me$; $R^2 = H$
c, $R^1 = H$; $R^2 = Br$
d, $R^1 = Me$; $R^2 = Br$

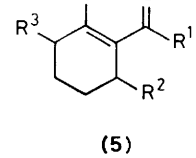


(3)

a, $R^1 = H$; $R^2 = OMe$
b, $R^1 = Me$; $R^2 = OMe$



(4)



(5)

a, $R^1 = Me$; $R^2 = R^3 = H$
b, $R^1 = Me$; $R^2 = Br$; $R^3 = H$
c, $R^1 = Me$; $R^2 = H$; $R^3 = Br$
d, $R^1 = H$; $R^2 = Br$; $R^3 = H$

[†] Bromination of (**1b**) *via* an oxime acetate (*cf.* ref. 1) or an acetal can be envisaged, but an acetal could not be prepared, and bromination (sunlamp, Br_2, CCl_4) of (**1b**) (C=NOAc replacing CO) gave a complex inseparable mixture.

[‡] New compounds reported here, except the labile bromo-derivatives (**2c**), (**2d**), and (**5b**), gave satisfactory chemical analyses and supporting spectroscopic data. The bromo-derivatives (**2c**) and (**2d**) were formed in good yields (>80%) but were unstable; they were characterised spectroscopically (n.m.r.) and converted without purification into (**3a**) and (**3b**). [Yields quoted are overall from (**2a,b**)]. Spectral data, *e.g.* for (**2d**): δ (^1H) ($CDCl_3$) 8.40 (1H, m, Ar-H), 7.65 (3H, m, Ar-H), 5.90 (1H, t, H-4), 4.05 (3H, s, OMe), 3.55 (1H, m, C*H*Me), 1.75—2.75 (2H, m, H-3,3), and 1.42 (3H, d, CH*Me*); spectral data for (**5b**): δ ($CDCl_3$) 6.62 (1H, t, CHBr), 2.50 (3H, s, Me), and 1.7—2.8 (6H, m, CH_2); i.r. 1585 and 1498 cm^{-1}; mass spectrum, m/e 249 and 247 ($M^{+\cdot} - F^{\cdot}$); 187 ($M^{+\cdot} - Br^{\cdot}$). By analogy with the bromination of difluoro(2-formylcyclohexanonato-*O,O′*)boron which gives (**5d**) (nuclear Overhauser effect), structure (**5b**) is tentatively preferred to (**5c**). Spectral data for (**5d**): δ (^1H) ($CDCl_3$) 8.35 (1H, br. s, CHO), 5.32 (1H, s, CHBr), and 1.7–2.8 (6H, m, CH_2). Irradiation of the resonance at δ 5.32 causes a 19% enhancement of the signal intensity at δ 8.35.

[§] Spectral data, *e.g.* for (**2a**): i.r. 1620, 1580, and 1541 cm^{-1}; $M^{+\cdot}$, m/e 290; δ (^1H) ($CDCl_3$) 8.58 (1H, m, Ar-H), 7.70 (3H, m, Ar-H), 3.82 (3H, s, OMe), 3.00 (4H, m, H-2,2,4,4), and 2.20 (2H, m, H-3,3); δ(^{13}C) ($CDCl_3$) 199.17 (C=O); *cf.* δ(^{13}C) ($CDCl_3$) 196.70 p.p.m. for C=O of (**1b**).

[¶] The major product (70%) was 1-hydroxy-2-methylanthraquinone.

Regioselective bromination [*cf.* (**2a** and **b**) → (**2c** and **d**)] of bicyclic difluoroboron complexes is also observed. Whereas a complex mixture is obtained from photochemical bromination (as above) of 2-acetylcyclohexanone, the difluoroboron complex (**5a**)[3] is transformed into the bromo derivative (**5b**),‡ m.p. 118.5—120.5 °C (77%).

We thank the S.E.R.C. for support.

Received, 21st December 1981; Com. 1451

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