

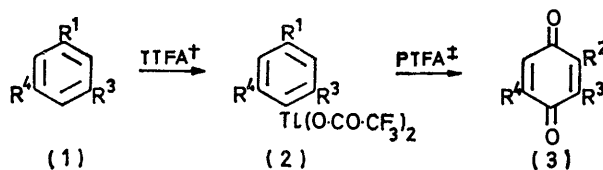
## Aryl Thallation as a Route to Substituted 1,4-Benzoquinones

By G. Kwong Chip and J. S. Grossert,\* Chemistry Department, Dalhousie University, Halifax, Nova Scotia, Canada

The reaction of arylthallium(III) trifluoroacetates with 90% hydrogen peroxide in trifluoroacetic acid is shown to give relatively good yields of 1,4-quinones. The oxidation takes place with either elimination or migration of the substituent group on the starting aromatic compound. The actual process that occurs depends on the nature of the substituent group, and on the electron density in the ring.

THE synthesis of 1,4-benzoquinones is usually achieved by the oxidation of suitably substituted phenols or amines,<sup>1</sup> although it is possible to oxidize some aromatic hydrocarbons electrochemically, which results in the direct production of quinones.<sup>2</sup> Recently, McKillop and Taylor have developed a direct route to *p*-quinones using *p*-substituted phenols and thallium(III) trifluoroacetate.<sup>3</sup> This reaction involves the formation of an aryloxythallium(III) trifluoroacetate, followed by oxidation of the ring to the quinone with concomitant elimination of the *para*-substituent, and reduction of the thallium. As a continuation of our investigations into the influence of transition- and heavy-metal compounds on the reactivity of peroxytrifluoroacetic acid,<sup>4</sup> we have explored the effects of this reactive electrophile<sup>5</sup> on arylthallium(III) derivatives.<sup>6-8</sup> We have found that this reaction gives *p*-quinones from a variety of aromatic compounds in yields ranging from fair to good. This new synthesis of *p*-quinones appears to be of general applicability because the arylthallation is subject to an unprecedented degree of directional control,<sup>8</sup> and because we find that the oxidation to the quinone takes place with either migration or elimination of the substituent on the aromatic ring.

The results of our studies are reported in the Table according to the reactions given in Scheme 1. Although



SCHEME 1

<sup>†</sup> Thallium(III) trifluoroacetate. <sup>‡</sup> 90% H<sub>2</sub>O<sub>2</sub> in trifluoroacetic acid (TFA); (1): PTFA molar ratio 1 : 2.

we made no special attempts to optimize yields, we did find that they were generally improved by isolation of the intermediate arylthallium(III) trifluoroacetates (2), followed by subsequent oxidation with 2 mol. equiv. of 90% hydrogen peroxide in a solution of trifluoroacetic acid. On the basis of the work reported by McKillop and Taylor,<sup>8</sup> we expected *p*-thallation for all the substrates which we examined. We identified our product from the oxidation of benzene by comparison (m.p., u.v., i.r., <sup>1</sup>H n.m.r., and mass spectrometry, and g.l.c.) with authentic 1,4-benzoquinone. In the case of mesitylene, thallation and oxidation gave a complex mixture of products from which no trimethyl-1,4-benzoquinone could be isolated. We did, however, isolate

<sup>5</sup> H. Hart, *Accounts Chem. Res.*, 1971, **4**, 337.

<sup>6</sup> E. C. Taylor and A. McKillop, *Accounts Chem. Res.*, 1970, **3**, 338.

<sup>7</sup> A. McKillop, J. D. Hunt, M. J. Zelesko, J. S. Fowler, E. C. Taylor, G. McGillivray, and F. Kienzle, *J. Amer. Chem. Soc.*, 1971, **93**, 4841.

<sup>8</sup> E. C. Taylor, F. Kienzle, R. L. Robey, A. McKillop, and J. D. Hunt, *J. Amer. Chem. Soc.*, 1971, **93**, 4845.

<sup>1</sup> (a) Z. E. Jolles in 'Chemistry of Carbon Compounds,' ed. E. H. Rodd, Elsevier, Amsterdam, 1956, vol. IIIB, p. 691; (b) H. Zimmer, D. C. Lankin, and S. W. Horgan, *Chem. Rev.*, 1971, **71**, 229.

<sup>2</sup> J. Cason, *Org. Reactions*, 1948, **4**, 305.

<sup>3</sup> A. McKillop, B. P. Swann, and E. C. Taylor, *Tetrahedron*, 1970, **26**, 4031.

<sup>4</sup> (a) J. S. Grossert and G. K. Chip, *Tetrahedron Letters*, 1970, 2611; (b) G. K. Chip and J. S. Grossert, *Canad. J. Chem.*, in the press.

2,6-dimethyl-1,4-benzoquinone from the mixture. Demethylations during formation of *p*-quinones are not unprecedented.<sup>1</sup> The structures of the quinones from

complexity; we make a plausible proposal for this mechanism in Scheme 2. It appears reasonable that the pseudoquinol (4) is a key intermediate in the oxidation

Arylthallium compound (2)			Thallation temp. (°C)	Thallation time (h)	Quinone (3)			Quinone yield* (%)	M.p. (°C)	Lit. m.p. (°C)
R <sup>1</sup>	R <sup>3</sup>	R <sup>4</sup>			R <sup>2</sup>	R <sup>3</sup>	R <sup>4</sup>			
H	H	H	22	17	H	H	H	65	114—115	111—113 <sup>b</sup>
Me	H	H	22	1.0	Me	H	H	68	67—68	68—69 <sup>c</sup>
Et	H	H	22	1.25	Et	H	H	70	37—38	37—39 <sup>d</sup>
Me	Me	H	22	1.0	Me	Me	H	55	57—58	56—57 <sup>e</sup>
Me	Me	Me	22	1.0	H	Me	Me	50	70—71	72—73 <sup>e</sup>
Bu <sup>f</sup>	H	H	22	4.5	H	H	H	20	56—58	49—50 <sup>e</sup>
Cl	H	H	75	0.75	H	H	H	42	114—115	111—113 <sup>b</sup>
OMe	H	H	-15	0.5	H	H	H	61	114—115	111—113 <sup>b</sup>
Naphthalene			-15	1.0	see note <sup>g</sup>			60	127—128	124—125 <sup>f</sup>

\* Based on starting aryl substrate. <sup>b</sup> H. W. Underwood and W. L. Walsh, *Org. Synth.*, Coll. Vol. II, 1943, p. 553. <sup>c</sup> R. K. Norris and S. Sternhell, *Austral. J. Chem.*, 1966, **19**, 617. <sup>d</sup> E. Clemmensen, *Ber.*, 1914, **47**, 56. <sup>e</sup> Product was 1,4-naphthoquinone. <sup>f</sup> L. F. Fieser, *Org. Synth.*, Coll. Vol. I, 2nd ed., 1961, p. 383.

mesitylene and other aromatic compounds were determined from their spectral characteristics, which were compared with published data.<sup>9</sup>

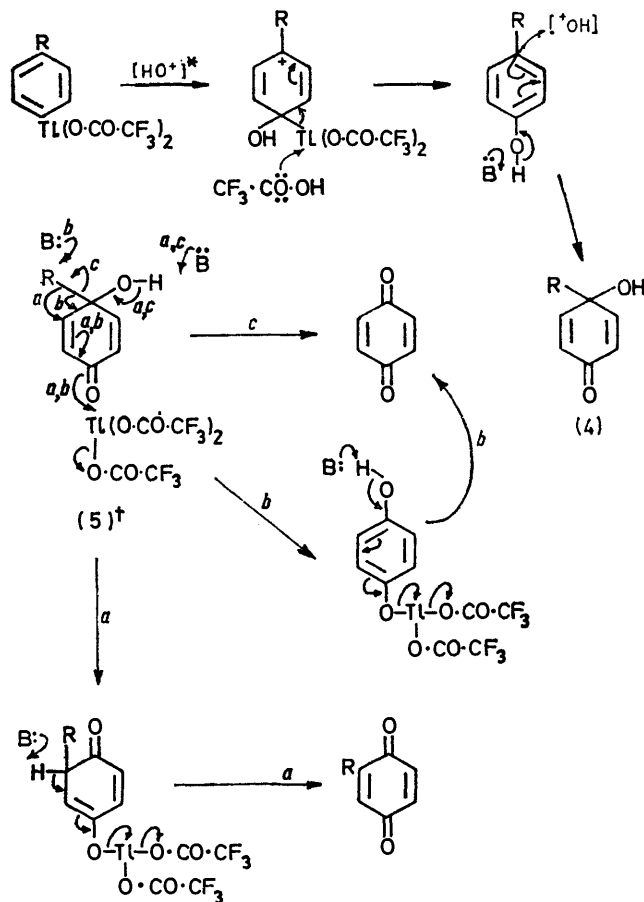
process. Alkyl-substituted pseudoquinols may be further oxidized by two competing pathways (*a* and *b*) as in (5). The reactions with *t*-butylbenzene, *m*-xylene, and mesitylene suggest that the predominant route must depend both on the difference between the electrophilicity (or 'leaving ability') and the 'migrating ability' of the alkyl group, and on the electron density within the ring system. Halogeno- or methoxy-substituted pseudoquinols will be converted into the quinone simply by expulsion of halide or methanol, respectively [cf. pathway *c* in (5)].

Since 1,4-quinones form a large class of natural products (cf. refs. 1a and 9) and are also useful intermediates for the synthesis of a wide variety of molecules, we suggest that this simple approach to the synthesis of a potentially wide range of quinones will be a useful addition to the arsenal of the synthetic chemist.

#### EXPERIMENTAL

**Instruments and Methods.**—M.p.s were taken on a Fisher-Johns apparatus and are uncorrected. The u.v., i.r., <sup>1</sup>H n.m.r., and mass spectra were obtained with Unicam SP 800, P-E 237B, Varian T-60, and DuPont-CEC 21-104 spectrometers, respectively. Samples for mass spectra were introduced into an all-glass system, with the ionizing voltage at 70 eV. G.l.c. analyses were carried out on an H-P 700 instrument with a flame ionization detector, using a stainless steel column (1.8 m × 3.17 mm) packed with 15% DC-200 and 10% QF-1 on acid-washed Chromosorb W, 80—100 mesh, at 175°, 50 ml min<sup>-1</sup> N<sub>2</sub> carrier flow rate. Commercial reagents were purified by distillation, except for trifluoroacetic acid (Eastmann), thallium(III) trifluoroacetate (TTFA) (Aldrich), and 90% H<sub>2</sub>O<sub>2</sub> (FMC Corporation), which were used as obtained.

**Thalliations.**—A standard solution of TTFA (0.5M) was prepared. Thallation was accomplished by mixing equimolar quantities of the TTFA solution and the aromatic substrate under the conditions described in the Table and in refs. 7 and 8. In some cases, the precipitated arylthallium compounds were filtered off; in others, the solution



\* [HO<sup>+</sup>] is used only to signify a species of this nature, and its use does not imply that HO<sup>+</sup> has a free existence. † R = Alkyl, pathways *a* and *b*; R = halide, etc., pathway *c*.

The mechanism of the oxidation by the arylthallium(III) bis(trifluoroacetates) to the quinones is not without

<sup>9</sup> R. H. Thompson, 'Naturally Occurring Quinones,' Academic Press, London, 2nd edn., 1971, ch. 2, and references therein.

was evaporated *in vacuo* at room temperature and the residue was washed with 1,2-dichloroethane.

*Oxidations.*—The arylthallium(III) trifluoroacetate (2.5 mmol) was dissolved in trifluoroacetic acid (10 ml), and dry dichloromethane (10 ml) was added. The solution was stirred vigorously while hydrogen peroxide (90%; 0.15 ml, 5 mmol) was added dropwise. In most cases, a moderate reaction ensued, and the mixture was stirred for 6–8 h, after which it was poured into ice-water which was extracted with  $\text{CHCl}_3$ . The extracts were washed with cold water, dried ( $\text{Na}_2\text{SO}_4$ ), and concentrated to a small volume which was purified on a silica gel column, with chloroform as eluant. In some cases, notably with mesitylene, several minor products of undetermined structure were also obtained. Yields and m.p.s are given in the Table. Spectroscopic properties agreed with those in the literature;<sup>9</sup> the

$^1\text{H}$  n.m.r. and mass spectrum of ethyl-1,4-benzoquinone, and the mass spectrum of *t*-butyl-1,4-benzoquinone have not been reported previously and we record our results for these.

(a) *Ethyl-1,4-benzoquinone*,  $\delta(\text{CDCl}_3)$  1.17 [t, 3H,  $J(\text{CH}_2, \text{Me})$  8 Hz, Me], 2.50 [q, 2H,  $J(\text{CH}_2, \text{Me})$  8,  $J(\text{CH}_2, 3\text{-H})$  1.0 Hz,  $\text{CH}_2$ ], 6.57 [t, 1H,  $J(3\text{-H}, \text{CH}_2)$  1.0 Hz, 3-H], and 6.73 p.p.m. (narrow m, 2H, 5- and 6-H); *m/e* (relative intensity) 138 (6), 137 (8), 136 ( $M^+$ , 100), 108 (97), 107 (50), 82 (55), 79 (92), 54 (86), and 39 (53).

(b) *t-Butyl-1,4-benzoquinone*, *m/e* (relative intensity) 166 (26), 165 (13), 164 ( $M^+$ , 100), 151 (66), 150 (98), 121 (90), 93 (48), 77 (55), 54 (44), 41 (82), 40 (77), and 39 (74).

We thank the National Research Council of Canada and Dalhousie University for financial support.

[1/2504 Received, 31st December, 1971]