

Thiele–Winter Acetoxylation of Quinones. Part VII.¹ Some Bromo-derivatives of Phenyl-1,4-benzoquinone

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The synthesis and the Thiele–Winter acetoxylation of several 1,4-benzoquinones has been studied. 2-Bromo-6-phenyl- and 2-bromo-5-phenyl-1,4-benzoquinone gave triacetates with the inserted acetoxy-group *ortho* to the bromine atom. 2-Bromo-3-phenyl-1,4-benzoquinone gave a mixture of both possible triacetates. 2,3-Dibromo-5-phenyl- and 2-bromo-3-phenyl-6-*t*-butyl-1,4-benzoquinone gave only the corresponding hydroquinone diacetates.

THIS paper describes the synthesis and the Thiele–Winter acetoxylation (T.W.A.) of five benzoquinones containing both bromo- and phenyl substituents. It completes our studies on bromo-, methoxy-, and phenyl-1,4-benzoquinones as outlined in the Introduction to Part VI.

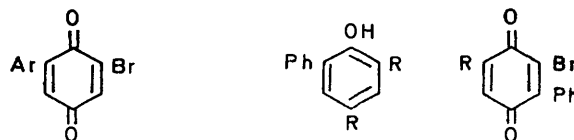
Preparation of Quinones.—2-Bromo-6-phenyl-1,4-benzoquinone (1) was made in 40% yield by oxidation of 3,5-dibromo-2-hydroxybiphenyl (5)² with chromic acid. Attempts to oxidise the dibromophenol (5) with nitric acid in ethanol at 20° resulted in nitrodebromination, the main product (80%) being 2-hydroxy-3,5-dinitrobiphenyl (6). When the dibromophenol was treated with fuming nitric acid at 20° it gave a mixture of 2-bromo-6-(2-nitrophenyl)- (2) and 2-bromo-6-(4-nitrophenyl)-1,4-benzoquinone (3), and other, unidentified products. Oxidation of the dibromophenol (5) with hydrogen peroxide in acetic acid gave 2-bromo-6-phenyl- (1) and 2-bromo-6-(4-bromophenyl)-1,4-benzoquinone (4) (38 and 5% respectively). The formation of the latter compound involves a migration of bromine. The same compound was also formed by oxidation of 3,4',5-tribromo-2-hydroxybiphenyl with chromic acid and its structure was confirmed by its n.m.r. spectrum.

¹ Part VI, J. M. Blatchly, R. J. S. Green, J. F. W. McOmie, and S. A. Saleh, preceding paper.

² K. Auwers and G. Wittig, *J. prakt. Chem.*, 1924, **108**, 99.

A few other examples of migration of bromine atoms during the formation of quinones have been reported.³

2-Bromo-5-phenyl-1,4-benzoquinone was made by addition of hydrogen bromide to 2-phenyl-1,4-benzoquinone followed by oxidation with iron(III) chloride. Phenylation of 2-bromo-1,4-benzoquinone by the



(1) Ar = Ph

(5) R = Br

(7) R = H

(2) Ar = *o*-NO₂C₆H₄

(6) R = NO₂

(8) R = Bu^t

(3) Ar = *p*-NO₂C₆H₄

(4) Ar = *p*-BrC₆H₄

method⁴ used with chloroquinone gave a mixture of the three isomeric phenylbromoquinones which required several days to separate by column chromatography and the yield of the 2,3-isomer (the last to be eluted) was only 8%.⁵ We therefore devised a new synthesis⁶ of 2-bromo-3-phenyl-1,4-benzoquinone (7) using the *t*-butyl

³ J. Cason, *Org. Reactions*, 1948, **4**, 305.

⁴ P. Brassard and P. L'Écuyer, *Canad. J. Chem.*, 1958, **36**, 814.

⁵ J. B. Searle, Ph.D. Thesis, University of Bristol, 1966.

⁶ J. F. W. McOmie and S. A. Saleh, *Tetrahedron*, 1973, **29**, 4003.

group as a protective group. Since then we have re-investigated the phenylation reaction and have found conditions for getting the 2,3-isomer in 31% yield (see Experimental section). Phenylation of 2,5-dibromo-1,4-benzoquinone gave 2,5-dibromo-3-phenyl-1,4-benzoquinone but phenylation of the 2,6-dibromoquinone gave an inseparable mixture containing starting material and two quinonoid products. Addition of hydrogen bromide to the 2-bromo-5-phenyl- and to 2-bromo-6-phenyl-quinones followed by oxidation gave the same product which must therefore be 2,3-dibromo-5-phenyl-1,4-benzoquinone.

Treatment of 2-phenyl-5-t-butylhydroquinone with 1 equiv. of bromine gave 2-bromo-3-phenyl-6-t-butylhydroquinone but with an excess of bromine, oxidation occurred to give 2-bromo-3-phenyl-6-t-butyl-1,4-benzoquinone (8). Some of the quinones described above were characterised by converting them into the corresponding hydroquinone diacetates and dimethyl ethers.

Thiele-Winter Reactions.—T.W.A. of the 2-bromo-6-phenylquinone proceeded readily with boron trifluoride, sulphuric acid, and with perchloric acid to give 2,4,5-triacetoxy-3-bromobiphenyl (9) in 62, 73, and 65% yield respectively. The orientation of substituents in the product was shown by its catalytic reduction to give 2,4,5-triacetoxybiphenyl. The combined hydrolysis and methylation of the bromobiphenyl gave an acetoxydimethoxybiphenyl which is assumed to have the 2-acetoxybiphenyl structure (10), since the 2-acetoxy-group appears to be more sterically hindered than those at positions 4 and 5 and hence is the most likely one to have resisted hydrolysis. Catalytic reduction of the 2-acetoxy-compound (10) at room temperature resulted in debromination and hydrolysis thereby giving 2-hydroxy-4,5-dimethoxybiphenyl. T.W.A. of the 2-bromo-5-phenylquinone with the three catalysts as above gave 2,3,5-triacetoxy-4-bromobiphenyl (11) (in 77, 80, and 76% yield) which was identified by debromination to give 2,3,5-triacetoxybiphenyl. The structure was confirmed by effecting a combined hydrolysis and methylation and then debrominating the methoxy-compound (12) to give 2,3,5-trimethoxybiphenyl which was also made by a crossed

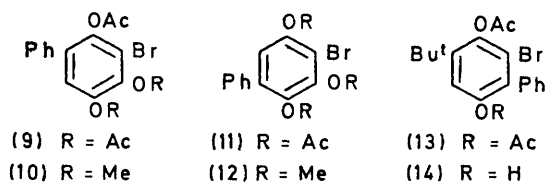
t.l.c. but its n.m.r. spectrum showed the presence of two isomers, and g.l.c. showed the presence of two compounds with closely similar retention times. Attempts to debrominate the mixture of triacetates by catalytic hydrogenation failed, possibly because of the large steric hindrance offered by the phenyl and acetoxy-groups (adjacent to the bromine atom) to the catalyst surface. Hydrolysis and methylation of the mixture of triacetates gave a viscous oil from which 2-bromo-3,4,6-trimethoxybiphenyl was isolated. When the latter was heated with hydrazine and palladium-charcoal catalyst it gave 2,4,5-trimethoxybiphenyl.

In contrast to the above results, the 2,3-dibromo-5-phenylquinone did not undergo T.W.A. but gave a low yield of the corresponding hydroquinone diacetate. T.W.A. of the 2,5-dibromo-3-phenylquinone (with BF_3 catalyst at 50° for 6 days) gave a mixture from which no pure product was isolated. The triacetate which might have been obtained by acetoxylation of this quinone was made by dibromination of 2,4,5-triacetoxybiphenyl. Under similar, but milder conditions, monobromination of 2,4,5-trimethoxybiphenyl gave 4'-bromo-2,4,5-trimethoxybiphenyl.¹

The 2-bromo-3-phenyl-6-t-butylquinone (8) reacted very slowly under the conditions of the T.W.A. and gave a low yield (11%) of the corresponding hydroquinone diacetate (13) together with a monoacetate (20%). In the latter the τ value of the acetoxy-group is 7.66 indicating that it is not situated *ortho* to the phenyl group¹ and hence the compound must be 3-acetoxy-2-bromo-6-hydroxy-4-t-butylbiphenyl (14). It is probably formed by partial hydrolysis of the less sterically hindered acetoxy-group of the diacetate compound (13) during purification. An alternative explanation is that the monoacetate is formed as a precursor to the diacetate, but then it would be expected that the more hindered 3-hydroxy-group would have escaped acetylation: this is contrary to the n.m.r. evidence, and moreover the formation of a hydroquinone monoacetate by T.W.A. is without precedent.⁷

Discussion of Results.—Previous work has shown that in the T.W.A. of 2-phenyl- and 2-bromo-1,4-benzoquinone the 'inserted' acetoxy-group mainly enters the quinone ring *para* to the original substituent.^{8,9}

The results obtained in the present work are similar to those obtained with the three bromo(methoxy)-1,4-benzoquinones, namely that acetoxylation occurs *ortho* to the bromine atom in the 2,5- and 2,6-isomers.¹⁰ The 2-bromo-3-methoxyquinone gave one product only, acetoxylation having occurred *para* to the bromine atom, whereas the 2-bromo-3-phenylquinone gave a mixture of the two possible products. Two of the three trisubstituted quinones, *i.e.* 2,3-dibromo-5-phenyl- and 2-bromo-3-phenyl-6-t-butyl- failed to undergo the T.W.A. but gave low yields of the corresponding hydroquinone diacetates. Many trisubstituted benzoquinones



Ullmann reaction between iodobenzene and 1-bromo-2,3,5-trimethoxybenzene. The product from the T.W.A. of the 2-bromo-3-phenylquinone with the three catalysts was a mixture (*ca.* 40:60) of the two possible triacetates. The mixture could not be separated by

⁷ J. F. W. McOmie and J. M. Blatchly, *Org. Reactions*, 1972, **19**, 199.

⁸ J. M. Blatchly and J. F. W. McOmie, *J. Chem. Soc.*, 1963, 5311.

⁹ J. M. Blatchly, J. F. W. McOmie, and J. B. Searle, *J. Chem. Soc. (C)*, 1969, 1350.

¹⁰ J. M. Blatchly, R. J. S. Green, J. F. W. McOmie, and J. B. Searle, *J. Chem. Soc. (C)*, 1969, 1353.

do undergo T.W.A.⁹ although tribromo-1,4-benzoquinone, which is similar in structure to 2,3-dibromo-5-phenyl-1,4-benzoquinone, gives only 4% of the triacetate together with 9% of the corresponding hydroquinone diacetate.⁹ 2-Bromo-3-phenyl-6-t-butyl-1,4-benzoquinone would not be expected to undergo T.W.A. unless displacement of the t-butyl group occurred since acetoxylation *ortho* to a t-butyl group rarely occurs.¹¹

EXPERIMENTAL

N.m.r. spectra were measured in CDCl_3 at 100 or 60 MHz and those for compounds marked with an obelus (†) are listed in Supplementary Publication No. SUP 21197 (3 pp.).* Petroleum refers to light petroleum (b.p. 60–80°) unless stated otherwise. For detailed descriptions of reductions of quinones, acetylation of hydroquinones, and of combined hydrolysis and methylation of di- and tri-acetoxybenzenes, see refs. 7–9.

2-Bromo-6-phenyl-1,4-benzoquinone (1).†—3,5-Dibromo-2-hydroxybiphenyl² (10.0 g) was dissolved in the minimum volume of acetic acid (*ca.* 20 ml) at 40–50°. To this solution was added dropwise, during 1 h, a solution of chromic oxide (1.8 g) in the minimum of water, diluted with twice the volume of acetic acid. During the addition, the temperature was kept at 30–40° by external cooling. The mixture was then stirred at 20° for 2 h and, after cooling the mixture to 5°, the crude product was collected by filtration. Recrystallisation from ethanol gave the *bromoquinone* (2.8 g), m.p. 97–99°. Concentration of the mother liquors gave a further crop of crystals (0.37 g), m.p. 96–98° (total yield 3.17 g, 40%). A sample sublimed at 70° and 0.1 mmHg had m.p. 97.5–98.5° (Found: C, 54.95; H, 2.8. $\text{C}_{12}\text{H}_7\text{BrO}_2$ requires C, 54.8; H, 2.7%). Reduction of the quinone with sodium dithionite gave 3-bromo-2,5-dihydroxybiphenyl (80% sublimed at 70° and 0.02 mmHg), m.p. 101–102° (Found: C, 54.1; H, 3.5; Br, 30.2. $\text{C}_{12}\text{H}_9\text{BrO}_2$ requires C, 54.4; H, 3.4; Br, 30.1%). Reductive acetylation of the quinone gave 2,5-diacetoxy-3-bromobiphenyl† (75% sublimed at 65° and 0.005 mmHg), m.p. 89–90° (Found: C, 55.2; H, 3.9; Br, 23.15. $\text{C}_{16}\text{H}_{13}\text{BrO}_4$ requires C, 55.0; H, 3.75; Br, 22.9%). A combined hydrolysis and methylation of the preceding diacetate gave 3-bromo-2,5-dimethoxybiphenyl as a viscous oil (84% yield) which sublimed at 45° and 0.03 mm (Found: M^+ , 294.008. $\text{C}_{14}\text{H}_{13}^{81}\text{BrO}_2$ requires M , 294.008).

3,5-Dinitro-2-hydroxybiphenyl (6).—3,5-Dibromo-2-hydroxybiphenyl (3.6 g) was added in portions to a stirred mixture of nitric acid (*d* 1.42; 1.2 ml) and ethanol (10 ml). The mixture was stirred for 1 h more at 20° and was then poured into water. The product, collected by filtration, gave the *dinitrobiphenyl* (2.3 g, 80%) as lemon needles (from ethanol), m.p. 201–203° (decomp.) (Found: C, 55.5; H, 3.4; N, 10.4. $\text{C}_{12}\text{H}_8\text{N}_2\text{O}_5$ requires C, 55.4; H, 3.1; N, 10.8%).

Action of Fuming Nitric Acid on 3,5-Dibromo-2-hydroxybiphenyl.—The hydroxybiphenyl (1.0 g) was added to nitric acid (*d* 1.5; 10 ml) at 20°. After 15 min the mixture was poured onto ice. The crude product was sublimed *in vacuo* then fractionally crystallised. The first crystals consisted of 2-bromo-6-(4-nitrophenyl)-1,4-benzoquinone (3) which formed orange-brown granules (from ethanol), m.p.

193–196° (Found: C, 46.9; H, 2.4; N, 4.6. $\text{C}_{12}\text{H}_6\text{BrNO}_4$ requires C, 46.8; H, 2.0; N, 4.55%). When the mother liquors were cooled to –20° the more soluble isomer, 2-bromo-6-(2-nitrophenyl)-1,4-benzoquinone (2) was obtained as golden yellow plates (from ethanol), m.p. 141–143° (Found: C, 46.7; H, 2.4; N, 4.7%).

Action of Peracetic Acid on 3,5-Dibromo-2-hydroxybiphenyl.—The hydroxybiphenyl (2.0 g) in acetic acid (10 ml) and concentrated sulphuric acid (0.05 ml) was treated dropwise with 30% hydrogen peroxide (1.4 ml), and the mixture was kept for 7 days at 20°. The product was collected and sublimed at 70° and 0.1 mmHg giving 2-bromo-6-phenyl-1,4-benzoquinone (0.6 g, 38%), m.p. 97–98.5°. When the temperature was raised to 100°, 2-bromo-6-(4-bromophenyl)-1,4-benzoquinone (4) (0.1 g, 5%) was obtained as deep red crystals (from ethanol), m.p. 138–140° (Found: C, 41.9; H, 1.8. $\text{C}_{12}\text{H}_6\text{Br}_2\text{O}_2$ requires C, 42.1; H, 1.7%).

The quinone (4) (52%) was also obtained by oxidising 2-hydroxy-3,4',5-tribromobiphenyl² with chromic oxide by the method described above for the oxidation of the dibromohydroxybiphenyl (5).

2-Bromo-5-phenyl-1,4-benzoquinone.†—A solution of hydrogen bromide in acetic acid (45% solution; 11.8 ml) was added dropwise to a suspension of phenyl-1,4-benzoquinone¹² (10.0 g) in acetic acid (100 ml). The mixture was stirred at 20° for 6 h, then a solution of anhydrous iron(III) chloride (33.0 g) in water (55 ml) was added. After the mixture had been heated on a water-bath for 10 min, it was cooled, diluted with water, and the precipitate (24 g) was collected. It gave 2-bromo-5-phenyl-1,4-benzoquinone (9.6 g) as yellow-orange needles (from petroleum), m.p. 130–131°. The mother liquor yielded a second crop (2.3 g), m.p. 130–132° (total yield 83%) (Found: C, 54.6; H, 2.8%).

The following derivatives of the quinone were made in the way described above for the derivatives of 2-bromo-6-phenyl-1,4-benzoquinone: 4-bromo-2,5-dihydroxybiphenyl (83%, sublimes at 65° and 0.03 mmHg), m.p. 103–104° (Found: C, 54.5; H, 3.4; Br, 29.85%); 2,5-diacetoxy-4-bromobiphenyl† (68%, sublimed at 60° and 0.005 mmHg), rod-like crystals, m.p. 117–118° (Found: C, 54.7; H, 3.75; Br, 22.65%); 4-bromo-2,5-dimethoxybiphenyl (90%, sublimed at 60° and 0.02 mmHg), long rods, m.p. 87–88° (Found: M^+ , 292.010. $\text{C}_{14}\text{H}_{13}^{79}\text{BrO}_2$ requires M , 292.010).

Phenylation of Bromo-1,4-benzoquinone.—Sodium nitrite (3.5 g) in water (12 ml) was added to aniline (4.65 g) in water (50 ml) and concentrated hydrochloric acid (12.5 ml) at 0°. This mixture was added to a vigorously stirred suspension of bromo-1,4-benzoquinone (7.1 g) in water (650 ml) containing sodium acetate hydrate (15.3 g). The mixture was stirred at room temperature for 21 h, then extracted with ether. The extract gave a deep red oil (8.3 g) which was filtered through a column of silica gel (M.F.C.) (75 g) with benzene as eluant. The partially purified material was then divided into two parts and each was chromatographed on a column of silica gel (M.F.C.) (250 g) using n-hexane–benzene (1:1) as eluant. The corresponding bands for the two columns were combined. The first yellow band to be eluted gave 2-bromo-5-phenyl-1,4-benzoquinone as yellow-orange needles (1.36 g, 14%), m.p. 129.5–130.5°, after sublimation. The next band

¹¹ J. M. Blatchly, R. J. S. Green, and J. F. W. McOmie, *J.C.S. Perkin I*, 1972, 2286.

¹² P. Brassard and P. L'Écuyer, *Canad. J. Chem.*, 1958, **36**, 700.

* For details of Supplementary Publications, see Notice to Authors No. 7 in *J.C.S. Perkin I*, 1973, Index issue.

gave 2-bromo-6-phenyl-1,4-benzoquinone as orange crystals (2.3 g, 23%), m.p. 96—97°, after sublimation. The last band gave 2-bromo-3-phenyl-1,4-benzoquinone (7)† as orange needles (3.1 g, 31%), m.p. 105—106°, after sublimation at 50° and 0.005 mmHg (Found: C, 54.8; H, 2.7; Br, 30.7%).

The following derivatives were made in the way described above for the 2-bromo-6-phenylquinone: 6-bromo-2,5-dihydroxybiphenyl (68%, sublimed at 60° and 0.005 mmHg), rod-like crystals, m.p. 131—132° (Found: C, 54.6; H, 3.6; Br, 30.4%); 2,5-diacetoxy-6-bromobiphenyl† (96%), needles (from ethanol), m.p. 95—96° (Found: C, 55.05; H, 3.8; Br, 23.1%); 6-bromo-2,5-dimethoxybiphenyl (76%, sublimed at 65° and 0.001 mmHg), prisms, m.p. 129—130° (Found: M^+ , 292.010. $C_{14}H_{13}^{79}BrO_2$ requires M , 292.010).

2,5-Dibromo-3-phenyl-1,4-benzoquinone.†—Diazotised aniline (2.8 g; cf. preceding experiment) was added to a stirred solution of the 2,5-dibromoquinone⁹ (8.0 g) in acetic acid (450 ml) containing hydrated sodium acetate (13.6 g). The mixture was kept at 35° for 6 h, for 24 h at 20°, and finally warmed to 45—50° for 2.5 h. The mixture was cooled to 10° and filtered to remove unchanged dibromoquinone (0.12 g). The filtrate was diluted with ice and water and the yellow solid was collected. It was extracted with boiling petroleum and the extract (3.1 g) was fractionally recrystallised from petroleum to give 2,5-dibromo-3-phenyl-1,4-benzoquinone (2.15 g, 21%), yellow needles, m.p. 144—145° (Found: C, 42.1; H, 1.8. $C_{12}H_8Br_2O_2$ requires C, 42.1; H, 1.8%).

2,3-Dibromo-5-phenyl-1,4-benzoquinone.†—(a) A mixture of 2-bromo-5-phenyl-1,4-benzoquinone (2.44 g), acetic acid (20 ml), and 45% hydrogen bromide in acetic acid (2 ml) was stirred at 20° for 12 h. Aqueous iron(III) chloride (9.4 ml; 60% w/v solution) was added, and the solution was heated on a water-bath for 10 min. The cooled solution was diluted with water and the red oil (4.2 g) was collected in chloroform. The crude product was crystallised from ethanol and gave the dibromoquinone (1.67 g, 52%) as orange needles, m.p. 103—105° (Found: M^+ , 339.873. $C_{12}H_8^{79}Br_2O_2$ requires M , 339.874).

(b) Similar treatment of 2-bromo-6-phenyl-1,4-benzoquinone gave the same dibromoquinone (51%).

2-Bromo-3-phenyl-6-*t*-butyl-1,4-benzoquinone (8).†—Bromine (0.86 g) in chloroform (10 ml) was added dropwise to a stirred solution of 2-phenyl-5-*t*-butylhydroquinone⁶ in chloroform (20 ml), and the mixture was stirred for 15 h. Removal of the solvent left an oil which was chromatographed on silica gel with benzene as eluant. The product (1.8 g, 75%) was recrystallised from petroleum and gave the quinone as yellow plates, m.p. 122—123° (Found: C, 59.95; H, 4.7; Br, 24.8. $C_{16}H_{15}BrO_2$ requires C, 60.2; H, 4.7; Br, 25.0%).

T.W.A. of 2-Bromo-6-phenyl-1,4-benzoquinone.—(a) A mixture of the quinone (1.65 g) in acetic anhydride (8 ml) and a 40% solution of boron trifluoride in acetic acid (0.4 ml) was kept at 50° for 96 h. The mixture was poured into water and the whole shaken for 4 h. The aqueous layer was decanted and the oil was chromatographed on silica gel. Elution with benzene-hexane (25:75) gave unchanged quinone (0.4 g). Elution with benzene then gave a solid (1.58 g, 62%) which was recrystallised twice from methanol to give 2,4,5-triacetoxy-3-bromobiphenyl (9),† m.p. 132.5—133.5° (Found: C, 53.3; H, 3.9. $C_{18}H_{15}BrO_6$ requires C, 53.1; H, 3.7%). The same biphenyl was obtained in 73 and 65% yield when concentrated sulphuric acid (80° for 2 h) and perchloric acid (20° for 24 h) re-

spectively were used as catalysts in place of boron trifluoride.

(b) A solution of 2,4,5-triacetoxy-3-bromobiphenyl (0.4 g) in ethanol (110 ml) was hydrogenated at room temperature and pressure using a palladium-charcoal catalyst prepared *in situ*. The crude product was isolated and then treated with acetic anhydride containing a little perchloric acid. This mixture was diluted with water and the triacetate collected in ether-benzene (1:1 v/v). Recrystallisation of the solid from ethanol then gave 2,4,5-triacetoxybiphenyl (0.25 g, 78%) as needles, m.p. and mixed m.p. 138—140°.

(c) A combined hydrolysis and methylation of the above bromobiphenyl gave 2-acetoxy-3-bromo-4,5-dimethoxybiphenyl (10)† (50%), m.p. 94—95° (from petroleum) (Found: C, 54.7; H, 4.5. $C_{16}H_{15}BrO_4$ requires C, 54.7; H, 4.3%).

(d) 2-Acetoxy-3-bromo-4,5-dimethoxybiphenyl (0.4 g) was catalytically hydrogenated as in (b) above except that the crude product was not reacylated. The crude product was recrystallised from petroleum and gave 4,5-dimethoxy-2-hydroxybiphenyl† (0.125 g, 48%) as needles, m.p. 150—151° (Found: C, 73.2; H, 6.05. $C_{14}H_{14}O_3$ requires C, 73.0; H, 6.1%). Methylation of this compound gave 2,4,5-trimethoxybiphenyl (54%), m.p. and mixed m.p. 87—88°, while acetylation of the same compound gave 2-acetoxy-4,5-dimethoxybiphenyl† (78%) as needles (from petroleum), m.p. 98—99° (Found: C, 70.6; H, 6.1. $C_{16}H_{16}O_4$ requires C, 70.6; H, 5.9%).

T.W.A. of 2-Bromo-5-phenyl-1,4-benzoquinone.—(a) A mixture of the quinone (1.65 g), acetic anhydride (8 ml), and 40% boron trifluoride in acetic acid (0.4 ml) was kept at 50° for 48 h. The oily product was chromatographed on a column of silica gel. Elution with benzene-hexane (30:70 v/v) gave unchanged quinone (0.1 g). Elution with benzene then gave 2,3,5-triacetoxy-4-bromobiphenyl (11)† (2.0 g, 77%) as crystals (from methanol), m.p. 125—127° (Found: C, 53.2; H, 3.75. $C_{18}H_{15}BrO_6$ requires C, 53.1; H, 3.7%). When sulphuric acid (80° for 2 h) and perchloric acid (20° for 24 h) were used in place of boron trifluoride the yields of triacetate were 80 and 76% respectively.

(b) Catalytic reduction of the above 4-bromobiphenyl was carried out as for the 3-bromo-compound above. After reacylation, the product was recrystallised from petroleum (b.p. 100—120°), then from ethanol and gave 2,3,5-triacetoxybiphenyl (36%), m.p. 103—104° (Found: C, 65.9; H, 4.9. $C_{18}H_{16}O_6$ requires C, 65.4; H, 4.9%).

(c) Combined hydrolysis and methylation of the 4-bromobiphenyl gave 4-bromo-2,3,5-trimethoxybiphenyl (12) (73%) as prisms (from petroleum), m.p. 79—80° (Found: C, 55.7; H, 4.6. $C_{15}H_{15}BrO_3$ requires C, 55.7; H, 4.7%).

(d) Reduction of compound (12) by heating it in ethanol with hydrazine hydrate and palladium-charcoal (by the method of Mosby¹³) gave 2,3,5-trimethoxybiphenyl (62%) as an oil (Found: C, 73.6; H, 6.7. $C_{15}H_{16}O_3$ requires C, 73.7; H, 6.6%). The same compound was obtained (78% yield) by combined hydrolysis and methylation of 2,3,5-triacetoxybiphenyl.

(e) A stirred mixture of copper bronze (5 g), iodobenzene (4.1 g), and 1-bromo-2,3,5-trimethoxybenzene (2.5 g) in *NN*-dimethylformamide (35 ml) was heated under reflux for 6 h. More copper (5 g) was added and heating was continued for 18 h; finally copper (5 g) was added and the mixture heated for 48 h. The mixture of products was separated by chromatography on silica gel (100 g), eluting

¹³ W. L. Mosby, *J. Org. Chem.*, 1959, **24**, 421.

first with hexane, then with hexane–benzene mixtures. The first fractions contained iodobenzene, biphenyl, and 1,2,4-trimethoxybenzene, then 1-bromo-2,3,5-trimethoxybenzene (1.2 g, 48% recovery), followed by 2,3,5-trimethoxybiphenyl (0.36 g, 15% based on the bromobenzene), and finally 2,2',3,3',5,5'-hexamethoxybiphenyl (0.24 g, 14%).

T.W.A. of 2-Bromo-3-phenyl-1,4-benzoquinone.—(a) A mixture of the quinone (3.3 g), acetic anhydride (15 ml), and boron trifluoride–ether complex (0.7 ml) was stirred magnetically at 48° for 114 h. The crude product was purified by t.l.c. on silica gel with methylene dichloride as eluant. The material in the yellowish band was extracted and distilled at 120° and 0.02 mmHg to give a mixture of 2,3,5- and 2,4,5-triacetoxy-6-bromobiphenyl (3.5 g, 69%), m.p. 39–40° (Found: C, 53.3; H, 3.5; Br, 19.6. Calc. for $C_{18}H_{15}BrO_6$: C, 53.1; H, 3.7; Br, 19.6%). With sulphuric acid (80° for 3.5 h) and perchloric acid (20° for 28 h) a similar mixture of products was obtained in 84 and 82% yield respectively.

A sample of the mixture, analysed by g.l.c. (1 m column, 10% Carbowax 20M on 60–80 mesh Diatoport 'S' at 200°), showed two peaks of relative areas *ca.* 40 : 60.

(b) Hydrolysis of the mixture of triacetates with trifluoroacetic acid⁶ gave 2-bromo-3,4,6(or 3,5,6)-trihydroxybiphenyl† as needles (43%), m.p. 118–120° (decomp.) (Found: M^+ , 279.973. $C_{12}H_9BrO_3$ requires M , 279.973). The n.m.r. spectrum indicated a single product.

(c) Hydrolysis and methylation of the mixture gave an oil which, on purification by chromatography on silica gel (methylene dichloride as eluant) followed by t.l.c. with benzene as eluant, gave 2-bromo-3,4,6-trimethoxybiphenyl† as needles (from hexane), m.p. 109–110° (Found: C, 55.8; H, 4.8. $C_{18}H_{15}BrO_3$ requires C, 55.7; H, 4.7%). The n.m.r. spectrum indicated a single product. Debromination of this bromobiphenyl by hydrazine hydrate and palladium–charcoal (*cf.* ref. 13) gave 2,4,5-trimethoxybiphenyl (22%) as granules (from hexane), m.p. and mixed m.p. 86–87°.

T.W.A. of 2,3-Dibromo-5-phenyl-1,4-benzoquinone.—The quinone (8.0 g) in acetic anhydride (25 ml) containing 72%

perchloric acid (0.5 ml) was kept at 45° for 16 days. The product was purified by chromatography on silica gel using benzene–hexane (35 : 65 v/v) as eluant. The first fraction consisted of unchanged quinone (3.4 g, 43% recovery). Elution with benzene–hexane (90 : 10 v/v) then gave 2,5-diacetoxy-3,4-dibromobiphenyl† (2.05 g, 21%) as needles (from ethanol), m.p. 139–140° (Found: M^+ , 427.908. $C_{16}H_{12}^{79}Br^{81}BrO_4$ requires M , 427.909). The same diacetate was obtained by treatment of the quinone with acetic anhydride, zinc dust, and a little triethylamine.

Bromination of 2,4,5-Triacetoxybiphenyl.—Bromine (0.54 g) in acetic acid (5 ml) was added dropwise to the biphenyl (1.0 g) in acetic acid (10 ml) at 50° during 4 h. The mixture was kept at 60° for 5 h more, then poured into water. The product was collected and treated with acetic anhydride (15 ml) containing a few drops of perchloric acid for 10 min. After chromatography on silica gel (benzene as eluant) the first fraction was recrystallised from ethanol giving 2,4,5-triacetoxy-3,6-dibromobiphenyl† (0.25 g, 17%), m.p. 168–170° (Found: C, 44.7; H, 2.7. $C_{18}H_{14}Br_2O_6$ requires C, 44.5; H, 2.9%).

*T.W.A. of 2-Bromo-3-phenyl-6-*t*-butyl-1,4-benzoquinone.*—The quinone (100 mg) in acetic anhydride (15 ml) containing 40% boron trifluoride in acetic acid (0.25 ml) was kept at 45–50° for 4 weeks. The mixture of products in chloroform was filtered through a column of silica gel (35 g) and then separated by preparative t.l.c. on silica gel using the same solvent. The first band contained unchanged quinone (48 mg); the second band gave 3,6-diacetoxy-2-bromo-4-*t*-butylbiphenyl (13)† (7 mg, 11%) as an oil (Found: M^+ , 406.060. $C_{20}H_{21}^{81}BrO_4$ requires M , 406.061); the third band gave 3-acetoxy-2-bromo-6-hydroxy-4-*t*-butylbiphenyl (14) (12 mg, 20%) as a viscous oil which slowly solidified (Found: M^+ , 364.049. $C_{18}H_{19}^{81}BrO_3$ requires M , 364.050). With sulphuric acid (70–75° for 7 h) and with perchloric acid (20° for 3 days) the yields of di- and mono-acetate were similar to those obtained using boron trifluoride as catalyst.

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