

Reactions of *o*-Quinones with 2,5-Dimethylthiophene-3,4-diylbis(methylenetriphenylphosphonium Chloride) in the Presence of Lithium Hydroxide. Application of Phase Transfer Catalysis

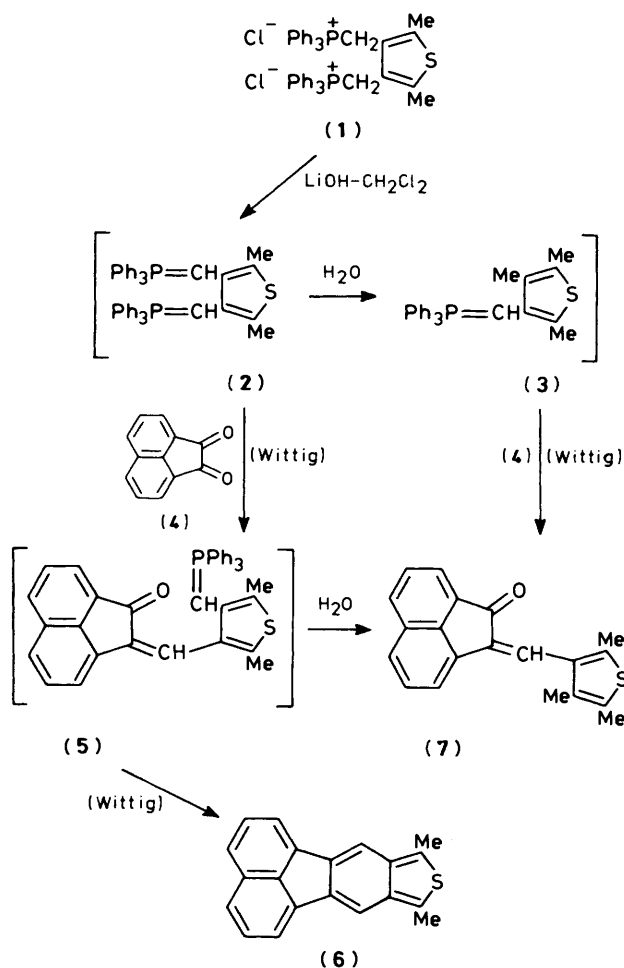
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The reactions of the 1,4-bisphosphonium salt (1) with quinones (4), (8), (14), and (25), in the presence of lithium hydroxide did not afford bis-Wittig products, with exception of compound (6). The quinone (4) in addition to compound (6) gave the *o*-quinomethane derivative (7), quinone (14) gave compounds (17), (18), and (19), *via* a simple Wittig reaction, followed by Michael addition of a second ylide species, while quinone (25) gave the 1,3-benzodioxole (26). A deviation of the typical Wittig procedure can account for the formation of compound (12) from the quinone (8). The reaction of the 1,4-bisphosphonium salt (20) with the dione (14) is also described. Significant hydrolysis of the formed ylide groups was observed in all reactions.

Recently we reported the one-step synthesis of some polycyclic aromatic compounds *via* bis-Wittig reactions between some *o*-quinones and α,α' -(*o*-phenylene)bis(methylenetriphenylphosphorane) (21), prepared *in situ* under nitrogen from α,α' -(*o*-phenylene)bis(methyltriphenylphosphonium bromide) (20) in the presence of lithium ethoxide, in dry DMF.¹ Soon after, Minsky and Rabinovitz applying phase transfer catalysis to reactions between the phosphonium salt (20) and the quinones (4) and (8) prepared, *via* a bis-Wittig reaction, some similar polycyclic hydrocarbons.² Recently we reported that reactions of a number of *o*-quinones with 1,3-, 1,5-, and 1,6-bisphosphonium salts in the presence of lithium ethoxide led to unexpected products *via* a Wittig olefination of only one quinone carbonyl followed usually by a Michael addition of the second ylide group to the initially produced *o*-quinomethane system and further transformations.³ In connection with this work, we now report the reactions of the title 1,4-bisphosphonium salt (1) with the quinones (4), (8), (14), and (25) under conditions of phase-transfer catalysis. The reaction between the quinone (14) and the 1,4-bisphosphonium salt (20), studied previously by us under dry conditions,¹ was also examined in order to investigate the influence of phase-transfer catalysis conditions on the reaction sequence.

Results and Discussion

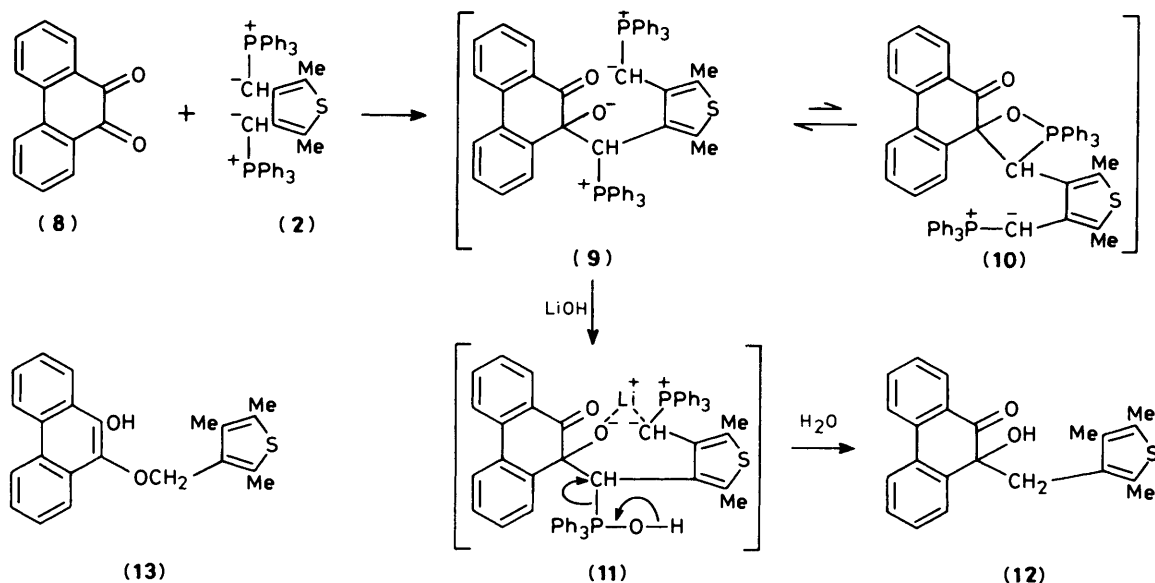
A dichloromethane solution of equimolar amounts of the bisphosphonium salt (1) and the quinone (4) was treated at room temperature with aqueous 5M-lithium hydroxide with efficient stirring for 80 h to give 8,10-dimethylfluorantheno-[8,9-*c*]thiophene (6) and 2-(2,4,5-trimethyl-3-thenylidene)-acenaphthylene-2-one (7) in 24 and 4% yield respectively (Scheme 1). The proposed structures for compounds (6) and (7) were confirmed by their elemental analyses and spectral data. Compound (7) was isolated in only one configuration, its formation arising either *via* the *o*-quinomethane ylide intermediate (5) or the monoyle (3). Intramolecular Wittig reaction of (5) gives the bis-Wittig product (6), while hydrolysis of the remaining ylide group of (5) results in the *o*-quinomethane compound (7). The formation of both products (6) and (7) can be rationalised by assuming that during the Wittig reaction between the 'reactive' ylide (2) and the dione (4), the intermediate (5) is formed as a mixture of *Z*- and *E*-isomers, with the *Z*-isomer as the major component.⁴ The *Z*-configuration favours the intramolecular Wittig reaction and the formation of compound (6) as the major final product, while



Scheme 1.

the hydrolysis of the *E*-isomer gives (7) in the *E*-configuration. However, the formation of compound (7) in the *Z*-form by the hydrolysis of the *Z*-isomer of (5), or *via* the monoyle (3) cannot be excluded.

The reaction of the salt (1) with phenanthrene-9,10-quinone (8) gave 10-hydroxy-10-(2,4,5-trimethyl-3-thenyl)phenanthrene-9-one (12) in 24% yield (Scheme 2).



Scheme 2.

Compound (12) exhibited in its i.r. spectrum, absorptions at 1 680 ($\nu_{C=O}$) and 3 480 cm^{-1} (ν_{OH}) and in its ^1H n.m.r. spectrum four singlets at δ 1.67 (3 H), 1.77 (3 H), 2.13 (3 H) and 2.90 (2 H), one broad singlet at δ 3.83 (1 H, which disappeared on addition of D_2O) and a multiplet at δ 8.10–7.22 (8 H), which were at higher field than the multiplet displayed for the aromatic protons of a fully conjugated phenanthrene system. In its mass spectrum the molecular ion was observed at m/z 348 and abundant ions at m/z 210, 208, 181, 180, 154, 153, 152, and 139 (100%, trimethylthiopyrylium ion), characteristic of the elimination of the thiophene ring system and the subsequent fragmentation of the formed phenanthrene-9,10-quinone daughter ion. The fragment recorded at m/z 153 (55%) was found in significantly higher abundance than that observed in the mass spectrum of the phenanthrene-9,10-quinone. This fragment can also be attributed to the formation of the trimethylthenoyl cation $\text{Me}_3\text{C}_4\text{SC}\equiv\text{O}^+$. The recorded fragmentation pattern could also arise from structure (13), but this structure is not in agreement with the other spectral data of the compound in question. It was considered that the above spectral data are in sufficient agreement with the proposed structure (12).

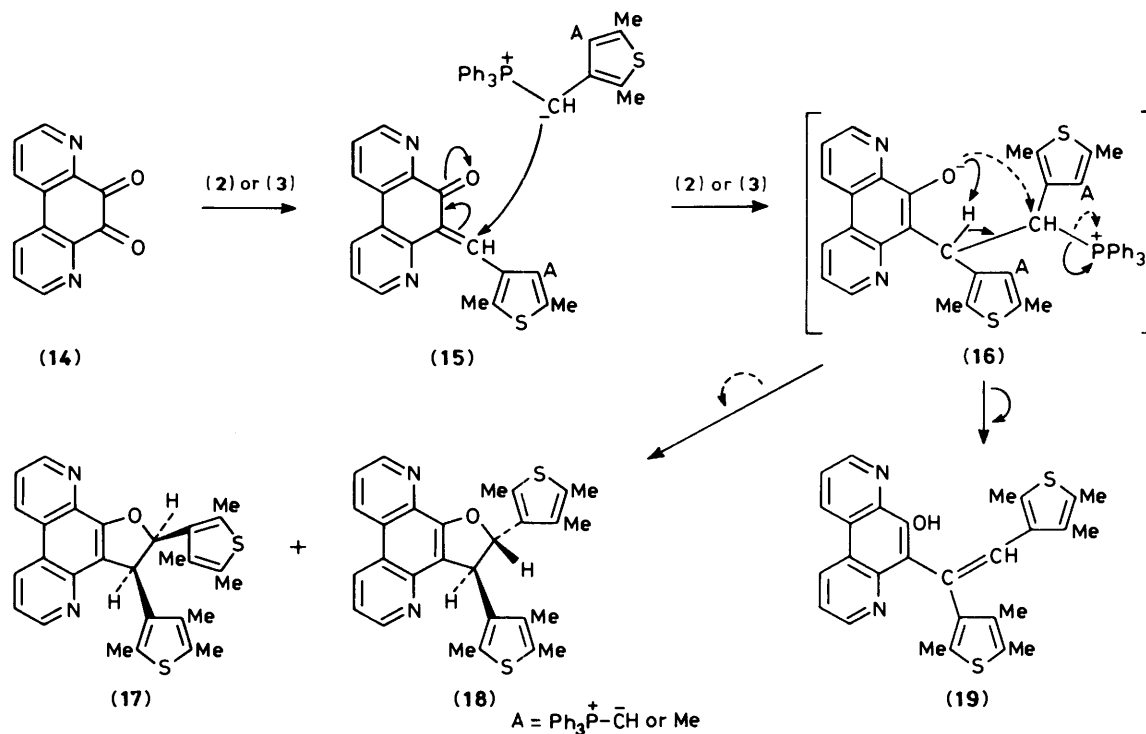
The mechanism proposed in Scheme 2 accounts for the formation of compound (12). It is believed that the phosphonium group of the betaine intermediate (9) formed is attacked by lithium hydroxide to give the intermediate (11), which is further hydrolysed to the final product (12). In this case it seems logical to consider that the betaine (9) is more stable than the oxaphosphetane (10), possibly because of stereochemical reasons and/or the action of the lithium ion. An analogous deviation from the typical Wittig procedure has also been reported previously in reactions between aldehydes and some 'reactive' ylides under special conditions (-78°C , dry conditions, presence of *n*-butyl-lithium) for the preparation and further reactions of β -oxido ylides, where the oxygen of the aldehyde component remained and was not eliminated as triphenylphosphine oxide.⁵

When a solution of equimolar amounts of the salt (1) and 4,7-phenanthroline-5,6-dione (14) was treated with aqueous lithium hydroxide as described above, instead of the expected bis-Wittig product, the isomers *cis*- (17) and *trans*-2,3-bis(2,4,5-trimethyl-3-thienyl)-2,3-dihydrofuro[2,3-*f*][4,7]phenanthroline (18) and 1-(5-hydroxy[4,7]phenanthrolin-6-yl)-1,2-bis(2,4,5-trimethyl-

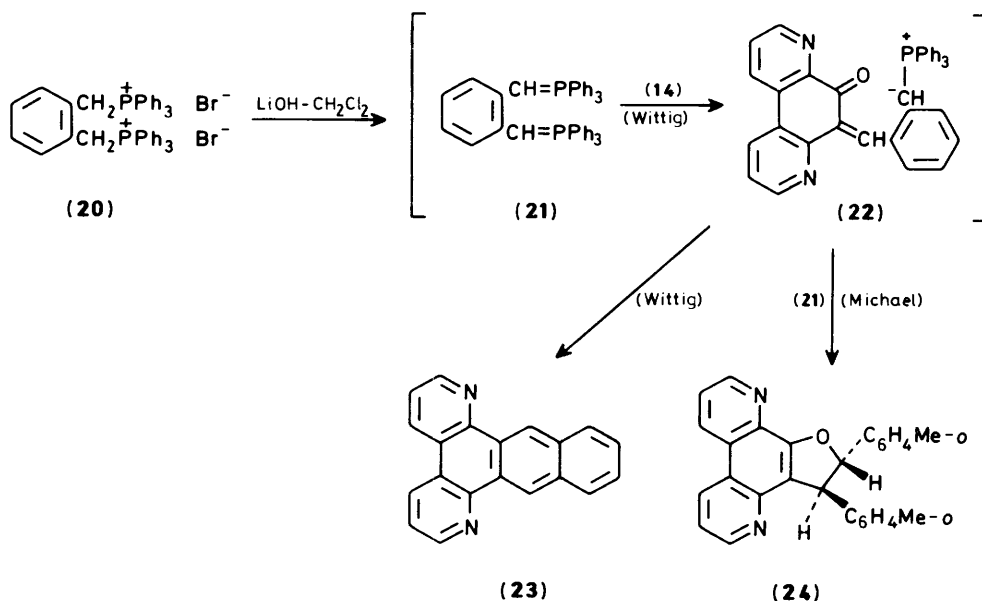
3-thienyl)ethylene (19) were isolated in 3, 7, and 3% yields respectively (Scheme 3). The proposed structures for compounds (17), (18), and (19) were confirmed by their elemental analyses and spectral data. The ^1H n.m.r. spectra of compounds (17) and (18) displayed two doublets at δ 6.58 (1 H, J 8 Hz), 5.69 (1 H, J 8 Hz) and 6.23 (1 H, J 4 Hz), 5.75 (1 H, J 4 Hz) respectively, similar to the reported spectrum of 2,3-diphenylphenanthro-[1]dihydrofuran,⁶ attributed to the α - and β -protons of the dihydrofuran ring. The proposed *cis*-structure for compound (17) with the larger coupling is also in good agreement with the observed lower yield of this isomer, because of the expected greater steric hindrance due to the multisubstituted thiophene rings. Both isomers gave very similar u.v. and mass spectra. Efforts towards their dehydrogenation by treatment with DDQ to the corresponding fully aromatic system failed. The i.r. spectrum of compound (19) exhibited the absorption of the hydroxy group at 3 340 cm^{-1} , while the mass spectrum showed a fragmentation pattern different to those observed for the isomers (17) and (18), with the more abundant fragment at m/z 139 (100%, trimethylthiopyrylium cation).

The mechanism proposed in Scheme 3 explains the formation of compounds (17), (18), and (19). Michael addition of a second ylide species (2) or (3) to the primarily formed *o*-quinomethane intermediate (15) affords the phenoxy intermediate (16). Intramolecular nucleophilic attack by the phenoxy anion at the α -carbon of the phosphonium group accompanied by the elimination of triphenylphosphine (and further hydrolysis of the remaining ylide groups for $\text{A}=\text{Ph}_3\text{P}=\text{CH}$) results in the isomers (17) and (18). On the other hand, Hoffman elimination of triphenylphosphine through an intramolecular abstraction of the β -hydrogen by the phenoxy anion gives compound (19).

From the proposed mechanisms it is obvious that compounds (7) (Scheme 1), and (17), (18), and (19) (Scheme 3) could be also formed by the reaction of the appropriate quinone with the mono-ylide (3). This suggestion is further supported by the fact that the expected bis-Wittig products in the reactions studied were not isolated with the exception of compound (6) (Scheme 1), which was prepared in a satisfactory yield for bis-Wittig reactions. From these observations we conclude that the desired bis-ylide (2) is in fact formed, but its existence in the reaction mixture is seriously affected by the presence of the



Scheme 3.



Scheme 4.

water. Furthermore, the formation of the products depends on the reactivity of the carbonyl compounds.

As already mentioned¹ the quinones (8) and (14), as well as naphtho-1,2-quinone, phenanthrene-3,4-quinone, and 4,5-dimethoxy-*o*-benzoquinone react with α,α' -*o*-(phenylene)bis(trimethylphosphonium bromide) (20) in the presence of lithium ethoxide in dry dimethylformamide, under nitrogen, at 90 °C, to give the corresponding bis-Wittig reaction products in 8–20% yields. On the other hand Minsky and Rabinovitz have also prepared, from the salt (20) and the quinones (4) and (8), the corresponding polycyclic hydrocarbons in 18 and 24% yields

respectively *via* the bis-Wittig procedure using the conditions presented here.² Therefore we attempted the reaction of the quinone (14) with 1.5 equiv. of the salt (20) in the presence of lithium hydroxide, and isolated the bis-Wittig product (23) in 11% yield, identical with previously prepared naphtho[2,3-*f*][4,7]phenanthroline¹ and 2,3-bis(*o*-tolyl)-2,3-dihydrofuro-[2,3-*f*][4,7]phenanthroline (24) in 34% yield (Scheme 4). The formation of compound (24) can be explained by a mechanism similar to that proposed for compounds (17) and (18) (Scheme 3). The ¹H n.m.r. spectrum of compound (24) displayed two one-proton doublets at δ 6.27 and 5.45 (*J* 5 Hz), very similar to those

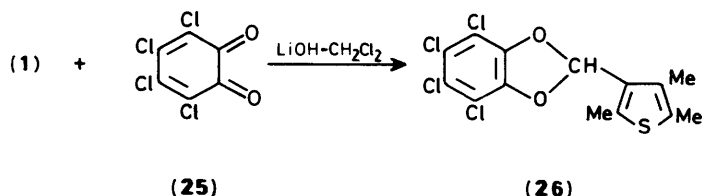


Figure 5.

of compound (18). For this product a *trans*-configuration is expected.

Finally, we attempted the reaction between the salt (1) and the quinone (25) in the presence of aqueous lithium hydroxide, and isolated 4,5,6,7-tetrachloro-2-(2,4,5-trimethyl-3-thienyl)-1,3-benzodioxole (26) in 21% yield (Scheme 5). Analogous 1,3-benzodioxole derivatives have been reported as the products of reaction between compound (25) and other monoylides,^{7,8} while the reaction of compound (25) with the salt (20) in the presence of lithium ethoxide under dry conditions gave rise to the corresponding bis-1,3-benzodioxole derivative.¹

From the above results we conclude that application of phase-transfer catalysis conditions in the reactions studied between the salts (1) and (20) and *o*-quinones causes hydrolysis of the *in situ* formed ylides which competes with the Wittig reaction. The final products depend on the reactivity of the ylide formed and the quinone used.

Experimental

M.p.s are uncorrected and were determined on a Kofler hot-stage apparatus. U.v. spectra were recorded on a Shimadzu UV-210A spectrophotometer for solutions in 95% ethanol. I.r. spectra were obtained with a Perkin-Elmer 297 spectrophotometer as Nujol mulls. ¹H N.m.r. spectra were recorded with deuteriochloroform as the solvent on a Varian A60-A spectrometer, with tetramethylsilane as the internal standard. Mass spectra were determined on a Hitachi Perkin-Elmer RMU-6L mass spectrometer. The ionisation energy was maintained at 70 eV. Light petroleum refers to the fraction of b.p. 40–60 °C.

General Procedure for the Reactions of 2,4-Dimethylthiophene-3,4-diylbis(methylenetriphenylphosphonium chloride) (1) with the *o*-Quinones (4), (8), (14), and (25).—A solution of the appropriate quinone (10 mmol) and the salt (1) (10 mmol) in dichloromethane (250 ml) was stirred by means of an efficient and swift mechanical stirrer. Freshly prepared aqueous lithium hydroxide (5M; 50 ml) was added as one portion to the mixture and the two-phase system was stirred at room temperature for 80–100 h. The mixture was then poured into water (200 ml) and extracted with dichloromethane (2 × 200 ml). The organic extract was dried (Na₂SO₄), the solvent removed under reduced pressure and the residue was chromatographed.

Reaction between the Salt (1) and Acenaphthylene-1,2-quinone (4): Preparation of Compounds (6) and (7).—Reaction of the salt (1) (6.33 g, 8.6 mmol) with compound (4) (1.57 g, 8.6 mmol) for 80 h, by the general procedure gave a reaction mixture which was separated by column chromatography on silica gel. Elution with chloroform afforded two fractions before the unchanged quinone (4). The first fraction gave after evaporation of the solvent compound (6) (0.64 g, 24%), as yellow crystals, m.p. 234–236 °C (from chloroform) (Found: C, 83.7; H, 4.7. C₂₀H₁₄S requires C, 83.89; H, 4.92%); λ_{max} 236sh, 261, 270sh, 300sh, 308, 347, 358sh, 365, 388, 411, and 438 nm (log ε 4.47,

4.32, 4.29, 4.65, 4.75, 3.64, 3.72, 3.82, 3.87, 3.92, and 3.74); δ 7.90–7.50 (8 H, m) and 2.73 (6 H, s); *m/z* 286 (*M*⁺, 100%), 271(13), 252(52), 239(21), and 226(24).

The second fraction after further separation by preparative t.l.c. on silica gel (eluting with chloroform) gave brown crystals of compound (7) (0.158 g, 4%), m.p. 131–132 °C (from dichloromethane–light petroleum) (Found: C, 78.6; H, 5.0. C₂₀H₁₆OS requires C, 78.91; H, 5.30%); ν_{max} 1 708 and 1 637 cm⁻¹; δ 8.22–7.15 (6 H, m), 8.03 (1 H, s), 2.37 (3 H, s), 2.28 (3 H, s), and 2.03 (3 H, s); *m/z* 304 (*M*⁺, 100%), 289 (46), 270 (28), 258 (9), 245 (11), 215 (8), 202 (9), 189 (11), and 152 (13).

Reaction of the Salt (1) with Phenanthrene-9,10-quinone (8): Preparation of Compound (12).—Reaction of the salt (1) (7.33 g, 10 mmol) with compound (8) (2.08 g, 10 mmol) for 100 h gave a reaction mixture which was separated by column chromatography on silica gel. Elution with chloroform afforded compound (12) (0.835 g, 24%), m.p. 61–62 °C (from ether) (Found: C, 75.5; H, 5.6. C₂₂H₂₀O₂S requires C, 75.83; H, 5.79); ν_{max} 3 480 and 1 680 cm⁻¹; δ 8.10–7.22 (8 H, m), 3.83 (1 H, br s, removed by D₂O), 2.90 (2 H, s), 2.13 (3 H, s), 1.77 (3 H, s), and 1.67 (3 H, s); *m/z* 348 (*M*⁺, 8%), 210 (49), 209 (15), 208 (25), 181 (37), 180 (67), 154 (51), 153 (55), 152 (48), 139 (100), 138 (45), and 125 (49). Further elution furnished unchanged quinone (8).

Reaction of the Salt (1) with 4,7-Phenanthroline-5,6-dione (14): Preparation of Compounds (17), (18), and (19).—Reaction of the salt (1) (7.33 g, 10 mmol) with compound (14) (2.1 g, 10 mmol) for 90 h gave a reaction mixture which was separated by column chromatography on silica gel. Elution with light petroleum–ethyl acetate (5:1) afforded three fractions. The first fraction gave light yellow crystals of compound (19) (70 mg, 3%), m.p. 228–230 °C (from chloroform–ether) (Found: C, 71.5; H, 5.9; N, 5.7. C₂₈H₂₆N₂OS₂ requires C, 71.45; H, 5.57; N, 5.95%); ν_{max} 3 340 cm⁻¹; δ 9.05–8.25 (m), 7.97–7.15 (m), 2.22 (6 H, s), 2.10 (3 H, s), 1.98 (3 H, s), 1.93 (3 H, s), and 1.85 (3 H, s); *m/z* 470 (*M*⁺, 1%), 345 (1.5), 333 (13), 332 (35), 317 (6), 316 (9), 315 (27), 314 (40), 313 (31), 139 (100), and 125 (43).

The second fraction was further chromatographed on silica gel (50 g) eluting with light petroleum–ethyl acetate (5:1) and 15-ml fractions were collected. Fractions 10–15 gave white crystals of compound (18) (0.165 g, 7%), m.p. 199–201 °C (from ether–light petroleum) (Found: C, 71.1; H, 5.7; N, 5.7. C₂₈H₂₆N₂OS₂ requires C, 71.45; H, 5.57; N, 5.95%); λ_{max} 239, 253, 279, 288, and 321 nm (log ε 4.66, 4.68, 4.30, 4.28, and 4.01); δ 9.17–8.67 (4 H, m), 7.75–7.18 (2 H, m), 6.23 (1 H, d, *J* 4 Hz), 5.75 (1 H, d, *J* 4 Hz), 2.17 (12 H, br s), and 1.98 (6 H, br s); *m/z* 470 (*M*⁺, 100%), 455 (60), 437 (8), 345 (47), 344 (63), 343 (39), 331 (29), 262 (26), 261 (29), 260 (31), 209 (47), 126 (50), and 125 (66).

The third fraction of the preliminary column chromatography was concentrated and the residue extracted with ether. The material remaining was triphenylphosphine oxide. The organic extract was further separated by preparative t.l.c. on silica gel [light petroleum–ethyl acetate (5:1)] to give before the triphenylphosphine oxide white crystals of compound (17) (67 mg, 3%), m.p. 200–202 °C (from ether–light petroleum) (Found: C, 71.1; H, 5.60; N, 5.65. C₂₈H₂₆N₂OS₂ requires C, 71.45; H, 5.57; N, 5.95%); λ_{max} 238, 252, 278, 287, and 319 nm (log ε 4.72, 4.70, 4.35, 4.29, and 4.07); δ 9.17–8.65 (4 H, m), 7.79–7.13 (2 H, m), 6.58 (1 H, d, *J* 8 Hz), 5.69 (1 H, d, *J* 8 Hz), 2.22 (3 H, s), 2.16 (3 H, s), 2.08 (3 H, s), 1.98 (3 H, s), 1.85 (3 H, s), and 1.76 (3 H, s); *m/z* 470 (*M*⁺, 100%), 455 (35), 437 (7), 345 (40), 344 (57), 343 (30), 331 (21), 262 (14), 261 (21), 260 (20), 126 (71), and 125 (92).

Reaction of the Salt (1) with 3,4,5,6-Tetrachloro-*o*-benzoquinone (25): Preparation of Compound (26).—Reaction of the

salt (1) (7.33 g, 10 mmol) with compound (25) (2.46 g, 10 mmol) for 80 h gave a reaction mixture which was separated by column chromatography on silica gel. Elution with chloroform afforded, by the gradual evaporation of the solvent, white crystals of compound (26) (0.805 g, 21%), m.p. 186–187 °C (from dichloromethane–light petroleum) (Found: C, 43.4; H, 2.7. $C_{14}H_{10}Cl_4O_2S$ requires C, 43.77; H, 2.62%; δ 7.09 (1 H, s), 2.43 (3 H, s), 2.25 (3 H, s), and 2.00 (3 H, s); m/z 388/386/384/382 (13%/55/100 M^+ , 79, calc. for $C_{14}H_{10}^{35}Cl_4O_2S$), 355 (17), 353 (18), 351 (19), 349 (39), 347 (34), 334 (15), 332 (16), 167 (13), 165 (13), 154 (12), 153 (55), 152 (24), 140 (16), 139 (16), 138 (25), 137 (13), 126 (22), 125 (36), and 124 (19).

*Reaction of α,α' -(*o*-Phenylene)bis(trimethylphosphonium bromide) (20) with 4,7-Phenanthroline-5,6-dione (14): Preparation of Compounds (23) and (24).*—The reaction between the dione (14) (2.1 g, 10 mmol) and (20) (11.82 g, 15 mmol) with lithium hydroxide (5M; 50 ml) was carried out according to the general procedure described for the reactions of the salt (1). After 60 h the reaction mixture was poured into water (200 ml) and extracted with dichloromethane (2 \times 200 ml). A solid which appeared between the two phases was filtered off and added to the residue obtained by the concentration of the organic extract. This mixture was washed several times with ethanol and ether. The remaining insoluble solid (330 mg) and the precipitate (516 mg) which was obtained by the gradual concentration of the ethanol–ether extraction was compound (24), white crystals, m.p. 295–297 °C (from chloroform) (Found: C, 84.0; H, 5.4; N, 7.0. $C_{28}H_{22}N_2O$ requires C, 83.55; H, 5.51; N, 6.96%; λ_{max} , 239, 253, 279, 288, and 321 nm (log ϵ 4.44, 4.43, 4.25, 4.20, and 3.93); δ

9.20–8.63 (4 H, m), 7.75–6.93 (10 H, m), 6.27 (1 H, d, J 5 Hz), 5.45 (1 H, d, J 5 Hz), 2.53 (3 H, s), and 2.25 (3 H, s); m/z 402 (M^+ , 100%), 387 (7), 385 (9), 311 (89), 283 (11), 281 (18), 280 (24), 209 (8), 201 (9), and 91 (20). The rest of the ethanol–ether solution was then chromatographed on silica gel. Chloroform eluted two fractions. The first fraction was compound (24) (0.506 g, total yield 34%) while the second fraction gave yellow crystals of compound (23) (0.32 g, 11%), m.p. 233–234 °C (from chloroform–light petroleum) (lit.,¹ 233–234 °C).

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