A Really Convenient Synthesis of 2',3""-Dimethyl-p-sexiphenyl

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fluor with high stability and fast response time.

Abstract: Modern cross-couplings of arylmagnesium bromides with dibromoarenes gave 3,3"-dimethylquaterphenyl and, from its dibromination product, 2',3""-dimethyl-*p*-sexiphenyl (DMSP) in high yield with use of the air-stable PdCl₂•dppb in catalytic amount. Arylboronic acids need not be prepared as intermediates, and use of pyrophoric aryllithiums was avoided. DMSP is a useful scintillation

Key words: quaterphenyl, sexiphenyl, cross-coupling, palladium, scintillation, fluor

The title compound 2',3""-dimethyl-p-sexiphenyl (DM-SP) was initially prepared as an economical variant of 3,3',2''',3""-tetramethyl-p-sexiphenyl.^{1,2} These oligophenylenes have a very desirable combination of photophysical properties as secondary fluors or waveshifters for polystyrene-based scintillators. These properties include high fluorescence quantum yield (Φ_f) of ≥ 0.8 , very rapid response, that is, a scintillation decay time (τ_s) of ≈ 1 nsec, and excellent radiation resistance and photochemical stability. While the *fluorescence* decay time (τ_f) of a number of tetraarylbutadienes is as fast as 0.3 nsec vs. 0.7 nsec for DMSP, their *scintillation* decay times are slower: $\tau_s = 2 - \tau_s$ 4 nsec, and their radiation resistance and photochemical stability are much poorer.^{3,4} A number of 2,5-dialkyl-poligophenylenes reported recently in this journal⁵ have a substitution pattern that hypsochromically shifts their absorption and fluorescence wavelengths and lowers $\Phi_{\rm f}$.^{1,2,6} The otherwise superior fluors⁷ derived from the o,o'bridging of *p*-oligophenylenes (fluorenes) have longer fluorescence decay times; for example, in a series of unbridged, mono-bridged and di-bridged p-quaterphenyls, *p*-quaterphenyl had $\tau_f = 0.9$ nsec; 2,7-diphenyl-9,9-dipropylfluorene, $\tau_f = 1.4-1.7$ nsec; and 9,9,9',9'-tetrapropyl-2,2'-bifluorene, 1.0-1.3 nsec.³

DMSP (6) was first synthesized in 1969⁸ as shown in Scheme 1 in 4 steps with an overall yield of 10%. Conversion of 4-bromobenzyl bromide (1) to the phosphonate ester 2 was facile, as was the Emmons–Horner condensation with α -methylcinnamaldehyde (3) to the diene 4. The conversion of the diene to a benzene ring by a method originally developed by Lohaus in 1938 was improved to a one-pot sequence with water-miscible solvents, then water, to give the *p*-terphenyl 5. The major pitfall was that, for the oxidative homocoupling, the then newly-reported⁹ catalyst thallium(I) bromide had to be used stoichiometrically in the proportion of 2 moles to 1 mole of the Grignard reagent from the *p*-terphenyl 5. This raised the problem of disposal of metallic thallium and organothallium compounds. Moreover, the sexiphenyl was greenish in color, indicating the presence of diarylthallium bromide.



Scheme 1

A synthesis of DMSP was reported in this journal that circumvented the problems of thallium disposal,¹⁰ by using biphenyl as the source of the middle two rings; but proceeded in 5 steps (counting only isolated intermediates) in 0.8% overall yield. In addition, the final product was not purified, since it was reported as "pale yellow", and no mp was given.

The related *p*-oligophenylenes of Galda and Rehahn⁵ were dependent on Suzuki couplings of bromoarenes with arylboronic acids. The latter involve an additional synthetic step using the pyrophoric butyllithium. The palladium catalyst employed was tetrakis(triphenylphosphine)palladium(0), an expensive and unstable material.

A 3-step synthesis of DMSP in 26% overall yield (Scheme 2) is now reported with experimental details below. The catalyst used for unsymmetrical couplings of Grignard reagents with haloarenes, PdCl₂•dppb, can be prepared with under an hour of direct effort,¹¹ and is stable at ambient conditions for several years.





An excess of 3-bromotoluene (7) is converted to its Grignard reagent and coupled with 4,4'-dibromobiphenyl (8) to give 3,3'''-dimethylquaterphenyl (9) in 86% yield. This quaterphenyl was reported once before, in 5 steps from 4,4'-dihydroxybiphenyl in <10% yield.¹² Iron-catalyzed bromination gave the dibromoquaterphenyl **10** in 43% yield, showing a lack of regiospecificity. Another coupling, catalyzed by $PdCl_2 \cdot dppb$, that of excess phenylmagnesium bromide with **10**, gave white DMSP in 70% yield, which was homogeneous on TLC. Both the UV maximum wavelength and the epsilon fit the relationships worked out by Seliskar^{13,14} for *p*-oligophenylenes, supporting the structure. The ¹H NMR spectrum showed the expected ratio of 6 methyl protons to 24 aromatic protons. The 8 centermost aromatic protons were peculiarly deshielded to $\delta = 7.756$, just as reported by Galda and Rehahn.⁵

Magnesium was of 99.98% purity (Reade RMC-3, Magnesium Elektron, Inc.); THF was Rgt. Grade from G. J. Chem. Co., Inc., dried over 3Å molecular sieves. The following commercial reagents were used as received: neutral alumina Brockmann grade I (Aldrich), 4,4'-dibromobiphenyl (Aldrich), bromobenzene (Aldrich), bromine (Fluka) and 3-bromotoluene (Diaz Chem. Corp.). The Grignard reactions were carried out under argon. The PdCl₂•dppb was prepared according to Minato et al.¹⁵ Purifications on an "Ace-Kau" means a continuous chromatographic extraction with Ace Glass 5879.¹⁶

The ¹H NMR spectrum was recorded on a Varian XL300 NMR spectrometer, the UV spectrum (slit 1 nm) on a Shimadzu spectrometer and the fluorescence emission on a Farrand Mk. I apparatus (slits 2.5 nm). Elemental analyses were carried out by Oneida Res. Services.

3,3"'-Dimethyl-*p*-quaterphenyl (9)

To Mg (28.9 g, 1.19 mol) at 45 °C initially was added a portion (100 mL) of a solution of 3-bromotoluene (7; 203 g, 1.19 mol) in THF (1 L). When the exotherm subsided, the remainder was added rapidly at reflux, followed by 1 h at reflux. The Grignard solution was allowed to cool to 62 °C when the catalyst, PdCl₂.dppb (1.2 g, 0.0020 mol) was added in 1 portion. At 60 °C initially the 4,4'-dibromobiphenyl (100 g, 0.320 mol) was added in portions to keep the exothermic reaction under control, after which the suspension was allowed to cool during 40 min to 48 °C, at which time MeOH (25 mL) was added very carefully, causing an exotherm and reflux, followed by MeOH (500 mL). The mixture was stirred overnight at 20 °C, filtered, and washed with MeOH (500 mL). The damp solid was mechanically stirred with 1:1 MeOH/H2O (750 mL) for 10 min, filtered, the solid washed wih the same solvent (250 mL), and dried to give 174 g of bulky white solid, which was extracted from a 4 cm high column of Brockmann grade I neutral alumina in a large Ace-Kau with xylenes (1 L). A Dean-Stark trap (Ace Glass 7725) was employed to remove water from the condensate. The extract was cooled overnight to 0 °C, the product was filtered, washed with heptane (250 mL), and dried to give 92.4 g (86%) of 9; mp 211.5-214.5 °C (Lit.¹² mp 213 °C).

4,4'-Dibromo-3,3"'-dimethyl-p-quaterphenyl (10)

With mechanical stirring a mixture of iron powder (1 g), 1,2-dichloroethane (1.8 L) and 3,3""-dimethyl-*p*-quaterphenyl (9; 91.4 g, 0.273 mol) were heated to 63 °C to dissolve most of 9. To this mixture was added a solution of Br₂ (31.2 mL, 97.2 g, 0.608 mol) made to 100 mL with 1,2-dichloroethane during 1.5 h. The reaction rate increased as the iron reacted, the mixture became clear and the product separated as the mixture was stirred for 2 h at 65 ± 3 °C. The mixture was kept at 20 °C for 3 d. The product was filtered, washed with MeOH (500 mL) and dried to give 58.4 g (43%) of 10; mp 277–281 °C. Note that the product has the same density as the solvent; d = 1.31 g/mL.

Anal. C₂₆H₂₀Br₂ (492.3): Calcd C, 63.44; H, 4.10; Br, 32.46. Found C, 64.14; H, 4.15; Br, 32.43

2',3""-Dimethyl-p-sexiphenyl (6)

To Mg (9.27 g, 0.381 mol) was added a portion (60 mL) of a solution of bromobenzene (59.8 g, 0.381 mol) in THF (600 mL). When the exotherm subsided, the remainder was added rapidly at reflux, followed by 1 h at reflux. The Grignard solution was allowed to cool to 68 °C when the catalyst PdCl₂•dppb (0.78 g, 0.00127 mol) was added in one portion. The mixture was boiled to extract 4,4'-dibromo-3,3"'-dimethyl-p-quaterphenyl (10; 58.3 g, 0.127 mol) from a plain extractor with a glass frit into the reaction mixture overnight. The reactor was removed from the heating mantle, and at 60 °C initially, MeOH was added in 1 mL portions to destroy excess Grignard; the 7th mL caused no exotherm. Then 6 M HCl (25 mL) was added in portions below the reflux temperature of the reaction mixture, followed by MeOH (200 mL). At 30 °C the solid was filtered, washed with MeOH (300 mL) and dried to give 46.7 g of crude 6; mp 255-260 °C (phase-change), 355-360 °C. This solid was extracted from a 4 cm high column of Brockmann grade I basic alumina in a large Ace-Kau with 3-chlorotoluene (500 mL) for a few h. The extract was allowed to cool to 20 °C, filtered, washed with toluene (100 mL) and dried to give 44.2 g, which was recrystallized from sulfolane (185 mL) at 230 °C, cooled only to 80 °C, filtered, washed with propan-2-ol (500 mL), and dried to give 43.5 g (70%) of shiny white plates, mp 259-260 °C (phase-change, Lit.17 260.3 °C), 362–365 °C (Lit.¹⁰ >320 °C). The solubility was ≈80 mg/L of toluene at 20 °C. A TLC of this solution on Analtech Alumina GF (eluent: benzene, short- and long-wave UV) gave a single round spot with violet fluorescence; R_f 0.90.

¹H NMR (CDCl₃, TMS): δ = 2.38 (s, 6 H, CH₃), 7.35 (d, 2 H, H-6',6'''', $J_{ortho} = 7.7$ Hz), 7.34–7.48 (m, 10 H, H 2-6,2''''-6''''), 7.55 (dd, 2 H, H 5',6''', $J_{ortho} = 7.7$, $J_{meta} = 2.0$ Hz), 7.58 (d, 2 H, H 3',2''', $J_{meta} = 2.0$ Hz), 7.75 (br s, 8 H, H 2'',3'',5''',6''',2''',3''',5''',6''').

UV (1.33x10⁻⁵ M in toluene): $\lambda_{max} = 311$ nm ($\epsilon = 61\ 000$).

Fluorescence Emission (corrected, 1.33×10^{-1} M in toluene): $\lambda_{max} = 375$ and 390 nm (equal intensity).

Anal. C₃₈H₃₀ (486.7): Calcd C, 93.79; H, 6.21. Found C, 93.43; H, 6.22.

The product of a later run had mp 264–266 $^{\circ}$ C (phase-change), 364–368 $^{\circ}$ C. (Anal. Found. C, 94.19; H, 5.91).

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References

- Berlman, I. B.; Wirth, H. O.; Steingraber, O. J. J. Phys. Chem. 1971, 75, 318.
- (2) Berlman, I. B. J. Phys. Chem. 1973, 77, 562.
- (3) Fluornoy, J. M. Radiat. Phys. Chem. 1988, 32, 265; Int. J. Radiat. Appl. Instrum. Part C, and unpublished data of 1989.
- (4) Moser, S. W., Bicron, Newbury, OH, USA, private commun., 7 Aug 98.
- (5) Galda, P.; Rehahn, M. Synthesis 1996, 614.
- (6) Zapka, W.; Brackmann, U., Appl. Phys. 1979, 20, 283.
- (7) Wunderly, S. W.; Kauffman, J. M. Appl. Radiat. Isotopes 1990, 41, 809.
- (8) Kauffman, J. M., Pilot Chemicals Div., New England Nuclear Corp., Watertown, MA, USA, previously unpublished data.
- (9) McKillop, A.; Elsom, L. F.,; Taylor, E. C. J. Am. Chem. Soc. 1968, 90, 2423.
- (10) Subramaniam, G.; Gilpin, R. K. Synthesis 1992,1232.
- (11) Kelley, C. J.; Ghiorghis, A.; Kauffman, J. M. J. Chem. Res. (S) 1997, 446; J. Chem. Res. (M) 1997, 2701.
- (12) Kern, W.; Ebersbach, H. W.; Ziegler, I. *Makromol. Chem.* **1959**, *29*, 154.
- (13) Seliskar, C. J.; Landis, D. A.; Kauffman, J. M.; Aziz, M. A.; Steppel, R. N.; Kelley, C. J.; Qin, Y.; Ghiorghis, A. *Laser Chem.* **1993**, *13*, 19.
- (14) Kauffman, J. M.; Litak, P. T.; Novinski, J. A.; Kelley, C. J.; Ghiorghis, A.; Qin, Y. J. Fluorescence **1995**, *5*, 295.
- (15) Minato, A.; Tamao, K.; Hayashi, T.; Suzuki, K.; Kumada, M. *Tetrahedron Lett.* **1981**, *22*, 5319.
- (16) Kauffman, J. M.; Bjorkman, C. O. J. Chem. Ed. 1976, 53, 33.
- (17) Subramaniam, G.; Gilpin, R. K. Mol. Cryst. Liq. Cryst. 1989, 166, 173.

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