

A Convenient Synthesis of 9,10-Bis(3-methylphenyl)anthracene on a Kilo-Lab Scale

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Abstract: Cross-coupling of 9,10-dihaloanthracene with arylmagnesium halides gave polymers when catalyzed by PdCl₂•dppb, but the expected 9,10-diarylanthracene was obtained using NiCl₂•dppp as the catalyst. The latter procedure was developed into a large-scale preparation of 9,10-dichloroanthracene.

Key words: diarylanthracene, cross-coupling, chlorination, palladium, nickel

Of interest as a scintillation fluor¹ and standard for fluorescence quantum yield,^{1–3} 9,10-diphenylanthracene (DPA) was not sufficiently soluble in aromatic solvents for a certain purpose, and was too difficult to purify on a kilo-lab scale, so a more soluble derivative which can be easily purified with similar photophysical properties was sought.

DPA was first prepared in 1906 by the action of phenylmagnesium bromide on anthraquinone to give the intermediate diols (*cis* and *trans*) in 10% yield, followed by reductive dehydration with potassium iodide and acetic acid. This diol formation was improved to 34% yield in 1926, and either the diols or the corresponding dichlorides could be converted to DPA in unspecified yield by means of zinc dust and acetic acid.⁴ By 1942 the yield of diols was improved to 63% by use of phenyllithium derived from bromobenzene; their subsequent conversion to DPA was achieved using potassium iodide and acetic acid (yield not specified).⁵

One approach to increase the solubility was the incorporation of an ethyl group onto anthracene in the 2-position. Phenyllithium and 2-ethylanthraquinone gave the *trans*-diol in 40% yield. The dehydration was carried out on a small scale over palladized asbestos catalyst at 550 °C in the vapor state to give the more soluble 2-ethyl-9,10-diphenylanthracene in 85% yield.⁶ In this laboratory no crystalline diol could be obtained.

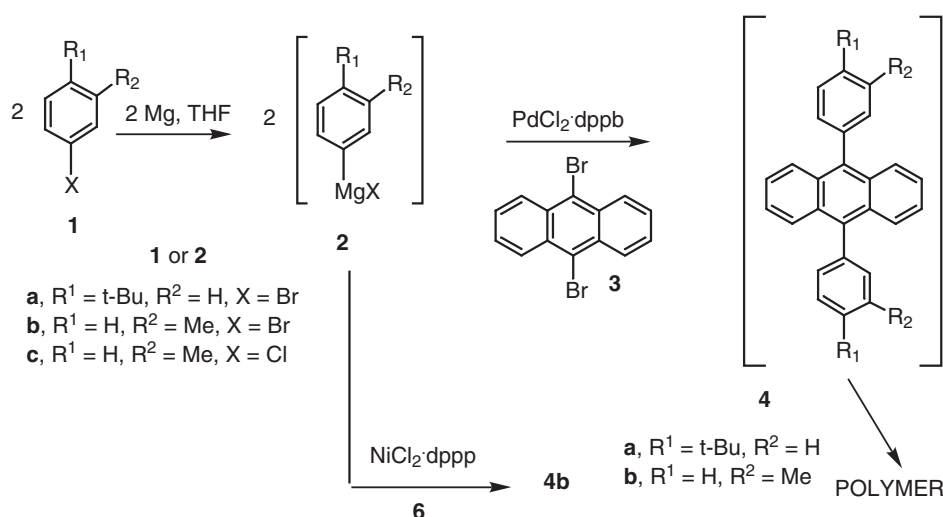
At this point it was thought that a transition metal-catalyzed unsymmetrical biaryl coupling (also known as cross-coupling) between 4-*tert*-butylphenylmagnesium bromide (**2a**) and 9,10-dibromoanthracene (**3**) would give a soluble homolog of DPA (**4a**) (Scheme 1). The catalyst used with success in this laboratory for a wide variety of couplings,^{7,8} [1,4-bis(diphenylphosphino)butane]dichloropalladium (PdCl₂•dppb), gave the desired coupling, as shown by the characteristic blue fluorescence of DPA, but immediately caused polymerization to a non-fluorescent polymer. On the supposition that the *t*-butyl group was

somehow responsible, the reaction was repeated using 3-methylphenylmagnesium bromide (**2b**); however, polymerization was observed again.

A related transition-metal catalyst, [1,4-bis(diphenylphosphino)propane]dichloronickel (NiCl₂•dppp), had been reported⁹ to give the best yield among several nickel-based catalysts in a related coupling. When we attempted the coupling between 3-methylphenylmagnesium bromide (**2b**) and 9,10-dichloroanthracene (**6**) using NiCl₂•dppp as the catalyst, 9,10-bis(3-methylphenyl)anthracene (**4b**) was obtained in 58–69% yield (range of 9 runs on a 1 molar scale) (Scheme 1). Attempts to use mixtures of 3-bromotoluene (**1b**) with the less expensive 3-chlorotoluene (**1c**) to prepare the mixed Grignard **2** were not successful. For example, on a 0.1 molar scale the use of 10 mol% 3-bromotoluene gave 47–55% yield, but on a 1–1.5 molar scale the use of 50 mol% 3-bromotoluene gave only 36–38% of **4b**. After the coupling, the reaction mixture in tetrahydrofuran was quenched in methanol rather than in water, both to give a more easily-filterable product, and to give a combustible filtrate that is easy to dispose of. Once dried, **4b** was then continuously extracted from acidic alumina in an extra large Ace-Kauffman column with boiling heptane, which could be recovered by distillation. A final recrystallization from 2-ethoxyethanol afforded pure product, and the solvent could be recovered by distillation.

The structure of **4b** was confirmed by the superimposability of the ultraviolet spectrum on that of DPA^{1,3} (for example, a peak at 373 nm, ε = 16,000 vs 373 nm, ε = 14,000 for DPA) and consideration of the 300 MHz ¹H NMR spectrum vs Sadtler Spectrum 16111 M for DPA.

Since the formation of **4a** or **4b** from 9,10-dibromoanthracene (**3**) was confirmed by their powerful fluorescences, and polymerization occurred subsequently, the change from bromo in **3** to chloro in **6** was thought unimportant in preventing polymerization. Unfortunately, the cost of **3** was too high for our project, and its standard preparation is more involved than might be thought. Moreover, the solvent choices of carbon tetrachloride or carbon disulfide make its synthesis all the more undesirable.¹⁰ Then the cost of **6** from Lancaster Synthesis unexpectedly increased during this project. The syntheses of **6** in the literature included the reaction of phosphorus pentachloride with 9-chloroanthracene in benzene, and the action of chlorine on **5** in hot *o*-dichlorobenzene. When chlorine reacts with **5** in carbon disulfide at 0–15 °C, a



Scheme 1

mixture of **6** and addition products is obtained, which must be decomposed and treated with more chlorine. The most recent well-described synthesis on a reasonable scale involved the use of sulfur monochloride on **5** in refluxing 1,2,4-trichlorobenzene to give 60% of impure **6**, with a melting point of 210 °C.¹¹

However, a preparation of **6** was reported by Maruyama et al. by reaction of **5** with anhydrous copper(II) chloride in hot chlorobenzene on a 1 mmol scale in 87% yield.¹² This process appeared amenable to development. The solvent was changed to the less toxic and odorous 3-chlorotoluene (**1c**), which, due to its higher boiling point, allowed a fast reaction and workup, e.g. filtration when hot, since **6** is very soluble in hot 3-chlorotoluene. The 3-chlorotoluene recovered from filtration of the crude **6** was used in the next run. The yield of **6** with mp 210–212.5 °C, was 86–97% (range of 10 runs on a 1.1 molar scale) (Scheme 2). The byproduct copper(I) chloride could be oxidized back to copper(II) chloride with hydrogen peroxide and dilute hydrochloric acid in a preliminary experiment, and thus it too was potentially recyclable.

Since a wide variety of polycyclic aromatic compounds may be chlorinated in this manner,^{12,13} many of their aryl and very possibly alkyl⁷ derivatives not otherwise accessible may be easily and safely synthesized by means of this method.

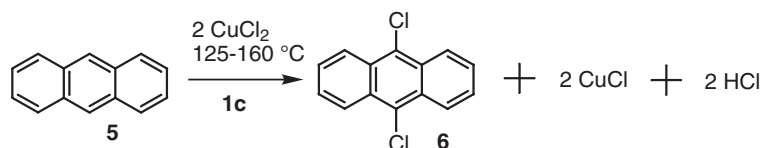
The excellent paper by Wagner et al., which appeared after this work was completed, utilized palladium(II) acetate

for related couplings of aryl Grignard reagents with 9,10-dibromoanthracene in equally good yields, and no polymerization was observed; but the products were yellow and would not have been suitable for use as scintillation fluors.¹⁴

Mg used was of 99.98% purity (Reade RMC-3, Magnesium Electron, Inc.); THF was reagent Grade from G. J. Chem. Co., Inc., dried over 3Å Mol Sieves. The Grignard reactions were carried out under argon. The PdCl₂·dppb was prepared according to Minato et al.¹⁵ and the NiCl₂·dppp was obtained from Aldrich. The 98% pure 3-chlorotoluene was procured from Lancaster and the 3-bromotoluene of 97.5% purity was purchased from Diaz Chem. Corp. of Holley, NY, USA. Purification on an "Ace-Kau" means a continuous chromatographic extraction with Ace Glass 5879,¹⁶ an Ace-Kauffman column. Anthracene was purchased from Lancaster, a gray product with no quinone content. Anhyd CuCl₂ chloride could be purchased, but it was more economical to dehydrate the dihydrate at 85 °C/25 Torr for 2 days. The alumina used was the acidic, Brockmann I, 95% from Aldrich. The elemental assays were carried out by Micro-Analysis of Wilmington, DE, USA.

9,10-Dichloroanthracene (**6**)

A 5-L 4-necked flask placed in a heating mantle was fitted with a mechanical stirrer, a combination thermometer and gas inlet adapter, an Allihn condenser of 400 mm working length fitted at the top with a gas outlet adapter leading to a hydrogen halide scrubber, and a straight adapter of 200 mm length on top of which was a funnel (with an ST29/42 joint) covered with a watch glass. Maximum vol-tage was applied to the mantle while 3-chlorotoluene (**1c**; 1350 mL of first filtrate from a previous run, and 1400 mL of redistilled), and anthracene (**5**; 196 g, 1.10 mol) were added. When the



Scheme 2

temperature of the solution had reached 130 ± 5 °C, the voltage was reduced to 2/3 maximum, and CuCl_2 (650 g, 4.83 mol) was added in about 50-g portions during about 20 min at 125 ± 5 °C. The reaction was endothermic and HCl evolved with foaming. Gray CuCl separated. More voltage was applied to the mantle to obtain a brisk reflux for 1 h, then the voltage was lowered. When the suspension had cooled to 125 ± 5 °C without stirring, it was filtered by decantation on a porcelain Büchner funnel with 15-cm Whatman #54 paper, which was pre-warmed by pouring about 100 mL of hot 3-chlorotoluene on it under 100 Torr pressure. Another 400 mL of hot 3-chlorotoluene was used to rinse the CuCl in the flask and the material on the funnel. The hot filtrate was transferred to a 6-L beaker covered with a watch glass and aluminum foil, and allowed to cool to r.t. Then it was placed in a -20 ± 10 °C freezer overnight. The product was filtered on 18.5 cm Whatman #54 paper in a porcelain Büchner. This first filtrate was removed for re-use or redistillation. The yellow solid was washed with 95% EtOH (500 mL) and dried at 85 °C/25 Torr for 16 h; yield: 233–263 g (86–97%); yellow needles; mp 210.5–212.5 °C (Lit.¹² mp 210 °C). It is a delayed-action (4–6 h) lachrymator and should be handled in a fume hood.

9,10-Di-*m*-tolylanthracene (4b)

A 5-L 4-necked flask placed in a heating mantle was fitted with a mechanical stirrer, a combination thermometer and gas inlet adapter, a quadruple-surface condenser of 500 mm working length fitted at the top with a gas outlet adapter leading to a fume hood inlet, and a straight adapter of 200 mm length on top of which was a funnel with an ST29/42 joint covered with a watch glass. Mg (73.0 g, 3.00 mol) was added, argon flow was started, and 40% of maximum voltage was applied to the mantle. The straight adapter and funnel were replaced with a 1-L addition funnel. When the temperature of the flask had reached 60 ± 10 °C, 100–200 mL of a solution of 3-bromotoluene (**1b**; 513 g, 354 mL, 3.00 mol) in THF (3 L) was added. The Grignard reaction usually started with some violence. The rest of the 3-bromotoluene in THF was added in a thin stream at a rate to maintain rapid reflux, usually for 1 h. Some heat was needed to maintain reflux toward the end, and reflux was then maintained by heating for 2 h. The addition funnel was replaced with a straight adapter and funnel. The mixture was allowed to cool to 60 ± 2 °C whereupon the catalyst $\text{NiCl}_2 \cdot \text{dppp}$ (2.0 g) was added through the straight adapter, cautiously at first. When any mild exotherm had subsided within a few minutes, 9,10-dichloroanthracene (**6**; 247 g, 1.00 mol) was added in portions as fast as the violent reaction allowed: ≈ 45 min. The black liquid was then allowed to cool to 50 ± 5 °C; then MeOH (50 mL) was added, very cautiously at first. An exotherm to 60 °C was a good indicator that excess Grignard reagent was present, as desired. The hot liquid mixture was then poured into MeOH (6 L) in a 12-L pail with mechanical stirring. Crude **4b** usually crystallized at once. After 10–30 min of stirring, the pail was covered and kept at -2 °C overnight. The crude was filtered on a 24 cm Büchner using polyethylene filter cloth,¹⁷ washed with 95% EtOH (500 mL), and slurried with H_2O (2 L) and 12 M HCl (90 mL) for 10–30 min, filtered on the same cloth, washed with minimum H_2O , and dried at 85 °C/25 Torr for 16 h. The dry **4b** (≈ 252 g) was loaded onto a 10-cm-high column of alumina sandwiched between 1 cm layers of sand in a side-arm extractor of 6 cm inside diameter and 60 cm working length.¹⁸ Continuous extraction was carried out with heptane (3.5 L) in a tared 5-L flask overnight. The extract was kept at -2 °C overnight. The heptane was decanted and the flask with **4b** was dried at 85 °C/25 Torr for 5 h. The yellow **4b** was recrystallized from 10 mL/g of 2-ethoxyethanol, usually 2.2 L, with transfer of the hot clear solution to a 6-L beaker, and kept at

r.t. overnight. The white **4b** was filtered on an 18.5 cm Büchner on Whatman #54 paper, and the filtrate removed for recycling. The product was washed with 95% EtOH (500 mL) and dried at 85 °C/25 Torr for 16 h; yield: 227 g (63%); mp 220–222.5 °C. The product was stored in an opaque container since it is slightly light-sensitive.

¹H NMR (CDCl_3/TMS): $\delta = 2.48$ (s, 6 H, CH_3), 7.24–7.37 [high-order m, 10 H, H-2,3,5,8, and $2 \times$ (H-2',4',6')], 7.46–7.51 (overlapped dd, 2 H, $2 \times$ H-5'), 7.68–7.74 (AA'BB' system, 4 H, H-1,4,6,7).

UV (5.7×10^{-5} M in toluene): $\lambda_{\text{max}} = 339$ nm ($\epsilon = 4200$), 355 (9600), 373 (16000), 393 (15100).

Anal. calcd for $\text{C}_{28}\text{H}_{22}$ (358.5): C, 93.81; H, 6.19. Found C, 93.75; H, 6.40.

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References

- (1) Berlmán, I. B. *Handbook of Fluorescence Spectra of Aromatic Molecules*, 2nd ed., Academic Press: New York, 1971.
- (2) Morris, J. V.; Mahaney, M. A.; Huber, J. R. *J. Phys. Chem.* **1976**, *80*, 969.
- (3) Hamal, S.; Hirayama, F. *J. Phys. Chem.* **1983**, *87*, 83.
- (4) Ingold, C. K.; Marshall, P. G. *J. Chem. Soc.* **1926**, 3080.
- (5) Willemart, A. *Bull. Soc. Chim. Fr.* **1942**, *9*, 83.
- (6) Étienne, A.; Arditti, G.; Chmelevsky, A. *Bull. Soc. Chim. Fr.* **1965**, 669.
- (7) Kelley, C. J.; Ghiorghis, A.; Kauffman, J. M. *J. Chem. Res. (S)* **1999**, *80*; (M), 401.
- (8) Kauffman, J. M. *Synthesis* **1999**, 918.
- (9) Rehn, R.; Schlüter, A.-D.; Feast, W. J. *Synthesis* **1988**, 386.
- (10) Heilbron, I. M.; Heaton, J. S. *Org. Syn. Coll. Vol. I, 2nd ed.* **1941**, 207.
- (11) Aryan, Z. S.; Wiles, L. A. *J. Chem. Soc.* **1962**, 1725.
- (12) Tanimoto, I.; Kushioka, K.; Kitagawa, T.; Maruyama, K. *Bull. Chem. Soc. Jpn* **1979**, *52*, 3586.
- (13) Jay, K.; Stieglitz, L. *Chemosphere* **1991**, *22*, 987.
- (14) Wagner, G.; Herrmann, R.; Scherer, W. *J. Organomet. Chem.* **1996**, *516*, 225.
- (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. Educ.* **1976**, *53*, 33.
- (17) A gift from National Filter Media, P. O. Box 156, 691 North 400 West, Salt Lake City, UT, 84110, USA; style 192 058 03.
- (18) Custom-made by Tom Cachaza, The Glassblowers, Turnersville, NJ, 08112, USA.

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