Synthesis of Unsymmetrical Polychlorinated Biphenyls

Louis A. Levy

Department of Health, Education & Welfare,
National Institutes of Health,
National Institute of Environmental Health Sciences,
P.O. Box 12233, Research Triangle Park, North Carolina 27709, U.S.A.

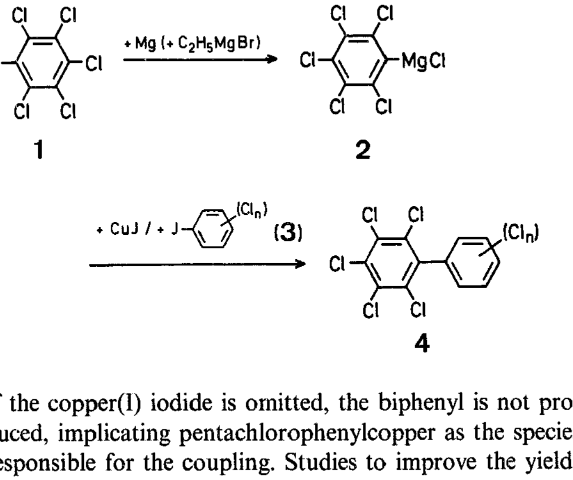
Polychlorinated biphenyls, of interest since the discovery of their widespread occurrence in the environment[1], have for the most part been prepared by the Ullmann or Gomberg reaction[2]. However, except for the simplest examples, these reactions are not satisfactory for the synthesis of unique isomers with different substituents in the two rings.

Recent work on the mechanism of the Ullmann synthesis[3] suggested the possibility of conducting this reaction in two distinct steps: the first step being the preparation of the presumed organocopper intermediate which is then coupled with an appropriate aromatic iodide to yield the desired biphenyl.

$$Ar^1Cu + Ar^2J \longrightarrow Ar^1{-}Ar^2$$

Aromatic copper species are strongly stabilized by electronegative substituents[4]. Pentachlorophenylcopper[5], easily prepared from the corresponding Grignard compound, was selected as a model to test the feasibility of this approach to the synthesis of unsymmetrically substituted polychlorinated biphenyls.

Although the literature reports the synthesis of pentachlorophenylmagnesium chloride[6] (**2**) by the very slow addition of hexachlorobenzene to magnesium with or without an equivalent of ethylene bromide as an entrainment agent, depending upon the solvent, it was found that this Grignard (**2**) reagent could be prepared directly from hexachlorobenzene (**1**) and magnesium if the reaction were initiated by a small amount of ethylmagnesium bromide. Addition to this Grignard compound of one equivalent each of copper(I) iodide and iodobenzene or any one of several chlorinated iodobenzenes (**3**), and subsequent refluxing of the resultant mixture for several hours yielded, after work-up, moderate yields (20 to 50%) of the respective isomeric chlorinated biphenyls (**4**)[7].



If the copper(I) iodide is omitted, the biphenyl is not produced, implicating pentachlorophenylcopper as the species responsible for the coupling. Studies to improve the yields and extend this technique to other polychlorinated biphenyls are in progress.

Melting points were taken on a Fisher-John apparatus and are uncorrected. I.R. spectra were determined in KBr pellets using a model 621 Perkin Elmer spectrometer. Microanalyses were performed by Galbraith Laboratories, Inc. Molecular weights were determined mass spectrometrically using a Finnigan model 1015 instrument.

2,3,4,5,6-Pentachlorobiphenyl:

In a thoroughly dried 100 ml three-necked flask equipped with a paddle-type stirrer and reflux condenser were placed magnesium turnings (1.2 g), hexachlorobenzene (3.5 g), and dry tetrahydrofuran (30 ml). The stirrer was started and a few drops of ethylmagnesium bromide (ether) were added to the mixture. The mixture was warmed with the hot air from a heat gun until the reaction started, as evidenced by the darkening of the reaction mixture and the maintenance of reflux without any external heating. Additional hexachlorobenzene (10.5 g, total = 0.05 mol) was added in portions so as to maintain a gentle reflux. The reaction mixture was allowed to cool to room temperature and then was further cooled with an ice bath. To the cool mixture, copper(I) iodide (9.6 g, 0.05 mol) was added and the resultant mixture was stirred at 0° for 1 hr. Addition of iodobenzene (10.2 g, 0.65 mol) and refluxing the mixture for 4 hr resulted in a black heterogeneous mixture. The cool mixture was filtered and the residue extracted several times with a total volume of 200 ml of hot benzene. The combined organic solutions were reduced in volume to 50 ml and chromatographed on a short alumina column. The product was eluted with benzene; yield 7.5 g (46%); tan crystals, m.p. 108–115°. Chromatography of a portion of this material on alumina yielded upon elution with hexane colorless crystals, m.p. 123–124° (Ref.[2], m.p. 124–125°).

$C_6H_{12}Cl_5$	calc.	C 44.15	H 1.54	Cl 54.31
	found	44.30	1.67	54.28

Mol. wt.: $C_{12}H_5{}^{35}Cl_4{}^{37}Cl$	calc.	326
	found	326

I.R. (KBr): $\nu_{max} = 1440$, 1380, 1365, 1340, 1320, 1260, 1150, 1145, 1065, 865, 770, 720, 695, 685 cm^{-1}.

2,3,4,5,6,2′-Hexachlorobiphenyl:
From 2-chloroiodobenzene; yield: 23%; m.p. 134–137° (ethanol).

$C_{12}H_4Cl_6$	calc.	C 39.93	H 1.12	Cl 58.95
	found	39.87	1.12	58.72

Mol. wt.: $C_{12}H_4{}^{35}Cl_5{}^{37}Cl$	calc.	360
	found	360

I.R. (KBr): $\nu_{max} = 1470$, 1430, 1380, 1360, 1345, 1320, 1280, 1245, 1120, 1080, 1040, 1030, 870, 860, 765, 735, 725, 680, 675 cm^{-1}.

2,3,4,5,6,3′-Hexachlorobiphenyl:
From 3-chloroiodobenzene; yield: 24%; m.p. 97–100° (ethanol).

$C_{12}H_4Cl_6$	calc.	C 39.93	H 1.12	Cl 58.95
	found	40.14	1.21	58.77

Mol. wt.: $C_{12}H_4{}^{35}Cl_5{}^{37}Cl$	calc.	360
	found	360

2,3,4,5,6,4′-Hexachlorobiphenyl:
From 4-chloroiodobenzene; yield: 17%; m.p. 160–165° (hexane).

$C_{12}H_4Cl_6$	calc.	C 39.93	H 1.12	Cl 58.95
	found	39.70	1.20	59.15

Mol. wt.: $C_{12}H_4{}^{35}Cl_5{}^{37}Cl$	calc.	360
	found	360

I.R. (KBr): $\nu_{max} = 1485$, 1475, 1390, 1380, 1370, 1340, 1315, 1290, 1260, 1250, 1100, 1080, 1065, 1010, 830, 745, 730, 670 cm^{-1}.

I.R. (KBr) ν_{max}: 1595, 1585, 1555, 1470, 1415, 1400, 1375, 1340, 1320, 1295, 1260, 1045, 1080, 995, 895, 880, 790, 770, 720, 675.

2,3,4,5,6,3′,4′-Heptachlorobiphenyl:
From 3,4-dichloroiodobenzene; yield: 42%; m.p. 116–118° (ethanol).

$C_{12}H_3Cl_7$	calc.	C 36.46	H 0.76	Cl 62.78
	found	36.76	0.79	62.50

Mol. wt.: $C_{12}H_3{}^{35}Cl_6{}^{37}Cl$	calc.	394
	found	394

I.R. (KBr): ν_{max} 1550, 1470, 1380, 1370, 1360, 1340, 1320, 1130, 1070, 1030, 900, 890, 825, 790, 735, 725, 685, 675 cm^{-1}.

Received: December 20, 1972

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[1] L. Fishbein, *Chromatographic Reviews* **68**, 345 (1972).

[2] O. Hutzinger, S. Safe, V. Zitko, *Bull. Environ. Contam. Tox.* **6**, 209 (1971).

[3] A. H. Lewin, T. Cohen, *Tetrahedron Lett.* **1965**, 4531.

[4] A. Cairncross, W. A. Sheppard, *J. Amer. Chem. Soc.* **90**, 7186 (1968).

[5] A. E. Jukes, S. S. Dua, H. Gilman, *J. Organomet. Chem.* **21**, 241 (1970).

[6] H. E. Ramsden, A. E. Balent, W. R. Whitford, J. J. Wellburn, R. Cserr, *J. Org. Chem.* **22**, 1202 (1957).
D. E. Pearson, D. Cowan, J. D. Bechler, *J. Org. Chem.* **24**, 504 (1959).

[7] Similar reactions of pentafluorophenylcopper with aryl halides have been described by R. J. de Pasquale, C. Tamborski, *J. Org. Chem.* **34**, 1736 (1969).