April, 1983] © *1983 The Chemical Society of Japan* *Bull. Chem. Soc. Jpn.,* ***56****, 1113—1115 (1983)* 1113

The Reductive Coupling of Organic Halide Using Hydrazine and a Palladium Amalgam Catalyst. II.[1] Homocoupling of Haloarene with Arylhydrazine

Riichiro NAKAJIMA,* Masaji KINOSADA,† Takashi TAMURA, and Tadashi HARA
Department of Chemical Engineering, Faculty of Engineering, Doshisha University,
Karasuma Imadegawa Kamikyo-ku, Kyoto 602

(Received July 28, 1982)

The function of palladium chloride in the reaction of an arylhydrazine with a haloarene was found to differ from those of other metal salts; palladium chloride was reduced with arylhydrazine, and the palladium metal produced was again oxidized with haloarene to give palladium halide. Thus the reductive coupling of haloarene occurred in the presence of a catalytic amount of palladium chloride. Addition of mercury(II) chloride promoted this reaction. The reaction of *o*-, *m*-, and *p*-bromotoluene with the corresponding tolylhydrazine gave the corresponding bitolyl in 99, 112, and 115% yield, respectively, based on the haloarene.

Monoarylhydrazines are readily oxidized like hydrazine itself by a variety of reagents, the products varying with the oxidant used. For example, when oxidation is effected by either silver(I) oxide, mercury(II) oxide,[2] or lead(IV) acetate[3] in aromatic solvents, an arylhydrazine is converted smoothly into the corresponding biaryl; bromo- or chlorobenzene reacted with phenylhydrazine to give bromo- or chlorobiphenyls without displacement of halogen. On the other hand, Bacon *et al.*[4] have observed catalytic effects of small amounts of phenylhydrazine on the coupling of bromo- or iodonitroarene with copper(I) oxide, but details are not clear. The present study has, therefore, been carried out in order to examine the reaction of haloarene with arylhydrazine in the presence of a palladium catalyst because in the latter case phenylhydrazine is anticipated to play the role of hydrazine in the Busch reaction. The reductive homocoupling of both iodo- and bromoarenes occurs in the presence of a palladium amalgam catalyst and arylhydrazines to give the corresponding halogen-free biaryls in good yield.

Results and Discussion

As Table 1 shows, when halobenzene (25.0 mmol) was treated with phenylhydrazine (10.0 mmol) in the presence of a catalytic amount (2 mol%) of palladium prepared *in situ* from palladium chloride in refluxing methanol for 6 h, the reductive coupling of bromo- or iodobenzene with phenylhydrazine occurred to give biphenyl. In contrast to the behavior of chlorobenzene, no phenylation of bromo- or iodobenzene occurred. This coupling was promoted by addition of mercury(II) chloride.

TABLE 1. COUPLING OF HALOBENZENE WITH PHENYLHYDRAZINE BY THE USE OF PALLADIUM METAL OR A PALLADIUM AMALGAM

Halobenzene	Yield of biphenyl/%[a]	
	Pd	Pd–Hg
Chlorobenzene	11.7[b]	7.8[b]
Bromobenzene	61.8	96.6
Iodobenzene	62.2	105.7

a) Based on halobenzene used. b) Traces of chlorobiphenyls were also formed.

It has long been known that the formation of biphenyl arises not only by oxidation of phenylhydrazine with metal oxides, metal acetates, *etc.*, but also by reductive coupling of halobenzenes with metals. To determine the source of the biphenyl, one of the aromatic rings in Eq. 1 was labeled with a substituent to distinguish it from the other.

$$ArX + ArNHNH_2 \xrightarrow{\text{Pd or Pd-Hg}} ArAr,\ \textit{etc.} \qquad (1)$$

The aryl group in the biaryls was derived mostly from the haloarene, independent of the presence of substituent, as listed in Table 2. When a palladium amalgam catalyst was used, about 75% of *p*-halotoluene was converted to 4,4′-dimethylbiphenyl, the remainder being consumed in the reaction with phenylhydrazine to give 4-methylbiphenyl and toluene. However, the homocoupling of *p*-bromotoluene was scarcely observed in the absence of a palladium catalyst and a large portion of bromotoluene was recovered. These results clearly indicate that the formation of the biaryl occurs mostly by the reductive coupling of haloarene, *i.e.*, Eq. 2.

$$2ArX + Pd \longrightarrow ArAr + PdX_2 \qquad (2)$$

Evidently the palladium(II) halide formed *in situ*, as described in Eq. 2, was also reduced with arylhydrazine, because both the palladium(II) salt and the mercury(II) salt used were recovered as the metals. It is known that the oxidation of phenylhydrazine with metal oxide in halobenzene yields benzene, biphenyl, azobenzene, and halobiphenyls, and the formation of these compounds can be explained in terms of a radical mechanism.[3,4] However, in the present system no halobiphenyls were obtained and one of the biphenyls isolated was formed by the displacement of halogen with the aryl group derived from arylhydrazine. These results can be best explained by the mechanism *via* arylhydrazine–palladium halide complex[5] (Eq. 3).

$$2NH_2NHPh + PdX_2 \longrightarrow PdX_2(NH_2NHPh)_2 \xrightarrow{-2HX\ -2H^+}$$

$$[Pd(NH{=}NPh)_2] \begin{cases} \longrightarrow 2PhH(\text{and/or } Ph_2+H_2)+2N_2+Pd \\ \longrightarrow 2NH{=}NPh+Pd \\ \xrightarrow{+2ArX} 2ArPh+2HX+2N_2+Pd \end{cases} \qquad (3)$$

---

† Present address: Toyo Kasei Kogyo Co. Ltd., 2900, Sonecho Takasago 676.

Table 2. Reaction of haloarene with arylhydrazine

ArX (12.5 mmol)	**Ar**NHNH$_2$ (12.5 mmol)	Catalyst (0.5 mmol)	Biaryls(mmol)		
			Ar$_2$	Ar**Ar**	**Ar**$_2$
p-Bromotoluene[a)]	Phenylhydrazine	None	0.10		0.48
p-Bromotoluene	Phenylhydrazine	Pd	1.69	1.11	0.63
p-Bromotoluene	Phenylhydrazine	Pd–Hg	4.75	1.51	0.79
Bromobenzene	*p*-Tolylhydrazine hydrochloride	Pd–Hg	2.56	1.03	0.04
p-Iodotoluene	Phenylhydrazine	Pd	2.73	0.73	0.17
Iodobenzene	*p*-Tolylhydrazine hydrochloride	Pd	3.43	1.89	0.41
p-Iodotoluene	Phenylhydrazine	Pd–Hg	4.83	1.64	0.75

a) A large portion of bromotoluene was recovered.

Table 3. Homocoupling of organic bromide with arylhydrazine in the presence of a palladium amalgam catalyst

Organic bromide	Arylhydrazine	Coupling products and yield/%[a)]
o-Bromotoluene	*o*-Tolylhydrazine hydrochloride	2,2'Dimethylbiphenyl/99[b)]
m-Bromotoluene	*m*-Tolylhydrazine hydrochloride	3,3'-Dimethylbiphenyl/112[b)]
p-Bromotoluene	*p*-Tolylhydrazine hydrochloride	4,4'-Dimethylbiphenyl/115[b)]
4-Bromo-*o*-xylene	3,4-Xylylhydrazine hydrochloride	3,3'4,4'-Tetramethylbiphenyl/88.4
1-Bromonaphthalene	Phenylhydrazine	1,1'-Binaphthyl/50.2 1-Phenylnaphthalene[c)] Biphenyl/6.4
2-Bromonaphthalene	Phenylhydrazine	2,2'-Binaphthyl/71.2 2-Phenylnaphthalene/4.7 Biphenyl/5.4
2-Bromopyridine	Phenylhydrazine	2,2'Bipyridyl/42[b)] 2-Phenylpyridine/0.6 Biphenyl/1.8
2-Bromothiophene	Phenylhydrazine	2,2'-Bithienyl/41.7 2-Phenylthiophene[c)] Biphenyl/1.4

a) Yield based on organic bromide used except that of biphenyl and determined by GLPC. b) Isolated yield. c) Not measured.

Consequently, the present reaction is a Busch-type reaction because arylhydrazine acts as a reducing agent and then the reductive homocoupling of haloarene proceeds in the presence of the palladium catalyst.

According to the present method, both iodo- and bromoarenes could be used as the starting materials for the preparation of biaryls. The previous method[1)] gave satisfactory yields of biaryls only when iodoarene was used and, therefore, the utility of the present method was examined in the coupling of bromoarenes (Table 3). Usually traces of arylamine, azoarene, and hydrazoarene, which are well known as the decomposition products of arylhydrazine, were detected, but these compounds were easily separated from the biaryls. Bromotoluenes and bromoxylene reacted with tolyl- and xylylhydrazine, respectively, to give the corresponding biaryls in high yield. 2,2'-Disubstituted biphenyl, which is difficult to prepare by ordinary symmetrical biaryl syntheses with haloarenes except the Ullmann reaction, was also obtained without the formation of 2,3'-isomer.[6)] Although the Busch reaction has been used when the Ullmann reaction is inefficient for the preparation of biaryl, the Busch reaction of bromonaphthalene[7)] and 2-bromopyridine[8)] has been inefficient. Treatment of bromonaphthalene, or bromopyridine with phenylhydrazine gave the corresponding binaphthyl or bipyridyl accompanying of small amounts of phenylnaphthalene or phenylpyridine, and biphenyl, which were easily removed at the isolation/purification stage, and the yield was higher than the previous one.[7,8)] Bithienyl was also prepared by the present method, but the yield is still somewhat modest. These results were always superior to those obtained under the Busch reaction conditions.

Experimental

Materials. The reagents used were commercial reagent grade materials except those noted below. 4-Bromo-*o*-xylene and 3,4-dimethylphenylhydrazine were prepared from 3,4-dimethylaniline according to the method of Bigelow,[9)] and Coleman,[10)] respectively. The following authentic samples were also prepared in accordance with the method given in the literature; 4-methylbiphenyl,[11)] 2,2'-, 3,3'-, and 4,4'-dimethylbiphenyl,[1)] 1,1'-, and 2,2'-binaphthyl,[12)] 2-phenylnaphthalene,[13)] and 2,2'-bithienyl.[14)]

Reductive Coupling of Halobenzene with Phenylhydrazine. Pd Catalyst: A mixture of halobenzene (25.0 mmol), PdCl$_2$ (0.50 mmol), phenylhydrazine (10.0 mmol), and NaOH (100 mmol) was stirred in refluxing MeOH (12 ml) for 6 h. The resulting mixture was filtered, and the residual metal was washed with benzene, and subsequently water. The organic layer separated from the aqueous layer was concentrated by rotary evaporation under reduced pressure, and analyzed by GLPC and GC–MS. The products exhibited spectral characteristics in accord with those of known samples.

Pd–Hg Catalyst: The reaction was carried out as described above except that both PdCl$_2$ (0.50 mmol), and HgCl$_2$ (0.50 mmol) were used in place of PdCl$_2$.

Reaction of Haloarene with Arylhydrazine. A mixture of haloarene (12.5 mmol), arylhydrazine (12.5 mmol), and NaOH (125 mmol) was refluxed in 16 ml of MeOH in the presence or absence of the catalyst (0.50 mmol of PdCl$_2$, or 0.50 mmol of PdCl$_2$ and 0.50 mmol of HgCl$_2$) for 9 h with stirring. The resulting mixture was worked up as described above.

Synthesis of Biaryls. The following procedure for the synthesis of 2,2'-dimethylbiphenyl is representative. A mixture of *o*-bromotoluene (25.0 mmol), *o*-tolylhydrazine hydrochloride (15.0 mmol), PdCl$_2$ (0.50 mmol), HgCl$_2$ (0.50 mmol), and NaOH (125 mmol) was refluxed in 16 ml of MeOH for 6 h with stirring. The resulting mixture was treated as above, and after analysis the concentrated organic layer was distilled *in vacuo* using a ball tube distillation apparatus to give 2,2′-dimethylbiphenyl (12.4 mmol, 99%).

2,2′-Bipyridyl: A mixture of 2-bromopyridine (25.0 mmol), phenylhydrazine (15.0 mmol), $PdCl_2$ (0.50 mmol), $HgCl_2$ (0.50 mmol), NaOH (125 mmol), and MeOH (16 ml) was processed as above. The distillate gave bipyridyl together with a small amount of phenylpyridine and biphenyl. This distillate (or the concentrated organic layer) was steam-distilled from iron(II) solution buffered at pH 4.4 to remove biphenyl and phenylpyridine, and the residue was then steam-distilled from a strongly basic medium to give 2,2′-bipyridyl (5.3 mmol, 42%) as crystals, mp 66.5—68.0 °C.

We wish to thank Messrs. M. Aoyama and T. Ikeda for their assistance in the experimental work. The present work was partially supported by the Asahi Glass Foundation For Industrial Technology.

References

1) Part I of this series: R. Nakajima, Y. Shintani, and T. Hara, *Bull. Chem. Soc. Jpn.*, **53**, 1767 (1980).

2) R. L. Hardie and R. H. Thomson, *J. Chem. Soc.*, **1957**, 2512.

3) J. B. Aylward, *J. Chem. Soc., C*, **1969**, 1663.

4) R. G. R. Bacon, S. G. Seeterram, and O. J. Stewart, *Tetrahedron Lett.*, **1967**, 2003; R. G. R. Bacon and O. J. Stewart, *J. Chem. Soc., C*, **1969**, 301.

5) J. Dehand, J. Jordanov, and M. Pfeffer, *J. Chem. Soc., Dalton Trans.*, **1976**, 1553; J. Dehand and M. Pfeffer, *Bull. Soc. Chim. Fr.*, **1974**, 2782; *Chem. Abstr.*, **82**, 179826s (1975.)

6) The absence of mercury resulted in the formation of 2,3′-dimethylbiphenyl and in the decrease of the yield of bitolyls; the same effects of mercury have been noted previously on the coupling of *o*-iodotoluene using hydrazine.[1]

7) M. Busch and W. Schmidt, *Ber.*, **62**, 2612 (1927); M. Busch and W. Weber, *J. Prakt. Chem.*, **146**, 1 (1936).

8) G. J. Moore, Ger. Offen. 2230562 (1973).

9) L. A. Bigelow, *Org. Synth.*, Coll. Vol. I, 136 (1956).

10) G. H. Coleman, *Org. Synth.*, Coll. Vol. I, 442 (1956).

11) W. E. Bachmann and R. A. Hoffman, "Organic Reactions," ed by R. Adams, John Wiley and Sons, Inc., New York (1944), Vol. II, p. 247.

12) D. A. Shirley, "Preparation of Organic Intermediates," John Wiley and Sons, Inc., New York (1951), p. 33.

13) J. C. W. Evans and C. F. H. Allen, *Org. Synth.*, Coll. Vol. II, 517 (1943).

14) R. Nakajima and T. Hara, 45th National Meeting of the Chemical Society of Japan, Tokyo, April 1982, Abstr. No. 2C12.