Synthetic Communications: An International Journal for Rapid Communication of Synthetic Organic Chemistry
Publication details, including instructions for authors and subscription information:
http://www.tandfonline.com/loi/lsyc20

Cupric Chloride-Catalyzed Synthesis of Symmetrical Azo Compounds from Primary Aromatic Amines

Ming Zhang [a], Rongli Zhang [a], Ai-Qin Zhang [b], Xinfei Li [a] & Haihua Liang [a]
[a] College of Chemistry, Jiangxi Normal University (Yaohu Campus), Nanchang, Jiangxi, China
[b] Department of Environmental and Chemical Engineering, Nanchang Institute of Aeronautical Technology, Nanchang, Jiangxi, China
Published online: 04 Sep 2009.

To cite this article: Ming Zhang , Rongli Zhang , Ai-Qin Zhang , Xinfei Li & Haihua Liang (2009) Cupric Chloride-Catalyzed Synthesis of Symmetrical Azo Compounds from Primary Aromatic Amines, Synthetic Communications: An International Journal for Rapid Communication of Synthetic Organic Chemistry, 39:19, 3428-3435, DOI: 10.1080/00397910902774034

To link to this article: http://dx.doi.org/10.1080/00397910902774034

Synthetic Communications®, 39: 3428–3435, 2009

ISSN: 0039-7911 print/1532-2432 online
DOI: 10.1080/00397910902774034

Taylor & Francis
Taylor & Francis Group

Cupric Chloride–Catalyzed Synthesis of Symmetrical Azo Compounds from Primary Aromatic Amines

Ming Zhang,[1] Rongli Zhang,[1] Ai-Qin Zhang,[2] Xinfei Li,[1] and Haihua Liang[1]

[1]College of Chemistry, Jiangxi Normal University (Yaohu Campus), Nanchang, Jiangxi, China

[2]Department of Environmental and Chemical Engineering, Nanchang Institute of Aeronautical Technology, Nanchang, Jiangxi, China

Abstract: Symmetrical azo compounds were synthesized from primary aromatic amines using n-BuMgBr as a base, oxygen as an oxidant, and $CuCl_2$ as a catalyst.

Keywords: Amines, azo compounds, copper, Grignard reactions, oxidations

INTRODUCTION

Azo compounds are useful compounds because of their applications in optical materials, molecular devices, and theoretical studies,[1] so synthesis of azo compounds is a worthwhile investigation. Symmetrical azo compounds can be synthesized from primary aromatic amines by lead tetraacetate,[2a] potassium permanganate,[2a–c] potassium ferricyanide,[2d,3] sodium hypobromide,[2a] chromic acid anhydride,[2a] manganese dioxide,[2a] lead peroxide,[2a] and cetyltrimethylammonium dichromate.[2b] Recently, four-electron oxidative formation of aryl diazenes using a tantalum redox-active ligand complex was reported.[2] Galvinoxyl[4a] or

Received September 9, 2008.

Address correspondence to Ming Zhang, College of Chemistry, Jiangxi Normal University, Yaohu Campus, 99 Ziyangdadao, Nanchang, Jiangxi 330022, China. E-mail: zmchem@163.com

2,4,6-tri-*tert*-butylphenol[4b] was used as phase-transfer catalyst to prepare symmetrical azo compounds from primary amines; the oxidant potassium ferricyanide was stoichiometric. The manganese(III) complex of 5,10,15, 20-tetrakis(4-aminophenyl)porphyrin covalently bound to cross-linked chloromethylated polystyrene was used as catalyst for oxidation of primary aromatic amines to corresponding azo compounds; the oxidant sodium periodate was stoichiometric.[5] Cupric chloride was used as catalyst to prepare symmetrical azo compounds from primary aromatic amines using air as oxidant; althogh this system is environmentally benign and safe, yields are poor.[6] Although synthesis of symmetrical azo compounds from primary aromatic amines is well established, there are many drawbacks in literature methods, such as stoichiometric amounts of oxidants,[2,3,5] expensive or toxic oxidants,[2a–c,4] poor yields,[2a,6] and long reaction time.[2d] Herein we report an efficient method for synthesis of symmetrical azo compounds from primary aromatic amines catalyzed by cupric chloride using oxygen as an oxidant.

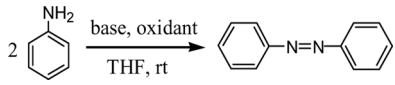
RESULTS AND DISCUSSION

Several reaction systems were investigated in the synthesis of azo benzene: various copper or iron compounds were used as oxidants, and K_2CO_3, Et_3N, or n-BuMgBr were used as bases. The results are listed in Table 1. It is efficient when the base is n-BuMgBr (2 equiv) and oxidant is $CuCl_2$ (2 equiv); the isolated yield is 95% in this case (entry 9, Table 1). It is successful when a catalytic amount of $CuCl_2$ (0.1 mmol, 10 mol%) is used and oxygen is used as an oxidant; the isolated yield is 93% in this case (entry 10, Table 1). Because the $CuCl_2$ is toxic and O_2 is cheap and nontoxic, the method in entry 10 (Table 1) is better than that in entry 9 (Table 1) in view of economic effects and environmental protection.

To explore the scope of the method using oxygen as an oxidant, n-BuMgBr as a base, and $CuCl_2$ as a catalyst, more primary aromatic amines were used as substrates. The results are listed in Table 2. When substituents are in the *meta*- or *para*-position to the amino group, the yields are 87–92% (entries 2–4, Table 2). When substituents are in *ortho*-position to the amino group, the yields are 82–85% (entries 5–7, Table 2). It shows that steric hindrance of primary aromatic amines has an effect on the formation of azo compounds.

When the substrate was *m*-nitroaniline, the product (2-n-butyl-3-nitroaniline, **9**) of nucleophilic substitution was obtained in 14% yield (Scheme 1), and no corresponding azo compound (**8**) was found.

Table 1. Optimization of reaction systems in the synthesis of azobenzene



Entry	Catalyst	Oxidant	Base	Reaction time (h)	Isolated yield (%)
1	—	2 mmol $Fe(acac)_3$	3 mmol Et_3N	72	0[a]
2	—	2 mmol $Fe(acac)_3$	2 mmol n-BuMgBr	72	Trace[a]
3	—	2 mmol $Cu(OAc)_2 \cdot H_2O$	2.5 mmol K_2CO_3	24	0[a]
4	—	2 mmol $Cu(acac)_2$	2 mmol n-BuMgBr	72	76[a]
5	—	2 mmol $Cu(acac)_2$	—	72	0[a]
6	—	2 mmol $CuCl_2$	—	72	0[a]
7	—	2 mmol $CuCl_2$	3 mmol Et_3N	72	Trace[a]
8	—	2 mmol $CuCl_2$	2.5 mmol K_2CO_3	72	Trace[a]
9	—	2 mmol $CuCl_2$	2 mmol n-BuMgBr	5	95[a]
10	0.1 mmol $CuCl_2$ (10 mol%)	O_2	2 mmol n-BuMgBr	24	93

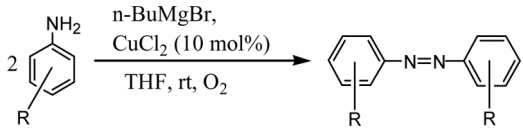
[a]Reaction conditions: Aniline (1 mmol) was added to a solution of a base in THF (8 mL). After stirring for 1/2 h, an oxidant was added to the reaction mixture, which was stirred at room temperature for the specified time.

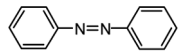
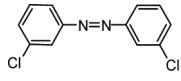
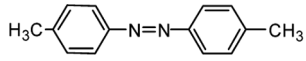
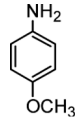
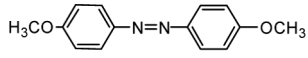
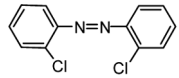
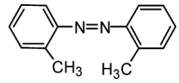
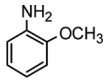
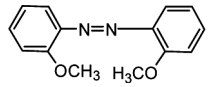
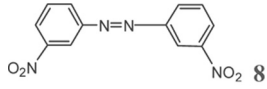
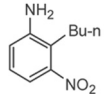
The yields by this present method are much greater than that by the literature method[5] in which CuCl was used as catalyst and air was used as oxidant (Table 3).

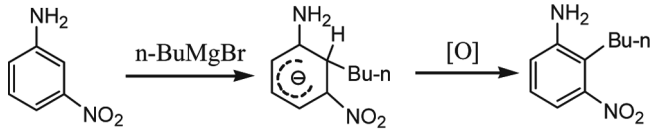
A possible mechanism is postulated as follows: n-BuMgBr acts as a base, oxygen acts as an oxidant, and $CuCl_2$ acts as a catalyst. The mechanism involves free radicals (Scheme 2). 1,2-Bis(3-nitrophenyl) diazene (**8**) could not be obtained from 3-nitroaniline; the possible reason was that the free radical could be captured by a nitro group.[7] This phenomenon is the same as that observed in the literature.[4b]

In conclusion, an efficient reaction system using n-BuMgBr as a base, oxygen as an oxidant, and $CuCl_2$ as a catalyst is reported for the synthesis of symmetrical azo compounds from primary aromatic amines.

Table 2. Synthesis of azo compounds catalyzed by $CuCl_2$



Entry	Substrate	Product	Isolated yield (%)	Mp (lit. mp)
1		 **1**	93	68–69 (67–68)[4]
2		 **2**	89	102–104 (99)[4]
3		 **3**	92	144–145 (144–145)[2b]
4		 **4**	87	153–154 (160)[2b]
5		 **5**	83	129–130 (136)[4]
6		 **6**	85	53–54 (54)[4]
7		 **7**	82	150–151 (143–145)[4]
8		 **8**	0	—
9		 **9**	14	56–57



(9)

Scheme 1. Nucleophilic substitution of *m*-nitroaniline.

EXPERIMENTAL

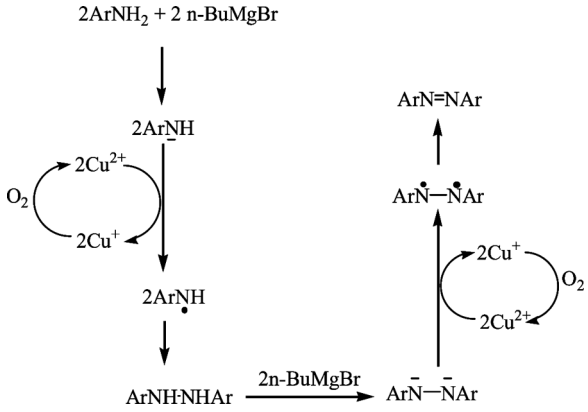
Melting points were determined in open capillaries and are uncorrected. ^{1}H NMR was measured on a Bruker 400-MHz spectrometer with tetramethylsilane (TMS) as internal standard. Infrared (IR) spectra were measured on a Nicolet Magna-IR550 spectrometer. Microanalyses were performed with a PE 2400 elemental analyzer. Tetrahydrofuran (THF) was distilled from Na/benzophenone immediately prior to use.

General Procedure for Catalyzed Synthesis of Symmetrical Azo Compounds

An amine (1 mmol) was added to a solution of 2 mmol n-BuMgBr in dry THF (8 mL). After stirring for 1/2 h, the catalyst $CuCl_2$ (0.1 mmol, 10 mmol%) was added to the reaction mixture. Dry O_2 was bubled into the reaction mixture; the rate of bubling was faster for the first 30 min, then it was very slow. The mixture was stirred at room temperature for 24 h under an atmosphere of O_2. Then a little amount of silica gel was added, and the resulting mixture was evaporated to dryness. Purification was done by column chromatography on silica gel to give the product

Table 3. Comparison of yields with literature method

Product	Yield by present method (%)	Yield by literature method (%)[5]
1	93	33
3	92	85
4	87	71
5	83	8
7	82	46



Scheme 2. Mechanism for catalyzed synthesis of azo compounds.

(ethyl acetate/petroleum ether 30–60°C as eluent solvent (1:9 for products **1–6**, 1:3 for products **7** and **9**).

Data

1,2-Bis(3-chlorophenyl)diazene (**2**)

Orange red solid. ^{1}H NMR ($CDCl_3$, 400 MHz): 7.47 (m, 4H), 7.84 (m, 2H), 7.90 (s, 2H). IR (KBr, cm^{-1}): 3072, 1585, 1569, 1464, 1417, 1201, 1067, 887, 793, 684. Elemental analysis: calcd. C, 57.37%; H, 3.19%; N, 11.16%; found C, 57.51%; H, 3.12%; N, 11.28%.

1,2-Bis(4-methoxyphenyl)diazene (**4**)

Yellow solid. ^{1}H NMR ($CDCl_3$, 400 MHz): 3.89 (s, 3H), 7.0 (dd, $J_1 = 2$ Hz, $J_2 = 4.8$ Hz, 2H), 7.88 (dd, $J_1 = 2$ Hz, $J_2 = 4.8$ Hz, 2H). IR (KBr, cm^{-1}): 3018, 2929, 1600, 1579, 1498, 1458, 1440, 1245, 1145, 1024, 843. Elemental analysis: calcd. C, 69.42%; H, 5.79%; N, 11.57%; found C, 69.22%; H, 6.02%; N, 11.45%.

1,2-Bis(2-chlorophenyl)diazene (**5**)

Orange red solid. ^{1}H NMR ($CDCl_3$, 400 MHz): 7.36 (m, 2H), 7.44 (m, 2H), 7.56 (m, 2H), 7.78 (m, 2H). IR (KBr, cm^{-1}): 3087, 1582, 1466,

1442, 1254, 1060, 764, 726. Elemental analysis: calcd. C, 57.37%; H, 3.19%; N, 11.16%; found C, 57.58%; H, 3.33%; N, 10.92%.

1,2-Bis(2-methoxyphenyl)diazene (**7**)

Orange red solid. ^{1}H NMR ($CDCl_3$, 400 MHz): 4.02 (s, 6H), 7.00 (t, $J = 8$ Hz, 2H), 7.06 (d, $J = 8.4$ Hz, 2H), 7.42 (m, 2H), 7.64 (m, 2H). IR (KBr, cm^{-1}): 3003, 2946, 1593, 1489, 1470, 1437, 1280, 1251, 1159, 765. Elemental analysis: calcd. C, 69.42%; H, 5.79%; N, 11.57%; found C, 69.54%; H, 5.91%; N, 11.49%.

2-n-Butyl-3-nitroaniline (**9**)

Brown solid. ^{1}H NMR ($CDCl_3$, 400 MHz): 0.97 (t, $J = 7.2$ Hz, 3H), 1.43 (m, 2H), 1.63 (m, 2H), 2.55 (t, $J = 7.6$ Hz, 2H), 4.00 (s, 2H), 7.14 (d, $J = 8$ Hz, 1H), 7.50 (d, $J = 2$ Hz, 1H), 7.57 (m, 1H). IR (KBr, cm^{-1}): 3486, 3394, 2956, 2928, 2870, 1633, 1511, 1464, 1437, 1346, 1289, 1278, 1106, 950, 874, 818, 737. Elemental analysis: calcd. C, 61.86%; H, 7.22%; N, 14.43%; found C, 62.07%; H, 7.35%; N, 14.19%.

REFERENCES

1. (a) Hirose, Y.; Yui, H.; Sawada, T. Effect of potential energy gap between the n-π^* and the π-π^* state on ultrafast photoisomerization dynamics of an azobenzene derivative. *J. Phys. Chem. A* **2002**, *106*, 3067–3071; (b) Liu, N.; Yu, K.; Smarsly, B.; Dunphy, D. R.; Jiang, Y.; Brinker, C. J. Self-directed assembly of photoactive hybrid silicates derived from an azobenzene-bridged silsesquioxane. *J. Am. Chem. Soc.* **2002**, *124*, 14540–14541; (c) Kamenjicki, M.; Asher, S. A. Photochemically controlled cross-linking in polymerized crystalline colloidal array photonic crystals. *Macromolecules* **2004**, *37*, 8293–8296; (d) Kurihara, S.; Nomiyama, S.; Nonaka, T. Photochemical control of the macrostructure of cholesteric liquid crystals by means of photoisomerization of chiral azobenzene molecules. *Chem. Mater.* **2001**, *3*, 1992–1997; (e) Harbron, E. J.; Vicente, D. A.; Hoyt, M. T. Fluorescence modulation via isomer-dependent energy transfer in an azobenzene-functionalized poly (phenylenevinylene) derivative. *J. Phys. Chem. B* **2004**, *108*, 18789–18792; (f) Ruslim, C.; Ichimura, K. Conformational effect on macroscopic chirality modification of cholesteric mesophases by photochromic azobenzene dopants. *J. Phys. Chem. B* **2000**, *104*, 6529–6535; (g) Syinivas, O.; Mitra, N.; Surolia, A.; Jayaraman, N. Photoswitchable multivalent sugar ligands: synthesis, isomerization, and lectin binding studies of azobenzene-glycopyranoside derivatives. *J. Am. Chem. Soc.* **2002**, *124*, 2124; (h) Lei, Y.; Hurst, J. K. Photoregulated

potassium ion permeation through dihexadecyl phosphate bilayers containing azobenzene and stilbene surfactants. *Langmuir* **1999**, *15*, 3424–3429.
2. Zarkesh, R. A.; Ziller, J. W.; Heyduk, A. F. Four-electron oxidative formation of aryl diazenes using a tantalum redox-active ligand complex. *Angew. Chem. Int. Ed. Engl.* **2008**, *47*, 4715–4718.
3. (a) Baer, E.; Tosont, A. L. Formation of symmetric azo-compounds from primary aromatic amines by lead tetraacetate. *J. Am. Chem. Soc.* **1956**, *78*, 2857–2858, and literature therein; (b) Patel, S.; Mishra, B. K. Cetyltrimethylammonium dichromate: A mild oxidant for coupling amines and thiols. *Tetrahedron Lett.* **2004**, *45*, 1371–1372; (c) Shaabani, A.; Lee, D. G. Solvent free permangnate oxidations. *Tetrahedron Lett.* **2001**, *42*, 5833–5836, and literature therein; (d) Goldstein, S.; Mcnelis, E. Chromyl chloride in acetone: α-Chloro ketones or ketones directly from olefins. *J. Org. Chem.* **1973**, *38*, 183–185.
4. (a) Wang, X. Y.; Wang, Y. L.; Li, J. P.; Sun, L. F.; Zhang, Z. Y. The synthesis of symmetrical azobenzenes from anilines by phase transfer catalysis. *Chin. Chem. Lett.* **1999**, *10*, 533–536; (b) Wang, X.; Wang, Y.; Li, J.; Wang, C.; Duan, Z.; Zhang, Z. A simple, efficient phase-transfer catalyzed method for preparing symmetrical azobenzenes from anilines. *Indian J. Chem.* **2000**, *39B*, 545–547.
5. Mirkhani, V.; Tangestaninejad, S.; Moghadam, M.; Karimian, Z. Oxidation of primary aromatic amines to azo derivatives with sodium periodate using polystyrene-bound manganese(III) porphyrin. *J. Chem. Res.* **2003**, *12*, 792–794.
6. Lu, W.; Xi, C. CuCl-catalyzed aerobic oxidative reaction of primary aromatic amines. *Tetrahedron Lett.* **2008**, *49*, 4011–4015.
7. Odlian, G. *Principles of Polymerization*; McGraw-Hill, New York, 1970.