



Original article

Metal-free synthesis of substituted phenols from arylboronic acids in water at room temperature

Min Jiang^a, Hai-Jun Yang^{a,b,*}, Yong Li^{a,b}, Zhi-Ying Jia^b, Hua Fu^b^a Beijing Key Laboratory for Analytical Methods and Instrumentation, Department of Chemistry, Tsinghua University, Beijing 100084, China^b Key Laboratory of Bioorganic Phosphorus Chemistry and Chemical Biology of Ministry of Education, Department of Chemistry, Tsinghua University, Beijing 100084, China

ARTICLE INFO

Article history:

Received 6 November 2013

Received in revised form 22 January 2014

Accepted 20 February 2014

Available online 15 March 2014

Keywords:

Arylboronic acids
Substituted phenols
Oxidative
Metal-free
Synthetic method

ABSTRACT

A convenient, efficient and practical metal-free method for the synthesis of substituted phenols from arylboronic acids has been developed. The protocol uses hydrogen peroxide as a hydroxylating agent, ammonium bicarbonate as an additive, and the reactions were conveniently performed in water at room temperature. The method shows an excellent tolerance of functional groups, so it will find a wide variety of applications in academic and industrial research.

© 2014 Hai-Jun Yang. Published by Elsevier B.V. on behalf of Chinese Chemical Society. All rights reserved.

1. Introduction

Phenols are important synthetic intermediates and are widely used in the synthesis of pharmaceuticals, polymers, and natural products [1]. Therefore, the synthesis of phenols has attracted much attention. Recently, great successes have been made using transition metals as catalysts to prepare phenols including palladium [2] or copper-catalyzed [3] hydroxylation of aryl halides with hydroxide salts to produce phenols. Arylboronic acids, usually prepared from aryl halides (such as aryl bromides and chlorides) or tosylates, are common chemicals [4] and have been used in the synthesis of phenols by copper-catalysis [5]. Very recently, we have developed a general copper-catalyzed transformation of arylboronic acids in water to different functionalized aromatic systems including phenols [6]. Obviously the environmentally benign transition metal-free approaches are preferred in organic synthesis. Metal-free organocatalysis has been around for over a century [7], but it was left largely unnoticed [8,9]. Only recently, there has been a remarkable renaissance in organocatalysis because environmentally friendly methods can avoid the

need for potentially toxic metal-based catalysts [10]. Several groups have reported the oxidation of organo-boronic compounds to produce phenols using oxidants such as hydrogen peroxide [11]. Very recently, phenols prepared by photocatalysis from arylboronic acids under light irradiation have been reported [12]. We recognized that the transformation of arylboronic acids to phenols was an oxidation procedure involved radicals. Herein, we report a transformation and its mechanism of arylboronic acids to substituted phenols with hydrogen peroxide and ammonium bicarbonate under mild conditions.

2. Experimental

All reagents and solvents were obtained from commercial suppliers and used without further purification. Aryl boronic acids were purchased from Alfa-Aesar, and other reagents were purchased from Beijing Ouhe Technology Co., Ltd. All reagents were weighed and handled in air at room temperature. Proton and carbon magnetic resonance spectra (¹H NMR and ¹³C NMR) were recorded using tetramethylsilane (TMS) in solvent of CDCl₃ as the internal standard (¹H NMR: TMS at 0.00 ppm, CHCl₃ at 7.24 ppm, ¹³C NMR: CDCl₃ at 77.0 ppm) or using tetramethylsilane (TMS) in the solvent of DMSO-*d*₆ as the internal standard (¹H NMR: TMS at 0.00 ppm, DMSO at 2.50 ppm; ¹³C NMR: DMSO at 40.0 ppm). The EPR measurement was performed on a X-band EPR (10.0 GHz) instrument JES FA200 (JEOL).

* Corresponding author at: Beijing Key Laboratory for Analytical Methods and Instrumentation, Department of Chemistry, Tsinghua University, Beijing 100084, China.

E-mail address: cyhj@tsinghua.edu.cn (H.-J. Yang).

General experimental procedure for the synthesis of compounds **2a–y**: 30% H₂O₂ solution (2 mmol, 0.12 mL), ammonium bicarbonate (1 mmol, 79.1 mg), arylboronic acid (1 mmol), H₂O (2.0 mL) were added to a 10 mL Schlenk tube equipped with a magnetic stirrer, and the reaction was performed under air at room temperature for 2 h. After the reaction finished, 4 mL of HCl (1 mol/L) was added to the solution till pH 2–3. The aqueous solution was extracted with ethyl acetate (4 × 5 mL), the combined organic phase was dried over anhydrous Na₂SO₄, and the targeted products (**2**) were obtained after the removal of the solvent. Data for three representative examples are given here.

Methylparaben (**2t**): yield 98% (149 mg), white solid, mp 125 °C. ¹H NMR (600 MHz, CDCl₃): δ 7.94 (d, 2 H, *J* = 8.94 Hz), 6.87 (d, 2 H, *J* = 8.94 Hz), 6.25 (s, 1H), 3.89 (d, 3H). ¹³C NMR (150 MHz, CDCl₃): δ 167.5, 160.4, 132.0, 122.3, 115.4, 52.2. GC–MS: *m/z* 152.2.

Naphthalen-1-ol (**2w**): yield 97% (140 mg), colorless solid, mp 109–112 °C. ¹H NMR (600 MHz, CDCl₃): δ 8.17 (m, 1H), 7.81 (m, 1H), 7.48 (m, 2H), 7.44 (d, 2H, *J* = 8.3 Hz), 7.29 (dd, 1H, *J* = 7.6, 8.3 Hz), 6.80 (d, 1H, *J* = 7.6 Hz), 5.26 (s, 1H). ¹³C NMR (150 MHz, CDCl₃): δ 151.3, 134.7, 127.6, 126.4, 125.8, 125.2, 124.3, 121.5, 120.7, 108.6. GC–MS: *m/z* 144.1.

Dibenzo[b,d]furan-4-ol (**2y**): yield 96% (177 mg), white solid, mp 135 °C. ¹H NMR (600 MHz, CDCl₃): δ 7.85 (d, 2H, *J* = 7.56 Hz), 7.48 (d, 1H, *J* = 8.25 Hz), 7.44 (d, 1H, *J* = 7.56 Hz), 7.38 (t, 1H, *J* = 7.56 Hz), 7.28 (t, 1H, *J* = 7.56 Hz), 7.15 (t, 1H, *J* = 7.22 Hz), 7.00 (d, 1H, *J* = 8.25 Hz), 5.86 (s, 1H). ¹³C NMR (150 MHz, CDCl₃): δ 156.1, 144.2, 141.2, 127.3, 125.9, 124.7, 123.8, 123.1, 121.1, 113.8, 112.9, 111.9. GC–MS: *m/z* 184.1.

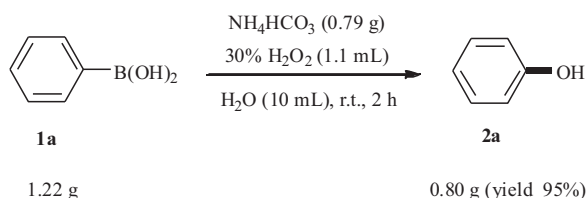
As shown in Scheme 1, the synthesis of phenol on gram scale went well under the standard conditions, demonstrating the practical applicability of the present method.

The characterization data and ¹H NMR and ¹³C NMR spectra of compounds **2a–y** can be found in Supporting information.

EPR measurement: 10 μL Phenylboronic acid (25 mmol) and 10 μL ammonium bicarbonate (25 mmol) was quickly mixed with 20 μL DMPO (100 mmol) and 10 μL H₂O₂ (50 mmol), the sample was subsequently transferred to an EPR flat cell, and spectra were taken by a JEOL EPR spectrometer. Typical spectrometer parameters were as follows: scan width 8 mT, center field 323.1 mT, time constant 0.1 s, scan time 2 min, modulation amplitude 0.1 mT, microwave power 1 mW, microwave frequency 9.056 GHz. A typical hydroxyl radical (*g* = 2.0023, *A_N* = 1.50 mT, *A_H* = 1.50 mT) and a carbon central radical (*g* = 2.0023, *A_N* = 1.58 mT, *A_H* = 2.38 mT) were observed, and the result showed occurrence of a phenyl free radical.

3. Results and discussion

Hydroxylation of phenylboronic acid (**1a**) to the corresponding phenol was used as a model to optimize reaction conditions including carbonate salts, amount of carbonate salts and hydrogen peroxide, and solvents. As shown in Table 1, eight carbonate salts were screened in the presence of two equiv. of hydrogen peroxide in water at room temperature for 2 h (entries 1–8), and sodium bicarbonate, potassium bicarbonate, cesium bicarbonate, ammonium bicarbonate, ammonium carbonate provided excellent yields



Scheme 1. Synthesis of phenol on gram scale under the standard conditions.

Table 1

Synthesis of phenol (**2a**) from hydroxylation of phenylboronic acid (**1a**) with hydrogen peroxide: optimization of conditions.^a

Entry	MCO ₃ (equiv.)	H ₂ O ₂ (equiv.)	Solvent	Yield (%) ^b
1	NaHCO ₃ (1)	2	CH ₃ CN	97
2	KHCO ₃ (1)	2	CH ₃ CN	97
3	CsHCO ₃ (1)	2	CH ₃ CN	97
4	NH ₄ HCO ₃ (1)	2	CH ₃ CN	97
5	(NH ₄) ₂ CO ₃ (1)	2	CH ₃ CN	97
6	Na ₂ CO ₃ (1)	2	CH ₃ CN	61
7	K ₂ CO ₃ (1)	2	CH ₃ CN	72
8	Cs ₂ CO ₃ (1)	2	CH ₃ CN	61
9	NH ₄ HCO ₃ (1)	1	CH ₃ CN	92
10	NH ₄ HCO ₃ (1)	0.5	CH ₃ CN	60
11	NH ₄ HCO ₃ (1)	–	CH ₃ CN	Trace
12	NH ₄ HCO ₃ (1)	3	CH ₃ CN	97
13	NH ₄ HCO ₃ (0.5)	2	CH ₃ CN	72
14	–	2	CH ₃ CN	89
15	NH ₄ HCO ₃ (1)	2	CH ₃ OH	97
16	NH ₄ HCO ₃ (1)	2	H ₂ O	97

^a Reaction conditions: phenylboronic acid (**1a**) (1 mmol), carbonate salt (0–3.0 mmol), H₂O₂ (0–3.0 mmol), water (2.0 mL), reaction time (2 h) at room temperature under air.

^b Isolated yield.

(entries 1–5). When the amount of hydrogen peroxide was reduced (entries 9 and 10), the yields decreased. Only trace amount of phenol was observed in the absence of hydrogen peroxide (entry 11). Three equiv. of hydrogen peroxide gave the same yield (entries 4 and 12). Amount of ammonium bicarbonate was also investigated (entries 4, 13 and 14), and one equiv. of ammonium bicarbonate was suitable (entry 4). Effect of solvents was explored (entries 4, 15 and 16), and water was more favorable (entry 16). Therefore, the optimal conditions for the hydroxylation of arylboronic acids are as follows: two equiv. of hydrogen peroxide as the hydroxylating agent, one equiv. of ammonium bicarbonate as the additive (adjusting pH value of the solution) in water at room temperature for 2 h.

With the optimum reaction conditions in hand, the scope of metal-free synthesis of substituted phenols was investigated. As shown in Table 2, all the examined substrates provided excellent yields, and all arylboronic acids were almost quantitatively transformed into the corresponding substituted phenols within 2 h. The reactions could tolerate various functional groups including ether (entries 8–10), C–Cl bond (entries 11 and 12), C–F bond (entry 13), hydroxyl (entry 14), nitro (entries 15 and 16), trifluoromethyl (entry 17), cyano (entry 18), acetyl (entry 19), ester (entry 20), carboxyl (entries 21 and 22), naphthalene ring (entries 23 and 24), and *O*-heterocycle (entry 25) in the substrates. Importantly, the work-up procedures were very simple, and the pure targeted products were obtained only by extraction with ethyl acetate after acidification of the resulting aqueous solution with 1 mol/L HCl.

The reaction mechanism for the synthesis of substituted phenols was also investigated by EPR. As shown in Fig. 1 (curve a), a typical hydroxyl free radical (black dot) (*g* = 2.0023, *A_N* = 1.50 mT, *A_H* = 1.50 mT) in Fig. 1 (curve b) and a carbon central free radical (star) (*g* = 2.0023, *A_N* = 1.58 mT, *A_H* = 2.38 mT) in Fig. 1 (curve c) from the hydroxylation of phenylboronic acids were observed. The simulation spectrum of the hydroxyl radical and carbon central radical (Fig. 1 (curve d)) was in agreement with the measurement. This result showed the presence of a phenyl

Download English Version:

<https://daneshyari.com/en/article/1257403>

Download Persian Version:

<https://daneshyari.com/article/1257403>

[Daneshyari.com](https://daneshyari.com)