

Organic Preparations and Procedures International

The New Journal for Organic Synthesis

ISSN: (Print) (Online) Journal homepage: <https://www.tandfonline.com/loi/uopp20>

Eco-friendly Solvent-free Route to Alkyl- and Aryl-Bisphenols Catalyzed by Perchloric Acid-Silica

Deepak Singh & Pradeep T. Deota

To cite this article: Deepak Singh & Pradeep T. Deota (2020): Eco-friendly Solvent-free Route to Alkyl- and Aryl-Bisphenols Catalyzed by Perchloric Acid-Silica, Organic Preparations and Procedures International, DOI: [10.1080/00304948.2020.1762459](https://doi.org/10.1080/00304948.2020.1762459)

To link to this article: <https://doi.org/10.1080/00304948.2020.1762459>



Published online: 13 Jul 2020.



Submit your article to this journal [↗](#)





View related articles [↗](#)



View Crossmark data [↗](#)



Eco-friendly Solvent-free Route to Alkyl- and Aryl-Bisphenols Catalyzed by Perchloric Acid-Silica

Deepak Singh^a  and Pradeep T. Deota^b 

^aHankuk University of Foreign Studies, Seoul, South Korea; ^bApplied Chemistry Department, Faculty of Technology and Engineering, The Maharaja Sayajirao University of Baroda, Vadodara, India

ARTICLE HISTORY Received 15 July 2019; Accepted 8 January 2020

Bisphenols, generally formed by condensation of phenols with carbonyl compounds, have found several useful applications.^{1–7} The literature records a number of methods for synthesis of bisphenols using a variety of catalysts such as mineral acids, bases, mesoporous silica, zeolites, and montmorillonite clays.^{8–13} As useful as they have been, however, some of these methods have their limitations, such as the corrosive nature of some of the reagents, the need of an inert atmosphere, harsh reaction conditions or cumbersome procedures. Despite extensive work on the synthesis of bisphenols, there is still a need for improvement.

In last few decades, solid acid catalysts have gained much importance in synthetic chemistry as they are eco-friendly, inexpensive and safe. They offer high efficiency of conversion under mild conditions.¹⁴ In particular, silica-supported perchloric acid ($\text{HClO}_4\text{-SiO}_2$) is one such system which is employed in a variety of organic transformations¹⁵ such as acylation,¹⁶ esterification,¹⁷ rearrangements,¹⁸ and Michael addition¹⁹ among many others.^{20–31}

Herein we describe a convenient and inexpensive method for the preparation of bisphenols *via* condensation of phenols with aldehydes or ketones under solvent-free conditions (Scheme 1). The moisture-stable catalyst (50 mg, 0.025 mol H^+)⁵ was easily prepared and used for our synthesis of bisphenols. To examine the catalytic activity of this supported reagent over aqueous HClO_4 , we carried out a model study with 2,6-dimethylphenol (**1**) and formaldehyde (**2**) using 1 mol % of the catalyst at room temperature under solvent-free conditions.

In order to find the optimum quantity of the silica supported perchloric acid, the reaction of 2,6-dimethylphenol and formaldehyde was carried out under varying amounts of the catalyst. Silica supported perchloric acid at 2 mol % gave an excellent yield in 4 h as shown in Table 2. The results shown in Table 3 suggest that silica supported perchloric acid catalyst is an efficient catalyst in terms of both time and yield, under solvent free conditions.

For optimizing the temperature of the reaction, we carried out a model study with 2,6-dimethylphenol and formaldehyde with 2 mol % of the catalyst at three different temperatures under solvent free conditions (Table 4).

CONTACT Pradeep T. Deota  deotapt@yahoo.com  Applied Chemistry Department, Faculty of Technology and Engineering, The Maharaja Sayajirao University of Baroda, Vadodara, 390001, India

© 2020 Taylor & Francis Group, LLC

Table 2. Reaction of 2,6-dimethylphenol and formaldehyde under different catalytic conditions.

Entry	Catalyst (mol %)	Time (h)	Yield (%) ^a
1	1	8	64
2	1.5	12	90
3	2	4	94
4	3	8	88
5	4	10	80

^aYields of the pure isolated products.

Table 3. Effect of solvents on the reaction of 2,6-dimethyl phenol and formaldehyde using silica supported perchloric acid catalyst.

Entry	Solvent	Time (h)	Yield (%) ^a
1	Methanol	10	84
2	Ethanol	10	88
3	Water	12	82
4	Chloroform	10	85
5	Dichloromethane	10	72
6	Solvent free	4	94

^aYields of the pure isolated products.

Table 4. Optimization of temperature using silica supported perchloric acid (2 mol %) as catalyst.

Entry	Temperature (°C)	Time (h)	Yield (%)
1	rt ^a	4	94
2	40	6	80
3	60	6	76

^aapproximately 30 °C.

eluents. **Safety Notes:** For safety purposes, all the experiments were performed in a fume hood, with personal protective equipment, emphasizing good practice. All workers must be thoroughly trained in the safe use of perchloric acid. These reactions were carried out on a scale of approximately 16 mmol.

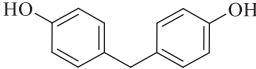
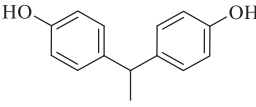
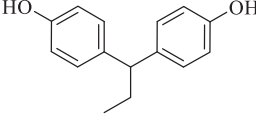
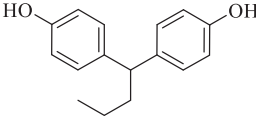
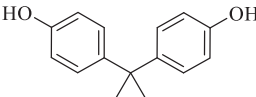
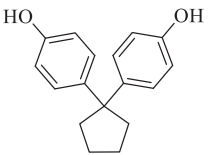
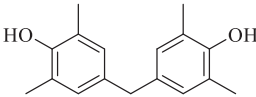
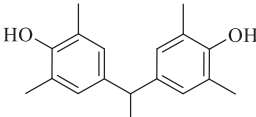
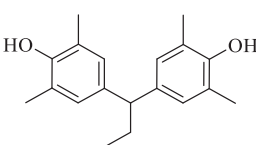
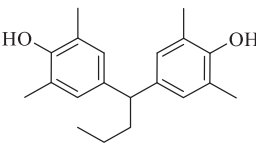
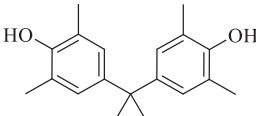
Preparation of silica supported perchloric acid (HClO₄-SiO₂) catalyst

Perchloric acid (1.8 g, 12.5 mmol as a 70% aq. solution) was added to a suspension of silica gel (23.5g, 230-400 mesh) in diethyl ether (50 ml) with stirring. The mixture was concentrated and the residue was heated at 100 °C for 72 h under vacuum, to obtain the catalyst (0.50 mmol/g) as a free flowing powder.

Typical procedure for preparation of bisphenols

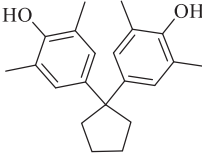
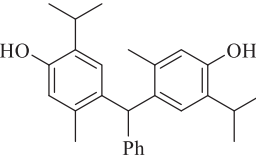
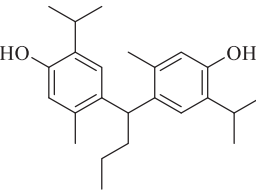
To a stirred mixture of phenol (16.39 mmol) and aldehyde or ketone (16.39 mmol) was added HClO₄-SiO₂ (640 mg, 2 mol %) over a period of 15 min at 60 °C and the mixture was further stirred for the appropriate time at the given temperature (Table 4). After completion of the reaction (TLC), ethyl acetate (50 ml) was added and the catalyst was separated by filtration. The filtrate was concentrated on a rotary evaporator under reduced pressure to give crude product which was purified by column chromatography over silica gel to furnish pure bisphenols in good to excellent yields (Table 5). The structures of known products were confirmed by ¹H NMR, mass analysis and

Table 5. Preparation of bisphenols using $\text{HClO}_4\text{-SiO}_2$ catalyst.

Entry	Bisphenol	Time (h)	Yield (%) ^a	mp (°C) lit mp ^b
3a		4	93	159-60 158 ³²
3b		5	92	123-24 122 ³²
3c		5	84	132-33 129 ³²
3d		4	86	139-40 137 ³²
3e		3.5	88	158-59 158 ³³
3f		4	87	156 156 ³³
3g		4	94	180-182 180-182 ³⁵
3h		5	91	141 143 ³⁶
3i		3.5	92	138-40 140.7-141 ³⁷
3j		4	94	176 176-77 ³⁸
3k		5	94	159-60 161-62 ³⁹

(continued)

Table 5. Continued.

Entry	Bisphenol	Time (h)	Yield (%) ^a	mp (°C) lit mp ^b
3l		4.5	86	181-82 181-82 ²
3m		5	92	172
3n		6	94	165-66

^aYields refer to the pure isolated products.^bReferences of known compounds in the literature.

comparison of melting points with those reported in the literature. The data for the novel compounds are given below.

4-((4-Hydroxy-5-isopropyl-2-methylphenyl)(phenyl)methyl)-2-isopropyl-5-methylphenol (3m)

White crystalline solid; mp. 172 °C ¹H NMR (400 MHz, CDCl₃): δ 1.06 (d, 12H, *J* = 6.8 Hz, 4CH₃), 2.09 (s, 6H, 2CH₃), 3.10 (m, 2H, CH), 4.52 (s, 2H, exchangeable phenolic OH), 5.55 (s, 1H, CH), 6.56 (s, 4H, aromatic), 7.02-7.29 (5H, aromatic). ¹³C NMR (100 MHz, CDCl₃): 19.09 (1C, CH₃), 22.47, 22.72 (2C, 2CH₃), 26.80 (1C, CH), 49.24 (1C, CH), 117.01, 125.92, 127.48, 128.10, 129.49, 130.90, 134.54, 134.77, 143.79, 150.56 (10C, aromatic). HRMS (*M* + *H*): Calcd for C₂₇H₃₂O₂ 389.2481. Found 389.2478.

Anal. Calcd for C₂₇H₃₂O₂: C, 83.46; H, 8.30. Found: C, 83.42; H, 8.24.

4-(1-(4-Hydroxy-5-isopropyl-2-methylphenyl) butyl)-2-isopropyl-5-methylphenol (3n)

White crystalline solid; mp. 165 °C ¹H NMR (400 MHz, CDCl₃): δ 0.96 (t, 3H, *J* = 3.6 Hz), 1.23 (d, 6H, *J* = 6.8 Hz, 2CH₃), 1.33 (d, 6H, 2CH₃), 1.37 (m, 2H, CH₂), 1.86 (m, 2H, CH₂), 2.20 (s, 6H, 2CH₃), 3.12 (m, 2H, CH₂), 4.11 (t, 1H, *J* = 7.6 Hz), 4.53 (s, 2H, exchangeable phenolic OH), 6.52 (s, 2H, aromatic), 6.99 (s, 2H, aromatic). ¹³C NMR (100 MHz, CDCl₃): 14.17, 19.06, 21.20 (3C, methyl), 22.77, 26.78 (2C, CH₂),

38.62, 41.11 (2C, CH), 116.89, 125.18, 131.14, 134.27, 135.41, 150.05 (6C, aromatic). HRMS (M + H): Calcd for C₂₄H₃₂O₂ 353.2481. Found 353.2480.

Anal. Calcd for C₂₄H₃₂O₂: C, 81.77, H, 9.15; Found: C, 81.74; H, 9.12.

Acknowledgment

The authors thank Prof. C. N. Murthy, Head of the Applied Chemistry Department, University of Baroda, for providing necessary facilities.

ORCID

Deepak Singh  <http://orcid.org/0000-0002-0546-3405>

Pradeep T. Deota  <http://orcid.org/0000-0002-9325-4717>

References

1. R. J. Sharma and B. J. Baruah, *Crystal Growth and Design*, **7**, 989 (2007). doi:10.1021/cg060899h
2. Y. Zhou, C. Jiang, Y. Zhang, W. Liu, L. Wang, C. Luo, T. Zhong, Y. Sun, L. Zhao, X. Xie, H. Jiang, N. Zhou, D. Liu and H. Liu, *J. Med. Chem.*, **53**, 5449 (2010). doi:10.1021/jm1000584
3. Y. Endo, T. Yoshimi, K. Ohta, T. Suzuki, and S. Ohta, *J. Med. Chem.*, **48**, 3941 (2005). doi:10.1021/jm050195r
4. P. R. Kym, K. L. Hummert, A. G. Nilsson, M. Lubin and A. Katzenellenbogen, *J. Med. Chem.*, **39**, 4897 (1996).
5. C. Maslen, T. R. Stevens and N. D. Hall, *J. Immunol. Methods*, **98**, 71 (1987). doi:10.1016/0022-1759(87)90437-6
6. J. P. Jaeg, E. Perdu, L. Dolo, L. Debrauwer, J. P. Cravedi and D. Zalko, *J. Agric. Food Chem.*, **52**, 4935 (2004).
7. A. D. Angelis, P. Ingallina and C. Perego, *Ind. Eng. Chem. Res.*, **43**, 1169 (2004). doi:10.1021/ie030429+
8. D. Singh, U. V. Chaudhary and P. T. Deota, *Tetrahedron*, **70**, 4485 (2014). doi:10.1016/j.tet.2014.05.020
9. D. Singh and P. T. Deota, *Tetrahedron Lett.*, **53**, 6527 (2012). doi:10.1016/j.tetlet.2012.09.077
10. D. Das, J. F. Lee and S. Cheng, *Chem. Comm.*, 2178 (2001). doi:10.1039/b107155f
11. H. E. Faith, *J. Am. Chem. Soc.*, **72**, 837 (1950). doi:10.1021/ja01158a049
12. P. T. Deota and D. Singh, *Synth. Commun.*, **43**, 292 (2013). doi:10.1080/00397911.2011.598440
13. N. Daito, N. Aoki, J. Yoshida and K. Mae, *Ind. Eng. Chem. Res.*, **45**, 4954 (2006). doi:10.1021/ie0601495
14. A. Croma and H. Garcia, *Adv. Synth. Catal.*, **348**, 1391 (2006). doi:10.1002/adsc.200606192
15. R. Dalpazzo, G. Bartoli, L. Sambri and P. Melchiorre, *Chem. Rev.*, **110**, 3501 (2010). doi:10.1021/cr9003488
16. A. K. Chakraborti and R. Gulhane, *Chem. Comm.*, 1896 (2003). doi:10.1039/B304178F
17. A. K. Chakraborti, B. Singh, S. V. Chankeshwara and A. R. Patel, *J. Org. Chem.*, **74**, 5967 (2009). doi:10.1021/jo900614s
18. A. Agarwal, S. Rani, and Y. D. Vankar, *J. Org. Chem.*, **69**, 6137 (2004). doi:10.1021/jo049415j
19. A. T. Khan, S. Ghosh and L. H. Choudhury, *Eur. J. Org. Chem.*, 2226 (2006). doi:10.1002/ejoc.200600006
20. B. Das, P. R. Reddy, C. Sudhakar and M. Lingaiah, *Tetrahedron Lett.*, **52**, 3521 (2011). doi:10.1016/j.tetlet.2011.05.001
21. M. I. Ansari, M. K. Hussain, N. Yadav, P. K. Gupta and K. Hajela, *Tetrahedron Lett.*, **53**, 2063 (2012).

22. H. R. Shaterian, H. Yarahmadi and M. Ghashang, *Tetrahedron*, **64**, 1263 (2008). doi:[10.1016/j.tet.2007.11.070](https://doi.org/10.1016/j.tet.2007.11.070)
23. G. Agnihotri and A. K. Misra, *Tetrahedron Lett.*, **47**, 3653 (2006). doi:[10.1016/j.tetlet.2006.03.133](https://doi.org/10.1016/j.tetlet.2006.03.133)
24. O. R. Ludek, W. Gu and J. C. Gildersleeve, *Carbohydrate Research*, **345**, 2074 (2010). doi:[10.1016/j.carres.2010.07.030](https://doi.org/10.1016/j.carres.2010.07.030)
25. S. Kantevari, S. V. N. Vuppapapati, D. O. Biradar and L. Nagarapu, *J. Mol. Catal. A: Chem.*, **266**, 109 (2007).
26. A. Heydari and L. Mamani, *Applied Organometallic Chemistry*, **22**, 12 (2007). doi:[10.1002/aoc.1339](https://doi.org/10.1002/aoc.1339)
27. D. S. Wankhede and P. B. Wagh, *Russ. J. Chem.*, **86**, 696 (2016). doi:[10.1134/S1070363216030300](https://doi.org/10.1134/S1070363216030300)
28. A. Si and A. K. Misra, *Chemistry Open*, **5**, 47 (2016). doi:[10.1002/open.201500129](https://doi.org/10.1002/open.201500129)
29. A. T. Khan, M. M. Khan, D. K. Das and M. Lal, *J. Heterocyclic Chem.*, **49**, 1362 (2012). doi:[10.1002/jhet.1017](https://doi.org/10.1002/jhet.1017)
30. R. Tadikonda, M. Nakka, M. B. Gajula, S. Rayavarapu, P. R. Gollamudi, and S. Vidavalur, *Synth. Commun.*, **44**, 1978 (2014). doi:[10.1080/00397911.2014.883633](https://doi.org/10.1080/00397911.2014.883633)
31. S. S. Mansoor, K. Aswin, K. Logaiya, P. N. Sudhan and S. Malik, *Res. Chem. Interm.*, **40**, 357 (2014).
32. W. C. Harden and E. E. Reid, *J. Am. Chem. Soc.*, **54**, 4325 (1932). doi:[10.1021/ja01350a027](https://doi.org/10.1021/ja01350a027)
33. M. E. McGreal, V. Niederl and J. B. Niederl, *J. Am. Chem. Soc.*, **61**, 345 (1939). doi:[10.1021/ja01871a032](https://doi.org/10.1021/ja01871a032)
34. E. Dyer and G. W. Bartels, *J. Am. Chem. Soc.*, **76**, 591 (1953). doi:[10.1021/ja01631a078](https://doi.org/10.1021/ja01631a078)
35. P. T. Deota, H. S. Parmar, V. B. Valodkar, P. R. Upadhyay and S. P. Sahoo, *Synth. Commun.*, **36**, 673 (2006).
36. B. N. Joseph, *J. Am. Chem. Soc.*, **63**, 1731 (1941).
37. F. Yamada, T. Nishiyama, M. Yamamoto and M. Tanaka, *Bull. Chem. Soc. Japan*, **62**, 3603 (1989).
38. I. Fleming, *Synthesis*, **11**, 937 (1982). doi:[10.1055/s-1982-30005](https://doi.org/10.1055/s-1982-30005)
39. J. R. Merchant and J. B. Mehta, *Ind. J. Chem.*, **4**, 76 (1966).