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Nilesh P. Tale^a, Amol V. Shelke^a & Nandkishor N. Karade^a ^a Department of Chemistry, Rashtrasant Tukadoji Maharaj Nagpur University, Nagpur, Maharashtra, India

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CERIC AMMONIUM NITRATE AS THE NOVEL OXIDIZING AGENT FOR THE FACILE SYNTHESIS OF (DICHLOROIODO)ARENES

Nilesh P. Tale, Amol V. Shelke, and Nandkishor N. Karade Department of Chemistry, Rashtrasant Tukadoji Maharaj Nagpur University, Nagpur, Maharashtra, India



Abstract Ceric ammonium nitrate (CAN) has been found to be a remarkable oxidizing agent for the oxidative conversion of iodoarenes to (dichloroiodo) arenes in acetic acid using aqueous HCl. The reaction of CAN with HCl generates in situ molecular chlorine, which is responsible for the oxidation. This method avoids the use of hazardous, toxic, and corrosive gaseous chlorine.

Keywords Ceric ammonium nitrate; chlorination; (dichloroiodo)arenes; HCl; hypervalent iodine; iodoarenes; oxidation

INTRODUCTION

(Dichloroiodo)arenes have found broad synthetic applications as reagents for chlorination and oxidation of various organic substrates.^[1] For example, 4-amino-3-chlroacetophenone, a common intermediate in the synthesis of cyclooxygenase-II selective inhibitors, was synthesized via regioselective monochlorination of 4-aminoacetophenone on a 24.8-kg scale using PhICl₂ in 87% yield.^[2] (Dichloroiodo) arenes have a practical advantage over gaseous elemental chlorine because of their safe handling and operational simplicity. Thus, ArICl₂ can be weighed accurately for chlorination reaction.^[3] Moreover, ArICl₂ can be readily converted to other important hypervalent iodine reagents, namely, iodosylbenzene, iodylarenes, (diacyloxylodo)arenes, (difluoroiodo)arenes, or diaryliodonium salts.^[4]

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Address correspondence to Nandkishor N. Karade, Department of Chemistry, Rashtrasant Tukadoji Maharaj Nagpur University, Nagpur, Maharashtra 440033, India. E-mail: nnkarade@gmail.com



Scheme 1. Willgerodt synthesis of (dichloroiodo)arenes.

The first synthesis of (dichloroiodo)benzene, PhICl₂, was reported by Willgerodt in 1885 by the reaction of iodobenzene with ICl_3 .^[5] Alternatively, an improved and high-yielding procedure for the preparation of ArICl₂ was again reported by Willgerodt in 1886 by passing the stream of Cl₂ through solutions of ArI dissolved in CHCl₃ at 0 °C (Scheme 1).^[6]

This strategy of passing chlorine gas to the respective iodoarenes has been also explored in the synthesis of recyclable chlorinating agents such as 4,4'-bis(dichloroiodo)biphenyl, 3-(dichloroiodo)benzoic acid,^[7] and polymer-supported^[8] and flurous^[9] (dichloroiodo)arenes. To circumvent the use of hazardous, toxic, and corrosive gaseous chlorine used in these methods, an environmentally benign oxidative halogenation process for in situ generation of molecular chlorine from the oxidation of chloride with suitable oxidant under monophasic and biphasic reaction conditions has been developed.^[10] Various oxidizing agents such as activated $KMnO_4$,^[11] MnO_2 ,^[11] CrO_3 ,^[12] concentrated HNO_3 ,^[13] $Na_2S_2O_8$,^[14] $KClO_3$,^[15] $NaClO_2$, and $NaClO^{[16]}$ have been reported for the synthesis of (dichloroiodo)arenes using hydrochloric acid either as a separate phase or cosolvent. Alternatively, the hydrogen peroxide^[17] and its derivatives such as sodium perborate (NaBO₃ H₂O),^[13] sodium percarbonate (Na₂CO₃ $1.5H_2O_2$,^[18] and urea hydrogen peroxide (UHP)^[19] can be also used for the synthesis of (dichloroiodo)arenes. Some of these reported methods for the synthesis of (dichloroiodo)arenes involve excess use of oxidant, strong reaction conditions, longer reaction time, and difficult isolation of the products. Thus, the development of alternative and more efficient strategies using a novel oxidizing agent for the synthesis of (dichloroiodo)arenes is of considerable relevance.

RESULTS AND DISCUSSION

Ceric ammonium nitrate (CAN) is a well-known single-electron oxidant used for various organic transformations.^[20] There are number of reports of bromination and iodination reactions mediated by CAN.^[21] Its applications for the chlorination reaction as well as its utility for the preparation of hypervalent iodine reagents are hitherto unknown. In continuation of our work on hypervalent iodine reagents,^[22] herein we report a facile and straightforward method for the preparation of (dichloroiodo)arenes from iodoarenes in dilute hydrochloric acid solution using CAN as an oxidant and acetic acid as cosolvent (Scheme 2). The reaction of CAN with aqueous hydrochloric acid generates in situ molecular chlorine, responsible for the oxidative conversion of iodoarenes to (dichloroiodo)arenes. This method avoids the use of gaseous chlorine and is relatively safe and inexpensive.

The optimum reaction conditions were investigated using the reaction of iodobenzene with various chlorides (LiCl, NaCl, and HCl) and CAN as the oxidant. The

$$2(\mathsf{NH}_4)_2[\mathsf{Ce}(\mathsf{NO}_3)_6] + 2\mathsf{HCI} + 12\mathsf{H}_2\mathsf{O} \longrightarrow \mathsf{Cl}_2 + 2\mathsf{Ce}(\mathsf{NO}_3)_3 \cdot \mathsf{6H}_2\mathsf{O} + 4\mathsf{NH}_4\mathsf{NO}_3 + 2\mathsf{HNO}_3$$

$$Arl \xrightarrow{(\mathsf{NH}_4)_2[\mathsf{Ce}(\mathsf{NO}_3)_6]}_{\mathsf{Arl}} \qquad Arl\mathsf{Cl}_2$$

$$Arl \mathsf{Cl}_2$$

$$r. t., stir$$

Scheme 2. Synthesis of (dichloroiodo)arenes using CAN.

combination of LiCl or NaCl with CAN in acetic acid or CCl₄ resulted in poor yield for the oxidative conversion of iodobenzene to PhICl₂. When CAN (10 mmol) was added to a stirred solution of iodobenzene (5 mmol) and aqueous HCl [made by mixing concentrated HCl (10 mL) and H₂O (20 mL)] in acetic acid, the resulting orange solution gradually turned dark yellow with the clean precipitation of product within 1 h. Filtration of the reaction mixture followed by petroleum ether wash resulted in the formation of PhICl₂ (mp 108–109 °C, lit.^[12a] 110–111 °C) in 92% yield with 94% HPLC purity. The absence of either water or acetic acid in the reaction mixture led to the poor yield of PhICl₂.

Having succeeded with iodobenzene, the methodology was extended to a wide range of iodoarenes possessing electron-withdrawing and electron-donating groups. The results are summarized in Table 1. In all the cases, the reactions were completed in 1 h with good to excellent yields of yellow solid crystalline (dichloroiodo)arenes. The reaction was successful for the iodoarenes with electron-withdrawing groups such as nitro. The synthesis of recyclable chlorinating agents such as 4,4'-bis(dichloroiodo)biphenyl and 3-(dichloroiodo)benzoic acid was also accomplished by the reaction of 4, 4'-diiodobiphenyl and 3-iodobenzoic acid respectively (Table 1, entries 2j and 2n) with appropriate stoichiometric ratio of CAN and aqueous HCl. Confirmation for the structures of all (dichloroiodo)arenes was established by comparison

Entry	Substrate ArI 1	Product ArICl ₂ 2	Yield (%) ^{<i>a</i>}	Mp (°C)	Lit. mp (°C)
a	C ₆ H ₅ I	C ₆ H ₅ ICl ₂	92	108-109	110-111 ^[12a]
b	2-CH ₃ C ₆ H ₄ I	2-CH ₃ C ₆ H ₄ ICl ₂	85	88-89	89–90 ^[19]
с	3-CH ₃ C ₆ H ₄ I	3-CH ₃ C ₆ H ₄ ICl ₂	87	100-102	97–98 ^[12a]
d	4-CH ₃ C ₆ H ₄ I	4-CH ₃ C ₆ H ₄ ICl ₂	83	105-107	108-111 ^[12a]
e	4-CH ₃ OC ₆ H ₄ I	$4-CH_3OC_6H_4ICl_2^b$	69	72–74	75–76 ^[12a]
f	3-ClC ₆ H ₄ I	3-ClC ₆ H ₄ ICl ₂	76	97–98	96–98 ^[12a]
g	4-ClC ₆ H ₄ I	4-ClC ₆ H ₄ ICl ₂	89	108-110	110-112 ^[12a]
h	3-BrC ₆ H ₄ I	3-BrC ₆ H ₄ ICl ₂	88	129-131	
i	4-BrC ₆ H ₄ I	4-BrC ₆ H ₄ ICl ₂	90	121-123	123-124 ^[15]
i	4, 4'-(C_6H_4I) ₂	4, 4'-($C_6H_4ICl_2$) ₂	76	159-161	156-158 ^[7]
k	$2-NO_2C_6H_4I$	$2-NO_2C_6H_4ICl_2$	68	92-93	92–94 ^[12a]
1	3-NO ₂ C ₆ H ₄ I	3-NO ₂ C ₆ H ₄ ICl ₂	73	91–93	94–95 ^[12a]
m	$4-NO_2C_6H_4I$	$4-NO_2C_6H_4ICl_2$	69	173-174	175-176 ^[15]
n	3-HO ₂ CC ₆ H ₄ I	3-HO ₂ CC ₆ H ₄ ICl ₂	75	182–184	183–185 ^[7]

 Table 1. Preparation of (dichloroiodo)arenes from iodoarenes using ceric ammonium nitrate and aqueous

 HCl at room temperature

^{*a*}Isolated yields.

^bUnstable yellow solid.

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of ¹H NMR spectra of the corresponding iodoarenes. The melting points of all the products (dichloroiodo)arenes, agreed well with the literature data.

Mechanistically, the reaction of CAN with aqueous HCl generates in situ molecular chlorine, which is responsible for the oxidative conversion of iodoarenes to (dichloroiodo)arenes. CAN was not observed to oxidize iodoarenes directly to iodine(III) species.

CONCLUSION

In conclusion, we have developed a general and efficient method for the synthesis of (dichloroiodo)arenes from iodoarenes in dilute hydrochloric acid solution using CAN as an oxidant and acetic acid as a cosolvent (biphasic system). This method is operationally simple because it avoids the use of toxic and corrosive gaseous chlorine. The products, (dichloroiodo)arenes, are formed in excellent purity with good yields in short reaction times (1 h).

EXPERIMENTAL

Representative Experimental Procedure

CAN (5.48 g, 10 mmol) was portionwise added to a stirred solution of iodoarenes (5 mmol) in a mixture of glacial AcOH (10 mL) and dilute HCl [made by mixing concentrated HCl (10 mL) and H₂O (20 mL)]. The progress of the reaction was followed by thin-layer chromatography (TLC). The mixture was stirred at room temperature for 1 h. The resulting orange solution gradually formed a yellow precipitate of solid product. The yellow precipitate was collected by filtration and washed well with ice-cold water (until the washings were colorless and neutral) and then with petroleum ether. The resulting product, (dichloroiodo)arene was obtained in excellent purity subsequently air dried in the dark. The melting points of all the products were determined immediately to avoid any probable decomposition.

(Dichloroiodo)benzene (2a)

¹H NMR (DMSO, 400 MHz): δ 7.18 (t, 1H, J = 7.6 Hz, ArH), 7.39 (t, 3H, J = 7.2 Hz, ArH), 7.73 (d, 1H, J = 7.6 Hz, ArH). ¹³C NMR (CDCl₃, 100 MHz): δ 125.36, 131.62, 132.16, 133.87.

2-Methyl(dichloroiodo)benzene (2b)

¹H NMR (CDCl₃, 400 MHz): δ 2.42 (s, 3H, ArCH₃), 6.85–6.87 (m, 1H, ArH), 7.23 (d, 2H, J = 6.8 Hz, ArH), 7.79 (d, 1H, J = 8 Hz, ArH).

3-Methyl(dichloroiodo)benzene (2c)

¹H NMR (CDCl₃, 400 MHz): δ 2.43 (s, 3H, ArCH₃), 7.33–7.4 (m, 2H, ArH), 7.96–7.99 (m, 2H, ArH).

4-Methyl(dichloroiodo)benzene (2d)

¹H NMR (CDCl₃, 400 MHz): δ 2.46 (s, 3H, ArCH₃), 7.27 (d, 2H, J = 8 Hz, ArH), 8.04 (d, 2H, J = 8 Hz, ArH). ¹³C NMR (CDCl₃, 100 MHz): δ 21.45, 122.03, 132.35, 133.87, 137.23.

3-Chloro(dichloroiodo)benzene (2f)

¹H NMR (CDCl₃, 400 MHz): δ 7.42 (t, 1H, J = 8.2 Hz, ArH), 7.57 (d, 1H, J = 7.6 Hz, ArH), 8.09 (d, 1H, J = 7.6 Hz, ArH), 8.19 (s, 1H, ArH).

4-Chloro(dichloroiodo)benzene (2g)

¹H NMR (CDCl₃, 400 MHz): δ 7.45 (d, 2H, J = 8.8 Hz, ArH), 8.11 (d, 2H, J = 9.2 Hz, ArH). ¹³C NMR (DMSO, 100 MHz): δ 91.05, 130.04, 133.36, 138.23.

3-Bromo(dichloroiodo)benzene (2h)

¹H NMR (CDCl₃, 400 MHz): δ 6.97 (t, 1H, J = 8 Hz, ArH), 7.46 (d, 1H, J = 8 Hz, ArH), 7.63 (d, 1H, J = 7.6 Hz, ArH), 7.87 (s, 1H, ArH).

4-Bromo(dichloroiodo)benzene (2h)

¹H NMR (CDCl₃, 400 MHz): δ 7.61 (d, 2H, J = 9.6 Hz, ArH), 8.04 (d, 2H, J = 8.4 Hz, ArH). ¹³C NMR (DMSO, 100 MHz): δ 93.44, 123.01, 134.4, 140.03.

1, 4-Bis(dichloroiodo)benzene (2i)

¹H NMR (CDCl₃, 400 MHz): δ 7.79 (d, 2H, J = 8.8 Hz, ArH), 7.88 (d, 2H, J = 8.8 Hz, ArH).

4,4'-Bis(dichloroiodo)biphenyl (2k)

¹H NMR (CDCl₃, 400 MHz): δ 7.27 (d, 4H, J = 8 Hz, ArH), 7.76 (d, 4H, J = 8.4 Hz, ArH).

2-Nitro(dichloroiodo)benzene (2I)

¹H NMR (CDCl₃, 400 MHz): δ 7.26 (t, 1H, J = 8.8 Hz, ArH), 7.49 (t, 1H, J = 8.4 Hz, ArH), 7.86 (d, 1H, J = 8 Hz, ArH), 8.03 (d, 1H, J = 8 Hz, ArH). ¹³C NMR (CDCl₃, 100 MHz): δ 86.24, 125.46, 129.07, 133.41, 141.93.

3-Nitro(dichloroiodo)benzene (2m)

¹H NMR (CDCl₃, 400 MHz): δ 7.29 (t, 1H, J = 8 Hz, ArH), 8.03 (d, 1H, J = 7.6 Hz, ArH), 8.21 (d, 1H, J = 7.6 Hz, ArH), 8.57 (s, 1H, ArH).

4-Nitro(dichloroiodo)benzene (2n)

¹H NMR (CDCl₃, 400 MHz): δ 7.90 (d, 2H, J = 9.2 Hz, ArH), 7.95 (d, 2H, J = 9.2 Hz, ArH). ¹³C NMR (DMSO, 100 MHz): δ 102.62, 124.33, 138.21, 147.14

3-(Dichloroiodo)benzoic Acid (2p)

¹H NMR (CDCl₃, 400 MHz): δ 7.23 (t, 1H, J = 8 Hz, ArH), 7.95 (d, 2H, J = 8 Hz, ArH), 8.08 (d, 2H, J = 8 Hz, ArH), 8.45 (s, 1H, ArH). ¹³C NMR (DMSO, 100 MHz): δ 94.09, 129.23, 130.4, 133.18, 138.89, 141.72, 167.26.

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REFERENCES

- Varvoglis, A. The Organic Chemistry of Polycoordinated Iodine; VCH Publishers, Inc.: New York, NY, USA, 1992; Chap 6 p. 99.
- 2. Zanka, A.; Takeuchi, H.; Kubota, A. Org. Proc. Res. Dev. 1998, 4, 270.
- (a) Shellhamer, D. F.; Oakes, M. L. J. Org. Chem. 1978, 43, 1316; (b) Dolbier, W. R.; Garza, O. T. J. Org. Chem. 1978, 43, 3848.
- (a) Formo, M. W.; Johnson, J. R. Org. Synth. Coll. 1955, 3, 486; (b) Beringer, F. M.; Lillien, I. J. Am. Chem. Soc. 1960, 82, 725; (c) Carpenter, W. J. Org. Chem. 1966, 31, 2688; (d) Taylor, R. T.; Stevenson, T. A. Tetrahedron Lett. 1988, 29, 2033.
- 5. Willgerodt, C. Die organischen Verbindungen mit mehrwertigem Jod; Enke Verlag: Stuttgart, Germany, 1914.
- 6. Willgerodt, C. J. Prakt. Chem. 1886, 33, 154.
- 7. Yusubov, M. S.; Drygunova, L. A.; Zhdankin, V. V. Synthesis 2004, 2289.
- 8. Šket, B.; Zupan, M.; Zupet, P. Tetrahedron 1984, 40, 1603.
- Podgoršek, A.; Jurisch, M.; Stavber, S.; Zupan, M.; Iskra, J.; Gladysz, J. A. J. Org. Chem. 2009, 74, 3133.
- 10. Podgoršek, A.; Zupan, M.; Iskra, J. Angew. Chem., Int. Ed. 2009, 48, 8424.
- 11. Skulski, L. Molecules 2000, 5, 1331.
- (a) Kazmierczak, P.; Skulski, L.; Obeid, N. J. Chem. Res., Synop. 1999, 64; (b) Obeid, N.; Skulski, L. Molecules 2001, 6, 869.
- 13. Obeid, N.; Skulski, L. Pol. J. Chem. 2000, 74, 1609.
- Baranowski, A.; Plachta, D.; Skulski, L.; Klimaszewska, M. J. Chem. Res., Synop. 2000, 435.
- 15. Krassowska-Swiebocka, B.; Prokopienko, G.; Skulski, L. Synlett. 1999, 1409.
- 16. Zhao, X. F.; Zhang, C. Synthesis 2007, 551.
- 17. Podgorsek, A.; Iskra, J. Molecules 2010, 15, 2857.
- 18. Koyuncu, D.; Mckillop, A.; Mclaren, L. J. Chem. Res., Synop. 1990, 21.
- 19. Zielinska, A.; Skulski, L. Tetrahedron Lett. 2004, 45, 1087.
- (a) Nair, V.; Deepthi, A. Chem. Rev. 2007, 107, 1862; (b) Nair, V.; Panicker, S. B.; Nair, L. G.; George, T. G.; Augustine, A. Synlett. 2003, 2, 156; (c) Molander, G. A. Chem. Rev. 1992, 92, 29.

- (a) Roy, S. C.; Guin, C.; Rana, K. K.; Maiti, G. Synlett 2001, 226; (b) Rodriguez-Franko, M. I.; Dorronsoro, I.; Higueras, A. I. H.; Antequera, G. Tetrahedron Lett. 2001, 42, 863.
- (a) Karade, N. N.; Gampawar, S. V.; Kondre, J. M.; Tiwari, G. B. *Tetrahedron Lett.* 2008, 49, 6698; (b) Karade, N. N.; Gampawar, S. V.; Kondre, J. M.; Shinde, S. V. *Tetrahedron Lett.* 2008, 49, 4402; (c) Karade, N. N.; Gampawar, S. V.; Tale, N. P.; Kedar, S. B. *J. Heterocycl. Chem.* 2010, 47, 740.