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A solvent-free synthesis of (dichloroiodo)arenes from iodoarenes

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Abstract—An efficient solid-state oxidation of iodoarenes, ArI, is described using the urea–hydrogen peroxide adduct (UHP), a stable, inexpensive, and easily handled oxidant. The reactions were complete in 15 min at 85 °C. The melts thus obtained were reacted with excess hydrochloric acid to afford crude (dichloroiodo)arenes, $ArICl_2$, in 64–98% yields.

1. Introduction

(Dichloroiodo)arenes, $ArICl_2$, have found growing importance in modern organic synthesis.[1] More stable, solid (dichloroiodo)arenes, for example, (dichloroiodo)benzene $PhICl_2$, are used as potent and fairly selective chlorinating and/or oxidizing agents. They have a practical advantage over elemental chlorine (dichlorine), due to their easy and safe handling. Moreover, they can be readily converted to other important organic hypervalent iodine reagents, which also play an important role in organic synthesis, viz. iodosylarenes, iodylarenes, (diacyloxyiodo)arenes, (difluoroiodo)arenes, or diaryliodonium salts, etc.[1]

(Dichloroiodo)arenes are yellow crystalline compounds, are light and heat sensitive and often unstable on storing. They do not usually give satisfactory microanalyses and due to their thermal liability, their melting points are rather *uncertain*, depending upon the purity of the crude products prepared, the time elapsed since their preparation, and the rate of heating during determinations of their melting/decomposition points.

In 1886, Willgerodt developed the most common method up to now for preparing $ArICl_2$, by passing a stream of Cl_2 through solutions of ArI dissolved in $CHCl_3$, at 0 °C; the yields are generally excellent when this method is applicable.[2] Quite recently, the repeated preparations of $PhICl_2$ (in 94% crude yield) on a 20 kg scale have been conducted by the direct chlorination of PhI (dissolved in CH_2Cl_2), at −3 to +4 °C. Furthermore it was possible to selectively monochlorinate 4-aminoacetophenone with crude $PhICl_2$ on a 25 kg scale, in 87% yield.[3]

The *inconvenient* use of hazardous gaseous Cl_2 to afford $ArICl_2$ from ArI can be avoided using a number of biphasic or monophasic procedures. They are related and discussed in our two latest reviews,[4,5] which cover in particular the novel methods devised in our laboratory; see Ref. 4, pp 1346–1352. Most of the reported methods demand the use of iodoarenes, ArI, as the starting substrates, which are *oxidatively chlorinated* at their iodine atoms. In 2001, we published two papers, where we reported relatively simple, two- or three-stage procedures for the *one-pot* conversions of various arenes, ArH, to the corresponding (dichloroiodo)arenes, which were obtained in high crude yields.[6,7]

In 1999, Varma and Naicker[8] reported an efficient *solid-state oxidation* of hydroxylated aldehydes and ketones (to hydroxylated phenols), sulfides (to sulfoxides or sulfones), nitriles (to amides), and nitrogen heterocycles (to N-oxides). The starting materials were added to the finely powdered urea–hydrogen peroxide adduct (UHP) in glass test tubes, and the reaction mixtures were placed in an oil bath at 85 °C for 7–180 min. The resulting reaction mixtures were extracted and typically further worked up to afford the crude products, which were purified by chromatography. The authors[8] emphasized that this *solvent-free* oxidative protocol using an inexpensive (commercially available), safe, and easily handled reagent, viz. UHP, was a simple and efficient

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Keywords: Solid-state oxidation; Urea–hydrogen peroxide adduct as oxidant; Iodoarenes; (Dichloroiodo)arenes.

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protocol, applicable to a variety of organic molecules. The operational simplicity, rapid reaction rates, and formation of pure products in high yields at a moderate temperature make their method superior to many existing protocols. Hence, we have decided to apply this method to oxidize ArI with solid UHP (used in 100% excess; larger excesses did not increase the yields), at 85 °C for 15 min, to obtain *composite mixtures* of urea with iodosylarenes, ArIO, probably also admixed with iodylarenes, $ArIO_2$ (which may also be formed therein by the thermal disproportionation of ArIO: $2ArIO \rightarrow ArIO_2 + ArI$) (Scheme 1).[1,2]

After cooling, the crushed melts thus obtained were added portionwise to excess concentrated (36%) hydrochloric acid, which resulted in effective formation of the desired (dichloroiodo)arenes (Scheme 2).

After 1 h, the yellow precipitates were isolated by filtration, then washed on the filter with water and *petroleum ether* (*toxic* chlorinated solvents, mostly used in the past, are less effective). After air drying in the dark, their melting/decomposition points were in good agreement with those reported in the literature (Table 1).

$$\text{Ar-I} + [\text{UREA}]\cdots H_2O \xrightarrow{85\,^{\circ}C} \text{ArIO} + [\text{UREA}] + H_2O$$

$$\text{Ar-I} + 2[\text{UREA}]\cdots H_2O \xrightarrow{85\,^{\circ}C} ArIO_2 + 2[\text{UREA}] + 2H_2O$$

Scheme 1.

In our opinion, the novel effective approach, presented in this paper, for the simple, quick, and safe synthesis of (dichloroiodo)arenes from iodoarenes is worthy of mention. Good crude yields (64–98%) and high purities (96–99%, by iodometry[9]) of the (dichloroiodo)arenes thus obtained (Table 1) support our opinion.

2. Experimental

2.1. General

All the reagents were purchased from Aldrich and were used without further purification. The melting/decomposition points of the *freshly prepared* (dichloroiodo)arenes (Table 1) are uncorrected and were measured as follows: after an approximate mp had been taken in an open capillary tube, a new sample was introduced about 10 °C below this point, and the temperature was raised at a rate of 10 °C min^{-1}, until consistent results were obtained.

2.2. Typical procedure

Iodoarene (4 mmol) was added to finely powdered UHP, 98% (768 mg, 8.0 mmol; 100% excess) in a glass test tube, and the uniformly dispersed (by shaking) reaction mixture was placed in an oil bath at 85 °C for 15 min. After cooling, the crushed melt was added portionwise, with stirring, to excess concd (36%) hydrochloric acid (75 mL,

$$\text{ArIO} + \text{conc. aq. HCl } \textit{(in excess)} \longrightarrow \downarrow \mathbf{ArICl_2} + H_2O \qquad \text{(see Refs. 1, 2)}$$

$$ArIO_2 + \text{conc. aq. HCl } \textit{(in excess)} \longrightarrow \downarrow \mathbf{ArICl_2} + 2H_2O + Cl_2 \qquad \text{(see Ref. 2, p 36)}$$

Scheme 2.

Table 1. Crude yields and melting points (with decomposition) of the (dichloroiodo)arenes prepared

Substrate	Product	Yield (%)	Mp (°C)	Literature mp (°C)
C_6H_5I	$C_6H_5ICl_2$	87[a]	111–112	112–113[7]
2-MeC_6H_4I	2-$MeC_6H_4ICl_2$	91	89–90	88[12]
3-MeC_6H_4I	3-$MeC_6H_4ICl_2$	88	97–98	97–98[11]
4-MeC_6H_4I	4-$MeC_6H_4ICl_2$	96	93–95	97–98[6]
2,4-$Me_2C_6H_3I$	2,4-$Me_2C_6H_3ICl_2$	73	89–91	90[10]
2-$MeOC_6H_4I$	2-$MeOC_6H_4ICl_2$[b]	82	68	63[10]
3-$MeOC_6H_4I$	3-$MeOC_6H_4ICl_2$[b]	74	70–71	74[10]
4-$MeOC_6H_4I$	4-$MeOC_6H_4ICl_2$[b]	88	72	75–76[7]
2-FC_6H_4I	2-$FC_6H_4ICl_2$	78	79–80	Not reported
4-FC_6H_4I	4-$FC_6H_4ICl_2$	90	104–105	104.5–105[11]
2-ClC_6H_4I	2-$ClC_6H_4ICl_2$	78	98–100	92.5–95[11]
3-ClC_6H_4I	3-$ClC_6H_4ICl_2$	69	98	96–97[11]
4-ClC_6H_4I	4-$ClC_6H_4ICl_2$	84	113–115	110–112[7]
2,4-$Cl_2C_6H_3I$	2,4-$Cl_2C_6H_3ICl_2$	64	95–97	93–95[7]
4-IC_6H_4I	4-$IC_6H_4ICl_2$	91	133–135	126–129, 136–138[7]
4-$O_2NC_6H_4I$	4-$O_2NC_6H_4ICl_2$	67	173–175	172[10]
2-$HOOCC_6H_4I$	2-$HOOCC_6H_4ICl_2$[b]	98	100–102	100–114[13]
3-$HOOCC_6H_4I$	3-$HOOCC_6H_4ICl_2$	92	184–186	183–185[7]
4-$HOOCC_6H_4I$	4-$HOOCC_6H_4ICl_2$	96	267–269	267[14]

[a] When we increased the preparative scale 10-fold, the crude yield was the same; mp 111–112 °C (dec), purity 98%.

[b] The compounds were unstable, and quickly decomposed on standing, even in a freezer; cf. Ref. 12.

ca. 850 mmol) in a fume hood. After 1 h, the yellow precipitate was collected by filtration, washed well with water (to remove HCl and urea) and petroleum ether (2×10 mL, to remove any unreacted ArI), and air dried in the dark. Iodometric titrations[9] indicated that the *freshly prepared* crude $ArICl_2$ had a 96–99% purity.

References and notes

1. (a) Varvoglis, A. *The Organic Chemistry of Polycoordinated Iodine*; VCH: Weinheim, 1992; (b) Stang, P. J.; Zhdankin, V. V. *Chem. Rev.* **1996**, *96*, 1123–1178; (c) Varvoglis, A. *Hypervalent Iodine in Organic Synthesis*; Academic: San Diego, 1997; (d) Zhdankin, V. V.; Stang, P. J. *Chem. Rev.* **2002**, *102*, 2523–2584; (e) *Hypervalent Iodine Chemistry*; Wirth, T., Ed.; Springer: Ijmuiden, Netherland, 2003; Vol. 224; (f) Stang, P. J. *J. Org. Chem.* **2003**, *68*, 2997–3008.
2. Willgerodt, C. *Die organischen Verbindungen mit mehrvertigem Jod*; Enke: Stuttgart, 1914.
3. Zanka, A.; Takeuchi, H.; Kubota, A. *Org. Process Res. Dev.* **1998**, *2*, 270–273.
4. Skulski, L. *Molecules* **2000**, *5*, 1331–1371.
5. Skulski, L. *Molecules* **2003**, *8*, 45–52.
6. Obeid, N.; Skulski, L. *Molecules* **2001**, *6*, 869–874.
7. Lulinski, P.; Obeid, N.; Skulski, L. *Bull. Chem. Soc. Jpn.* **2001**, *74*, 2433–2434.
8. Varma, R. S.; Naicker, K. P. *Org. Lett.* **1999**, *1*, 189–191.
9. Lucas, H. J.; Kennedy, E. R.; Formo, M. W. *Org. Synth.* **1942**, *22*, 70.
10. Beringer, F. M.; Gindler, E. M. *Iodine Abstr. Rev.* **1956**, *3*, 1–70.
11. Obeid, N.; Skulski, L. *Pol. J. Chem.* **2000**, *74*, 1609–1615.
12. Koyuncu, D.; McKillop, A.; McLaren, L. *J. Chem. Res. (S)* **1990**, 21.
13. Karele, B. Ya.; Neiland, O. Ya. *Latv. PSR Zinat. Akad. Vestis, Kim. Ser.* **1970**, 587–590; *Chem. Abstr.* **1971**, *74*, 42033.
14. Keefer, R. M.; Andrews, L. J. *J. Am. Chem. Soc.* **1958**, *80*, 277–281.