

One-Pot Preparations of (Dichloroiodo)arenes from Some Arenes

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Arenes (ArH) were substituted with some transient I^{3+} species, generated in situ in appropriate, *anhydrous* $I_2/NaIO_4$ or $NaIO_3/AcOH/Ac_2O/concd\ H_2SO_4$ mixtures, to form soluble organoiodine(III) intermediates, $ArISO_4$. Next, excess *concd* hydrochloric acid was added to precipitate out the title $ArICl_2$, and isolated in 46–88% optimized crude yields.

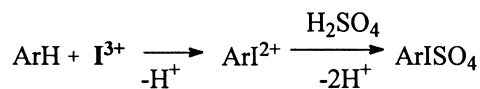
(Dichloroiodo)arenes ($ArICl_2$) have been finding growing importance in organic synthesis as moderate and selective chlorinating and/or oxidizing agents. Moreover, they may be converted to other important hypervalent iodine reagents, e.g. $ArIO$, $ArIO_2$, $ArI(OAc)_2$, diaryliodonium salts, etc.^{1,2}

$ArICl_2$, yellow crystalline compounds, are light- and heat-sensitive and often unstable to be stored; some more stable $ArICl_2$, e.g. $PhICl_2$, may be stored in a cooler for a few days. They do not usually give satisfactory microanalyses, and their melting/decomposition points are uncertain, depending upon the purity of their freshly prepared batches, the time elapsed since their preparation, and the rate of heating.^{1–3}

In 1886 Willgerodt³ developed the most common method up to now for preparing $ArICl_2$, by passing a stream of Cl_2 through solutions of ArI in $CHCl_3$. Recently, Japanese industrial chemists⁴ repeatedly produced $PhICl_2$ from PhI (in 94% crude yield) on a 20 kg scale using the classic Willgerodt method.³

In order to avoid any hazardous use of gaseous Cl_2 to afford $ArICl_2$ from ArI , a number of various either *two-phase* ($CCl_4/concd\ aq\ HCl$) or monophasic *liquid-phase* methods were reported.^{1,2} A full account of all those methods is given in our latest review (Ref. 2, pp. 1346–1352).

However, all former methods^{1–4} demanded the application of *costly* iodoarenes (ArI) as the starting substrates, to be subsequently chlorinated at their iodine atoms. In this paper we present a quite novel, one-pot (two-stage) method for preparing eleven $ArICl_2$ from the corresponding **arenes** (ArH), used by us as the starting substrates (Table 1). ArH were at first, oxidatively substituted in *anhydrous* $I_2/NaIO_4$ or $NaIO_3/AcOH/Ac_2O/concd\ H_2SO_4$, mixtures (*vide infra*) with some transient *iodine(III)* species, I^{3+} , to form in situ the respective organoiodine(III) intermediates, $ArISO_4$ (Scheme 1).



Scheme 1.

Next, excess *concd* (36%) hydrochloric acid was added to the resulting (final) reaction mixtures, containing soluble $ArISO_4$ intermediates, to precipitate out the corresponding $ArICl_2$, isolated in 46–88% crude yields (Scheme 2).



Scheme 2.

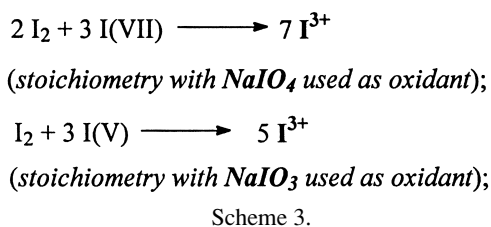
Table 1. Yields (possibly optimized) and Melting Points (with decomposition) of Crude (Dichloroiodo)arenes Prepared from Arenes, as well as Four Variable Reactions Parameters (*cf.* Ref. 5)

Substrate, ArH	Product, $ArICl_2$ ^{a)}	Yield/%	Oxidant	Concd H_2SO_4 ^{b)}	Time/h; Temp/°C ^{c)}	Mp/°C	Lit, mp/°C
PhH	$PhICl_2$	88	$NaIO_4$	1.07 mL; 20 mmol	2, r.t.	112–113	111–112 ⁸
PhH	$PhICl_2$	87	$NaIO_3$	4.26 mL; 80 mmol	2, r.t.	111–112	111–112 ⁸
PhF	4- $FC_6H_4ICl_2$	70	$NaIO_4$	2.13 mL; 40 mmol	2, r.t.	105–106	106–107 ⁸
PhCl	4- $ClC_6H_4ICl_2$	70	$NaIO_4$	2.13 mL; 40 mmol	2, r.t.	110–112	110–112 ⁸
PhBr	4- $BrC_6H_4ICl_2$	75	$NaIO_4$	2.13 mL; 40 mmol	2, r.t.	119–122	123–124 ⁷
PhBr	4- $BrC_6H_4ICl_2$	63	$NaIO_3$	4.26 mL; 80 mmol	2, r.t.	123–126	123–124 ⁷
PhI	4- $IC_6H_4ICl_2$	81	$NaIO_4$	3.20 mL; 60 mmol	2, r.t.	126–129	136–138 ⁷
$PhCO_2H$	3- $HO_2CC_6H_4ICl_2$	86	$NaIO_4$	4.26 mL; 80 mmol	3, r.t.	185–186	183–185 ⁸
$PhCO_2H$	3- $HO_2CC_6H_4ICl_2$	80	$NaIO_3$	5.33 mL; 100 mmol	2, r.t.	183–185	183–185 ⁸
$PhCO_2Me$	3- $MeO_2CC_6H_4ICl_2$	69	$NaIO_4$	4.26 mL; 80 mmol	3, r.t.	117–118	108–110 ⁸
$PhCO_2Me$	3- $MeO_2CC_6H_4ICl_2$	64	$NaIO_3$	5.33 mL; 100 mmol	2, r.t.	117–118	108–110 ⁸
$PhCO_2Et$	3- $EtO_2CC_6H_4ICl_2$	74	$NaIO_4$	4.26 mL; 80 mmol	3, r.t.	102–103	98–100 ⁸
$PhCF_3$	3- $F_3CC_6H_4ICl_2$	57	$NaIO_4$	7.99 mL; 150 mmol	1, r.t.; 3, 65	85–87	81–83 ¹⁰
$PhOMe$	4- $MeOC_6H_4ICl_2$	57	$NaIO_4$	0.27 mL; 5 mmol	0.5, r.t.; 2, 60	75–76	75–76 ⁸
1,3- $Cl_2C_6H_4$	2,4- $Cl_2C_6H_3ICl_2$	46	$NaIO_4$	4.26 mL; 80 mmol	2, r.t.	93–95	96–98 ⁸

a) Satisfactory homogeneities of the crude $ArICl_2$ were checked with TLC, after their reduction to the corresponding iodoarenes.

b) The amount of *concd* H_2SO_4 added dropwise to each of the cooled and stirred reaction mixtures. c) Time of stirring the individual reaction mixture at given temperature to complete the iodination reaction, *after* the addition of *concd* H_2SO_4 .

To explain the present method, it is necessary to recall our former paper;⁵ alternatively, see our review,² p. 1337, where the supposed structures of the I^{3+} species and $ArISO_4$ intermediates are also shown and explained. In our former work,⁵ we oxidatively substituted halobenzenes and deactivated arenes in *anhydrous* liquid systems, $I_2/NaIO_4$ or $NaIO_3/AcOH/Ac_2O/concd\ H_2SO_4$, in which the said transient species, I^{3+} , played a predominant role in electrophilic substitutions of the reacted arenes, ArH . These species were generated there as Scheme 3.



Next, the said strongly electrophilic I^{3+} species readily substituted ArH (Scheme 1). After pouring the resulting reaction mixtures into excess aq. Na_2SO_3 solutions, the corresponding *iodoarenes* were afforded: $ArISO_4 + Na_2SO_3 + H_2O \rightarrow ArI + Na_2SO_4 + H_2SO_4$. Alternatively, the same resulting reaction mixtures were reacted upon with excess aq ammonium acetate solutions to afford (*diacetoxyiodo*)arenes:^{2,6} $ArISO_4 + 2AcONH_4 \rightarrow ArI(OAc)_2 + (NH_4)_2SO_4$. Consequently, in the present work we added excess *concd* (36%) hydrochloric acid to the same resulting (final) reaction mixtures to precipitate out the corresponding (*dichloroiodo*)arenes, $ArICl_2$ (Scheme 2). For more details see Experimental and Table 1.

Our novel, *environmentally benign* method for the preparation of crude $ArICl_2$ from the respective *arenes* (Table 1) avoids the hazardous application of gaseous Cl_2 and chlorinated solvents, and the use of *costly* iodoarenes, previously applied as starting substrates for preparing $ArICl_2$. Strongly acidic wastes obtained in the present method, after their neutralization and dilution, did *not* contain any toxic by-products, in contrast to many former methods.^{1,2} Thus, our present method would be particularly suitable for *large-scale preparations* of, for example, (*dichloroiodo*)benzene; cf. Ref. 4. Of course, only those isomeric $RC_6H_4ICl_2$ may predominantly be obtained from the monosubstituted benzenes, RC_6H_5 , which are formed in agreement with common orientation rules in the electrophilic substitutions of the used RC_6H_5 (Table 1) by the said strongly electrophilic I^{3+} transient species (Scheme 1).

Experimental

The melting/decomposition points of crude $ArICl_2$ (Table 1) were uncorrected and were determined as previously described.^{7,8} All commercial reagents and solvents (Aldrich) were purified or dried, if necessary, prior to use. Diiodine was *finely powdered* in order to facilitate its dissolution in the reaction mixtures.

Optimized Procedures for the Preparation of $ArICl_2$ from Arenes, ArH . $NaIO_4$ (1.41 g, 6.6 mmol; 10% excess) [or: $NaIO_3$ (1.43 g, 7.2 mmol; 20% excess)] and I_2 (1.12 g, 4.4 mmol; 10%

excess) [or: I_2 (0.61 g, 2.4 mmol; 20% excess), when $NaIO_3$ was used as an oxidant] were suspended in a stirred mixture of glacial $AcOH$ (10 mL) with Ac_2O (5 mL) cooled to 5 °C. *Varied quantities* (see Table 1) of *concd* (98%) H_2SO_4 were very slowly added dropwise with vigorous stirring while keeping the temperature below 10 °C. An appropriate arene (14 mmol; 0% excess) [or: arene (10 mmol; 0% excess), when $NaIO_3$ was used as an oxidant] was added portionwise or dropwise with stirring. Then, the *notably individualized reaction conditions* shown in Table 1 [i. e. the differentiated times of a further stirring at given temperatures to complete the iodinating reactions] were applied for each of the arenes iodinated (cf. Ref. 5). Dark-brown initial reaction mixtures faded to be finally yellowish. The resulting reaction mixtures, containing optimized quantities of the respective $ArISO_4$ intermediates, were cooled to ca. 5 °C, and *concd* (36%) hydrochloric acid (15 mL, ca. 170 mmol) was added with stirring while keeping the temperature at 5–10 °C. After ca. 30 min, the resulting suspensions were poured into stirred ice-water (ca. 300 g). After 15 min, yellow precipitates were collected by filtration, washed well with ice-cold water, until the filtrates were *neutral*, then with a little CCl_4 , and air-dried⁹ *in the dark*. Their melting points (Table 1) were taken immediately in the way explained in Refs. 7 and 8. The crude yields (Table 1) were calculated from the total amounts of the *arenes*, used in strictly stoichiometric quantities (0% excess). Iodometric titrations³ indicated that the freshly prepared crude $ArICl_2$ had 90–96% purity.

Note. Exceptionally, PhI (3.14 g, 15.4 mmol; 10% excess) was oxidatively iodinated, but with strictly stoichiometric quantities of $NaIO_4$ (1.28 g, 6.0 mmol; 0% excess) and I_2 (1.02 g, 4.0 mmol; 0% excess); see Table 1 for the other reaction parameters. The crude yield for 4- $IC_6H_4ICl_2$ (Table 1) was calculated from the total amount of the *diiodine* consumed.

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