Rapid microwave-promoted solvent-free synthesis of hypervalent iodine reagents

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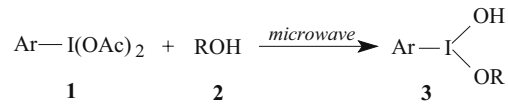
Hypervalent hydroxy(sulfonyloxy)iodoarenes, hydroxy(phosphoryloxy)iodoarenes and bis(trifluoroactoxy)iodobenzene have been synthesised by a fast and convenient solvent-free ligand exchange reaction from the (diacetoxyiodo)arene under microwave irradiation, providing a simple method for the synthesis of these hypervalent iodine reagents in good yield and in a short time.

Keywords: hypervalent iodine reagent, microwave irradiation

Hypervalent iodine reagents have found wide application in organic chemistry and are frequently used in synthesis.[1-3] Because hypervalent iodine reagents are nonmetallic oxidising reagents, they avoid the issues of toxicity of many transition metals that are commonly involved in such processes. Therefore, they have a high potential for the improvement of known reactions not only from an environmental and pharmaceutical point of view, but also as interesting reagents for the development of completely new synthetic transformations. Since many hypervalent iodine reagents have a low solubility in the most ecologically harmful organic solvents and usually need a substantial volume for their reactions, the development of solvent-free reactions is a big step forward and should lead to an increased use of this chemistry. Solvent-free reactions have many advantages including reduced pollution, lower costs and the simplicity of the processes involved.[4] Here we would like to report a fast and convenient solvent-free reaction for the synthesis of hypervalent iodine reagents under microwave irradiation (Scheme 1). To the best of our knowledge this is the first report of a rapid synthesis of hypervalent iodine reagents under microwave irradiation.

Microwave-assisted organic synthesis is a new and quickly growing area in synthetic organic chemistry.[5,6] This technique is based on the empirical observation that some organic reactions proceed much faster and with higher yields under microwave irradiation compared to conventional heating. In many cases reactions that normally require many hours at reflux temperature under classical conditions can be completed within several minutes or seconds in a microwave oven, even



Scheme 1

at comparable reaction temperature. Recently interest has been focused on the use of microwave-irradiated procedures in water as a medium or under solvent-free condition for organic synthesis due to their efficient and environmentally benign conditions.[7,8] In this paper, only iodine (III) reagents have been considered for these reactions because some iodine (V) compounds are known to be shock and pressure sensitive.[9] The iodine (III) reagents described here have been safely used on a millimolar scale.

In our initial investigations, we used (diacetoxyiodo)benzene **1a** (Ar = Ph) as a representative, hypervalent iodine reagent since it is commercially available and can also easily be prepared.[10] Ligand exchange reactions on this compound are known and have been used frequently to prepare other hypervalent iodine reagents.[11] We found that when **1a** was mixed with an equivalent amount of *p*-toluenesulfonic acid monohydrate **2a** and then heated in a glass tube in a microwave oven for only 20 seconds, the ligand exchange reaction was completed and a yield of 98% [hydroxyl(tosyloxy)iodo]benzene **3a** (Koser's reagent) was obtained. This is usually prepared in an organic solvent such as CH_2Cl_2 or CH_3CN.[12] This result prompted us to investigate further the solvent-free reactions of (diacetoxyiodo)arenes **1** with sulfonic acids, dialkyl phosphates

Table 1 The results of the synthesis of hypervalent iodine reagents

Entry	**1**: Ar	**2**: R	Product **3**	Yield/%[a]
1	Ph **1a**	*p*-Me-$C_6H_4SO_2$ **2a**	**3a**	98
2	**1a**	$MeSO_2$ **2b**	**3b**	93
3	**1a**	(1*R*)-10-camphory- sulfonyl **2c**	**3c**	94
4	**1a**	$(PhO)_2PO$ **2d**	**3d**	91
5	**1a**	$(PhCH_2O)_2PO$ **2e**	**3e**	90
6	**1a**	CF_3CO **2f**	**3f**	71
7	4-Cl-C_6H_4 **1b**	**2a**	**3g**	97
8	**1b**	**2d**	**3h**	94
9	2-Toluene **1c**	**2a**	**3i**	95

[a]Isolated yield

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and trifluoroacetic acid **2** under microwave irradiation. We found that these similar reactions were usually completed in 20 seconds to afford the corresponding hypervalent iodine reagents in good to excellent yields (Table 1).

It can be seen in Table 1 that, except for the reaction of trifluoroacetic acid **2f** with (diacetoxyiodo)benzene **1a** which gave [bis(trifluoroactoxy)iodo]benzene **3f** in yield of 71%, all the reactions gave provided products in excess of 90% yields. Compared to sulfonic acids, the yields of diphenyl phosphate **3d** and dibenzyl phosphate **3f** produced in the reactions were somewhat lower. All formed hypervalent iodine reagents were characterised by ^{1}H NMR, IR, MS spectra and melting points, which were consistent with the literature data.

In summary, a rapid and convenient method for the formation of hypervalent iodine reagents is afforded by the microwave-promoted solvent-free ligand exchange reaction. It is simple, fast and gives good to excellent yields in synthesis of hypervalent iodine reagents.

Experimental

Melting points were determined on a digital m.p. apparatus and were not corrected. IR spectra were recorded on a FT-170 SX instrument, ^{1}H NMR spectra were measured on a VARIAN-400 spectrometer, and mass spectra were determined on MS-EI instrument (FINNIGAN Trace DSQ) mass spectrometer. Microwave irradiation was carried out with an LWMC-201 domestic microwave oven at full power (650 W). (Diacetoxyiodo)arenes **1** were prepared according to the literature procedures.[10,13] All acids **2** are commercially available.

A typical procedure for synthesis of hypervalent iodine reagents
(Diacetoxyiodo)benzene **1a** (200 mg, 0.62 mmol, 1.0 equiv) and *p*-toluenesulfonic acid monohydrate **2a** (118 mg, 0.62 mmol, 1.0 equiv) were mixed in a 10 ml glass tube. The mixture tube was placed inside in an alumina bath and irradiated for 20 seconds in a microwave oven at full power (650 W). After cooling, the solid residue was washed with ethyl ether (5 ml) and dried under high vacuum to afford [hydroxyl (tosyloxy)iodo]benzene **3a** (238 mg, 98% yield).

[Hydroxy(tosyloxy)iodo]benzene **(3a):** M.p. 133–135 °C (Lit.[12] 135–138 °C); ^{1}H NMR (400 MHz, DMSO-d_6), δ: 2.35 (s, 3H), 7.14 (d, J = 6.4 Hz, 2H), 7.41–7.45 (m, 2H), 7.52–7.54 (m, 1H), 7.57 (d, J = 6.4 Hz, 2H), 8.12 (d, J = 6.4 Hz, 2H); IR (KBr), ν/cm^{-1}: 3045, 1574, 1464, 1444, 1240, 1207.

[Hydroxy[(methysulfonyl)oxy]iodo]benzene **(3b):** M.p.118–120 °C (Lit.[14] 120–122 °C); ^{1}H NMR (400 MHz, DMSO-d_6), δ: 2.39 (s, 3H), 7.56–7.67 (m, 3H), 8.18–8.32 (m, 2H); IR (KBr), ν/cm^{-1}: 3050, 1570, 1468, 1437, 1318, 1230, 1190, 1057.

[Hydroxy[((1R)-10-camphorylsulfonyl)oxy]iodo]benzene **(3c):** M.p. 116–118 °C (Lit.[15] 118–120 °C); ^{1}H NMR (400 MHz, DMSO-d_6), δ: 0.79 (s, 3H), 0.98 (s, 3H), 1.32–1.37 (m, 1H), 1.56–1.62 (m, 1H), 1.88 (d, J = 14.8 Hz, 1H), 1.90–1.96 (m, 1H), 2.03–2.05 (m, 1H), 2.31–2.39 (m, 2H), 2.77 (d, J = 12.0 Hz, 1H), 3.30 (d, J = 12.0 Hz, 1H), 7.45-7.56 (m, 3H), 8.17 (d, J = 6.8 Hz, 2H); IR (KBr), ν/cm^{-1}: 3048, 1735, 1450, 1300, 1250, 1150.

[Hydroxy[(bis(phenyloxy)phosphoryl)oxy]iodo]benzene **(3d):** M.p. 101–103 °C (Lit.[16] 102–105 °C); ^{1}H NMR (400 MHz, $CDCl_3$), δ: 7.05–7.09 (m, 6H), 7.20–7.28 (m, 6H), 7.39–7.42 (m, 1H), 7.89 (d, J = 4.4 Hz, 2H); IR (KBr), ν/cm^{-1}: 3399, 3058, 1743, 1295, 1192.

[Hydroxy[(bis(benzoyloxy)phosphoryl)oxy]iodo]benzene **(3e):** Oil[16]; ^{1}H NMR (400 MHz, DMSO-d_6), δ: 4.74 (d, J = 5.6 Hz, 4H), 7.27–4.34 (m, 10H), 7.49–7.52 (m, 2H), 7.56–7.58 (m, 1H), 8.12 (d, J = 5.6 Hz, 2H); IR (KBr), ν/cm^{-1}: 3369, 3061, 2951, 1268, 1215, 1024.

[Bis(trifluoroactoxy)iodo]benzene **(3f):** M.p. 119–122 °C (Lit.[17] 122–125 °C).; ^{1}H NMR (400 MHz, $CDCl_3$), δ: 7.17–7.22 (m, 2H), 7.74–7.76 (m, 1H), 8.16 (d, J = 8.0 Hz, 2H); IR (film), ν/cm^{-1}: 3420, 1791, 1681, 1471, 1438, 1208, 1142.

[Hydroxy(tosyloxy)iodo]-4-Cl-benzene **(3g):** M.p. 157–159 °C (Lit.[18] 159–161 °C); ^{1}H NMR (400 MHz, $CDCl_3$), δ: 2.33 (s, 3H), 7.08–7.13 (m, 4H), 7.58–7.62 (m, 2H), 7.85 (d, J = 4.0 Hz, 2H); IR (film), ν/cm^{-1}: 3045, 1570, 1454, 1240, 1093, 798.

[Hydroxy[(bis(phenyloxy)phosphoryl)oxy]iodo]-4-Cl-benzene **(3h):** M.p. 95–97 °C; ^{1}H NMR (400 MHz, $CDCl_3$), δ: 7.05–7.11 (m, 6H), 7.16 (d, J = 6.8 Hz, 2H), 7.21–7.26 (m, 4H), 7.73 (d, J = 6.4 Hz, 2H); IR (film), ν/cm^{-1}: 3392, 3063, 1268, 1207, 1109, 1084; EI-MS (*m/z*): 504 (M^+, 100); HRMS: Calcd for $C_{18}H_{15}ClIO_5P$ = 503.9391, found M^+ = 503.9378.

[Hydroxy(tosyloxy)iodo]-2-toluene **(3i):** M.p. 107–109 °C (Lit.[18] 108–110 °C); ^{1}H NMR (400 MHz, $CDCl_3$), δ: 2.27 (s, 3H), 2.43 (s, 3H), 6.92–7.40 (m, 7H), 7.92 (d, J = 6.8 Hz, 1H); ν/cm^{-1}: 3386, 3045, 1567, 1247, 1207, 1115, 1008.

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