Synthesis of Bromo- and Iodohydrins from Deactivated Alkenes by Use of *N*-Bromo- and *N*-Iodosaccharin[‡]

Damijana Urankar,[a] Irena Rutar,[a,b] Barbara Modec,[a] and Darko Dolenc*[a]

Keywords: Bromohydrins / Iodohydrins / Enones / Halogenation

N-Bromo and *N*-iodosaccharin react with electron-deficient alkenes such as α,β-unsaturated ketones, acids, esters and nitriles in aqueous organic solvents, yielding the corresponding halohydrins in good yields. The reactions take place at room temperature, mostly within short reaction times and with high *anti* stereoselectivity.

Introduction

Halohydrins are valuable reaction intermediates that can be transformed into epoxides,[1] ketones[2] and other derivatives.[3–5] Conversely, epoxides are also frequently opened to form halohydrins. This is achieved by the use of hydrogen halides or other reagents.[6–8] Halohydrins can also be synthesized by a variety of methods other than from epoxides, most often by functionalization of alkenes with appropriate reagents including, among others, hypohalous acids or elemental halogens in water,[1,9,10] halogens or halides used together with oxidants,[11–13] interhalogen compounds,[14] iodine(I) compounds (e.g., $I(Py)_2BF_4$),[15] bromates or iodates(V) in combination with $NaHSO_3$.[16] Halohydrins can also be obtained enantioselectively, with the aid of intramolecular or external chiral auxiliaries.[17,18] *N*-Haloamides are also versatile reagents for converting alkenes into the corresponding halohydrins.[9,19–22]

Functionalization of electron-rich double bonds presents no problem, regarding the choice of reagents or reaction times. In contrast, electrophilic additions to electron-poor alkenes might be very slow, or might even not take place at all. In such cases, strongly electrophilic reagents are required. Among the haloamides, the most popular of these are *N*-halosuccinimides, which are moderately reactive, but the electrophilicity of such compounds can be enhanced by replacement of one (or both) carbonyl group(s) with sulfonyl groups. *N*-Halosaccharins belong to one such class of reagents. All four *N*-halosaccharins are known, but their applicability has yet to be fully explored. Although *N*-iodosaccharin was the last to be described in the literature, it has already found some application in the field of iodination of organic compounds.[23,24,25] Introduction of iodine as an electrophile into deactivated alkenes is particularly difficult, and reactive iodination reagents such as *N*-iodosaccharin could prove suitable for this purpose.

This paper describes the results of bromination and iodination of some electron-deficient alkenes (e.g., enones, cyanoalkenes and haloalkenes) by *N*-bromo- and *N*-iodosaccharin (NBSac and NISac) in aqueous or alcoholic media.

Results and Discussion

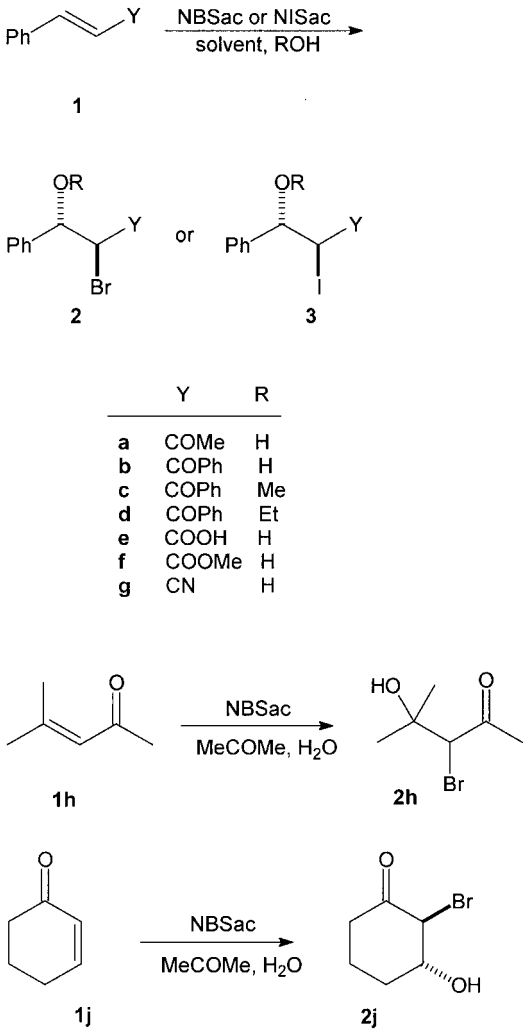
N-Iodo- and *N*-bromosaccharin react with α,β-unsaturated ketones, acids or esters at room temperature in mixtures of acetonitrile or acetone and water, to yield the corresponding halohydrins. The stereochemistry of the addition is predominantly *anti*, so addition to (*E*)-alkenes results in the formation of halohydrins with *erythro* or (mostly) *like* (*l*) configuration.[26] Aqueous acetone reacts slowly with the halogenating agent, thus limiting the applicability of this solvent to relatively fast reactions.[27]

Brominations take place very quickly; the reactions are typically complete within a few minutes at room temperature and concentrations of each reactant of approx. 1 M. The exception is the nitrile (**1g**), which was converted into the corresponding bromohydrin in two days. Brominations of related compounds with *N*-bromosuccinimide (NBS) were reported to be substantially slower.[28] Our preliminary estimation, made by NMR, of the rates of bromination of benzylideneacetone (**1a**) in $[D_4]$MeOH with NBS and with NBSac revealed that the reactivity of the latter is approximately 400 times that of the former. Bromination of benzylideneacetophenone (**1b**) and methyl (*E*)-cinnamate (**1f**) with NBS in 10% excess required approx. 48 hours to achieve the complete conversion of the starting alkene, with a yield comparable to that attained with NBSac.

[‡] Presented in part at the national meeting "Slovenski kemijski dnevi 2002" Maribor, Slovenia, September 2002. Book of abstracts, pp. 197–200.

[a] University of Ljubljana, Faculty of Chemistry and Chemical Technology,
Aškerčeva 5, 1000 Ljubljana, Slovenia
Fax: +386-1-2419-220
E-mail: darko.dolenc@fkkt.uni-lj.si
[b] Present address: Šolski Center Nova Gorica,
Delpinova 9, 5000 Nova Gorica, Slovenia

 DOI: 10.1002/ejoc.200400829



Scheme 1.

Under similar conditions, iodinations are slower, the reactions usually being complete after several hours. Again, related iodinations with *N*-iodosuccinimide are reported to be considerably slower or even not to take place at all.[22]

Iodination of benzylideneacetophenone (**1b**) in methanol or ethanol resulted in the formation of the corresponding α-iodo-β-methoxy(**3c**) or β-ethoxy-α-iodoketone (**3d**).

The melting points of our methoxy (**3c**) and ethoxy (**3d**) compounds differ substantially from the literature values.[29] As there was a minor chance that we had obtained an (*R**,*S**) isomer instead of the expected (*R**,*R**) form, a structure determination of our product **3c** by X-ray diffraction was carried out, confirming that the compound was the (*R**,*R**) isomer.[30]

Bromination of (*E*)-1-bromo-1,2-diphenylethene (**1i**) in acetonitrile/water yielded 2-bromo-1,2-diphenylethanone (**2i**) as the only product.[31] This transformation could be explained by the formation of an unstable bromohydrin (**4i**), which in turn eliminates HBr, forming **2i**.[32]

Aliphatic enones were brominated rapidly, yielding the corresponding α-bromo-β-hydroxyketones. Bromination of cyclohex-2-ene-1-one (**1j**) resulted in the formation of *trans*-

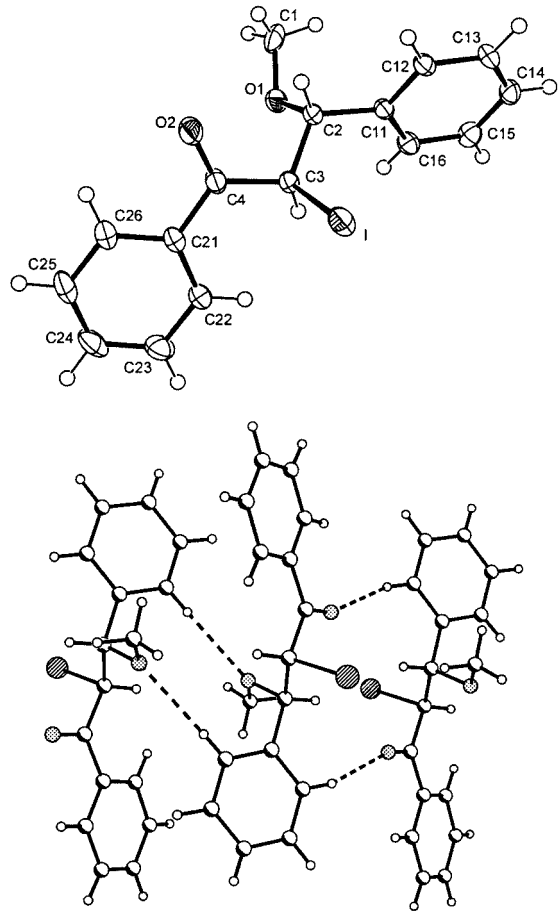
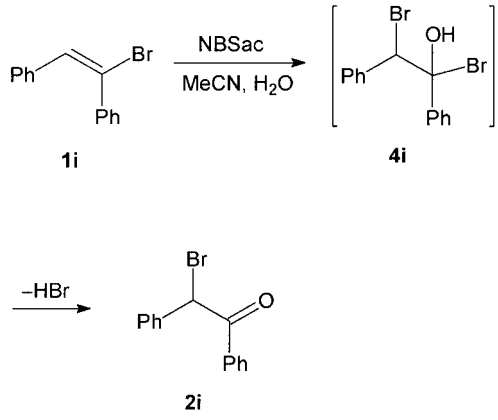
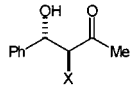
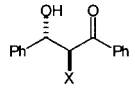
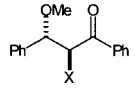
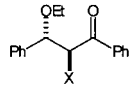
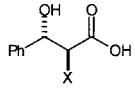
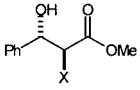
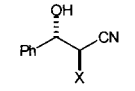
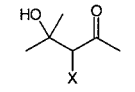
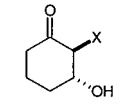


Figure 1. Top: An ORTEP picture of **3c**, drawn with 50% probability displacement ellipsoids and with hydrogen atoms shown as arbitrarily sized spheres. Bottom: The molecules in **3c** are associated by weak hydrogen bonding interactions into infinite chains that propagate along the *b* axis. Each molecule is linked to two neighbouring ones: to one through a pair of hydrogen bonds formed between carbonyl oxygens and phenyl protons, with lengths O(2)···C(12)^{i} = 3.289(3) Å ((i) 2 –*x*, 1 –*y*, 1 –*z*), and to another through a pair of hydrogen bonds formed between methoxy oxygens and phenyl protons, with lengths O(1)···C(16)^{ii} = 3.434(3) Å ((ii) 2 –*x*, –*y*, 1 –*z*).



Scheme 2.

Table 1. Bromination and iodination of alkenes with *N*-bromo- and *N*-iodosaccharin.[a]

		Bromination			Iodination		
Alkene	Product		Time/min	Yield[b] (%)		Time/h	Yield[b] (%)
1a		**2a**	10	94[c]	**3a**	24	85 (51)
1b		**2b**	10	96 (71)	**3b**	24	95 (71)
		2b	48 h[d]	89			
1b			–	–	**3c**	4	97 (64)[e]
1b			–	–	**3d**	24	87 (55)[f]
1e		**2e**	10	88 (58)	**3e**	24	72 (53)
1f		**2f**	10	93 (78)	**3f**	24	89 (66)
		2f	48 h[d]	92			
1g		**2g**	42 h	77 (48)	**3g**	5 days	(41)[g]
1h		**2h**	10	65 (35)[c]		–	–
1j		**2j**	5	83 (38)		–	–

[a] Reactions carried out at room temperature in mixtures of acetone or acetonitrile and water (4:1), unless stated otherwise. [b] Isolated yield (in parentheses after purification by crystallization or chromatography). [c] Ref.[16] [d] Brominated with NBS. [e] In methanol. [f] In ethanol. [g] See Experimental Section.

2-bromo-3-hydroxycyclohexan-1-one (**2j**), accompanied by a small amount of compound with similar NMR and mass spectrum, most probably a stereo- or regioisomer. Chromatographic purification (silica, Et_2O + hexane) gave reasonably pure **2j**.

The attempted bromination of cholest-4-en-3-one resulted in a complex mixture, which contained virtually no bromohydrin.

Since saccharin, formed in the halogenation reactions, is a moderately strong acid (pK_a = 2.32),[33] it can easily be removed after the reaction by washing the reaction mixture with aqueous hydrogen carbonate or even with a weaker base. Because it is a stronger acid than the majority of carboxylic acids, it can be removed selectively from a reaction mixture containing a carboxylic acid. The acids **2e** and **3e** were isolated, after completion of each reaction, by washing the ether solutions of the reaction mixtures with aqueous solutions of one equivalent of sodium hydrogen carbonate.

Conclusions

In conclusion, we can report that *N*-bromo- and *N*-iodosaccharin are potent halogenating reagents suitable for introduction of halogen atoms into relatively unreactive, electron-poor alkenes, such as enones and related compounds. The reactions proceed with high *anti* stereoselectivity in short reaction times and under mild conditions, not affecting other functional groups present, such as esters or nitriles.

Experimental Section

General: Solvents and reagents (Fluka, Aldrich, Merck) were used as purchased. *N*-Bromosaccharin[34] and *N*-iodosaccharin[23] were prepared by the published procedures. (*Z*)-1-Bromo-1,2-diphenylethene was synthesized from *trans*-stilbene.[35] NMR spectra were measured on a Bruker Avance 300 DPX spectrometer (300 MHz) with tetramethylsilane as internal standard, IR spectra on a BIO-RAD Excalibur FT-IR spectrometer, mass spectra on a VG-Analytical Autospec EQ or a Hewlett–Packard HP 6890 GC-MS combination. Elemental analyses were performed with a Perkin–Elmer 2400 CHN Analyser. Crystallographic data were collected on a Nonius Kappa CCD diffractometer with use of monochromated Mo-Kα radiation. The crystal was directly mounted on a diffractometer under a stream of cold nitrogen gas.

Typical Procedure for Bromination and Iodination of Alkenes: The alkene (1.0 mmol), the *N*-halosaccharin (1.1 mmol) and the solvent (1–2 mL) were stirred at room temperature until the complete conversion of a starting alkene. The reaction mixture was diluted with diethyl ether and transferred into a separating funnel. The organic layer was washed with a solution of sodium hydrogen carbonate and sodium thiosulfate and then with water and was dried with anhydrous sodium sulfate. The solvent was evaporated at reduced pressure and the resulting product was purified by crystallization or column chromatography.

(2*R,3*R**)-2-Bromo-3-hydroxy-1,3-diphenylpropan-1-one (2b):** M.p. 84–85 °C. ^{1}H NMR ($CDCl_3$):[36] δ = 3.51 (d, J = 5.1 Hz, 1 H), 5.22 (d, J = 8.3 Hz, 1 H), 5.33 (dd, J = 8.3, 5.1 Hz, 1 H), 7.33–8.02 (m, 10 H) ppm. ^{13}C NMR ($CDCl_3$): δ = 47.9, 74.8, 127.3, 128.4, 128.6, 128.8, 129.0, 134.1, 134.6, 139.4, 194.6 ppm.

(2*R,3*R**)-2-Bromo-3-hydroxy-3-phenylpropanoic Acid(2e):** After the complete conversion of starting *trans*-cinnamic acid, the reaction mixture was diluted with diethyl ether and washed with an aqueous solution of 1 equivalent of sodium hydrogen carbonate. The organic phase was dried and the solvent was evaporated. M.p. 121–123 °C (lit.[37] 125 °C). ^{1}H NMR ([D$_6$]acetone):[38] δ = 4.39 (d, J = 9.4 Hz, 1 H), 5.04 (d, J = 9.4 Hz, 1 H), 7.31–7.50 (m, 5 H) ppm. ^{13}C NMR ([D$_6$]acetone): δ = 49.7, 75.8, 128.4, 128.97, 129.01, 141.7, 170.2 ppm.

Methyl (2*R,3*R**)-2-Bromo-3-hydroxy-3-phenylpropanoate (2f):** M.p. 57–59 °C (lit.[39] 62 °C). ^{1}H NMR ($CDCl_3$):[22] δ = 3.25 (s, 1 H), 3.80 (s, 3 H), 4.38 (d, J = 8.3 Hz, 1 H), 5.08 (d, J = 8.3 Hz, 1 H), 7.26–7.40 (m, 5 H) ppm. ^{13}C NMR ($CDCl_3$): δ = 47.5, 53.2, 75.3, 127.0, 128.6, 128.8, 139.0, 169.9 ppm.

(2*R,3*S**)-2-Bromo-3-hydroxy-3-phenylpropanenitrile (2g):** M.p. 70–72 °C. ^{1}H NMR ($CDCl_3$): δ = 2.78 (d, J = 3.9 Hz, 1 H), 4.47 (d, J = 4.3 Hz, 1 H), 5.06 (dd, J = 4.3, 3.9 Hz, 1 H), 7.26–7.46 (m, 5 H) ppm. ^{13}C NMR ($CDCl_3$): δ = 34.4, 75.0, 114.9, 126.4, 128.9, 129.6, 137.01. IR (KBr disc): $\tilde{\nu}$ = 3420 (OH), 2259 (CN) cm^{-1}. MS (*m*/*z* (%)): 227 [M + 2]$^+$ (1), 225 [M^+] (1), 129 (7), 107 (100), 79 (52), 77 (32), 51 (15). C_9H_8BrNO (226.07): C 47.82, H 3.57, N 6.20; found C 47.52, H 3.64, N 6.57.

***trans*-2-Bromo-3-hydroxycyclohexanone (2j):**[40] Oil, ^{1}H NMR ($CDCl_3$): δ = 1.64 (m, 1 H), 1.82 (m, 1 H), 2.08 (m, 1 H), 2.38 (m, 2 H), 2.6 (br. s, 1 H), 2,75 (m, 1 H) 4.00 (ddd, J = 3.6, 7.0, 7.5 Hz, 1 H), 4.40 (dd, J = 1.1, 7.0 Hz, 1 H) ppm. ^{13}C NMR ($CDCl_3$): δ = 20.1, 30.6, 38.7, 61.7, 75.2, 200.5 ppm. IR (liquid film): $\tilde{\nu}$ = 3439 (OH), 1720 (CO) cm^{-1}. MS (*m*/*z* (%)): 194 [M + 2]$^+$ (1), 192 [M]$^+$ (1), 134 (14), 113 (100), 95 (22), 71 (65), 60 (75), 43 (31).

(3*R,4*R**)-4-Hydroxy-3-iodo-4-phenylbutan-2-one (3a):** M.p. 63.7–65.5 °C. ^{1}H NMR ($CDCl_3$): δ = 2.46 (s, 3 H), 3.4 (d, J = 5.2 Hz, 1 H), 4.71 (d, J = 8.5 Hz, 1 H), 5.10 (dd, J = 5.1, 8.5 Hz, 1 H), 7.4 (m, 5 H) ppm. ^{13}C NMR ($CDCl_3$): δ = 27.4, 35.5, 75.8, 127.0, 128.5, 128.6, 139.7, 203.9 ppm. IR (KBr disc): $\tilde{\nu}$ = 3406 (OH), 1704 (CO) cm^{-1}. MS (*m*/*z* (%)): 290 [M]$^+$ (0.5), 230 (14), 184 (100), 163 (38), 107 (72), 105 (20), 103 (39), 91 (23), 79 (47), 77 (45). $C_{10}H_{11}IO_2$ (290.10): C 41.40, H 3.82; found C 41.40, H 3.65.

(2*R,3*R**)-3-Hydroxy-2-iodo-1,3-diphenylpropan-1-one (3b):** M.p. 122–124 °C. ^{1}H NMR ($CDCl_3$): δ = 3.8 (br. s, 1 H), 5.36 (d, J = 8.0 Hz, 1 H), 5.54 (d, J = 8.0 Hz, 1 H), 7.3–7.6 (m, 8 H), 8.0 (m, 2 H) ppm. ^{13}C NMR ($CDCl_3$): δ = 29.1, 76.0, 127.2, 128.46, 128.52, 128.73, 128.78, 134.0, 134.2, 139.9, 196.1 ppm. IR (KBr disc): $\tilde{\nu}$ = 3482 (OH), 1661 (CO) cm^{-1}. MS (*m*/*z* (%)): 246 (82), 225 (30), 207 (19), 105 (100), 91 (19), 77 (72). $C_{15}H_{13}IO_2$ (352.17): C 51.16, H 3.72; found C 51.03, H 3.77.

(2*R,3*R**)-2-Iodo-3-methoxy-1,3-diphenylpropan-1-one (3c):** M.p.86–87 °C (lit.[28] 96 °C). ^{1}H NMR ($CDCl_3$): δ = 3.20 (s, 3 H), 4.90 (d, J = 10.1 Hz, 1 H), 5.39 (d, J = 10.1 Hz, 1 H), 7.3–7.6 (m, 8 H), 8.0–8.1 (m, 2 H) ppm. ^{13}C NMR ($CDCl_3$): δ = 28.6, 58.0, 84.2, 128.27, 128.30, 128.67, 128.75, 128.80, 133.5, 134.8, 138.5, 194.2 ppm. MS (*m*/*z* (%)): 366 [M]$^+$(0.1), 239 (64), 230 (18), 223 (24), 207 (25), 121 (59), 105 (100), 103 (35), 91 (31), 77 (88).

(2*R,3*R**)-3-Ethoxy-2-iodo-1,3-diphenylpropan-1-one (3d):** M.p. 97–99 °C (lit.[28] 75–76 °C). ^{1}H NMR ($CDCl_3$): δ = 0.98 (t, J = 7.0 Hz, 3 H), 3.38 (m, 2 H), 5.00 (d, J = 10.2 Hz, 1 H), 5.37 (d, 1 H, J = 10.2 Hz, 1 H), 7.3–7.6 (m, 8 H), 8.0–8.1 (m, 2 H) ppm. ^{13}C NMR ($CDCl_3$): δ = 15.1, 29.2, 65.9, 82.6, 128.2, 128.6, 128.7, 133.4, 135.0, 139.3, 194.1 ppm.

(2*R,3*R**)-3-Hydroxy-2-iodo-3-phenylpropanoic Acid (3e):** Isolation procedure: see **2e**. M.p. 136–138 °C (lit.[41] 141–142 °C). ^{1}H NMR ([D$_6$]acetone):[14] δ = 4.54 (d, J = 9.7 Hz, 1 H), 5.06 (d, J = 9.7 Hz, 1 H), 7.3–7.5 (m, 5 H) ppm. ^{13}C NMR ([D$_6$]acetone): δ = 27.2, 76.8, 128.3, 128.91, 128.93, 142.2, 171.9 ppm.

Methyl (2*R,3*R**)-3-Hydroxy-2-iodo-3-phenylpropanoate (3f):** M.p. 60–62 °C. ^{1}H NMR ($CDCl_3$): δ = 3.4 (d, J = 5.8 Hz, 1 H), 3.77 (s, 3 H), 4.58 (d, J = 8.3 Hz, 1 H), 5.09 (dd, J = 5.8, 8.3 Hz, 1 H), 7.4 (m, 5 H) ppm. ^{13}C NMR ($CDCl_3$): δ = 24.9, 53.5, 76.7, 127.4, 129.0, 129.2, 139.8, 172.1 ppm. IR (KBr disc): $\tilde{\nu}$ = 3441 (OH), 1710 (CO). MS (*m*/*z* (%)): 306 [M]$^+$ (4), 200 (78), 179 (10), 168 (15), 107 (100), 91 (32), 79 (50), 77 (41). $C_{10}H_{13}IO_3$ (308.12): C 39.24, H 3.62; found C 39.24, H 3.44.

(2*R,3*S**)-3-Hydroxy-2-iodo-3-phenylpropanenitrile (3g):** The reaction was conducted for 5 days at approx. 40 °C with a 20% excess of NISac, until the conversion of starting nitrile reached 60%. The product was purified by column chromatography (silica, diethyl ether/hexane, 1:2) and crystallized from dichloromethane/hexane, M.p. 100–102 °C. ^{1}H NMR ($CDCl_3$): δ = 2.8 (br. s, 1 H), 4.45 (d, J = 4.6 Hz, 1 H), 4.96 (d, J = 4.6 Hz, 1 H), 7.4 (m, 5 H) ppm. ^{13}C NMR ($CDCl_3$): δ = 5.8, 75.5, 116.8, 126.3, 128.8, 129.4, 137.8 ppm. IR (KBr disc): $\tilde{\nu}$ = 3417 (OH), 2250 (CN) cm^{-1}. MS (*m*/*z* (%)): 273 [M]$^+$ (1), 166 (2), 127 (8), 107 (100), 91 (20), 79 (53), 77 (37). C_9H_8INO (273.07): C 39.59, H 2.95, N 5.12; found C 39.75, H 3.03, N 4.97.

[1] M. B. Smith, J. March, *Advanced Organic Chemistry*, 5th ed.; Wiley-Interscience, New York, **2001**, p. 478 and references cited therein.
[2] D. Dolenc, M. Harej, *J. Org. Chem.* **2002**, *67*, 312–313.
[3] S. Boukhris, A. Souizi, *Tetrahedron Lett.* **2003**, *44*, 3259–3261.
[4] S. Boukhris, A. Souizi, A. Robert, *Tetrahedron Lett.* **1998**, *39*, 6281–6282.
[5] S. Cho, S. Kang, G. Keum, S. B. Kang, S. Y. Han, Y. Kim, *J. Org. Chem.* **2003**, *68*, 180–182.
[6] See e.g. M. B. Smith, J. March, *Advanced Organic Chemistry*, 5th ed., Wiley-Interscience, New York, **2001**, p. 520 and references cited therein.
[7] H. Sharghi, M. M. Eskandari, *Synthesis* **2002**, 1519–1522.
[8] M. A. Reddy, K. Surendra, N. Bhanumathi, K. R. Rao, *Tetrahedron* **2003**, *59*, 2363–2363.
[9] M. B. Smith, *Organic Synthesis*; McGraw–Hill, New York, **1994**, pp. 182–183 and references cited therein.
[10] S. Cerritelli, M. Chiarini, G. Cerichelli, M. Capone, M. Marsili, *Eur. J. Org. Chem.* **2004**, 623–630.
[11] A. R. De Corso, B. Panunzi, M. Tingoli, *Tetrahedron Lett.* **2001**, *42*, 7245–7247.
[12] B. F. Sels, D. E. De Vos, P. A. Jacobs, *J. Am. Chem. Soc.* **2001**, *123*, 8350–8359.
[13] J. Barluenga, M. Marco-Arias, F. Gonzalez-Bobes, A. Ballestros, J. M. Gonzalez, *Chem. Eur. J.* **2004**, *10*, 1677–1682.
[14] N. S. Zefirov, G. A. Sereda, S. E. Sosonuk, N. V. Zyk, T. I. Likhomanova, *Synthesis* **1995**, 1359–1361.
[15] J. Barluenga, *Pure Appl. Chem.* **1999**, *71*, 431–436.
[16] H. Masuda, K. Takase, M. Nishio, A. Hasegawa, Y. Nishiyama, Y. Ishii, *J. Org. Chem.* **1994**, *59*, 5550.
[17] S. Raghavan, S. R. Reddy, K. A. Tony, C. N. Kumar, A. K. Varma, A. Nangia, *J. Org. Chem.* **2002**, *67*, 5838–5841.
[18] S. A. Boyes, A. T. Hewson, *J. Chem. Soc. Perkin Trans. 1* **2000**, 2759–2765.
[19] R. Rodebaugh, B. Fraser-Reid, *Tetrahedron* **1996**, *52*, 7663–7678.
[20] Y. Guindon, B. Guérin, C. Chabot, W. Ogilvie, *J. Am. Chem. Soc.* **1996**, *118*, 12528–12535.
[21] S. P. L. de Souza, J. F. M. da Silva, M. C. S. de Mattos, *J. Braz. Chem. Soc.* **2003**, *14*, 832–835.
[22] M. Smietana, V. Gouverneur, C. Mioskowski, *Tetrahedron Lett.* **2000**, *41*, 193–195.
[23] D. Dolenc, *Synlett* **2000**, 544–546.
[24] M. Aloui, A. J. Fairbanks, *Synlett* **2001**, 797–799.
[25] D. Dolenc, *Synthetic Commun.* **2003**, *33*, 2917–2924.
[26] Although the "*erythro*/*threo*" designation is out-of-date and imprecise, in this case all products of the *anti* addition to (*E*)-alkenes have *erythro* configurations. The more precise *like*/*unlike* or (*R**,*S**) notation is compound-specific and it yields different relative configurations for the products of reactions of equal stereochemical course. For the original discussion on the *like*/*unlike* stereochemical descriptors see: D. Seebach, V. Prelog, *Angew. Chem. Int. Ed. Engl.* **1982**, *21*, 654–660.
[27] With long reaction times in acetone as a solvent, the excess of the reagent was consumed and a product with lachrimatory vapours appeared. This was not investigated further, but most probably a haloacetone was formed.

[28] C. Shin, Y. Yonezawa, K. Unoki, J. Yoshimura, *Bull. Chem. Soc. Jpn.* **1979**, *52*, 1657–1660.
[29] E. B. Middleton, *J. Am. Chem. Soc.* **1923**, *45*, 2763–2769.
[30] SHELXL-97 [G. M. Sheldrick, SHELXS-97 and SHELXL-97, Programs for Crystal Structure Solution and Refinement, University of Göttingen, **1997**] was employed for the structure solution and refinement. All the hydrogen atoms, with the exception of those belonging to the methyl moiety, were located from the difference Fourier maps and were refined with isotropic displacement parameters. The methyl hydrogen atoms were added in calculated positions. Crystal data for **3c**: $C_{16}H_{15}IO_2$, M_r = 366.18, triclinic, space group $P\bar{1}$, a = 6.9967(2). b = 9.5820(2), c = 11.4778(3) Å, α = 72.7315(11), β = 85.6043(10), γ = 89.2023(11)°, V = 732.62(3) Å^3, Z = 2, T = 150(2) K, μ(Mo-$K\alpha$) = 2.181 mm^{-1}, 5823 reflections measured, 3255 unique (R_{int} = 0.0163). From all data the final R_1 and wR_2 factors are 0.0247 and 0.0573. CCDC-241543 contains the supplementary crystallographic data for this paper. These data can be obtained free of charge from the Cambridge Crystallographic Data Centre via www.ccdc.cam.ac.uk/data_request/cif.
[31] The transformation of a vinyl bromide into an α-bromoketone can also be achieved by the action of phenylselenenyl chloride on vinyl bromide. M. Tiecco, L. Testaferri, M. Tingoli, D. Chianelli, D. Bartoli, *Tetrahedron* **1988**, *44*, 2273–2282.
[32] D. P. Bauer, R. S. Macomber, *J. Org. Chem.* **1975**, *40*, 1990–1992.
[33] G. W. Gokel, *Dean's Handbook of Organic Chemistry*, 2nd ed.; McGraw–Hill, New York, **2004**.
[34] B. Zajc, *Synthetic Commun.* **1999**, *29*, 1779–1784.
[35] J. Wislicenus, F. Seeler, *Ber. Dtsch. Chem. Ges.* **1895**, *28*, 2693–2703.
[36] T. Imamoto, T. Kusumoto, M. Yokoyama, *Tetrahedron Lett.* **1983**, *24*, 5233–5236.
[37] P. D. de la Mare, M. A. Wilson, *J. Chem. Soc. Perkin Trans. 2* **1973**, 653–656.
[38] M. Brink, E. Schjånberg, *Spectrochimica Acta* **1977**, *33A*, 1–5.
[39] M. A. Wilson, P. D. Woodgate, *J. Chem. Soc. Perkin Trans. 2* **1976**, 141–147.
[40] G. Righi, P. Bovicelli, A. Sperandio, *Tetrahedron Lett.* **1999**, *40*, 5889–5892.
[41] E. L. Jackson, L. Pasiut, *J. Am. Chem. Soc.* **1928**, *50*, 2249–2260.

Received: November 22, 2004

