



A versatile synthesis of 2-haloalk-2(*Z*)-en-1-ols and 1-chloro-1(*Z*)-alkenes from trichloromethylcarbinols

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Received 7 January 2002; revised 24 January 2002; accepted 25 January 2002

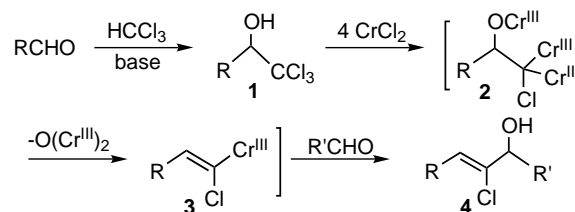
Abstract—CrCl₂ converts trichloromethylcarbinols under mild conditions to (*E*)- α -haloalkylidene chromium carbenoids which add to aldehydes or are quenched with water affording 2-haloalk-2(*Z*)-en-1-ols and 1-chloro-1(*Z*)-alkenes, respectively, in high yield. © 2002 Elsevier Science Ltd. All rights reserved.

The continuing demand for ever more efficacious and stereospecific synthetic methodology has stimulated broad interest in organochromium chemistry and led to the introduction of several chromium-containing reagents,¹ including several contributions from our laboratories.² Of special note is the discovery of (*E*)-halovinylidene chromium carbenoids **3**.^{2a} In the accompanying communication,³ we report the facile, in situ generation of **3** from a wide variety of aldehydes using CCl₄ and CrCl₂ and its tandem addition to a second aldehyde giving rise to ‘symmetrical’ 2-haloalk-2(*Z*)-en-1-ols **4**, i.e. adducts from 2 equiv. of the same aldehyde (R = R′). Based upon prior mechanistic studies,^{2a} the chromate ester of trichloromethylcarbinol **1** was postulated³ to be the initial intermediate leading to bis-chromylmethylene **2** upon further reduction by 4 equiv. of CrCl₂. Herein, we report that **1**, independently prepared by addition of trichloromethyl anion to aldehydes,⁴ is transformed stereoselectively into **3** which can be subsequently added to a different aldehyde furnishing ‘unsymmetrical’ 2-haloalk-2(*Z*)-en-1-ols **4** (R ≠ R′) or quenched with water to provide the corresponding 1-chloro-1(*Z*)-alkene **3** (Cr^{III}=H) (Scheme 1).

Treatment of the known 2-phenyl-1,1,1-trichloroethanol⁵ **5** with CrCl₂ in the presence of benzaldehyde (Barbier conditions) at room temperature for 8 h

afforded (*Z*)-chloroalkenol **6**⁶ in good yield (Table 1, entry 1). Repetition of the preceding addition employing hydrocinnamaldehyde as the electrophile led to **7** (entry 2). In sharp contrast to earlier procedures,⁷ no 1,1-dichlorostyrene and/or related side-products were observed during these reactions. Styrene **8**⁵ and aliphatic aldehyde **11**⁸ behaved similarly with benzaldehyde and hydrocinnamaldehyde furnishing adducts **9** (entry 3), **10** (entry 4), **12** (entry 5), and **13** (entry 6), respectively. It is worth noting that while the transformations summarized in entries 2 and 5 both utilize the same initial precursors, i.e. benzaldehyde and hydrocinnamaldehyde, the resultant adducts are isomeric as a consequence of their differing sequence of reactions.

When the chromium carbenoids **3** generated from **5**, **8**, or **11** were quenched with water (Table 2), the corresponding 1-chloro-1(*Z*)-alkenes **14** (entry 1), **15** (entry 2), and **16** (entry 3), respectively, were formed in synthetically useful yields. In all cases, the (*Z*)-stereoisomer was formed exclusively, indicating that only (*E*)-halovinylidene chromium carbenoids^{2a} are generated from trichloromethylcarbinols **1**.

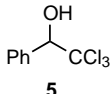
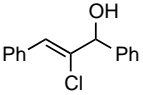
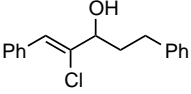
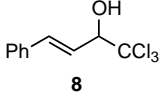
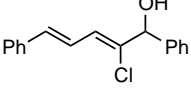
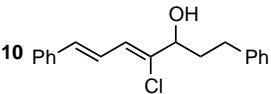
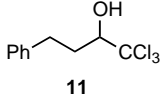
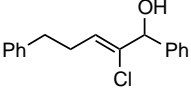
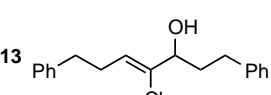


Scheme 1.

Keywords: chromium; alkenylation; alcohols; vinylation; stereocontrol.

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Table 1. Synthesis of 2-chloroalk-2(Z)-en-1-ols

Substrate	Entry	Aldehyde	Product	Yield (%)
 5	1	PhCHO	 6	78
	2	PhCH ₂ CH ₂ CHO	 7	82
 8	3	PhCHO	 9	91
	4	PhCH ₂ CH ₂ CHO	 10	80
 11	5	PhCHO	 12	61
	6	PhCH ₂ CH ₂ CHO	 13	73

General procedure

2-Haloalk-2(Z)-en-1-ols (4): A solution of trichloromethylcarbinol **1** (1 mmol) and aldehyde (1 mmol) in THF (4 mL) was added to a stirring, room temperature suspension of CrCl₂ (4 mmol; Strem Chem., 99.9%) in THF (6 mL) under an argon atmosphere. After 8 h, the resultant reddish reaction mixture was quenched with water, extracted thrice with ether, and the combined ethereal extracts were evaporated in vacuo. The residue was purified by SiO₂ chromatography affording 2-haloalk-2(Z)-en-1-ol **4** in the indicated yield (Table 1).

1-Chloro-1(Z)-alkenes: A solution of trichloromethylcarbinol **1** (1 mmol) in THF (4 mL) was added to a stirring, room temperature suspension of CrCl₂ (4 mmol; Strem Chem., 99.9%) in THF (6 mL) under an argon atmosphere. After 8 h, the resultant reddish

reaction mixture was quenched with water and the resultant 1-chloro-1(Z)-alkene was isolated as described above (Table 2).

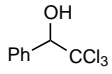
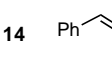
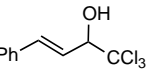
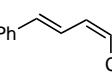
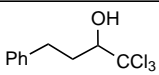
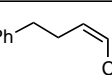
Acknowledgements

Financial support provided by the Robert A. Welch Foundation, NIH (GM31278, DK38226), CNRS, Institut de Recherches Pierre Fabre (to R.B.), and an unrestricted grant from Taisho Pharmaceutical Co., Ltd. Dr. E. R. Fogel is warmly thanked for insightful discussions.

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Table 2. Synthesis of 1-chloro-1(Z)-alkenes

Entry	Substrate	Product	Yield (%)
1	 5	 14	86
2	 8	 15	81
3	 11	 16	72

- (e) α -Chlorovinylolation: Falck, J. R.; Barma, D. K.; Mioskowski, C.; Schlama, T. *Tetrahedron Lett.* **1999**, *40*, 2091–2094; (f) Synthesis of 1-chloro-1(*Z*)-alkenes: Baati, R.; Barma, D. K.; Krishna, U. M.; Mioskowski, C.; Falck, J. R. *Tetrahedron Lett.* **2002**, *43*, 959–961; (g) Synthesis of 2-haloalk-2(*Z*)-en-1-ols: Barma, D. K.; Baati, R.; Mioskowski, C.; Falck, J. R. *Org. Lett.* **2001**, *3*, 4237–4238; (h) Selective deprotection of sugars: Falck, J. R.; Barma, D. K.; Venkataraman, S. K.; Baati, R.; Mioskowski, C. *Tetrahedron Lett.* **2002**, *43*, 963–966.
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 4. (a) NaH (1.5 mmol) was added to a DMF (5 mL) solution of aldehyde (1 mmol) and dry CHCl_3 (1.5 mmol) at 0°C . After 3 h, the reaction mixture was neutralized with 1N HCl and the product was isolated by Et_2O extraction (66–71%); (b) via CHCl_3/DBU : Aggarwal, V. K.; Mereu, A. *J. Org. Chem.* **2000**, *65*, 7211–7212; (c) via $\text{Cl}_3\text{CCO}_2\text{Na}$: Wang, Z.; Campagna, S.; Yang, K.; Xu, G.; Pierce, M. E.; Fortunak, J. M.; Confalone, P. N. *J. Org. Chem.* **2000**, *65*, 1889–1891.
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 6. Spectral data for **6**, **9**, and **12**, see Ref. 2g; for **14–16**, see Ref. 2f; for **13**, see Ref. 3. Spectral data for **7**: ^1H NMR (CDCl_3 , 300 MHz) δ 7.55–7.10 (m, 10H), 6.62 (s, 1H), 4.52–4.31 (m, 1H), 2.62 (d, 1H, $J=4.5$ Hz), 2.45 (t, 2H, $J=8.0$ Hz), 2.20–2.05 (m, 2H); ^{13}C NMR (CDCl_3 , 75 MHz) δ 138.5, 134.2, 133.4, 130.1, 129.8, 128.7, 128.5, 127.9, 127.6, 126.9, 126.1, 79.9, 34.2, 30.8. Compound **10**: ^1H NMR: δ 7.45–6.95 (m, 11H), 6.65 (d, 1H, $J=15$ Hz), 6.43 (d, 1H, $J=14$ Hz), 4.44–4.13 (m, 1H), 2.62 (d, 1H, $J=4.0$ Hz), 2.43 (t, 2H, $J=7.0$ Hz), 2.25–1.90 (m, 2H); ^{13}C NMR (CDCl_3 , 75 MHz) δ 138.7, 137.2, 136.4, 134.6, 133.1, 130.2, 129.7, 129.3, 128.6, 128.1, 127.5, 126.4, 80.1, 34.8, 31.2.
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