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3,3-DICHLOROTETRAHYDROFURANS BY REDUCTIVE ADDITION OF 3-BROMO-1,1,1-TRICHLOROALKANES TO CARBONYL COMPOUNDS$^{1)}$

H. Claus and H.J. Schäfer*
Organisch-Chemisches Institut der Universität, Orleansring 23,
D-4400 Münster, FRG

Abstract.- 3,3-Dichlorotetrahydrofurans 5 are prepared by cathodic reduction of 3-bromo-1,1,1-trichloroalkanes 1 in the presence of aldehydes aund ketones; 5 can be partially or fully dechlorinated.

Trichloromethyl compounds can be added by cathodic reduction to aldehydes and ketones to yield trichloromethyl carbinols$^{2)}$. We wish to report that 3-bromo-1,1,1-trichloroalkanes 1, which are readily available by radical addition of bromotrichloromethane to alkenes$^{3)}$, can be reductively added to carbonyl compounds to produce 3,3-dichlorotetrahydrofurans 5 (eq. 1, table).
For the product formation the following pathway seems reasonable: The dichloromethyl anion 2, generated from 1 at the cathode, adds to the carbonyl compound 3, which is present in the electrolyte, to form the 4-bromoalkoholate 4, which undergoes an intramolecular nucleophilic substitution to yield 5. Competing with the addition is the protonation of 2 to 6, either by dimethylformamide or by protons from the anolyte. With ketones (table, entry 9, 10) or the probably less reactive anions 2b, 2c (entry 11, 12, table) the protonation becomes the main reaction. Reduction of 1a in 0.2m $LiClO_4$ dimethylformamide without a carbonyl compound affords 97 % 3-bromo-1,1-dichlorononane (6a).

(1)

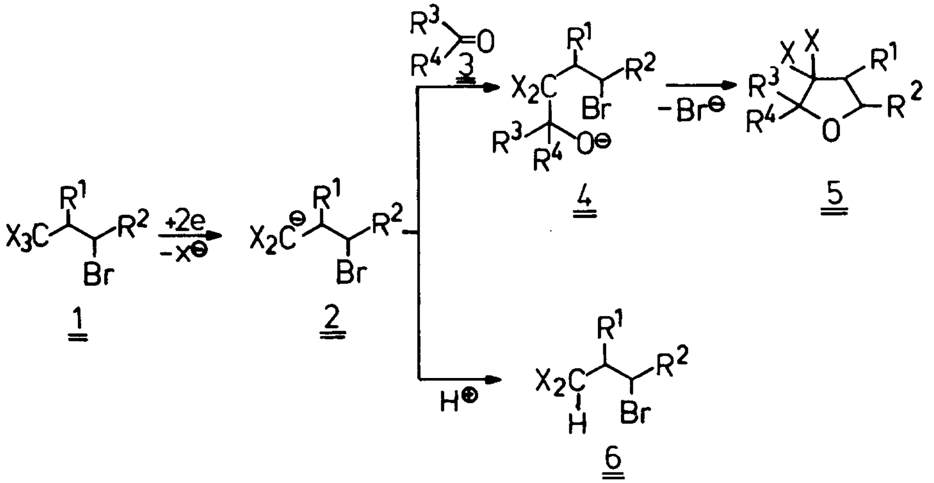
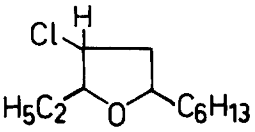


Table: Yields of 3,3-dihalotetrahydrofurans 5 and 3-bromo-1,1-dihaloalkanes 6 from the cathodic addition of 1 to carbonyl compounds

Entry	1 R^1	R^2	X	3 R^3	R^4	Yield (%) 5	6
1	a: C_6H_{13}	H	$Cl^{a)}$	C_2H_5	H	a: 40	a: 26
2	a: C_6H_{13}	H	Cl	C_9H_{19}	H	b: 41	a: 25
3	a: C_6H_{13}	H	Cl	c-C_6H_{11}	H	i: 40	a: 27
4	a: C_6H_{13}	H	Cl	C_6H_5	H	a: 43	a: 28
5	a: C_6H_{13}	H	Cl	C_6H_5-CH(CH_3)-	H	e: 39	a: 34
6	a: C_6H_{13}	H	Cl	Furyl(2)	H	f: 37	a: 45
7	a: C_6H_{13}	H	Cl	2-Norbornenyl(2)	H	g: 37	a: 41
8	a: C_6H_{13}	H	Cl	^{t}Butyl	H	h: 24	a: 73
9	a: C_6H_{13}	H	Cl	- $(CH_2)_4$ -		i: 5	a: 67
10	a: C_6H_{13}	H	Cl	Vinyl	CH_3	j: 9	a: 63
11	b: - $(CH_2)_3$ -		$Cl^{a)}$	C_2H_5	H	k: 20	b: 40
12	c: C_6H_{13}	H	$Br^{b)}$	C_2H_5	H	l: 8	c: 44

Halfwave reduction potentials (at dme vs. sce): a) -1.70 V; b) -1.30 V.



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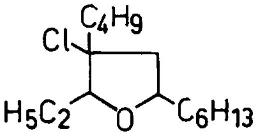

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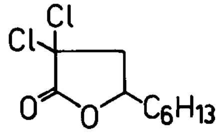

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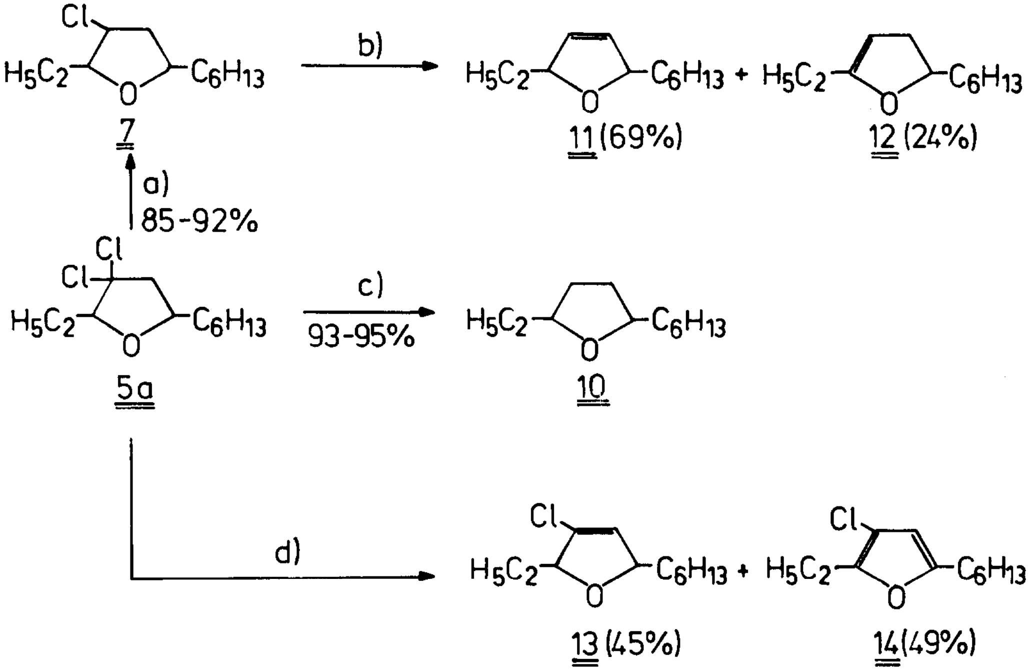
5a is quite inert to hydrolysis or substitution. Treatment with oxalic acid (2d at 120° C), silver trifluoroacetate[4] (4 equiv., 12 h reflux in aqueous acetonitrile), sodium iodide (1d reflux in acetone) or sodium butanethiolate (3d reflux in butanethiol) leaves 5a unchanged. The reaction of 5a with n-butyllithium (2 equiv. at -78° C in hexane) leads to 3-chloro-2-ethyl-5-hexyltetrahydrofuran (7, 50 % by glc) and 3-butyl-3-chloro-2-ethyl-5-hexyltetrahydrofuran (8, 36 % by glc) as main products.

The oxidation of 5a proceeds so far unsatisfactorily. 5a exhibits an anodic oxidation potential of about +2.3 V (vs. Ag/0.1m Ag^+) in 0.1m $LiClO_4$ acetonitrile. Oxidations with TEBA·MnO_4[5], aqueous bromine[6] or chromium trioxide in sulfuric acid, chromyl acetate in acetic acid[7] produce a multitude of products.

With chromyl acetate in acetic anhydride 10 % 3,3-dichloro-5-hexyltetrahydro-2-furanone (9) are obtained after chromatography (silica gel, CH_2Cl_2), similarly chromyl chloride yields 16 % 9 at -20° C. Pyridinium chlorochromate (1d in CH_2Cl_2 at r.t.) or ruthenium tetroxide (1d in refluxing CCl_4) does not alter 5a.

5a can be selectively mono- or dihydrogenated to 7 or 10 (eq. 2). Dehydrohalogenation of 7 leads to a mixture of the dihydrofurans 11 and 12. The dehydrohalogenation of 5a produces 13 and surprisingly also 14.

(2)



a) -2.63 V vs. sce at Hg pool cathode in 0.2 m Bu_4NBF_4 DMF (85 %) or 1 equiv. $LiAlH_4$ in THF (86 %) or 1 equiv. Bu_3SnH (92 %); b) KOH in EtOH; c) 2 equiv. $LiAlH_4$ in THF or 2 equiv. Bu_3SnH; d) KOH in EtOH or KO^tbut in THF.

Preparation of 3,3-dichlorotetrahydrofurans (5): 20 mmol 1 and 30 mmol 2 in 50 ml of a 0.2 m $LiClO_4$ solution in dry DMF[8)] were electrolysed under nitrogen at the half wave potential of 1 at 0° C. The divided cell is equipped with a glass frit (P 5) diaphragm, mercury pool cathode (20 cm^2), graphite anode (10 cm^2) and a Marple reference electrode[9)]. After the consumption of 2 F/mol the catholyte is poured into 200 ml of saturated brine and extracted three times with 100 ml ether. The organic layers are dried with $MgSO_4$ and afterwards rotoevaporated.
5 and 6 are isolated by liquid chromatography and are characterized by their IR, NMR, MS spectra and elemental analyses[10)].

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10) **5a**: ^{1}H-NMR ($CDCl_3$) δ 0.9 (m, 3H), 1.1 (m, 3H), 1.2-1.9 (m, 12H), 2.4 (dd, 1H, J=13.0, 9.0 Hz), 2.9 (dd, 1H, J=13.0, 6.0 Hz), 3.9 (m, 1H), 4.2 (m, 1H); IR (film) 2960, 2940, 2880, 2860, 1470, 1460, 1445, 1440, 1380, 1080, 850, 730 cm^{-1}; MS (m/e) 223, 225 (0.48%, 0.25%, $M^+-C_2H_5$), 59 (100%); Anal. Calcd. for $C_{12}H_{22}OCl_2$: C, 56.92; H, 8.76; Cl, 28.00. Found: C, 57.05; H, 8.77; Cl, 27.95; n_D^{20} = 1.4592.

5b: ^{1}H-NMR ($CDCl_3$) δ 0.9 (m, 6H), 1.2-1.9 (m, 26H), 2.4 (dd, 1H, J=13.0, 9,0 Hz), 2.9 (dd, 1H, J=13.0, 6.0 Hz), 3.9 (m, 1H), 4.2 (m, 1H); IR (film): 2960, 2940, 2880, 2860, 1445, 1440, 1380, 1100, 850, 730 cm^{-1}; MS (m/e) 265, 267 (1.1%, 0.7%, $M^+-C_6H_{13}$), 83 (100%); Anal. Calcd. for $C_{19}H_{36}OCl_2$: C, 64.94; H, 10.33; Cl, 20.18. Found: C, 64.72; H, 10.15; Cl, 19.99; n_D^{20} = 1.4665.

7: ^{1}H-NMR ($CDCl_3$) δ 0.9 (m, 6H), 1.2-2.1 (m, 12H), 2.15-2.6 (m, 2H), 3.65-4.45 (m, 3H); IR (film): 2960, 2940, 2880, 2860, 1470, 1460, 1440, 1380, 1060 cm^{-1}; MS (m/e) 218 (0.66%, M^+), 133 (100%); Anal. Calcd. for $C_{12}H_{23}OCl$: C, 65.88; H, 10.60. Found: C, 66.02; H, 10.78; n_D^{20} = 1.4680.

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