Notes

Solid State Oxidation of Alcohols Using 1-Butyl-4-aza-1-azoniabicyclo[2.2.2]octane Chlorochromate

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Oxidation of organic compounds is one of the most important reactions in modern organic synthesis. For this purpose, some new oxidizing reagents have been prepared.[1-10] Unfortunately most of them suffer at least from one of the following disadvantages: 1) high cost of preparations, 2) long reaction time, 3) hygroscopisity, 4) high acidity, 5) instability, 6) no selectivity, 7) photosensitivity, 8) dangerous procedures for their preparation and 9) tedious work-up procedures. The quest for effective oxidant that use inexpensive oxidant, which works under solvent-free or non-aqueous and neutral conditions for converting alcohols to carbonyl compounds, remain an important challenge.[10,11]

Chromium(VI) reagents have been widely used in organic chemistry for the oxidation of alcohols to the corresponding carbonyl compounds.[12-15] Very recently, we have introduced new reagents for oxidation of alcohols under solvent-free or non-aqueous conditions.[10,11]

In recent years, there has been an increasing interest in reactions that proceed in the absence of solvents due to their reduced pollution, low costs and simplicity in process and handling.[10,12] Because of our interest in development of solvent-free reactions.[10,16] we now wish to report the synthesis and use of 1-butyl-4-aza-1-azoniabicyclo[2.2.2]octane chlorochromate **1** as an efficient and selective reagent for the oxidation of alcohols **2** to the corresponding carbonyl compounds **3** under solvent-free conditions.

1-Butyl-4-aza-1-azoniabicyclo[2.2.2]octane chlorochromate (BAAOC) **1**, a mild, efficient, stable and inexpensive reagent, is an orange powder, which is quite soluble in dichloromethane, chloroform, acetone and acetonitrile and insoluble in non-polar solvents such as carbon tetrachloride, *n*-hexane and diethyl ether. This reagent is readily prepared in quantitative yield by the dropwise addition of an aqueous solution of 6 N HCl solution of CrO_3 to an aqueous solution of 1-butyl-4-aza-1-azoniabicyclo[2.2.2]octane chloride at room temperature. Filtration and drying of the precipitates produced an orange powder. The reagent can be stored for month at room temperature without loosing its activity.

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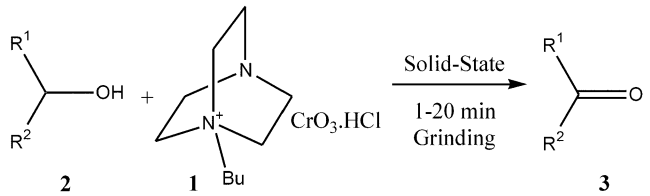
Table 1. Oxidation of alcohols **2** with reagent **1** to carbonyl compounds **3** under solvent-free conditions[a,b]

Entry	Substrate (2)	Time (min)	Yield (%)
1	Benzylalcohol	1.0	98
2	4-Nitrobenzylalcohol	10.0	80
3	3,4-Dimethoxybenzylalcohol	5.0	98
4	4'-Phenyl-1-phenylethanol	3.0	98
5	2-Pyridyl-methanol	6.0	94
6	1-Phenylethanol	1.0	100
7	4-Methoxybenzylalcohol	2.0	99
8	2-Methoxybenzylalcohol	2.0	99
9	Diphenyl-methanol	4.0	100
10	3-Methoxybenzylalcohol	5.0	99
11	4-Chloroybenzylalcohol	7.0	95
12	2-Chloroybenzylalcohol	4.5	88
13	1,2, Diphenyl-methanol	4.5	95
14	4'-Bromo-1-phenylethanol	5.0	99
15	4'-Chloro-1-phenylethanol	1.5	85
16	Benzoin	10.0	100
17	2,3-Dimethoxybenzylalcohol	3.0	93
18	Cyclohexanol	4.0	90
19	1-Tetralol	1.5	93
20	*n*-Heptanol	4.5	75
21	*n*-Pentanol	4.5	78
22	L-Menthol	20.0	92
23	1-Indanol	3.0	89
24	9-Fluorenol	4.0	88
25	4-*t*-butylcyclohexanol	4.5	87
26	2-naphthalene-methanol	2.0	92
27	2-Phenylethanol	20.0	75
28	3-Methylcyclohexanol	4.0	88
29	4'-Methyl-1-Phenylethanol	1.5	98
30	3-Phenylpropanol	20.0	88
31	Cyclooctanol	15.0	85
32	Admantan-2-ol	15.0	94
33	Geraniol	10.0	88
34	Cynamylalcohol	20.0	85
35	2-Nitrobenzylalcohol	15.0	85
36	2-Hydroxy-5-nitro-benzyl alcohol	8.0	92
37	4-Chlorobenzhydrol	10.0	90
38	1-(4-Chlorophenyl) ethanol	20.0	92

[a]Confirmed by comparison with authentic samples (IR, TLC and NMR).[10,11] [b]Yield of isolated pure product after work-up.



R^1, R^2 = Alkyl, aryl, allyl and H

Scheme 1

Alcohols **2** are oxidized to the corresponding carbonyl compounds **3** under solid-state conditions in good to excellent yields in 1-20 min; benzoin was converted to benzil in 100 yields after 10 min (Scheme and Table 1). In comparison to benzylic and allylic alcohols, oxidation of aliphatic alcohols with this reagent occurs with lower yields and longer reaction time. As it is shown in table **1** this reagent is also able to oxidize efficiently the solid alcohols to the corresponding carbonyl compounds under solvent-free conditions.

In order to show the oxidative ability of this reagent (BAAOC), we compared some of our results with those reported for pyridinium chlorochromate (PCC),[12] pol[vinyl-(pyridinum chlorochromate)] (PVPCC),[13] 4-(dimethylamino)-pyridinum chlorochromate (DMAPCC),[14] and 2,2'-bipyridinum chlorochromate (BPCC)[15] (Table 2). This reagent is superior to pyridinum chlorochromate (PCC),[10] poly[vinyl-(pyridinum chlorochromate)] (PVPCC),[13] 4-(dimethylamino)-pyridinum chlorochromate (DMAPCC),[14] and 2,2'-bipyridinum chlorochromate (BPCC)[15] in term of selectivity, high yields, cost, purity of products and easy of work-up.

In conclusion we report a new and efficient methodology for the oxidation of aliphatic and aromatic alcohols to the corresponding aldehydes and ketones at room temperature and in the absence of solvent. The stability, easy preparation of the reagent and straightforward work-up make this method a novel and useful method. Also, this method does not require a large excess of reagent nor long reaction times.

Experimental Section

General: All the reported yields refer to isolated products after work-up. All of the products were characterized by comparison of their spectral (IR, ^{1}H-NMR and TLC) and physical data (melting and boiling points) with those of authentic samples.[10,11] All ^{1}H-NMR spectra were recorded at 90 and 300 MHz in $CDCl_3$ and d_6-DMSO relative to TMS as an internal standard and IR spectra were recorded on Shimadzu 435 IR spectrometer. All of the reactions were carried out in the absence of solvent at room temperature in fume hood with strong ventilation.

Preparation of 1-Butyl-4-aza-1-azoniabicyclo[2.2.2]-octane Chlorochromate. A solution of 1-butyl-4-aza-1-azoniabicyclo[2.2.2]octane chloride (12.45 g, 50 mmol) in 50 mL of water was prepared, and then CrO_3 (5.0 g, 50 mmol) in HCl 6 N (50 mL) was added dropwise to the above solution and stirred for 10 min. at room temperature. The resulting orange precipitate was filtered and washed with cooled distilled water (2 × 50 mL), and dried in a desiccator under vacuum over calcium chloride to afford an orange powder (12.85 gr, 42.1 mmol, 84.4% yield), which decomposed at 130-132 °C to a dark-brown material. ^{1}H-NMR (d_6-DMSO, 300 MHz): δ = 3.66 (m, 12H), 1.48 (d, 5H), 0.92 (s, 4H). ^{13}C-NMR (d_6-DMSO, 75 MHz) δ = 64.74, 51.86, 44.93, 41.45, 41.29, 41.12, 40.95, 40.79; 40.62, 40.46, 24.69, 20.42, 14.83. Anal. Calcd. For $C_{10}H_{21}N_2CrO_3Cl$: C, 39.41; H, 6.95; N, 9.19. Found: C, 39.56; H, 6.7256; N, 9.25.

Typical Procedure for Solvent-free Oxidation of Alcohols 1: Reaction of Benzylalcohol. 1-Butyl-4-Aza-1-Azoniabicyclo[2.2.2]Octane Chlorochromate (0.31 g, 1

Table 2. Comparison of oxidation of some alcohols with BAAOC, BTPPPS, BAAOP and BTPPPI

Entry	Substrate	Yield % (min) (molar ratio of reagent)				
		BAAOC[a]	**PCC**[b]	**PVPCC**[c]	**DMAPCC**[d]	**BPCC**[e]
1	$PhCH_2OH$	98 (1)	100 (90)	95 (15)	64 (180)	79 (150)
2	Ph_2CHOH	100 (4)	–	–	–	–
3	PhCHOHCOPh	100 (10)	90 (90)	–	–	–
4	3-Phenylpropanol	88 (20)	–	–	–	–
5	Cycloheganol	90 (4)	–	82 (210)	–	–
6	Admantan-2-ol	94 (15)	–	–	–	–
7	Geraniol	88 (10	–	–	–	91 (198)
8	Menthol	92 (20)	–	–	–	–
9	1-Tetralol	93 (1.5)	–	–	–	–
10	1-Indanol	89 (3)	–	–	–	–
11	9-Fluorenol	88 (4)	–	–	–	–
12	4-*t*-butylcyclohexanol	87 (4.5)	97 (90)	–	–	–
13	1-Heptanol	75 (4.5)	78 (90)	–	–	82 (150)

[a]Substrate/Reagent (1 : 1). [b]Substrate/Reagent (1 : 1.5). [c]Substrate/Reagent (1 : 1.1 to 1 : 4.5). [d]Substrate/Reagent (1 : 3). [e]Substrate/Reagent (1 : 2 to 1 : 4).

mmol) was added to a mixture of benzyl alcohol (0.11 g, 1 mmol) in a mortar. The reaction mixture was ground by pestle at room temperature under solvent-free condition. After disappearance of benzyl alcohol as monitored by TLC, the mixture was washed with cyclohexane and filtered. The filtrate was evaporated under reduced pressure and the resulting crude material was purified by flash chromatography on SiO_2 (eluent: EtOAc : hexane, 10 : 90) to afford benzaldehyde.

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