An Efficient and Selective Oxidation of Benzylic Alcohols to the Corresponding Carbonyl Compounds under Solvent-Free Conditions

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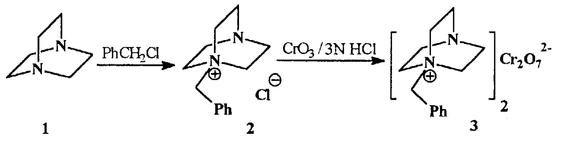
1-Benzyl-4-aza-1-azoniabicyclo[2.2.2]octanedichromate is a useful reagent for selective oxidation of benzylicalcohols and α-hydroxy ketones to the corresponding carbonyl compounds. The reaction was carried out under solvent-free conditions without or in the presence of a catalytic amount of aluminum chloride.

Oxidation of organic compounds under non-aqueous and aprotic conditions has an important role in the modern organic synthesis. For this purpose, some new oxidizing reagents have been prepared.[1-8] 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.

In continuous to our previous works[6–8] here, we wish to introduce an efficient, mild and rapid method for selective oxidation of alcohols to their corresponding carbonyl compounds by using 1-benzyl-4-aza-1-azoniabicyclo[2.2.2]octane dichromate, which is readily prepared by reaction of an aqueous solution of l-benzyl-4-aza-1-azoniabicyclo[2.2.2]octane chloride **2** with CrO_3 in 3M solution of HCl at room temperature as shown in Scheme 1.

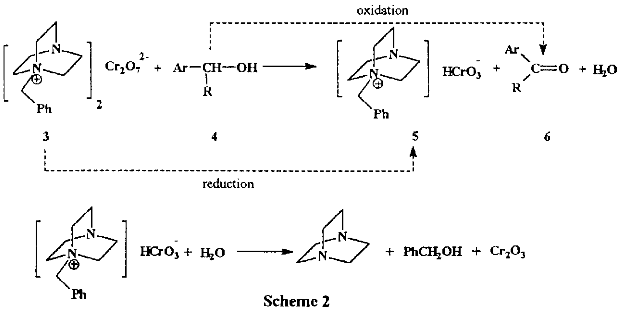


Scheme 1

The resulting orange powder which can be stored for months without loss of activity is soluble in acetonitrile, acetone and *N,N*-dimethylformamide and slightly soluble in chloroform, ethylacetate and dichloromethane, but is not soluble in carbon tetrachloride, *n*-hexane and diethylether. This new oxidant has several advantages: 1) In comparing with the previously reported method,[9] does not require a large excess of reagent and long reaction time. 2) Because of the low reactivity of aliphatic alcohols, only benzylic alcohols could be converted to the corresponding carbonyl compounds, 3) Due to its mild behavior, no further oxidation to the carboxylic acid was observed.

The oxidation reaction was performed via two methods. In method A, one equimolar of different alcohols and reagent were mixed in a mortar and ground with a pestle until TLC showed complete disappearance of starting alcohols. Following the reaction by TLC shows that by disappearing the starting alcohols spots, the carbonyl compounds spots appear. As well as this spot, a new spot was also detected, which appeared lower than the starting alcohol. Adding a large excess of reagent not only can not dissolve this problem but also reinforce this spot. In order to investigate the reaction mechanism. 15 mL $CC1_4$ was added to the reaction mixture and after vigorous stirring, the mixture was filtered off, then the solvent was evaporated and the residue separated by column chromatography on silica gel (eluent: $CC1_4$). One of the extracted materials was the carbonyl compound which produced during the reaction. The second one in all reactions was benzyl alcohol and no sign of the starting alcohol was observed. According to the above results, we have proposed the following mechanism:

The Cr(IV) that is produced in the initial step is not stable and this species is capable of a further one-electron oxidation step as well as reagent **5** cleavage. It is believed that a part of the substrate is oxidized via a free radical intermediate resulting from oxidation by Cr(IV).[10] Scheme 3 also includes Cr(V) as a participant in the mechanism:



Scheme 2

During the reaction, DABCO was collected as a by-product, which remained on the filter paper after filtration and its structure was confirmed by ^{1}H-NMR. The time required to complete these reactions varied between 10 to 30 min. To accelerate the reaction rate, a catalytic amount of $AlC1_3$ (0.1 mole ratio of oxidant) was added to the reaction mixture (method B). By adding this catalyst to the reaction media the reaction time reduced from 15-30 min to 30-60 s and the benzyl alcohol spot which was produced as a by-product, disappeared.

$$R_2CHOH + Cr(IV) \longrightarrow R_2\dot{C}OH + Cr(III) + H^+$$

$$R_2\dot{C}OH + Cr(VI) \longrightarrow R_2C=O + Cr(V) + H^+$$

$$R_2CHOH + Cr(V) \longrightarrow R_2C{=}O + Cr(III) + 2H^+$$

Scheme 3

According to these observations here we propose another mechanism (Scheme 4). $AlC1_3$ may be linked to the two oxygens of the chromate and increased the positive charge and reactivity of the Cr(VI). This behavior accelerates the reaction rate and reduces the time of reaction.

On the other hand, the presence of $AlC1_3$ in the reaction media acts as an H_2O attracting group and avoided the H_2O molecules to attack to the reductive reagent **8** and consequently produced $Al(OH)_3$ and a very stable complex i.e. l-benzyl-4-aza-1-azoniabicyclo[2.2.2]octane chloride **2** and no sign of

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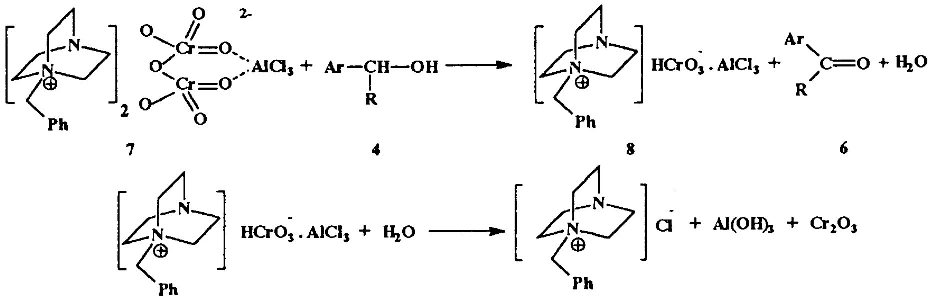
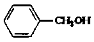
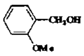
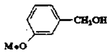
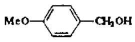
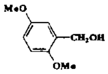
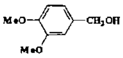
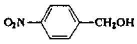
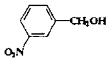
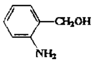
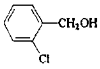
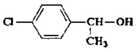
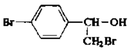
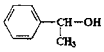
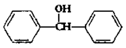
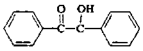
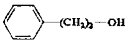
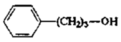
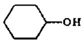
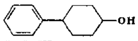


Scheme 4

Table 1. Oxidation of alcohols **4** to carbonyl compounds **6** [a]

Alcohols		Time[b]		Yield (%)	
		A(min)	B(sec)	A	B
4a		10	30	58	81
4b		20	40	83	92
4c		20	30	79	98
4d		25	50	83	95
4f		30	60	81	96
4g		23	40	86	93
4h		28	50	68	91
4i		29	30	72	96
4j		25	35	81	97
4k		30	60	79	94
4l		20	40	84	98
4m		18	30	88	92
4n		20	30	71	96
4o		30	60	68	93
4p		29	50	73	94
4q		——[c]	——[c]	——[c]	——[c]
4r		——[c]	——[c]	——[c]	——[c]
4s		——[c]	——[c]	——[c]	——[c]
4t		——[c]	——[c]	——[c]	——[c]

[a] All of the compound were characterized bv comparing with known compounds. [b] Time required to compelet the reaction via two methods A & B.
[c] No reaction was occured even after 45 min grinding

benzyl alcohol was observed.

The reactions were completed within 0.5-1 min and the pure carbonyl compound was obtained by a simple work-up. The resulting aldehydes and ketones were characterized by IR and ^{1}H-NMR in $CC1_4$.

In conclusion we report here an efficient, rapid, easy and inexpensive method for the selective oxidation of benzylic alcohols to the corresponding carbonyl compounds. This procedure is clean, rapid and with quantitative yield.

Products were characterized by comparison with authentic samples (IR and ^{1}H-NMR spectrum). All ^{1}H-NMR were recorded at 90 MHZ in $CC1_4$ relative to TMS (0.00 ppm) and IR spectra were recorded on Shimadzu 435 IR spectrophotometer. Spectra of solids were carried out using KBr pellets.

The oxidation of 3,4-dimethoxybenzyl alcohol is representative of the general procedure employed. In method A, 3,4-dimethoxybenzyl alcohol (0.2 mL, 0.23 gr, 1.39 mmol) was added to 1 -benzyl-4-aza-1-azoniabicyclo[2.2.2]octane dichromate (0.87 g, 1.39 mmol) and the mixture was ground with a pestle until TLC showed complete disappearance of starting alcohols which required 23 min (Table 1). $CC1_4$ (15 mL) was added to the reaction mixture and after vigorous stirring, the mixture was filtered off and the solvent was evaporated by rotary evaporator. The residue was purified by column chromatography on silica gel using $CC1_4$ to give 3 ,4-dimethoxybenzaldehyde. In method B, a mixture of 3,4-dimethoxybenzyl alcohol (0.2 mL, 0.23 gr, 1.39 mmol), 1-benzyl-4-aza-1-azoniabicyclo[2.2.2] octanedichromate (0.87 gr, 1.39 mmol) and aluminum chloride (19 mg, 0.14 mmol) was crushed with a mortar and pestle until TLC showed complete disappearance of starting alcohols which required 40 s (Table l). $CC1_4$ (15 mL) was added to the reaction mixture and after vigorous stirring, the mixture was filtered off and the solvent was evaporated by rotary evaporator. The pure 3,4-dimethoxybeazaldehyde was obtained.

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