Iranian Journal of Organic Chemistry 1 (2008) 13-17

Trichloromelamine and Triphenylphosphine as a Versatile and Efficient System for Oxidation of Alcohols under Solvent-free Condition

Bi Bi Fatemeh Mirjalili,[a*] Abdolhamid Bamoniri,[b] Mohammad Ali Amrollahi,[a] Ebrahim Dastan[a]
[a]*Department of Chemistry, College of Science, Yazd University, P.O. Box 89195-741, Yazd. Iran*
[b]*Department of Chemistry, College of Science, University of Kashan, Kashan, Iran*

Abstract-TCM/PPh_3/$NaHCO_3$(CH_3COONa) system is a safe, versatile, cheap and eco-friendly system for oxidation of alcohols to corresponding carbonyl or α-chloro carbonyl compounds under solvent free condition.

Keywords: Trichloromelamine, Triphenylphophine, Oxidation, Alcohols, Carbonyl compounds

Introduction

Aldehydes and ketones have been prepared by oxidation of corresponding alcohols with oxidizing agents such as polymer supported TEMPO [1], Os/O_2 [2], Co(II)phtalocyanine [3], ruthenium/TEMPO [4], $KMnO_4$ [5], H_2O_2/$FeBr_3$ [6], periodic acid or iodic acid in the presence of a catalytic amount of KBr [7], $H_{14}[NaP_5W_{30}O_{110}]/SiO_2$ [8] and heteropolyphosphatotungstate [9]. Recently more and more attention has been to the replacement of positive halogen compounds such as I_2/TEMPO [10], NCS/N-*tert*-butylbenzenesulfenamide [11], trichloroisocyanuric acid/$RuCl_3$ [12], NIS/CH_3COOAg [13], NBS/Bu_4NI [14], DABCO-Br_2 [15] as a green oxidant to the traditional oxidation agents.
Chloroamines such as trichloromelamine (TCM) are used as bleaching agent, disinfectants and bactericides, due to their function as chlorinating agents and oxidant. Trichloromelamine or N_2,N_4,N_6-trichloro-2,4,6-triamino-1,3,5-triazine, is an active disinfectant for fruit, vegetable and service areas.

Although solvent-free reactions are of general interest because of their potential applications in organic chemistry, only a few solvent free oxidation of alcohols procedures have been reported.

Whereas carbonyl compounds are useful synthetic intermediates, oxidation of alcohols to the corresponding carbonyl compounds is one of the most important reactions in organic synthesis. In this article we hope to describe an efficient and simple procedure for oxidation of alcohols to carbonyl or α-chloro carbonyl compounds using a cheap and efficient oxidant, trichloromelamine (TCM).

Results and Discussion

We have decided to apply TCM for oxidation of alcohols at room temperature under solvent free condition. For this purpose, oxidation of benzyl alcohol to benzaldehyde was chosen as a model reaction. In the first step, several mmoles of TCM per one mmole of benzyl alcohol were screened (Table 1). Because of low nucleophilicity of oxygen in alcohols, in every molar ratio of benzyl alcohol to TCM, the yield of production has been low (10-20 %). After checking of a variety of nucleophiles such as PPh_3, dimethylsulfide, dibenzylsulfide, thiourea, sodium thiosulfate and dimethylsulfoxide, we have found that triphenylphosphine was the most effective co-reagent for this reaction. By applying of TCM/PPh_3 system, the yield of oxidation reaction was increased (50-60%). Probably, PPh_3 forms an active species, $(PPh_3\text{-}Cl)^+$, that can promote the other steps of oxidation reaction very fast.

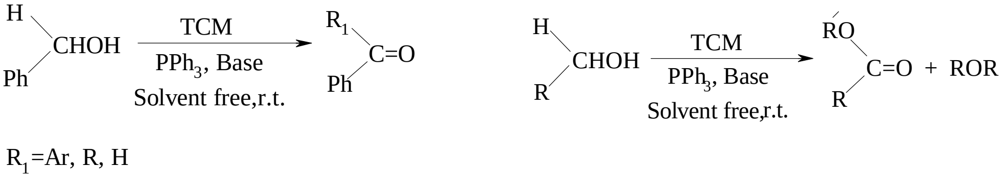
Table 1: Oxidation of one mmole of benzyl alcohol to benzaldehye in various molar ratio of reagents at room temperature under solvent free condition.

Entry	mmol of TCM	mmol of PPh_3	mmol of $NaHCO_3$	Yeild (%)
1	0.6	0	0	~10
3	1	0	0	~15
4	1.5	0	0	~20
5	1	1	0	~60
6	1	0.5	0	~60
7	1	0.2	0	~60
8	0.5	0.2	0	~60
9	0.4	0.2	0.5	~85
10	0.5	0.2	0.5	>95
11	0.3	0.2	0.5	~80
12	0.5	0.2	1	>95

Whereas, in this reaction the *insitu* HCl formation could activize the TCM by protonation, thus, the reaction has taken place very fast and uncontrollable with medium

---

*Corresponding author. Fax: +(98) 351 8210644; E-mail: fmirjalili@yazduni.ac.ir yield. Therefore, the reaction has needed a base for neutralization of HCl. After screening some bases such as Et_3N, hexamethylenetetramine, K_2CO_3, $NaHCO_3$ and CH_3COONa, we have found that $NaHCO_3$ and CH_3COONa were the most effective bases in this reaction. In most cases, $NaHCO_3$ was used as a base except in oxidation of 4-methoxybenzyl alcohol. When one portion of TCM was added to mixture of alcohols, PPh_3 and base, the products were detected in low yield. It was further found that the slow addition of TCM to mixture of alcohols, PPh_3 and base and grinding of mixture for 5-10 min improved the yield of product up to 80 %. Probably because of the operation suppressed the fast interaction of TCM with PPh_3 and alcohols. We have examined the oxidation of benzyl alcohol in the presence of $TCM/PPh_3/NaHCO_3$ system with grinding under solvent free condition or mixing in solvents such as dichloromethane, *n*-hexane, acetonitrile or 1,2-dichloroethane at room temperature. Meanwhile, we have concluded that all of the above mentioned conditions are well for this reaction. The best molar ratio of alcohol:TCM:PPh_3:base for this reaction is 1:0.5:0.2:0.5 (Table 1). Because of the importance of solvent free condition in organic synthesis, we have oxidized a wide range of alcohols in the presence of TCM/PPh_3/base with high yield (Scheme 1 and Table 2).



Scheme 1

Table 2: oxidation of alcohols to corresponding carbonyl compounds in the presence of TCM/PPh_3/Base in solvent free condition.[a]

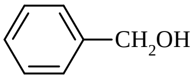
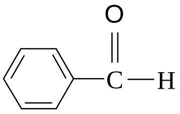
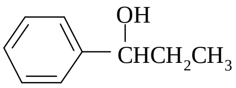
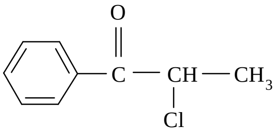
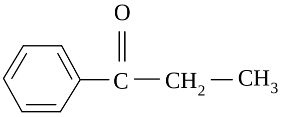
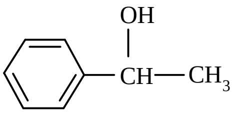
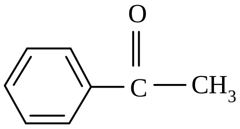
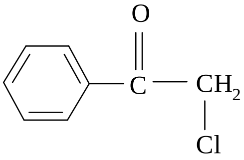
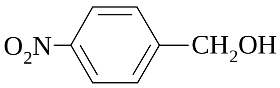
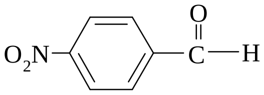
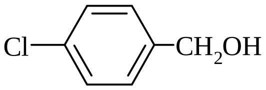
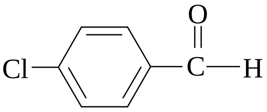
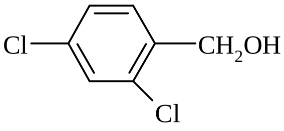
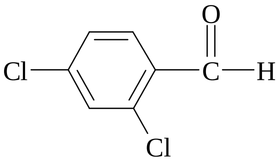
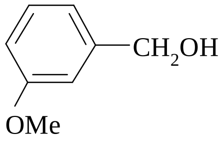
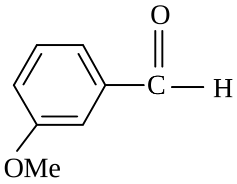
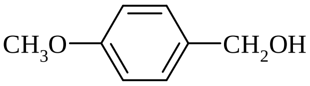
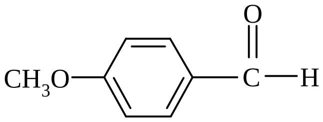
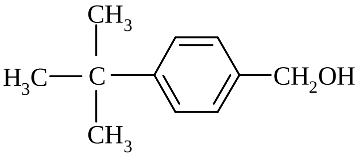
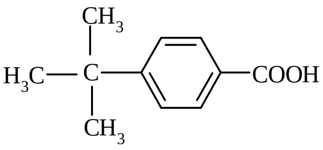
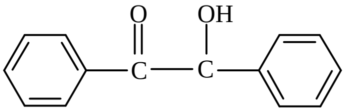
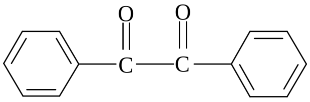
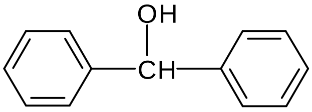
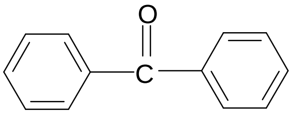
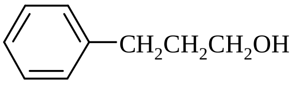
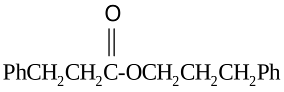
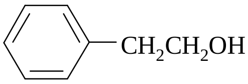
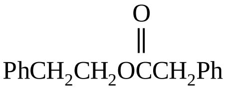
Entry	Alcohol	Product	Base	Time	Yield (%)
1			$NaHCO_3$	5	90[b]
2			$NaHCO_3$	5	23[b]
			$NaHCO_3$	5	66[b]
3			$NaHCO_3$	5	20[b]
			$NaHCO_3$	5	65[b]

Table 2. Continued

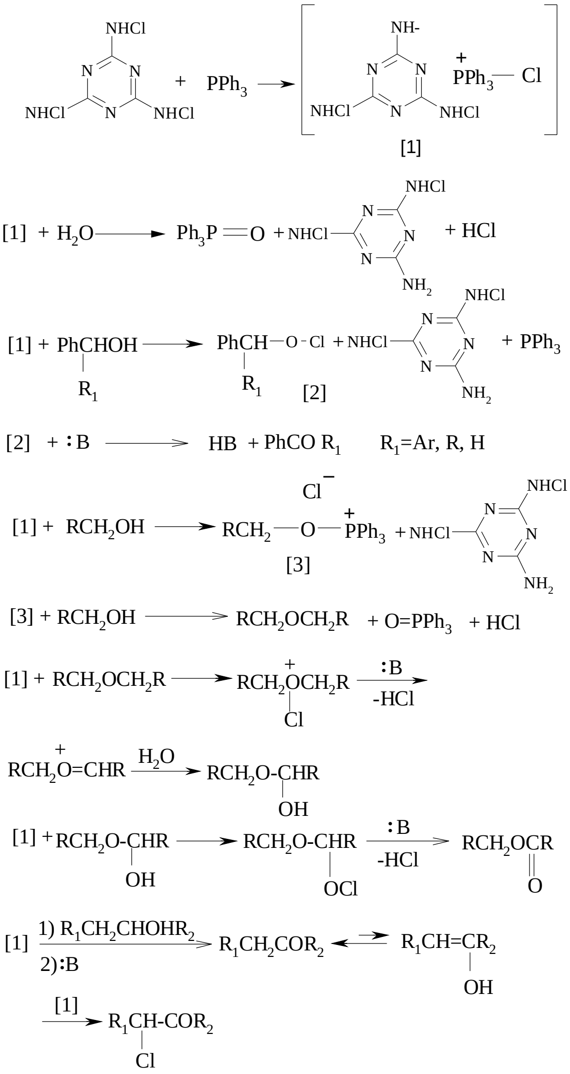
4			$NaHCO_3$	10	82[c]
5			$NaHCO_3$	10	90[c]
6			$NaHCO_3$	10	86[c]
7			$NaHCO_3$	10	85[c]
8			$NaHCO_3$	5	50[b]
			CH_3COONa	10	92[c]
9			$NaHCO_3$	5	92[b]
10			$NaHCO_3$	15	95[c]
11			$NaHCO_3$	5	94[b]
12		 $PhCH_2CH_2\overset{\overset{O}{\|}}{C}\text{-}OCH_2CH_2CH_2Ph$	$NaHCO_3$	5	40
		$PhCH_2CH_2CH_2OCH_2CH_2CH_2Ph$	$NaHCO_3$	5	45
13		 $PhCH_2CH_2O\overset{\overset{O}{\|}}{C}CH_2Ph$	$NaHCO_3$	5	45
		$PhCH_2CH_2OCH_2CH_2Ph$	$NaHCO_3$	5	45

a) molar ratio of alcohol:TCM:PPh_3:base for this reaction is 1:0.5:0.2:0.5
b) these products were obtained under grinding condition at room temperature.
c) these products were obtained under heating in 90-100 °C

When simple benzylic alcohols with no H_α were used as substrate, the corresponding carbonyl compounds were obtained. But alcohols with H_α, such as 1-phenylpropanol and 1-phenylethanol were converted to corresponding ketones and α-chloro ketones.

Since, the nucleophilicity of oxygen in alcohol and the conjugation of carbonyl group in products are important factors in the progressing of this reaction, primary and secondary benzylic alcohols or benzylic alcohols with electron donating groups were oxidized at room temperature under grinding condition with good to excellent yields (90-95%).

4-*tert*-butylbenzyl alcohol can be oxidized to corresponding acid, on the other hand, primary aliphatic alcohols such as 2-phenylethanol and 3-phenylpropanol were converted to the corresponding ethers and esters in this procedure.



Scheme 2

The benzylic alcohols with electron-withdrawing groups such as 2,4-dichlorobenzyl alcohol or 4-nitrobenzyl alcohol were oxidized at 90-100°C.

According to our proposed mechanism for oxidation of alcohols to mentioned products with TCM/PPh_3/base (Scheme 2), PPh_3 with a positive chloride in TCM forms an active species $(PPh_3\text{-Cl})^+$ [1]. We believe that $(PPh_3\text{-Cl})^+$ reacts with benzylic alcohol to form another active species ($PhCHR_1O\text{-}Cl$). The resulted species readily reacts with base (B^-) and losses HB to form aldehyde or ketones. Primary aliphatic alcohols react with $(PPh_3\text{-Cl})^+$ and form the active species ($RCH_2O\text{-}PPh_3^+$). If one molecule of primary alcohol reacts with $RCH_2O\text{-}PPh_3^+$ as a nucleophile, ether and $O{=}PPh_3$ are formed. The obtained ether and the enol form of ketone react with $(PPh_3\text{-Cl})^+$ species for preparation of esters or α-chloro ketones, respectively. In this procedure, triphenylphosphinoxide was prepared as by- product in interaction of water or primary alcohols with $(PPh_3\text{-Cl})^+$

In conclusion, we report here that TCM/PPh_3/$NaHCO_3$(CH_3COONa) is a versatile and efficient system for oxidation of alcohols to corresponding carbonyl or α-chloro carbonyl compounds under solvent free condition with good to excellent yields.

Experimental

General

Products were characterized by IR, ^{1}H-NMR, TLC and by comparison of their physical properties with those reported in the literature. IR spectra were run on a Bruker, Eqinox 55 spectrometer. ^{1}H-NMR were obtained using a Bruker Avans 400 MHz spectrometer and Bruker Avans 500 MHz spectrometer (DRX).

General Procedure for Oxidation of Alcohols in the Presence of TCM/ PPh_3/ $NaHCO_3$

In a mortar, a mixture of alcohol, Ph_3P and $NaHCO_3$ (Table 2) was pulverized, TCM was added in several portions and the mixture was pulverized at room temperature until TLC analysis indicates a completed reaction. In general, the oxidations are complete within 3-5 min. The reaction mixture was then worked up by dilution with cold *n*-hexane and filtration. Evaporation of solvent has given a product that has acceptable purity for most purpose. In some cases that alcohol was as impurity in product, we have converted the carbonyl compound to corresponding semicarbazone derivative or purified by preparative TLC or column chromatography by using ether:petroleum ether (1:1) as eluent.

Acknowledgment

Financial support for this work by the Research Council of Yazd University is gratefully acknowledged

References

[1] Tanyeli, C.; Gumus, A. *Tetrahedron Lett.* **2003**, *44*, 1639.
[2] Dobler, C.; Mehltretter, G. M.; Sundermeier, U.; Eckert, M.; Militzer, H- C.; Beller, M. *Tetrahedron Lett.* **2001**, *42*, 8447.
[3] Sharma, V. B.; Jaim, S. L.; Sain, B. *Tetrahedron Lett.* **2003**, *44*, 383.
[4] Dijksman, A.; Marino-Gonzalez, A.; Payeras, A. M.; Arends, I. W. C. E.; Sheldon, R. A. *J. Am. Chem. Soc.* **2001**, *123*, 6826.
[5] Shaabani, A.; Lee, D. G. *Tetrahedron Lett*. **2001**, *42*, 5833.
[6] Miller, R. A.; Hoerrner, R. S. *Org. Lett.* **2003**, *5*, 285.
[7] Zolfigol, M. A.; Shirini, F.; Chehardoli, G.; Kolvari, E. *J. Mol. Catal. A: Chem.* **2007**, *265*, 272.
[8] Heravi, M.; Zadsirjan, V.; Bakhtiari, K.; Oskooie, H.; Bamoharram, F. *Catal. Commun*. **2007**, *8*, 315.
[9] Zhang, S.; Gao, S.; Xi, Z.; Xu, J. *Catal. Commun.* **2007**, *8*, 531.
[10] Matsuo, J.; Iida, D.; Yamanaka, H.; Mukaiyama, T. *Tetraherdron* **2003,** *59*, 6739.
[11] Yamaoka, H.; Moriya, N.; Ikunaka, M. *Organic Process Research & Development* **2004**, *8*, 931.
[12] Beebe, R. T.; Hensley, L. V.; Ng, W. F.; Noe, A. R.; Scott, J. D. *J. Org. Chem.* **1985**, *50*, 3015.
[13] Beebe, R. T.; Boyd, L.; Fonkeng, B. S. *J. Org. Chem.* **1995**, *60*, 6602.
[14 Martin, E. S.; Garrone, A. *Tetrahedron Lett.* **2003**, *44*, 549.
[15] Heravi, M. K.; Derikvand, F.; Ghassemzadeh, M.; Neumuller, B. S. *Tetrahedron Lett*. **2005**, *46*, 6243.