Oxidation of Alcohols with Benzyltriphenylphosphonium Periodate under Non-Aqueous Conditions

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Abstract: A variety of alcohols were converted to their corresponding carbonyl compounds by using benzyltriphenylphosphonium periodate **1** as a useful reagent under non-aqueous conditions.

Key words: oxidation, benzyl alcohol, non-aqueous conditions

Oxidation of organic compounds under non-aqueous and aprotic conditions has an important role in modern organic synthesis.[1–8] For this purpose, some new oxidizing reagents have been prepared, and several techniques have been used. Most of them suffer at least from one of the following disadvantages: 1) high costs of preparations, 2) long reaction times, 3) hygroscopicity, 4) high acidity, 5) instability, 6) no selectivity, 7) photosensitivity, 8) dangerous procedures for their preparation and 9) tedious work-up procedures.

In continuation of our previous works,[9,10] we introduce an efficient, mild and rapid method for the selective oxidation of alcohols to their corresponding carbonyl compounds by using benzyltriphenylphosphonium periodate **1** which is readily prepared by reaction of an aqueous solution of benzyltriphenylphosphonium chloride with $NaIO_4$ solution at room temperature (Scheme 1).

$$Ph_3P^+CH_2PhCl^- + NaIO_4 \xrightarrow{H_2O} Ph_3P^+CH_2PhIO_4^-$$

Scheme 1

The resulting white powder, which can be stored for months without loss of its reactivity, is soluble in acetonitrile, acetone, dimethylformamide, chloroform, ethyl acetate, and dichloromethane, and insoluble in carbon tetrachloride, n-hexane and diethyl ether.

Here we wish to report the oxidation of aliphatic and benzylic alcohols to the corresponding carbonyl compounds in refluxing acetonitrile. The oxidation of alcohols with **1** in the presence of catalytic amounts of Lewis acid proceeds under non-aqueous conditions. The effect of various solvents such as cyclohexane, CH_2Cl_2, THF, $CHCl_3$ and CH_3CN on the oxidation of benzyl alcohol with **1** in the presence of $AlCl_3$ was examined. TLC was used to monitor the rate of the oxidation. Only acetonitrile was a suitable solvent for this oxidation system (Table 1).

Table 1 Oxidation of Benzyl Alcohol with Reagent **1** in Different Refluxing Solvents

Entry	Solvent	Time (min)	Yield (%)[a,b]
1	cyclohexane	180	50
2	THF	120	40
3	CH_2Cl_2	120	60
4	$CHCl_3$	170	70
5	CH_3CN	90	100

[a] Monitored by TLC analysis.
[b] Oxidant/Alcohol/$AlCl_3$ (1:1:0.2).

Oxidation of benzyl alcohol to its corresponding aldehyde with reagent **1** in the presence of various Lewis acids such as $ZnCl_2$, $FeCl_3$, $BiCl_3$ and $AlCl_3$ were also examined in refluxing acetonitrile. Surprisingly, only $AlCl_3$ was shown to be an effective catalyst for this purpose (Table 2). The reaction in the presence of $ZnCl_2$, $FeCl_3$, and $BiCl_3$ (0.5 mmol) proceeds with lower efficiency even with a higher molar ratio of the oxidant (1.5 mmol) in comparison with the amount of oxidant used in the presence of $AlCl_3$ (0.3 mmol). This could be the effect of hardness or high solubility of $AlCl_3$ in comparison with the other Lewis acids, which have been used in these experiments. Alcohols **2** are oxidized to the corresponding carbonyl compounds **3** in refluxing acetonitrile in the presence of aluminum chloride in good to excellent yields; benzoin was converted to benzil in high yield (Scheme 2).When we tried to oxidize

Table 2 Oxidation of Benzyl Alcohol with Reagent **1** with Different Lewis Acids in Refluxing Acetonitrile[a,b]

Entry	Lewis acid	Time (min)	Yield (%)
1	$ZnCl_2$[c]	120	50
2	$FeCl_3$[c]	120	60
4	$BiCl_3$[c]	80	65
3	$AlCl_3$[b]	40	100

[a] Monitored by TLC analysis.
[b] Oxidant/Alcohol/Lewis acid (1:1:0.3).
[c] Oxidant/Alcohol/Lewis acid (1.5:1:0.5).

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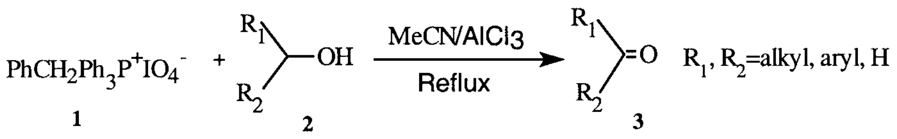

Scheme 2

the allylic alcohols with this reagent several by-products were obtained. Therefore this reagent is not suitable for oxidizing allylic alcohols. Table 3 shows the experimental results.

The functional groups such as NO_2 and MeO, decrease the rate of reaction. This could be the effect of producing complexes of these functional groups with $AlCl_3$ (Table 3).

In order to evaluate the synergy between aluminum chloride and this reagent, we tried several experiments. When we tried the reaction of benzyl alcohol with **1** in refluxing acetonitrile without using any aluminum chloride, the reaction proceeds in 30% yield after 220 min. We also tried the oxidation of benzyl alcohol with $NaIO_4$ in refluxing acetonitrile as well as in a mixture of water and acetonitrile (50:50) without using any aluminum chloride. In the case of reaction with $NaIO_4$ in acetonitrile under refluxing conditions the reaction does not proceed at all after 220 min, but in a mixture of water and acetonitrile (50:50) the corresponding aldehyde was obtained in 20% yield after

Table 3 Oxidation of Alcohols **2a-v** with Reagent **1** in Acetonitrile under Refluxing Conditions[a]

Alcohols		Time (h)	Yield (%)	mp (°C) or bp (°C)/Torr	
				Found	Reported[11]
2a	$PhCH_2OH$	1:30	78	176–177/760	178–179/760
2b	$2\text{-}MeOC_6H_4CH_2OH$	4:10	82	36–39	37–39
2c	$3\text{-}MeOC_6H_4CH_2OH$	4:00	90	100–103/10	143/50
2d	$4\text{-}MeOC_6H_4CH_2OH$	3:45	86	118–120/13	248/760
2f	$2,5\text{-}(MeO)_2C_6H_3CH_2OH$	3:55	90	50–52	49–52
2g	$3,4\text{-}(MeO)_2C_6H_3CH_2OH$	3:20	86	41–43	42–45
2h	$4\text{-}NO_2C_6H_4CH_2OH$	6:00	84	105–107	105–108
2I	$3\text{-}NO_2C_6H_4CH_2OH$	6:20	81	56–59	57–59
2j	$2\text{-}NH_2C_6H_4CH_2OH$	7:00	82	38–40	39–40
2k	$2\text{-}ClC_6H_4CH_2OH$	3:30	90	212–214/760	209–215/760
2l	$4\text{-}ClC_6H_4CH(CH_3)OH$	3:10	83	230/760	232/760
2m	$4\text{-}BrC_6H_4CH(CH_2Br)OH$	9:00	90	107–108	108–110
2n	$PhCH(CH_3)OH$	9:25	95	200/760	202/760
2o	Ph_2CHOH	8:40	89	49–50	49–51
2p	PhCOCH(OH)Ph	2:00	83	93–94	94–95
2q	$Ph(CH_2)_2OH$	14:00	81	193–196/760	195/760
2r	$Ph(CH_2)_3OH$	14:00	88	103–105/13	104–105/13
2s	$CH_3(CH_2)_2CH_2OH$	3:50	95	76–79	78–80
2t	cyclohexanol	7:00	100	153–155/760	155/760
2u	menthol	8:00	87	208–210/760	207–210/760
2v	β-citronellol	9:00	82	207–208/760	207–208/760

[a] All compounds were characterized by comparing with known samples.

Table 4 Reaction of Benzyl Alcohol under Refluxing Conditions

Entry	Reagent	Solvent	Lewis acid	Time (min)	Yield[a] (%)
1	BTPPPI	CH_3CN	–	220	30
2	$NaIO_4$	CH_3CN	–	220	N.R
3	$NaIO_4$	CH_3CN-H_2O	–	220	20
4[b]	$NaIO_4$-BTPPPI	CH_3CN	–	180	10
5[c]	$NaIO_4$	CH_3CN	$AlCl_3$	120	30
6[c]	BTPPPI	CH_3CN	$AlCl_3$	90	100

[a] Monitored by TLC.
[b] BTPPPI was used as catalytic amount (0.2 mmol).
[c] Oxidant/Alcohol/Lewis acid (1:1:0.3).

220 min refluxing. In another reaction, we tried the reaction of benzyl alcohol with $NaIO_4$ in the presence of a catalytic amount of **1** (0.2 mmol) in refluxing acetonitrile and the reaction proceeded in 10% yield after 3 h. We also investigated the use of $NaIO_4$ in the presence of aluminum chloride in refluxing acetonitrile and observed that the reaction does not complete after 2 h and the corresponding aldehyde was obtained in 30% yield. The results of these experiments are summarized in Table 4.

This observation is in contrast to what is reported by us for 1-benzyl-4-aza-1-azoniabicyclo[2.2.2]octane dichromate, which decomposes upon standing in solution.[10] The stability of this reagent in comparison with 1-benzyl-4-aza-1-azoniabicyclo[2.2.2]octane dichromate is the reflection of the presence of the phosphonium cation in the reagent, which is more stable than ammonium cation.

In summary, we report here the preparation of benzyltriphenylphosphonium periodate **1** as a mild, inexpensive and stable oxidizing reagent. This oxidizing reagent is easily prepared from commercially available starting materials and could be stored for months without losing its activity. The reagent is soluble in acetonitrile, chloroform, dichloromethane, dimethylformamide and ethyl acetate, and insoluble in carbon tetrachloride, ether and hexane. This compound is an efficient and novel reagent for oxidation of benzylic and aliphatic alcohols to the corresponding carbonyl compounds under non-aqueous conditions in the presence of catalytic amounts of $AlCl_3$. The reactivity of benzylic alcohols with this oxidizing agent is higher than aliphatic alcohols.

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(12) **Preparation of Benzyltriphenylphosphonium Periodate(1).** A solution of benzyltriphenylphosphonium chloride (10.3 g, 26 mmol) in 50 mL of water was prepared, then $NaIO_4$ (5.56 g, 26 mmol) in water (50 mL) was added

dropwise to the above solution and stirred for 20 min at r.t. The resulting precipitate was filtered and washed with cooled distilled H_2O (50 mL) and dried in a desiccator under vacuum over calcium chloride to afford a white powder (13.9 g, 98% yield), which decomposed at 138–140 ºC to a dark-brown material. ^1H NMR: 7.93–6.87 (m, 20 H), 4.7(d, *J* = 25.6 Hz, CH2-P). ^{13}C NMR: 135.28, 135.25, 134.32, 134.24, 131.07, 131.03, 130.19, 130.09, 128.99, 128.97, 128.69, 128.66, 127.45, 127.43, 118.01, 117.36, 29.68 (d, J = 193 Hz, C-P). IR (KBr): 1298, 1269, 1600, 1510, 1450, 1100, 1040, 960, 940,800, 750, 658, 590 cm^{-1}. Anal. Calcd for $C_{25}H_{22}IO_{4P}$: C, 55.14; H, 4.04%. Found: C, 55.40; H, 4.17%.

Oxidation of alcohols 2 to the corresponding carbonyl compounds 3 with reagent 1 in refluxing CH_3CN in the presence of $AlCl_3$. General Procedure. In a round-bottomed flask, a solution of alcohol **2** (1 mmol) in CH_3CN (10 mL) was treated with $PhCH_2P^+Ph_3IO_4^-$ (0.54 g, 1 mmol) and aluminum chloride (0.04 g, 0.3 mmol) and refluxed for 1.30–14 h. TLC (cyclohexane/EtOAc, 8:2) was used to monitor the reaction progress. The reaction mixture was cooled to r.t. and the solid filtered off and washed with CH_3CN (15 mL). The filtrates were evaporated on a rotary evaporator and the resulting crude material was purified by column chromatography on silica gel with an appropriate eluent or distillation in vacuum to afford pure carbonyl compounds in 78–100% yields (Table 3).