Polyaniline-Supported Sulfuric Acid Salt as a Powerful Catalyst for the Protection and Deprotection of Carbonyl Compounds

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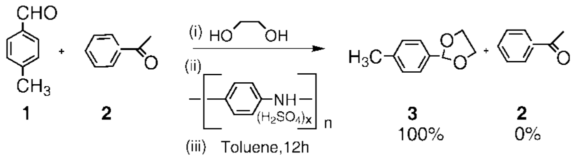
Abstract: Structurally different carbonyl compounds were converted into their corresponding cyclic acetals using polyaniline-sulfate salt as catalyst in dry toluene in excellent yield. In turn, useful deacetalization in aqueous medium was demonstrated. Chemoselective protection of carbonyl compounds was also demonstrated. The advantages of the polyaniline-sulfate salt are ease of preparation and handling, stability, reusability and activity.

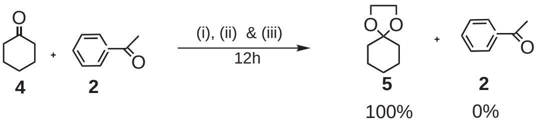
Key words: protection, deprotection, chemoselectivity, polyaniline-sulfate salt, carbonyl compounds

Protection and deprotection of carbonyl compounds are frequently encountered synthetic steps in the preparation of complex compounds.[1,2] The protective reaction may be catalyzed by protic acids,[3] Lewis acids,[4] iodine,[5] *N*-bromosuccinamide,[6] lanthanides,[7] metal-catalysts,[8] zeolites,[9] sulfated zirconia,[10] montmorillonite clay,[11] zeolite HSY-360[12] and graphite.[13] In recent years, the development of more economical and environmental friendly conversion processes is gaining interest in the chemical community. In this communication, polyaniline-sulfate salt is used for chemoselective protection, deprotection of carbonyl compounds. The polyaniline-sulfate salt can be prepared easily[14a] and possesses useful handling properties with regard to recovery, reusability, stability and activity.[14b]

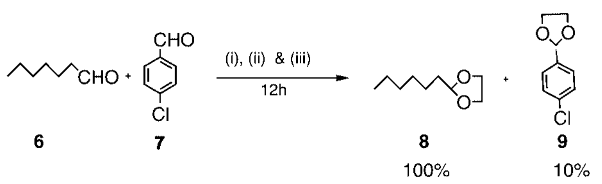
We found that polyaniline-sulfate salt could be used for protection and deprotection of carbonyl compounds with 1,2-ethane-diol in dry toluene. There was no appreciable reaction when benzaldehyde was allowed to react with 1,2-ethane-diol in the absence of catalyst in toluene. However, the presence of polyaniline-sulfate salt (20 wt% with respect to carbonyl compound) provided 98% yield of protected benzaldehyde (Table 1, entry 1) in a clean reaction with simple work up procedure.[15a] Encouraged by this result, we carried out further investigations on several carbonyl compounds (Table 1, entries 2–15). Aldehydes containing electron-donating groups (90–98% yield in 45 min, entries 2–5) react faster than those containing electron-withdrawing group (85% yield in 180 min, entry 7).



Scheme 1



Scheme 2



Scheme 3

However, *p*-hydroxybenzaldehyde takes a longer time to give the product (85% in 150 min, entry 6) and this may be due to the lower solubility of *p*-hydroxybenzaldehyde in toluene. The protection reaction carried out on naphthaldehyde resulted in 95% yield in 90 minutes (entry 9); slower than that of cinnamaldehyde (96% in 60 min., entry 8), possibly because of the bulkier nature of naphthaldehyde. Catalytic application of the polyaniline-sulfate salt was extended to protection of different types of ketones such as acetophenone and benzophenone (entries 10 and 11). The time required for the completion of the reaction was found to be longer for benzophenone (90% yield in 240 min, entry 11) than acetophenone (95% yield in 80 min, entry 10). Furthermore, excellent yields were observed with alicyclic keto compounds (entries 12, 13), acyclic aliphatic aldehydes (entry 14) and β-keto esters (entry 15).

Reusability of the catalyst was checked by the protection of *p*-chlorobenzaldehyde with 1,2-ethanediol with polyaniline-sulfate salt in dry toluene medium, which results in 96% yield. The polyaniline-sulfate salt was recovered and reused for a further seven times and resulted in 93–96% yields. This indicates that polyaniline-sulfate salt does not lose its activity and can be reused.

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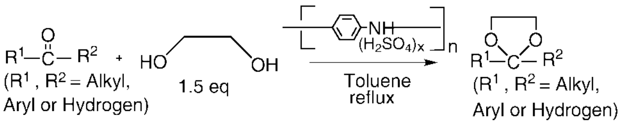
Table 1 Protection of Carbonyl Compounds with 1,2-Ethanediol in Prescence of Polyaniline-Sulfate Salt (20% w.r.t. Carbonyl Compounds) in Toluene



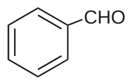
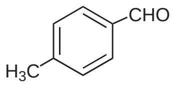
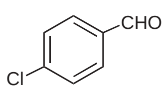
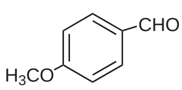
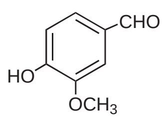
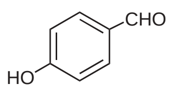
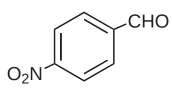
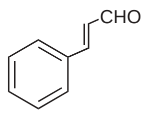
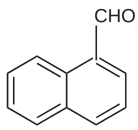
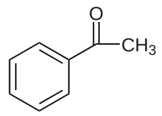
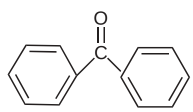
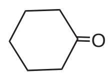
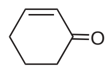
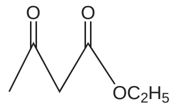
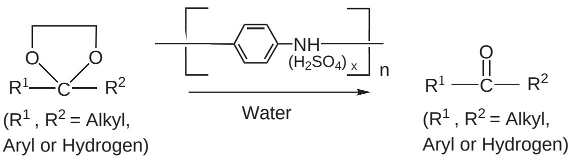
Entry	Substrate	Time (min)	Isolated yield (%)
1		45	98
2		45	97
3		45	96
4		45	98
5		45	90
6		150	85
7		180	85
8		60	96
9		90	95
10		80	95
11		240	90
12		60	90
13		90	85
14		90	95
15		90	90

Table 2 Deprotection of Protected Carbonyl Compounds with Water Using Polyaniline-Sulfate Salt (20% w.r.t. Protected Carbonyl Compounds)



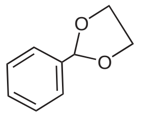
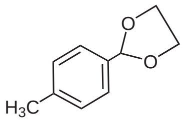
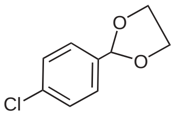
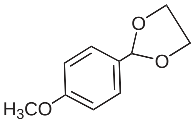
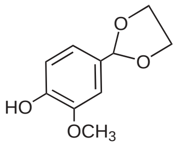
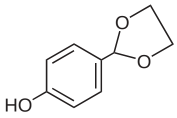
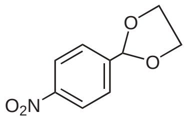
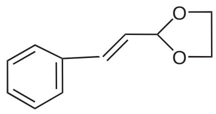
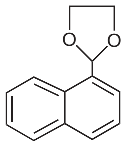
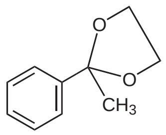
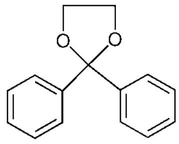
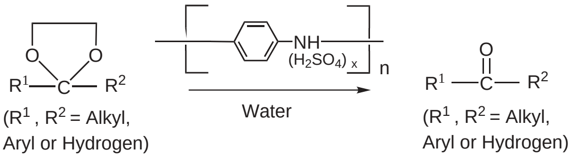
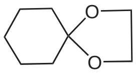
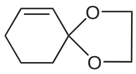
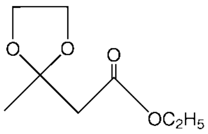
Entry	Substrate	Time (min)	Isolated yield (%)
1		30	95
2		30	96
3		30	96
4		45	90
5		40	95
6		45	90
7		90	95
8		30	95
9		120	90
10		45	95
11		180	90

Table 2 Deprotection of Protected Carbonyl Compounds with Water Using Polyaniline-Sulfate Salt (20% w.r.t. Protected Carbonyl Compounds) (continued)



Entry	Substrate	Time (min)	Isolated yield (%)
12		45	95
13		45	90
14		30	96
15		45	90

We observed that the protection of aldehydes takes place faster in the presence of polyaniline-sulfate salt when compared to the ketones (Table 1). The difference in reactivity of the polyaniline-sulfate salt towards aldehydes and ketones gave us the impetus to study chemoselective reactions. We carried out an initial experiment with an equimolar (1.0 equiv) mixture of *p*-methylbenzaldehyde (**1**) and acetophenone (**2**) with 1.5 equivalent of 1,2-ethanediol and polyaniline-sulfate salt (20 wt% with respect to *p*-methylbenzaldehyde) in dry toluene. The ratio of the products was determined by ^1H NMR analysis. The reaction resulted in complete conversion of *p*-methylbenzaldehyde (**3**) and no conversion of acetophenone (**2**). One can infer that the reaction with the aromatic aldehyde takes place faster than with the aromatic ketone in the presence of polyaniline-sulfate salt (Scheme 1). Likewise we were able to achieve selective protection of an alicyclic ketone (**4**) in the presence of an aromatic ketone (**2**) by this method (Scheme 2). Furthermore we studied chemoselective protection of an aliphatic aldehyde (**6**) in the presence of an aromatic aldehyde (**7**), which also exhibited more selectivity towards the heptaldehyde (100% conversion) (**8**) than *p*-chlorobenzaldehyde (10%) (**9**) (Scheme 3). Polyaniline-sulfate salt thus demonstrates pronounced selectivity between these functionalities.

The cyclic acetals and ketals were deprotected to their corresponding carbonyls in excellent yields (90–96%) using polyaniline-sulfate salt in aqueous medium[15b] and the results are shown in Table 2 (entries 1–15). Cyclic acetals of aromatic aldehydes (entries1–6), conjugated aldehydes (entry 8), aromatic ketones (entry 10), alicyclic ketones (entries12, 13), acyclic aliphatic aldehydes (entry 14) and β-keto esters (entry 15) are effectively deprotected in 30–45 minutes. However, the cyclic acetal of naphthaldehyde takes 120 minutes, (entry 9) and benzophenone takes 180 minutes, (entry 11) and *p*-nitro benzaldehyde takes 90 minutes, presumably due to the electron-withdrawing group in this latter case (entry 7).

In summary, we have demonstrated that polyaniline-sulfate salt acts as a highly efficient polymer supported acid catalyst in protection and deprotection of carbonyl compounds with 1,2-ethanediol. Furthermore, a very useful chemoselectivity for aliphatic and aromatic carbonyl compounds has also been demonstrated. This work leads to a simple, convenient, mild and efficient protection and deprotection of carbonyl compounds in organic synthesis.

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(14) (a) **Preparation of Polyaniline-Sulfate Salt:** In a typical experiment, benzoyl peroxide (24.2 g, 0.1 M) was dissolved in 300 mL acetone. Then 200 mL aqueous solution containing 10 g of sodium lauryl sulfate (0.034 M) was added into the above solution slowly. To this solution, 465 mL aqueous solution containing 27 mL of (1.0 N) sulfuric acid and 9.3 g aniline (0.1 M) was added dropwise over 15–20 min and the mixture was stirred at 40 °C for 8 h. The precipitated polyaniline salt was filtered, washed with distilled H_2O, followed by MeOH and acetone. The sample was dried at 100 °C to a constant weight. (b) **Physical Data of Polyaniline-Sulfate Salt:** Yield: 82.1 % with respect to the amount of aniline used. Conductivity (0.04 S/cm), Sulfuric acid group present in polyaniline salt (30 %), Pellet density (1.15 g/cm^3), Particle size (0.3–75 μm), Elemental analysis: C, 52.5%; H, 3.3%; N, 10.7%; S, 7.4 %.

(15) **General Experimental Procedures:** (a) For protection: In a 50 mL round-bottom flask was placed *p*-methylbenzaldehyde (1 g, 8 mmol), 1,2-ethanediol (0.75 g, 12 mmol), 200 mg activated polyaniline-sulfate salt (20 wt%

with respect to *p*-methylbenzaldehyde) and 25 mL of toluene. This was refluxed for 45 min with a Dean–Stark apparatus for azeotropic removal of H_2O; reaction being monitored by TLC until the starting material disappeared. The reaction mixture was cooled and filtered to remove the catalyst. The filtrate was washed with H_2O and the organic phase separated, dried over Na_2SO_4, filtered and concentrated in vacuum. The crude mixture was purified by preparative column chromatography (1:99 EtOAc:hexane) affording the cyclic acetal of *p*-methylbenzaldehyde (Table 1). (b) **For Deprotection:** The cyclic acetal of *p*-methylbenzaldehyde (1 g, 6 mmol), 200 mg activated polyaniline-sulfate salt (20 wt% with respect to cyclic acetal of *p*-methylbenzaldehyde) and 25 mL of water in a 50 mL round bottom flask were refluxed for 30 min, and the reaction was monitored by TLC. The reaction mixture was cooled and filtered to remove the catalyst. The filtrate was extracted with $CHCl_3$ and the organic extract dried over Na_2SO_4, filtered and concentrated in vacuum. The resultant sample was purified by preparative column chromatography (1:99 EtOAc:hexane) affording the parent *p*-methylbenzaldehyde (Table 2).