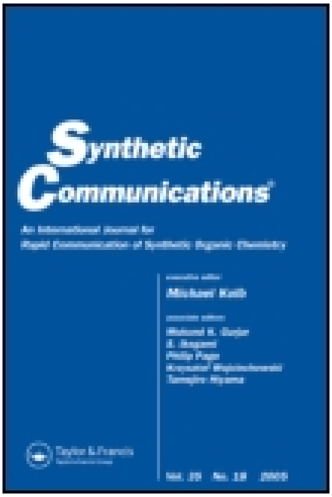

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Zeolite-Catalyzed Environmentally Friendly Tetrahydropyranylation of Alcohols and Phenols

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Zeolite-Catalyzed Environmentally Friendly Tetrahydropyranylation of Alcohols and Phenols

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ABSTRACT

A simple and environmentally friendly tetrahydropyranylation of various alcohols and phenols at room temperature was elaborated by using a small pore size zeolite. The material is also suitable for the deprotection but with less efficiency.

Key Words: Green chemistry; Tetrahydropyranylation; Zeolite.

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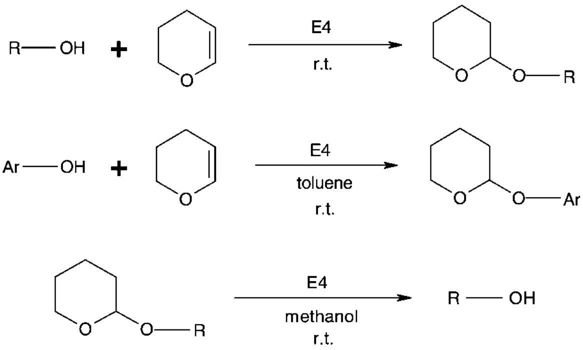
INTRODUCTION

Tetrahydropyranylation (THP) is a common and widely used method to protect alcoholic and phenolic hydroxyl groups. The THP ethers are resistant to oxidizing and reducing agents, unreactive under neutral and basic conditions, and the THP-group is easy to remove.[1]

Numerous catalysts have been developed for tetrahydropyranylation of hydroxy groups, such as the classical concentrated hydrochloric acid[2] and *p*-toluenesulfonic acid[3] as well as trimethyliodosilane,[4] zirconium sulfophenyl phosphonate,[5] *bis*[trimethylsilyl]sulfate,[6] lithium perchlorate–diethyl ether,[7] vanadyl(IV)acetate,[8] polyaniline salts,[9] lithium triflate,[10] and tributylammonium bromide.[11] Because most of these catalysts are dangerous or harmful for the environment, cleaner and safer methods were also developed by using, for example, ionic liquids[12] and some heterogeneous catalysts: heteropolyacids,[13] K10 montmorillonite,[14] sulfonated charcoal,[15] HY zeolite,[16] HSZ zeolite,[17] Envirocat EPZG,[18] etc. Similarly, a lot of methods were described for the cleavage of the THP group, thus pyridinium *p*-toluenesulfonate (PPTS) in ethanol,[19] *p*-toluenesulfonic acid,[20] zinc chloride,[21] and also environmentally friendly catalysts (e.g., bentonitic clay[22] and heteropolyacid[13]).

In this article we report that Ersorb-4 (E4) is also an excellent and effective catalyst to tetrahydropyranylation of alcohols and phenols under mild conditions. E4 is a weakly acidic zeolite-type adsorbent with 4 Å pore size. It can adsorb small molecules such as water, hydrochloric acid, ammonia, methanol, etc. It has several advantages—it is environmentally friendly, nontoxic, recoverable, reusable, and inexpensive. Recently we found that E4 showed good activity in different condensation reactions such as acylation of aminoacids with aromatic acid chlorides,[23] cyclization of β-aminoalcohols with carboxylic acids into oxazoline derivatives,[24] and synthesis of 2-arylimidazoline derivatives and 2-arylbenzoxazole derivatives.[25]



EXPERIMENTAL

All tetrahydropyranyl ethers are known compounds and were characterized by ^{1}H NMR spectroscopy. Spectra were made on Bruker Avanche 300 spectrometer in $CDCl_3$ using TMS as internal standard. Gas chromatography was performed on Agilent 4890D instrument.

The commercial chemicals were purchased from Merck-Hungary Ltd. except E4, which is the product of Erdőkémia-ker Ltd., Hungary.

Pretreatment of the Catalyst

Before the experiments, a sample of E4 was powdered and heated at 120°C for 2 hr.

General Method for Tetrahydropyranylation of Alcohols

A mixture of alcohol (20 mmol), 3,4-dihydro-2*H*-pyran (26 mmol), and 1g E4 was stirred at room temperature for 30 min. The solid was then filtered out, the product was obtained by simple distillation and was characterized by ^{1}H NMR.

General Method for Tetrahydropyranylation of Phenols

A mixture of phenol (20 mmol), 3,4-dihydro-2*H*-pyran (26 mmol), and 1g E4 in toluene was stirred at room temperature for 3 hr. The solid was then filtered out, the filtrate was evaporated, and the residue was characterized.

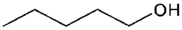
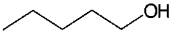
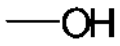
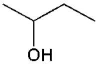
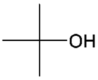
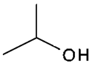
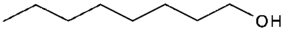
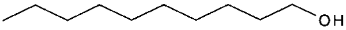
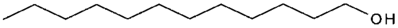
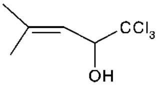
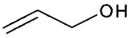
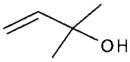
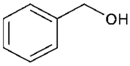
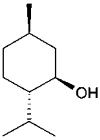
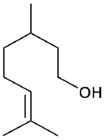
General Method for Deprotection of Tetrahydropyranyl Ethers

A mixture of THP ether (20 mmol), 1g E4, and 15 mL methanol was stirred at room temperature, and the progress of the reaction was monitored by GC.

RESULTS AND DISCUSSION

Several types of alcohols (primary, secondary, tertiary, benzylic, and allylic) and phenols with different substituents were converted to the corresponding THP ethers in high yields (see Tables 1 and 2). The zeolite can be

Table 1. Tetrahydropyranylation of alcohols in the presence of E4.

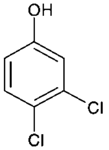
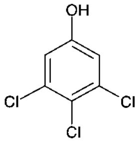
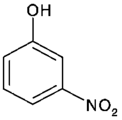
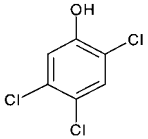
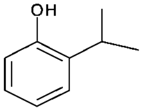
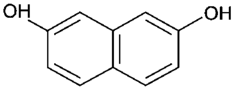
Entry	Alcohol	Reaction time (min)	Yield (%)[a]
1		30	83 (100)
2		30	81 (100)[b] 80 (100)[c]
3		30	85 (100)
4		30	76 (97)
5		30	71 (89)
6		30	77 (93)
7		30	80 (100)
8		30	76 (98)
9		30	84 (95)
10		60	73 (87)
11		60	(79)
12		60	(74)
13		60	82 (100)
14		90	(98)
15		90	(96)

[a] Isolated yield; the values in parentheses refer to the conversion estimated by the ^1H NMR spectra.

[b] Recycled E4.

[c] Third use of the catalyst.

Table 2. Tetrahydropyranylation of phenols in the presence of E4 in toluene.

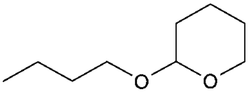
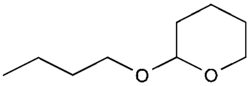
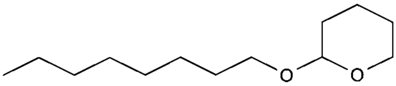
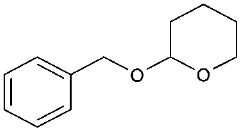
Entry	Phenol	Reaction time (hr)	Yield (%)[a]
1		3	58 (71)
2		3	55 (67)
3		3	51 (69)
4		3	51 (61)
5		4	44 (53)
6		4	57 (65)[b]

[a] Isolated yield; the values in parentheses refer to the conversion estimated by the ^{1}H NMR spectra.
[b] In dioxane.

reused without significant loss of activity (see Table 1, Entry 2). In the phenols without solvent, vigorous reaction and the formation of tarry product was observed. Thus, the reaction was performed in toluene. The reaction time was longer than in the case of the aliphatic alcohols, and the yield was lower, especially at the *ortho*-substituted derivatives, probably due to a steric hindrance of the substituents.

The removal of the tetrahydropyranyl group can be carried out under similar mild reaction conditions, but the reaction was significantly longer and the conversions are moderate, as it shown in Table 3.

Table 3. Deprotection of tetrahydropyranyl ethers in methanol in the presence of E4.

Entry	THP ether	Reaction time (hr)	Yield (%)[a]
1		4	52
2		7	73
3		6	55
4		6	61

[a]GC yield.

CONCLUSION

The modified zeolite-type adsorbent E4 is a suitable agent for tetrahydropyranylation of alcohols and phenols. The method is simple, convenient, cheap, and environmentally friendly, and the catalyst can be recycled without any loss of activity.

ACKNOWLEDGMENTS

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