Monatshefte für Chemie 135, 279–282 (2004)
DOI 10.1007/s00706-003-0083-4

Monatshefte für Chemie
Chemical Monthly
Printed in Austria

$Al(HSO_4)_3$ as an Efficient Catalyst for the Acetylation of Alcohols in Solution and Under Solvent Free Conditions

Farhad Shirini[1,*], **Mohammad A. Zolfigol**[2], and **Masoumeh Abedini**[1]

[1] Department of Chemistry, Faculty of Science, Guilan University, Rasht, Iran
[2] Department of Chemistry, College of Science, Bu-Ali Sina University, Hamadan, Iran

Received May 12, 2003; accepted (revised) June 4, 2003
Published online January 27, 2004

Summary. Alcohols are acetylated in a mild, clean, and efficient reaction with acetic anhydride in the presence of a catalytic amount of $Al(HSO_4)_3$ in solution and under solvent free conditions. All reactions were performed at room temperature in good to high yields.

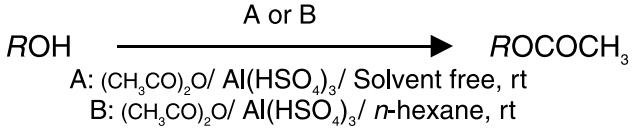
Keywords. Acetylation; Acetic anhydride; $Al(HSO_4)_3$; Alcohols; Solvent free conditions.

Introduction

The conversion of alcohols to esters is an important synthetic transformation that has received considerable attention [1]. Conversion of an alcohol to the corresponding acetate is typically carried out using acetic anhydride or acetyl chloride in the presence of triethyl amine or pyridine as a catalyst [2]. 4-(Dimethylamino)pyridine (*DMAP*) is known to cause a remarkable rate acceleration in this reaction [3].

In addition to catalysis by tertiary amines, protic or *Lewis* acids have also been reported to catalyze the acetylation of alcohols. Examples include *TMSCl* [4], magnesium bromide [5], $Sc(AcO)_3$-$(CF_3SO_2)_2NH$ [6], $TiCl_4 + AgClO_4$ [7], $CoCl_2$ [8], *NBS* [9], $Sn(OTf)_2$ [10], $Cu(OTf)_2$ [11], $In(OTf)_3$ [12], $Bi(OTf)_3$ [13, 14], $Sc(OTf)_3$ [15], *p*-toluenesulfonic acid [16], and sulfamic acid [17]. However, most of the reported methods suffer from one or more of the following disadvantages: long rection time, vigorous reaction conditions, the occurrance of side reactions, use of expensive or unavailable reagents, and poor yields of the desired product. Thus, there is still a demand to develop new and mild methods for the acetylation of alcohols in the presence of inexpensive and bench top reagents.

* Corresponding author. E-mail: shirini@guilan.ac.ir



Scheme 1

In continuation of our studies on the applications of inorganic acidic salts [18–20], we wish to report a new method for the acetylation of alcohols with acetic anhydride in the presence of a catalytic amount of $Al(HSO_4)_3$ in solution and under solvent free conditions (Scheme 1).

Results and Discussion

Acetylation of different types of alcohols including primary, allylic, benzylic, secondary, and sterically hindered tertiary alcohols, using Ac_2O in the presence of $Al(HSO_4)_3$ with and without a solvent were performed (Scheme 1, Table 1). In a simple procedure, a mixture of reactants was stirred at room temperature for the

Table 1. Acetylation of alcohols catalyzed by $Al(HSO_4)_3$[a]

Entry	Substrate	Product	Acetylation in the absence of solvent		Acetylation in solution	
			Time/min	Yield/%[b]	Time/min	Yield/%[b]
1	$C_6H_5CH_2OH$	$C_6H_5CH_2OAc$	1	95	2	87
2	2-$BrC_6H_4CH_2OH$	2-$BrC_6H_4CH_2OAc$	1	85	1	84
3	2-$ClC_6H_4CH_2OH$	2-$ClC_6H_4CH_2OAc$	1	90	1	90
4	2-$MeC_6H_4CH_2OH$	2-$MeC_6H_4CH_2OAc$	1	92	1	86
5	4-$ClC_6H_4CH_2OH$	4-$ClC_6H_4CH_2OAc$	1	95	1	89
6	4-$(Me)_3CC_6H_4CH_2OH$	4-$(Me)_3CC_6H_4CH_2OAc$	1	92	2	85
7	3-$NO_2C_6H_4CH_2OH$	3-$NO_2C_6H_4CH_2OAc$	1	85	1	85
8	$C_6H_5CH(OH)C_6H_5$	$C_6H_5CH(OAc)C_6H_5$	3	90	3	85
9	$C_6H_5CH_2CH(OH)CH_3$	$C_6H_5CH_2CH(OAc)CH_3$	1	90	1	86
10	$C_6H_5CH(CH_3)CH_2OH$	$C_6H_5CH(CH_3)CH_2OAc$	1	86	3	85
11	$C_6H_5CH_2CH_2CH_2OH$	$C_6H_5CH_2CH_2CH_2OAc$	1	82	1	85
12	$C_6H_5CH_2CH_2OH$	$C_6H_5CH_2CH_2OAc$	1	90	1	80
13	$C_6H_5CH{=}CHCH_2OH$	$C_6H_5CH{=}CHCH_2OAc$	8	60	10	60
14	Cyclohexanol	Cyclohexyl acetate	4	85	3	85
15	1-Octanol	1-Octyl acetate	4	90	5	85
16	(−)-Menthol	(−)-Menthyl acetate	4	87	4	85
17	1-Methylcyclohexanol	1-Methylcyclohexyl acetate	4	85	4	80
18	*tert*-Butyl alcohol	*tert*-Butyl acetate	10	90	10	80
19	1-Adamantanol	1-Adamantanyl acetate	8	95	8	82
20	2-Adamantanol	2-Adamantanyl acetate	8	86	8	85
21	$C_6H_5CH(OH)CH_2OH$	$C_6H_5CH(OAc)CH_2OAc$	2	70	3	80[c, d]

[a] Products were characterized by their physical constants, comparison with authentic samples, and IR and NMR spectroscopy; [b] Isolated yield; [c] Yield refers to isolated pure diacetate; [d] 2.5 mmol of acetic anhydride were used

appropriate time (Table 1). Alcohols reacted efficiently and the corresponding acetates were isolated in good to high yields.

In order to compare the obtained results with those obtained in solution, we studied the acetylation reaction in *n*-hexane. As shown in Table 1, there are only small differences between the results obtained in solution and those under solvent free conditions. However, by ommiting the solvent, in addition to an easy work-up procedure, the need for a solvent is avoided. In the case of allylic alcohols, in addition to the desired acetate, two unidentified products were also produced (Table 1, Entry 13).

In conclusion, we have shown that $Al(HSO_4)_3$ is a very efficient and versatile catalyst for the acetylation of alcohols. The advantage of the method is that even hindered substrates can be acetylated in good to high yields under mild reaction conditions. Investigations on further applications of $Al(HSO_4)_3$ are ongoing in our laboratory.

Experimental

Preparation of $Al(HSO_4)_3$

A 500 cm^3 suction flask was equipped with a constant- pressure dropping funnel. A gas outlet was connected to a vacuum system through an absorbing solution (H_2O) and an alkali trap. The flask was charged with 66.7 g of anhydrous $AlCl_3$ (0.5 mol) and 147.1 g of conc. H_2SO_4 (1.5 mol) was added dropwise over a period of 40 min at room temperature. HCl gas evolved immediately. After completion of the addition of H_2SO_4, the mixture was shaken for 30 min, meanwhile, the residual HCl was exhausted by suction. A white solid material (158.5 g) was obtained.

General Procedure for Acetylation of Alcohols in n-Hexane

A mixture of 1 mmol of alcohol, 1.5 mmol of acetic anhydride, and 0.05 mmol of $Al(HSO_4)_3$ in 5 cm^3 of *n*-hexane was stirred at room temperature. The progress of the reaction was monitored by TLC or GC. After completion of the reaction, the solvent was evaporated and 10 cm^3 of H_2O were added. The mixture was extracted with 2×10 cm^3 of CH_2Cl_2. The organic layer was separated, washed with 2×10 cm^3 of saturated $NaHCO_3$ solution and 5 cm^3 of H_2O, and dried over anhydrous $MgSO_4$. Evaporation of the solvent followed by column chromatography on silica gel afforded the pure acetate.

General Procedure for Acetylation of Alcohols Under Solvent Free Conditions

A mixture of 1 mmol of alcohol, 1.5 mmol of acetic anhydride, and 0.05 mmol of $Al(HSO_4)_3$ was agitated at room temperature. The progress of the reaction was monitored by TLC or GC. After completion of the reaction, 10 cm^3 of H_2O were added and the mixture was extracted with 2×10 cm^3 of CH_2Cl_2. The organic layer was seperated, washed with 2×10 cm^3 of saturated $NaHCO_3$ solution and 5 cm^3 of H_2O, and dried over anhydrous $MgSO_4$. Evaporation of the solvent followed by column chromatography on silica gel afforded the pure acetate.

Acknowledgement

Partial support of this work by the Guilan University Research Council is acknowledged.

References

[1] a) Green TW, Wuts PGM (1999) Protective Groups in Organic Synthesis, 3rd ed. Wiley, New York; b) Hanson JR (1999) Protective Groups in Organic Synthesis, 1st ed. Blackwell Science Malden, MA
[2] Stork G, Takahashi T, Kawamoto I, Suzuki T (1978) J Am Chem Soc **100**: 8272
[3] a) Höfle G, Steglich W, Vorbrüggen H (1978) Angew Chem, Int Ed Engl **17**: 569; (b) Steglich W, Höfle G (1969) Angew Chem, Int Ed Engl **8**: 981
[4] Kumareswaran R, Gupta A, Vanaka YD (1997) Synth Commun **27**: 277
[5] Vedejs E, Daugulis O (1996) J Org Chem **61**: 5702
[6] Ishihara K, Kubota M, Yamamoto H (1996) Synlett 265
[7] Miyashita M, Shiina I, Miyoshi S, Mukaiyama T (1993) Bull Chem Soc Jpn **66**: 1516
[8] Iqbal J, Srivastava RR (1992) J Org Chem **57**: 2001
[9] Karimi B, Seradj H (2001) Synlett 519
[10] Mukaiyama T, Shiina I, Miyashita M (1992) Chem Lett 625
[11] Saravanan P, Singh VK (1999) Tetrahedron Lett **40**: 2611
[12] Chauhan KK, Frost CG, Love L, Waite D (1999) Synlett 1743
[13] Mohammadpoor-Baltork I, Aliyan H, Khosropour AR (2001) Tetrahedron **57**: 5851
[14] Orita A, Tanahashi C, Kakuda A, Otera J (2000) Angew Chem, Int Ed Engl **39**: 2877
[15] Ishihara K, Kubota M, Kurihara H, Yamamoto H (1996) J Org Chem **61**: 4560
[16] Cope AC, Herrick EC (1963) Org Synth **4**: 304
[17] Jin TS, Ma YR, Zhang ZH, Li TS (1998) Synth Commun **28**: 3173
[18] Shirini F, Zolfigol MA, Mallakpour B, Mallakpour SE, Hajipour AR, Mohammadpoor-Baltork I (2002) Tetrahedron Lett **43**: 1555
[19] Shirini F, Zolfigol MA, Mallakpour B, Mallakpour SE, Hajipour AR (2001) Aust J Chem **54**: 405
[20] Zolfigol MA, Shirini F, Ghorbani Choghamarani A, Mohammadpoor-Baltork I (2002) Green Chem **4**: 562