Available online at www.sciencedirect.com
ScienceDirect
Chinese Chemical Letters 20 (2009) 1453–1456
CHINESE CHEMICAL LETTERS
www.elsevier.com/locate/cclet

Boric acid as an efficient catalyst for the synthesis of 1,1-diacetate under solvent-free condition

K.F. Shelke, S.B. Sapkal, G.K. Kakade, P.V. Shinde, B.B. Shingate, M.S. Shingare *

Organic Research Laboratory, Department of Chemistry, Dr. Babasaheb Ambedkar Marathwada University, Aurangabad, MS 431004, India

Received 14 May 2009

Abstract

Boric acid (BO_3H_3) is an inexpensive, efficient and mild catalyst for the synthesis of 1,1-diacetate (acylal) from the various aromatic and heteroaryl aldehydes with acetic anhydride at room temperature under solvent-free condition. The present method does not involve any hazardous organic solvents or catalysts. This method gives notable advantages such as excellent chemoselectivity, mild reaction condition, short reaction times and excellent yield.

Keywords: Aromatic and heteroaryl aldehyde; Boric acid; 1,1-Diacetate; Solvent-free

---

The protection of carbonyl group is often necessary during the synthesis of multi-functional complex molecules and natural products. Acylal formation is one of the most useful method to protect carbonyl groups due to the stability of the resulting acylals. They are stable in neutral and basic media [1]. Acylals are synthetically important precursors for the preparation of 1-acetoxydienes for Diels–Alder reaction [2]. Chiral allylic esters have been obtained using palladium catalysts by an asymmetric allylic alkylation of gem-diesters [3]. The preparation of homoallylic acetates by allylation of acylal has also been reported [4].

Generally, acylals have been prepared by the reaction of aldehydes with acetic anhydride catalyzed by (sulphuric, phosphoric and methanesulfonic acid) [5], I_2 [6], $InCl_3$ [7], $Cu(OTf)_3$ [8], $H_6P_2W_{18}O_{62}\cdot 24H_2O$ [9], [Hmim]HSO_4 [10], SnC_{14}/SiO_2 [11], $GaCl_3$ [12] and CAN [13]. However, in above some reported methods suffer from one or more drawbacks such as prolonged reaction times, use of environmentally unfavorable solvents and frequently low yields. Thus, the development of a new method for the synthesis of acylal derivatives would be highly desirable.

The solvent-free organic synthesis have offered more advantages as compared to their homogeneous counterparts due to the growing concern for the influence of organic solvent on the environment as well as on human body, economical demands and simplicity in the processes [14].

In recent years, boric acid [BO_3H_3 or $B(OH)_3$] have gained special attention as catalyst in organic synthesis because excellent solubility in water, uncomplicated handling, inexpensiveness, eco-friendly nature and readily available. Recently, several synthetically useful organic transformations using boric acid as a catalyst have been reported in the literature [15].

---

* Corresponding author.
E-mail address: msshingare_org@rediffmail.com (M.S. Shingare).

1001-8417/$ – see front matter © 2009 M.S. Shingare. Published by Elsevier B.V. on behalf of Chinese Chemical Society. All rights reserved.
doi:10.1016/j.cclet.2009.07.009

1. Experimental

The uncorrected melting points of all compounds were taken in an open capillary in a paraffin bath. The progress of the reaction was monitored by TLC. IR spectra were recorded in KBr discs on a FTIR instrument. ^{1}H and ^{13}C NMR spectra were recorded on 300 MHz and 75 MHz spectrometers, respectively, using $CDCl_3$ as a solvent and TMS as an internal standard.

1.1. *Typical experimental procedure*

Aldehyde (1 mmol), acetic anhydride (2 mmol) and boric acid (0.5 mol%) were taken in a round bottom flask and stirred at room temperature. The time required for each reaction is indicated in Table 1. The reaction was followed by TLC (*n*-Hexane:EtOAc, 9:1). After completion of the reaction, the mixture was diluted with ethyl acetate (15 mL). The organic layer was washed with 10% $NaHCO_3$ solution and water and then dried over anhydrous Na_2SO_4. The solvent was evaporated under reduced pressure to give pure **2**(**a**–**n**) in excellent yields.

2. Results and discussion

In continuation of our work on the protection of aldehydes and ketones [13,16], study of 4-oxo-(4*H*)-1-benzopyran-3-carbaldehydes [17] and interest in the development of novel synthetic methodology [18], herein, we would like to report a simple, mild, efficient and rapid method for the synthesis of acylals from variety of aromatic and heteroaryl aldehydes with acetic anhydride in the presence of catalytic amount of boric acid at room temperature under solvent-free condition (Scheme 1).

To optimize the reaction condition, the reaction of benzaldehyde (**1a**) and acetic anhydride was selected as model to investigate the effects of the catalyst at different amount of catalyst on the yield. The best result was obtained by carrying out the reaction with 1:2 mol ratios of benzaldehyde:acetic anhydride and 0.5 mol% of boric acid at room temperature under solvent-free condition and under this condition **2a** was obtained in 97% yield after 5 min (Table 1, compound **2a**). To determine the role of boric acid, the model reaction was carried out in the absence of catalyst at room temperature under solvent-free condition; the desired product was not obtained after 120 min. This result indicates that boric acid exhibits a high catalytic activity in this transformation.

The substrate, 4-oxo-(4*H*)-1-benzopyran-3-carbaldehyde has three active centers such as α,β-unsaturated carbonyl group, a carbon–carbon double bond and a formyl group. Of these three reactive centers, the reaction chemoselectively

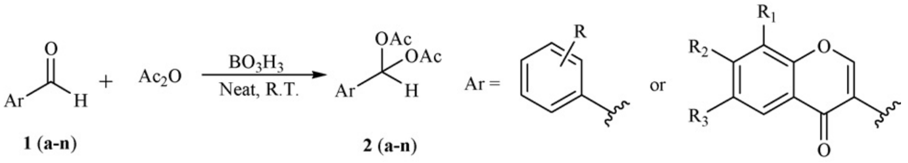
Table 1
Boric acid catalyzed synthesis of 1,1-diacetate.[a].

Compound[b]	Aldehyde	Time (min)	Yield (%)[c]	M.P. (°C) Found	M.P. (°C) Reported
2a	R = H	5	97	44–46	44–46 [11]
2b	R = 4-OMe	10	93	64–65	64–65 [11]
2c	R = 4-Me	10	95	82–83	81–82 [11]
2d	R = 4-Cl	5	93	80–82	79–81 [11]
2e	R = 4-Br	5	94	92–94	93–95 [11]
2f	R = 4-NO_2	10	95	124–126	125–126 [11]
2g	2-Furyl	5	89	52–54	52–53 [10]
2h	R_1 = H, R_2 = H, R_3 = H	10	94	130–132	131–132 [12]
2i	R_1 = H, R_2 = H, R_3 = CH_3	15	92	148–150	150 [13]
2j	R_1 = H, R_2 = H, R_3 = Cl	10	87	170–171	170 [13]
2k	R_1 = Cl, R_2 = H, R_3 = Cl	10	95	190–191	189 [13]
2l	R_1 = CH_3, R_2 = H, R_3 = Cl	15	91	160–162	162 [13]
2m	R_1 = H, R_2 = H, R_3 = Br	5	90	170–172	171 [13]
2n	R_1 = H, R_2 = H, R_3 = F	5	93	154–156	156 [13]

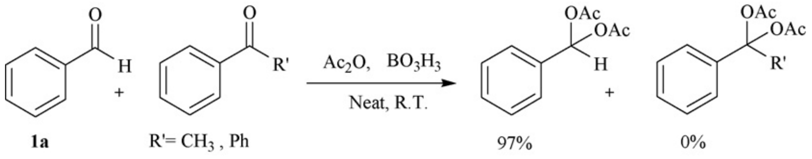
[a] *Reaction condition*: aromatic and heteroaryl aldehydes (1 mmol), acetic anhydride (2 mmol), boric acid (0.5 mol%) at room temperature under solvent-free condition.

[b] All compounds were characterised by spectroscopic technique and compared with literature [19].

[c] Isolated yield based upon starting aldehyde.



Scheme 1.



Scheme 2.

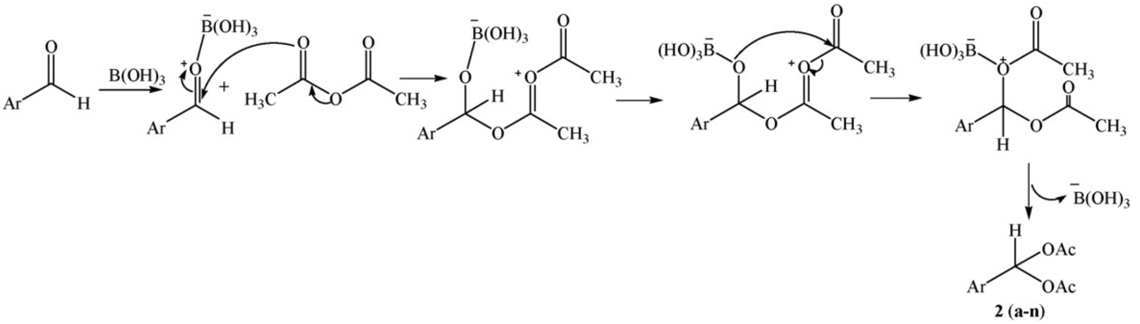
Table 2
Comparison of some other procedure with the present method for synthesis of acylals.[a].

Entry	Catalyst	Mol %	Time	Yield (%)	Reference
4-Nitrobenzaldehyde (**1f**)					
1	I_2	10	2 h	99	[6]
2	$InCl_3$	10	4 h	88	[7]
3	$Cu(OTf)_3$	2.5	4 h	94	[8]
4	$H_6P_2W_{18}O_{62}\cdot 24H_2O$	1	30 min	92	[9]
5	$[Hmim]HSO_4$	3.8	40 min	89	[10]
6	$B(OH)_3$	0.5	10 min	95	–
4-Oxo-(4*H*)-1-benzopyran-3-carbaldehyde (**1h**)					
1	$GaCl_3$	5	12 min	92	[12]
2	CAN	6	2 h	89	[13]
3	$B(OH)_3$	0.5	10 min	94	–

[a] *Reaction condition*: aldehydes (1 mmol), acetic anhydride (2 mmol), boric acid (0.5 mol%) at room temperature.

occurs at formyl group. We found that aldehydes containing different functional group at different positions worked well and did not show remarkable differences in the yield of products and reaction times. The acylals were prepared at room temperature and isolated by simple quenching in water and neutralization with $NaHCO_3$. All the reactions were completed within 5–15 min with excellent yields (87–97%). This methodology avoids the use of corrosive acids, solvents and requires only catalytic amount of the boric acid to promote the reaction.

In order to show the high selectivity of the procedure, we investigated competitive reactions for the synthesis of the acylals from benzaldehyde in the presence of acetophenone or benzophenone using a catalytic amount of boric acid.



Scheme 3. Proposed reaction mechanism.

We found that ketones did not produce any acylals under the optimized reaction condition. This observation indicates that aldehydes are more reactive than ketones and this may be due to higher electrophilicity of aldehyde in comparison to ketones (Scheme 2).

In Table 2, the data presented in this table show the promising features of this method in terms of molar ratio of the catalyst, reaction rate and yield of the product compared with those reported in the literature.

The possible mechanism of this reaction is as shown in Scheme 3.

3. Conclusion

We conclude that, this method is highly selective for the synthesis of acylals from aromatic and heteroaryl aldehydes in the presence of ketones. The notable merits of the present method are short reaction times, mild reaction condition, excellent chemoselectivity, simple work-up procedure and excellent yield of products. Moreover, the catalyst used is easily available, inexpensive, mild and eco-friendly nature.

Acknowledgement

We gratefully acknowledge the funding support received for this work from the University Grants Commission, New Delhi.

References

[1] K.S. Kochhar, B.S. Bal, R.P. Deshpande, S.N. Rajadhyaksha, H.W. Pinnick, J. Org. Chem. 48 (1983) 176.
[2] B.B. Snider, S.B. Amin, Synth. Commun. 8 (1978) 117.
[3] B.M. Trost, C.B. Lee, J. Am. Chem. Soc. 123 (2001) 3687.
[4] J.S. Yadav, B.V.S. Reddy, C. Madhuri, G. Sabitha, Chem. Lett. (2001) 18.
[5] I. Freeman, E.M. Karcherski, J. Chem. Eng. Data 22 (1977) 355.
[6] N. Deka, D.J. Kalita, R. Borah, J.C. Sarma, J. Org. Chem. 62 (1997) 1563.
[7] J.S. Yadav, B.V.S. Reddy, C. Srinivas, Synth. Commun. 32 (2002) 1175.
[8] K.L. Chandra, P. Saravanan, V.K. Singh, Synlett (2000) 359.
[9] G.P. Romanelli, H.J. Thomas, G.T. Baronetti, J.C. Autino, Tetrahedron Lett. 44 (2003) 1301.
[10] A.R. Hajipour, L. Khazdooz, A.E. Ruoho, Catal. Commun. 9 (2008) 89.
[11] Y.Q. Li, L.H. Cheng, Chin. Chem. Lett. 12 (2001) 565.
[12] S. Kumar, A. Saini, J.S. Sandhu, Arkivoc xiv (2007) 27.
[13] S.S. Shindalkar, B.R. Madje, R.V. Hangarege, M.S. Shingare, Ind. J. Chem. 44B (2005) 2409.
[14] K.F. Tanaka, Chem. Rev. 100 (2000) 1025.
[15] (a) A. Kumar, R.A. Maurya, Tetrahedron Lett. 49 (2008) 5471;
    (b) K.F. Shelke, S.B. Sapkal, S.S. Sonar, B.R. Madje, B.B. Shingate, M.S. Shingare, Bull. Korean Chem. Soc. 30 (2009) 1057.
[16] R.V. Hangarge, A.S. Mane, V.P. Chavan, M.S. Shingare, Indian J. Chem. 41B (2002) 1302.
[17] (a) R.V. Hangarge, S.A. Sonawane, D.V. Jarikote, M.S. Shingare, Green Chem. 3 (2001) 310;
    (b) R.V. Hangarge, D.V. Jarikote, M.S. Shingare, Green Chem. 4 (2002) 266;
    (c) S.S. Shindalkar, B.R. Madje, M.S. Shingare, J. Korean Chem. Soc. 49 (2005) 377.
[18] (a) S.S. Pawar, D.V. Dekhane, M.S. Shingare, S.N. Thore, Chin. Chem. Lett. 19 (2008) 1055;
    (b) K.F. Shelke, S.B. Sapkal, M.S. Shingare, Chin. Chem. Lett. 20 (2009) 283;
    (c) S.B. Sapkal, K.F. Shelke, B.B. Shingate, M.S. Shingare, Tetrahedron Lett. 50 (2009) 1754;
    (d) K.F. Shelke, B.R. Madje, S.B. Sapkal, B.B. Shingate, M.S. Shingare, Green Chem. Lett. Rev. 2 (2009) 3.
[19] Spectral data. (**2a**) IR (KBr, cm^{-1}): 3060, 1755, 1605, 1470, 1375, 1245, 1205, 1065, 1010, 760, 700. ^{1}H NMR ($CDCl_3$, δppm): 7.6 (s, 1H), 7.4–7.2 (m, 5H), 1.92 (s, 6H). (**2f**) IR (KBr, cm^{-1}): 3124, 1762, 1610, 1529, 1345, 1210, 1200, 1090, 1000, 960, 850. ^{1}H NMR ($CDCl_3$, δppm): 8.07 (d, $J = 8.4$ Hz, 2H), 7.54 (s, 1H), 7.51 (d, $J = 8.4$ Hz, 2H), 1.96 (s, 6H). (**2k**). IR (KBr, cm^{-1}): 3080 (ArC–H), 1657 (C=O, chromone), 1776 ($OCOCH_3$), 990 (C–Cl). ^{1}H NMR ($CDCl_3$, δppm): 2.13 (s, 6H), 7.77 (s, 1H), 7.72 (d, 1H, $J = 2.20$ Hz), 8.06 (d, 1H, $J = 2.20$ Hz), 8.18(s, 1H), ^{13}C NMR ($CDCl_3$) δ: 173.58, 168.59, 155.31, 150.95, 134.68, 131.90, 126.31, 124.94, 124.45, 120.60, 84.91, 21.08. (**2m**) IR (KBr, cm^{-1}): 3060 (ArC–H), 1650 (C=O, chromone), 1750 ($OCOCH_3$), 1016 (C–Br). ^{1}H NMR ($CDCl_3$, δppm): 2.14 (s, 6H), 7.40 (d, 1H, $J = 8.78$ Hz), 7.80 (dd, 2H, $J = 2.30$ and 8.70 Hz), 8.19 (s, 1H), 8.4 (s, 1H). ^{13}C NMR ($CDCl_3$, δppm): 173.56, 168.17, 154.93, 137.09, 128.53, 125.38, 120.07, 119.84, 77.63, 76.36, 20.68.