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A simple and efficient method for the synthesis of *gem*-diacetates from aldehydes and ketones catalysed by gallium triiodide

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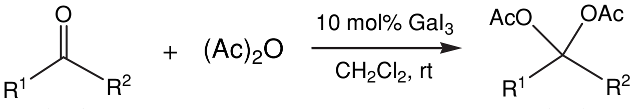
Aldehydes or ketones reacted with acetic anhydride in dichloromethane at ambient temperature to produce *gem*-diacetates in good to excellent yields in the presence of gallium triiodide, which was generated *in situ* from gallium and iodine. This catalyst was also useful for the deprotection of carbonyl compounds in the presence of water.

Keywords: gallium triiodide, catalysis, *gem*-diacetate

Carbonyl compounds are frequently protected as *gem*-diacetates in the course of a total synthesis because of the stability in neutral and basic media of *gem*-diacetates.[1] *Gem*-diacetates are also important precursors for the preparation of many useful compounds such as acyloxydienes,[2a] homoallyl acetates[2b, 2c] and α,β-unsaturated ketones.[2d] *Gem*-diacetates are usually generated from the reaction of carbonyl compounds with acetic anhydride in the presence of strong protic acids such as H_2SO_4,[3] H_3PO_4[4] and CH_3SO_3H,[5] or Lewis acids such as $FeCl_3$,[6] $ZnCl_2$,[7] $Sc(OTf)_3$,[8] $Bi(OTf)_2$,[9] $InCl_3$,[10] $Zn(BF_4)_2$[11] and Zr salts.[12] Other catalysts such as NBS,[13] CAN,[14] zeolites[15] and heteropolyacids[16] are also found to be effective for this transformation. However, many of these methods have several drawbacks. For example, strong protic acids are corrosive, NBS and CAN are oxidative, metal triflates are highly expensive, some of these Lewis acids are moisture sensitive and require special care in handling and storage and some of these methods proceed slowly and therefore need a high reaction temperature or a long reaction time especially for aliphatic carbonyl compounds. Moreover, most of these methods are not suitable for ketones.

In the course of our recent work on Lewis acid catalysed organic reactions, we have found that gallium triiodide has emerged as a powerful Lewis acid catalyst in some reactions such as the Sakurai reaction,[17a] the tetrahydropyranylation of alcohols and phenols,[17b] and the coupling reaction of carbonyl compounds, amines and diethyl phosphite.[17c] Another evident advantage with this reagent is that it can be prepared *in situ* by the reaction of gallium with iodine. We expect that it will have a great potential for use in organic synthesis. Here we report the use of gallium triiodide in the synthesis of *gem*-diacetates.

Gem-diacetates were synthesised by the reaction of carbonyl compounds and acetic anhydride under the catalysis of gallium triiodide (Scheme 1) in dichloromethane. The results are summarised in Table 1. The Lewis acid catalyst, gallium triiodide was generated easily *in situ* by the reaction of gallium metal and iodine, and a small excess of either Ga or I_2 did not make any difference to the normal course of reaction. GaI_3 exhibited a powerful catalytic activity in an amount as low as 10 mol%, which was enough to complete the reaction at room temperature within a short reaction time for most of the substrates we used. A larger amount of catalyst or higher reaction temperature (under reflux) could not enhance the reaction or increase the yields. Dichloromethane was found to be the effective solvent for this conversion. The catalyst dissolved in it to form a homogeneous solution, and the strong electrostatic activation to the substrates made the reaction take place smoothly. Commercial dichloromethane could be used directly and further purification was not needed. One of the most evident characteristics with this method is that it is suitable for not only aldehydes but also ketones. The reaction of acid sensitive substrates like furfural and cinnamaldehyde gave the corresponding products and no side products were found. The reaction could also proceed as smoothly with aliphatic as with aromatic carbonyl compounds.


1(a~l) 2(a~l)

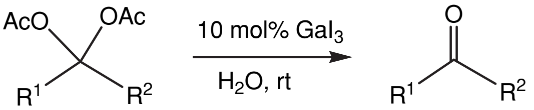
Scheme 1

Table 1 The reaction of carbonyl compounds and acetic anhydride

Entry	R^1	R^2	*t*/h	Product	Yield[a]/%
1	Ph	H	1.0	**2a**[10]	88
2	*o*-$O_2NC_6H_4$	H	0.5	**2b**[6b]	96
3	*p*-BrC_6H_4	H	1.0	**2c**[6c]	92
4	*p*-ClC_6H_4	H	1.0	**2d**[10]	90
5	*o*-ClC_6H_4	H	1.0	**2e**[10]	90
6	*p*-FC_6H_4	H	1.0	**2f**	95
7	*p*-$MeOC_6H_4$	H	1.5	**2g**[6b]	87
8	2-furyl	H	0.5	**2h**[10]	90
9	$CH_3CH_2CH_2$	H	2.0	**2i**[6b]	85
10	*trans*-PhCH=CH	H	2.5	**2j**[10]	82
11	-$(CH_2)_5$-	3.0	**2k**[12a]	84	
12	Ph	CH_3	3.0	**2l**[12b]	86

[a] Isolated yields. The structures of the products were confirmed by IR and ^1H NMR spectra.

Furthermore, gallium triiodide proved to be a very useful catalyst for the deprotection of carbonyl compounds. When 2 ml of water was added to the mixture of 1 mmol of a *gem*-diacetate and 10 mol% gallium triiodide and the mixture was stirred for 0.5 to 1 h at room temperature, the carbonyl compound was obtained almost quantitatively (Scheme 2). The method was applicable for both aldehydes and ketones.



Scheme 2

In summary, we have developed a new and efficient procedure for the preparation of *gem*-diacetates catalysed by GaI_3. The method offers several advantages such as mild reaction conditions, short reaction time, high yields and simple experimental operation leading to a useful and attractive process for the protection and deprotection of carbonyl group. GaI_3 is an effective and useful Lewis acid catalyst and its further application in organic synthesis is currently being explored in our laboratory.

Experimental

General procedure for the preparation of gem-diacetates.
Gallium (single piece of metal, 0.1 mmol) and iodine (0.15 mmol) were added to 2 ml dichloromethane. The mixture was stirred and

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refluxed under a nitrogen atmosphere until the reaction was complete (the reactants disappeared in about 1 h) and then cooled to room temperature. To this solution was added the carbonyl compound (1.0 mmol) and acetic anhydride (2.0 mmol). The resulting mixture was stirred at room temperature for an appropriate time (see Table 1, monitored by TLC or GC) and quenched with water. The mixture was then extracted with CH_2Cl_2. The organic layer was washed with water and dried over anhydrous Na_2SO_4. The residue was then purified by column chromatography on silica gel with hexane/ethyl acetate (10:1) as eluent to yield the product.

General procedure for the deacetylation of carbonyl compounds. Gem-diacetate (1 mmol) was added to the catalyst (0.1 mmol) which was prepared as above in 2 ml water. The mixture was stirred at room temperature for an appropriate time (0.5–1h) to complete the reaction. GC showed that it gave almost pure product. The reaction mixture was diluted with water and extracted with CH_2Cl_2. The organic layer was washed with water and dried over anhydrous Na_2SO_4 then concentrated *in vacuo* to give the corresponding carbonyl compound.

Selected data on gem-diacetates

2a:[10] ^{1}H NMR ($CDCl_3$, 400 MHz): δ=2.14 (s, 6H), 7.43 (m, 3H), 7.54 (m, 2H), 7.70 (s, 1H). IR (KBr): 3015, 1755, 1512, 1250, 1221 cm^{-1}.

2b:[6b] ^{1}H NMR ($CDCl_3$, 400 MHz): δ=2.16 (s, 6H), 7.72 (m, 1H), 7.74 (m, 2H), 8.06 (d, *J*=10.0 Hz, 1H), 8.22 (s, 1H). IR (KBr): 3012, 1760, 1605, 1512, 1256, 975, 912 cm^{-1}.

2e:[10] ^{1}H NMR ($CDCl_3$, 400 MHz): δ=2.15 (s, 6H), 7.30 (m, 2H), 7.39 (m, 1H), 7.63 (d, *J*=9.6 Hz, 1H), 7.78 (s, 1H). IR (KBr): 3024, 1758, 1602, 1522, 1250, 910, 725 cm^{-1}.

2f: ^{1}H NMR ($CDCl_3$, 400 MHz): δ=2.14 (s, 6H), 7.09 (d, *J*=8.8 Hz, 2H), 7.53 (d, *J*=8.8 Hz, 2H) (apparent pair of doublets from AA'XX' System), 7.66 (s, 1H). IR (KBr): 3020, 1758, 1605, 1525, 1242, 1112, 916 cm^{-1}. Calcd for $C_{11}H_{11}FO_4$: C, 58.4; H, 4.9. Found: C, 58.5; H, 4.85.

2j:[10] ^{1}H NMR ($CDCl_3$, 400 MHz): δ=2.15 (s, 6H), 6.22 (dd, *J*=15.2, 6.4 Hz, 1H), 6.75 (d, *J*=15.2 Hz, 1H), 7.27–7.63 (m, 6H). IR (KBr): 3015, 1755, 1608, 1532, 1244, 1210, 962cm^{-1}.

2k:[12a] ^{1}H NMR ($CDCl_3$, 400 MHz): δ=1.58–1.76 (m, 10H), 2.12 (s, 6H). IR (KBr): 2990, 1752, 1245 cm^{-1}.

2l:[12b] ^{1}H NMR ($CDCl_3$, 400 MHz): δ=1.95 (s, 3H), 2.12 (s, 6H), 7.32 (m, 3H), 7.45 (d, *J*=8.8 Hz, 2H). IR (KBr): 3018, 1760, 1605, 1536, 1246, 910 cm^{-1}.

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References

1 T.W. Greene and P.G.M. Wuts, *Protective Groups in Organic Synthesis*, 3rd edn, John Wiley and Sons, New York, 1999.

2 (a) R.E. Banks, J.A. Miller, N.J. Nunn, P. Stanley, T.J.R. Weakley and Z.J. Ullah, *J. Chem. Soc., Perkin Trans. 1*, 1981, 1096; (b) J.S. Yadav, B.V.S. Reddy, C. Madhuri and G. Sabitha, *Chem. Lett*., 2001, **30**, 18; (c) J.S. Yadav, B.V.S. Reddy and P. Srihari, *Synlett*, 2001, 673; (d) X.X. Wang and Y.M. Zhang, *Chin. Chem. Lett.*, 2004, **15**, 511.

3 M. Tomita, T. Kikuchi, K. Bessho, T. Hori and Y. Inubushi, *Chem. Pharm. Bull*., 1963, **11**, 1484.

4 W. Davey and J.R. Gwilt, *J. Chem. Soc*., 1957, 1008.

5 I. Freeman and E.M. Karchefski, *J. Chem. Eng. Data*, 1977, **22**, 355.

6 (a) B.M. Trost, C.B. Lee and J.M. Weiss, *J. Am. Chem. Soc.*, 1995, **117**, 7247; (b) C.D. Wang and M.H. Li, *Synth. Commun.*, 2002, **32**, 3469; (c) Y.Q. Li, *Synth. Commun.*, 2000, **30**, 3913.

7 I. Scriabine, *Bull. Soc. Chim. Fr*., 1961, 1194.

8 V.K. Aggarwal, S. Fonquerna and G.P. Vennall, *Synlett*, 1998, 849.

9 M.D. Carrigan, K.J. Eash, M.C. Oswald and R.S. Mohan, *Tetrahedron Lett*., 2001, **42**, 8133.

10 J.S. Yadav, B.V.S. Reddy and C. Srinivas, *Synth. Commun.*, 2002, **32**, 2169.

11 B.C. Ranu, J. Dutta and A. Das, *Chem. Lett*., 2003, **32**, 366.

12 (a) M. Curini, F. Epifano, M.C. Marcotullio, O. Rosati and M. Nocchetti, *Tetrahedron Lett.*, 2002, **43**, 2709; (b) S.V.N. Raju, *J. Chem. Res. (S)*, 1996, 68.

13 B. Karimi, H. Seradj and G.R. Ebrahimian, *Synlett*, 2000, 623.

14 S.C. Roy and B. Banerjee, *Synlett*, 2002, 1677.

15 R. Ballini, M. Bordoni, G. Bosica, R. Maggi, and G. Sartori, *Tetrahedron Lett*., 1998, **39**, 7587.

16 G.P. Romanelli, H.J. Thomas, G.T. Baronetti and J.C. Autino, *Tetrahedron Lett*., 2003, **44**, 1301.

17 (a) P.P. Sun, Y.F. Xian and Y.P. Xiao, *J. Chem. Res.*, 2004, 216; (b) P.P. Sun and Z.X. Hu, *Chin. J. Chem*., 2004, **22**, 1341; (c) P.P. Sun, Z.X. Hu and Z.H. Huang, *Synth. Commun.,* 2004, **34**, 4293.