Silica sodium carbonate catalyzed chemoselective synthesis of *geminal* diacetates

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Abstract

Silica supported sodium carbonate is an efficient catalyst for the conversion of aldehydes **(1a-p/3a-c)** into gem-diacetates or acylals **(2a-p/3a-c).** The catalyst has been found to be recoverable and reusable. However, ketones did not form acylals; giving rise to chemoselectivity.

Index Terms: Silica sodium carbonate, Acylals, Chemoselectivity, Acetic anhydride

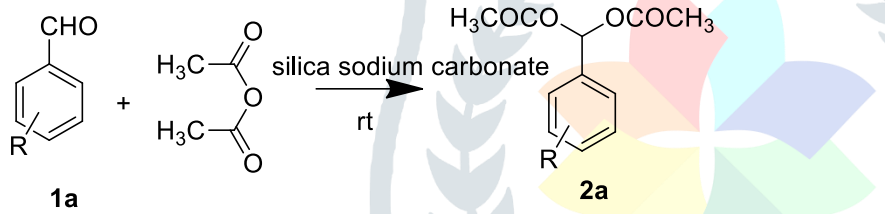
I. Introduction

The *gem*-bisacyloxyalkanes or *geminal* diacetates or acylals[1] are stable to neutral and basic conditions[2] and can be easily converted back to parent aldehydes. This property of gem diacetates as protecting groups for carbonyl compounds has been used in. Various catalysts have been reported in the synthesis of 1,1-diacetates such as H_2SO_4,[3] Lewis acids like $Sc(OTf)_3$,[4] $InBr_3$,[5] I_2,[6] NBS,[7] $LiBF_4$,[8] zeolite Y,[9] HZSM-5,[10] expansive graphite,[11] Nafion-H,[12] $Bi(NO_3)_3.5H_2O$,[13] $AlPW_{12}O_{40}$,[14] and $Bi(OTf)_3$,[15] alum,[16] MTSA[17].The environmental issues mainly the toxic effects associated with the handling and disposal of the inorganic acids lead to the development of newer green methodologies. In continuation of our work on acylals, we wish to synthesize 1,1-diacetates from aldehydes in the presence of Silica sodium carbonate.[18] silica is used as support for preparation of catalysts as its more environmentally safe , good mechanical stabilities, ease of scalability and no swelling.

II. Results and Discussion

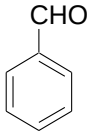
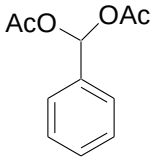
When a mixture of benzaldehyde **1a** (1 mmol), freshly distilled acetic anhydride (2 mmol) and Silica sodium carbonate (0.01 mmole) was stirred in distilled acetonitrile (1 mL) at room temperature, an exothermic reaction took place immediately. After 20 minutes, the temperature of the reaction mixture went down to room temperature and the mixture solidified. At this stage, TLC analysis showed that benzaldehyde had been completely consumed and the formation of a newer compound was noticed which was isolated in 90% yield (**Scheme 1)**. This compound **2a** was found to be α,α-diacetoxytoluene (benzylidene acetate) as revealed by

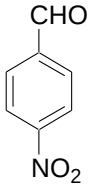
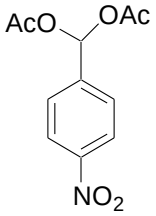
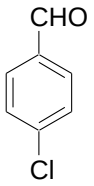
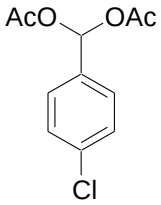
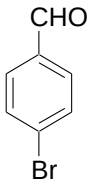
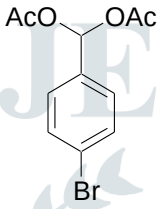
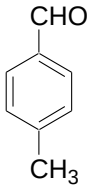
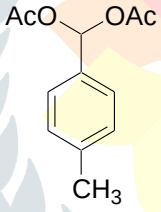
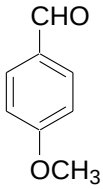
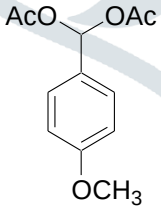
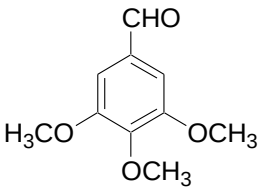
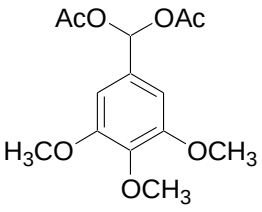
the comparison of its spectral and physical data with the authentic sample.[14] ^{1}H-NMR spectrum showed singlet at δ 7.7 (Ar-CH), multiplet at δ 7.5 – 7.3 corresponding to five aromatic protons Ar-H and singlet at δ 2.1 (2 × CH_3). The IR and mass spectra of compounds were also in consonance with the structures envisaged. IR spectrum showed peak at 1760 cm^{-1} (C=O). ^{13}C NMR spectrum showed peaks at δ 168, 135, 129, 128, 126, 89 and 20 ppm. Acylals were formed in good yields by both aromatic as well as aliphatic aldehydes. Deactivated aldehydes with electron withdrawing groups; heterocyclic aldehydes and *α,ß*-unsaturated aldehydes, furfural, 2-hydroxybenzaldehyde, 4-hydroxybenzaldehyde and vanillin were also found to be reactive. However, acetic anhydride used in somee reactions was in the ratio 1:3. Sterically hindered substrates like *α*-naphthaldehyde, and 3,4,5-trimethoxybenzaldehyde were also efficiently converted into their corresponding 1,1-diacetates. Alicyclic and aromatic ketones such as cyclohexanone and acetophenone did not yield acylals under same reaction conditions. The chemoselectivity of the present method as depicted in **Table 2**.

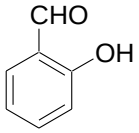
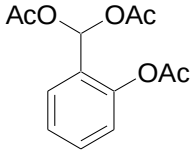
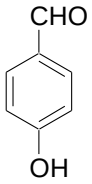
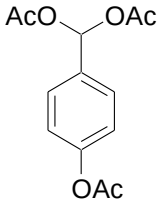
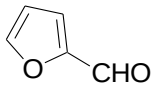
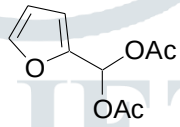
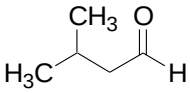
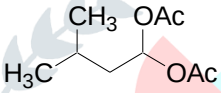
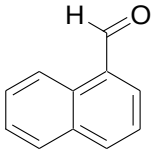
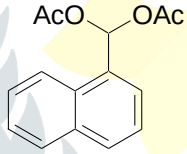
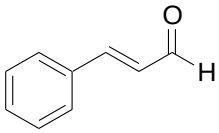
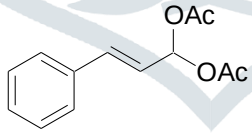
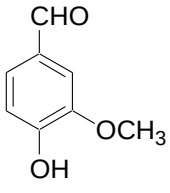
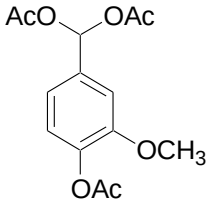


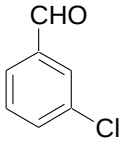
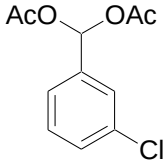
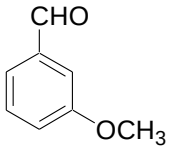
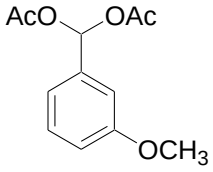
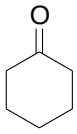
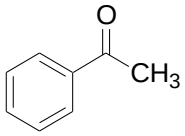
Scheme 1: Synthesis of acylals

III. Table 1: SSC catalysed synthesis of *geminal* 1,1-diacetates

Entry	Substrate	Product	Time (min.)	Yield[a] %	Melting point (°C)[b] Obs.
1	 **1a**	 **2a**	20	90	43

2	 **1b**	 **2b**	70	87	90
3	 **1c**	 **2c**	65	87	81
4	 **1d**	 **2d**	65	85	93
5	 **1e**	 **2e**	25	87	80
6	 **1f**	 **2f**	50	85	65
7	 **1g**	 **2g**	75	85	61 – 62

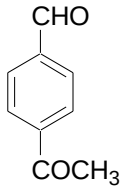
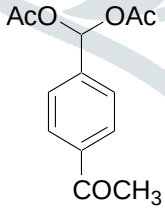
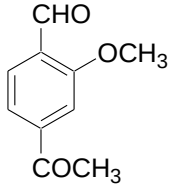
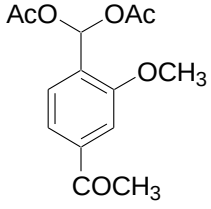
8	 **1h**	 **2h**	55	83	102
9	 **1i**	 **2i**	75	85	90
10	 **1j**	 **2j**	65	84	51
11	 **1k**	 **2k**	75	84	180
12	 **1l**	 **2l**	80	80	110
13	 **1m**	 **2m**	35	84	84
14	 **1n**	 **2n**	80	85	90

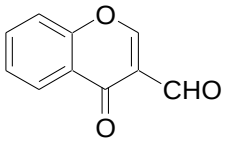
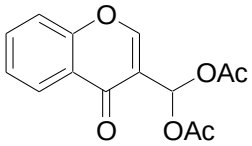
15	 **1o**	 **2o**	70	88	66
16	 **1p**	 **2p**	35	83	Oil
17		-	180	NR	-
18		-	180	NR	-

[a] The yields refer to the isolated pure products. [b] All melting points are uncorrected.

NR = No reaction.

IV. Table 2: Chemoselective synthesis of acylals using ketoaldehydes

Entry	Substrate	Product	Time (min.)	Yield[a] %	Melting point (°C)[b] Obs.
1	 **3a**	 **4a**	80	82	90
2	 **3b**	 **4b**	90	78	91

3			100	52	178-180
	3c	**4c**			

[a] The yields refer to the isolated pure products. [b] All melting points are uncorrected.

III. Experimental Section

All experiments were performed in an oven dried glass apparatus. Melting points were determined on a Buchi melting point apparatus and are uncorrected. Elemental analysis was performed on Leco CHNS-932.IR spectra on KBr were recorded on Perkin-Elmer FTIR spectrophotometer. NMR (^{1}H broadband decoupled and ^{13}CNMR) spectra were recorded on Brucker Ac-200 (300 MHz and 75 MHz respectively) spectrometer. ESI-MS spectra were recorded on Micro-Mass VG- 7070 H mass spectrometer. The flash chromatography was performed over silica gel (230-400 mesh) with graded (1:9) solvent system of ethyl acetate – petroleum ether.

IV. General procedure for the synthesis of (2a-p/4a-c)

To a homogenized mixture of aldehydes (1 mmol) and silica sodium carbonate (0.01mmole), freshly distilled acetic anhydride (2 mmol) was added at room temperature with progress of reaction monitored by TLC plates. The catalyst was then filtered and washed with dichloromethane; the organic layer was washed twice with a 5% solution of sodium bicarbonate, dried over anhydrous sodium sulphate and evaporated under reduced pressure. The residue was subjected to flash chromatography with graded solvent system of ethyl acetate–petroleum ether to give the corresponding 1,1-diacetates.

V. Spectral data of the synthesized compounds (2a-p), (4a-c)

2a α,α-Diacetoxytoluene (Benzylidene diacetate)

^{1}H NMR ($CDCl_3$, 300 MHz) δ: 7.7 (1H, s), 7.5–7.3 (5H, m), 2.1 (6H, s); ^{13}C NMR ($CDCl_3$, 75 MHz) δ: 168, 135, 129, 128, 126, 89, 20; IR (KBr) ν_{max}/cm^{-1}: 3060, 2930, 1760; ESI-MS m/z = 209 $(M+H)^+$; *Anal Calcd.* for $C_{11}H_{12}O_4$: C, 63.40; H, 5.75. Found: C, 63.73; H, 6.08.

2b α,α-Diacetoxy-4-nitrotoluene (4-Nitrobenzylidene diacetate)

^{1}H NMR ($CDCl_3$, 300 MHz) δ: 8.2 (1H, s), 8.0-7.5 (4H, m), 2.1 (6H, s); IR (KBr) ν_{max}/cm^{-1}: 3060, 2930, 1760; *Anal Calcd.* for $C_{11}H_{11}NO_6$: C, 52.10; H, 4.30; N, 5.50. Found: C, 52.42; H, 4.54; N, 5.87.

2c α,α-Diacetoxy-4-chlorotoluene (4-Chlorobenzylidene diacetate)

^{1}H NMR ($CDCl_3$, 300 MHz) δ: 7.8 (1H, s), 7.7-7.3 (4H, m), 2.1 (6H, s); IR (KBr) ν_{max}/cm^{-1}: 3060, 2930, 1780; ESI-MS m/z = 243 (100) $(M+H)^+$, 245 (30) $(M+H)^+$; *Anal Calcd.* for $C_{11}H_{11}ClO_4$: C, 54.45; H, 4.55. Found: C, 54.92; H, 4.83.

2d α,α-Diacetoxy-4-bromotoluene (4-Bromobenzylidene diacetate)

^{1}H NMR ($CDCl_3$, 300 MHz) δ: 7.7 (1H, s), 7.6–7.2 (4H, m), 2.1 (6H, s); IR (KBr) ν_{max}/cm^{-1}: 3060, 2930, 1780; ESI-MS m/z = 288 (100) $(M+H)^+$, 290 (93) $(M+H)^+$; *Anal Calcd.* for $C_{11}H_{11}BrO_4$: C, 46.02; H, 3.86. Found: C, 46.35; H, 4.19.

2e α,α-Diacetoxy-*p*-xylene (4-Methylbenzylidene diacetate)

^{1}H NMR ($CDCl_3$, 300 MHz) δ: 7.6 (1H, s), 7.4-7.2 (4H, m), 2.2 (6H, s), 2.1 (3H, s); ^{13}C NMR ($CDCl_3$, 75 MHz) δ: 168, 139, 132, 129, 126, 89, 21, 20;. IR (KBr) ν_{max}/cm^{-1}: 3060, 2930, 1650; *Anal Calcd.* for $C_{12}H_{14}O_4$: C, 64.85; H, 6.35. Found: C, 65.12; H, 6.69.

2f α,α-Diacetoxy-3-methoxytoluene (3-Methoxybenzylidene diacetate)

^{1}H NMR ($CDCl_3$, 300 MHz) δ: 7.7 (1H, s), 7.5-7.1 (4H, m), 3.7 (3H, s), 2.1 (6H, s); IR (KBr) ν_{max}/cm^{-1}: 3060, 2930,1650; *Anal Calcd.* for $C_{12}H_{14}O_5$: C, 60.55; H, 5.90. Found: C, 60.88; H, 6.24.

2g α,α-Diacetoxy-3,4,5-trimethoxytoluene (3,4,5-Trimethoxybenzylidene diacetate)

^{1}H NMR ($CDCl_3$, 300 MHz) δ: 7.6 (1H, s), 7.4-7.1 (2H, s), 3.7-3.5 (9H, s), 2.1 (6H, s); IR (KBr) ν_{max}/cm^{-1}: 3060, 2930, 1750; ESI-MS m/z = 321 $(M+Na)^+$; *Anal Calcd.* for $C_{14}H_{18}O_7$: C, 56.37; H, 6.08. Found: C, 56.71; H, 6.40.

2h α,α,2-Triacetoxytoluene (2-Acetoxybenzylidene diacetate)

^{1}H NMR ($CDCl_3$, 300 MHz) δ: 7.7 (1H, s), 7.5–7.1 (4H, m), 3.6 (3H, s), 2.1 (6H, s); IR (KBr) ν_{max}/cm^{-1}: 3060, 2930, 1600; *Anal Calcd.* for $C_{13}H_{14}O_6$: C, 58.60; H, 5.30. Found: C, 58.94; H, 5.62.

2i α,α,4-Triacetoxy-3-methoxytoluene (4-Acetoxy-3-methoxybenzylidene diacetate)

^{1}H NMR ($CDCl_3$, 300 MHz) δ: 7.6 (1H, s), 7.5 - 7.2 (3H, m), 3.7 (3H, s), 2.9 (3H, s), 2.1 (6H, s); IR (KBr) ν_{max}/cm^{-1}: 3060, 2930, 1600; *Anal Calcd.* for $C_{14}H_{16}O_7$: C, 56.75; H, 5.45. Found: C, 57.08; H, 5.79.

2j 2-Diacetoxymethylfuran (2-Furylmethylene diacetate)

^{1}H NMR ($CDCl_3$, 300 MHz) δ: 7.9 (1H, s), 7.4-6.3 (3H, m), 2.1 (6H, s); IR (KBr) ν_{max}/cm^{-1}: 3020, 2930, 1750; ESI-MS m/z = 221 $(M+Na)^+$; *Anal Calcd.* for $C_9H_{10}O_5$: C, 54.55; H, 5.09. Found: C, 54.89; H, 5.41.

2k 1,1-Diacetoxy-3-methylbutane (3-Methylbutylidene diacetate)

^{1}H NMR ($CDCl_3$, 300 MHz) δ: 6.7 (1H, t, *J* = 7.2 Hz), 2.1 (6H, s), 1.5–1.4 (2H, m), 1.3-1.2 (1H, m), 1.1 (6H, d, *J* = 6.8 Hz; IR (KBr) $\nu_{max}/cm^{-1:}$ 2930, 1760; *Anal Calcd.* for $C_9H_{16}O_4$: C, 57.43; H, 8.57. Found: C, 57.75; H, 8.91.

2l α-Diacetoxymethylnaphthalene (α-Naphthylmethylene diacetate)

^{1}H NMR ($CDCl_3$, 300 MHz) δ: 8.1 (1H, s), 7.9-7.5 (7H, m), 2.1 (6H, s); IR (KBr) ν_{max}/cm^{-1}: 3060, 2930, 1775; ESI-MS m/z = 259 $(M+H)^+$; *Anal Calcd.* for $C_{15}H_{14}O_4$: C, 69.76; H, 5.46. Found: C, 70.04; H, 5.80.

2m 3,3-Diacetoxy-1-phenyl-1-propene (Cinnamylidene diacetate)

^{1}H NMR ($CDCl_3$, 300 MHz) δ: 7.6–7.4 (5H, m), 7.2 (1H, d, *J* = 15.1 Hz), 6.7 (1H, dd, *J* = 15.1 and 6.8 Hz), 6.2 (1H, dd, *J* = 15.1 and 6.8 Hz), 2.1 (6H, s); IR (KBr) ν_{max}/cm^{-1}: 3060, 2930, 1755; *Anal Calcd.* for $C_{13}H_{14}O_4$: C, 66.66; H, 6.02. Found: C, 66.98; H, 6.36.

2n α,α,4-Triacetoxy-3-methoxytoluene (4-Aceto-3-methoxybenzylidene diacetate)

^{1}H NMR ($CDCl_3$, 300 MHz) δ: 7.7 (1H, s), 7.5-6.9 (3H, m), 3.9–3.7 (6H, br s), 2.1 (6H, s); IR (KBr) ν_{max}/cm^{-1}: 3020, 2980, 1655; *Anal Calcd.* for $C_{13}H_{16}O_6$: C, 58.20; H, 6.00. Found: C, 58.58; H, 6.32.

2o α,α-Diacetoxy-3-chlorotoluene (3-Chlorobenzylidene diacetate)

^{1}H NMR ($CDCl_3$, 300 MHz) δ: 7.9 (1H, s), 7.7-7.1 (4H, m), 2.1 (6H, s); ^{13}C NMR ($CDCl_3$, 75 MHz) δ: 168, 137, 134, 129, 126, 124, 88, 20; IR (KBr) ν_{max}/cm^{-1}: 3020, 2980, 1770; *Anal Calcd.* for $C_{11}H_{11}ClO_4$: C, 54.4; H, 4.55. Found: C, 54.81; H, 4.89.

2p α,α-Diacetoxy-3-methoxytoluene (3-Methoxybenzylidene diacetate)

^{1}H NMR ($CDCl_3$, 300 MHz) δ: 7.8 (1H, s), 7.6-7.1 (4H, m), 3.8 (3H, s), 2.1 (6H, s); IR (KBr) ν_{max}/cm^{-1}: 3010, 2980, 1650; *Anal Calcd.* for $C_{12}H_{14}O_5$: C, 60.55; H, 5.90. Found: C, 60.88; H, 6.24.

4a 4-Diacetoxymethylacetophenone (4-Acetobenzylidene diacetate)

^{1}H NMR ($CDCl_3$, 300 MHz) δ: 7.8 (1H, s), 7.6-7.2 (4H, m), 3.2 (3H, s), 2.1 (6H, s); IR (KBr) ν_{max}/cm^{-1}: 3060, 2930, 1680; ESI-MS m/z = 273 $(M+Na)^+$; *Anal Calcd.* for $C_{13}H_{14}O_5$: C, 62.43; H, 5.65. Found: C, 62.78; H, 5.99.

4b 4-Diacetoxymethyl-3-methoxyacetophenone(4-Aceto-2-methoxybenzylidene diacetate)

^{1}H NMR ($CDCl_3$, 300 MHz) δ: 7.7 (1H, s), 7.5-7.1 (3H, m), 3.7 (3H, s), 2.2-2.1 (9H, s); IR (KBr) ν_{max}/cm^{-1}: 3060, 2930, 1680; *Anal Calcd.* for $C_{14}H_{16}O_6$: C, 59.94; H, 5.78. Found: C, 60.29; H, 6.12.

4c 3-Diacetoxymethyl-γ-chromone (4-Oxo-4*H*-Chromen-3-yl-methylene diacetate)

^{1}H NMR ($CDCl_3$, 300 MHz) δ: 8.2 (1H, s), 8.1–7.8 (4H, m), 7.7 (1H, s), 2.1 (6H, s); IR (KBr) ν_{max}/cm^{-1}: 3060, 2930, 1680; *Anal Calcd.* for $C_{14}H_{12}O_6$: C, 60.85; H, 4.40. Found: C, 61.28; H, 4.74.

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