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Selective transformation of acetonides to orthoesters: an application of a photoinduced electron transfer process

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Abstract—Irradiation of α,β-acetonides of polyols and sugars in the presence of benzene 1,2,4,5-tetracarbonitrile causes cleavage of a methyl radical and generates an α,α-dioxy carbocation. The subsequent nucleophile addition gives different kinds of derivatives depending on the acetonide structure. Cyclic othoesters are formed when a δ-hydroxyl group is present, while in the other case, intermolecular trapping by moisture, present in the solvent (acetonitrile) or by added alchols occurs and gives orthoacids. With galactopyranose acetonide, efficient intermolecular trapping by a second molecule of sugar has been obtained. Useful synthetic intermediates such as hydroxy acetates are in turn obtained by selective hydrolysis of the methoxyethylidene derivatives.

1. Introduction

The protection of vicinal hydroxy groups as acetonides is widely used in synthetic chemistry.[1] Both the introduction and the removal of this protecting group are usually carried out under acid conditions, while it is inert under alkaline and neutral conditions. Both the methods of preparation and the hydrolysis mechanism have been reviewed.[2] A selective deprotection and/or a subsequent transformation of such acetonides into a different protective group should be useful for the derivatization of carbohydrates. For this purpose, the results reported herein show some applications of the recently developed photosensitezed carbon–carbon bond fragmentation of acetal radical cations.[3] It has been demonstrated that this heterolytic cleavage is efficiently obtained under mild conditions by photoinduced single electron oxidation.[4] Both species so generated, the cation and the radical, may be exploited in view of synthetic application.[5]

At first, the most appealing side of this method has been the generation of carbon-centred radicals, and thus their use for carbon–carbon bond forming reactions.[6] The positively charged fragment might have some interesting applications if a carbocation is generated. The photosensitized fragmentation of an aliphatic acetal is a suitable example, because in this way, an α,α-dioxycarbocation is formed.[3a] The subsequent nucleophile addition transforms the acetal into a different protective group (orthoester or orthoacid) so realising a mild conversion of a ketone to an ester function. Examples of this kind of selective protective group elaboration in some sugars and polyols, are presented in the following.

2. Results and discussion

In a previous work, we considered the reaction of the simplest acetonide, 2,2-dimethyl-1,3-dioxolane (**1**).[3a] This can be taken as a 'model reaction' for the general mechanism on which this method is based. Electron transfer from dioxolane to the singlet excited state of benzene 1,2,4,5-tetracarbonitrile (TCB) followed by fragmentation of the donor radical cation gave a methyl radical and a α,α-dioxycarbocation. The first species was trapped by TCB radical anion to yield methylbenzenetricarbonitrile **2**, while product **3** arose from the trapping of the cation by the moisture present in the solvent to give an orthoacid, which in turn was hydrolyzed to the 2-hydroxy ethyl acetate. If a nucleophile was purposely added, for example methanol, the orthoester **4** was obtained (Scheme 1).

In the present work the reaction was successfully extended to some acetonides and diacetonides of polyols and sugars. In every case a methyl radical was selectively removed and the acetalic moiety underwent one of two different reactions, viz *intermolecular trapping* (path a in Scheme 2) to give hydroxy acetates or orthoesters and *intramolecular trapping* (path b in Scheme 2) to give cyclic-orthoesters when an hydroxyl group was present in δ position. The hydrolysis of cyclic orthoesters was highly selective yielding again hydroxy acetates which are useful synthetic intermediates.[7] The results reported in the following are discussed according to the reaction path observed, inter- or intramolecular.

Keywords: photochemistry; electron transfer; acetonides; orthoesters.

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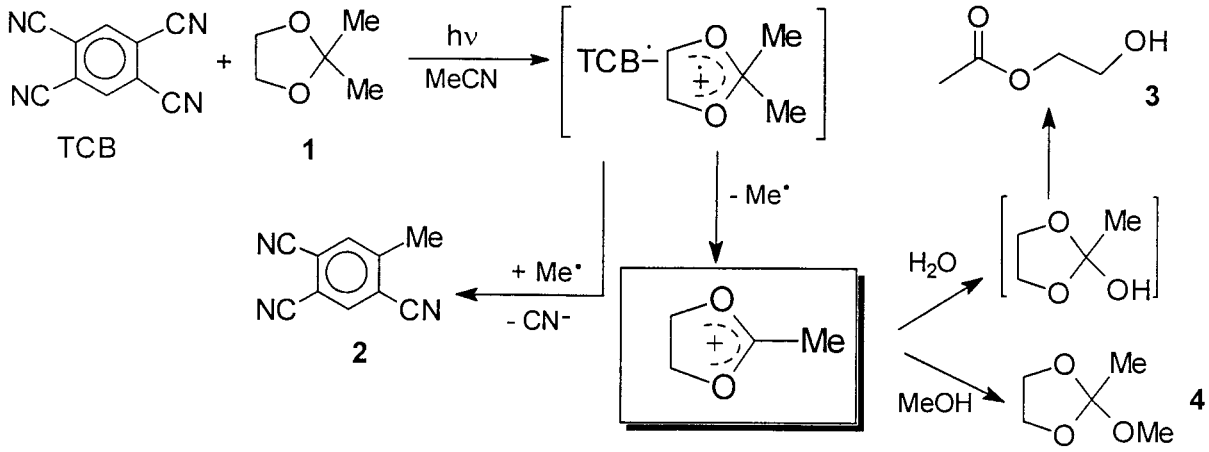


Scheme 1.

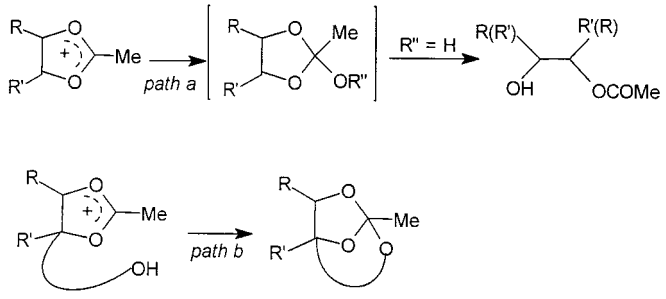
2.1. Intermolecular trapping

The presence of a γ-hydroxyl group in an α,β-acetonide did not change the course of the reaction. Thus, 2,2-dimethyl-4-hydroxymethyl-1,3-dioxolane (**5**) reacted with TCB in the same way as **1**. Besides nitrile **2**, two products generated from the cationic moiety were revealed by ^{1}H NMR of the crude photolyzate. These were bulb to bulb distilled and recognized as a 1:1 mixture of the isomeric 2-acetoxy-propane-1,3-diol (**6**) and 3-acetoxy-propane-1,2-diol (**7**) When we turned to diacetonides, we found that with mannitol derivatives the results obtained, viz *intermolecolar* or *intramolecolar* trapping, depended on their structure. We first considered the non-symmetric diacetonide. By irradiation of a MeCN solution of TCB and 1,2:4,5-Di-*O*-isopropylidene-D-mannitol (**8**), 50% of the diacetonide was converted into a mixture of mono acetyl monoacetonides. In order to determine the position of the remaining acetonide group, the mixture was acetylated; 1,2,3,6-tetra-*O*-acetyl-4,5-*O*-isopropylidene-D-mannitol (**9**) and 3,4,5,6-tetra-*O*-acetyl-1,2-*O*-isopropylidene-D-mannitol (**10**) were the products isolated (Scheme 3).

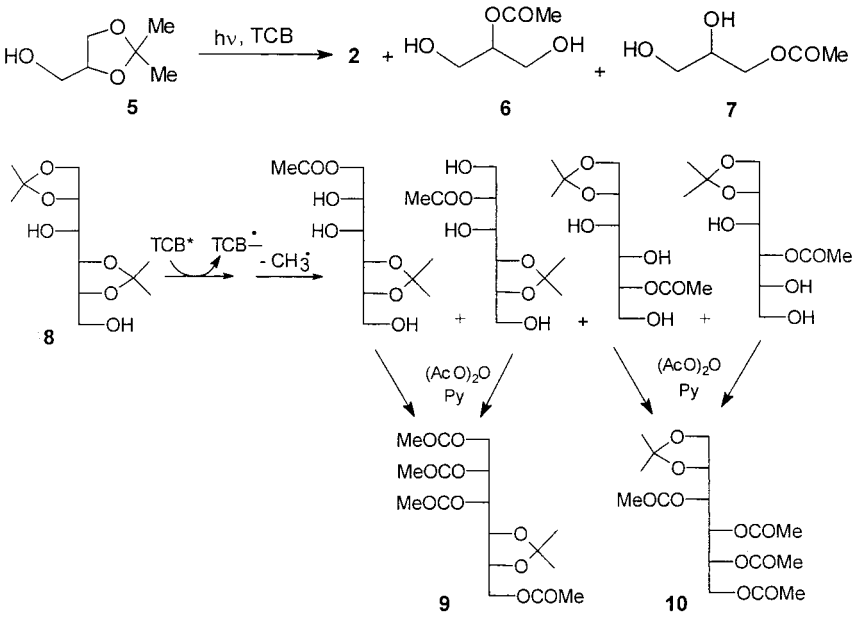
These results indicate that both acetonides are involved in the electron transfer process and behave as if they were separated. This is reasonable considering that neither of the acetonide moietiesis subject to steric hindrance which could disfavour the interaction with TCB. The product distribution is completely in agreement with the mechanism depicted in Scheme 2 (path a). The hydrolyis of the ortho-acid intermediate is not selective and both acetyl derivatives are formed. In contrast to from the case of mannitol derivative **16** discussed below, the reaction does not proceed after the cleavage of an isopropylidene group, and the second protecting group remains intact. It may be that the acetyl group formed in the first step acts as a competitive electron donor moiety, decreasing the rate and efficiency of the main process.[8]

In the reaction with a mannose diacetonide, the 2,3:5,6-di-*O*-isopropilidene-α-D-mannofuranose (**11**), the less hindered acetonide was converted to an ester function while the trioxabicyclooctane moiety was unaffected. The crude photolyzed material contained a 1:1 mixture of the 6-*O*- and 5-*O*-acetyl derivatives (**12** and **13**), but chromatographic separation under buffered conditions converted the secondary acetate (**13**) into the primary isomer (**12**) (Scheme 4). The shift of an acetyl group towards a primary position in partially acylated sugars has precedent and is favoured by the non acidic conditions of chromatographic separation (see Experimental).[10]

An interesting case of *intermoleuolar trapping* was discovered with 1,2:3,4-di-*O*-isopropyliden-D-galactopyranose (**14**). After prolonged irradiation, a mixture of two diastereoisomeric orthoesters was isolated. These derivatives contained two sacharridic units but were not symmetric dimers. One of the units was unchanged except for the



Scheme 2.



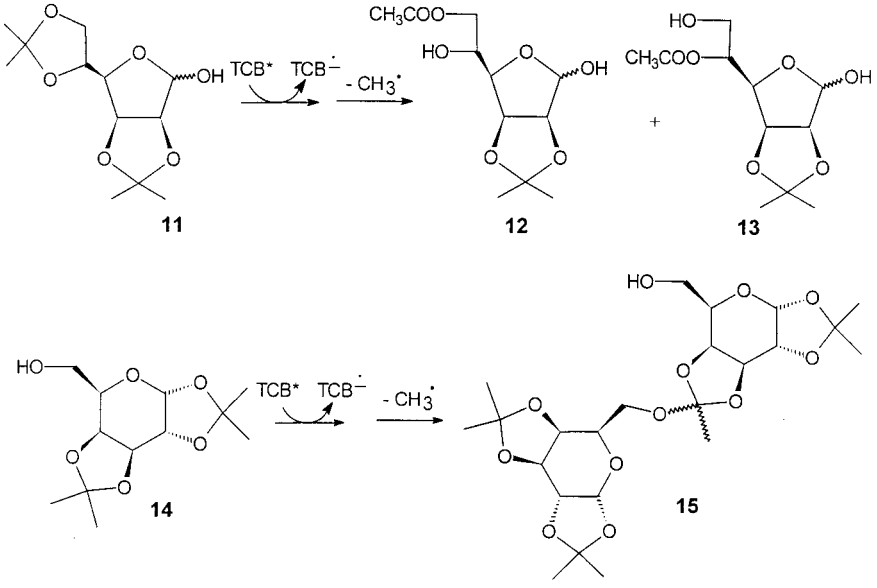
Scheme 3.

fact that the hydroxyl group was functionalized, while in the second unit a methyl group was missing. All the spectroscopic data supported the structure of 1,2-*O*-isopropylidene-3,4-*O*-[1-(1,2:3,4-di-*O*-isopropylidene-D-galactopyranosyl)-ethylidene]-D-galactopyranose (**15a**,**b**) for the two diastereoisomers (Scheme 4). In contrast to the previous case, the sugar has a free primary hydroxy group and this acts as nucleophile, being present in high concentration. Derivative **15** is an interesting example of a carbohydrate ortho ester in which the anomeric carbon is not part of the alkoxydioxolane ring. Previously known sacharridic orthoesters are either bicyclic compounds in which an orthoester 2-alkoxydioxolane ring is fused to the furanose or pyranose ring with the fusion involving the anomeric carbon, either tricyclic orthoesters in which all of three of the orthoester oxygens are bonded to the carbohydrate skeleton.[11]

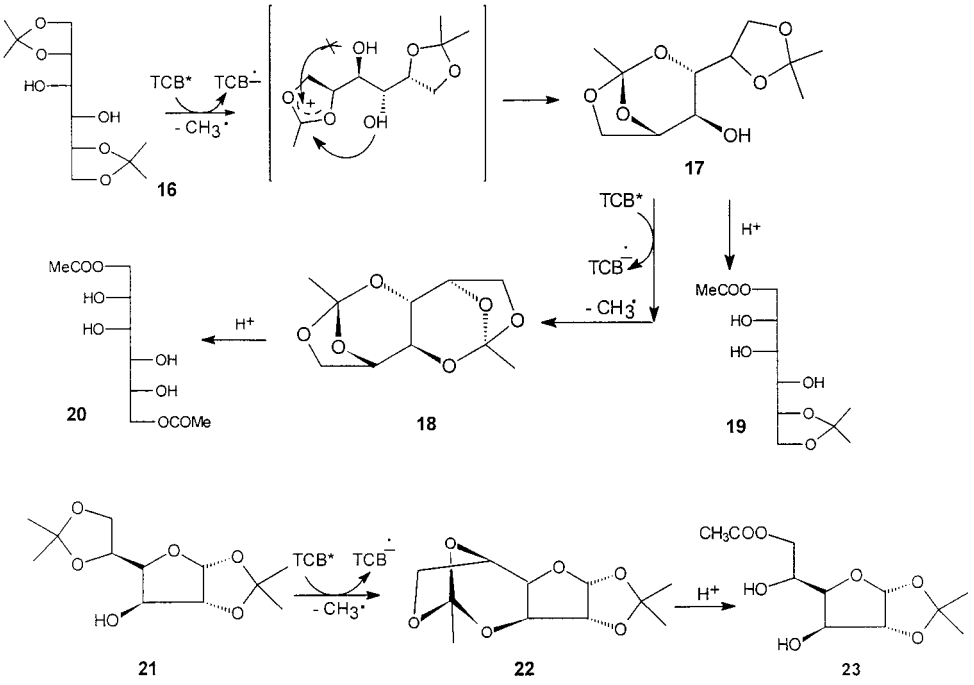
The mild hydrolysis with traces acetic acid was not selective giving the starting galactopyranose **14** and its partially acylated derivatives (3- and 4-*O*-acetyl-1,2-*O*-isopropylidene-galactopyranose).

2.2. Intramolecular trapping

Symmetric 1,2:5,6-di-*O*-isopropylidene-D-mannitol (**16**), differently from isomeric **8**, underwent an interesting intramolecular reaction. By irradiation in the usual conditions, two derivatives were formed. In the first one, a methyl radical had been removed and the carbocation intramolecularly trapped by the δ-hydroxyl group to give 1,2,4-*O*-orthoacetyl-5,6-*O*-isopropylidene-D-mannitol (**17**). The second compound had a symmetric structure in which the second acetonide had also reacted and the carbocation had



Scheme 4.



Scheme 5.

been trapped by the δ-hydroxyl group to yield the 1,2,4:5,6,3-di-*O*-orthoacetyl-D-mannitol (**18**) (Scheme 5). This peculiar and selective intramolecular trapping is worth some consideration. Attack by the δ-hydroxyl group to give a 1,3-dioxane ring (fused with a 1,3-dioxolane ring) was the exclusive process. No competitive attack by the γ-hydroxyl group (which would lead to two fused five-member rings) takes place, consistent with the occurrence of intramolecular rather than intermolecular trapping in the reaction with the isomeric **8** (see above). Moreover the fast intramolecular ring closure shows the absence of either steric or torsional hindrances in achieving a conformation suitable for the cyclization to give the stable six membered ring. The presence of any such effect would be evidenced by some intermolecular trapping, while the ^{1}H NMR spectrum of the crude photolyzate showed the absence of any such products. In this case both the bicyclic and the tetracyclic orthoesters underwent easy and selective hydrolysis, partially occurring also upon crystallization. The 1-*O*-acetyl-5,6-*O*-isopropylidene-D-mannitol (**19**) and the 1,6-di-*O*-acetyl-D-mannitol (**20**) were obtained from **17** and **18**, respectively.

A second example of *intramolecular trapping* is offered by 1,2:5,6-di-*O*-isopropylidene-α-D-glucofuranose (**21**). After prolonged irradiation, 50% of **21** was converted into a tetracyclic derivative recognized as the 1,2-*O*-isopropylidene-3,5,6-*O*-orthoacetyl-α-D-glucofuranose (**22**). As in the previous case, the formation of this tetracyclic orthoester was due to an intramolecular reaction of the dioxy carbocation with the free hydroxy group, which is in a suitable position for the formation of a heterobicyclic derivative (Scheme 5). This method may be an alternative way for preparing this kind of derivative in neutral conditions at room temperature, while in the previously reported synthesis, it was obtained through acid catalyzed ortho esterification of the 1,2-*O*-isopropylidene-glucofuranose with 1,1-dimethoxyethene.[12] The synthetic utility for further elaboration is linked to the selective hydrolysis under mild acidic conditions to give 6-acetyl-1,2-*O*-isopropylidene-α-D-glucofuranose (**23**). The mechanism of this reaction has been previously studied.[12]

3. Conclusion

Several different substrates have been considered in this work in order to test possible synthetic applications of the mild generation of α,α-dioxycarbocations from acetonides through photoinduced electron transfer. The results obtained prove that an extension to the acetonides of sugars and polyols is feasible and leads to a few interesting derivatives such as cyclic orthoesters. In turn, these are useful substrates for further elaboration, due the ease of their hydrolytic removal under acidic conditions. Some general considerations may be deduced from the observed pattern. As for the regio- and chemoselectivity of the process, it should be noted that the formation of the carbocation takes place selectively for the less hindered moiety, at least in polycyclic structures where steric hindrance is an important factor in affecting the interaction with the TCB excited state. Also importantly, there is no competition from the hemiacetal moiety, and the anomeric carbon is not involved in this reaction even when it is a part of the alkoxydioxolane ring.

As for the following elaboration of the α,α-dioxycarbocation formed after photoinduced ET, this undergoes nuclephile addition in a mode which depends on the structure of the acetonide itself. If the molecule contains a δ-hydroxyl group, intramolecular trapping is observed and this process represents a new method for preparing cyclic orthoesters which have also received a great interest as glycosidation reagents.[13] Otherwise, when the hydroxyl

group is not suitably located for a fast cyclization, intermolecular nucleophiles intervene, viz. the moisture present in the solvent, an added alcohol or the sugar itself if it contains a free primary hydroxyl group. Summing up, photoinduced electron transfer is an alternative method for the activation of the acetal protecting group under mild and neutral conditions and leads to orthoesters by inter- or intramolecular nucleophile addition. In both cases, the subsequent hydrolysis in mild acidic conditions gives the corresponding hydroxy acetate. On the basis of these encouraging results, we are considering a further extension of this method for the selective protecting group elaboration of other derivatives, as well as the use of different nucleophiles as cationic traps.

4. Experimental

4.1. General

TCB and acetonides **5**, **8**, **11**, **14**, **17** and **18** were commercial products. ^{1}H, ^{13}C, ^{13}C-DEPT135 and 2D-Correlated NMR spectra were recorded on a Bruker AC300 spectrometer and mass spectra on Finnigan Mat 8222 instrument. Chemical shifts are reported in ppm downfield from TMS. The yields were calculated on the starting acetonide concentration.

4.1.1. Reaction with 2,2-dimethyl-4-hydroxymethyl-1,3-dioxolane (5). A solution 0.01 M in TCB (106 mg, 0.6 mmol) and 0.02 M in dioxolane **5** (1.2 mmol, 158 mg) in MeCN (60 mL, subdivided in three quartz tubes), was purged with argon and irradiated for 12 h with a multilamp reactor fitted with six 15-W phosphor-coated lamps (emission maximum, 320 nm). The reaction course was monitored by TLC and GC. In this case, as well as in the following, TCB was completely consumed yielding the 5-methyl-1,2,4-benzene-tricarbonitrile (**2**).[3a] The crude photolyzate was concentrated in vacuo and then bulb to bulb distilled (20 mmm Hg, 150°C). A 1:1 mixture of the isomeric 2-acetoxy-propane-1,3-diol (**6**) and 3-acetoxy-propane-1,2-diol (**7**) (oil 70 mg, 43%) was separated from the aromatic derivative. The reaction was repeated, irradiating a solution 0.01 M in both reagents for 24 h; in this case about 90% of the dioxolane was converted into acetates **6** and **7**.

2-Acetoxy-propane-1,3-diol (**6**) δ_H (300 MHz, $CDCl_3$) 2.12 (s, 3H, COCH_3), 3.5 (1H, br, exch, OH), 3.7 4H, d, J=5 Hz, CH_2OH), 4.6 (1H, br, exch, OH), 4.7 (1H, qui, J=5 Hz, *CH*OCO). δ_C (75.5 MHz, $CDCl_3$): 20.9, 61.7, 71.9, 171.2. 3-acetoxy-propane-1,2-diol (**7**) δ_H (300 MHz, $CDCl_3$) 2.1 (3H, s, COCH_3), 2.9 and 3.3 (2H, br, exch, OH); 3.65 (2H, m, CH_2OH); 3.94 (1H, m, *CH*OH), 4.15 (2H, m, CH_2OCO). δ_C (75.5 MHz, $CDCl_3$) 20.6, 63.1, 65.1, 69.9, 171.4. ν_{max} (liquid film) 3300–3500 (br), 1720, 1340, 1250, 1120 cm^{-1}. [Found: C, 44.6; H, 5.8. $C_5H_{10}O_4$ requires C, 44.77; H, 5.71].

4.1.2. Reaction with 1,2:4,5-di-*O*-isopropylidene-D-mannitol (8). A solution 0.01 M in TCB and 0.02 M (314 mg) in mannitol **8** was irradiated for 24 h as above. The work up procedure involved concentration in vacuo of the crude photolyzed material and chromatographic separation employing Merck 60 silica gel and cyclohexane–ethyl acetate mixtures of increasing polarity as eluant (0.1% of NEt_3 was added to avoid acetonide decomposition by silica gel acidity). 140 mg (44%) of a mixture of four mannitol derivatives in the ratio 10:7:3:1 was obtained. The ^{1}H and ^{13}C spectra showed that each compound contained one acetyl group (174.5, 174.6, 174.4 and 174.1 ppm were the chemical shifts of the ester carbonyls) and one isopropylidene group (100.9, 112.1, 111.4 and 111.9 ppm were the chemical shifts of the acetalic carbons). The other resonances were superimposed so that it was not possible to ascertain the correct position of the acetyl group in each one. Acetylation with acetic anhydride-pyridine gave in 90% yield only two acetylated derivatives identified as the 1,2,3,6-tetra-*O*-acetyl-4,5-*O*-isopropylidene-D-mannitol (**9**) and the 3,4,5,6-tetra-*O*-acetyl-1,2-*O*-isopropylidene-D-mannitol (**10**).

1,2,3,6-Tetra-*O*-acetyl-4,5-*O*-isopropylidene-D-mannitol (**9**) (mp 104–106°C) δ_H (300 MHz, $CDCl_3$) 1.33 (3H, s, CH_3), 1.5 (3H, s, CH_3), 2.05 (3H, s, COCH_3), 2.06 (3H, s, COCH_3), 2.05 (3H, s, COCH_3), 2.08 (3H, s, COCH_3), 4.02–4.25 (2H, m, CH_aH$_b$OCO and C*H*OR), 4.35–4.4 (2H, m, CH$_a$$H_b$OCO and C*H*OR), 4.49 (1H, dd, J=12.5, 3 Hz, CH_aH$_b$OR), 4.17 (1H, dd, J=12.5, 5 Hz, CH$_a$$H_b$OR), 5.16 (1H, ddd, J=3, 5, 8 Hz, C*H*OCO), 5.33 (1H, dd, J=3, 5 Hz, C*H*OCO). δ_C (75.5 MHz, $CDCl_3$) 20.6, 20.6, 20.7, 20.8, 25.3, 25.8, 61.7, 62.4, 68.3, 71.5, 74.8, 74.9, 109.4, 169.5, 169.6, 170.4, 170.5. ν_{max} (Nujol) 1720, 1340, 1250, 1120 cm^{-1} $[\alpha]_D^{20}$=+14 (*c* 0.1, $CHCl_3$) [Found: C, 52.1; H, 6.9. $C_{17}H_{26}O_{10}$ requires C, 52.3; H, 6.7]. 3,4,5,6-Tetra-*O*-acetyl-1,2-*O*-isopropylidene-D-mannitol (**10**) ^{1}H NMR date were in agreement with those previously reported.[14] δ_C (75.5 MHz, $CDCl_3$) 20.5, 20.6, 20.6, 20.7, 25.0, 25.3, 61.8, 65.4, 68.1, 68.9, 69.8, 74.8, 109.25, 169.3, 169.8, 169.9, 170.5. $[\alpha]_D^{20}$=+27 (*c* 0.1, $CHCl_3$).[13] [Found: C, 52.2; H, 6.8. $C_{17}H_{26}O_{10}$ requires C, 52.3; H, 6.7].

4.1.2. Reaction with 2,3:5,6-di-*O*-isopropylidene-D-mannofuranose (11). A solution 0.01 M in TCB and 0.02 M in **11** (312 mg) was irradiated for 24 h as above and two mannofuranose derivatives were formed. The ^{1}H and ^{13}C NMR analysis of the crude photolyzed material, identified them as a mixture 1:1 of 6-*O*-acetyl-2,3-*O*-isopropylidene-D-mannofuranose (**12**) and 5-*O*-acetyl-2,3-*O*-isopropylidene-D-mannofuranose (**13**) (135 mg, 43%). After silica gel chromatography (cyclohexane–EtOAc with 0.1% of NEt_3), the secondary acetyl derivative **13** was converted into the primary one (**12**) (130 mg, 41%, oil).

6-*O*-Acetyl-2,3-*O*-isopropylidene-D-mannofuranose (**12**) δ_H (300 MHz, $CDCl_3$) 1.3 (3H, s, CH_3), 1.45 (3H, s, CH_3), 2.9 (1H, br, exch, O*H*), 3.05 (1H, br, exch, O*H*), 2.05 (3H, s, COCH_3), 4.13 (2H, m, C*H*OR and C*H*OH), 4.2 and 4.8 (2H, m, C$H_a$$H_b$OCO), 4.64 (1H, d, J=5.5 Hz, C*H*OR), 4.9 (1H, dd, J=5.5, 3.5 Hz, C*H*OR), 5.4 (1H, s, ROC*H*OH). δ_C (75.5 MHz, $CDCl_3$) 20.7, 24.4, 25.8, 66.2, 68.5, 78.8, 79.9, 85.2, 100.9, 112.7, 171.3. ν_{max} (liquid film) 3300–3500 (br), 1720, 1335, 1240, 1120 cm^{-1} $[\alpha]_D^{20}$=+23 (*c* 0.2, $CHCl_3$) [Found: C, 50.5; H, 7.0. $C_{11}H_{18}O_7$ requires C, 50.4; H, 6.9]. 5-*O*-Acetyl-2,3-*O*-isopropylidene-D-mannofuranose (**13**) (not isolated) (data obtained from the NMR spectra of the crude mixture photolyzed) δ_H (300 MHz

CD_3CN) 1.25 (3H, s, CH_3); 1.4 (3H, s, CH_3), 2.0 (3H, s, COCH_3), 3.6 (1H, dd,, J=12.5, 5 Hz, CH_aH$_b$OH), 3.8 (1H, dd, J=12.5, 3 Hz, CH$_a$$H_b$OH), 4.0 (1H, m, C$H$OR), 4.5 (1H, d, J=5.5, CHOR), 4.7 (1H, dd, J=5.5, 3.5 Hz, CHOR), 5.02 (1H, ddd, ^3J=5, 3, 8 Hz, CHOAc), 5.15 (1H, s, 1H, ROCHOH). δ_C (75.5 MHz, CD_3CN) 20.4, 24.0, 25.4, 61.7, 77.7, 78.4, 79.8, 84.9, 100.5, 112.0, 169.8.

4.1.3. Reaction with 1,2:3,4-di-*O*-isopropylidene-D-galactopyranose (14). A solution 0.01 M in TCB and 0.02 M in galactopyranose **8** was irradiated for 24 h as above. After work-up as above and two chromatographic separation (80% cyclohexane/ethyl acetate) 220 mg (oil, 36 %) of 1,2-*O*-isopropylidene-3,4-*O*-[1-(1,2:3,4-di-*O*-isopropylidene-D-galactopyranosyl)ethylidene]-D-galactopyranose (**15a**,**b**) as a mixture of two diastereoisomers in about the same ratio were obtained. The above structure was attributed on the basis of the spectroscopic data. In the proton spectrum the resonances of four anomeric protons were clearly separated as well as the methyl group on the orthoester carbons (1.6 and 1,65 ppm). Because of the overcrowding in the range between 3.5 and 4.7 ppm, the *HH* coupling constants could not be analyzed accurately. In the ^{13}C NMR spectrum most of the signals were separated (except for the region between 70 and 72 ppm, R_2-CH–O– groups).

1,2-*O*-Isopropylidene-3,4-*O*-[1-(1,2:3,4-di-*O*-isopropylidene-D-galactopyranosyl)ethylidene]-D-galactopyranose (**15a**,**b**) δ_H (300 MHz, $CDCl_3$) 1.33–1.55 (36H, s, 12 CH_3), 1.6 (3H, s, CH_3 orthoester), 1.65 (3H, s, CH_3 orthoester), 3.5–3.9 (8H, m, RCH_2-O–), 3.8–4.7 (16H, m, R_2CH-O–), 5.5, 5.51, 5.53 and 5.57 (4H, d, J=5 Hz, four anomeric hydrogens, ROCHOR), 2.1–2.3 (broad, exch, 2 OH). δ_C (75.5 MHz, $CDCl_3$) (the chemical shifts of the second diastereoisomer are reported in square brakets when separated) 19.8 [20.5] (CH_3), 24.4 [24.2] (CH_3), 24.8 (CH_3), 25.8–25.9 (all other CH_3), 62.1[61.7] (CH_2–O), 62.2 [61.9] (CH_2–O), 66.4 [66.6] (CH), 68.3 [67.9] (CH–O), 70.0 [70.2] (CH–O), 70.4–70.2 (R_2CH–O–), 91.5 [91.5] (CH), 91.54 [91.52] (CH), 108.4 [108.1], 109.1, 109.4, 120.3 [121.7]. ν_{max} (Nujol) 3300–3500 (br), 1330, 1230, 1110 cm^{-1}. [Found: C, 54.8; H, 7.3. $C_{23}H_{36}O_{12}$ requires C, 54.74; H, 7.20]. M^+: 522 (CI with ammonia).

4.1.4. Reaction with 1,2:5,6-di-*O*-isopropylidene-D-mannitol (16). A solution 0.01 M in TCB and 0.02 M in mannitol derivative **16** was irradiated for 24 h as above. After work-up as above and chromathographic separation (80% cyclohexane/ethyl acetate), 97 mg (33%) of 1,2,4-*O*-orthoacetyl-5,6-*O*-isopropylidene-D-mannitol (**17**) and 34 mg of 1,2,4:5,6,3-di-*O*-orthoacetyl-D-mannitol (**18**) (12%) were obtained. The ratio between mono and bis orthoester depended on the irradiation time as confirmed by separate experiments. After 6 h, **17** was the main product. These two orthoesters were more easily hydrolyzed than the previous ones; in solution during chromathographic separation and crystallization gave the corresponding 1-*O*-acetyl-5,6-*O*-isopropylidene (**19**) and 1,6-di-*O*-acetyl (**20**) derivatives.

1,2,4-*O*-Orthoacetyl-5,6-*O*-isopropylidene-D-mannitol (**17**) δ_H (300 MHz, $CDCl_3$) 1.4 (3H, s, CH_3), 1.45 (3H, s, CH_3), 1.65 (3H, s, CH_3), 2.6 (1H, exch, d, J=10 Hz, OH), 3.6 (1H, bdt, J=10, 2 Hz, CHOH), 3.8 (1H, dd, J=8.5, 2 Hz, CHOR), 3.95 and 4.06 (2H, m, C$H_a$$H_b$OR), 3.97 (2H, m, C$H_a$$H_b$OR), 4.28 (1H, ddd, J=4.5, 8.5, 6 Hz, CHOR), 4.68 (1H, dt, J=4, 2 Hz, CHOR). δ_C (75.5 MHz, $CDCl_3$) 21.4, 25.05, 26.8, 64.8, 66.7, 66.7, 72.5, 73.1, 77.1, 109.2, 119.0. 1,2,4:5,6,3-Di-*O*-orthoacetyl-D-mannitol (**18**) (mp 103–104°C) δ_H (300 MHz, $CDCl_3$) 1.7 (3H,s, CH_3), 3.75 (1H, d, J=1 Hz, CHOR); 3.95 (2H, m, C$H_a$$H_b$OR), 4.6 (1H, dd, J=5, 1 Hz, CHOR). δ_C (75.5 MHz, $CDCl_3$) 21.59, 64.82, 66.67, 75.1, 119.2. 1-*O*-Acetyl-5,6-*O*-isopropylidene-D-mannitiol (**19**) δ_H (300 MHz, $CDCl_3$) 1.3 (3H, s, CH_3), 1.4 (3H, s, CH_3), 2.2 (3H, s, CH_3COOR), 2.7–3.0 (3H, br, OH);3.7 and 3.85 (2H, m, C$H_a$$H_b$OR), 3.95–4.1 (2H, m, 2H, CHOR), 4.15–4.25 (2H, m, 2H, CHOR), 4.38 (2H, m, C$H_a$$H_b$OCOR). δ_C (75.5 MHz, $CDCl_3$) 20.8, 25.1, 26.5, 66.3, 66.7, 70.1, 71.1, 71.5, 76.2, 109.3, 171.9. $[\alpha]_D^{20}$=+3 (c 0.1 $CHCl_3$). ν_{max} (Nujol) 3200–3600 (br), 1720, 1320, 1210, 1115 cm^{-1}. [Found: C, 49.8; H, 7.7. $C_{11}H_{20}O_7$ requires C, 49.9; H, 7.6]. 1,6-Di-*O*-acetyl-D-mannitol (**20**): the spectroscopic data were in agreement with those reported. [15]

4.1.5. Reaction with 1,2:5,6-di-*O*-isopropylidene-α-D-glucofuranose (19). A solution 0.01 M in TCB and 0.02 M in glucofuranose **19** was irradiated for 24 h as above. After the usual work-up and chromathographic separation, 120 mg (40%) 1,2-*O*-isopropylidene-3,5,6-*O*-orthoacetyl-α-D-glucofuranose (**20**) (mp 131–132°C) were obtained. The spectroscopic and chemical physical data were in accordance with those previously reported.[12] $[\alpha]_D^{20}$=−39 (c 0.2, $CHCl_3$).[12] The hydrolysis to 6-*O*-acetyl-1,2-*O*-isopropylidene-D-glucofuranose (**21**) was performed in NMR tube adding traces of acetic acid to the chloroform solution and monitoring the course of the reaction course by ^{1}H NMR spectrometry.

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