3.1 Introduction

Aryl-*C*-glycosides are important class of compounds that display various biological activities [1]. Among the different types, the 2-deoxy aryl-*C*-glycoside motifs are found in various bio-active molecules and natural products [1]. For instance, the natural products pluramycins, angucyclines and benzoisochromanequinones consist of 2-deoxy aryl *C*-glycoside units [2]. There are few different routes that have been developed for the preparation of 2-deoxy aryl glycosides [1, 3, 4]. Among them, a direct coupling of aryl donors such as aryl halides, arylboronic acids, arylhydrazines, aryl carboxylic acids, arylsulfonyl halides, etc. with glycals has received considerable attention in carbohydrate synthesis [4] (*Refer the section 1.6 in chapter 1*). *Notably, all these methods provide 2-deoxy α-aryl C-glycosides while most of the naturally occurring 2-deoxy aryl-C-glycosides exist in β-configuration at the anomeric center.*

Aryldiazonium salts are highly useful synthetic intermediates that have been explored in many organic reactions [5]. In particular, palladium catalyzed Heck coupling of allyl alcohols, allyl ethers and vinyl ethers with aryldiazonium salts received considerable attention in the past few decades because such reactions are taking place at room temperature in the absence of any ligands [6]. In this context, Correia and Schmidt research groups independently explored a palladium-catalyzed arylation of different cyclic enol ethers using aryldiazonium salts [6c-n].

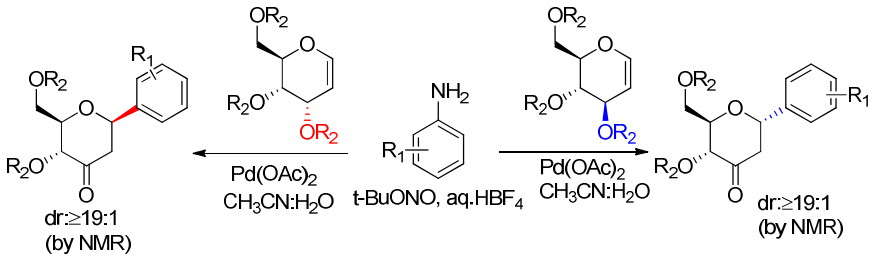
As discussed in the Chapter 2, we have demonstrated a stereo-controlled synthesis of 2,3-deoxy 3-keto α-aryl-*C*-glycosides from glycals and aryldiazonium salts in the presence of palladium acetate at room temperature [7]. Along with our report, Ye *et al.* reported a palladium catalyzed one-pot synthesis of 2-deoxy aryl *C*-glycosides from

glycals and anilines using nitrosoniumtetrafluoroborate as the nitrosating reagent [8]. The important advantage of this one-pot method is that the isolation of unstable aryldiazonium salt intermediate is not required. However, the use of nitrosoniumtetrafluoroborate ($NOBF_4$) as a nitrosating agent has some disadvantages. For instance, nitrosoniumtetrafluoroborate is not only expensive reagent but also highly reactive which necessitates low temperature *(i.e.* -40 $^{\circ}$C) and moisture free condition for the diazotization process [8]. *Therefore, we believed that the development of an alternative one-pot procedure using inexpensive, stable and easy accessible nitrosating agent is important to achieve 2-deoxy aryl-C-glycosides from glycals and anilines under mild conditions.*

3.2 *tert*-Butyl Nitrite

tert-Butyl nitrite (TBN) is an efficient nitrosating reagent that has been explored in many organic transformations [9]. Diazotization of anilines have been successfully achieved using *tert*-butyl nitrite under mild conditions [10]. Moreover, *tert*-butyl nitrite-mediated diazotization followed by cross-coupling reactions have also been successfully demonstrated in organic synthesis [9c, 9d]. The other advantages of TBN are cheap and commercially available, cheap and easy to store and handle. We have recently demonstrated a different applications of *tert*-butyl nitrite in organic synthesis including *N*-nitrosation of secondary amines [11], oxidative dimerization of thioamides [12], conversion of *o*-phenylenediamines into triazoles [13], nitration of *N*-alkyl anilines [14] and one-pot transamidation of secondary amides [15]. *In continuation of these works and* ***chapter 2****, here we report palladium catalyzed one-pot synthesis of*

*both anomers of 2,3-deoxy 3-keto aryl-C-glycosides(i.e. α/β) from glycals and anilines in the presence of tert-butyl nitrite under mild conditions (**Scheme 3.1**).*

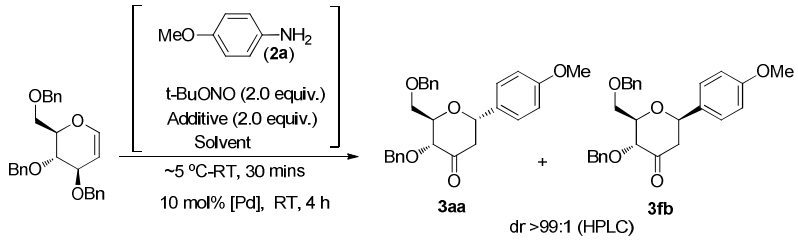


Scheme 3.1 Palladium catalyzed stereo-selective synthesis of 2-deoxy aryl-*C*-glycosides.

3.3 Results and Discussion

At the outset, optimization of the reaction conditions was performed using tri-*O*-benzyl glucal (**1a**) and 4-methoxy aniline (**2a**) in the presence of TBN and $Pd(OAc)_2$. Initially, the 4-methoxy aniline was treated with 2.0 equiv of TBN at ~ 5 ^oC (in ice bath) in different solvents including acetonitrile-water, THF or methanol and subjected for the coupling reaction with glucal (**1a**) in the presence of 10 mol% $Pd(OAc)_2$ at room temperature (**Table 3.1, entries 1-3**). However, the desired coupling product was not obtained. Hence, the reaction was performed using different acid additives including HBF_4, $BF_3.OEt_2$, HPF_6, PTSA, CSA, AcOH, and HCl in acetonitrile-water mixture (**Table 3.1, entries 4-10**). To our delight, the desired coupling product **3aa** was obtained as a single isomer (i.e. α-anomer) with most of these acid additives. Among these acid additives, HBF_4 was found to be the most efficient to provide the desired product in 76% yield (dr>99:1) (**Table 3.1, entry 4**). It is also interesting to note that the corresponding β-anomer **3fb** was not observed in TLC as well as in HPLC analysis.

Table 3.1 Optimization of the reaction condition.[a]

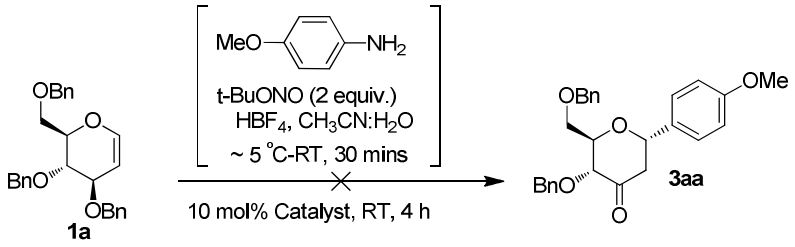


Entry	Additive	Catalyst	Solvent	Yield(%)[b] 3aa
1	---	$Pd(OAc)_2$	CH_3CN: H_2O	<5
2	---	$Pd(OAc)_2$	THF	nr
3	---	$Pd(OAc)_2$	MeOH	nr
4	**HBF_4 (aq. 48%)**	**$Pd(OAc)_2$**	**CH_3CN: H_2O**	**76**
5	$BF_3.OEt_2$ (48%)	$Pd(OAc)_2$	CH_3CN: H_2O	56
6	HPF_6 (Aq. 55%)	$Pd(OAc)_2$	CH_3CN: H_2O	72
7	$CSA.H_2O$	$Pd(OAc)_2$	CH_3CN: H_2O	10
8	$PTSA.H_2O$	$Pd(OAc)_2$	CH_3CN: H_2O	7
9	AcOH	$Pd(OAc)_2$	CH_3CN: H_2O	5
10	HCl (aq. 31%)	$Pd(OAc)_2$	CH_3CN: H_2O	<5
11	HBF_4 (aq. 48%)	$Pd(OAc)_2$	CH_2Cl_2	<5
12	HBF_4 (aq. 48%)	$Pd(OAc)_2$	Toluene	nr
13	HBF_4 (aq. 48%)	$Pd(OAc)_2$	CH_3CN	66
14	HBF_4 (aq. 48%)	$Pd(OAc)_2$	THF	54
15	HBF_4 (aq. 48%)	$Pd(OAc)_2$	Dioxane	65
16	HBF_4 (aq. 48%)	$Pd(OAc)_2$	Acetone	60
17	HBF_4 (aq. 48%)	$Pd(OAc)_2$	DMF	10
18	HBF_4 (aq. 48%)	$Pd(OAc)_2$	DMSO	<5
19	HBF_4 (aq. 48%)	$Pd(OAc)_2$	MeOH	5
20	HBF_4 (aq. 48%)	$Pd(OAc)_2$	AcOH	<5
21	HBF_4 (aq. 48%)	$PdCl_2$	CH_3CN: H_2O	55
22	HBF_4 (aq. 48%)	$Pd(TFA)_2$	CH_3CN: H_2O	40
23	HBF_4 (aq. 48%)	$Pd(dba)_2$	CH_3CN: H_2O	70
24	HBF_4 (aq. 48%)	$Pd_2(dba)_3$	CH_3CN: H_2O	67
25	HBF_4 (aq. 48%)	$Pd(PPh_3)_4$	CH_3CN: H_2O	69

[a]**Reaction conditions:** Glucal**1a** (52 mg, 0.125 mmol) and catalyst (0.012 mmol 10 mol%) were added to the solution of *in situ* generated aryldiazonium compounds from aniline **2a** (30 mg, 0.25 mmol, 2.0 equiv.) and *tert*-butyl nitrite (0.029 mL, 0.25 mmol, 2.0 equiv.) in the appropriate solvent (4 mL). [b]Isolated yield.

It is noteworthy that recently, Mabit*et al.* demonstrated a palladium catalyzed stereospecific synthesis of α and β 2-deoxy aryl-*C*-glycosides from glycals and haloarenes [4i]. In this report, the authors have shown that the stereochemistry at the pseudo-anomeric position is controlled by the stereo-center at *C*-3 position in glycals. In fact, a similar mechanistic aspect has been previously proposed by Schmidt *et al.* in the preparation of diarylheptanoids using diazonium salts [6j].

Further, the reaction was optimized with different solvents in the presence of HBF_4 (**Table 3.1 entries 11-20**). Among them, acetonitrile-water mixture has remained the best solvent for the coupling reaction. In all these conditions, only α-isomer **3aa** was obtained while β-anomer **3fb** was not detected in TLC. Further, different palladium catalysts including $PdCl_2$, $Pd(TFA)_2$, $Pd(dba)_2$, $Pd_2(dba)_3$ and $Pd(PPh_3)_4$ were screened in the presence of TBN and HBF_4 (**Table 3.1, entries 21-25**). Similar to palladium acetate, $Pd(dba)_2$, $Pd_2(dba)_3$ and $Pd(TFA)_2$ have shown similar reactivity to that of palladium acetate in the coupling reaction.



Scheme 3.2 Arylation of tri-*O*-benzyl glucal **(1a)** with 4-methoxyaniline **(2a)** with different metal and non-metal catalysts.

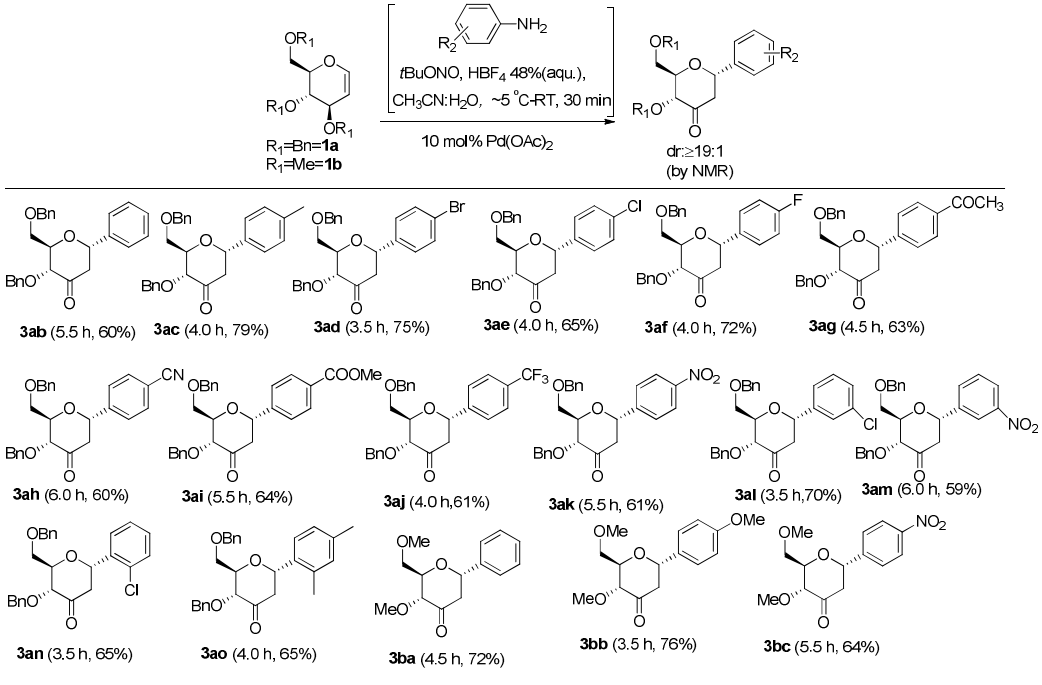
Furthermore, optimization of the reaction conditions was investigated with different metal and non-metal catalysts (those were known for the activation of aryl diazonium

salts) including CuCl, CuI, $CuBr_2$, CuOAc, $Cu(OAc)_2$, $NiCl_2$, ascorbic acid and tetrathiafulvalene (**Scheme 3.2**) [5]. Unfortunately, none of these catalysts yielded the desired product.

3.4 Substrates Scope

With optimized conditions in our hand, different functionalized anilines were subjected for the diazotization followed by coupling reaction with protected glucal in the presence of TBN, aq. HBF_4 and palladium acetate (**Table 3.2**).

Table 3.2 Reaction of protected glucal with different anilines.[a]

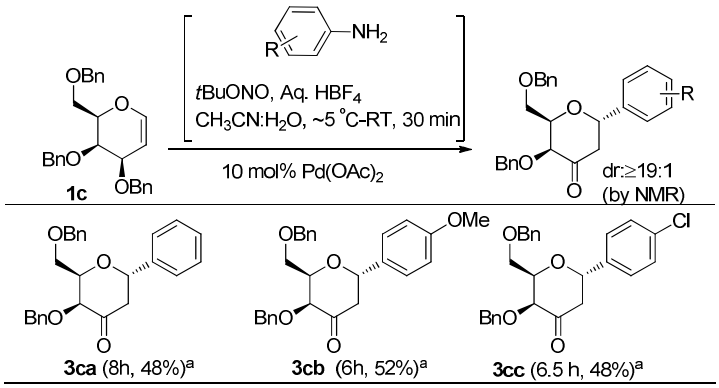


[a]**Reaction conditions:** See the general procedure. [b]Isolated yield.

Alkyl, halo, cyano, nitro and carbonyl functionalized anilines underwent coupling reactions with perbenzylated and permethylated glucals (**1a** and **1b**, respectively) and provided the desired products **3ab**-**3bc** as a single diastereomer (α) in 59-79% yields

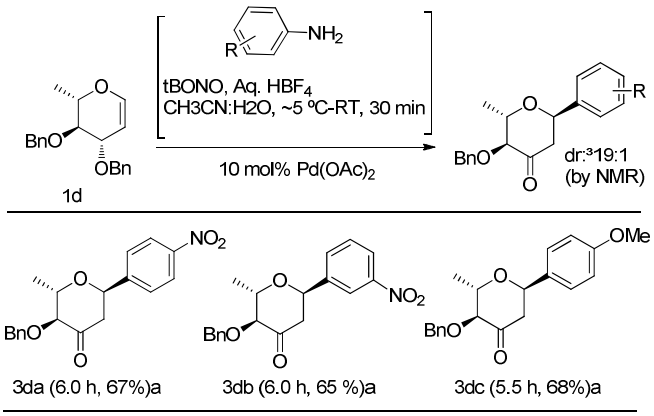
(**Table 3.2**). It is noteworthy that sterically hindered *ortho*-substituted anilines (Table 3.2, entries 13-14) also led to the coupling product with similar efficiency as with *para*and *meta*-substituted anilines. In general, electron withdrawing group functionalized anilines (e.g. CN, NO_2, and CF_3) took slightly longer time for completion when compared with electron donating functionalized anilines.

Further, tri-*O*-benzyl galactal (**1c**) was subjected for one-pot *C*-arylation with different anilines under optimized condition (**Scheme 3.3**). The desired products (**3ca-3cc**) were obtained in 48-52% yields.



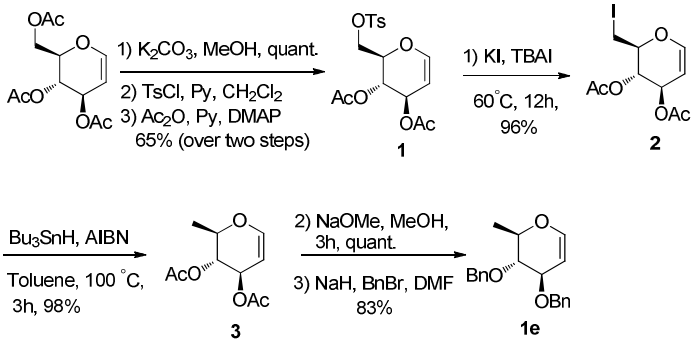
Scheme 3.3 Reaction of tri-*O*-benzyl galactal with anilines. Reaction conditions: See general procedure. [a](Time and isolated yield)

Having studied the scope of different diazonium salts with D-glucal and D -galactal, the developed one-pot methodology was further evaluated with di-*O*-benzyl L-Rhamnal (**1d**) under optimized conditions (**Scheme 3.4**).To our delight, 2-deoxy *C*-arylated L-rhamnose derivatives (**3da-3dc**) were obtained as a single diastereomer (i.e. α anomer) in 65-68% yields.

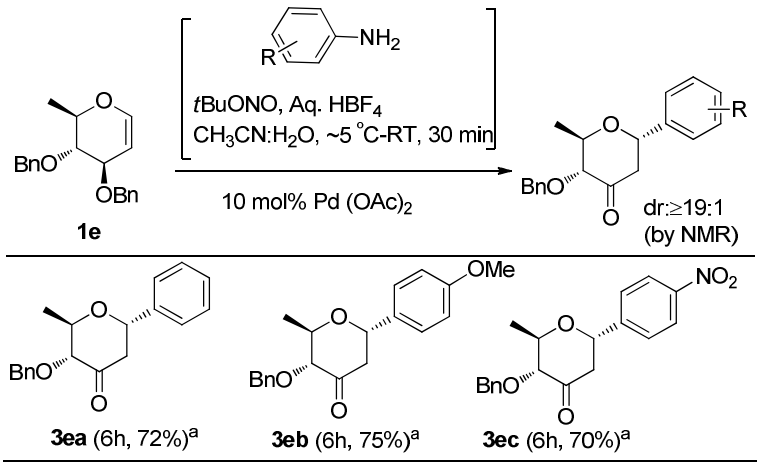


Scheme 3.4 Reaction of benzyl protected L-rhamnal with different anilines. Reaction conditions: See the general procedure. [a](Time and isolated yield)

Among the different aryl-*C*-glycosides, 2-deoxy aryl-*C*-rhamnoside (D-rhamnose) motifs are found in many natural products and bioactive molecules [1, 2]. Hence, di-*O*-benzyl D-rhamnal (**1e**) was synthesized from tri-*O*-acetyl glucal (**Scheme 3.5**) and subjected for the *C*-arylation with different anilines under optimized conditions (**Scheme 3.6**). All these reactions proceeded smoothly and gave the desired products in 70-75% yields.



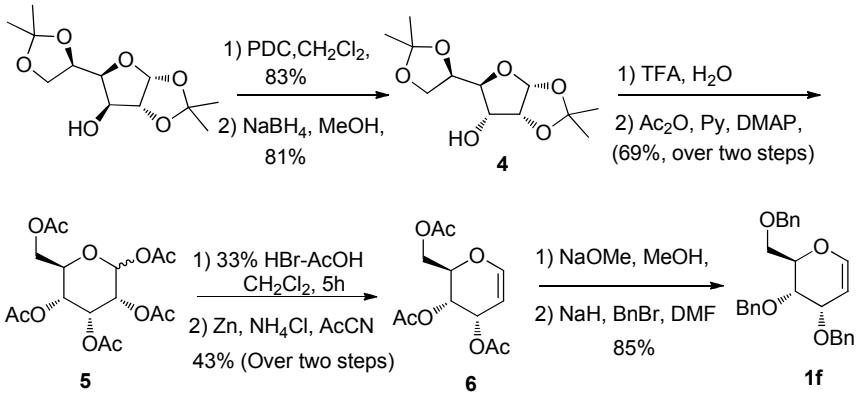
Scheme 3.5 Synthesis of di-*O*-benzyl-D-rhamnal from D-glucal



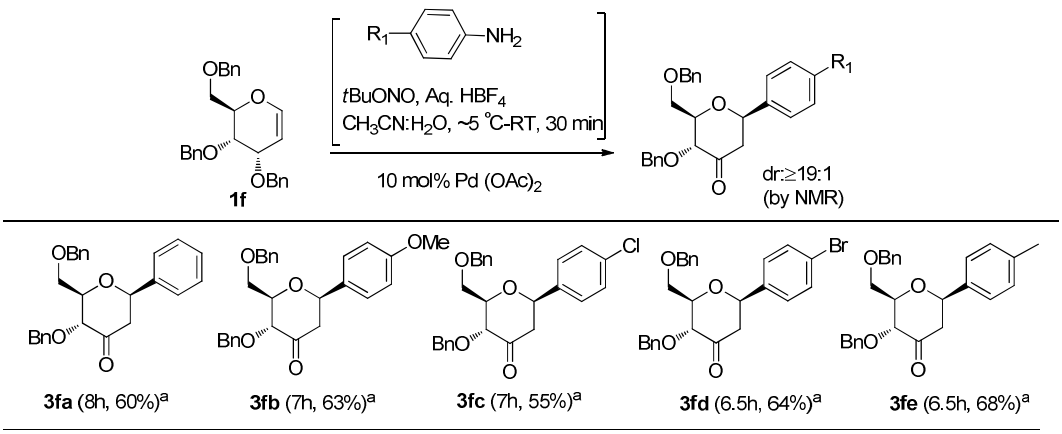
Scheme 3.6 Reaction of benzyl protected D-rhamnal with different anilines. Reaction conditions: See the general procedure. [a](Time and isolated yield)

3.5 Synthesis of Anti-Glycal and 2-Deoxy-β-Aryl-*C*-Glycoside

To understand the stereo-specificity of the reaction, we have synthesized tri-*O*-benzyl D-alltral (**1f**, i.e. *C*-3 inverted glucal) from 1,2:5,6-di-*O*-isopropylidene-*α*-D-glucofuranose (**Scheme 3.7**) and subjected for the coupling reaction with different anilines under optimized conditions.

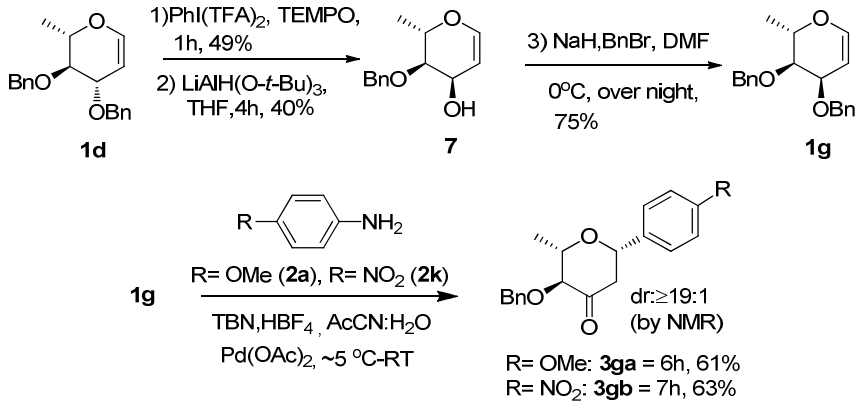


Scheme 3.7 Synthesis of tri-*O*-benzyl- D-altral from 1,2:5,6-di-*O*-isopropylidene-α- D-glucofuranose.



Scheme 3.8 Reaction of tri-*O*-benzyl-D-altral with different anilines. Reaction conditions: See the general procedure. [a](Time and isolated yield)

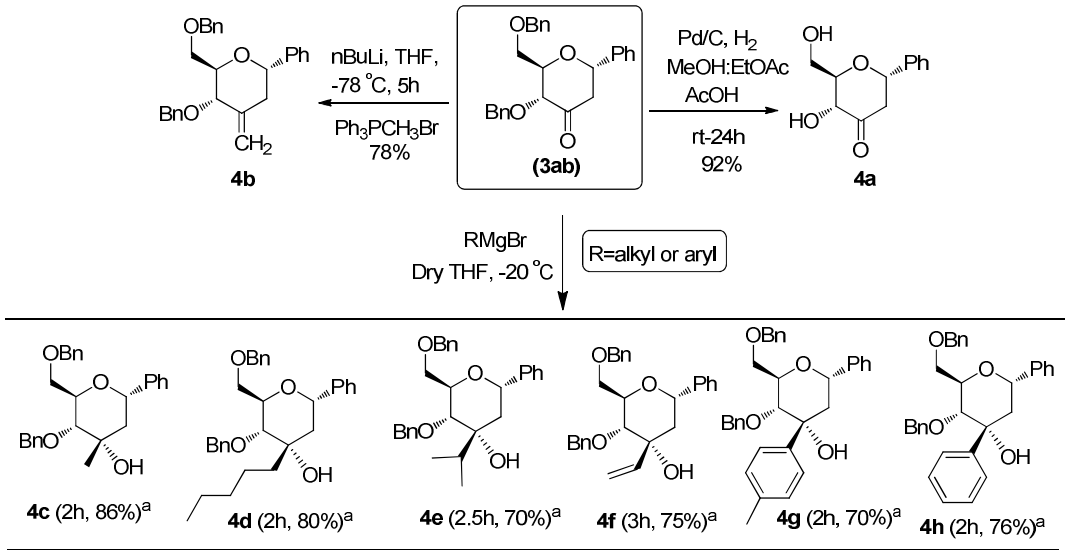
To our delight, the reactions proceeded smoothly and provided β-aryl glycosides (**3fa-3fg**) in good yields at room temperature (**Scheme 3.8**).



Scheme 3.9 Synthesis and reaction of di-*O*-benzyl 6-deoxy-L-allal with 4-methoxy aniline.

Likewise, di-*O*-benzyl 6-deoxy-L-allal **1g** (i.e. *C*-3 inverted L-Rhamal) prepared from di-*O*-benzyl L-rhamnal was subjected for the coupling reaction with 4-methoxyaniline under optimized conditions (**Scheme 3.9**). As desired, the reaction gave only 2-deoxy β-aryl-*C*-glycoside **3ga** in 61% yield.

3.6 Synthetic Applications of 2-Deoxy-α-Aryl-*C*-Glycoside



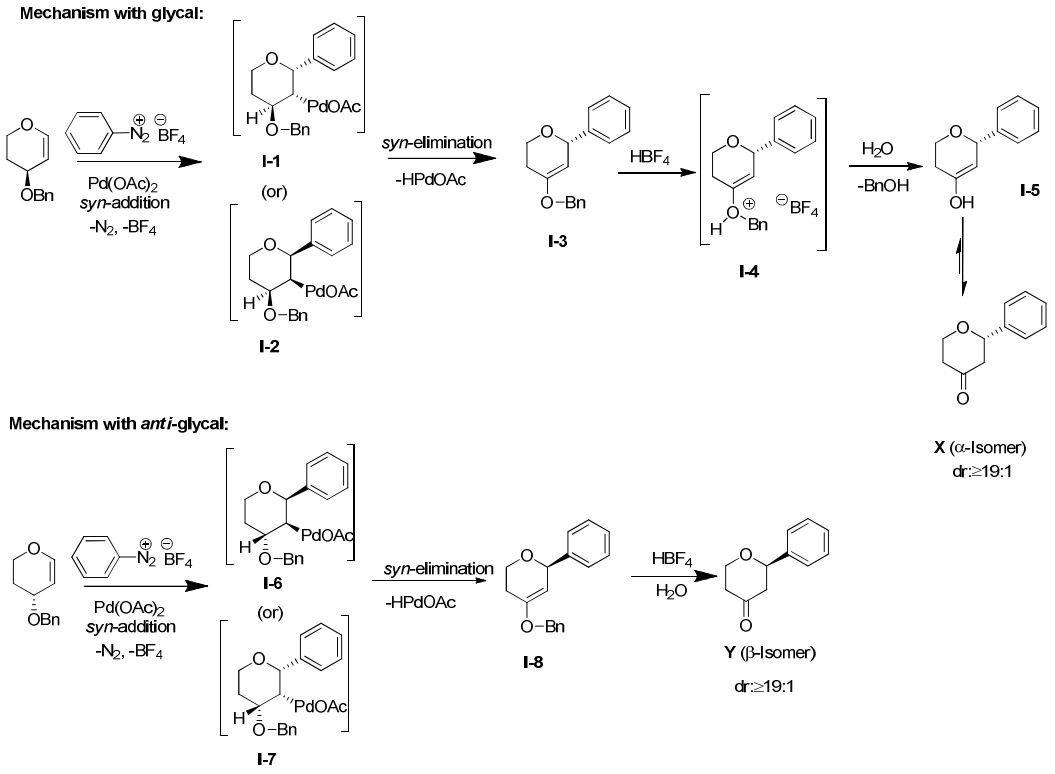
Scheme 3.10 Different transformations of 2,3-deoxy 3-keto aryl-*C*-glycoside **3ab**. Reaction conditions: See the general procedure. [a](Time and isolated yield), Stereo-selectivity dr:19:1 (by NMR).

Having established a simple one-pot procedure, different transformations of synthesized 2,3-deoxy 3-keto aryl-*C*-glycoside **3ab** were investigated (**Scheme 3.10**). The reduction of **3ab** with Pd/C-H_2 provides the de-benzylated product **4a** in quantitative yield. Wittig reaction of **3ab** with methyltriphenylphosphonium bromide in the presence of n-BuLi furnished the corresponding alkene **4b** in 80% yield. Treatment of **3ab** with methylmagnesium bromide gave 3-methyl 3-hydroxyl *C*-glycoside **4c** as a single diastereomer in 86% yield.

3.7 Plausible Reaction Mechanism

A plausible mechanism for the palladium catalyzed stereospecific *C*-arylation of glycal is shown in (**Scheme 3.11).** *Mechanism with glycal:* The oxidative *syn*-addition of the palladium to the aryldiazonium salt in the presence of glycal would provide the

intermediates **I-1** or **I-2**. In the next step, **I-1** or **I-2** intermediate has to undergo *syn*-β-elimination to form enol ether **I-3.** However, in the case of **I-2** intermediate, there is no possibility for the *syn*-β-elimination due to lack of *syn*-β-hydrogen. Therefore, we believe that there is only **I-1** intermediate formed during the reaction**.** In the presence of HBF_4-water, enol ether-**I-3** undergoes hydrolysis to enol **I-5** via **I-4** which provides the desired product **X** (i.e. α-*C*-aryl glycosides, (dr≥ 19:1)).



Scheme 3.11 Plausible mechanism for palladium catalyzed *C*-arylation of glycals

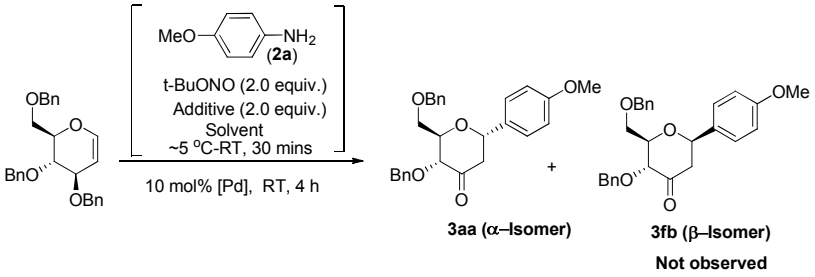
Mechanism with anti-glycal: Similarly, the reaction of *C*-3 inverted-glycals (i.e. anti-glycals) with aryldiazonium salt and palladium acetate would provide the intermediates **I-6** or **I-7**.Due to lack of *syn*-β-hydrogen in **I-7**, only **I-6** intermediate is formed and

undergoes *syn*-β-elimination to provide the β-*C*-aryl glycosides (dr≥ 19:1) stereo-specifically as described in themechanism.

3.8 Summary and Conclusion

In summary, an efficient one-pot procedure for the stereospecific synthesis of α and β-aryl-*C*-glycosides using glycals and anilines in the presence of palladium acetate and *tert*-butyl nitrite was demonstrated. All the reactions proceeded at room temperature and provided the desired aryl-*C*-glycosides in good yields. The configuration at *C*-3 position in glycals basically dictates the anomeric selectivity (i.e. either α or β).

3.9 HPLC Analysis of Compound 3aa, 3fb and Reaction mixture



In the above reaction, both anomers i.e. α and β show different R_f values in TLC. The R_f value (in 20% EtOAc:Hex) of **3aa**: 0.40, **3fb**: 0.42. The compound **3fb** was not observed in TLC analysis in all the conditions shown in Table 3.1 of the manuscript.

We have performed HPLC analysis for one experiment in the manuscript, i.e. Table 3.1, entry 2.

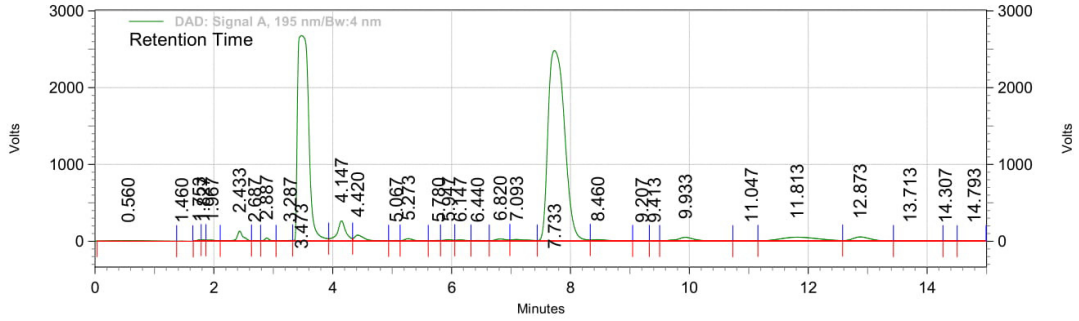
HPLC analysis was performed on Agilent LC/192168254.11. C-8 Reverse phase column was used for the analysis with solvent acetonitrile:water=70:30. Flow rate was maintained 1mL/minute. 10 Micro litre sample was injected for each analysis.

The HPLC analysis is also in agreement with TLC observation. For instance, pure compounds **3aa** and **3fb** was injected in the HPLC to obtain the retention of time. Both compounds showed different retention of time. The compound **3aa** showed retention of time at 7.733 minutes while compound **3fb** showed retention of time at 7.827 minutes. Further, the reaction mixture (Table 3.1, entry 2) was injected which shows the retention of time at 7.713 minutes and no peak was observed at ~7.827. This supports the TLC observation that β-anomer is not formed in the reaction.

3.9.1. HPLC Analysis of compound 3aa

Area % Report

Data File: C:\DATA\MSMUTHU\REPORT\JK SAMPLES7030 0105.rslt\3aa 1MG.dat
Method: C:\DATA\SST\AVANISH\Piyoosh\All compounds 90-10.met
Acquired: 01-05-2019 13:06:39 (GMT +05:30)
Printed: 10-05-2019 15:38:52 (GMT +05:30)



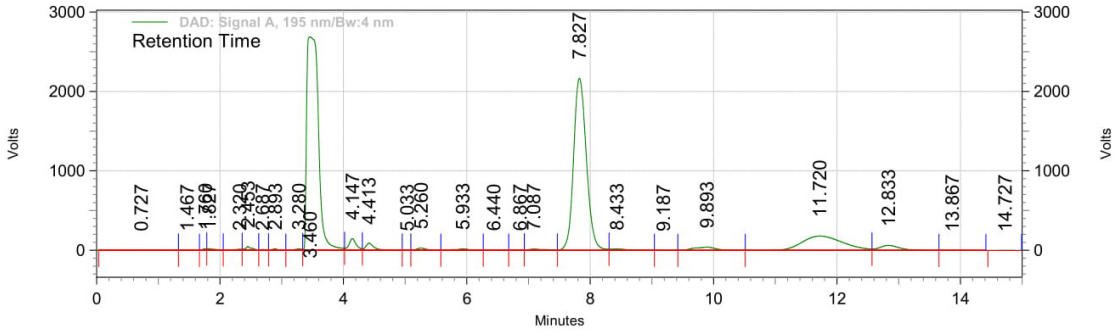
DAD: Signal A, 195 nm/Bw:4 nm
Results

Retention Time	Area	Area %	Height	Height %
0.560	551432	0.27	12288	0.10
1.460	22225	0.01	3209	0.02
1.753	165638	0.08	38623	0.30
1.827	173268	0.09	39454	0.31
1.967	363619	0.18	33130	0.26
2.433	2184740	1.08	278154	2.16
2.687	175990	0.09	20951	0.16
2.887	561251	0.28	88939	0.69
3.287	268239	0.13	24232	0.19
3.473	72914460	36.00	5614774	43.70
4.147	5628347	2.78	558882	4.35
4.420	2156288	1.06	168764	1.31
5.067	212747	0.11	22156	0.17
5.273	891706	0.44	70565	0.55
5.780	222027	0.11	23314	0.18
5.947	494039	0.24	44558	0.35
6.147	466344	0.23	36948	0.29
6.440	364922	0.18	21494	0.17
6.820	895656	0.44	63934	0.50
7.093	964926	0.48	49805	0.39
7.733	100813918	49.78	5207692	40.53
8.460	1011508	0.50	44240	0.34
9.207	159082	0.08	10376	0.08
9.413	97886	0.05	9629	0.07
9.933	2390635	1.18	108599	0.85
11.047	176400	0.09	11712	0.09
11.813	5202511	2.57	110096	0.86

3.9.2. HPLC Analysis of compound 3fb

Area % Report

Data File: C:\DATA\MSMUTHU\REPORT\JK SAMPLES7030 0105.rslt\3fb 1MG.dat
Method: C:\DATA\SST\AVANISH\Piyoosh\All compounds 90-10.met
Acquired: 01-05-2019 12:50:07 (GMT +05:30)
Printed: 10-05-2019 15:39:23 (GMT +05:30)



DAD: Signal A, 195 nm/Bw:4 nm Results

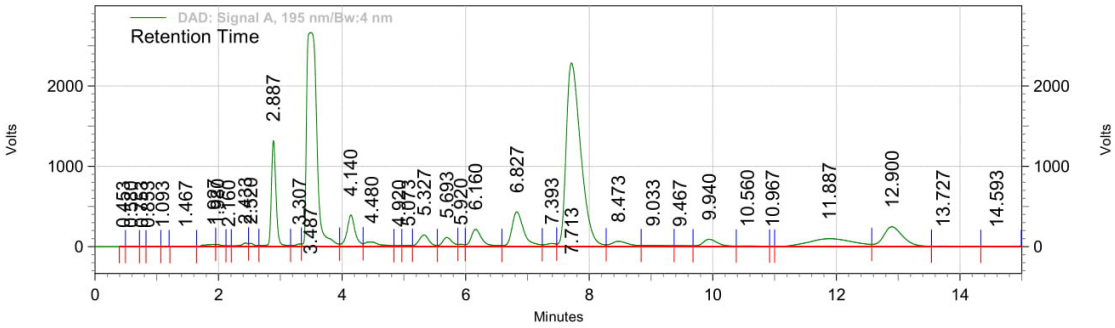
Retention Time	Area	Area %	Height	Height %
0.727	488396	0.28	10500	0.09
1.467	99304	0.06	7768	0.07
1.760	188740	0.11	43563	0.37
1.827	435919	0.25	44573	0.38
2.320	371128	0.21	29336	0.25
2.453	777703	0.45	101482	0.85
2.687	180873	0.10	23373	0.20
2.893	307582	0.18	42623	0.36
3.280	330745	0.19	42500	0.36
3.460	74403709	42.63	5640715	47.48
4.147	2591439	1.48	311641	2.62
4.413	2030051	1.16	191066	1.61
5.033	99230	0.06	12398	0.10
5.260	737338	0.42	63324	0.53
5.933	789664	0.45	41466	0.35
6.440	301373	0.17	17559	0.15
6.867	191448	0.11	16501	0.14
7.087	719186	0.41	35223	0.30
7.827	65461919	37.51	4548372	38.29
8.433	795594	0.46	38843	0.33
9.187	88606	0.05	4955	0.04
9.893	2250723	1.29	89972	0.76
11.720	17642226	10.11	382060	3.22
12.833	3165404	1.81	136486	1.15
13.867	63903	0.04	2145	0.02
14.727	24465	0.01	1367	0.01

3.9.3. HPLC Analysis of compound Reaction Mixture

Area % Report

Data File: C:\DATA\MSMUTHU\REPORT\JK SAMPLES7030 0105.rslt\REACTION MIXTURE 1MG.dat

Method: C:\DATA\SST\AVANISH\Piyoosh\All compounds 90-10.met
Acquired: 01-05-2019 13:23:10 (GMT +05:30)
Printed: 10-05-2019 15:39:54 (GMT +05:30)



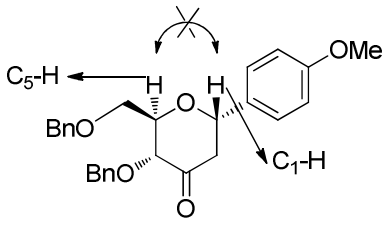
DAD: Signal A, 195 nm/Bw:4 nm
Results

Retention Time	Area	Area %	Height	Height %
0.453	399	0.00	92	0.00
0.580	3297	0.00	247	0.00
0.753	2309	0.00	374	0.00
0.853	3510	0.00	399	0.00
1.093	531	0.00	107	0.00
1.467	38734	0.02	4286	0.02
1.927	727921	0.32	61341	0.35
1.980	412462	0.18	60780	0.34
2.160	116555	0.05	23762	0.13
2.433	808632	0.36	96418	0.54
2.520	556541	0.25	88534	0.50
2.887	14620686	6.50	2766891	15.58
3.307	514465	0.23	71446	0.40
3.487	64043160	28.47	5587848	31.46
4.140	7631311	3.39	824907	4.64
4.480	2093835	0.93	119239	0.67
4.920	207000	0.09	28118	0.16
5.073	332903	0.15	35240	0.20
5.327	3470939	1.54	305435	1.72
5.693	2593919	1.15	239735	1.35
5.920	422758	0.19	62452	0.35
6.160	5589219	2.48	453387	2.55
6.827	12096733	5.38	906520	5.10
7.393	937138	0.42	80946	0.46
7.713	77951574	34.66	4794063	26.99
8.473	2674969	1.19	137527	0.77

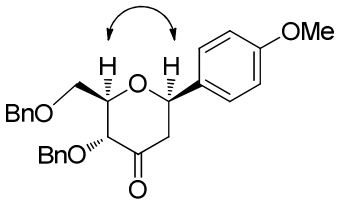
3.10 Assignment of the Configuration at the Anomeric Position of Aryl-*C*-Glycosides

The assignment of the α-configuration at the anomeric center of **3aa** was based on its 1 H NMR data as described in the literature (*J. Org. Chem.* **1992**, *57*, 4612-4616). The compound **3aa** adopts a $^4C_1$(D) conformation bearing two benzyl group in equatorial positions and the phenyl group in an axial position at the anomeric center. On the basis of this conformation, the coupling constant for the anomeric proton (5.36 ppm) is small (J = 6.5 Hz) as the result of an axial-equatorial coupling, consistent with an axial aryl group. The lack of epimerization at C_4 and the axial-axial relationship of C_4-H and C_5-H in compound **3aa** was confirmed by the doublet at 4.16 ppm with a large coupling constant (d, J = 8.5 Hz, 1H).

Similarly in the **3fb** we observed the doublet of doublet for anomeric proton at (4.65 ppm). The lack of epimerization at C_4 and the axial-axial relationship of C_4-H and C_5-H in compound **3fb** was confirmed by the doublet at 4.26 ppm with a large coupling constant (d, J = 9.0 Hz, 1H).



3aa

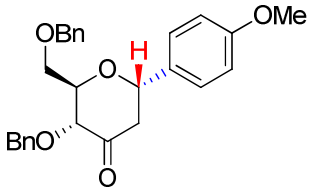
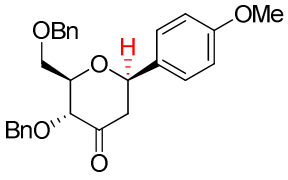
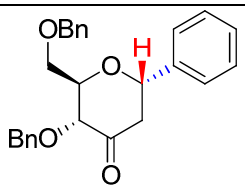
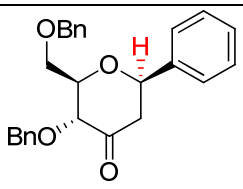
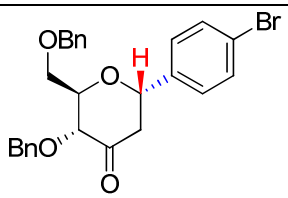
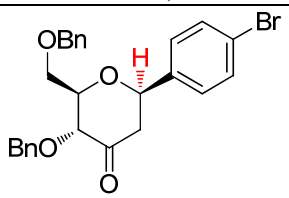


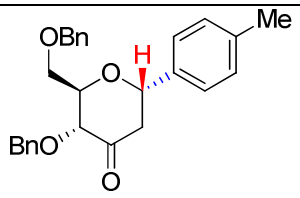
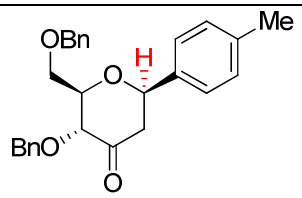
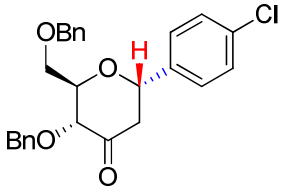
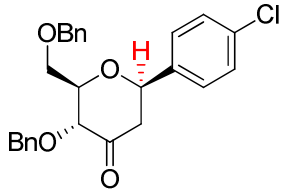
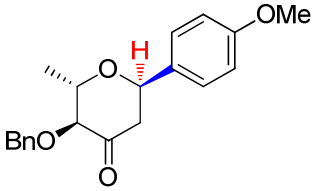
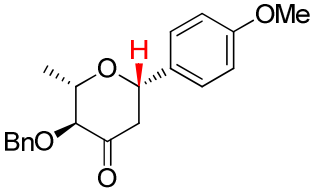
3fb

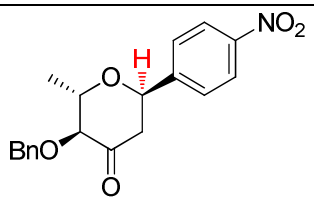
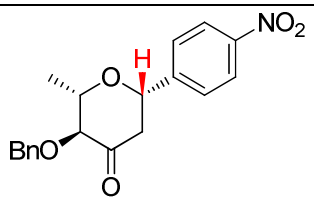
COSY,HSQC and NOESY experiment also support the above statement. From NOESY experiment we found that C_5-H proton showing interaction with anomeric proton (C_1-H) in **3fb** because of syn conformation of both the protons. In the case of **3aa** no such

interaction was observed in NOESY, because of trans arrangement of C_1 and C_5 protons.Mabit, T.; Siard, A.; Legros, F.; Guillarme, S.; Martel, A.; Lebreton, J.; Carreaux, F.; Dujardin, G.; Collet, S. *Chem. Eur. J.* **2018,***24* , 14069-14074

Table 3.3 Comparison of both isomers of a known adduct with the literature values

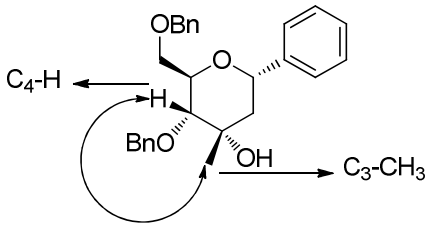
SI No	Chemical shift (J value) Anomeric proton (α isomer)	Chemical shift (J value) Anomeric proton (β isomer)
1	 **3aa** Observed δ (ppm, $CDCl_3$): 5.36 (dd, *J* = 6.5, 2.5 Hz) Reported δ (ppm, $CDCl_3$): 5.44 (dd, *J* = 6.2,2.6 Hz) [12]	 **3fb** Observed δ (ppm, $CDCl_3$): 4.55 (dd, *J* = 10.5 , 3.0 Hz) Reported δ (ppm, $CDCl_3$): 4.63 (dd, *J* = 10.6, 2.9 Hz)[12]
2	 **3ab** Observed δ (ppm, $CDCl_3$): 5.41 (dd, *J* = 6.5, 2.5 Hz) Reported δ (ppm, $CDCl_3$): 5.48 (dd, *J* = 6.6, 3.1 Hz) [12]	 **3fa** Observed δ (ppm, $CDCl_3$): 4.61 ((t, *J* = 7.2 Hz) Reported δ (ppm, $CDCl_3$): 4.69 (t, *J* = 7.0 Hz) [12]
3	 **3ad**	 **3fd**

	Observed δ (ppm, $CDCl_3$): 5.33 (dd, *J* = 6.0, 3.5 Hz) Reported δ (ppm, $CDCl_3$): 5.41 (dd, *J* = 5.5, 3.9 Hz) [12]	Observed δ (ppm, $CDCl_3$): 4.57 (dd, J = 10.5, 3.0 Hz) Reported δ (ppm, $CDCl_3$): 4.65 (dd, *J* = 11.1, 3.3 Hz) [12]
4	 **3ac** Observed δ (ppm, $CDCl_3$): 5.37 (dd, *J* = 6.5, 2.5 Hz) **Not reported**	 **3fe** Observed δ (ppm, $CDCl_3$): 4.67 (dd, *J* = 10.8, 2.9 Hz) **Not reported**
5	 **3ae** Observed δ (ppm, $CDCl_3$): 5.43 (dd, *J* = 6.5, 3.5 Hz, 1H) **Not reported**	 **3fc** Observed δ (ppm, $CDCl_3$): 4.64 (dd, *J* = 10.4, 3.2 Hz, 1H) **Not reported**
6	 **3dc** Observed δ (ppm, $CDCl_3$): 5.27 (dd, *J* = 7.0, 3.0 Hz) Reported δ (ppm, $CDCl_3$): 5.27 (dd, J = 6.7, 3.3 Hz) [12]	 **3ga** Observed δ (ppm, $CDCl_3$): 4.62 (dd, *J* = 11.0, 3.0 Hz) Reported δ (ppm, $CDCl_3$): 4.62 (dd, J = 10.5, 3.5 Hz) [12]

7	 **3da** Observed δ (ppm, $CDCl_3$): 5.24 (t, *J* = 5.5 Hz, 1H) **Not reported**	 **3gb** Observed δ (ppm, $CDCl_3$): 4.78 (dd, *J* = 12.0, 2.5 Hz, 1H) **Not reported**

3.11 Assignment of the Stereochemistry of Grignard Reaction

From NOESY experiment of **4c** we decided the stereochemistry of Grignard reactions. There is lack of epimerization at C_4-H in compound **4c**. From NOESY experiment we observed that C_3-CH_3 group is syn with C_4-H proton which showing relation because they are in axial-equatorial i.e. cis conformation.



3.12 Experimental Section

3.12.1. Preparation of 3,4-Di-*O*-acetyl-6-*O*-tosyl-D-glucal (1) [16]

Potassium carbonate (0.5 g, 3.6 mmol, 0.1 equiv) was added to a solution of tri-*O*-acetyl-D-glucal (10.0 g, 36.7 mmol, 1.0 equiv) in MeOH (70 mL) and stirred at room temperature for 4 h. After completion, the reaction mixture was filtered through celite and concentrated in rota-evaporator to give D-glucal as viscous oil in quantitative yield (~5.3 g) and used in the next step without further purification. The above crude product

(5.3 g, 36.4 mmol) was dissolved in a mixture of dry CH_2Cl_2 (73 mL) and dry pyridine (73 mL) cooled to 0°C to which p-toluenesulfonyl chloride (10.4 g, 54.6 mmol, 1.5 equiv) was added. The mixture was stirred for 8 h at room temperature and cooled to 0 °C to which water (30 mL) was added and stirred for 30 min more at 0 °C.The reaction mixture was diluted with CH_2Cl_2 and the organic layer was separated washed with water and brine. The combined organic layer was dried over Na_2SO_4 and concentrated to afford the desired 6-*O*-tosylate which was directly used in the next step without further purifications.The crude tosylate was stirred in pyridine (50 mL) to which Ac_2O (5.0 mL) was added slowly at room temperature and allowed to stir for 24 h.After completion, the reaction mixture was diluted with ethyl acetate and washed with water and brine, dried over anhydrous Na_2SO_4. The organic layer was evaporated and the residue was purified by silica gel chromatography (petroleum-EtOAc 80:20) to give the compound **1.**Yield: 9.1 g (65%); white solid; mp 104 °C; Lit.[25] 106-107°C. $[\alpha]_D^{27}$ = +28.9 (c = 1.0, CHCl3), lit. $[\alpha]_D^{25}$ = +7.1 (c 0.51, $CHCl_3$)[17]. **^{1}H NMR** (500 MHz, $CDCl_3$): δ = 7.73 (d, *J* = 8.5 Hz, 2H), 7.28 (d, *J* = 8.0 Hz, 2H), 6.28 (dd, *J* = 6.0, 1.0 Hz, 1H), 5.20 (t, *J* = 4.0 Hz, 1H), 5.07-5.05 (m, 1H), 4.75 (dd, *J* = 6.5, 3.5 Hz, 1H), 4.21-4.16 (m, 2H), 4.16-4.11 (m, 1H), 2.38 (s, 3H), 1.97 (s, 3H), 1.96 (s, 3H). **^{13}C NMR** (125 MHz, $CDCl_3$): δ = 170.2, 169.4, 145.2, 145.1, 132.5, 129.8, 128.0, 98.9, 73.1, 66.9, 66.5, 66.3, 21.6, 20.9, 20.7.

3.12.2. Preparation of 6-Iodo-3,4-di-*O*-acetyl-D-glucal (2)[16]

To a solution of **1** (9.1 g, 23.6 mmol, 1.0 equiv) in DMF (118 mL) was added tetrabutylammonium iodide (TBAI) (8.72 g, 23.6 mmol, 1.0 equiv), KI (11.7 g, 71 mmol, 3.0 equiv). The solution was stirred at 80 °C for 7 h and then cooled to room

temperature and diluted with water and extracted using EtOAc. Further, the organic layer was washed with saturated aqueous $Na_2S_2O_3$ and brine, dried over anhydrous Na_2SO_4. The organic later was evaporated and the residue was purified by silica gel chromatography (petroleum-EtOAc 90:10) to give **2.**Yield: 7.7 g (96%);viscous oil.$[\alpha]_D^{27}$= -33.7 (c = 1.0, $CHCl_3$), lit. $[\alpha]_D^{25}$= –35.2 (c 1.02, $CHCl_3$) [17]. **^{1}H NMR** (500 MHz, $CDCl_3$): δ = 6.46-6.42 (m, 1H), 5.27-5.18 (m, 2H), 4.84-4.79(m, 1H), 4.08-4.02 (m, 1H), 3.41-3.27 (m, 2H), 2.07-1.99 (m, 6H). **^{13}C NMR** (125 MHz, $CDCl_3$): δ = 170.2, 169.4, 145.3, 98.8, 74.7, 69.7, 66.5, 20.9, 20.8, 1.9.

3.12.3. Preparation of 3,4-Di-*O*-acetyl-D-rhamnal (3) [17]

To a solution of 6-Iodo-3,4-di-*O*-acetyl-D-glucal **2** (2.42 g, 7.12 mmol, 1.0 eq) in dry toluene (50 mL) was added Bu_3SnH (3.12 g, 2.88 mL, 10.7 mmol, 1.5 eq) and azobisisobutyronitrile (AIBN) (117 mg, 712 µmol, 0.1 eq). The resulting mixture was refluxed at 100 °C for 3 h and cooled to room temperature. The solvent was removed under reduced pressure and dissolve in ethyl acetate and washed with water. The organic later was evaporated and the residue was purified by silica gel chromatography. Purification by column chromatography (Petroleum ether / EtOAc = 80:20) afforded 6-deoxy glucal **3**.Yield: 1.49 g (98%); colorless liquid. $[\alpha]_D^{27}$ = -56.1 (c = 1.0, $CHCl_3$), lit. $[\alpha]_D^{25}$= –54.5° (c 0.98, $CHCl_3$) [17]. **^{1}H NMR** (500 MHz, $CDCl_3$): δ = 6.42 (dd, *J* = 6.0, 1.5 Hz, 1H), 5.34-5.32 (m, 1H), 5.01 (dd, *J* = 8.5, 6.5 Hz, 1H), 4.76 (dd, *J* = 6.5, 3.0 Hz, 1H), 4.12-4.07 (m, 1H), 2.07 (s, 3H), 2.03 (s, 3H), 1.30 (d, *J* = 6.5 Hz, 3H)**. ^{13}C NMR** (125 MHz, $CDCl_3$): δ = 170.6, 169.8, 145.9, 98.7, 72.4, 71.8, 68.2, 21.0, 20.8, 16.5.

3.12.4. Preparation of 3,4-di-*O*-benzyl-D-rhamnal (1e) [7]

The compound **3** (1 g, 4.67 mmol) was stirred in MeOH (30 mL) at 0°C to which NaOMe (22 mg, 0.46 mmol) was added. The resulting mixture was stirred for 3 h and the solvent was evaporated to dryness. To the same flask, dry DMF (15 mL) was added and cooled to 0°C to which NaH (447 mg, 60% in mineral oil, 18 mmol) was added portion wise. The mixture was stirred for 20 min at the same temperature to which benzyl bromide (1.66 mL, 14 mmol) was slowly added dropwise. The resulting mixture was stirred for overnight and quenched by saturated aqueous NH_4Cl (6 mL) and diluted with ethyl acetate (25 mL). The organic phase was washed with water and brine, dried over anhydrous Na_2SO_4. The organic layer was evaporated under reduced pressure and purified by column chromatography (SiO_2, hexane:ethyl acetate = 90:10) to afford **1e.** Yield: 1.2 g (83 %); colorless oil. $[\alpha]_D^{27}$ = -30.1 (c = 1.0, $CHCl_3$), lit. $[\alpha]_D^{20}$ = -33 (c = 1.0, $CHCl_3$) [23]. **^{1}H NMR** (500 MHz, $CDCl_3$): δ = 7.36-7.27 (m, 11H), 6.35 (d, *J* = 6.0 Hz, 1H), 4.89-4.84 (m, 2H), 4.70 (d, *J* = 11.5 Hz, 1H), 4.65 (d, *J* = 12.0 Hz, 1H), 4.57 (d, *J* = 11.0 Hz, 2H), 4.20 (d, *J* = 6.5 Hz, 1H), 3.97-3.92 (m, 1H), 3.48 (dd, *J* = 8.5, 6.5 Hz, 1H), 1.37 (d, *J* = 6.5 Hz, 3H). **^{13}C NMR** (125 MHz, $CDCl_3$): δ = 144.7, 138.4, 138.2, 128.3, 128.3, 127.9, 127.7, 127.7, 127.6, 100.1, 79.5, 76.4, 74.0, 73.9, 72.0, 70.5, 17.4.

3.12.5. 1,2: 5,6-di-*O*-isopropylidene-a-D-allofuranose (4) [19]

Pyridinium dichromate (10.8 g, 28.7 mmol) and acetic anhydride (11 mL, 116 mmol) was stirred in dichloromethane (100 mL) to which a solution of 1,2:5,6-di-*O*-isopropylidene-α-D-glucofuranose (10.0 g, 3.84 mmol) in dichloromethane (30 mL)

was added. The resulting mixture was refluxed for 2 h at 40 °C and cooled to room temperature. The solvent was evaporated and diluted with ethyl acetate (100 mL) and filtered through Celite. The filtrate was concentrated under reduced pressure to give the ketone compound as viscous oil (8.20 g, 83%) which was used without further purification.

To ketone compound (8.0 g, 31.0 mmol), dissolved in 56% aq. EtOH (43 mL) and cooled to 0°C, sodium borohydride (1.29 g, 34.0 mmol) was added portion wise. The reaction mixture was brought to room temperature and stirred for 3 h. After completion, the reaction mixture was diluted with dichloromethane (50 mL) and washed with water. The combined organic layers were dried over anhydrous Na_2SO_4, and evaporated to dryness. The residue was purified by column chromatography (SiO_2, hexane:ethyl acetate = 75:25) to provide 1,2:5,6-di-*O*-isopropylidene-α-D-allofuranose **4.** Yield: 6.5 g (81 %); white solid; mp 74°C; Lit.[24] 73 °C**.** $[\alpha]_D^{27}$ +54 (c 0.1, $CHCl_3$),lit. $[\alpha]_D^{25}$ +39.8 (c 0.42, $CHCl_3$) [24]**.** **^{1}H NMR** (500 MHz, $CDCl_3$): δ = 5.81 (d, *J* = 3.5 Hz, 1H), 4.63-4.61 (m, 1H), 4.33-4.29 (m, 1H), 4.10-4.00 (m, 3H), 3.84-3.81(m, 1H), 1.58 (s, 3H), 1.47 (s, 3H), 1.38 (d, *J* = 6.5 Hz, 6H).**^{13}C NMR** (125 MHz, $CDCl_3$): δ = 112.8, 109.8, 103.8, 79.6, 78.9, 75.5, 72.4, 65.8, 26.5, 26.4, 26.2, 25.2.

3.12.6. Preparation of D-allopyranosepentaacetate (5) [19]

1,2:5,6-di-*O*-isopropylidene-α-D-allofuranose**4** (6.00 g, 23.05 mmol) was dissolved in a mixture of trifluoroacetic acid/water (1:1, 24 mL) and stirred at room temperature for 24 h. After completion, the solvent was removed in rota-evaporator and co-evaporated with toluene. The resulting yellow syrup was dissolved in 1:1 acetic anhydride/pyridine

mixture (80 mL) and stirred at room temperature overnight. The mixture was concentrated in vacuo and co-evaporated with toluene. The resulting white solid was dissolved in ethyl acetate and washed with 1N hydrochloric acid, saturated aqueous sodium bicarbonate and brine. The organic layer was dried over anhydrous Na_2SO_4, concentrated and purified by silica gel column chromatography (SiO_2, hexane:ethyl acetate = 80:20) to afford D-allopyranosepentaacetate (mix. α:β) **5.**Yield: 6.2 g (69 %); colourless syrup. **^{1}H NMR** (500 MHz, $CDCl_3$): δ = 6.11-5.94 (m, 1H), 5.65-5.44 (m, 1H), 5.27-4.92 (m, 2H), 4.36-4.00 (m, 3H), 2.11 (s, 3H), 2.07 (s, 3H), 2.03 (s, 3H), 1.96-1.95 (m, 6H). **^{13}C NMR** (125 MHz, $CDCl_3$): δ = 170.4, 170.2, 169.6, 169.5, 169.1, 169.0, 168.9, 168.8, 168.7, 98.1, 89.8, 79.8, 77.20, 74.1, 70.8, 70.8, 67.9, 67.9, 65.4, 61.9, 61.6, 20.7, 20.7, 20.5, 20.5, 20.4, 20.3, 20.2, 20.2.

3.12.7 Preparation of 3,4,6-tri-*O*-acetyl-D-alltral (6) [20]

D-Allopyranosepentaacetate **5** (4.00 g, 10.25 mmol) was dissolved in CH_2Cl_2 (20 mL) and HBr solution (33 wt % in acetic acid, 22.60 mL, 92.00 mmol) was added at 0 °C. The resulting solution was stirred for 5 hours at room temperature. After completion, the reaction mixture was diluted with CH_2Cl_2 (25 mL) and washed successively with saturated solution of sodium bicarbonate and brine. The organic layer was dried over anhydrous Na_2SO_4 and concentrated. To the crude allopyranosyl bromide was dissolved in CH_3CN (25 mL) zinc dust (5.0 g, 76.80 mmol) and ammonium chloride (4.10 g, 76.80 mmol) were added. The resulting mixture was stirred at 50°C for 2.5 h. After completion, the reaction mixture is filtrated and the filtrate was concentrated and purified by column chromatography (SiO_2, hexane:ethyl acetate = 85:15) to afford

3,4,6-tri-*O*-acetyl-alltral (**6**). Yield: 1.2 g (43 %); colourless oil. $[\alpha]_D^{27}$ = +58.1 (c = 1.0, $CHCl_3$). **^{1}H NMR** (500 MHz, $CDCl_3$): δ = 6.47 (d, *J* = 6.0 Hz, 1H), 5.38 (dd, *J* = 6.0, 4.0 Hz, 1H), 5.07 (dd, *J* = 11.0, 4.0 Hz, 1H), 4.86 (t, *J* = 6.0 Hz, 1H), 4.31-4.19 (m, 3H), 2.02 (s, 6H), 1.97 (s, 3H). **^{13}C NMR** (125 MHz, $CDCl_3$): δ = 170.5, 170.2, 169.3, 147.7, 97.4, 70.4, 66.3, 62.5, 61.8, 20.9, 20.6, 20.5.

3.12.8. 3,4,6-tri-*O*-benzyl-D-alltral (1f) [20]

The compound 3,4,6-tri-*O*-acetyl-D-alltral (**6**) (1.0 g, 3.6 mmol) was stirred in MeOH (20 mL) at 0°C and NaOMe (19.0 mg, 0.37 mmol) was added. The mixture was stirred for 3 h and then solvent was evaporated to dryness. To the same flask, dry DMF (15 mL) was added, cooled to 0°C and NaH (528 mg, 60% in mineral oil, 22.0 mmol) was added portion wise. The resulting mixture was stirred for 20 min at the same temperature then benzyl bromide (1.74 mL, 15 mmol) was slowly added dropwise. The resulting mixture was stirred for overnight and quenched with saturated aqueous NH_4Cl (8 mL) and diluted with ethyl acetate (50 mL). The organic phase was washed with H_2O, brine and dried over anhydrous Na_2SO_4. The organic layer was evaporated under reduced pressure and the crude product was purified by column chromatography (SiO_2, hexane:ethyl acetate = 90:10) to afford 3,4,6-tri-*O*-benzyl-alltral (**1f**).Yield: 1.3 g (85 %); colourless oil. $[\alpha]_D^{27}$ = +71.1 (c = 1.0, $CHCl_3$). **^{1}H NMR** (500 MHz, $CDCl_3$): δ = 7.29-7.15 (m, 15H), 6.38 (dd, *J* = 6.0, 2.5 Hz, 1H), 4.82-4.79 (m, 1H), 4.63 (d, *J* = 12.0 Hz, 1H), 4.57-4.53 (m, 3H), 4.49 (d, *J* = 12.0 Hz, 1H), 4.39 (d, *J* = 11.5 Hz, 1H), 4.23-4.21 (m, 1H), 3.89-3.86 (m, 1H), 3.76-3.76 (m, 2H), 3.72-3.69 (m, 1H). **^{13}C NMR** (125

MHz, $CDCl_3$): δ = 146.6, 138.6, 138.0, 137.8, 128.3, 127.9, 127.8, 127.7, 127.6, 127.5, 127.5, 98.0, 73.8, 73.5, 73.0, 71.2, 70.3, 68.8, 65.4.

3.12.9. Di-*O*-benzyl-6-deoxy-L-allal (1g) [21]

The compound 3,4-di-*O*-benzyl-L-rhamnal (1.50 g, 4.83 mmol) was stirred in CH_2Cl_2 (35 ml) then $PhI(OCOCF_3)_2$ (4.16 g, 9.67 mmol), 2,2,6,6-Tetramethylpiperidine 1-oxyl (TEMPO) (151 mg, 0.96 mmol) and water (87 μL, 4.83 mmol) were added at 0°C under argon atmosphere. The resulting reaction mixture was stirred for 30 min at the same temperature. After completion (monitored by TLC), the reaction mixture was quenched with saturated solution of $NaHCO_3$ and extracted with CH_2Cl_2 (twice). The combined organic layers were washed with brine and dried over anhydrous Na_2SO_4. The organic layer was evaporated and residue was purified by column chromatography (SiO_2, hexane:ethyl acetate = 85:15) to give 3-keto L-rhamnal as a product (0.520 g, 49%). To a solution of 3-keto L-rhamnal (0.50 g, 2.29 mmol) in dry THF (10 mL) at 0°C under argon atmosphere was added a solution of lithium tri(*tert*-butoxy)aluminium hydride (0.73 g, 2.98 mmol) in THF. The resulting reaction mixture was brought to room temperature and stirred for 4h. After completion, the reaction mixture was quenched with saturated NH_4Cl solution and extracted with ethyl acetate (twice). The combined organic layers were washed with brine solution and dried over anhydrous Na_2SO_4. The organic layer was evaporated and residue purified by column chromatography (SiO_2, hexane:ethyl acetate = 85:15)to obtain 4-*O*-benzyl 6-deoxy-L-allal (**7**) 40% Yield(0.204 g). The compound **t** (200 mg, .908 mmol) was stirred in dry DMF (8 mL) at 0°C and NaH (60% suspension in para□n oil, 43.00 mg, 1.82 mmol) was added followed by

benzyl bromide (161.0 μL, 1.36 mmol). The reaction mixture was stirred at room temperature for 10h. After completion, the reaction mixture was quenched with ice water and extracted with ethyl acetate. The combined organic layers were washed with brine solution and then dried over anhydrous Na_2SO_4. The solvent was evaporated and the residue was purified by column chromatography (SiO_2, hexane:ethyl acetate = 90:10) to provide (**1g**). Yield: 210 mg (75 %); colourless syrup.$[\alpha]_D^{27}$ = -250 (c = 1.0, $CHCl_3$) lit. $[\alpha]_D^{20}$= -259.4 (c = 1.1 $CHCl_3$) [22]. **^{1}H NMR** (500 MHz, $CDCl_3$) : δ = 7.35-7.26 (m, 10H), 6.35 (dd, *J* = 6.0, 1.5 Hz, 1H), 4.88- 4.84 (m, 2H), 4.69 (d, *J* = 11.0 Hz, 1H), 4.65 (d, *J* = 11.5 Hz, 1H), 4.56 (d, *J* = 11.5 Hz, 1H), 4.21-4.19 (m, 1H), 3.97-3.91 (m, 1H), 3.48 (dd, *J* = 9.0, 6.5 Hz, 1H), 1.38 (d, *J* = 6.5 Hz, 3H).**^{13}C NMR** (125 MHz, $CDCl_3$): δ = 144.7, 138.3, 138.2, 128.3, 128.3, 127.9, 127.7, 127.5, 100.0, 79.4, 76.4, 74.0, 73.9, 70.4, 17.4.

3.12.10 General experimental procedure for the preparation of *C*-glycosides:

Aniline (**2a-2k**) (0.25 mmol, 2.0 equiv.) was dissolved in a mixture of acetonitrile: water (3:1, 4 mL) and stirred at ~ 5 °C (ice bath) then 48% aq. HBF_4 (2.0 equiv.) was added. After 5 mins, *t*-BuONO (0.25 mmol, 2.0 equiv.) was added and the resulting mixture was allowed to attain room temperature. After 30 mins, glycal (**1a-1g**) (0.125 mmol) and palladium acetate (2.80 mg,10mol%) were added at room temperature and stirred for required time. After completion, the reaction mixture was diluted with ethyl acetate and washed with water. The organic layer was dried over Na_2SO_4, concentrated and purified by column chromatography (cc) on silica gel with ethyl acetate and hexane.

3.13 Analytical Data of the Synthesized Aryl-*C*-Glycoside

3.13.1. (*2R,3R,6S*)-3-(Benzyloxy)-2-((benzyloxy)methyl)-6-(4-methoxyphenyl) dihydro-2H-pyran-4(3H)-one (3aa) [7]

Yield: 41 mg (76%); white foam; cc: 15% EtOAc/hexane; Rf = 0.40 (20% EtOAc/hexane). $[\alpha]_D^{26}$ = +126 (c = 0.1, $CHCl_3$), lit. $[\alpha]_D^{21}$ = +120.8 (c 1.4, $CHCl_3$) [12]. **^{1}H NMR** (500 MHz, $CDCl_3$): δ = 7.26-7.18 (m, 12H), 6.79-6.76 (m, 2H), 5.36 (dd, *J* = 6.5, 2.5 Hz, 1H), 4.77 (d, *J* = 11.0 Hz, 1H), 4.51 (d, *J* = 12.5 Hz, 1H), 4.40 (d, *J* = 12.0 Hz, 1H), 4.35 (d, *J* = 11.0 Hz, 1H), 4.16 (d, *J* = 8.5 Hz, 1H), 3.70 (s, 3H), 3.63-3.54 (m, 3H), 3.01 (dd, *J* = 14.5, 3.5 Hz, 1H), 2.97-2.93 (m, 1H). **^{13}C NMR** (125 MHz, $CDCl_3$): δ = 206.7, 159.4, 137.9, 137.4, 130.6, 128.8, 128.3, 128.3, 128.1, 127.8, 127.8, 127.7, 114.0, 79.7, 74.8, 74.2, 73.5, 73.4, 69.1, 55.2, 44.0.

3.13.2. (*2R,3R,6S*)-3-(Benzyloxy)-2-((benzyloxy)methyl)-6-phenyldihydro-2H-pyran-4(3H)-one (3ab) [7]

Yield: 30 mg (60%); white foam; cc: 10% EtOAc/hexane; Rf = 0.62 (20% EtOAc/hexane). $[\alpha]_D^{27}$= +140 (c = 0.1, $CHCl_3$)), lit. $[\alpha]_D^{19}$ = +85.3 (c 0.2, $CHCl_3$) [12]. **^{1}H NMR** (500 MHz, $CDCl_3$): δ = 7.31-7.30 (m, 2H), 7.27-7.19 (m, 12H), 5.41 (dd, *J* = 6.5, 2.5 Hz, 1H), 4.76 (d, *J* = 11.0 Hz, 1H), 4.52 (d, *J* = 12.2 Hz, 1H), 4.40 (d, *J* = 12.0 Hz, 1H), 4.34 (d, *J* = 11.0 Hz, 1H), 4.17 (d, *J* = 8.5 Hz, 1H), 3.66-3.56 (m, 3H), 3.05 (dd, *J* = 14.5, 3.0 Hz, 1H), 2.99-2.95 (m, 1H). **^{13}C NMR** (125 MHz, $CDCl_3$): δ = 206.4, 138.5, 137.8, 137.3, 128.7, 128.3, 128.3, 128.2, 128.1, 127.9, 127.8, 127.7, 127.3, 79.5, 75.1, 74.5, 73.5, 73.4, 69.0, 43.8.

3.13.3. (*2R,3R,6S*)-3-(Benzyloxy)-2-((benzyloxy)methyl)-6-(p-tolyl)dihydro-2H-pyran-4(3H)-one (3ac) [7]

Yield: 41 mg (79%); white foam; cc: 10% EtOAc/hexane; Rf = 0.60 (20% EtOAc/hexane). $[\alpha]_D^{26}$ = +60.0 (c = 0.05, $CHCl_3$). **^{1}H NMR** (500 MHz, $CDCl_3$): δ = 7.26-7.18 (m, 12H), 7.06-7.05 (m, 2H), 5.37 (dd, *J* = 6.5, 2.5 Hz, 1H), 4.77 (d, *J* = 11.5 Hz, 1H), 4.51 (d, *J* = 12.5 Hz, 1H), 4.40 (d, *J* = 12.0 Hz, 1H), 4.35 (d, *J* = 11.0 Hz, 1H), 4.15 (d, *J* = 9.0 Hz, 1H), 3.65-3.55 (m, 3H), 3.02 (dd, *J* = 14.5, 3.0 Hz, 1H), 2.97-2.92 (m, 1H), 2.23 (s, 3H). **^{13}C NMR** (126 MHz, $CDCl_3$): δ = 206.5, 137.9, 137.9, 137.4, 135.5, 129.3, 128.3, 128.3, 128.1, 127.8, 127.8, 127.7, 127.4, 79.6, 75.0, 74.4, 73.5, 73.4, 69.1, 44.0, 21.0.

3.13.4. (*2R,3R,6S*)-3-(Benzyloxy)-2-((benzyloxy)methyl)-6-(4-bromophenyl) dihydro-2H-pyran-4(3H)-one (3ad) [7]

Yield: 45 mg (75%); white foam; cc: 10% EtOAc/hexane; Rf = 0.56 (20% EtOAc/hexane). $[\alpha]_D^{27}$= +57 (c = 0.1, $CHCl_3$), lit. $[\alpha]^{19}$= +104.5 (c 0.2, $CHCl_3$) [12]. **^{1}H NMR** (500 MHz, $CDCl_3$): δ = 7.39-7.36 (m, 2H), 7.26-7.16 (m, 12H), 5.33 (dd, *J* = 6.0, 3.5 Hz, 1H), 4.75 (d, *J* = 11.0 Hz, 1H), 4.49 (d, *J* = 12.0 Hz, 1H), 4.40 (d, *J* = 12.5 Hz, 1H), 4.34 (d, *J* = 11.0 Hz, 1H), 4.14 (d, *J* = 8.5 Hz, 1H), 3.65-3.56 (m, 3H), 2.99-2.91 (m, 2H). **^{13}C NMR** (126 MHz, $CDCl_3$): δ = 205.9, 137.7, 137.7, 137.2, 131.8, 129.0, 128.3, 128.3, 128.1, 127.9, 127.8, 127.7, 122.3, 79.4, 75.0, 74.6, 73.5, 73.3, 69.1, 43.9.

3.13.5. (*2R,3R,6S*)-3-(Benzyloxy)-2-((benzyloxy)methyl)-6-(4-chlorophenyl) dihydro-2H-pyran-4(3H)-one (3ae) [7]

Yield: 35 mg (65%); white foam; cc: 10% EtOAc/hexane; Rf = 0.56 (20% EtOAc/hexane). $[\alpha]_D^{26}$ = +112 (c = 0.1, $CHCl_3$). **^{1}H NMR** (500 MHz, $CDCl_3$): δ = 7.34-7.24 (m, 14H), 5.43 (dd, *J* = 6.5, 3.5 Hz, 1H), 4.82 (d, *J* = 11.5 Hz, 1H), 4.57 (d, *J*

= 12.0 Hz, 1H), 4.47 (d, *J* = 12.0 Hz, 1H), 4.41 (d, *J* = 11.0 Hz, 1H), 4.22 (d, *J* = 9.0 Hz, 1H), 3.71-3.63 (m, 3H), 3.08-2.99 (m, 2H).**^{13}C NMR** (125 MHz, $CDCl_3$): δ = 206.0, 137.7, 137.2, 137.1, 134.1, 128.8, 128.7, 128.3, 128.3, 128.1, 127.9, 127.7, 127.7, 79.4, 77.2, 74.8, 74.5, 73.5, 73.3, 69.0, 43.9.

3.13.6. (*2R,3R,6S*)-3-(Benzyloxy)-2-((benzyloxy)methyl)-6-(4-fluorophenyl) dihydro-2H-pyran-4(3H)-one (3af) [7]

Yield: 38 mg (72%); white foam; cc: 10% EtOAc/hexane; Rf = 0.56 (20% EtOAc/hexane). $[\alpha]_D^{26}$ = +144 (c = 0.1, $CHCl_3$). **^{1}H NMR** (500 MHz, $CDCl_3$): δ = 7.29-7.17 (m, 12H), 6.95-6.92 (m, 2H), 5.36 (dd, *J* = 6.0, 3.0 Hz, 1H), 4.75 (d, *J* = 11.0 Hz, 1H), 4.50 (d, *J* = 12.0 Hz, 1H), 4.40 (d, *J* = 12.0 Hz, 1H), 4.35 (d, *J* = 11.5 Hz, 1H), 4.15 (d, *J* = 9.0 Hz, 1H), 3.64-3.56 (m, 3H), 3.01-2.92 (m, 2H). **^{13}C NMR** (125 MHz, $CDCl_3$): δ = 206.1, 163.4, 161.4, 137.7, 137.2, 134.4, 129.2, 129.1, 128.3, 128.3, 128.1, 127.9, 127.8, 127.7, 115.6, 115.4, 79.5, 74.7, 74.6, 73.5, 73.3, 69.1, 44.0.

3.13.7. (*2R,3R,6S*)-6-(4-Acetylphenyl)-3-(benzyloxy)-2-((benzyloxy)methyl) dihydro-2H-pyran-4(3H)-one (3ag)

Yield: 35 mg (63%); white foam; cc: 20% EtOAc/hexane; Rf = 0.50 (20% EtOAc/hexane). $[\alpha]_D^{26}$ = +89 (c = 0.1, $CHCl_3$). IR (neat) = 2971-2811, 1721, 1680, 1130, 881 cm^{-1}. **^{1}H NMR** (500 MHz, $CDCl_3$): δ = 7.85 (d, *J* = 8.5 Hz, 2H), 7.41 (d, *J* = 8.5 Hz, 2H), 7.27-7.18 (m, 10H), 5.43 (dd, *J* = 6.5, 4.0 Hz, 1H), 4.75 (d, *J* = 11.0 Hz, 1H), 4.51 (d, *J* = 12.0 Hz, 1H), 4.41 (d, *J* = 12.0 Hz, 1H), 4.34 (d, *J* = 11.5 Hz, 1H), 4.16 (d, *J* = 8.0 Hz, 1H), 3.66-3.63 (m, 1H), 3.61-3.61 (m, 2H), 3.04 (dd, *J* = 14.5, 3.5 Hz, 1H), 2.98 (dd, *J* = 14.5, 6.5 Hz, 1H), 2.50 (s, 3H). **^{13}C NMR** (125 MHz, $CDCl_3$): δ = 205.7, 197.5, 143.8, 137.6, 137.1, 136.7, 128.7, 128.4, 128.3, 128.1, 127.9, 127.8,

127.4, 79.3, 75.3, 74.8, 73.5, 73.3, 69.1, 43.9, 26.6. HRMS (ESI): m/z $[M + H]^+$calcd for $C_{28}H_{29}O_5$: 445.2015; found: 445.2021.

3.13.8. 4-((*2S,5R,6R*)-5-(Benzyloxy)-6-((benzyloxy)methyl)-4-oxotetrahydro-2H-pyran-2-yl)benzonitrile (3ah) [7]

Yield: 32 mg (60%); white foam; cc: 20% EtOAc/hexane; Rf = 0.25 (20% EtOAc/hexane). $[\alpha]_D^{27}$= +97 (c = 0.1, $CHCl_3$). **^{1}H NMR** (500 MHz, $CDCl_3$): δ = 7.56-7.54 (m, 2H), 7.42 (d, *J* = 8.5 Hz, 2H), 7.27-7.19 (m, 10H), 5.39 (t, *J* = 5.5 Hz, 1H), 4.72 (d, *J* = 11.5 Hz, 1H), 4.49 (d, *J* = 12.5 Hz, 1H), 4.40 (d, *J* = 12.0 Hz, 1H), 4.34 (d, *J* = 11.0 Hz, 1H), 4.12 (d, *J* = 8.5 Hz, 1H), 3.69-3.67 (m, 1H), 3.61-3.60 (m, 2H), 3.00-2.891 (m, 2H). **^{13}C NMR** (125 MHz, $CDCl_3$): δ = 205.1, 144.1, 137.5, 137.0, 132.4, 128.4, 128.4, 128.1, 128.0, 127.8, 127.7, 118.3, 112.0, 79.1, 75.8, 74.5, 73.5, 73.2, 69.2, 43.9.

3.13.9. Methyl-4-((*2S,5R,6R*)-5-(Benzyloxy)-6-((benzyloxy)methyl)-4-oxotetrahydro-2H-pyran-2-yl)benzoate (3ai) [7]

Yield: 37 mg (64%); white foam; cc: 20% EtOAc/hexane; Rf = 0.40 (20% EtOAc/hexane). $[\alpha]_D^{27}$ = +62 (c = 0.1, $CHCl_3$). **^{1}H NMR** (500 MHz, $CDCl_3$): δ = 7.94-7.91 (m, 2H), 7.39 (d, *J* = 8.5 Hz, 2H), 7.27-7.17 (m, 10H), 5.42 (dd, *J* = 6.5, 4.0 Hz, 1H), 4.74 (d, *J* = 11.5 Hz, 1H), 4.51 (d, *J* = 12.0 Hz, 1H), 4.40 (d, *J* = 12.0 Hz, 1H), 4.34 (d, *J* = 11.5 Hz, 1H), 4.15 (d, *J* = 8.5 Hz, 1H), 3.83 (s, 3H), 3.68-3.65 (m, 1H), 3.63-3.58 (m, 2H), 3.04 (dd, *J* = 14.5, 3.5 Hz, 1H), 2.98-2.94 (m, 1H). ^{13}C NMR (125 MHz, $CDCl_3$): δ = 205.7, 166.5, 143.7, 137.6, 137.1, 129.9, 129.9, 128.4, 128.3, 128.1, 127.9, 127.8, 127.7, 127.1, 79.3, 75.2, 74.8, 73.5, 73.2, 69.1, 52.1, 43.9.

3.13.10. (*2R,3R,6S*)-3-(Benzyloxy)-2-((benzyloxy)methyl)-6-(4-(trifluoromethyl) phenyl)dihydro-2H-pyran-4(3H)-one (3aj)

Yield: 36 mg (61%); white foam; cc: 10% EtOAc/hexane; Rf = 0.52 (20% EtOAc/hexane). $[\alpha]_D^{27}$ = +87.0 (c = 0.1, $CHCl_3$). IR (neat) = 2911, 2791, 1718, 1130, 881 cm^{-1}. **^{1}H NMR** (500 MHz, $CDCl_3$): δ = 7.52-7.51 (m, 2H), 7.44-7.42 (m, 2H), 7.27-7.17 (m, 10H), 5.43-5.41 (m, 1H), 4.74 (d, *J* = 11.0 Hz, 1H), 4.50 (d, *J* = 12.0 Hz, 1H), 4.40 (d, *J* = 12.0 Hz, 1H), 4.34 (d, *J* = 11.0 Hz, 1H), 4.15 (d, *J* = 8.5 Hz, 2H), 3.66-3.58 (m, 3H), 3.04-2.94 (m, 2H). **^{13}C NMR** (125 MHz, $CDCl_3$): δ = 205.6, 142.6, 137.6, 137.1, 130.4, 130.2, 128.4, 128.3, 128.2, 128.0, 127.8, 127.5, 125.6, 125.6, 125.6, 124.9, 122.7, 79.2, 75.3, 74.6, 73.5, 73.3, 69.1, 43.9. **HRMS** (ESI): m/z $[M + H]^+$calcd for $C_{27}H_{26}F_3O_4$: 471.1783; found: 471.1784.

3.13.11. (*2R,3R,6S*)-3-(Benzyloxy)-2-((benzyloxy)methyl)-6-(4-nitrophenyl) dihydro-2H-pyran-4(3H)-one (3ak) [8]

Yield: 34 mg (61%); white foam; cc: 20% EtOAc/hexane; Rf = 0.45 (20% EtOAc/hexane). $[\alpha]_D^{27}$= +39 (c = 0.1, $CHCl_3$), lit. $[\alpha]D^{23}$ = +74.1 (c 2.3, $CHCl_3$) [12]. **^{1}H NMR** (500 MHz, $CDCl_3$): δ = 8.12-8.10 (m, 2H), 7.49-7.48 (m, 2H), 7.27-7.17 (m, 10H), 5.44 (t, *J* = 5.5 Hz, 1H), 4.72 (d, *J* = 11.5 Hz, 1H), 4.49 (d, *J* = 12.5 Hz, 1H), 4.41 (d, *J* = 12.0 Hz, 1H), 4.34 (d, *J* = 11.5 Hz, 1H), 4.13 (d, *J* = 8.0 Hz, 1H), 3.72-3.69 (m, 1H), 3.62-3.61 (m, 2H), 3.02-2.93 (m, 2H). **^{13}C NMR** (125 MHz, $CDCl_3$): δ = 205.0, 147.5, 146.1, 137.5, 136.9, 128.4, 128.3, 128.1, 128.0, 127.9, 127.8, 127.7, 123.8, 79.0, 75.9, 74.3, 73.5, 73.1, 69.2, 44.0.

3.13.12. (*2R,3R,6S*)-3-(Benzyloxy)-2-((benzyloxy)methyl)-6-(3-chlorophenyl) dihydro-2H-pyran-4(3H)-one (3al)

Yield: 37 mg (70%); colourless oil; cc: 10% EtOAc/hexane; Rf = 0.64 (20% EtOAc/hexane). $[\alpha]_D^{27}$= +67 (c = 0.1, $CHCl_3$). IR (neat) = 2931, 2797, 1724, 1488, 1120, 754 cm^{-1}. **^{1}H NMR** (500 MHz, $CDCl_3$): δ = 7.32 (s, 1H), 7.29-7.17 (m, 13H), 5.35 (dd, *J* = 6.0, 3.5 Hz, 1H), 4.75 (d, *J* = 11.0 Hz, 1H), 4.51 (d, *J* = 12.0 Hz, 1H), 4.40 (d, *J* = 12.0 Hz, 1H), 4.34 (d, *J* = 11.0 Hz, 1H), 4.15 (d, *J* = 8.5 Hz, 1H), 3.69-3.66 (m, 1H), 3.64-3.58 (m, 2H), 3.00 (dd, *J* = 14.5, 3.5 Hz, 1H), 2.95-2.91 (m, 1H). **^{13}C NMR** (125 MHz, $CDCl_3$): δ = 205.7, 140.7, 137.6, 137.1, 134.8, 129.9, 128.4, 128.3, 128.2, 127.9, 127.8, 127.7, 127.4, 125.2, 79.3, 75.1, 74.5, 73.5, 73.3, 69.1, 43.8. **HRMS** (ESI): m/z $[M + H]^+$calcd for $C_{26}H_{26}ClO_4$: 437.1520; found: 437.1511.

3.13.13. (*2R,3R,6S*)-3-(Benzyloxy)-2-((benzyloxy)methyl)-6-(3-nitrophenyl) dihydro-2H-pyran-4(3H)-one (3am)

Yield: 33 mg (59%); yellow oil; cc: 20% EtOAc/hexane; Rf = 0.42 (20% EtOAc/hexane). $[\alpha]_D^{27}$ = +89 (c = 0.1, $CHCl_3$). IR (neat) = 2911, 2747, 1724, 1537, 1358, 1120 cm^{-1}. **^{1}H NMR** (500 MHz, $CDCl_3$): δ = 8.21 (m, 1H), 8.08-8.06 (m, 1H), 7.64-7.62 (m, 1H), 7.45 (t, *J* = 7.5 Hz, 1H), 7.27-7.19 (m, 10H), 5.45 (t, *J* = 5.5 Hz, 1H), 4.73 (d, *J* = 11.5 Hz, 1H), 4.51 (d, *J* = 12.5 Hz, 1H), 4.41 (d, *J* = 12.0 Hz, 1H), 4.35 (d, *J* = 11.5 Hz, 1H), 4.15 (dd, *J* = 8.0, 0.5 Hz, 1H), 3.75-3.72 (m, 1H), 3.64-3.63 (m, 2H), 3.03 (dd, *J* = 15.0, 5.0 Hz, 1H), 2.98-2.94 (m, 1H). **^{13}C NMR** (125 MHz, $CDCl_3$): δ = 205.0, 148.5, 141.2, 137.5, 136.9, 132.7, 129.7, 128.4, 128.4, 128.2, 128.0, 127.8, 127.8, 123.0, 122.2, 79.0, 75.9, 74.3, 73.6, 73.1, 69.2, 44.1. **HRMS** (ESI): m/z $[M + H]^+$calcd for $C_{26}H_{26}NO_6$: 448.1760; found: 448.1764.

3.13.14. (*2R,3R,6S*)-3-(Benzyloxy)-2-((benzyloxy)methyl)-6-(2-chlorophenyl) dihydro-2H-pyran-4(3H)-one (3an)

Yield: 36 mg (66%); colourless viscous oil; cc: 10% EtOAc/hexane; Rf = 0.60 (20% EtOAc/hexane). $[a]_D{}^{27}$ = +97 (c = 0.1, $CHCl_3$). IR (neat) = 2922, 2790, 1718, 1488, 1120, 745 cm^{-1}. **^{1}H NMR** (500 MHz, $CDCl_3$): δ = 7.44-7.42 (m, 1H), 7.30-7.15 (m, 13H), 5.70 (t, *J* = 6.0 Hz, 1H), 4.74 (d, *J* = 11.0 Hz, 1H), 4.49 (d, *J* = 12.0 Hz, 1H), 4.41-4.38 (m, 2H), 4.14-4.03 (m, 1H), 3.90-3.87 (m, 1H), 3.62-3.62 (m, 2H), 2.93-2.89 (m, 1H), 2.78 (dd, *J* = 15.0, 6.5 Hz, 1H). **^{13}C NMR** (126 MHz, $CDCl_3$): δ = 206.3, 137.7, 137.3, 137.2, 133.1, 129.8, 129.3, 128.4, 128.3, 128.1, 127.9, 127.6, 127.6, 126.9, 79.2, 75.9, 73.5, 72.9, 71.9, 69.7, 44.6. **HRMS** (ESI): m/z $[M + H]^+$calcd for $C_{26}H_{26}ClO_4$: 437.1520; found: 437.1527.

3.13.15. (*2R,3R,6S*)-3-(Benzyloxy)-2-((benzyloxy)methyl)-6-(2,4-dimethylphenyl) dihydro-2H-pyran-4(3H)-one (3ao)

Yield: 35 mg (65%); colourless viscous oil; cc: 10% EtOAc/hexane; Rf = 0.60 (20% EtOAc/hexane). $[a]_D{}^{27}$ = +59 (c = 0.1, $CHCl_3$). IR (neat) = 2977-2820, 1714, 1512, 1118, 1041 cm^{-1}. **^{1}H NMR** (500 MHz, $CDCl_3$): δ = 7.24-7.18 (m, 11H), 7.07 (d, *J* = 8.0 Hz, 1H), 6.91 (s, 1H), 6.85 (d, *J* = 8.0 Hz, 1H), 5.50 (t, *J* = 5.0 Hz, 1H), 4.81 (d, *J* = 11.5 Hz, 1H), 4.48 (d, *J* = 12.0 Hz, 1H), 4.38 (d, *J* = 11.5 Hz, 2H), 4.16 (d, *J* = 8.5 Hz, 1H), 3.59-3.56 (m, 1H), 3.53-3.47 (m, 2H), 2.97-2.96 (m, 2H), 2.30 (s, 3H), 2.19 (s, 3H). **^{13}C NMR** (125 MHz, $CDCl_3$): δ = 207.5, 138.2, 137.8, 137.5, 137.4, 133.5, 131.9, 128.3, 128.3, 128.1, 127.8, 127.7, 127.6, 127.5, 126.3, 79.7, 73.7, 73.5, 73.4, 72.8, 69.1, 44.3, 20.9, 19.5. **HRMS** (ESI): m/z $[M + H]^+$calcd for $C_{28}H_{31}O_4$: 431.2222; found: 431.2227.

3.13.16. (*2R,3R,6S*)-3-methoxy-2-(Methoxymethyl)-6-phenyldihydro-2H-pyran-4(3H)-one (3ba) [7]

Yield: 23 mg (72%); white foam; cc: 20% EtOAc/hexane; Rf = 0.50 (35% EtOAc/hexane). $[\alpha]_D^{26}$ = +53 (c = 0.05, $CHCl_3$). **^{1}H NMR** (500 MHz, $CDCl_3$): δ = 7.31-7.19 (m, 5H), 5.39 (dd, *J* = 7.0, 2.5 Hz, 1H), 3.89 (d, *J* = 7.5 Hz, 1H), 3.53-3.51 (m, 3H), 3.42 (s, 3H), 3.35 (s, 3H), 3.05-3.01 (m, 1H), 2.98-2.93 (m, 1H). **^{13}C NMR** (126 MHz, $CDCl_3$): δ = 206.5, 138.3, 128.6, 128.1, 127.3, 81.6, 75.1, 74.3, 71.5, 59.4, 59.3, 43.6.

3.13.17. (*2R,3R,6S*)-3-methoxy-2-(methoxymethyl)-6-(4-methoxyphenyl)dihydro-2H -pyran-4(3H)-one (3bb) [7]

Yield: 27 mg (76%); white foam; cc:20% EtOAc/hexane; Rf = 0.28 (35% EtOAc/hexane).$[\alpha]_D^{27}$ = +167 (c = 0.1, $CHCl_3$), lit. $[\alpha]_D^{17}$ = +128.8 (c 0.4, $CHCl_3$) [12]. **^{1}H NMR** (500 MHz, $CDCl_3$): δ = 7.21 (d, *J* = 8.5 Hz, 2H), 6.78 (d, *J* = 9.0 Hz, 2H), 5.34 (dd, *J* = 6.5, 2.5 Hz, 1H), 3.87 (d, *J* = 8.5 Hz, 1H), 3.71 (s, 3H), 3.53-3.46 (m, 3H), 3.43 (s, 3H), 3.34 (s, 3H), 2.99 (dd, *J* = 14.5, 3.0 Hz, 1H), 2.96-2.92 (m, 1H).**^{13}C NMR** (125 MHz, $CDCl_3$): δ = 206.7, 159.4, 130.5, 128.8, 114.0, 81.8, 74.8, 73.9, 71.5, 59.5, 59.3, 55.2, 43.8.

3.13.18. (*2R,3R,6S*)-3-methoxy-2-(methoxymethyl)-6-(4-nitrophenyl)dihydro-2H-pyran-4(3H)-one (3bc) [7]

Yield: 24 mg (64%); white foam; cc: 25% EtOAc/hexane; Rf = 0.25 (35%EtOAc/hexane). $[\alpha]_D^{26}$ = +104 (c = 0.1, $CHCl_3$). **^{1}H NMR** (500 MHz, $CDCl_3$): δ = 8.14 (d, *J* = 9.0 Hz, 2H), 7.51 (d, *J* = 8.5 Hz, 2H), 5.43 (t, *J* = 5.5 Hz, 1H), 3.87 (d, *J* = 8.0 Hz, 1H), 3.62-3.60 (m, 1H), 3.57-3.56 (m, 2H), 3.41 (s, 3H), 3.35 (s, 3H), 3.02-2.94

(m, 2H). **^{13}C NMR** (125 MHz, $CDCl_3$): δ = 205.1, 147.6, 146.0, 127.9, 123.8, 81.4, 75.8, 74.4, 71.8, 59.4, 59.2, 43.8.

3.13.19. (*2R,3S,6S*)-3-(benzyloxy)-2-((benzyloxy)methyl)-6-phenyldihydro-2H-pyran-4(3H)-one (3ca) [7]

Yield: 24 mg (48%); white foam; cc: 10% EtOAc/hexane; Rf = 0.62 (20% EtOAc/hexane). $[\alpha]_D^{27}$ = +112 (c = 0.1, $CHCl_3$). **^{1}H NMR** (500 MHz, $CDCl_3$): δ = 7.29-7.18 (m, 15H), 5.25 (dd, *J* = 10.0, 3.5 Hz, 1H), 4.86 (d, *J* = 12.0 Hz, 1H), 4.50 (d, *J* = 4.5 Hz, 1H), 4.48 (d, *J* = 5.0 Hz, 1H), 4.42 (d, *J* = 12.5 Hz, 1H), 4.38-4.35 (m, 1H), 4.09 (dd, *J* = 6.5, 1.0 Hz, 1H), 3.78-3.71 (m, 2H), 2.73 (dd, *J* = 14.5, 4.0 Hz, 1H), 2.59-2.54 (m, 1H). **^{13}C NMR** (125 MHz, $CDCl_3$): δ = 204.1, 140.5, 137.9, 137.4, 128.5, 128.4, 128.3, 128.0, 127.9, 127.8, 127.6, 127.5, 125.9, 79.2, 76.4, 74.7, 73.5, 72.6, 68.4, 47.9.

3.13.20. (*2R,3S,6S*)-3-(benzyloxy)-2-((benzyloxy)methyl)-6-(4-methoxyphenyl) dihydro-2H-pyran-4(3H)-one (3cb) [8]

Yield: 28 mg (52%); white foam; cc: 15% EtOAc/hexane; Rf = 0.45 (20% EtOAc/hexane). $[\alpha]_D^{27}$ = +124 (c = 0.1, $CHCl_3$), lit. $[\alpha]D^{19}$ = +39.5 (c 0.3, $CHCl_3$) [12]. **^{1}H NMR** (500 MHz, $CDCl_3$): δ = 7.31-7.17 (m, 12H), 6.80 (d, *J* = 8.5 Hz, 2H), 5.20 (dd, *J* = 9.5, 4.0 Hz, 1H), 4.85 (d, *J* = 12.0 Hz, 1H), 4.50-4.49 (m, 2H), 4.42 (d, *J* = 12.5 Hz, 1H), 4.34-4.31 (m, 1H), 4.07 (dd, *J* = 6.5, 1.0 Hz, 1H), 3.77-3.70 (m, 5H), 2.73 (dd, *J* = 14.5, 4.0 Hz, 1H), 2.61-2.56 (m, 1H). **^{13}C NMR** (125 MHz, $CDCl_3$): δ = 204.4, 159.4, 137.9, 137.4, 132.5, 128.4, 128.3, 127.9, 127.8, 127.6, 127.6, 127.4, 113.9, 79.3, 76.2, 74.5, 73.5, 72.6, 68.4, 55.3, 47.6.

3.13.21. (*2R,3S,6S*)-3-(benzyloxy)-2-((benzyloxy)methyl)-6-(4-chlorophenyl) dihydro-2H-pyran-4(3H)-one (3cc)

Yield: 26 mg (48%); white foam; cc: 10% EtOAc/hexane; Rf = 0.64 (20% EtOAc/hexane). $[\alpha]_D^{27}$ = +97 (c = 0.1, $CHCl_3$). IR (neat) = 2945, 2861, 1727, 1487, 1128, 734 cm^{-1}. **^{1}H NMR** (500 MHz, $CDCl_3$): δ = 7.28-7.19 (m, 14H), 5.22 (dd, *J* = 10.0, 3.5 Hz, 1H), 4.87 (d, *J* = 12.0 Hz, 1H), 4.51-4.47 (m, 2H), 4.42 (d, *J* = 12.5 Hz, 1H), 4.36-4.33 (m, 1H), 4.07 (dd, *J* = 6.5, 1.5 Hz, 1H), 3.78-3.70 (m, 2H), 2.71 (dd, *J* = 14.5, 3.5 Hz, 1H), 2.52-2.47 (m, 1H). **^{13}C NMR** (125 MHz, $CDCl_3$): δ = 203.8, 139.1, 137.8, 137.3, 133.7, 128.7, 128.5, 128.3, 128.0, 127.8, 127.6, 127.3, 79.0, 76.5, 74.1, 73.6, 72.7, 68.4, 47.9. **HRMS** (ESI): m/z $[M + H]^+$calcd for $C_{26}H_{26}ClO_4$: 437.1520; found: 437.1521.

3.13.22. (*2S,3S,6R*)-3-(Benzyloxy)-2-methyl-6-(4-nitrophenyl)dihydro-2H-pyran-4(3H)-one (3da) [7]

Yield: 29 mg (67%); white foam; cc: 15% EtOAc/hexane; Rf = 0.25 (20% EtOAc/hexane). $[\alpha]_D^{27}$ = -49 (c = 0.1, $CHCl_3$). **^{1}H NMR** (500 MHz, $CDCl_3$): δ = 8.14-8.11 (m, 2H), 7.50 (d, *J* = 8.5 Hz, 2H), 7.27-7.22 (m, 5H), 5.24 (t, *J* = 5.5 Hz, 1H), 4.73 (d, *J* = 11.5 Hz, 1H), 4.40 (d, *J* = 11.5 Hz, 1H), 3.81 (p, *J* = 6.5 Hz, 1H), 3.61 (d, *J* = 7.0 Hz, 1H), 3.06 (dd, *J* = 14.5, 5.0 Hz, 1H), 2.89-2.85 (m, 1H), 1.24 (d, *J* = 6.5 Hz, 3H). **^{13}C NMR** (125 MHz, $CDCl_3$): δ = 205.5, 147.5, 146.4, 136.9, 128.4, 128.1, 128.1, 127.7, 123.8, 84.1, 73.6, 73.2, 72.8, 44.4, 17.5.

3.13.23. (*2S,3S,6R*)-3-(Benzyloxy)-2-methyl-6-(3-nitrophenyl)dihydro-2H-pyran-4(3H)-one (3db) [8]

Yield: 28 mg (65%); white foam; cc: 15% EtOAc/hexane; Rf = 0.25 (20% EtOAc/hexane). $[\alpha]_D^{27}$= -84 (c = 0.1, $CHCl_3$), lit. $[\alpha]D^{19}$ = -87.3 (c 0.3, $CHCl_3$) [12].

^{1}H NMR (500 MHz, $CDCl_3$) δ 8.22 (s, 1H), 8.08-8.07 (m, 1H), 7.64 (d, *J* = 7.5 Hz, 1H), 7.46 (t, *J* = 8.0 Hz, 1H), 7.27-7.22 (m, 5H), 5.24 (t, *J* = 5.5 Hz, 1H), 4.74 (d, *J* = 11.5 Hz, 1H), 4.41 (d, *J* = 11.5 Hz, 1H), 3.83 (p, *J* = 6.5 Hz, 1H), 3.62 (d, *J* = 7.0 Hz, 1H), 3.09 (dd, *J* = 14.5, 5.5 Hz, 1H), 2.88 (dd, *J* = 14.0, 6.0 Hz, 1H), 1.25 (d, *J* = 6.5 Hz, 3H). **^{13}C NMR** (125 MHz, $CDCl_3$): δ = 205.5, 148.5, 141.5, 136.9, 132.6, 129.7, 128.4, 128.2, 128.1, 123.0, 122.0, 84.1, 73.5, 73.1, 72.8, 44.5, 17.5.

3.13.24. (*2S,3S,6R*)-3-(Benzyloxy)-6-(4-methoxyphenyl)-2-methyldihydro-2H-pyran-4(3H)-one (3dc) [8]

Yield: 28 mg (68%); white foam; cc: 15% EtOAc/hexane; Rf = 0.30 (20% EtOAc/hexane). $[\alpha]_D^{27}$ = -64 (c = 0.1, $CHCl_3$), lit. $[\alpha]_D^{20}$ = -141.2 (c 1.1, $CHCl_3$) [12]. **^{1}H NMR** (500 MHz, $CDCl_3$): δ = 7.35-7.28 (m, 7H), 6.86 (d, *J* = 9.0 Hz, 2H), 5.27 (dd, *J* = 7.0, 3.0 Hz, 1H), 4.87 (d, *J* = 11.5 Hz, 1H), 4.49 (d, *J* = 11.5 Hz, 1H), 3.82-3.73 (m, 4H), 3.66 (d, *J* = 8.0 Hz, 1H), 3.11 (dd, *J* = 14.5, 3.0 Hz, 1H), 2.95-2.91 (m, 1H), 1.28 (d, *J* = 6.5 Hz, 3H). **^{13}C NMR** (125 MHz, $CDCl_3$): δ = 206.6, 159.2, 137.2, 131.0, 128.6, 128.3, 128.2, 127.9, 113.9, 84.8, 74.3, 73.0, 71.4, 55.2, 44.5, 18.2.

3.13.25. (*2R,3R,6S*)-3-(Benzyloxy)-2-methyl-6-phenyldihydro-2H-pyran-4(3H)-one (3ea)

Yield: 27 mg (72%); white foam; cc: 10% EtOAc/hexane; Rf = 0.45 (10% EtOAc/hexane). $[\alpha]_D^{27}$ = +153 (c = 0.1, $CHCl_3$). IR (neat) = 2949, 2877, 1730, 1514, 1166 cm^{-1}. **^{1}H NMR** (500 MHz, $CDCl_3$): δ = 7.39-7.23 (m, 10H), 5.28 (dd, *J* = 6.5, 4.0 Hz, 1H), 4.84 (d, *J* = 11.5 Hz, 1H), 4.48 (d, *J* = 11.5 Hz, 1H), 3.81 (p, *J* = 6.5 Hz, 1H), 3.66 (d, *J* = 7.5 Hz, 1H), 3.14 (dd, *J* = 14.0, 3.5 Hz, 1H), 2.93-2.89 (m, 1H), 1.28 (d, *J* = 6.5 Hz, 3H). **^{13}C NMR** (126 MHz, $CDCl_3$): δ = 206.3, 139.0, 137.2, 128.6, 128.3,

128.1, 128.0, 127.9, 127.0, 84.6, 74.5, 72.9, 71.8, 44.4, 18.0. HRMS (ESI): m/z [M + H]$^+$calcd for $C_{19}H_{21}O_3$: 297.1491; found: 297.1497.

3.13.26. (*2R,3R,6S*)-3-(Benzyloxy)-6-(4-methoxyphenyl)-2-methyldihydro-2H-pyran-4-(3H)-one (3eb) [8]

Yield: 30 mg (75%); white foam; cc: 15% EtOAc/hexane; Rf = 0.25 (20% EtOAc/hexane). $[\alpha]_D$ ^{27}= +150 (c = 0.1, $CHCl_3$), lit. $[\alpha]D^{19}$ = +102.8 (c 0.4, $CHCl_3$) [12]. **^{1}H NMR** (500 MHz, $CDCl_3$): δ = 7.35-7.28 (m, 7H), 6.87-6.85 (m, 2H), 5.27 (dd, *J* = 6.5, 3.0 Hz, 1H), 4.87 (d, *J* = 11.5 Hz, 1H), 4.49 (d, *J* = 11.5 Hz, 1H), 3.82-3.73 (m, 4H), 3.66 (d, *J* = 8.0 Hz, 1H), 3.12 (dd, *J* = 14.5, 3.0 Hz, 1H), 2.94 (dd, *J* = 14.0, 6.5 Hz, 1H), 1.28 (d, *J* = 6.0 Hz, 3H). **^{13}C NMR** (125 MHz, $CDCl_3$): δ = 206.6, 159.2, 137.2, 131.0, 128.6, 128.3, 128.2, 127.9, 113.9, 84.8, 74.3, 73.0, 71.4, 55.2, 44.5, 18.2.

3.13.27. (*2R,3R,6S*)-3-(Benzyloxy)-2-methyl-6-(4-nitrophenyl)dihydro-2H-pyran-4(3H)-one (3ec)

Yield: 30 mg (70%); white foam; cc: 15% EtOAc/hexane; Rf = 0.35 (20% EtOAc/hexane). $[\alpha]_D$ ^{27} = +87 (c = 0.1, $CHCl_3$). IR (neat) = 2949, 2877, 1724, 1531, 1356 cm^{-1}. **^{1}H NMR** (500 MHz, $CDCl_3$): δ = 8.21-8.19 (m, 2H), 7.57 (d, *J* = 8.5 Hz, 2H), 7.36-7.28 (m, 5H), 5.31 (t, *J* = 5.5 Hz, 1H), 4.80 (d, *J* = 11.5 Hz, 1H), 4.48 (d, *J* = 11.5 Hz, 1H), 3.89 (p, *J* = 6.5 Hz, 1H), 3.70 (dd, *J* = 7.0, 0.5 Hz, 1H), 3.13 (dd, *J* = 14.5, 5.0 Hz, 1H), 2.96-2.92 (m, 1H), 1.32 (d, *J* = 6.5 Hz, 3H). **^{13}C NMR** (125 MHz, $CDCl_3$): δ = 205.5, 147.5, 146.4, 136.9, 128.4, 128.1, 128.0, 127.7, 123.8, 84.1, 73.6, 73.2, 72.8, 44.5, 17.5. **HRMS** (ESI): m/z [M + H]$^+$calcd for $C_{19}H_{20}NO_5$: 342.1341; found: 342.1344.

3.13.28. (*2R,3R,6R*)-3-(Benzyloxy)-2-((benzyloxy)methyl)-6-phenyldihydro-2H-pyran-4(3H)-one (3fa) [8]

Yield: 30 mg (60%); white foam; cc: 10% EtOAc/hexane; Rf = 0.63 (20% EtOAc/hexane). $[\alpha]_D{}^{27}$= +65 (c = 0.05, $CHCl_3$), lit. $[\alpha]D^{20}$ =+84.8 (c 0.2, $CHCl_3$)[12]. **^{1}H NMR** (500 MHz, $CDCl_3$): δ = 7.32-7.19 (m, 15H), 4.86 (d, *J* = 11.0 Hz, 1H), 4.61-4.57 (m,1H) 4.61 ((t, *J* = 7.2 Hz, 1H), 4.50 (d, *J* = 12.5 Hz, 1H), 4.42 (d, *J* = 11.5 Hz, 1H), 4.20-4.18 (m, 1H), 3.77-3.75 (m, 3H), 2.69-2.67 (m, 2H). **^{13}C NMR** (125 MHz, $CDCl_3$):δ = 205.7, 139.9, 138.1, 137.3, 128.5, 128.3, 128.3, 128.2, 128.1, 127.9, 127.6, 127.6, 125.6, 80.8, 79.6, 79.3, 73.5, 69.1, 49.9.

3.13.29. (*2R,3R,6R*)-3-(Benzyloxy)-2-((benzyloxy)methyl)-6-(4-methoxyphenyl) dihydro-2H-pyran-4(3H)-one (3fb) [8]

Yield: 34 mg (63%); white foam; cc: 15% EtOAc/hexane; Rf = 0.42 (20% EtOAc/hexane).$[\alpha]_D{}^{27}$ = +106 (c = 0.1, $CHCl_3$), lit. $[\alpha]D^{16}$ =+105.0 (c 0.1, $CHCl_3$) [12]. **^{1}H NMR** (500 MHz, $CDCl_3$): δ = 7.33-7.29 (m, 12H), 6.89 (d, *J* = 8.5 Hz, 2H), 4.93 (d, *J* = 11.5 Hz, 1H), 4.65-4.63 (m, 1H) 4.55 (dd, *J* = 10.5 , 3.0 Hz, 1H), 4.56 (d, *J* = 12.5 Hz, 1H), 4.49 (d, *J* = 11.0 Hz, 1H), 4.26 (d, *J* = 9.0 Hz, 1H), 3.82-3.79 (m, 6H), 2.78-2.69 (m, 2H). **^{13}C NMR** (125 MHz, $CDCl_3$): δ = 205.9, 159.4, 138.1, 137.4, 132.1, 128.3, 128.3, 128.2, 127.9, 127.7, 127.6, 127.0, 113.9, 80.7, 79.6, 79.1, 73.5, 73.5, 69.1, 55.3, 49.9

3.13.30. (*2R,3R,6R*)-3-(Benzyloxy)-2-((benzyloxy)methyl)-6-(4-chlorophenyl) dihydro-2H-pyran-4(3H)-one (3fc)

Yield: 30 mg (55%); white foam; cc: 10% EtOAc/hexane; Rf = 0.58 (20% EtOAc/hexane). $[\alpha]_D{}^{27}$ = +53 (c = 0.05, $CHCl_3$). IR (neat) = 2949, 2870, 1727, 1514, 1166, 742 cm^{-1}. **^{1}H NMR** (500 MHz, $CDCl_3$): δ = 7.34-7.26 (m, 14H), 4.93 (d, *J* = 11.0

Hz, 1H), 4.66-4.62 (m, 1H) 4.64 (dd, *J* = 10.4, 3.2 Hz, 1H), 4.56 (d, *J* = 12.5 Hz, 1H), 4.48 (d, *J* = 11.0 Hz, 1H), 4.26-4.24 (m, 1H), 3.84-3.80 (m, 3H), 2.74-2.66 (m, 2H). **^{13}C NMR** (125 MHz, $CDCl_3$): δ = 205.2, 138.5, 138.0, 137.3, 133.8, 128.7, 128.3, 128.3, 128.2, 127.9, 127.6, 127.0, 80.7, 79.5, 78.5, 73.5, 73.5, 69.0, 49.8. **HRMS** (ESI): m/z $[M + H]^+$calcd for $C_{26}H_{26}ClO_4$: 437.1520; found: 437.1525.

3.13.31. (*2R,3R,6R*)-3-(Benzyloxy)-2-((benzyloxy)methyl)-6-(4-bromophenyl) dihydro-2H-pyran-4(3H)-one (3fd) [8]

Yield: 38 mg (64%); white foam; cc: 10% EtOAc/hexane; Rf = 0.58 (20% EtOAc/hexane). $[\alpha]_D^{27}$ = +69 (c = 0.1, $CHCl_3$), lit. $[\alpha]D^{20}$ =+133.6 (c 0.2, $CHCl_3$) [12]. **^{1}H NMR** (500 MHz, $CDCl_3$): δ = 7.42 (d, *J* = 8.5 Hz, 2H), 7.26-7.18 (m, 12H), 4.86 (d, *J* = 11.0 Hz, 1H), 4.56-4.55 (m, 1H) 4.57 (dd, J = 10.5, 3.0 Hz, 1H), 4.49 (d, *J* = 12.5 Hz,1H), 4.42 (d, *J* = 11.0 Hz, 1H), 4.19-4.17 (m, 1H), 3.76-3.73 (m, 3H), 2.68-2.59 (m, 2H). **^{13}C NMR** (125 MHz, $CDCl_3$): δ = 205.2, 139.0, 138.0, 137.3, 131.7, 128.4, 128.3, 128.2, 128.0, 127.7, 127.3, 122.0, 80.7, 79.5, 78.6, 73.5, 73.5, 69.0, 49.8.

3.13.32. (*2R,3R,6R*)-3-(Benzyloxy)-2-((benzyloxy)methyl)-6-(p-tolyl)dihydro-2H-pyran-4(3H)-one (3fe)

Yield: 35 mg (68%); white foam; cc: 10% EtOAc/hexane; Rf = 0.62 (20% EtOAc/hexane). $[\alpha]_D^{27}$ = +74 (c = 0.1, $CHCl_3$). IR (neat) = 2952, 2894, 1729, 1515, 1248, 833 cm^{-1}. **^{1}H NMR** (500 MHz, $CDCl_3$): δ = 7.40-7.39 (m, 1H), 7.36-7.30 (m, 11H), 7.20 (d, *J* = 8.0 Hz, 2H), 4.96 (d, *J* = 11.0 Hz, 1H), 4.72-4.67 (m, 1H) 4.67 (dd, *J* = 10.8, 2.9 Hz, 1H), 4.59 (d, *J* = 12.5 Hz, 1H), 4.52 (d, *J* = 11.0 Hz, 1H), 4.30 (d, *J* = 9.0 Hz, 1H), 3.86-3.83 (m, 3H), 2.82-2.73 (m, 2H), 2.37 (s, 3H). **^{13}C NMR** (125 MHz, $CDCl_3$): δ = 205.9, 138.1, 137.9, 137.4, 137.0, 129.2, 128.5, 128.3, 128.3, 128.2, 127.9,

127.7, 127.6, 126.9, 125.6, 80.8, 79.6, 79.3, 73.5, 73.5, 69.1, 49.9, 21.1. **HRMS** (ESI): m/z $[M + H]^+$calcd for $C_{27}H_{29}O_4$: 417.2066; found: 417.2061.

3.13.33. (*2S,3S,6S*)-3-(Benzyloxy)-6-(4-methoxyphenyl)-2-methyldihydro-2H-pyran-4(3H)-one (3ga) [8]

Yield: 25 mg (61%); white foam; cc: 15% EtOAc/hexane; Rf = 0.35 (20% EtOAc/hexane). $[\alpha]_D^{27}$ = -109 (c = 0.1, $CHCl_3$), lit. $[\alpha]_D^{22}$ = -224.9 (c 0.7, $CHCl_3$) [12]. **^{1}H NMR** (500 MHz, $CDCl_3$): δ = 7.41-7.35 (m, 4H), 7.32 (d, *J* = 7.0 Hz, 1H), 7.28 (d, *J* = 9.0 Hz, 2H), 6.90-6.88 (m, 2H), 4.99 (d, *J* = 11.5 Hz, 1H), 4.62 (dd, *J* = 11.0, 3.0 Hz, 1H), 4.54 (d, *J* = 11.5 Hz, 1H), 3.80 (s, 3H), 3.77-3.76 (m, 2H), 2.78-2.68 (m, 2H), 1.45 (d, *J* = 5.5 Hz, 3H). **^{13}C NMR** (125 MHz, $CDCl_3$): δ = 205.6, 159.4, 137.4, 132.2, 128.4, 128.2, 128.0, 127.0, 114.0, 84.8, 78.9, 77.6, 77.2, 73.2, 55.3, 49.9, 19.3.

3.13.34. (*2S,3S,6S*)-3-(Benzyloxy)-6-(4-nitrophenyl)-2-methyldihydro-2H-pyran-4(3H)-one (3gb)

Yield: 27 mg(63%); white foam; cc: 20% EtOAc/hexane; Rf = 0.30 (20% EtOAc/hexane). $[\alpha]_D^{27}$ = -106 (c = 0.1, $CHCl_3$). IR (neat) = 2911, 2821, 1734, 1514, 1358, 841 cm^{-1}. **^{1}H NMR** (500 MHz, $CDCl_3$): δ = 8.23 (d, *J* = 9.0 Hz, 2H), 7.54 (d, *J* = 8.5 Hz, 2H), 7.41-7.30 (m, 5H), 5.99 (d, *J* = 11.5 Hz, 1H), 4.78 (dd, *J* = 12.0, 2.5 Hz, 1H), 4.55 (d, *J* = 11.5 Hz, 1H), 3.85-3.76 (m, 2H), 2.81-2.77 (m, 1H), 2.67-2.61 (m, 1H), 1.48 (d, *J* = 5.5 Hz, 3H). **^{13}C NMR** (125 MHz, $CDCl_3$): δ = 204.2, 147.6, 147.2, 137.2, 128.5, 128.3, 128.1, 126.3, 123.9, 84.5, 77.8, 77.8, 73.4, 49.7, 19.2. **HRMS** (ESI): m/z $[M + H]^+$calcd for $C_{19}H_{20}NO_5$: 342.1341; found: 342.1338.

3.14 Experimental Section for Application of Synthesized α-Aryl-*C*-Glycoside

3.14.1 Preparation of (*2R,3R,6S*)-3-Hydroxy-2-(hydroxymethyl)-6-phenyldihydro-2H-pyran-4(3H)-one (4a)

To a solution of **3ab** (100 mg, 0.25 mmol) in methanol: EtOAc: AcOH (1:1:2) was added 10% Pd/C (25 mg), and the suspension was stirred for 24 h at room temperature in the presence of H_2 (balloon). The Pd/C was removed from the reaction by filtration through celite and the filtrate was concentrated. The crude product was purified by a column chromatography (SiO_2, hexane:ethyl acetate = 50:50) to afford the pure product (**4a**). Yield: 52 mg (92 %); colourless oil. $[\alpha]_D^{26}$ = +57 (c = 0.1, $CHCl_3$). IR (neat) = 3353, 1721, 831 cm^{-1}. **^{1}H NMR** (500 MHz, $CDCl_3$): δ = 7.32-7.21 (m, 5H), 5.48 (d, *J* = 7.5 Hz, 1H), 4.25 (d, *J* = 10.0 Hz, 1H), 3.79-3.72 (m, 2H), 3.57 (s, 1H), 3.27-3.23 (m, 1H), 3.17-3.14 (m, 1H), 3.10-3.06 (m, 1H), 2.24 (s, 1H).**^{13}C NMR** (125 MHz, $CDCl_3$): δ = 207.8, 137.8, 128.8, 128.3, 127.4, 76.2, 75.4, 73.6, 62.5, 41.6.**HRMS** (ESI): m/z [M + H]$^+$calcd for $C_{12}H_{15}O_4$: 223.0970; found: 223.0957.

3.14.2 Preparation of (*2R,3S,6S*)-3-(Benzyloxy)-2-((benzyloxy)methyl)-4-methylene-6-phenyltetrahydro-2H-pyran (4b)

A solution of *n*-BuLi in n-hexane (1.6 M, 0.6 mL, 1.0 mmol) was added to the stirred suspension of methyltriphenylphosphonium bromide(355 mg, 1.0 mmol) in dry THF (10 mL) at –20 °C. The reaction mixture was stirred at the same temperature for another 1 h after which a solution of compound **3ab** (200 mg, 0.5 mmol) in dry THF (5 mL) was added. After the addition, the reaction mixture was allowed to stir at room temperature for 3h. After completion, the reaction mixture was poured into ice-water, extracted with CH_2Cl_2. Further, the organic layer was washed with brine, dried over

anhydrous Na_2SO_4 and evaporated. The crude product was purified by column chromatography (SiO_2, hexane:ethyl acetate = 90:10) to afford pure compound alkene (**4b**). Yield: 155 mg (78 %); colourless viscous oil. $[a]_D{}^{27}$ = +17 (c = 0.1, $CHCl_3$). IR (neat) = 2842, 1615, 1248, 814 cm^{-1}. **^{1}H NMR** (500 MHz, $CDCl_3$): δ = 7.33 (d, *J* = 7.5 Hz, 2H), 7.25-7.15 (m, 13H), 5.03 (s, 1H), 4.91 (s, 1H), 4.59 (dd, *J* = 9.5, 3.5 Hz, 1H), 4.54 (d, *J* = 11.5 Hz, 1H), 4.44 (s, 2H), 4.30 (d, *J* = 12.0 Hz, 1H), 4.17-4.14 (m, 1H), 3.80 (d, *J* = 3.0 Hz, 1H), 3.60 (dd, *J* = 10.0, 6.0 Hz, 1H), 3.53 (dd, *J* = 10.0, 7.0 Hz, 1H), 2.67 (dd, *J* = 13.5, 10.0 Hz, 1H), 2.33 (dd, *J* = 13.5, 3.5 Hz, 1H). **^{13}C NMR** (125 MHz, $CDCl_3$): δ = 141.5, 141.0, 138.2, 138.0, 128.3, 128.3, 128.2, 127.7, 127.6, 127.6, 127.4, 126.2, 113.8, 76.8, 76.1, 74.4, 73.0, 70.0, 67.7, 37.9. **HRMS** (ESI): m/z [M + H]$^+$calcd for $C_{27}H_{29}O_3$: 401.2117; found: 401.2113.

3.14.3. General procedure for Grignard reaction:

To a stirred solution of compound **3ab** (100 mg, 0.25 mmol) in dry THF(10 mL) at –20°C was added dropwise a solution of RMgBr in THF or Et_2O (0.35 mmol) through a syringe. The resulting mixture was stirred at this temperature for 30 min and then at room temperature for another 2-3 h. After completion, the reaction mixture was diluted with ice cold water and extracted with CH_2Cl_2. The organic layer was washed with brine, dried over anhydrous Na_2SO_4 and evaporated in vacuo. The residue was purified by column chromatography (SiO_2, hexane:ethyl acetate) to afford the product (**4c-4h**) in (75-86% yield).

3.14.3.1. Preparation of (*2R,3R,4S,6S*)-3-(Benzyloxy)-2-((benzyloxy)methyl)-4-methyl-6-phenyltetrahydro-2H-pyran-4-ol (4c)

$[a]_D$ ^{26} = +26 (c = 0.1, $CHCl_3$). IR (neat) = 3460, 2914, 2894, 1515, 1248, 798 cm^{-1}.Yield: 89 mg (86%); yellowish viscous oil; cc: 15% EtOAc/hexane; Rf = 0.70 (20% EtOAc/hexane). **^{1}H NMR** (500 MHz, $CDCl_3$): δ = 7.39 (d, *J* = 7.5 Hz, 2H), 7.31-7.11 (m, 13H), 4.94 (dd, *J* = 6.0, 4.0 Hz, 1H), 4.61 (d, *J* = 12.0 Hz, 1H), 4.54-4.47 (m, 3H), 3.88-3.85 (m, 1H), 3.68 (d, *J* = 3.5 Hz, 2H), 3.48 (d, *J* = 8.0 Hz, 1H), 2.43 (dd, *J* = 14.5, 3.5 Hz, 1H), 2.01 (dd, *J* = 14.5, 6.5 Hz, 2H), 1.23 (s, 3H). **^{13}C NMR** (125 MHz, $CDCl_3$): δ = 141.2, 137.9, 137.7, 128.3, 128.3, 128.0, 128.0, 127.7, 127.7, 127.6, 126.6, 126.0, 79.0, 74.5, 73.5, 72.3, 70.2, 70.2, 69.3, 38.8, 27.6. **HRMS** (ESI): m/z [M + H]$^+$calcd for $C_{27}H_{31}O_4$: 419.2222; found: 419.2217.

3.14.3.2. (*2R,3R,4S,6S*)-3-(benzyloxy)-2-((benzyloxy)methyl)-4-pentyl-6-phenyltetrahydro-2H-pyran-4-ol (4d)

Yield: 94 mg (80%); yellowish viscous oil; cc: 10% EtOAc/hexane; Rf = 0.70 (20% EtOAc/hexane). $[a]_D$ ^{26} = +26 (c = 0.1, $CHCl_3$). IR (neat) = 3252, 2894, 1500, 1244, 811 cm^{-1}. **^{1}H NMR** (500 MHz, $CDCl_3$): δ = 7.47-7.45 (m, 2H), 7.39-7.36 (m, 2H), 7.34-7.26 (m, 8H), 7.22-7.16 (m, 3H), 5.03 (dd, *J* = 6.0, 4.5 Hz, 1H), 4.69 (d, *J* = 12.0 Hz, 1H), 4.59-4.53 (m, 3H), 4.94-3.92 (m, 1H), 3.75 (d, *J* = 3.5 Hz, 2H), 3.60 (d, *J* = 8.5 Hz, 1H), 2.45 (dd, *J* = 14.5, 3.5 Hz, 1H), 2.06 (dd, *J* = 14.5, 6.5 Hz, 1H), 1.65-1.59 (m, 1H), 1.51-1.43 (m, 2H), 1.35-1.24 (m, 5H), 0.90 (t, *J* = 7.0 Hz, 3H). **^{13}C NMR** (125 MHz, $CDCl_3$): δ = 141.5, 137.9, 137.8, 128.9, 128.5, 128.4, 128.3, 128.3, 128.0, 127.7, 127.6, 127.6, 126.6, 126.0, 77.8, 74.4, 73.5, 72.4, 72.3, 70.2, 69.6, 40.0, 35.9, 32.4, 22.86, 22.6, 14.0. **HRMS** (ESI): m/z [M + H]$^+$calcd for $C_{31}H_{39}O_4$: 475.2848; found: 475.2845.

3.14.3.3. (*2R,3R,4R,6S*)-3-(benzyloxy)-2-((benzyloxy)methyl)-4-isopropyl-6-phenyltetrahydro-2H-pyran-4-ol (4e)

Yield: 77 mg (70%); colourless viscous oil; cc: 10% EtOAc/hexane; Rf = 0.68 (20% EtOAc/hexane). $[a]_D^{26}$ = +17 (c = 0.05, $CHCl_3$). IR (neat) = 3311, 2886, 1522, 1212, 836 cm^{-1}. **^{1}H NMR** (500 MHz, $CDCl_3$): δ = 7.48-7.46 (m, 2H), 7.39-7.26 (m, 10H), 7.23-7.21 (m, 1H), 7.14 (dd, *J* = 7.5, 2.0 Hz, 2H), 5.09 (dd, *J* = 6.5, 3.5 Hz, 1H), 4.71 (d, *J* = 12.0 Hz, 1H), 4.57-4.54 (m, 3H), 3.93-3.87 (m, 2H), 3.78-3.72 (m, 2H), 2.34 (dd, *J* = 14.5, 3.5 Hz, 1H), 2.10-2.04 (m, 1H), 2.00-1.94 (m, 1H), 1.04 (d, *J* = 7.0 Hz, 3H), 1.01 (d, *J* = 7.0 Hz, 3H). **^{13}C NMR** (125 MHz, $CDCl_3$): δ = 141.7, 138.0, 137.9, 128.3, 128.3, 128.0, 127.9, 127.7, 127.6, 127.4, 126.5, 126.1,77.20, 74.9, 74.8, 74.0, 73.6, 72.4, 70.1, 69.8, 34.0, 18.1, 16.2. **HRMS** (ESI): m/z $[M + H]^+$calcd for $C_{29}H_{35}O_4$: 447.2535; found: 447.2531.

3.14.3.4. (*2R,3R,4R,6S*)-3-(benzyloxy)-2-((benzyloxy)methyl)-6-phenyl-4-vinyltetrahydro-2H-pyran-4-ol (4f)

Yield: 80 mg (75%); yellowish viscous oil; cc: 10% EtOAc/hexane; Rf = 0.65 (20% EtOAc/hexane). $[a]_D^{26}$ = +59 (c = 0.1, $CHCl_3$). IR (neat) =3261, 2869,1519, 1248, 825 cm^{-1}. **^{1}H NMR** (500 MHz, $CDCl_3$): δ = 7.49-7.48 (m, 2H), 7.38-7.24 (m, 10H), 7.21-7.20 (m, 1H), 7.10-7.09 (m, 2H), 5.98 (dd, *J* = 17.0, 10.5 Hz, 1H), 5.46 (d, *J* = 17.0 Hz, 1H), 5.20 (d, *J* = 10.5 Hz, 1H), 5.09 (d, *J* = 5.5 Hz, 1H), 4.69 (d, *J* = 12.0 Hz, 1H), 4.55 (dd, *J* = 10.5, 3.5 Hz, 2H), 4.44 (d, *J* = 10.5 Hz, 1H), 3.92-3.89 (m, 1H), 3.74 (d, *J* = 3.5 Hz, 2H), 3.70 (d, *J* = 9.0 Hz, 1H), 2.49 (dd, *J* = 14.5, 2.0 Hz, 1H), 2.24 (dd, *J* = 15.0, 7.0 Hz, 1H). **^{13}C NMR** (126 MHz, $CDCl_3$): δ = 143.4, 140.9, 138.0, 137.6, 128.5, 128.4, 128.3, 128.2, 128.0, 127.9, 127.8, 127.7, 127.7, 127.6, 126.5, 126.2, 125.9,

114.40, 77.4, 74.4, 73.6, 72.7, 72.0, 69.3, 69.2, 36.6. **HRMS** (ESI): m/z $[M + H]^+$calcd for $C_{28}H_{31}O_4$: 431.2222; found: 431.2228.

3.14.3.5. (*2R,3R,4R,6S*)-3-(benzyloxy)-2-((benzyloxy)methyl)-6-phenyl-4-(p-tolyl)tetrahydro-2H-pyran-4-ol (4g)

Yield: 86 mg (70%); colourless viscous oil ; cc: 10% EtOAc/hexane; Rf = 0.70 (20% EtOAc/hexane). $[\alpha]_D^{26}$ = +27 (c = 0.1, $CHCl_3$). IR (neat) = 3221, 2886, 1511, 1236, 789 cm^{-1}. **^{1}H NMR** (500 MHz, $CDCl_3$): δ = 7.53-7.47 (m, 4H), 7.39-7.37 (m, 2H), 7.35-7.27 (m, 6H), 7.20-7.12 (m, 5H), 6.77 (dd, *J* = 7.5, 1.5 Hz, 2H), 5.21 (d, *J* = 6.5 Hz, 1H), 4.71 (d, *J* = 12.0 Hz, 1H), 4.55 (d, *J* = 12.0 Hz, 1H), 4.11-4.06 (m, 2H), 3.99-3.96 (m, 2H), 3.75-3.72 (m, 4H), 2.74 (s, 1H), 2.71-2.68 (m, 1H), 2.58 (dd, *J* = 15.5, 7.5 Hz, 1H), 2.36 (s, 3H). **^{13}C NMR** (125 MHz, $CDCl_3$): δ = 143.3, 141.0, 138.0, 137.4, 136.6, 128.9, 128.3, 128.0, 128.0, 127.9, 127.7, 127.6, 127.5, 126.4, 126.2, 125.2, 78.8, 74.2, 74.1, 73.6, 72.5, 69.5, 69.4, 67.9, 39.2, 20.9. **HRMS** (ESI): m/z $[M + H]^+$calcd for $C_{33}H_{35}O_4$: 495.2535; found: 495.2539.

3.14.3.6. (*2R,3R,4R,6S*)-3-(benzyloxy)-2-((benzyloxy)methyl)-4,6-diphenyltetrahydro-2H-pyran-4-ol (4h)

Yield: 91 mg (76%); colourless viscous oil ; cc: 10% EtOAc/hexane; Rf = 0.68 (20% EtOAc/hexane). $[\alpha]_D^{26}$ = +29 (c = 0.1, $CHCl_3$). IR (neat) = 3251, 2785, 1541, 833 cm^{-1}. **^{1}H NMR** (500 MHz, $CDCl_3$): δ = 7.62-7.60 (m, 2H), 7.54-7.52 (m, 2H), 7.40-7.21 (m, 11H), 7.15-7.10 (m, 3H), 6.74-6.72 (m, 2H), 5.22 (d, *J* = 6.5 Hz, 1H), 4.71 (d, *J* = 12.5 Hz, 1H), 4.56 (d, *J* = 12.5 Hz, 1H), 4.12 (d, *J* = 9.5 Hz, 1H), 4.07 (d, *J* = 10.5 Hz, 1H), 4.00-3.97 (m, 1H), 3.78-3.73 (m, 2H), 3.68 (d, *J* = 10.5 Hz, 1H), 2.72 (dd, *J* = 15.0, 1.5 Hz, 1H), 2.60 (dd, *J* = 15.0, 6.5 Hz, 1H). **^{13}C NMR** (125 MHz, $CDCl_3$): δ = 146.2,

140.9, 138.0, 137.3, 128.3, 128.2, 128.0, 128.0, 127.9, 127.6, 127.6, 127.5, 127.0, 126.4, 126.1, 125.3, 78.8, 77.20, 74.3, 74.2, 73.6, 72.5, 69.5, 69.4, 39.1. **HRMS** (ESI): m/z $[M + H]^+$calcd for $C_{32}H_{33}O_4$: 481.2379; found: 481.2384.

3.15 Spectra of Few Compounds

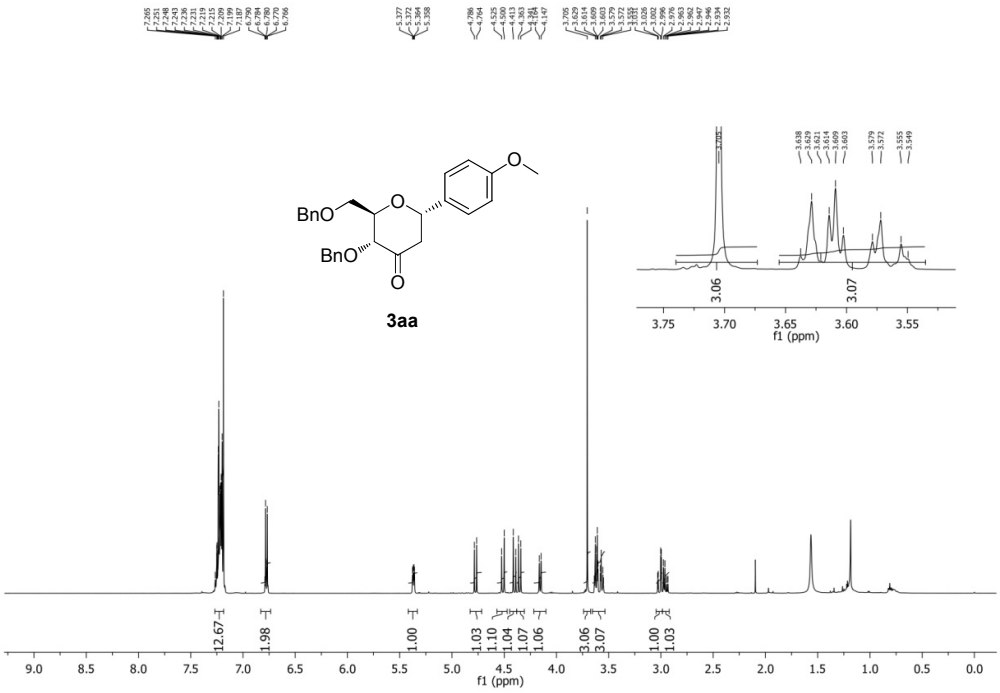


Figure 3.1 ^{1}H NMR Spectra for **3aa** in **$CDCl_3$**

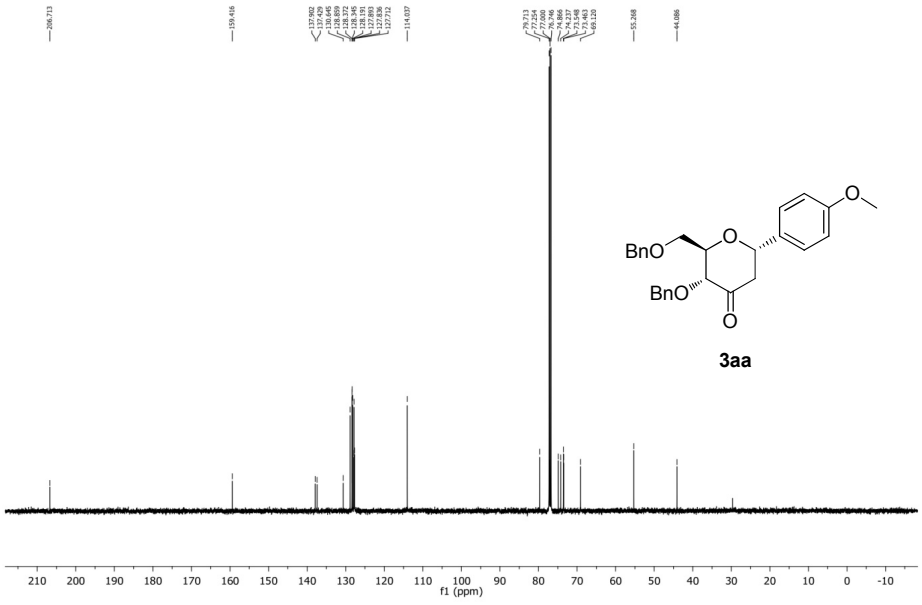


Figure 3.2 ^{13}C NMR Spectra for **3aa** in **$CDCl_3$**

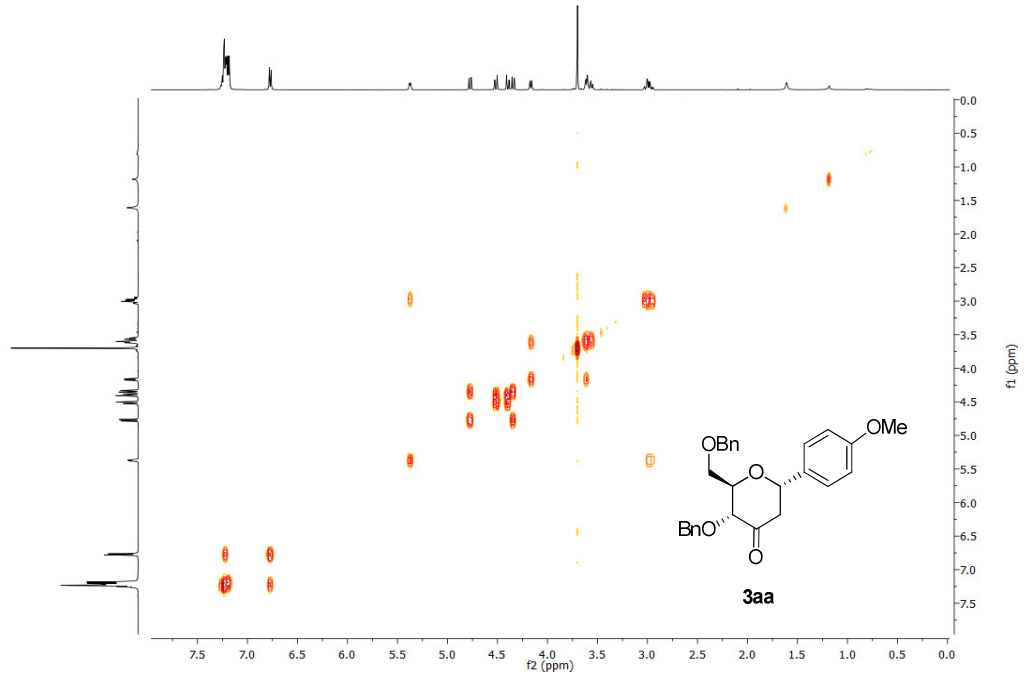


Figure 3.3 COSY Spectra for **3aa** in **$CDCl_3$**

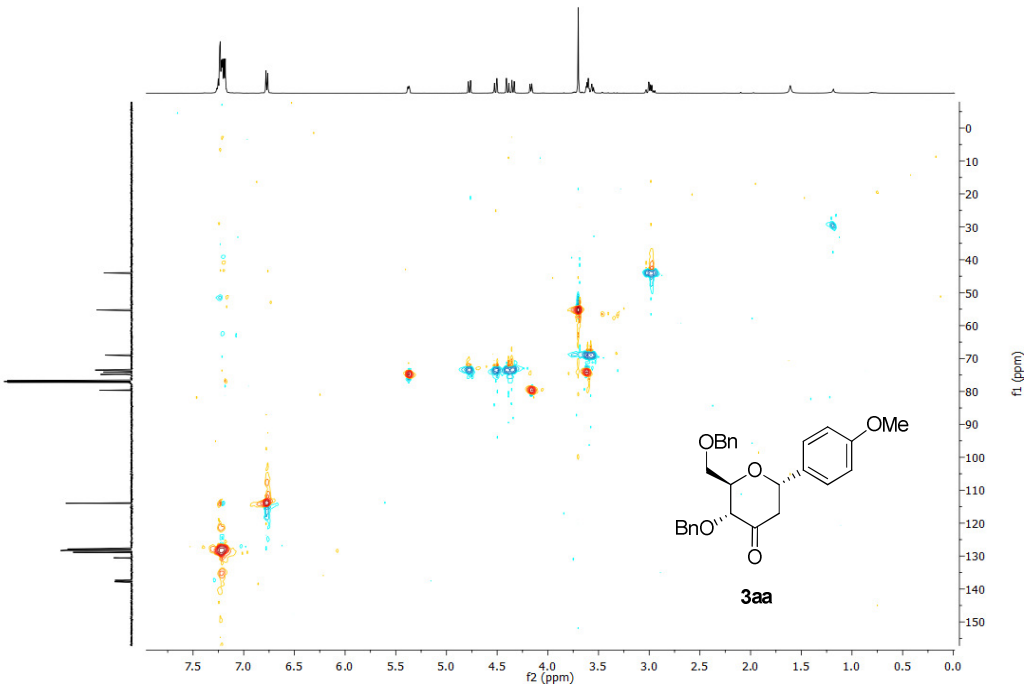


Figure 3.4 HSQC Spectra for **3aa** in **$CDCl_3$**

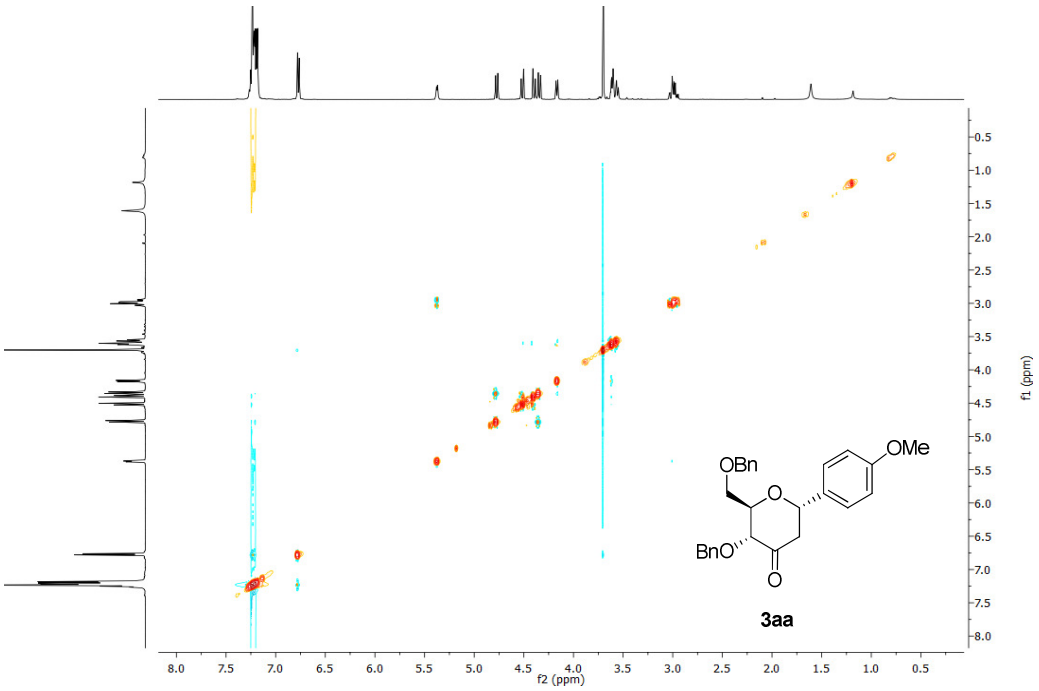


Figure 3.5 NOESY Spectra for **3aa** in **$CDCl_3$**

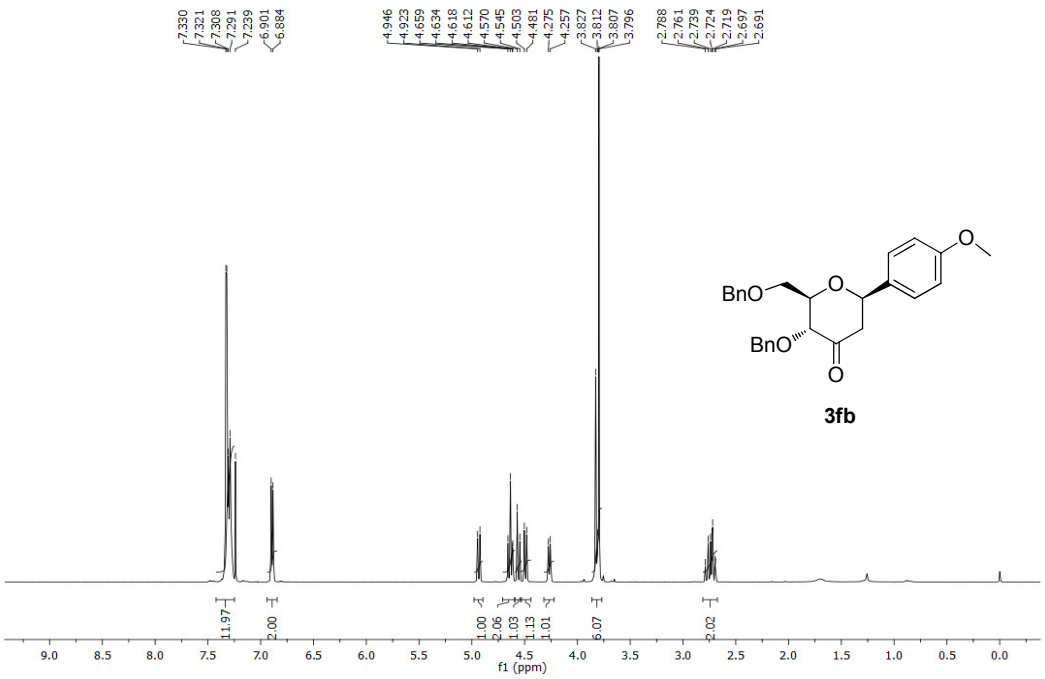


Figure 3.6 ^{1}H NMR Spectra for **3fb** in **$CDCl_3$**

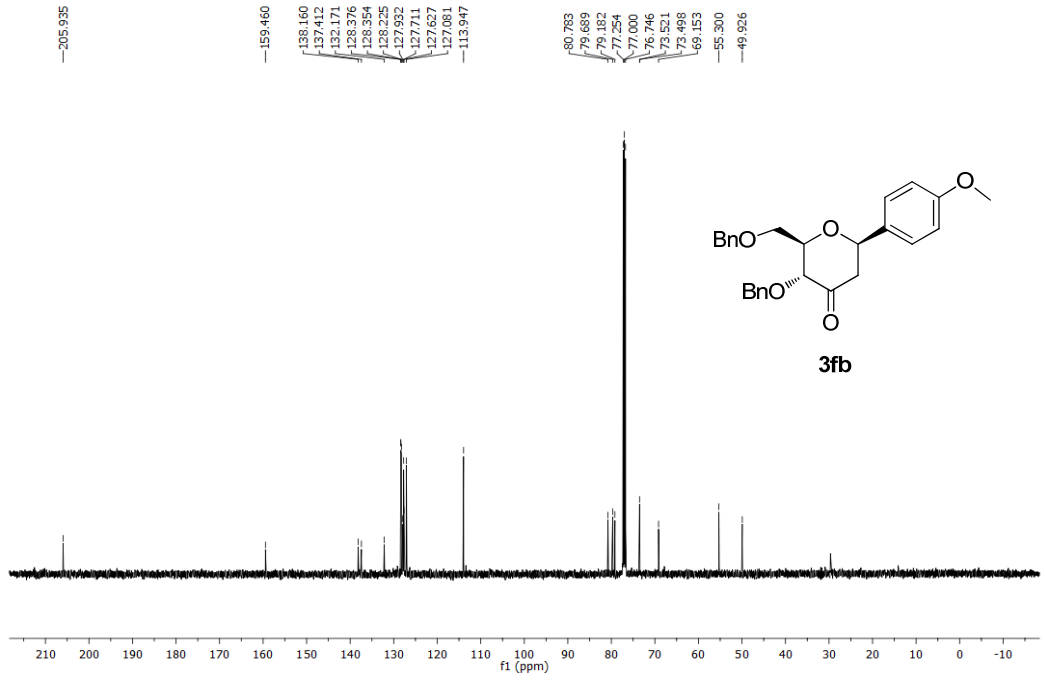


Figure 3.7 ^{13}C NMR spectra for **3fb** in **$CDCl_3$**

3.16 References

[1]. (a) D. E. Levy, C. Tang, The Chemistry of *C*-glycosides; Elsevier Science: Tarrytown, NY, 1995; (b) M. H. D. Postema, *C*-Glycoside Synthesis; CRC Press: Ann Arbor, MI, 1995; (c) Y. Du, R. J. Linhardt, I. R. Vlahov, "Recent Advances in Stereo-Selective *C*-Glycoside Synthesis," *Tetrahedron*, **54**(1998) 9913-9959; (d) K. Kitamura, Y. Ando, T. Matsumoto, K. Suzuki, "Total Synthesis of Aryl *C*-Glycoside Natural Products: Strategies and Tactics," *Chemical Reviews,* **118**(2018) 1495-1598; (e) Y. Yang, B. Yu, "Recent Advances in the Chemical Synthesis of *C*-Glycosides," *Chemical Reviews,* **117**(2017) 12281-12356; (f) T. Bililign, B. R. Griffith, J. S. Thorson, "Structure, Activity, Synthesis and Biosynthesis of Aryl-*C*-Glycosides," *Natural product reports,* **22**(2005) 742-60; g) D. C. Koester, M. Leibeling, R. Neufeld, D. B. Werz, "A Pd-Catalyzed Approach to (1→6)-Linked C-Glycosides," *Organic Letters,* **12**(2010) 3934-3937; h) D. C. Koester, D. B. Werz, "Sonogashira-Hagihara Reactions of Halogenated Glycals," *Beilstein Journal of Organic Chemistry,* **8**(2012) 675-682; i) D. C. Koester, E. Kriemen, D. B. Werz, "Flexible Synthesis of 2-Deoxy-*C*-Glycosides and (1→2)-, (1→3)-, and (1→4)-Linked C-Glycosides," *Angewandte Chemie International Edition,* **52**(2013) 2985-2989.

[2]. (a) J. Rohr, R. Thiericke, "Angucycline Group Antibiotics," *Natural product reports.* **9**(1992) 103-37; (b) H. Nadig, U. Sèquin, "Isolation and Structure Elucidation of Some Components of the Antitumor Antibiotic Mixture 'Rubiflavin'," *Helvetica Chimica Acta,* **70**(1987) 1217-1228.

[3]. (a) D. E. Kaelin, O. D. Lopez, S. F. Martin, "General Strategies for the Synthesis of the Major Classes of *C*-Aryl Glycosides," *Journal of American Chemical Society,* **123**(2001) 6937-6938; (b) F. Zhu, J. Rodriguez, T. Yang, I. Kevlishvili, E. Miller, D. Yi, S. O'Neill, M. J. Rourke, P. Liu, M. A. Walczak, "Glycosyl Cross-Coupling of Anomeric Nucleophiles: Scope, Mechanism, and Applications in the Synthesis of Aryl *C*-Glycosides," *Journal of American Chemical Society,* **139**(2017) 17908-17922; (c) D. Yi, F. Zhu, M. A. Walczak, "Glycosyl Cross-Coupling with Diaryliodonium Salts: Access to Aryl *C*-Glycosides of Biomedical Relevance," *Organic Letters,* **20**(2018) 1936-1940;

[4]. (a) C. F. Liu, D. C. Xiong, X. S. Ye, "Ring Opening–Ring Closure" Strategy for the Synthesis of Aryl-*C*-glycosides," **79**(2014) 4676-4686; (b) A. K. Kusunuru, C. K. Jaladanki, M. B. Tatina, P. V. Bharatam, D. Mukherjee, "TEMPO-Promoted Domino Heck–Suzuki Arylation: Diastereoselective Cis-Diarylation of Glycals and Pseudoglycals," *Organic Letters,* **17**(2015) 3742-3745; (c) D. C. Xiong, L. H. Zhang, X. S. Ye, "Oxidant-Controlled Heck-Type C-Glycosylation of Glycals with Arylboronic Acids: Stereoselective Synthesis of Aryl 2-Deoxy-C-glycosides," *Organic Letters,* **11**(2009) 1709-1712; (d) Y. G. Bai, L. M. H. Kim, H. Z. Liao, X. W. Liu, "Oxidative Heck Reaction of Glycals and Aryl Hydrazines: A Palladium-Catalyzed *C*-Glycosylation," *Journal of Organic Chemistry*, **78**(2013) 8821-8825; (e) H. H. Li,; X. S. Ye, "Regio- and Stereo-Selective Synthesis of Aryl 2-Deoxy-*C*-Glycopyranosides By Palladium-Catalyzed Heck Coupling Reactions of Glycals and Aryl Iodide," *Organic & Biomolecular Chemistry,* **7**(2009) 3855-3861; (f) S. H. Xiang,; S. T. Cai,; J. Zeng,; X. W. Liu,

"Regio- and Stereoselective Synthesis of 2-Deoxy-C-aryl Glycosides via Palladium Catalyzed Decarboxylative Reactions," *Organic Letters,* **13**(2011) 4608-4611; (g) J. Ramnauth, O. Poulin, S. Rakhit, S. P. Maddaford, "Palladium(II) Acetate Catalyzed Stereoselective *C*-Glycosidation of Peracetylated Glycals with Arylboronic Acids," *Organic Letters,* **3**(2001) 2013-2015; (h) A. K. Kusunuru, S. K. Yousuf, M. Tatina, D. Mukherjee, "Desulfitative *C*-Arylation of Glycals by Using Benzenesulfonyl Chlorides," *European Journal of Organic Chemistry,* (2015) 459-462; (i) T. Mabit, A. Siard, F. Legros, S. Guillarme, A. Martel, J. Lebreton, F. Carreaux, G. Dujardin, S. Collet, "Stereospecific *C*-Glycosylation by Mizoroki-Heck Reaction: A Powerful and Easy-to-Set-Up Synthetic Tool to Access α- and β-Aryl-C-Glycosides," *Chemistry A European Journal,* **24**(2018) 14069-14074.

[5]. (a) A. Roglans, A. Pla-Quintana, M. Moreno-Manas, "Diazonium Salts as Substrates in Palladium-Catalyzed Cross-Coupling Reactions," *Chemical Reviews,* **106**(2006) 4622-4643; (b) F. Y. Mo, G. B. Dong, Y. Zhang, J. B. Wang, "Recent Applications of Arene Diazonium Salts In Organic Synthesis," *Organic & Biomolecular Chemistry,* **11**(2013) 1582-1593; (c) A. P. Colleville, R. A. J. Horan, S. Olazabal, N. C. O. Tomkinson, "*C–H* Arylation of Heterocyclic *N*-Oxides Through in Situ Diazotisation Of Anilines without Added Promoters: A Green And Selective Coupling Process," *Organic Process Research & Development,* **20**(2016) 1283−1296; (d) J. A. Murphy, F. Rasheed, S. J. Roome, N. Lewis, "Termination of Radical-Polar Crossover Reactions by Intramolecular Nucleophiles," *Chemical Communication,* (1996) 737-738; (e) I. P. Beletskaya, A. S. Sigeev, A. S. Peregudov, P. V. Petrovskii, "Catalytic Sandmeyer Bromination," *Synthesis*, (2007) 2534-2538

[6]. (a) J. Masllorens, S. Bouquillon, A. Roglans, F. Henin, J. Muzart, "The Heck-Type Arylation of Allylic Alcohols With Arenediazonium Salts," *Journal of Organometallic Chemistry,* **690**(2005) 3822-3826; (b) Li. Zhilong, T. F. Leung, R. Tong, "Total Syntheses of (±)-Musellarins A–C," *Chemical Communication,* **50**(2014) 10990-10993; (c) C. Frota, E. C. Polo, H. Esteves, C. R. D. Correia, "Regioselective and Stereoselective Heck–Matsuda Arylations of Trisubstituted Allylic Alkenols and Their Silyl and Methyl Ether Derivatives To Access Two Contiguous Stereogenic Centers: Expanding the Redox-Relay Process and Application in the Total Synthesis of meso-Hexestrol," *Journal of Organic Chemistry,* **83**(2018) 2198-2209; (d) P. R. R. Meira, A. V. Moro, C. R. D. Correia, "Stereoselective Heck-Matsuda Arylations of Chiral Dihydrofurans with Arenediazonium Tetrafluoroborates; An Efficient Enantioselective Total Synthesis of (-)-Isoaltholactone," *Synthesis-Stuttgart,* (2007) 2279-2286; (e) E. A. Severino, E. R. Costenaro, A. L. L. Garcia, C. R. D. Correia, "Probing the Stereoselectivity of the Heck Arylation of Endocyclic Enecarbamates with Diazonium Salts. Concise Syntheses of (2S,5R)-Phenylproline Methyl Ester and Schramm's C-Azanucleoside," *Organic Letters,* **5**(2003) 305-308; (f) D. F. Oliveira, E. A. Severino, C. R. D. Correia, "Heck Reaction of Endocyclic Enecarbamates with Diazonium Salts. Formal Enantioselective Syntheses of Alkaloids (-)-Codonopsine And (-)-Codonopsinine, and the Synthesis of a New *C*-

Aryl Azasugar," *Tetrahedron Letters,* **40**(1999) 2083-2086; (g) A. H. L. Machado, M. A. de Sousa, D. C. S. Patto, L. F. S. Azevedo, F. I. Bombonato, C. R. D. Correia, "The Scope of The Heck Arylation of Enol Ethers With Arenediazonium Salts: A New Approach to the Synthesis Of Flavonoids, *Tetrahedron Letters,* **50**(2009) 1222-1225; (h) F. A. Siqueira, J. G. Taylor, C. R. D. Correia, "The First Intramolecular Heck–Matsuda Reaction and its Application in the Syntheses of Benzofurans and Indoles," *Tetrahedron Letters,* **51**(2010) 2102-2105; (i) P. Prediger, A. R. D. Silva, C. R. D. Correia, "Construction of 3-Arylpropylamines Using Heck Arylations. The Total Synthesis of Cinacalcet Hydrochloride, alverine, and tolpropamine," *Tetrahedron,* **70**(2014) 3333-3341; (j) B. Schmidt, F. Holter, A. Kelling, U. Schilde, "Pd-Catalyzed Arylation Reactions with Phenol Diazonium Salts: Application in the Synthesis of Diarylheptanoids," *Journal of Organic Chemistry,* **76**(2011) 3357-3365; (k) B. Schmidt, F. A Holter, "A Stereodivergent Synthesis of All Stereoisomers of Centrolobine: Control of Selectivity by a Protecting-Group Manipulation," *Chemistry A European Journal,* **15**(2009) 11948-11953; (l) B. Schmidt, A. Biernat, "Synthesis of 3-Deoxy Glycals via Tandem Metathesis Sequences and Their Use in an Intermolecular Heck Arylation," *European Journal of Organic Chemistry,* (2008) 5764-5769; (m) B. Schmidt, "Heck Arylation of Cyclic Enol Ethers with Aryldiazonium Salts: Regio- and Stereoselective Synthesis of Arylated Oxacycles," *Chemical Communication,* (2003) 1656-1657; (n) B. A. Schmidt, "A de Novo Synthesis of 2,6-Dideoxy-*C*-aryl Glycosides Based on Ring Closing Metathesis and Diastereoselective Epoxide Cleavage/Anomerization Reactions," *Organic Letters,* **2**(2000) 791-794.

[7]. A. K. Singh, J. Kandasamy, "Palladium Catalyzed Stereocontrolled Synthesis of *C*-Aryl Glycosides Using Glycals And Arenediazonium Salts at Room Temperature," *Organic & Biomolecular Chemistry,* **16**(2018) 5107-5112.

[8]. S. Tang, Q. Zheng, D. C. Xiong, S. Jiang, Q. Li, X. S. Ye, "Stereocontrolled Synthesis of 2-Deoxy-*C*-glycopyranosyl Arenes Using Glycals and Aromatic Amines," *Organic Letters,* **20**(2018) 3079-3082.

[9]. (a) P. F. Li, X. D. Jia, "*tert*-Butyl Nitrite (TBN) as a Versatile Reagent in Organic Synthesis," *Synthesis,* **50**(2018) 711-722; (b) F. Csende, "Alkyl Nitrites as Valuable Reagents in Organic Synthesis," *Mini-Reviews in Organic Chemistry,* **12**(2015) 127-148; (c) L. M. He, G. Y. S. Qiu, Y. Q. Gao, J. Wu, "Removal of Amino Groups From Anilines Through Diazonium Salt-Based Reactions," *Organic & Biomolecular Chemistry,* **12**(2014) 6965-6971; (d) N. Oger, M. d'Halluin, E. L. Le Grognec, F. X. Felpin, "Using Aryl Diazonium Salts in Palladium-Catalyzed Reactions under Safer Conditions," *Organic Process Research & Development,* **18**(2014) 1786-1801.

[10]. (a) K. Barral, A. D. Moorhouse, J. E. Moses, "Efficient Conversion of Aromatic Amines into Azides: A One-Pot Synthesis of Triazole Linkages, *Organic Letters,* **9**(2007) 1809-1811; (b) B. Schmidt, N. Elizarov, N. Riemer, F. Holter, "Acetamidoarenediazonium Salts: Opportunities for Multiple Arene Functionalization," *European Journal of Organic Chemistry,* (2015) 5826-5841; (c) M. P. Doyle, W. J. Bryker, "Alkyl Nitrite-Metal Halide Deamination

Reactions. 6. Direct Synthesis of Arenediazonium Tetrafluoroborate Salts From Aromatic Amines, *tert*-Butyl nitrite, and Boron Trifluoride Etherate in Anhydrous Media," *Journal of Organic Chemistry,* **44**(1979) 1572-1574.

[11]. P. Chaudhary, S. Gupta, N. Muniyappan, S. Sabiah, J. Kandasamy, "An Efficient Synthesis of *N*-Nitrosamines Under Solvent, Metal and Acid Free Conditions Using *tert*-Butyl Nitrite," *Green. Chemistry,* **18**(2016) 2323-2330.

[12]. S. Chauhan, P. Chaudhary, A. K. Singh, P. Verma, V. Srivastava, J. Kandasamy, "*tert*-Butyl Nitrite Induced Radical Dimerization of Primary Thioamides and Selenoamides at Room Temperature," *Tetrahedron Letters,* **59**(2018) 272-276.

[13]. S. Azeez, P. Chaudhary, P.Sureshbabu, S. Sabiah, J. Kandasamy, "*tert*-Butyl Nitrite Mediated Nitrogen Transfer Reactions: Synthesis of Benzotriazoles and Azides at Room Temperature," *Organic & Biomolecular Chemistry,* **16**(2018) 6902-6907.

[14]. P. Chaudhary, S. Gupta, N. Muniyappan, S. Sabiah, J. Kandasamy, "Regioselective Nitration of *N*-Alkyl Anilines using *tert*-Butyl Nitrite under Mild Condition," *Journal of Organic Chemistry,* **84**(2019) 104-119.

[15]. P. Sureshbabu, S. Azeez, P. Chaudhary, J. Kandasamy, "*tert*-Butyl Nitrite Promoted Transamidation of Secondary Amides Under Metal And Catalyst Free Conditions," *Organic & Biomolecular Chemistry,* **17**(2019) 845-850.

[16]. J. Zeng, G. Sun, W. Yao, Y. Zhu, R. Wang, L. Cai, K. Liu, Q. Zhang, X. W. Liu, Q. Wan, "3-minodeoxypyranoses in Glycosylation: Diversit-Oriented Synthesis and Assembly in Oligosaccharides," *Angewandte Chemie International Edition English,* **56**(2017) 5227-5231.

[17]. H. Hattori, J. Roesslein, P. Caspers, K. Zerbe, H. M. Ondozabal, D. Ritz, G. Rueedi, K. Gademann, "Total Synthesis and Biological Evaluation of the Glycosylated Macrocyclic Antibiotic Mangrolide A," *Angewandte Chemie International Edition,* **57**(2018) 11020-11024.

[18]. A.p. Wang, C. Liu, S. Yang, Z. Zhao, P. Lei, "An Efficient Method to Synthesize Novel 5-*O*-(6'-Modified)-Mycaminose 14-Membered Ketolides," *Tetrahedron,* **72**(2016) 285-297.

[19]. G. M. J. L. Snow, N. Araujo, S. F. Jenkinson, R. F. Martinez, Y. Shimada, C. Y. Yu, A. Kato, G. W. J. Fleet, "Azetidine Iminosugars from the Cyclization of 3,5-Di-*O*-triflates of α-Furanosides and of 2,4-Di-*O*-triflates of β-Pyranosides Derived from Glucose, *Organic. Letters,* **14**(2012) 2142-2145.

[20]. R. Xiao, E. L. Dane, J. Zeng, C. J. McKnight, M. W. Grinsta, "Synthesis of Altrose Poly-amido-saccharides with β-*N*-(1→2)-d-amide Linkages: A Right-Handed Helical Conformation Engineered in at the Monomer Level," *Journal of American Chemical Society,* **139**(2017) 14217-14223.

[21]. A. Chennaiah, A. K. Verma, Y. D. Vankar, "TEMPO-Catalyzed Oxidation of 3-O-Benzylated/Silylated Glycals to the Corresponding Enones Using a PIFA-Water Reagent System," *Journal of Organic Chemistry,* **83**(2018) 10535-10540.

[22]. S. Kopper, I. Lundt, C. Pedersen, J. Thiem, "Synthesen Gezielt Alkylierter Enolether der L-ribo-Reihe," *Liebigs Annalender Chemie,* **(1987)** 531-535.

[23]. J. M. Beau, G. Jaurand, J. Esnault, P. Sinay, "Synthesis of the Disaccharide C−D Fragment Found in Everninomicin-C and -D, Avalamycin-A and -C and

Curamycin-A: Stereochemistry at the Spiro-ortholactone Center," *Tetrahedron Letters,* **28**(1987) 1105-1108.

[24]. O. Loiseleur, D. Ritson, M. Nina, P. Crowley, T. Wagner, S. Hanessian, "Ring-Modified Analogues and Molecular Dynamics Studies To Probe the Requirements for Fungicidal Activities of Malayamycin A and Its *N*-Nucleoside Variants," *Journal of Organic Chemistry,* **72(2007)** 6353-6363.

[25]. J. Zhaoa, S, Weia, X, Ma, H, Shao, "A Simple and Convenient Method for the Synthesis of Pyranoid Glycals," *Carbohydrate Research,* **345**(2010) 168-171.