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The anomerisation of glycosidic linkages

By

Mark Farrell

A Thesis presented to

The National University of Ireland

For the degree of

Doctor of Philosophy

Based on the research carried out in the

School of Chemistry,

National University of Ireland,

Galway

Under the supervision and direction of

Prof. Paul V. Murphy

National University of Ireland,

Galway

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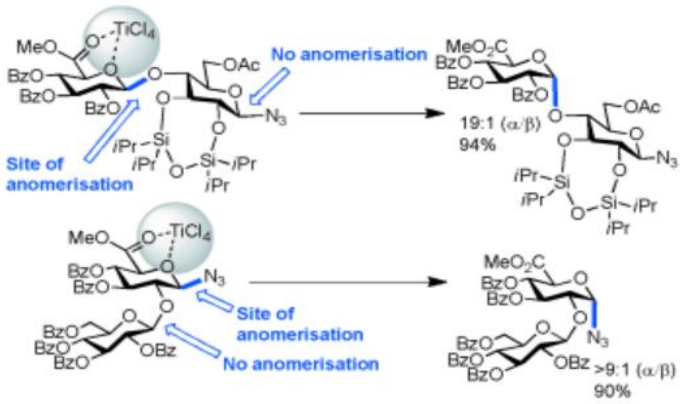
To my beautiful daughter Emilia, I dedicate this work to you.

Abstract

This thesis deals with the anomerisation of glycosidic linkages using $TiCl_4$ and $SnCl_4$. Methods involving the Lewis acid induced anomerisations of glycosides have been published over the past decade, however this methodology has not been widely utilised in carbohydrate chemistry due to low yields, large variations in selectivity, and the need for specific functional groups (e.g., carbamate). It is felt that a better understanding of the anomerisation reaction could be achieved by probing the effects of protecting groups and pushing the reaction to it limits.

Chapter 1 deals with the anomerisation of glycosyl azides. Previous work by Murphy *et al*. has led to reasonable but not high selectivity using $SnCl_4$. Since this work was carried out a seminal publication by Murphy *et al*. demonstrated the advantages of using $TiCl_4$ in anomerisation reactions. The application of $TiCl_4$ and varying the carboxylic functionality from acid to ester gave the desired high selectivities in good yields. Chapter 2 applies this successful approach to the anomerisation of disaccharide substrates, resulting in regioselective anomerisations and giving the desired α-products in high selectivities and yields.



Scheme 1: the anomerisation of glycosyl azides and disaccharides

Chapter 3 deals with the influence of protecting groups on the rate of the anomerisation reaction. The rate of anomerisation for has been quantified for 34 substrates in an attempt to elucidate the influence of the steric and electronic effects. It was evident from the results obtained that both steric and electronic effects have an influence on the rate of anomerisation.

Table of Contents

Symbols and Abbreviations

α	alpha
β	beta
δ	chemical shift in ppm downfield from TMS
$[\alpha]_D$	specific rotation
°C	degrees Celsius
2,2-DMP	2,2-dimethoxypropane
Å	Ångstrom
Ac	acetate
Ac_2O	acetic anhydride
AcCl	acetyl chloride
AcOH	acetic acid
AgOTf	silver triflate
BAIB	(diacetoxyiodo)benzene
$BF_3{\cdot}OEt_2$	boron trifluoride diethyl etherate
Bn	benzyl
BnBr	benzyl bromide
Bu	butyl
Bu_4NHSO_4	tetrabutylammonium hydrogen sulfate
Bu_4NI	tetrabutylammonium iodide
Bu_4NN_3	tetrabutylammonium azide
Bz	benzoate

BzCl	benzoyl chloride
COSY	Correlation Spectroscopy
d	doublet
D_2O	deuterium oxide
DBU	1,8-diazabicycloundec-7-ene
dd	Doublet of doublets
ddd	Doublet of doublets of doublets
DEPT	Distortionless Enhancement by Polarisation Transfer
DMAP	4-dimethylaminopyridine
DMC	2-chloro-1,3-dimethylimidazolinium chloride
DMF	dimethylformamide
DMTST	N,N-dimethyl-N'-p-tolyl-sulfamide
dt	doublet of triplets
ES-HRMS	High-Resolution Mass Spectrometry - Electrospray Ionization
Et_3N	triethylamine
Et_3SiH	triethylsilane
EtOAc	ethylacetate
FT-IR	Fourier Transform Infrared (spectroscopy)
gHMBCAD	Heteronuclear Multiple Bond Correlation
gHSQCAD	Heteronuclear Single Quantum Correlation
h	hours

HPLC	High Performance Liquid Chromatography
Hz	hertz
J	coupling constant, in Hz
m	multiplet
M	Molar
M^+	Mass of the molecular ion (mass spectrometry)
Me	methyl
Me_4Si	tetramethylsilane
MeOH	methanol
MHz	Megahertz
min	minutes
mL, μL	milliliter, microliter
mol, mmol	mole, milimole
MP	methoxyphenyl
NBS	*N*- bromosuccinimide
NIS	*N*- iodosuccinimide
NMR	Nuclear Magnetic Resonance
NOE	Nuclear Overhauser Effect
NOESY	Nuclear Overhauser Effect Spectroscopy
OTf	triflate
Ph	phenyl

Piv	pivaloyl
ppm	parts per million
Py	pyridine
q	quartet
RT	room temperature
s	singlet
S_N2	bimolecular nucleophilic substitution
t	triplet
TBAF	tetrabutylammoniumflouride
TBDPS	*tert*-butyldiphenylsilyl
TBS	*tert*-butyldimethylsilyl
td	triplet of doublets
TEMPO	2,2,6,6-Tetramethyl-1-piperidinyloxy
TfOH	trifluoromethanesulfonic acid
TLC	Thin Layer Chromotography
TMSI	trimethylsilyl iodide
$TMSN_3$	trimethylsilyl azide
TMSOTf	trimethylsilyl trifluoromethanesulfonate

Chapter 1: Introduction to carbohydrate chemistry and anomerisation

1.1 Introduction to carbohydrates

Previously looked upon as merely structural and energy storage biomolecules, carbohydrates are now seen clearly to be among the essential classes of biomolecules. Carbohydrates are the most abundant class of biomolecules found in nature and can be found in various forms, spanning from the simple monosaccharide to complex polysaccharides and glycoconjugates.[1–3]

In the past 60 years carbohydrates have been implicated in many biological processes such as cellular proliferation, viral and bacterial infection, cell-cell recognition, fertilization, embryogenesis, neuronal development and hormone activities[4–8]. The importance of carbohydrates has lead to an ever growing area of research, which is receiving more attention from the scientific community and the pharmaceutical industry, due to the potential to discover possible drug candidates. As it stands, over 50 synthetically prepared FDA approved drugs contain carbohydrates, while many more have evolved from carbohydrates with the use of medicinal chemistry[9]. In the case of some mono-, di- and trisaccharide conjugates, removal of the carbohydrate moiety greatly diminished the therapeutic value of the drug[9].

One major issue is the availability of the biologically important glycans. Although they are the most abundant class of biomolecules, their diversity and complexity, which is taken advantage of in signalling systems, results in minute quantities of a single molecule forms being available for isolation[10]. It is at this point where synthetic carbohydrate chemistry enters the fray. Synthesis has been used as a tool to prepare adequate quantities of well defined natural glycans to probe their functional roles[1]. It is also a leading tool in the preparation of carbohydrate based therapeutics, due to the possibility of producing not just the natural glycans but various analogous glycans and glycojugates.

In nature oligosaccharide fragments are synthesised inside the cell, in the Golgi apparatus. Monosaccharides are taken up by the cell, converted into activated building blocks which can then be assembled by enzymatic means to form oligosaccharides and these oligosaccharides are then transported to their site of functionality[1].

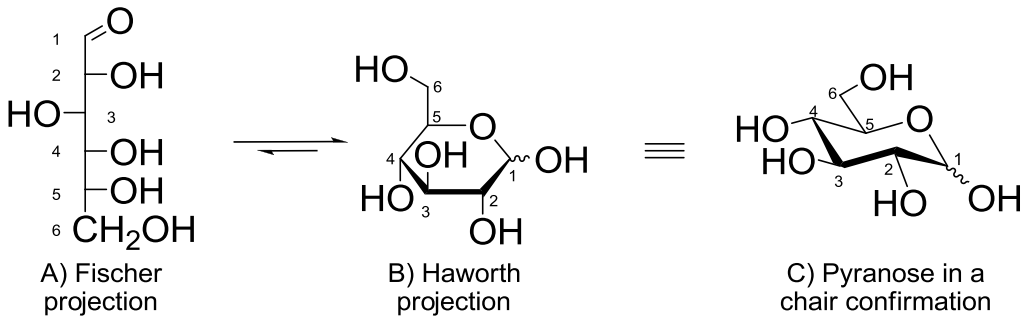
Organic chemists have taken inspiration from nature for the chemical synthesis of oligosaccharides[11]. However, differentiation between the various hydroxyl groups and the need to form stereoselective linkages, a feat which is achieved so elegantly in nature by enzymes, must now be achieved by chemical means. Although the majority of desired glycans are in theory accessible by chemical means, the synthesis of these complex structures is far from trivial. In 1982 Professor Hans Paulsen, declared: "*Although we have now learned to synthesize oligosaccharides, it should be emphasized that each oligosaccharide synthesis remains an independent problem, whose resolution requires considerable systematic research and a good deal of know-how. There are no universal reaction conditions for oligosaccharide syntheses.*"[12]. This is due in no small part to the issue of achieving stereoselectivity when preparing glycosidic linkages[13].

The following sections will introduce some carbohydrate terminology, as well as stereoelectronic effects, and will briefly discuss glycosidic bond formation including approaches towards stereoselective glycoside synthesis.

1.2 Carbohydrate terminology

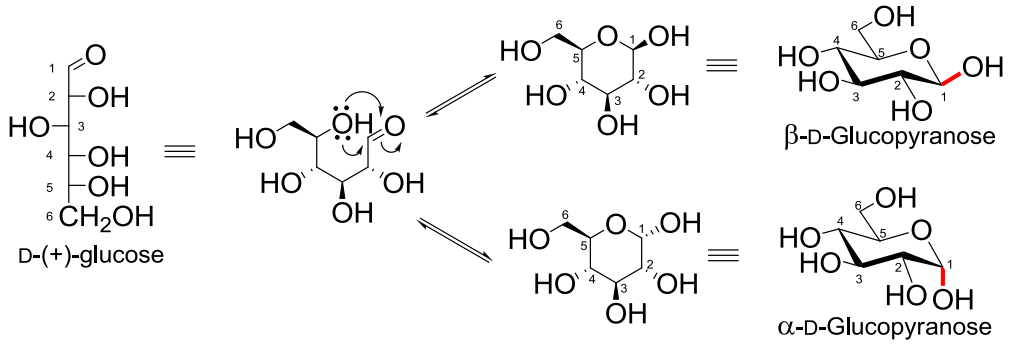
The IUPAC nomenclature for carbohydrates is highly complex and for this reason it shall only be briefly addressed to help further understand the forthcoming concepts. The IUPAC nomenclature for carbohydrates has evolved away from the common systematic naming system used for organic compounds and in many cases trivial names are widely used and trival names are often used[14]. For example (2*R*,3*S*,4*R*,5*R*)-2,3,4,5,6-pentahydroxyhexanal is more commonly referred to as D-glucose. Carbohydrates can exist in cyclic and acyclic forms which can rapidly interconvert in solution, however cyclic forms tend to dominate (Scheme 2)[15,16]. For example an aqueous solution of solution D-glucose, the 5 membered furanose and the acyclic aldehyde, are collectively present to a level less than 1%[16].

Monosaccharides are numbered along the carbon chain of the Fischer projection (A) and this translates to the Haworth projection form (B).



Scheme 2: Cyclisation and carbohydrate numbering

Due to the aforementioned cyclisation of the open chain form, a stereogenic centre is formed which is referred to as the anomeric centre. The two resulting stereoisomers are referred to as α- and β-anomers. The oritation of the anomeric substituent in the Haworth projection determines which anomer is present. If the anomeric substituent is pointing in the Haworth projection then the β-anomer is present, while if it is pointing down the α-anomer is present. The cyclic hemiacetal form of both protected and non-protected carbohydrates can freely interconvert between the axial and equatorial orientations via its non cyclic form (Scheme 3). It is relevant to note that such interconversions do not happen freely when dealing with glycosides and a greater energy barrier must be overcome to achieve anomerisation in such cases.

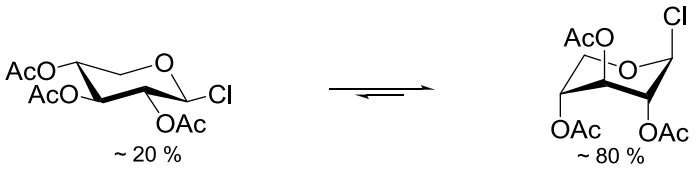


Scheme 3: Interconversion between anomers of glucose

1.2.1 The anomeric effect

During undergraduate chemistry courses, students are taught that substituents on a cyclohexane ring favour an equatorial orientation for steric reasons. However, it

has been shown that carbohydrates and similar systems, show preference for a conformation or configuration yielding an electron withdrawing substituent in an axial orientation at the anomeric centre, even in the case of bulky substituents (Scheme 4)[17]. This phenomenon is due to a stereoelectronic effect known as the anomeric effect.



Scheme 4: Preference for an EWG to favour an axial conformation[17]

The anomeric effect does not only apply to carbohydrates, but also too many similar systems. The generalized anomeric effect applies to segments of the form R-X-A-Y, where R represents a carbon atom in the ring, X is a heteroatom in the ring which possesses lone pairs, A is the anomeric carbon and Y is an electronegative element or group. It is stated that there is a preference for an electron withdrawing substituent to lie in a gauche rather than in an anti position (Figure 1)[18]. This preference has been explained by electrostatic and molecular orbital models.

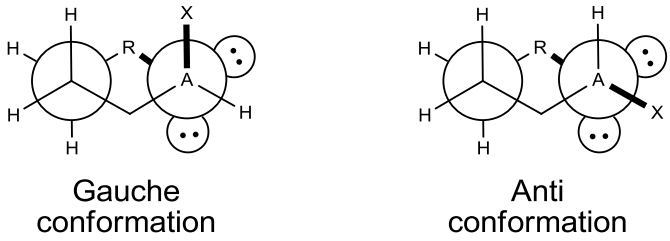


Figure 1: Newman projection depicting gauche and anti conformations[18]

Originally the anomeric effect was explained solely in terms of electrostatic interactions. This model postulated that a minimization of an unfavourable dipole interaction occurs when the electronegative substituent is in an axial orientation[19]. In the axial orientation the dipoles are perpendicular and partially cancel each other out (Figure 2).

Figure 2: Electrostatic model for the anomeric effect

In studies carried out to further reinforce this model the effect of solvent polarity on the anomeric preference showed mixed results, further complicating the theory. It was predicted that a polar solvent would stabilize the more polar equatorial configuration thus driving the equilibrium to favour the equatorial anomer. Studies carried out on 2-methoxy tetrahydropyran followed this trend[20]. However a study using 2-carbomethoxy-1,3-dithiane showed that the axial conformation was preferred in polar solvents at low temperatures[21]. These experiments showed that the electrostatic model was not solely sufficient in explaining the anomeric effect.

The observation, involving the bond lengthening between the anomeric carbon and the aglycon atom, led to the explanation by a molecular orbital model[22]. The stabilization and bond lengthening can be explained as being due to molecular orbital overlap, where the *n*-molecular orbital of the endocyclic oxygen donates electrons into the σ* orbital of the C-X bond (Figure 3). This donation of electrons can only occur when the anomeric substituent is in an axial orientation due to the requirement of the oxygen orbital and the anti-bonding orbital's to be anti-periplanar. The degree of stabilization is inversely proportional to the energy difference between the interacting orbitals. Greatest stabilization is achieved between two orbitals of similar energies[17].

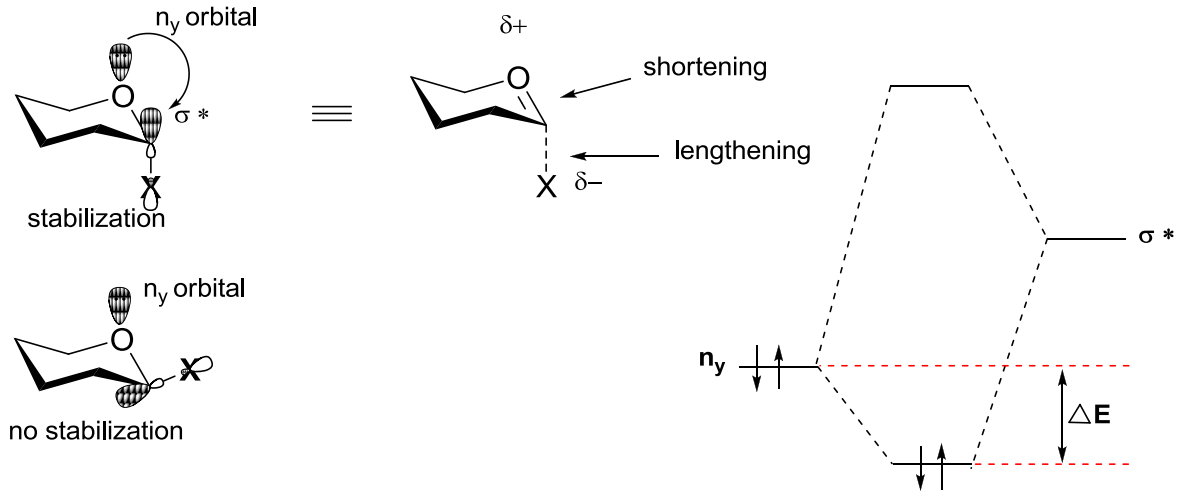


Figure 3: Molecular orbital model

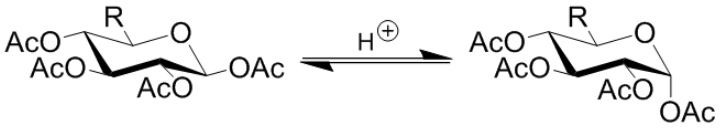
For the purpose of this thesis it is also of interest to note factors which affect the magnitude of the anomeric effect, such as the nature of the aglycon and other ring substituents. The effect of the aglycon's electron withdrawing character has been well studied[17,23]. For example, variation of the anomeric substituent of tri-*O*-benzoate derivatives of xylopyranose, resulted in an increased preference for the $^1C_4$ conformation as the electron withdrawing character of the aglycon increases[17].

X	% of $^1C_4$ conformer
H	19
MeO	26
AcO	47
BzO	50
F	90-100
Cl	98
Br	90-100

Table 1: Conformational equilibria of xylose derivatives[17]

The magnitude of the anomeric effect has also been shown to be influenced by the electronegativity of the equatorial C-5 substituent[18]. A study carried out by

varying the equatorial C-5 substituent of tetra-*O*-acetate derivatives of glucose supports this theory, indicating that electron withdrawing groups increase the anomeric effect[18].



R	Anomeric effect, Kcal/mol
H	1.3
CH_3	1.31
CH_2I	1.35
CH_2Cl	1.43
CH_2OAc	1.45
CH_2OTs	1.75

Table 2: Effect of substituent's at C-5[18]

In compounds with an aglycon, where the atom bonded to the anomeric carbon possesses lone pairs, electron donation may occur in the opposite direction which is known as the exo-anomeric effect. This involves an interaction between the lone pairs of the aglycon and the antibonding orbital of the carbon-ring oxygen bond (Figure 4)[24]. It has been stated that the exo anomeric effect is responsible for influencing glycoside conformation, which is a significant observation when one considers the importance of carbohydrate interactions[25].

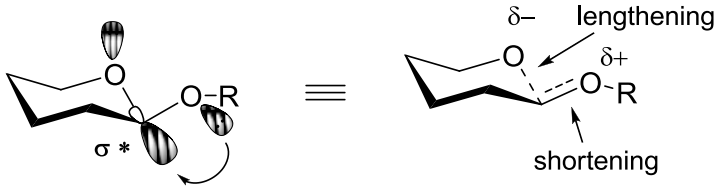
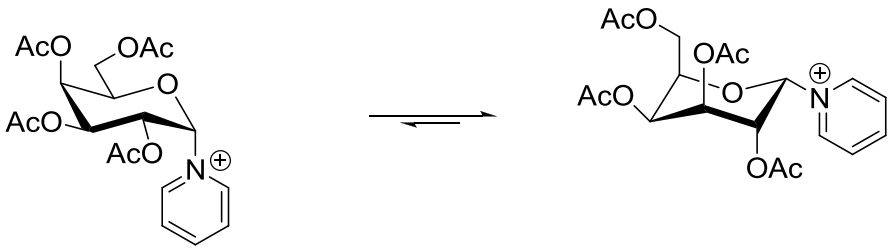


Figure 4: The exo-anomeric effect[24]

Another related stereoelectronic effect, where a positively charged aglycon predominently exists in an equatorial position, is known as the reverse anomeric

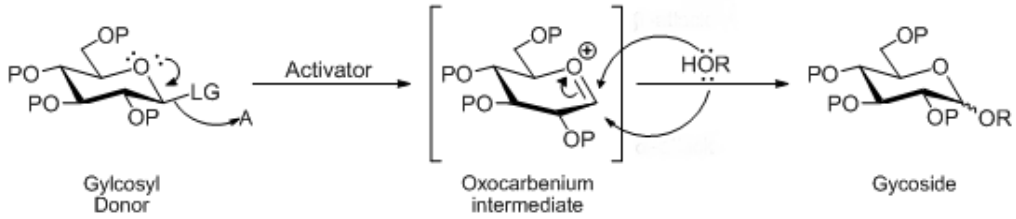
effect (Scheme 5)[26]. This has been the topic of much debate and as of yet no clear theoretical or experimental models fully explain the effect.



Scheme 5: Reverse anomeric Effect[26]

1.2.2 Glycosidic bond formation

As previously stated glycosidic linkages in nature are prepared in a regio- and stereospecific manner by nature's enzymatic toolkit. Glycosyltransferases couple activated carbohydrates (donor) to a hydroxyl group of another carbohydrate (acceptor). The *in vitro* synthesis of glycosidic linkages has been inspired by this type of reaction. However the lack of specificity in chemical synthesis, leads to the requirement of fully protected donors bearing a leaving group at the anomeric centre and a protected glycosyl acceptor bearing a free hydroxyl group (Scheme 6). The most common approach to chemical glycosidation involves the chemoselective activation of the leaving group on the donor molecule, leading to a highly reactive oxocarbenium intermediate. The planar nature of the oxocarbenium intermediate allows for attack from either face, leading to two possible diastereomeric products i.e., α- or β- anomers. It is important to note that although it is long assumed that glycosylation reactions go through an oxocarbenium ion, the intermediate has only been observed by mass spectrometry or in silico [27–31].

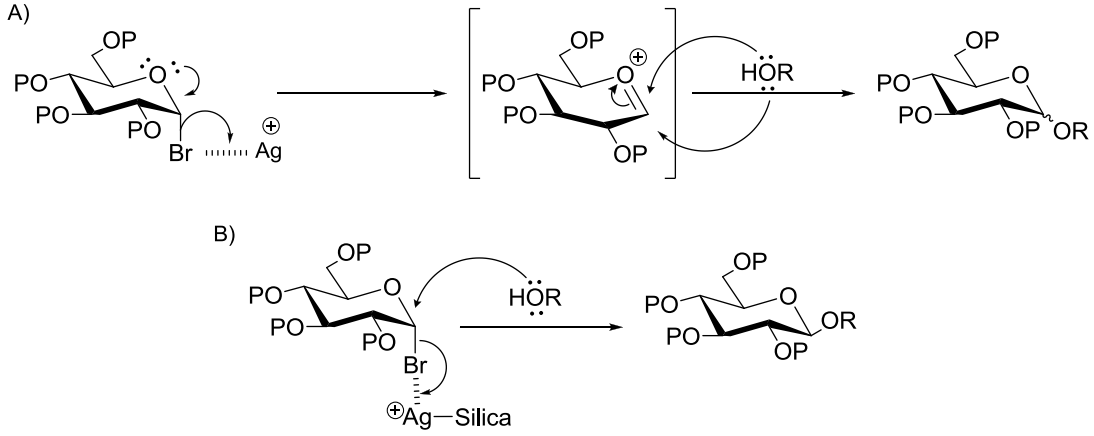


Scheme 6: Generalised glycosylation reaction

The nature of the anomeric leaving group has a great impact on a glycosylation reaction. Although various types of leaving groups can be found in the literature[32,11], three in particular dominate and shall be discussed briefly:

I. Glycosyl halides

Köenigs-Knorr type glycosylations were first introduced in 1901 and involve the activation of glycosyl bromides and chlorides using halophilic salts (e.g. AgOTf, Ag_2CO_3, HgBr, $Hg(CN)_2$)[33]. The solubility of the salt largely controls the nature of the reaction. Soluble salts are believed to lead to the formation of an oxocarbenium intermediate, which can lead to the formation of either the α- or β-anomer (Scheme 7a). Insoluble salts give the reaction greater S_N2 like character, resulting in an inversion of the stereochemistry at the anomeric centre (Scheme 7b)[34–36].

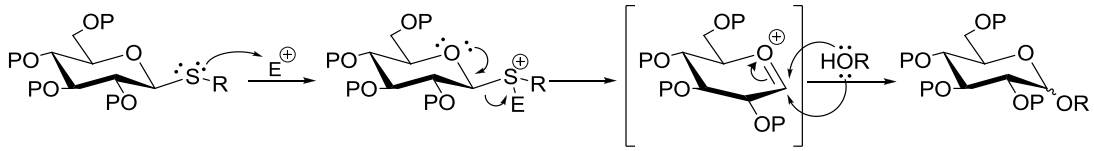


Scheme 7: Köenigs-Knorr glycosylations

II. Thioglycosides.

Thioglycosides were first reported in 1909 by Fischer[37] and have received much attention, even to this day, with various methods of preparation and activation being reported[38]. However it was not until the 1970s that they were utilized in polysaccharide synthesis[39]. The stability, ease of preparation, the abundance of activation systems available and their tunable reactivity, has led to thioglycosides being used widely by the synthetic carbohydrate community[11,38]. The activation of thioglycosides can be carried out in a highly chemoselective manner, with thiophilic reagents being widely utilized (Scheme 8). The NIS/TfOH system introduced by van Boom[40] has been successful for a variety of systems and resulted in a trend towards a variety of halonium based systems[11,38]. Recently organosulfur compounds have been investigated as activating agents, with reagents such as DMTST, MeSOTf and PhSOTf receiving much attention[11]. It has been observed that sulfinates and

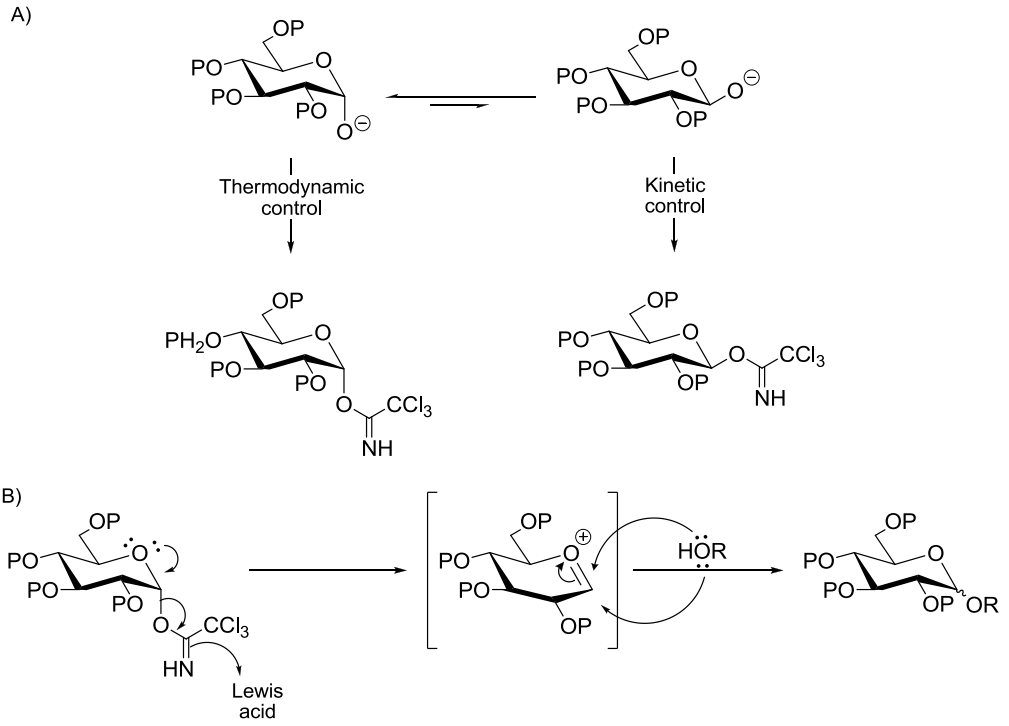
sulfoxides in the presence of Tf_2O can activate 'disarmed' donors, even at low temperatures[41–43]. One notable advantage of the variety of activation methods, particularly at lower temperatures, is the ability to preferentially activate donors, allowing for the further development of one pot strategies[44].



Scheme 8: Thioglycoside activation

III. Trichloroacetimidates

The trichloroacetimidate method, introduced by Schmidt and co-workers in 1980[45], was the first universal glycosylation method which avoided the use of heavy metals and where activation could be achieved with catalytic quantities of Lewis acid. Although primarily used in the synthesis of *O*-glycosides, examples of its use in the synthesis of *S*-, *N*-, *P*- and *C*-glycosides have been described in the literature[46]. Trichloroacetimidate donors are seen to be reasonably stable, but lack the stability associated with thioglycosides. Nonetheless, they are easily prepared from the corresponding hemiacetal with trichloroacetonitrile in the presence of base, with strong bases giving thermodynamically favoured α-imidate and weak bases giving the kinetically favoured β-imidate (Scheme 9a). Mild Lewis acids, such as $BF_3.OEt_2$ and TMSOTf, have been shown to efficiently and catalytically activate anomeric imidates at room temperature and at lower temperatures (Scheme 9b). Such mild conditions have resulted in trichloroacetimidate donors being successfully applied in solid phase carbohydrate synthesis[11].



Scheme 9a) Trichloroacetimidate synthesis; b) Trichloroacetimidate activation

1.2.2 Factors effecting carbohydrate reactivity

The nature of the substituents about the pyranose ring has the largest effect on the carbohydrate reactivity. In 1908, Glover *et al*. reported that the rate of glycoside hydrolysis was directly related the number of axial substituents about the ring[47]. It was initially proposed that this was a result of a decrease in steric strain, leading from the reactant to the planar oxocarbenium intermediate[19]. However, studies carried out by the group of Withers have shown that the rate of glycoside hydrolysis decreases when a hydroxyl group is replaced by a more electron withdrawing fluorine atom, while the corresponding deoxy derivative shows an increase in the rate of hydrolysis[48,49]. These results indicate that the reactivity of glycosides, at least towards hydrolysis, is mainly dependent on the electronic properties of the substituents.

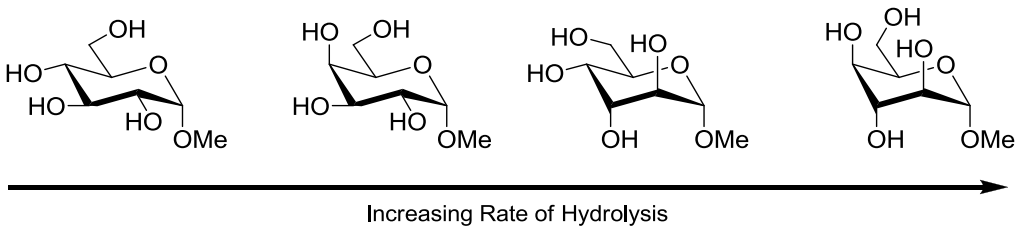


Figure 1: Effect of substituent orientation on the rate of hydrolysis[48]

Bols *et al*. further investigated this phenomenon using a variety of amino sugar model compounds, where they noted that the basicity of the endocyclic nitrogen was similarly dependent on the substituents about the ring[50,51]. They then proposed that equatorial substituents have greater electron withdrawing power than the corresponding axial substituent, due to charge dipole interactions[52]. This interaction, although not fully explained, is believed to be due to the dipole associated with the respective hydroxyl groups. This further explains the rate increase observed with an increasing number of axial substituents, as the more electron rich pyranose can better stabilise the positive charge build up leading to the oxocarbenium ion intermediate. Additional studies also showed that steric effects do not largely impact the reactivity of carbohydrates towards hydrolysis, thus disproving the Edwards hypothesis[53].

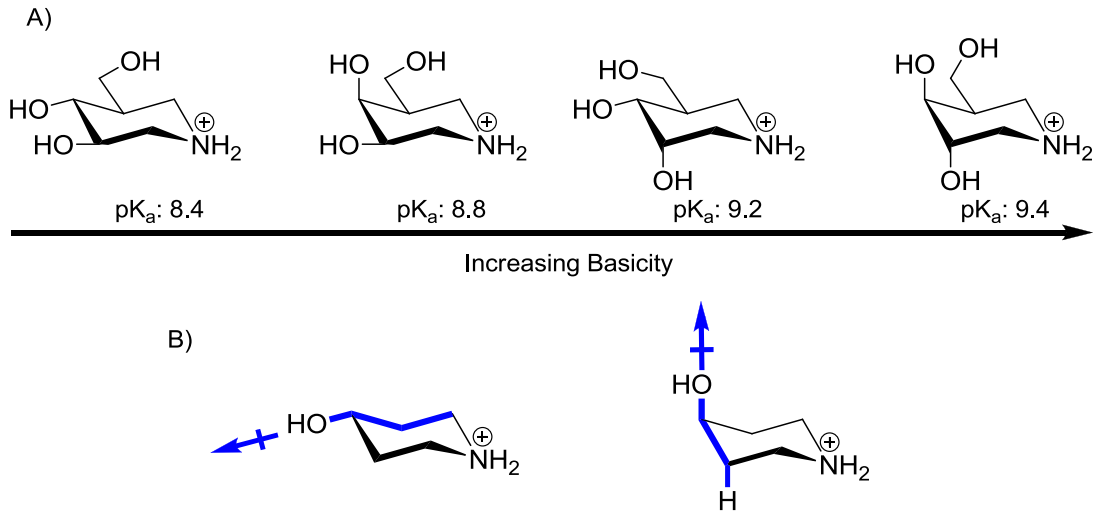
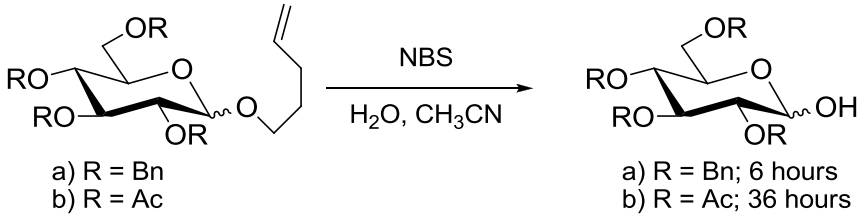


Figure 2a) Basicity of substituted amino sugars[51]; b) Electron withdrawing ability based on dipole effects[52]

As one may imagine, protecting groups can further emphasize the reactivity dependence on electronic effects. The "armed-disarmed" terminology is widely used to depict the reactivity of protected carbohydrates. In 1982, Paulsen noted that "*benzyl protected compounds are always more reactive than the acetylated or benzoylated derivatives*"[12]. Following this, Fraiser-Reid investigated the effect of protecting groups on the oxidative hydrolysis of *n*-pentenyl glycosides, which resulted in the benzyl derivative (armed) reaching completion six times faster than the corresponding acetate derivative (disarmed) (Scheme 10)[54]. The difference in reactivity is due to the inductive properties of the protecting groups. The electron inducing benzyl ethers accelerated activation of the leaving group and they are said

to be activating, whereas electron withdrawing esters, partially retard the activation and are said to be deactivating. In general the same rules apply for the protecting groups on glycosyl acceptors, where the greater electron density about the ring leads to a more reactive acceptor[12,54].



Scheme 10: Effect of protecting groups on the hydrolysis pentenyl glycosides[54]

Conformational changes also influence the reactivity of carbohydrates. For example, glucose in the $^1C_4$ conformation has a greater number of axial substituents than glucose in the $^4C_1$ conformation and thus the $^1C_4$ conformation is more reactive towads hydrolysis. The relative rate of hydrolysis of the 3,6-anhydrosugar shown below exemplifies this[55].

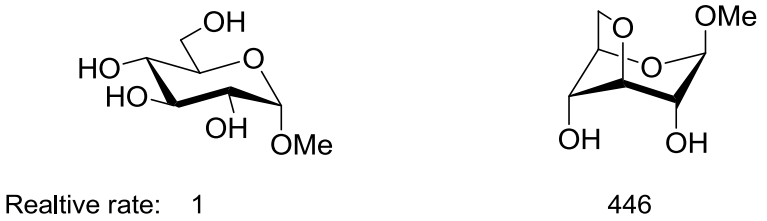
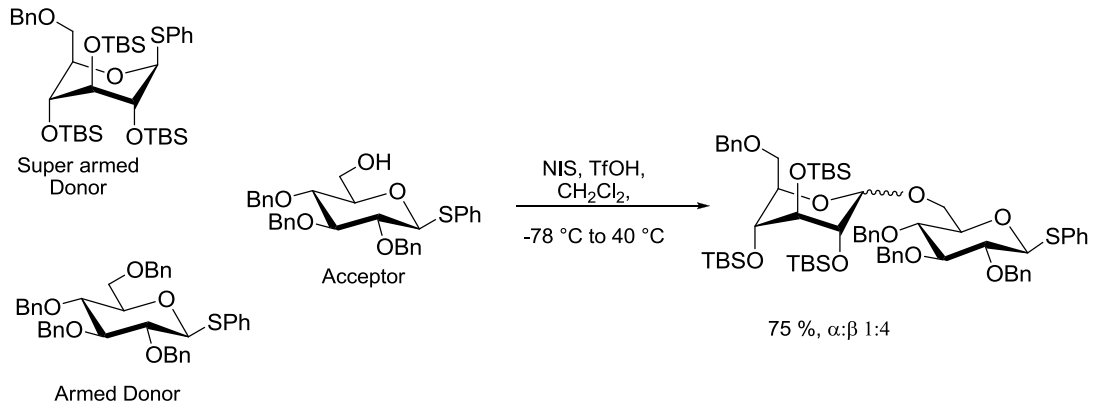


Figure 7: Effects of conformational changes on reactivity[55]

Bulky silyl protecting groups have also been used to induce a ring flip to the more reactive $^1C_4$ conformation[56–58]. Donors and acceptors of this sort are said to be "super armed" and can be selectively activated at low temperature and therefore such compounds are useful in one pot strategies (Scheme 11).



Scheme 11: Competition experiment carried out by Bols *et al*.[56]

1.3 The stereoselective synthesis of glycosides

The formation of a stereoselctive glycoside bond is possibly the biggest challenge in carbohydrate syntheses. Glycosides are classified according the relative and absolute configuration at C-1 and C-2, namely 1,2-*trans* and 1,2-*cis* (Figure 8)[59].

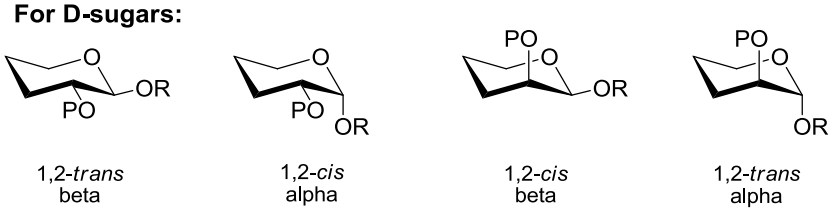


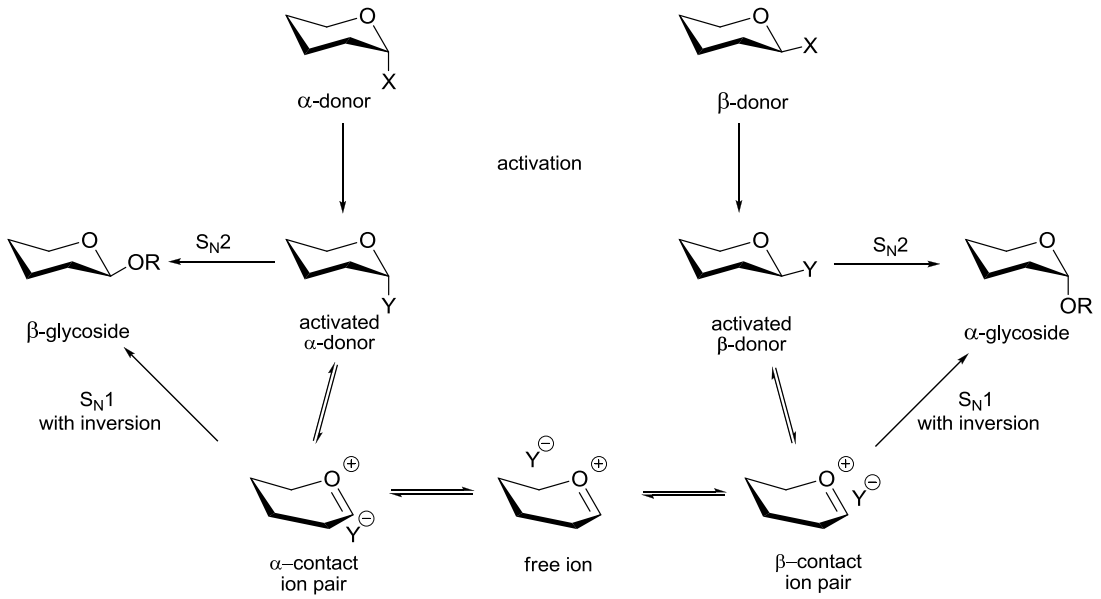
Figure 8: Types of glycosidic linkages

Although this area is well studied and many of the challenges have been overcome[13], there remains a need for a general method of stereoselective glycoside formation. The introduction of a desired stereochemistry is in the majority of cases carried out in the glycosidic bond forming step. An alternative method is to carry out an anomerisation reaction post-glycosidic bond formation.

1.3.1 Stereochemical control in glycosylation reactions

In section 1.2.2, a basic mechanism of glycosylation reactions is presented, however in reality the numerous possible intermediates can impact the stereochemical outcome of a glycosylation reaction (Scheme 12). The activated glycosyl donors can undergo S_N2 type nucleophilic attack leading to inversion of the

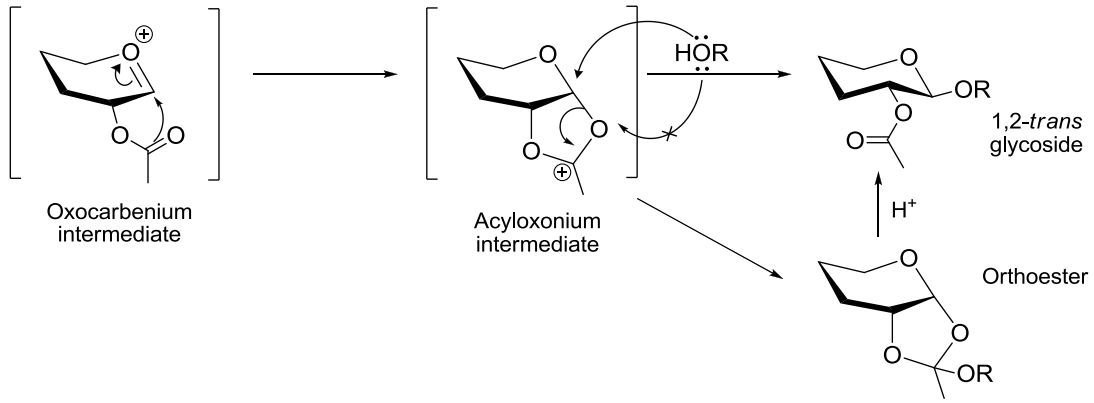
anomeric stereochemistry. Partial dissociation results in contact ion pairs, in which the anion can block nucleophilic attack on the partially associated face, thus leading to an S_N1 with inversion. Upon full dissociation a solvent separated ion pair is thought to occur and the outcome of the reaction is dependent on the relative energy of the transition states leading the product(s). The figure below omits the influence of solvent and directing protecting groups which, in conjunction with the glycosyl donors and the method of activation, play important roles in the stereochemical outcome of a glycosylation reaction. A summary of methods utilized to control the anomeric selectivity in glycosylation reactions shall therefore be presented below.



Scheme 12: Mechanism of glycosylation[i]

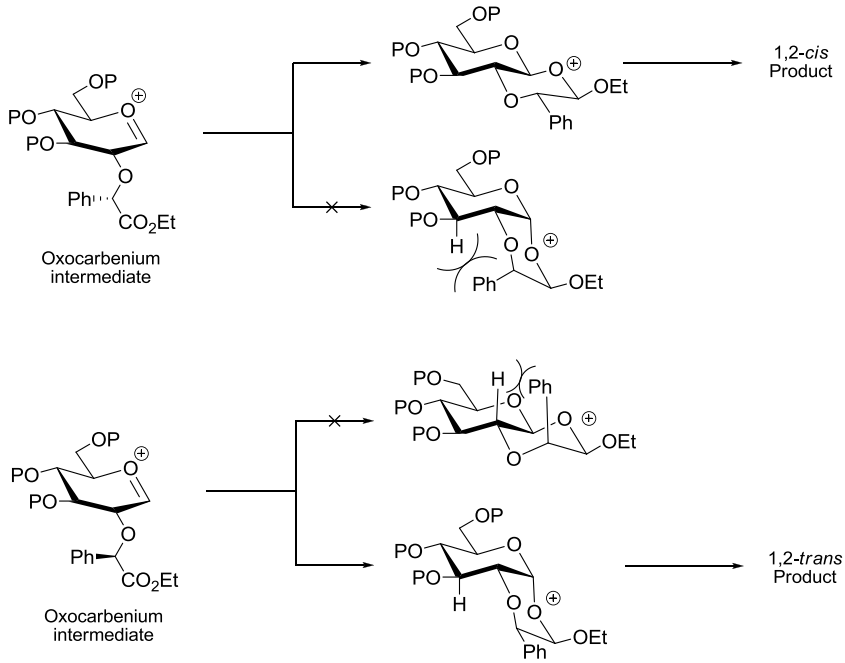
The synthesis of 1,2-*trans* glycosides can be trivial relative to the synthesis of 1,2-*cis* glycosides. The use of a participating protecting group (ester or amide) at position 2, allows for the preparation of a 1,2-*trans* linkage in a highly selective manner. The selectivity is derived from the attack of the carbonyl of the participating group on the oxocarbenium intermediate, giving rise to an acyloxonium intermediate. The S_N2 type nucleophilic attack on this intermediate leads to the 1,2-*trans* product (Scheme 13)[60]. An orthoester side product can result but can be rearranged to the desired glycoside under acidic conditions.

[i] Recreated from 'Stereoselective Glycosylation' notes of Prof. David Crich.



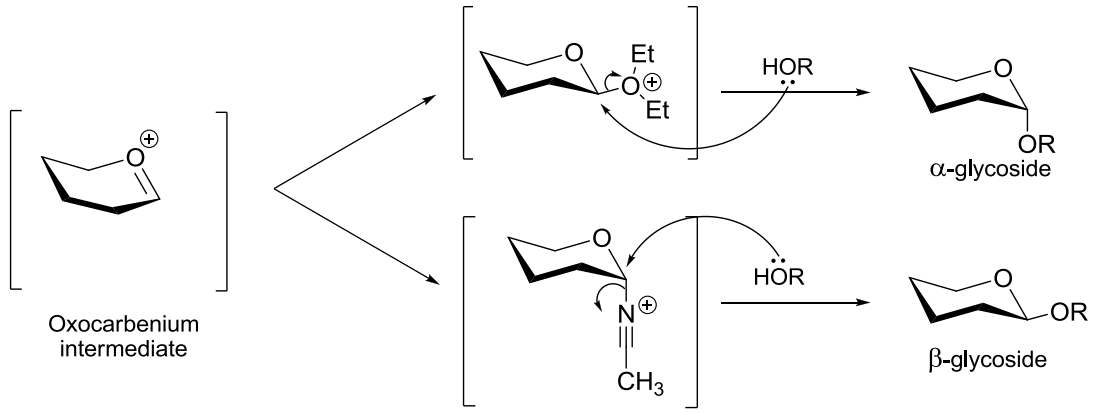
Scheme 13: Neighbouring group participation

Novel protecting group systems have also been utilized to induce anomeric selectivity. Boons et al. developed a method involving a (ethoxycarbonyl)benzyl ether at the 2-position where the stereochemical configuration of the protecting group determines the selectivity attained (Scheme 14)[61]. The ethyl ester of the protecting group, can nucleophilically add to the oxocarbenium intermediate, forming an acyloxonium intermediate. The steric interactions of the phenyl group, determines the stereochemistry of this intermediate and subsequent S_N2 type nucleophilic attack leads to the glycosidic bond formation. Similar approaches involving cyclic sulfonium donors[62] and picolyl protecting groups[63] have also been employed.



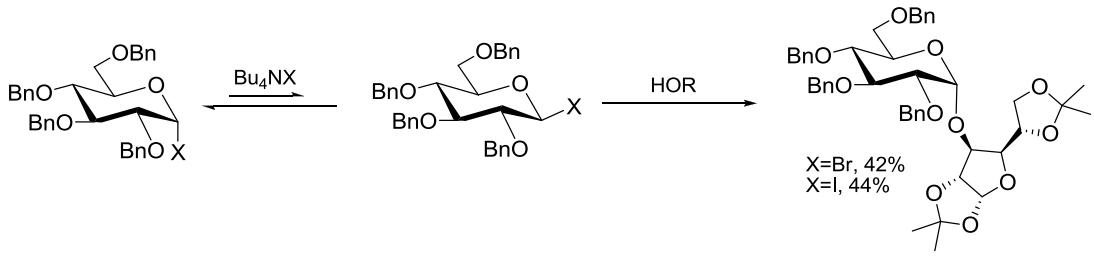
Scheme 14: Neighbouring group participation of (ethoxycarbonyl)benzyl ether protecting groups[61]

The choice of reaction solvent or co-solvent can help in achieving the desired stereoselectivity. Ethers, such as diethyl ether and THF, have been seen to increase the α-selectivity of a reaction[64–66]. The oxygen of the ether adds to the oxocarbenium ion, resulting in a beta oxonium intermediate, guided by a preference for ether to take an equatorial orientation. The reactive intermediate can be displaced leading to higher α-selectivities. In contrast the use of acetonitrile as a solvent or co-solvent is seen to result in increased β-selectivity[65]. In this case, an α-nitrilium intermediate is believed to occur and inverse displacement results in high quantities of β-anomer[65,67,68].



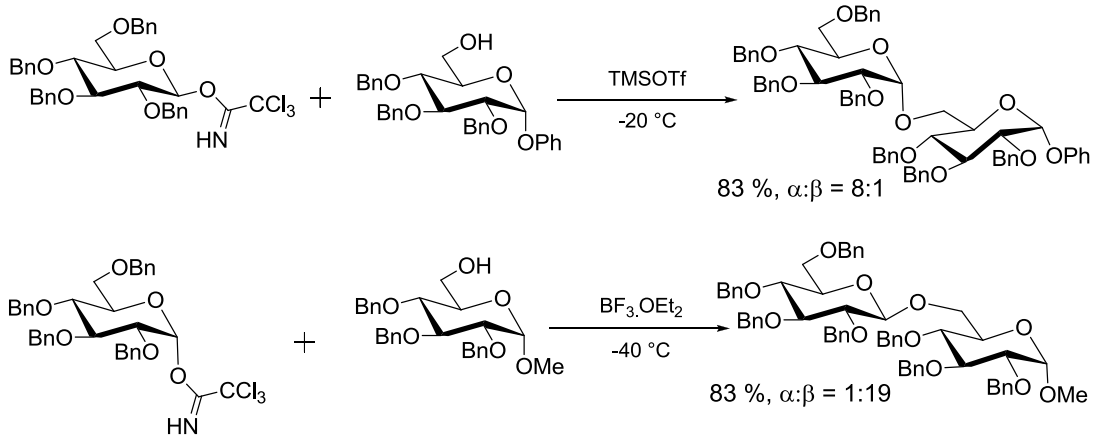
Scheme 15: Solvent effects on glycosylation reactions

As previously mentioned, glycosyl halides activated with insoluble salts, can be displaced with anionic nucleophiles, inverting the stereochemistry[34–36]. Anomeric halides preferentially exist as the α-anomer which, will be displaced to give the β-glycoside. Addition of tetrabutyl ammonium halide leads to an anomerisation of the α-halide. The more reactive β-halide is readily displaced by non anionic nucleophiles and thus can be used in *O*-glycoside synthesis using alcohols. Lemieux pioneered this system in 1975 using glycosyl bromides and Bu_4NBr[69]. Similarly Gervay-Hague investigated the reactivity of glycosyl iodides in the presence of Bu_4NI, resulting in reasonable α-selectivities[70,71].



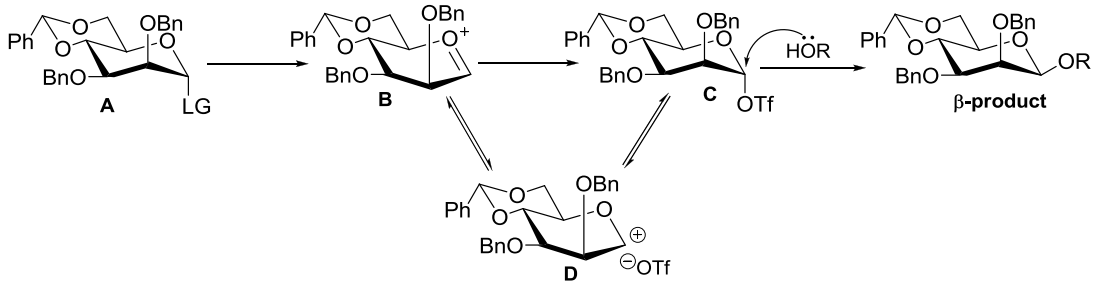
Scheme 16: In-situ β-halide formation[69]

Trichloroacetimidates have also been shown to undergo S_N2 type reactions. The relative ease with which α- and β-trichloroacetimidates can be selectively prepared makes this an attractive procedure. Lewis acid activation at low temperatures has lead to imidate displacement, thus inverting the stereochemistry at the anomeric centre[45,72,73].



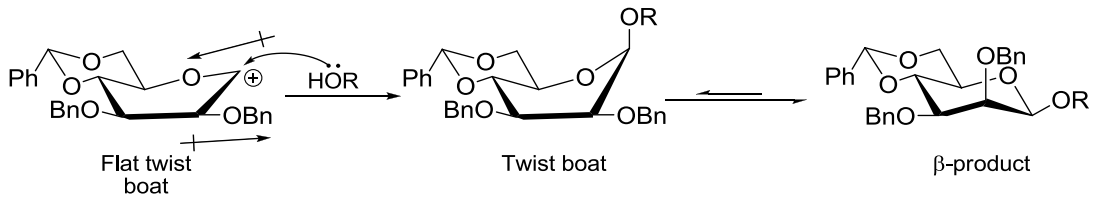
Scheme 17: The S_N2 type displacement of trichloroacetimidates[72,73]

Preactivation in the presence of Tf_2O results in high β-selectivities in the case of 4,6-benzylidene protected mannosyl thioglycosides and sulfoxides[42,74]. Crich and co-workers, with the aid of low temperature NMR studies, postulate that the acceptor reacts to give an α-anomeric triflate(C) or the corresponding contact ion pair(D), rather than the free oxocarbenium ion(B) (Scheme 18)[75]. It was thought that the benzylidene protecting group invokes torsional ring strain which disfavours the formation of the planar oxocarbenium ion.



Scheme 18: Mechanism proposed by Crich.

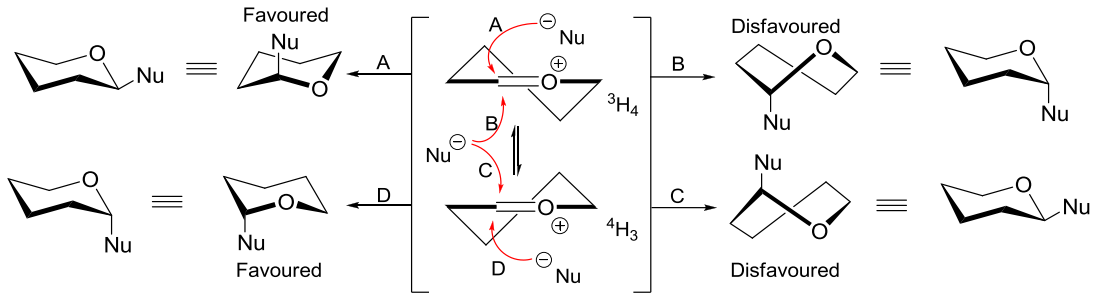
Schmidt showed that the activation of 4,6-benzylidene protected mannosyl trichloroacetimidates with TMSOTf also resulted in high β-selectivity[76]. He suggested a flattened twist boat conformer as the reactive intermediate, as this conformer would favour attack from the β-face for steric and electronic reasons[76,77].



Scheme 19: Mechanistic proposal of Schmidt[76,77]

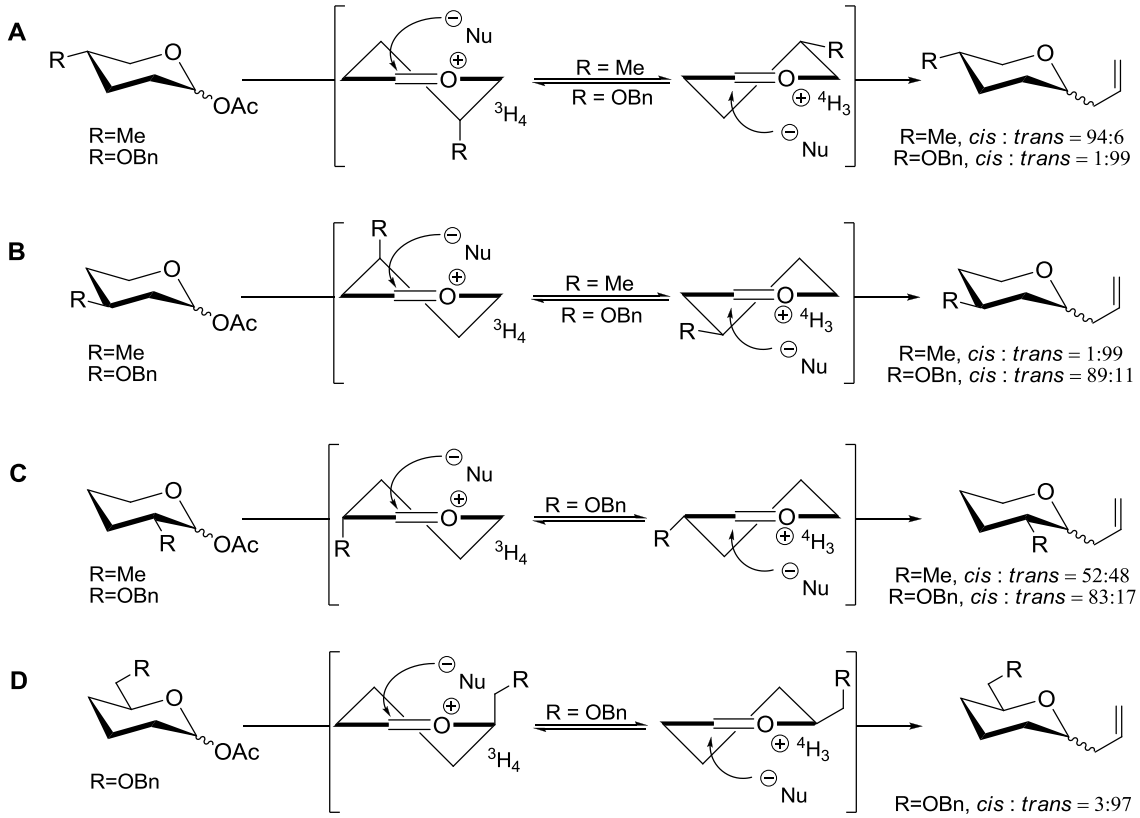
Interestingly analogous glucose donors result in high α-glycoside selectivity and it is thought they favour an S_N1 like mechanism, with nucleophilic attack on a free oxocarbenium intermediate[78]. This additionally questions the effect of the C-2 substituent and Schmidt proposed that in the case of the mannose type structures, the electron withdrawing C-2 substituent would further favour his proposed intermediate, due to a favourable dipole interaction[77]. However it is also fair to suggest that an electron withdrawing group at C-2 may disfavour the formation of an oxocarbenium intermediate, thus favouring the anomeric triflate or corresponding contact ion pair[79]. When investigating the kinetic isotope effect on the reaction, Crich showed that the reaction went through a S_N1 type mechanism, suggesting that the anomeric triflate dissociates prior to nucleophilic attack[80]. Whitfield *et al*. have suggested that this may be the case in all types of glycosylations[60]. He suggests that rather than S_N2 type displacement of a covalently bonded leaving group, it is nucleophilc displacement of the corresponding contact ion intermediate pair which results in the stereochemical outcome of the reaction.

Thus far, the role of various leaving groups, additives and auxiliaries has been discussed, but what of the free oxocarbenium ion (assuming it is formed) and how can the resulting selectivities be rationalised? A free oxocarbenium ion can exist in a variety of conformations, however the $^4H_3$ and $^3H_4$ conformations dominate[81,82]. Nucleophilic addition to these half chair conformers occurs in a pseudo axial fashion, with attack on the face leading to a favoured chair transition state rather than a twist boat transition state.



Scheme 20: Nucleophilic attack on free oxocarbenium ion conformers.

Much insight on the effect of substituents has emerged from the work carried out by the group of Woerpel, were they have extensively studied the effect of substituents about the pyranose ring and the resulting stereoselectivities[83]. It has been shown that electronegative substituents at C-3 and C-4 favour an axial orientation, electrostatically stabilising the oxocarbenium ion, thus favouring one conformer over the other[81,82]. It is somewhat of an assumption that these factors also stabilise the transition states, however studies on model substrates, investigating the effects individually exonerate these claims (Scheme 21 A & B)[84,85]. In the case of substituents at C-5 and C-2, steric interactions seem to be greater and influence the outcome as shown in Figure 29 examples C & D.



Scheme 21: Effect of electron withdrawing substituent's at C-3 & C-4[84,85]

Woerpel *et al*., also investigated pyranose rings bearing multiple substituents[86]. The outcome of these reactions is less predictable, as steric interactions between the substituents and the incoming nucleophiles come into play. In such situations the product may not arise from the stereoelectronically stabilised conformation (A), as steric interactions result in a higher energy barrier leading to the associated transition state (TS A) for product formation. The energy barrier leading to the transition state for conformational interconversion (TS C) is relatively low, consequently conformational interconversion may readily occur. According to the Curtin Hammet principle, the product may therefore arise from an energetically less favoured conformation (B) in which the energy barrier leading to the associated transition state (TS B) for product formation is less.

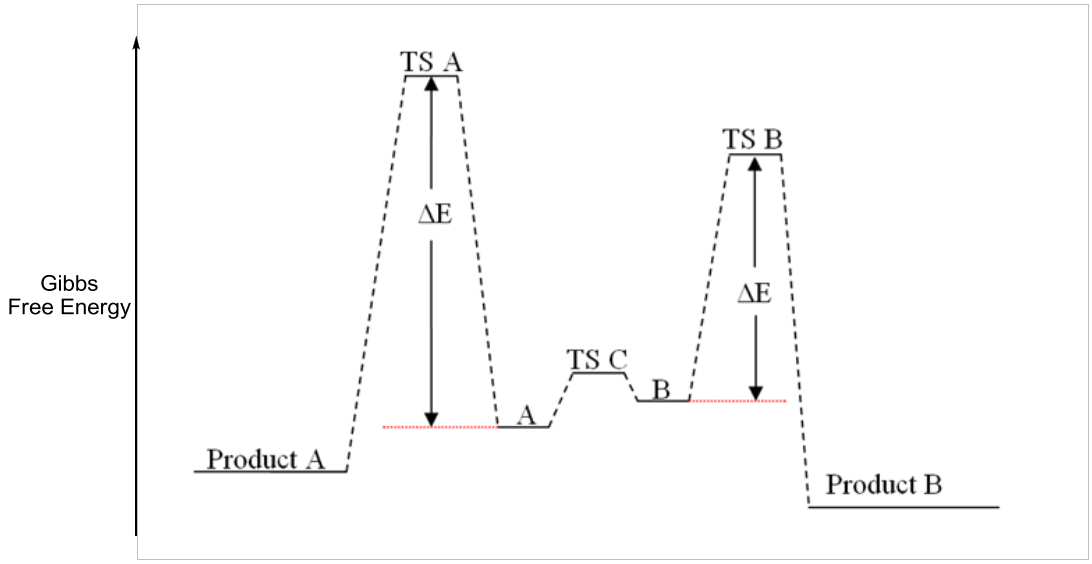
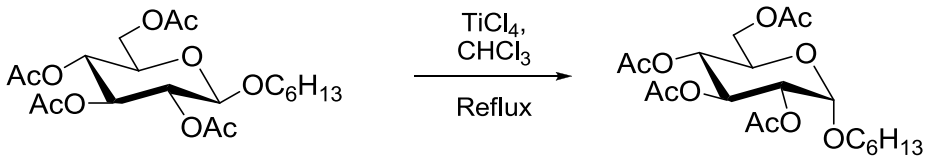


Figure 9: Curtin Hammet principle

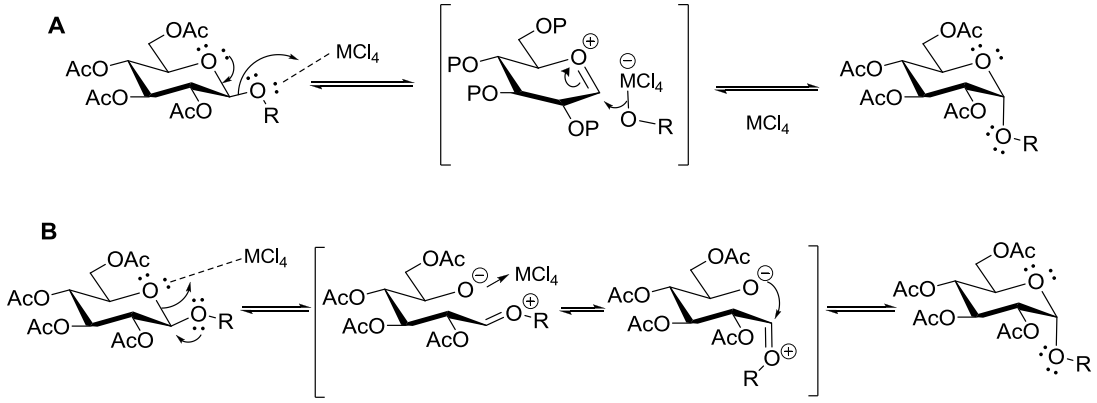
1.3.2 Anomerisation

The anomerisation of glycosides involves an acid or base induced reaction, which results in the formation of the thermodynamically favoured anomer. Anomerisation reactions have been studied for the best part of a century, with the first Lewis acid anomerisations being reporting by Pacsu in the late 1920s and early 1930s[87,88].



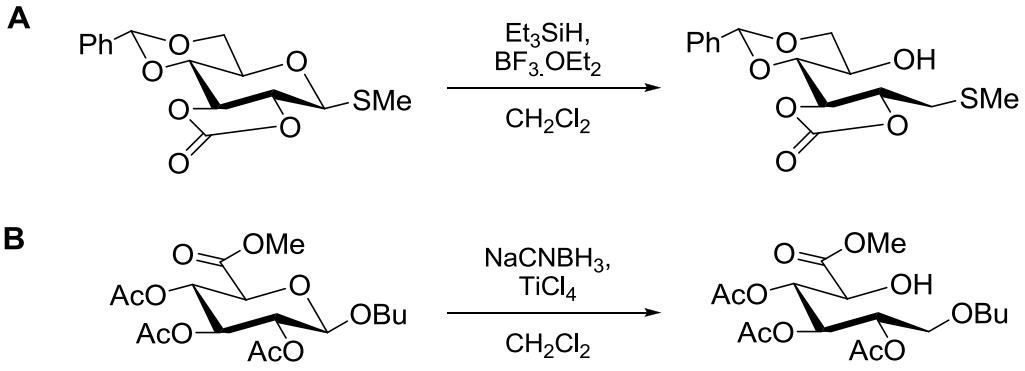
Scheme 22: Example of the work carried out by Pacsu[87,88]

The mechanism of such Lewis acid induced anomerisations has been debated, with two alternative pathways being proposed. Lemieux proposed an exocylic mechanism, where the anomeric substituent is activated by the Lewis acid, thus leading to a contact ion oxocarbenium intermediate. The cleaved aglycon can then attack the oxocarbenium leading to either the α- or β-glycoside. As this reaction is reversible, at reaching equilibrium the α-anomer is thermodynamically favoured (Scheme 23A)[89,90]. Lindberg proposed an alternative mechanism involving endocyclic cleavage. This involves Lewis acid coordination to the ring oxygen, leading to cleavage of the O5-C1 bond resulting in an open chain intermediate. Rotation about the C1-C2 bond and nucleophilic addition of O-5 leads to the thermodynamically favoured product (Scheme 23B)[91].



Scheme 23: Suggested anomerisation pathways; A) Exocyclic cleavage; B) Endocyclic cleavage.

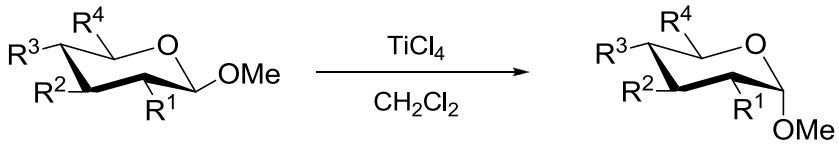
It is now widely accepted that both pathways can occur, but that Lewis acid induced anomerisations predominantly follow the endocyclic pathway. Crossover experiments have indicated that both pathways might operate but the exocylic pathway seems much slower if it occurs[92]. Murphy *et al*. and Manabe *et al*. have also carried out trapping experiments, which resulted in the trapping of an open chain intermediate that arises from endocyclic cleavage (Scheme 24)[93,94].



Scheme 24: Trapping experiments: A) Manabe *et al.*[94]; B) Murphy *et al.*[93]

As with glycosylation reactions, work has been invested into understanding the factors which alter the rate and the selectivity in anomerisation reactions. The anomeric ratios resulting from an anomerisation reaction seem to be related to the magnitude of the anomeric effect in the compound. Factors influencing the anomeric effect have been previously outlined in section 1.1.2.

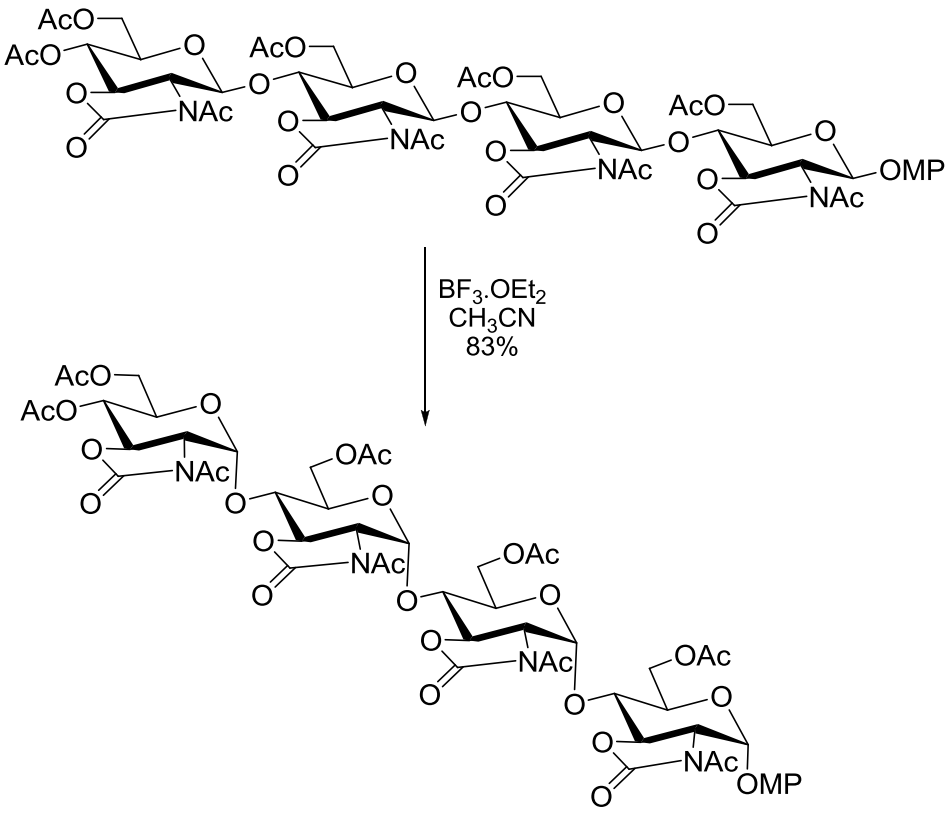
The nature of the protecting group plays a key role in both the rate and stereochemical outcome of anomerisation reactions. Even somewhat slight variations have resulted in substantial reactivity differences. For example, replacing acetate protecting groups with benzoate protecting groups leads to an increase in the rate of the reaction and an increased amount of α-anomer[93,95]. Koto *et al*. investigated the effect of ether protecting groups relative to acetate protecting groups, observing a significant increase in the rate of reaction when the acetate of O-6 was replaced with a benzyl or methyl ether[96]. This suggested that increasing the electron density at O-6 enhances the ability of the oxygen to chelate to the Lewis acid. Studying the anomerisation reactions of substrates lacking the functionality confirmed this hypothesis[96]. Further studies investigating electronic effects, demonstrated that per-benzylated systems anomerised much faster than *para*-chlorobenzylated protected sytems, indicating that increasing the electron density about the pyranose ring stabilises the transition state leading to the reaction intermediate resulting in a faster reaction[97].



Entry	R^1	R^2	R^3	R^4	Time (s)	% of α-anomer
1	OBn	OBn	OBn	CH_2OBn	4	90
2	OAc	OAc	OAc	CH_2OAc	300	3
3	OAc	OAc	OAc	CH_2OBn	4	59
4	OAc	OAc	OAc	CH_2OCH_3	4	74
5	OBn	OBn	OBn	CH_3	4	12
9	OBn	OBn	OBn	H	4	7

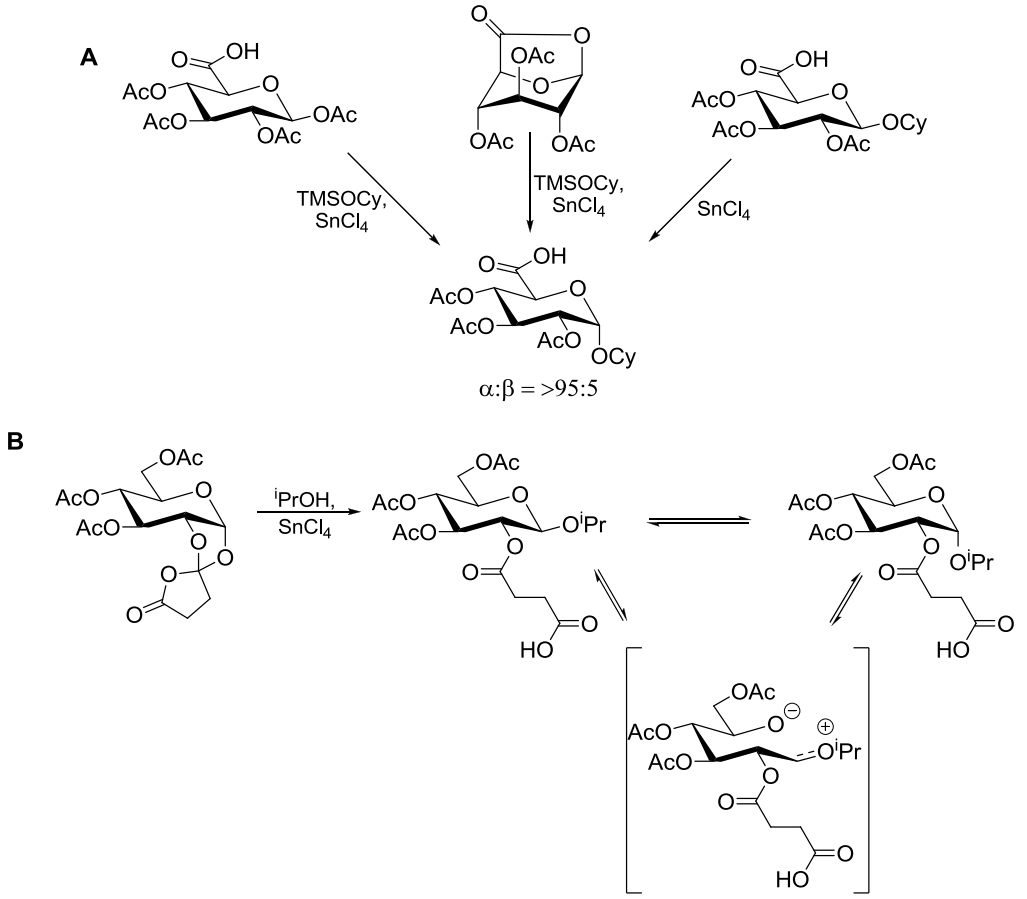
Table 3: Effect of substituents at C-5 studied by Koto *et al*.[96]

Protecting groups inducing ring strain such as 2,3-*trans*-carbamates and carbonates have been more recently employed in anomerisation reactions[98–101]. Reactions carried out involving a 2,3-*trans*-carbamate glucosyl thiol donor, resulted in unusually high α-selectivity[102]. It is speculated that the carbamate protecting group locks the carbohydrate in a $^4C_1$ conformation and the ring strain encourages endocyclic cleavage[94]. Crich *et al*. have recently disclosed their unsuccessful attempts to study the mutarotation of 4,5-*trans*-carbamate protected sialosyl hemiacetals, due to a preference for the open chain keto form, reflecting the strain imposed by the presence of the cyclic carbamate[103]. Ye *et al*. developed a one pot glycosylation-anomerisation utilizing a 2,3-*trans*-carbonate to great effect[101]. More recently Manabe *et al*. have demonstrated the anomerisation of multiple β-glycosidic linkages in a single reaction, where the nature of the substituent on the nitrogen of the carbamate is seen to have an important influence on the resulting anomeric ratio[104].



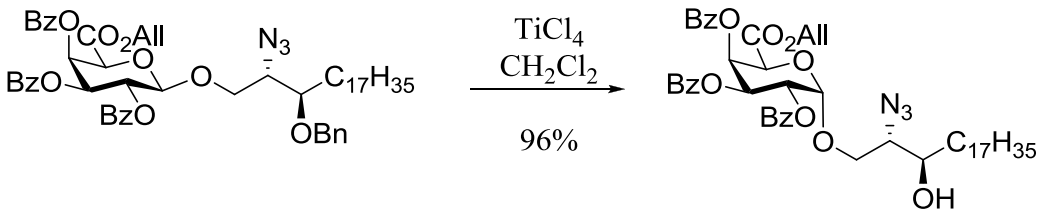
Scheme 25: Multiple glycosidic linkage anomerisation by Manabe and co-workers[104]

The Murphy group have utilised a rate increase associated with having a carbonyl group at C-6 of the pyranose ring[92,93,105–109]. While carrying out glycosylation reactions with glucuronic acid derivites using $SnCl_4$ as the activating agent, it was noticed that an α favourable mixture was achieved even in the presence of a participating group at C-2[105,108]. Further investigations, involving a series of β-glycosides and treating them with $SnCl_4$ resulted in the formation of comparable anomeric mixtures, thus concluding that a glycosylation-anomerisation reaction was occurring (Scheme 26A) [92]. A glycosylation-anomerisation reaction has also been disclosed by Hindsgaul and Lemieux in 1980[110] where the presence of a carboxylic acid group in a group at the 2-position led to an increase in anomerisation rate.



Scheme 26: Glycosylation anomerisation; A) Murphy *et al.*[92]; B) Hindsgaul & Lemieux[110]

The electronic nature of the aglycon has a large effect on the rate and the stereochemical outcome of the reaction, where *O*-cyclohexylglycosides (electron inducing) were seen to be faster than *O*-phenyl glycosides (electron withdrawing) [105]. A similar effect has been demonstrated by Magnusson *et al.* in 1998[111]. Altering the carboxyl functionality also has an effect on the reaction outcome. While carboxylic acids result in the greatest rate enhancement, esters gave rise to higher ratios in favour of the α-product[92,93].



Scheme 27: Glycolipid synthesis with anomerisation as the key step[107]

The choice of Lewis acid is key and in some cases system specific. For example, $TiCl_4$ is not compatible with the carbonate or carbamate type systems while $BF_3.OEt_2$ has been applied successfully[101]. Conversely $SnCl_4$ and $TiCl_4$ have led to anomerisation in simple per-acylated systems in dichloromethane, whereas $BF_3.OEt_2$ requires the use of $MeNO_2$ as a solvent, thus increasing its Lewis acidity [93,111]. It has been shown that the concentration and stoichiometry of the Lewis acid does not only affect the rate of the reaction but the selectivity also[93,96]. Increases in both concentration and stoichiometry have been demonstrated to further favour the α-anomer, although the latter does not proceed in a linear fashion and is substrate specific[93]. The reaction temperature also affects the anomeric ratio at equilibrium, with lower temperatures resulting in higher quantities of α-anomer[93].

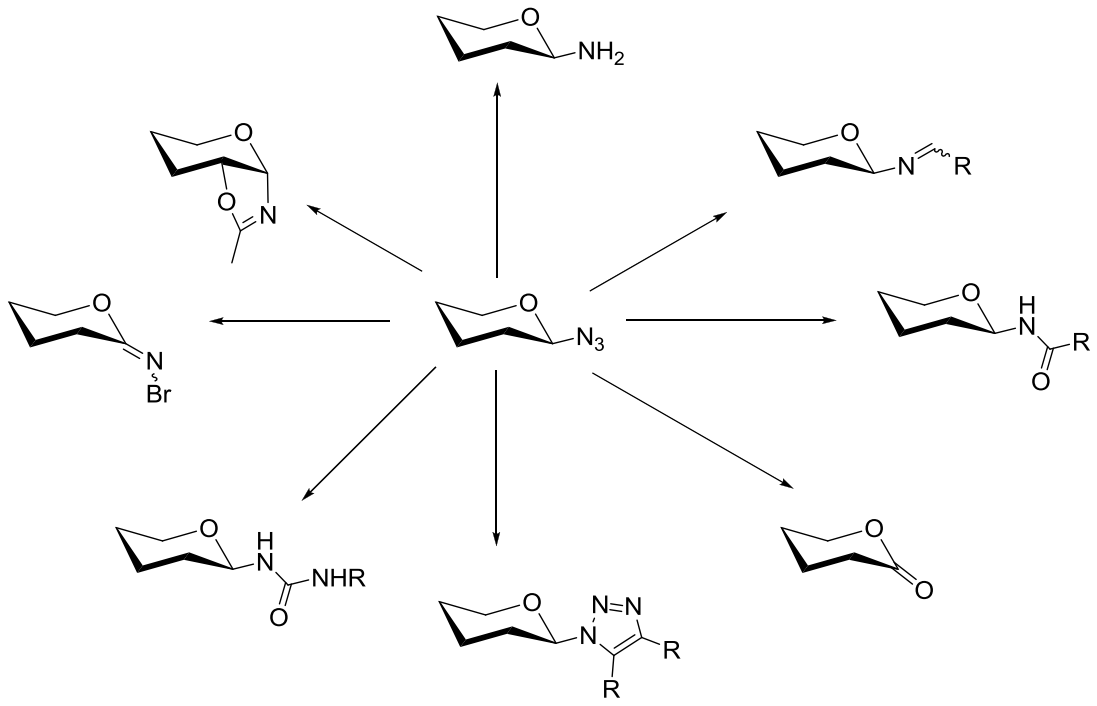
Main aim of this thesis work

Although anomerisation reactions have been studied for the best part of a century, the literature available relative to that of glycosylation based methodology is minimal. This is due to the anomerisation requiring somewhat specific structural features, which may not be straightforward to introduce. Low yields often resulted due to Lewis acid assisted ether cleavage and degradation in the presence of benzyl groups. It has been the primary aim of this thesis to further develop an understanding of $SnCl_4$ and $TiCl_4$ induced anomerisation reactions of substrates which have acyl protecting groups, with a view of expanding the applicability of the reaction in the synthesis of glycosides.

Chapter 2: The anomerisation of glycosyl azides

2.1 Introduction to glycosyl azides

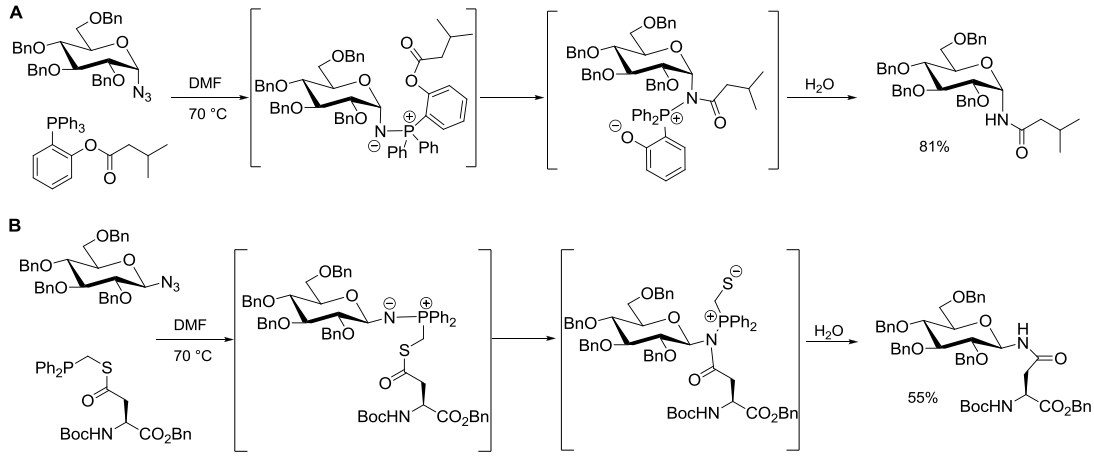
Carbohydrates exist predominantly in biological systems as glycoconjugates and are omnipresent on cellular surfaces[1]. This being the case there is a need for straightforward methods to prepare both natural and unnatural structures to probe the functionality of these carbohydrates. Glycosyl azides serve as a useful class of intermediates in carbohydrate chemistry due to their stability and versatility, and are frequently used as precursors in the synthesis of natural and unnatural *N*-linked structures of biological importance (Scheme 28).



Scheme 28: Glycosyl azide transformations[112–123]

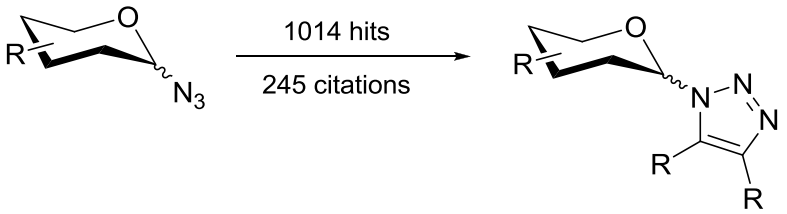
The posttranslational *N*-glycosylation of proteins has a great impact on the functionality of the protein in its biological environment[124,125]. However, isolated *N*-linked glycopeptides and glycoproteins are usually heterogeneous, thus chemical synthesis can be used to elucidate the structural detail and biological activity[126]. One of the major difficulties associated with the synthesis of *N*-linked glycopeptides is the stereoselctive preparation of the glycoside amide[123]. Preparation via a glycosyl azide using classical Staudinger conditions can result in anomeric mixtures due to

anomerisation of the iminophosphorane intermediate, however optimization has led to highly stereocontrolled reactions[119–122]. Traceless Staudinger ligations were later applied, yielding much success, due to the intramolecular nature of the reaction (Scheme 29) [127,128].



Scheme 29: Traceless Staudinger ligations; A) Bernardi *et al.*[127]; B) Kiessling *et al.*[128]

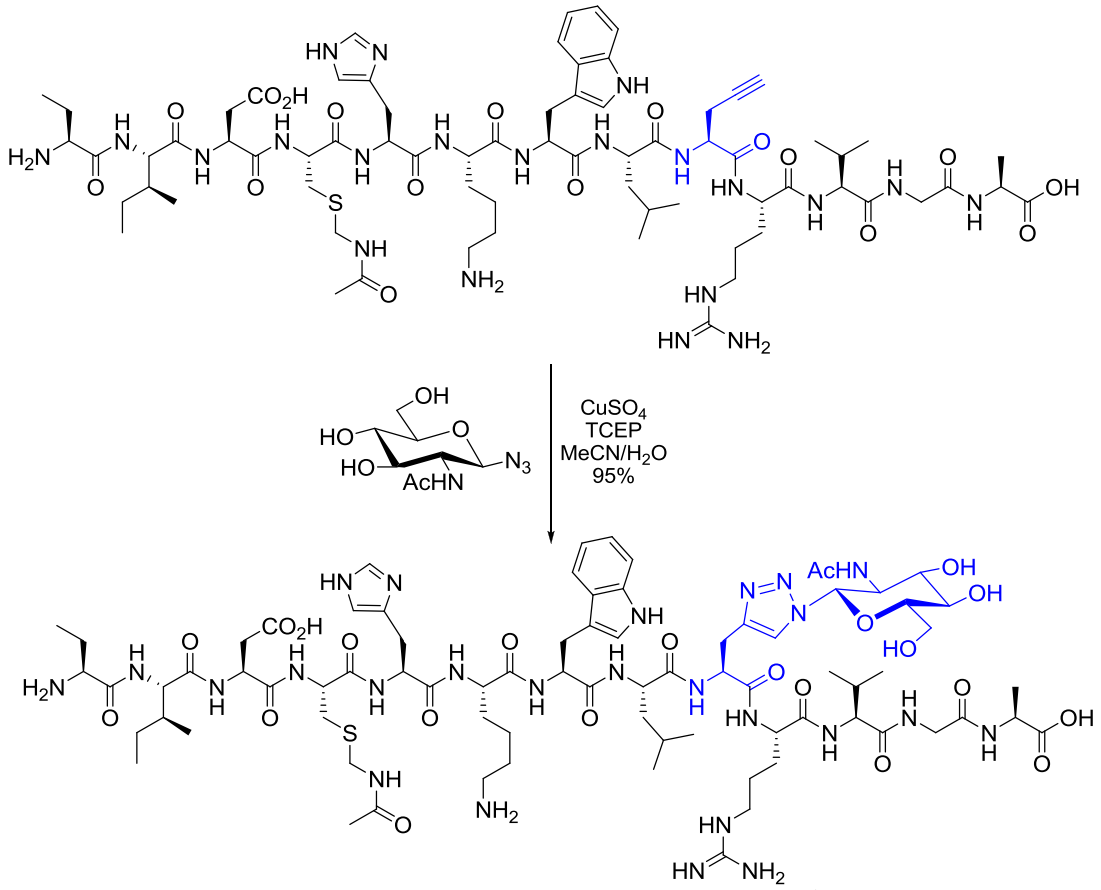
The reinvigoration of the azide-alkyne Huisgen cycloaddition in the last ten years by click chemistry associated methodologies has led to the reaction being widely used in all branches of chemistry, with carbohydrate chemistry being no exception[129–139]. A simple Reaxys® search results in 1014 hits from 245 research articles where the starting material is a glycosyl azide and the product is a result of an azide-alkyne Huisgen cycloaddition. The robust nature of the triazole functionality makes it ideal for coupling sugars to solid surfaces and to incorporate carbohydrates into molecules with potential therapeutic value[129].



Scheme 30: Generalised Reaxys® structure search March 2014

It has been shown that triazoles effectively mimic *trans*-amide bonds[140–146], and due to this various neoglycopeptides containing carbohydrates appended to the peptide via a triazole have been synthesised [147–155]. This linkage is prepared from a glycosyl azide and alkyne containing amino acid derivative or vice versa. These

triazole containing neoglycopeptides offer an alternative to C-linked derivatives which are tedious to prepare and are often low yielding[147]. The increased stability of these neoglycopeptides to enzymatic cleavage can increase the half life of the molecule in biological systems and may possibly increase the biological activity[156].



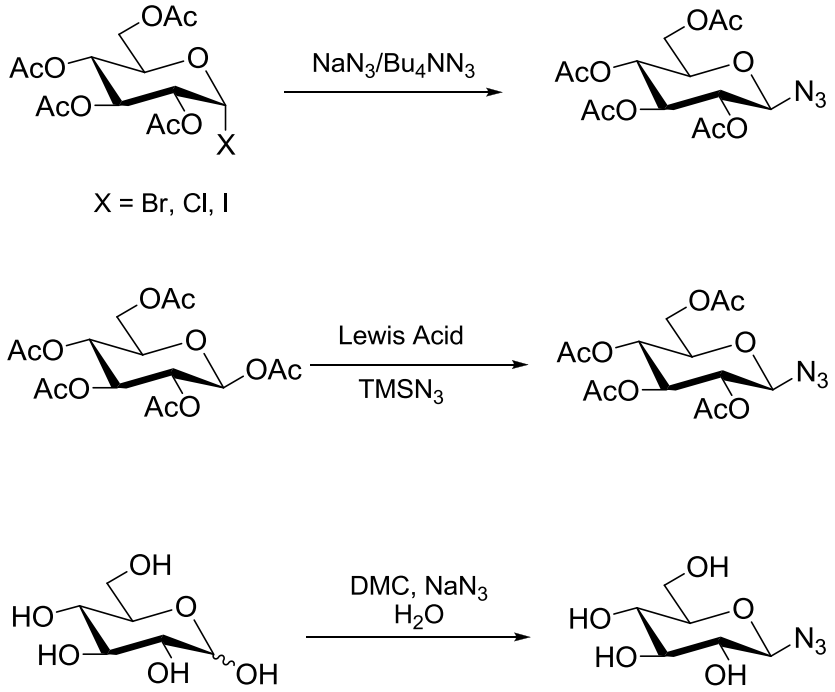
Scheme 31: Neoglycoconjugate synthesis[157]

Carbohydrates involved in signalling pathways can interact with carbohydrate binding proteins known as lectins. It has been shown that multivalency is important in such interactions and that individual carbohydrate structures show only low affinity[158,159]. A variety of such multivalent structures showing biological activity have been prepared via glycosyl azides[160–166].

2.2 Synthesis of glycosyl azides.

The first glycosyl azide was synthesised by Bertho in 1930 with the displacement of a glycosyl bromide with NaN_3[167]. Procedures of this type usually require high temperatures, which is preferably avoidable with azides. Protocols utilizing phase transfer catalysis in a diphase system can be carried out at room temperature and

result in comparable yields[168]. Garvey-Hague *et al*. have also shown the successful preparation of glycosyl azides via a glycosyl iodide intermediate in a one pot procedure[169]. Lewis acid catalysed activation of an anomeric acetate in the presence of $TMSN_3$ has been shown to prepare glycosyl azides in high yields with initial methods using $SnCl_4$ [33]. More recently catalytic amounts of $FeCl_3$ have been applied, resulting in glycosyl azide formation in greater than 85% yield[170]. The preparation of glycosyl azides from unprotected carbohydrates has recently been explored by Shoda *et al*., using DMC to selectively activate the anomeric hydroxyl group in the presence of base and sodium azide, resulting in exclusively β-selectivity[171].

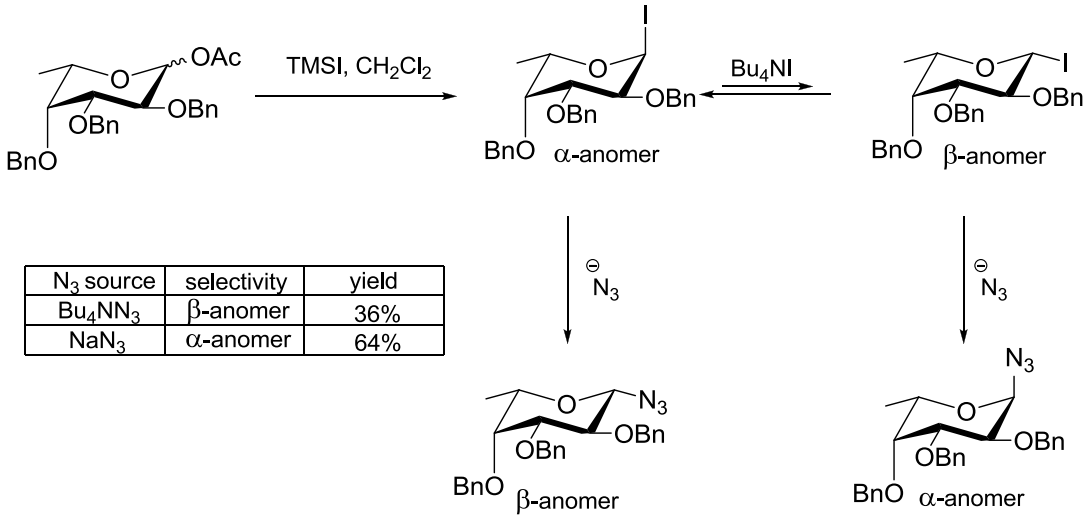


Scheme 32: General procedures for the preparation of glycosyl azides

2.2.1 The preparation of 1,2-*cis* glycosyl azides.

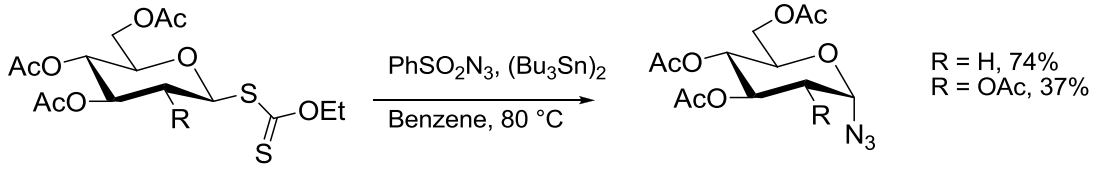
Thus far the methodologies described above result in the formation of 1,2-*trans* glycosyl azides, although some can be altered to invert the selectivity. For example 1,2-*cis* glycosyl azides can be prepared from anomeric halides, where the nucleophilic azide source displaces the less stable β-halide which can be prepared directly or in situ from the α-halide using a tetrabutylammonium halide salt. Both methods have been utilized with a variety of azide sources, however selectivity and reaction yields vary dramatically[172–177]. While attempting to prepare α-azides of L-fucose derivatives from the corresponding α-iodide in the presence of Bu_4NI,

Bernardi *et al.* showed the influence of azide source on the selectivity of the reaction[127]. Reactions carried out using Bu_4NN_3 resulted in β-azide formation while NaN_3 gave the desired α-product. The reaction outcome was attributed to the relative solubilities of the azide sources.



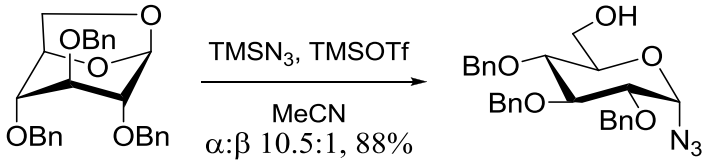
Scheme 33: Effects of azide source on stereochemical outcome[127]

The preparation of glycosyl azide via free radical chemistry has been documented by Renaud *et al.* in 2001[178]. As with many radical reactions involving carbohydrates, complete α-selectivity was achieved[179]. The reaction when carried out with 2-deoxy glucose dithiocarbonate derivative results in product formation in good yield, however the yield from the glucose dithiocarbonate derivative is poor as the 2-*O*-acetyl group impedes the reaction and it is proposed that this is due to β-alkoxy effect[180].



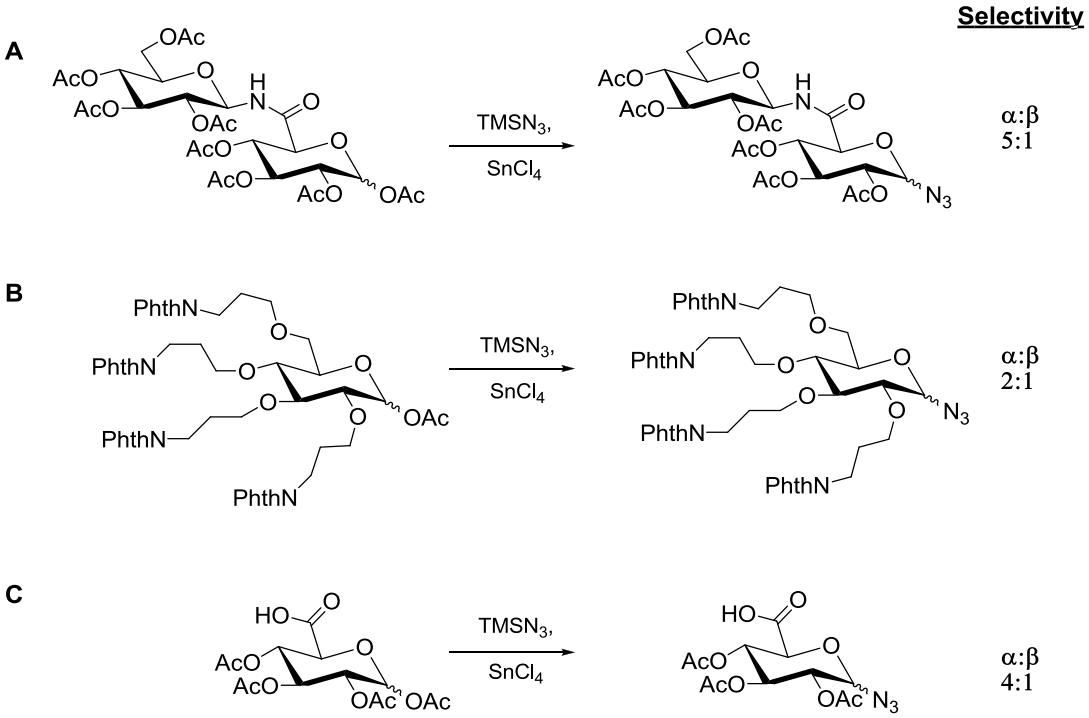
Scheme 34: α-azide preparation via free radical chemistry[180]

More recently Compain *et al.* published the preparation of α-glycosyl azide via 1,6-Anhydro sugars[181]. These reactions are catalysed by TMSOTf and selectivities ranging from 1:1 to >20:1 α:β are reported in moderate to good yields. Interestingly the stereochemical outcome of the reaction is rationalised based on preferential nucleophilic attack on the $^4H_3$ oxocarbenium intermediate.



Scheme 35: α-azide preparation via 1,6-Anhydro sugars[181]

The preparation of glycosyl azides via Lewis acid promoted glycosylation has been referred to above. These reactions are usually carried out with catalytic quantities of $SnCl_4$ for 2-10 hours. The stereochemical outcome of the reaction is dependent on the nature of the substituent at C-2. Under these conditions and the presence of a participating protecting group at C-2, 1,2-*trans* selectivity is observed. However it has been seen that increasing the quantity of $SnCl_4$ and the reaction time can result in anomerisation and a mixture of the α- and β-glycosyl azides[92,108,182–186]. The effects of substituents on such anomerisation reactions have been studied extensively by Murphy *et al.*[92,93].



Scheme 36: Synthesis of glycosyl azides via glycosylation-anomerisation reactions[108,182,184]

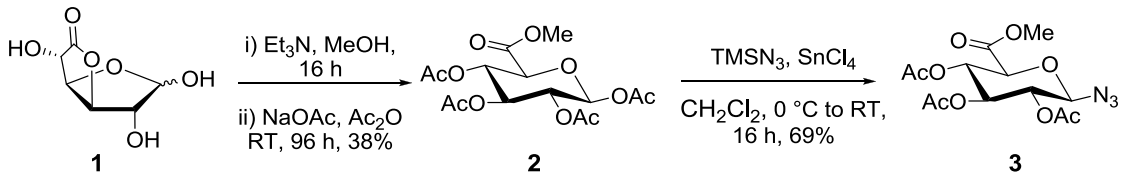
2.3 Objectives.

Although the reported method to prepare α-glycosyl azides by Murphy *et al.* results in respectable α-selectivity[108], it was envisioned that increasing the anomeric

selectivity and the yield towards the synthesis of such compounds, would further enhance their synthetic utility. Recent studies have shown that $TiCl_4$ results in faster anomerisations and greater amounts of the α-anomer[93,106,107]. It was proposed that varying the carbonyl substituent at C-6 and opting for $TiCl_4$ rather than $SnCl_4$ may provide the desired result. It was also felt that carrying out the glycosylation and anomerisation reactions separately will lead to a greater understanding of the anomerisation reaction.

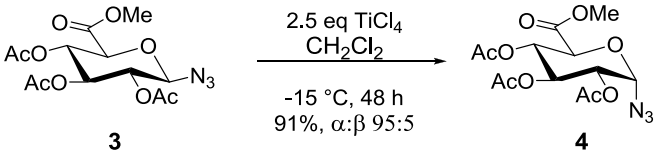
2.4 Results and discussion.

Initial studies were carried out on methyl 2,3,4-tri-O-acetyl-1-azido-1-deoxy-β-D-glucopyranuronate **3**, which was prepared in 3 steps from D-glucurono-6,3-lactone **1** according to literature procedures[187].



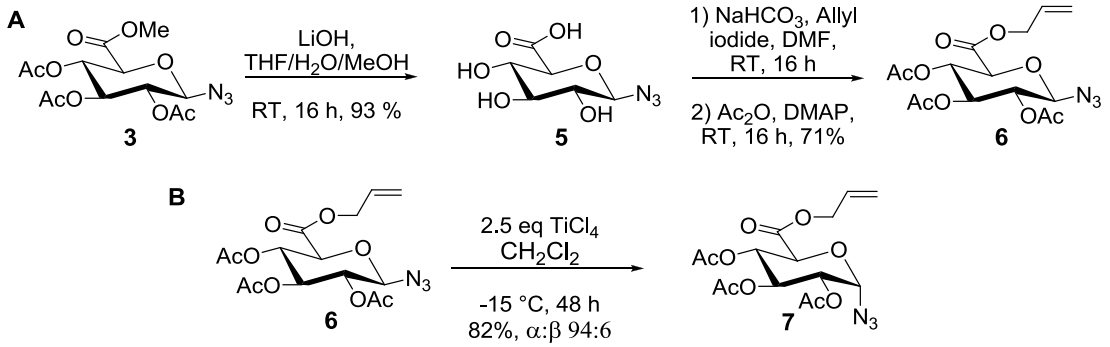
Scheme 37: Synthesis β-glucopyranuronate azide

Carrying out the anomerisation reaction with 2.5 equivalents of $TiCl_4$ at room temperature overnight proved promising, with greater than 90% α-selectivity being observed. However the yield of the reaction was as low as 47%, this being mainly due to the presence of side products and the formation of a thick emulsion upon workup with saturated aqueous $NaHCO_3$. Lowering the reaction to -15 °C inhibited the formation of side products and resulted in an increase in the yield of reaction to 65%. This result indicated that to further increase the reaction yield, emulsion formation had to be prevented. A variety of aqueous quenches were investigated, such as a 1M $KHSO_4$ wash which prevents emulsion formation in reactions with $SnCl_4$, however it did not prove successful in this case. Washing with 1M HCl or brine, followed by a sat. aq. $NaHCO_3$ wash was also unsuccessful. Washing once with sat. aq. NH_4Cl reduced emulsion formation in the sat. aq. $NaHCO_3$ wash. Washing twice with sat. aq. NH_4Cl completely prevented emulsion formation, with the yield being increased to 91% and an α:β ratio of 95:5 being observed.



Scheme 38: Optimized anomerisation conditions

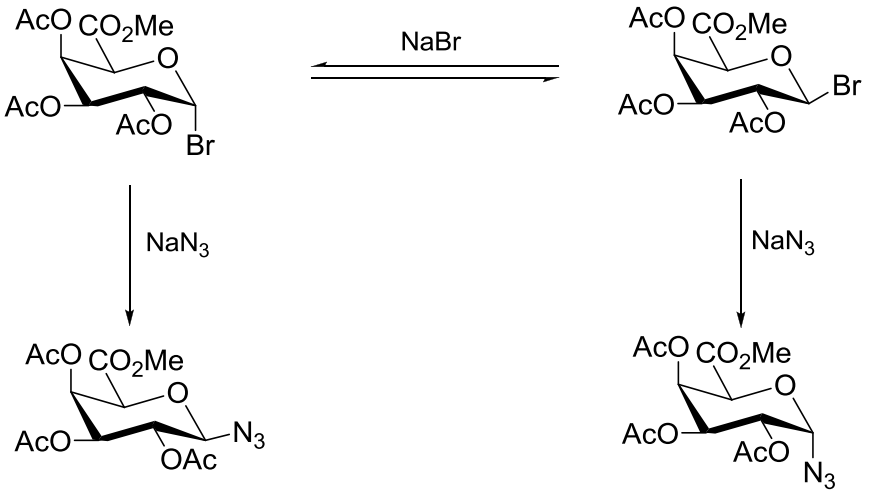
Following this work-up optimisation, the effect of the ester on the stereoselectivity was investigated. The allyl ester derivative **6** was prepared from **3,** which underwent saponification with LiOH in a THF/H_2O/MeOH to give **5** in 93% yield. Treatment of **5** with allyl iodide in DMF, followed by the addition of Ac_2O and DMAP gave **6** in 71% yield[92]. Treatment of the allyl ester under optimised anomerisation conditions gave **7** in 82% with an α:β ratio of 94:6. It has been reported that the presence of an allyl ester results in faster anomerisation and higher anomeric selectivities[93,107], however in this case the difference seemed negligible, hence the methyl ester was utilised from this point on in the study.



Scheme 39: A) Synthesis of allyl ester derivative 6; B) Anomerisation of 6

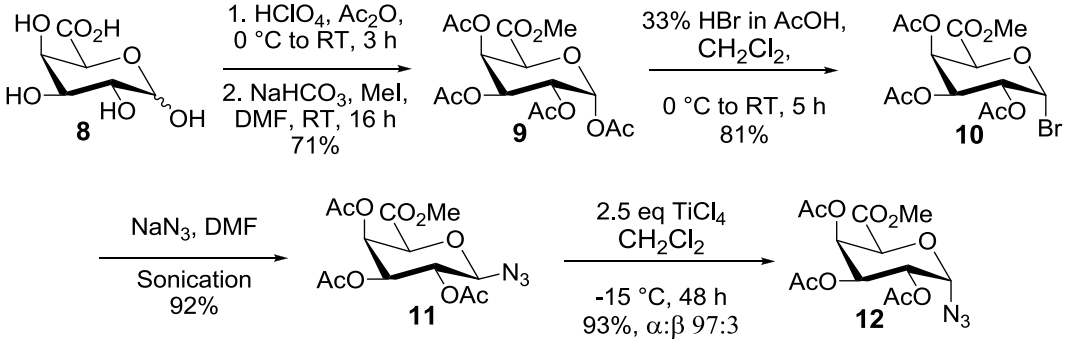
With the glucopyranuronate ester derivatives in hand, interest turned towards other monosaccharide substrates. The galactopyranuronate methyl ester was an obvious choice, however an analogous synthetic pathway to that utilised for the synthesis of **3** proved unsuccessful, as the $SnCl_4$ catalysed glycosylation resulted in an anomeric mixture of the glycosyl azide. Anomerisation studies with galactose substrates has shown them to undergo anomerisation at a faster rate than the corresponding glucose derivatives due to the greater electron density about the pyranose ring[52,93], hence even catalytic amounts of $SnCl_4$ and short reaction times resulted in undesired anomerisation. Attempts to prepare the β-galactopyranuronate

azide via an α-glycosyl bromide in DMF in the presence of NaN_3 with conventional heating also resulted in anomeric mixtures, which may be due to the solubility of NaN_3, as it is only partially soluble under such conditions. The slow nature of the reaction, allows the soluble NaBr side product to displace the α-bromide resulting in the more reactive β-bromide, which can also be nucleophilically displaced by anionic azide, resulting in anomeric mixtures (Scheme 40).



Scheme 40: Proposed mechanism for the formation of anomeric mixtures under standard reaction conditions

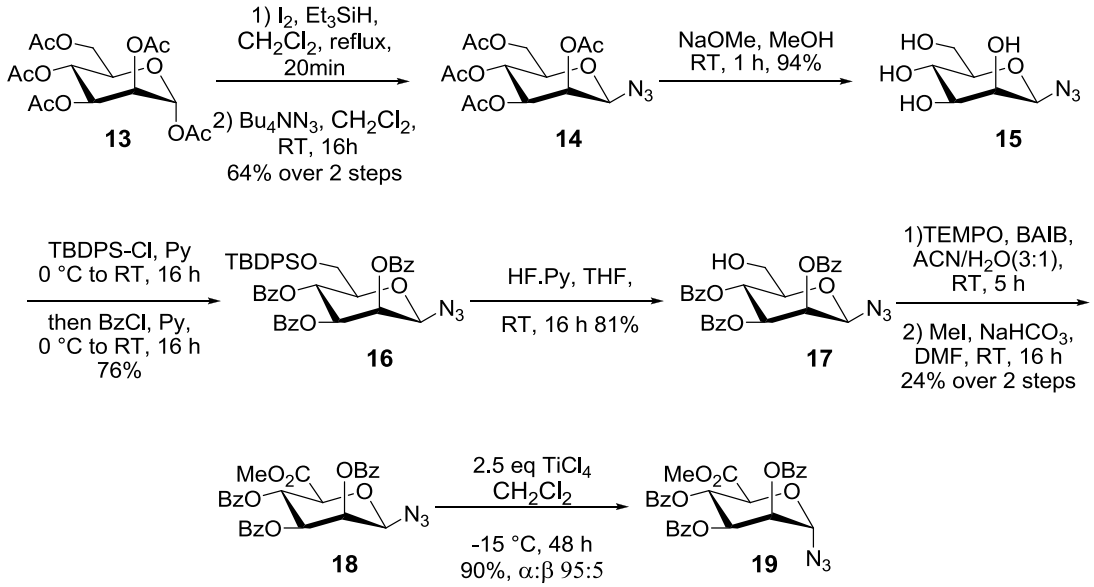
Interestingly, carrying out the reaction in sealed Biotage microwave vial with the aid of sonication gave the β-azide **11** exclusively in 92% yield[188]. Anomerisation of **11** gave **12** in high yield and high selectivity.



Scheme 41: Synthesis and anomerisation of the galactopyranuronate ester derivitive 11

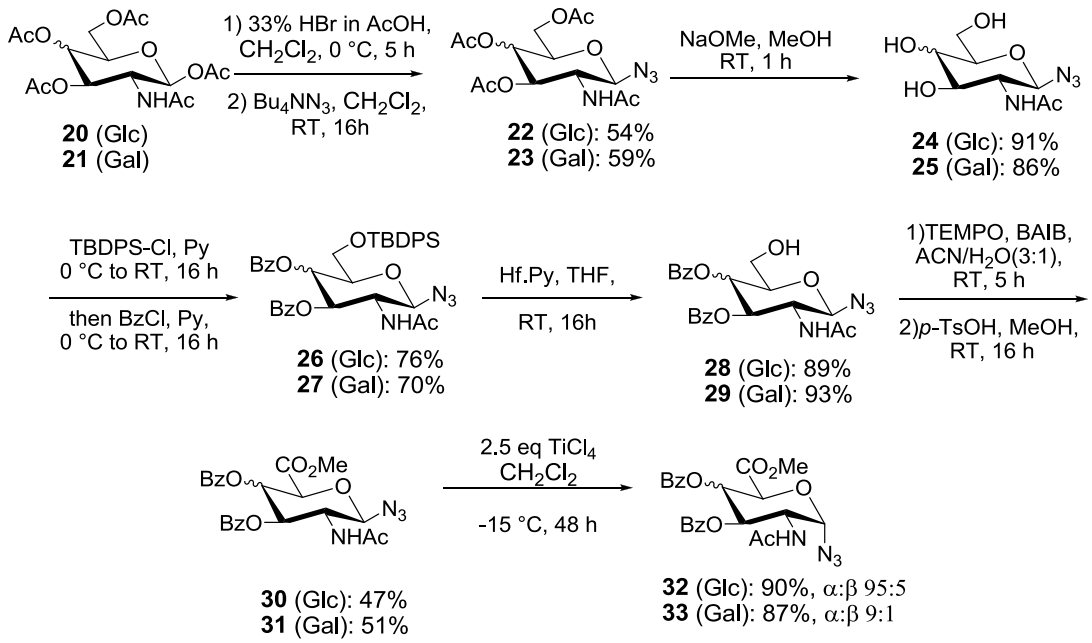
The commercial unavailability of mannuronic acid led to the preparation of the mannopyranuronate methyl ester **18** derivative via D-mannose. Treatment of the peracetylated compound **13** with I_2 and Et_3SiH in DCM, gave an intermediate

glycosyl iodide which was immediately reacted with Bu_4NN_3 in DCM to give **14** in 64% yield[169,189]. The resulting azide was then subjected to Zemplén deacetylation, followed by a one pot silylation-benzoylation to give **16**[54]. Removal of the silyl protecting group with HF-pyridine gave **17** in 85% yield. TEMPO/BAIB mediated oxidation, followed by base catalysed esterification gave **18**. The anomerisation of **18** gave **19** in high yield and high selectivity.



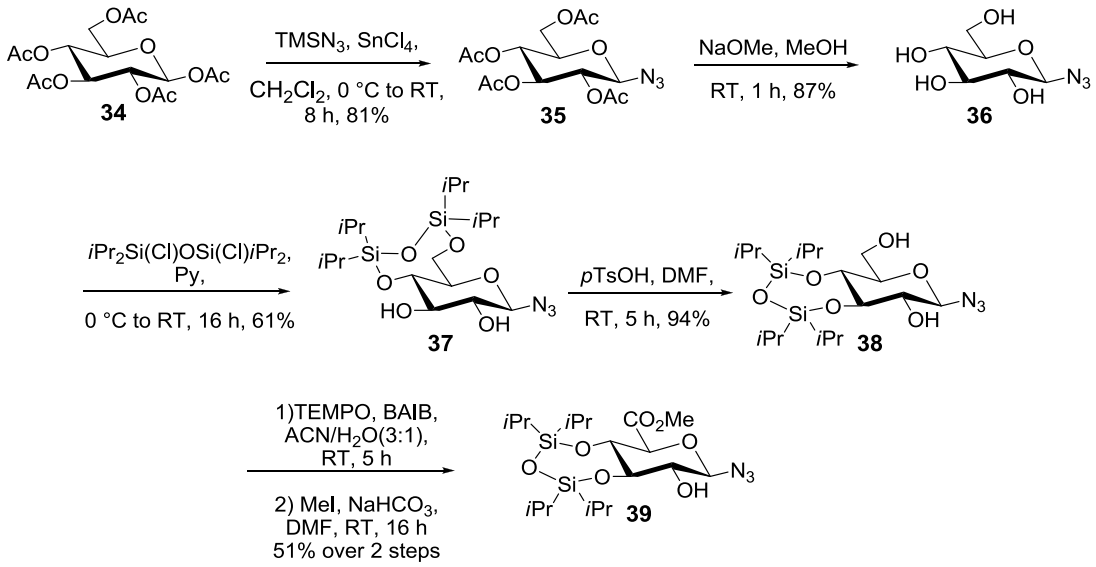
Scheme 42: Synthesis and anomerisation of the mannopyranuronate ester derivitive 18

Attention then turned to the preparation of the 2-deoxy-*N*-acetyl- glucuronides **30** and **31**, which were prepared in a similar manner to **18**. An analogous synthesis has also recently been published by Burn *et al* [190]. The peracetylated precursor was treated with HBr to give the glycosyl bromide which was treated directly with Bu_4NN_3 to give glycosyl azides **22** and **23**[157]. Deacetylation followed by one pot silylation and benzoylation gave **24** and **25**, both in good yield. The silyl group was then removed with HF-pyridine to reveal the primary hydroxyl group which was oxidised with TEMPO/BAIB. Esterification attempts under basic condition, resulted in low yield, hence acid catalysed esterification was utilized giving **30** and **31**. Gratifyingly the *N*-acetyl group did not affect the outcome of the anomerisation reaction and high selectivities and yields were achieved.



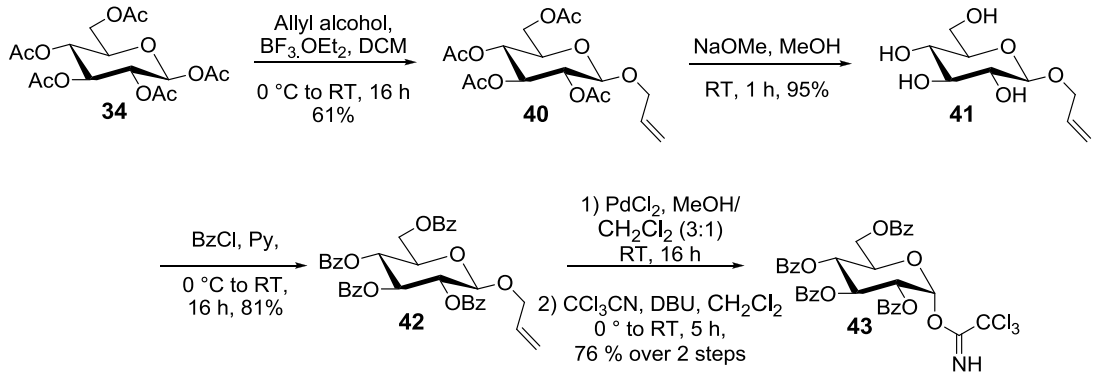
Scheme 43: Synthesis and anomerisation of 2-deoxy-*N*-acetyl-glycuronides 30 and 31

To probe the regioselectivity of the reaction, disaccharide **45** was prepared. The glycosyl acceptor **39** was prepared from **34** in 6 steps in 23% overall yield. The synthesis began with the preparation of the glycosyl azide **35** form pentaacetyl glucose via Lewis acid promoted glycosylation followed by Zemplén deacetylation to give **36** in 77% yield over the 2 steps. Treatment of **36** with $TIPDSCl_2$ gave the 4,6-disiloxane intermediate **37**, which upon treatment with TsOH rearranged to give the 4,3-disiloxane **38**[191,192]. Selective TEMPO/BAIB mediated oxidation of the primary alcohol, followed by base catalysed esterification gave acceptor **39**.



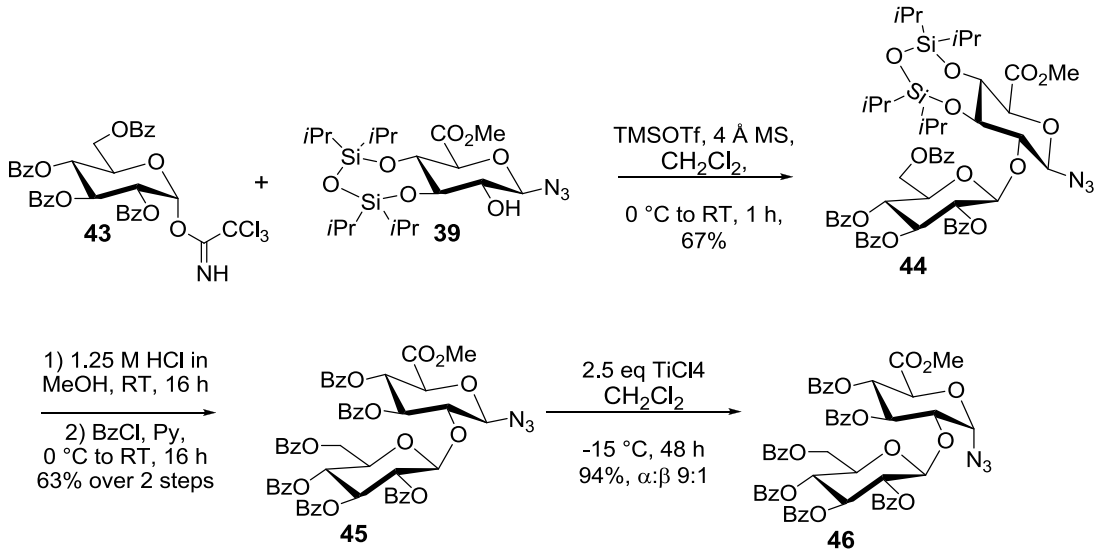
Scheme 44: Synthesis of glycosyl acceptor 39

Donor **43** was also prepared form pentaacetyl glucose. $BF_3{\cdot}OEt_2$ mediated *O*-allylation gave **40**, which was then deacetylated and benzoylated to give **42** in 88% yield. Removal of the anomeric protecting group with $PdCl_2$ and subsequent treatment of the hemiacetal with trichloroacetonitrile in the presence of catalytic DBU gave trichloroacetimidate donor **43**.



Scheme 45: Synthesis of glycosyl donor 43

The glycosylation reaction was carried out with catalytic TMSOTf and gave **44** in 67% yield. The disiloxane group was removed with methanolic HCl and the diol intermediate was benzoylated to give **45**. The anomerisation of **45** went smoothly with only the anomeric azide being anomerised.



Scheme 46: Synthesis and anomerisation of disaccharide 45

2.5 Conclusions.

In summary an optimised method for the anomerisation of azido glycopyranuronate esters has been developed. Seven substrates have been synthesised and the anomerisation of said substrates resulted in high yields and selectivities. This work has been published in Chemistry a European Journal in 2012[109].

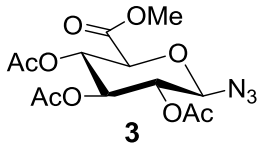
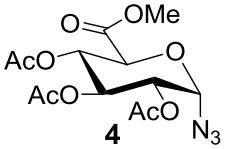
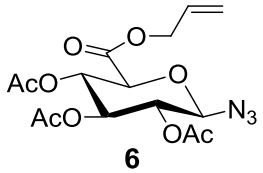
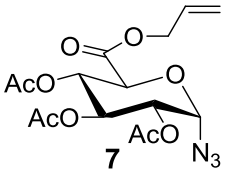
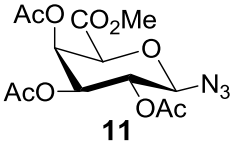
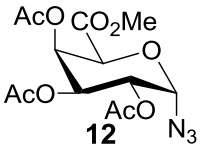
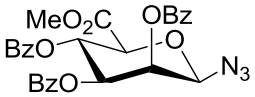
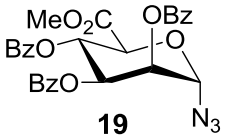
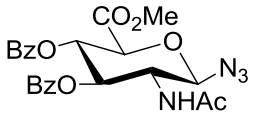
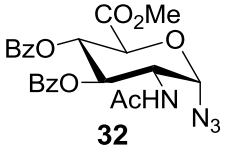
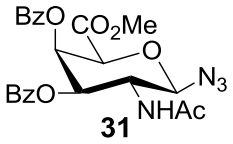
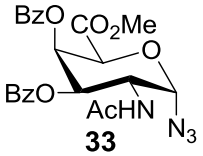
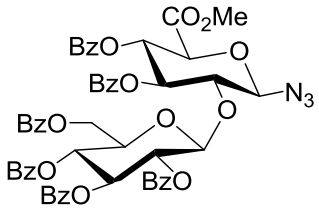
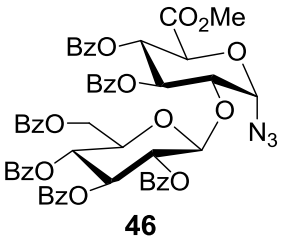
Substrate	Product	α:β	% Yield
 **3**	 **4**	95:5	91 %
 **6**	 **7**	94:6	82 %
 **11**	 **12**	97:3	93 %
 **18**	 **19**	95:5	90%
 **30**	 **32**	95:5	90%
 **31**	 **33**	9:1	87%
 **45**	 **46**	9:1	94%

Table 4: Summary of the anomerisation study

Thus far the method has been applied in the Murphy group to prepare novel triazole linked glycolipids[193] and a variety of multivalent compounds of biological interest. It is important to note the reduction of the uronic acid went smoothly to give

the α-galactosyl azide. Such studies show the potential of this methodology to prepare compounds of biological interest. The versatility and the regioselctivity of the reaction further enhances the utility of this methodology.

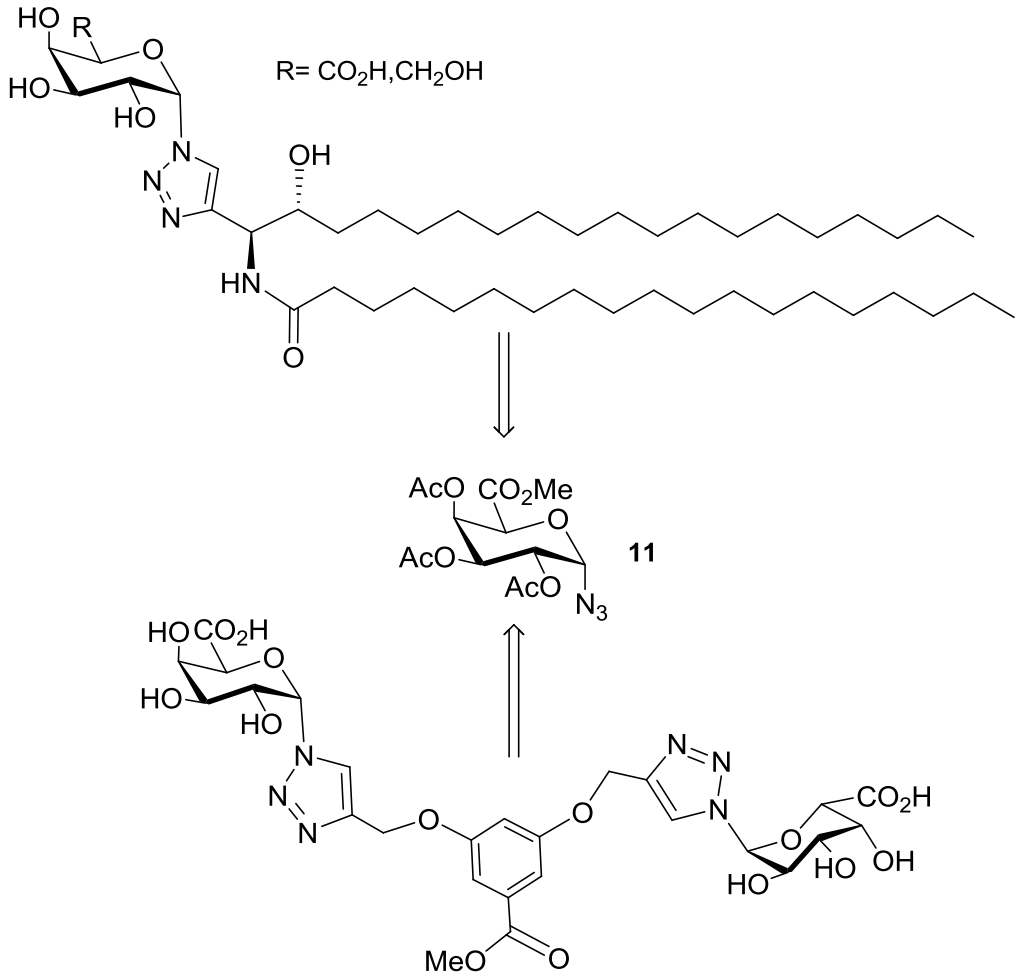


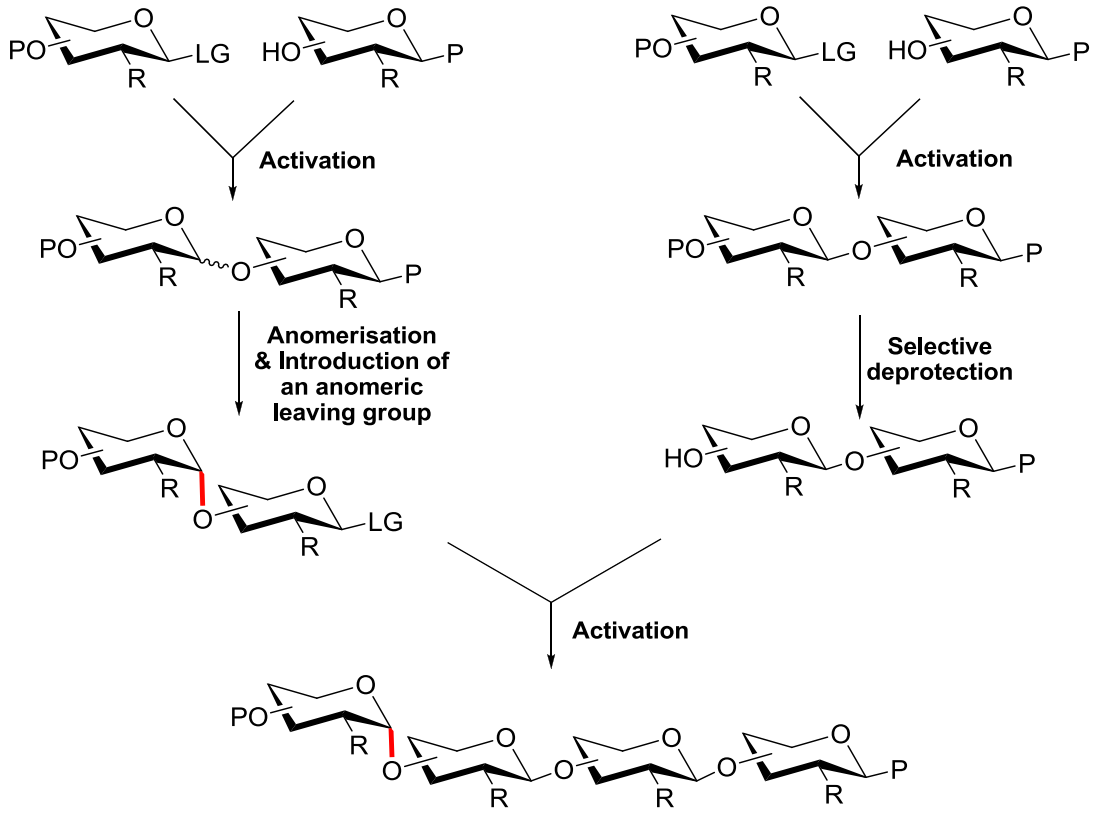
Figure 10: Application of anomerisation methodology

Chapter 3: The regiospecific anomerisation of benzoylated disaccharides

3.1 Disaccharides as building blocks in oligosaccharide synthesis.

The efficient synthesis of both natural and analogous unnatural polysaccharides is essential to investigate applications for such structures. Although the majority of synthetic strategies begin from deprotected monosaccharides, the synthesis of polysaccharides where one sugar unit is added at time is inefficient and can be synthetically risky especially where the introduction of a 1,2-*cis* glycosidic linkage is required. In the ideal situation, disaccharide building blocks can be prepared containing the desired selectivity and the polysaccharide synthesis is then carried out in a convergent manner. This approach is particularly useful in the synthesis of polysaccharides with repeating units[194–197]. For example, a variety of publications can be found on the preparation of disaccharide building for the synthesis of heparin and heparin sulphate libraries[194,196,198–200].

The synthesis of such disaccharides does not always result in the desired selectivity. As the reactivity and selectivity of carbohydrates varies greatly depending on the monosaccharide in question and the protecting group strategy applied about the pyranose ring, slight differences in the structure can lead to big difference in selectivity and yield for the glycosylation reaction, as such no generalised method has yet been achived[59]. Although the yield of glycosylation reactions is important, it is sometimes sacrificed in order to achieve the desired selectivity. In cases where an α-glycosidic linkage is desired and an anomeric mixture is achieved, anomerisation of the glycosidic linkage could to be used to prepare the desired linkage and remove the need for tedious optimisation and/or separation of the resulting anomers.



Scheme 47: Convergent oligosaccharide synthesis utilizing anomerisation

3.2 Synthetic utility.

The methodology presented below involves the anomerisation of uronic acid dervivitaves. Galcturonans are an interesting and important class of biopolymers which contain this functionality[197]. It is envisioned that this methodology would allow for the synthesis of disaccharide building towards the preparation of defined molecules of this class and to prepare compounds to inhibit enzymatic hydrolysis of such compounds.

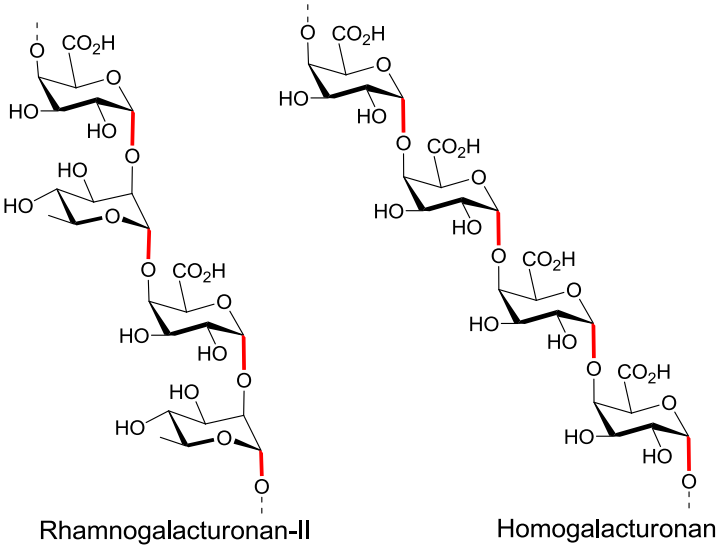


Figure 11: Possible galacturonan targets

In the concluding remarks of Chapter 2 it is noted that the uronic acid building block was successfully reduced to the α-galactosyl azide. This broadens the utility of the methodology and allows it to be applied to the preparation of oligosaccharides without a uronic acid. Building blocks for the synthesis of interesting compounds could be prepared utilizing anomerisation to gain the desired selectivity, followed by reduction and protecting group manipulation.

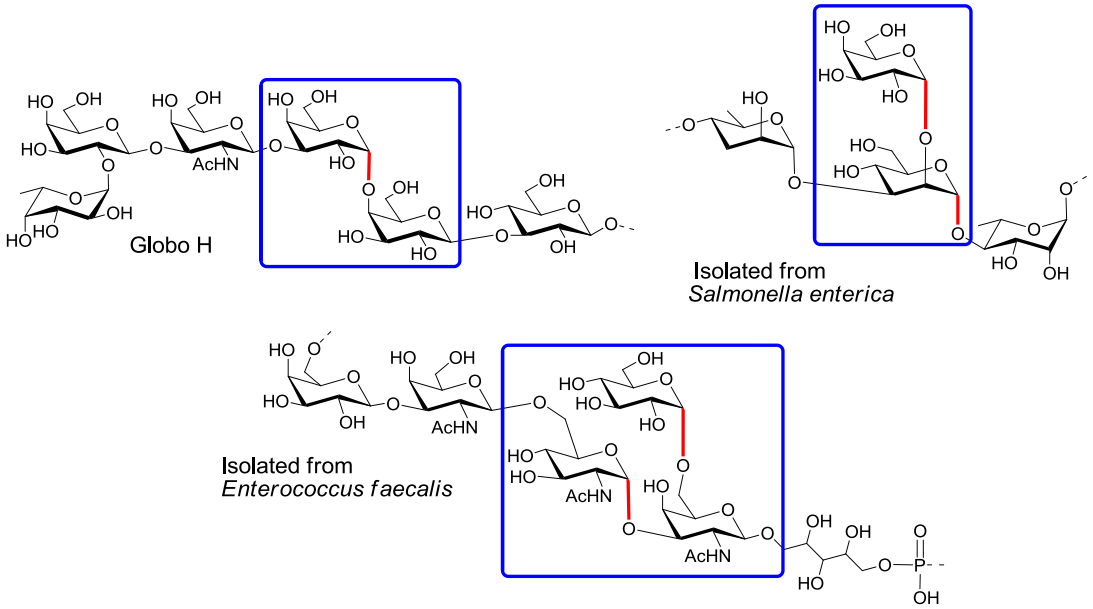
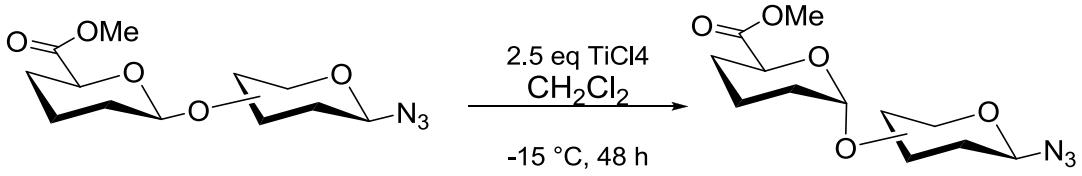


Figure 12: Potential synthetic targets[201–203]

3.2 Objectives.

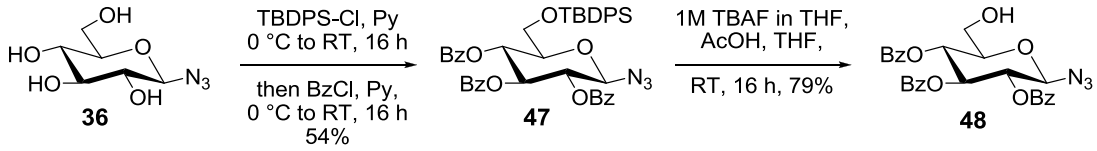
Encouraged by previous results discussed in Chapter 2, it was thought that applying the optimized conditions to disaccharide substrates may result in anomerisation in a regioselective manner. Previous attempts carried out on a disaccharide under similar conditions by Murphy *et al*. resulted in 36:64 α:β selectivity[92]. This chapter looks at the anomerisation of a variety of disaccharide compounds, probing the utility of the reaction. While planning the study, it was proposed that having a glycosyl azide at the anomeric centre of the sugar lacking ester functionality could prove beneficial, as glycosyl azides of this type are often inert to anomerisation. This would deconvolute the outcome of the reaction as only one anomerisation would be observed, if the reaction was successful.



Scheme 48: Proposed disaccharide anomerisation

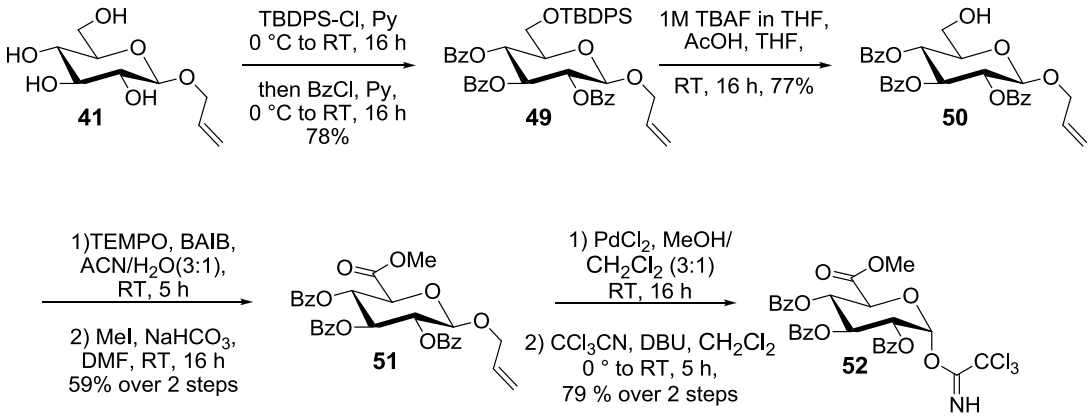
3.3 Results and Discussion.

The study began by preparing the 1,6-linked compound **53**, via a glycosylation reaction with imidate donor **52** and acceptor **48**. Acceptor **48** was synthesised form previously prepared **36**, which underwent a one-pot silylation benzoylation followed by removal of the TBDPS group with TBAF to give the acceptor in 43% yield over the 2 steps.



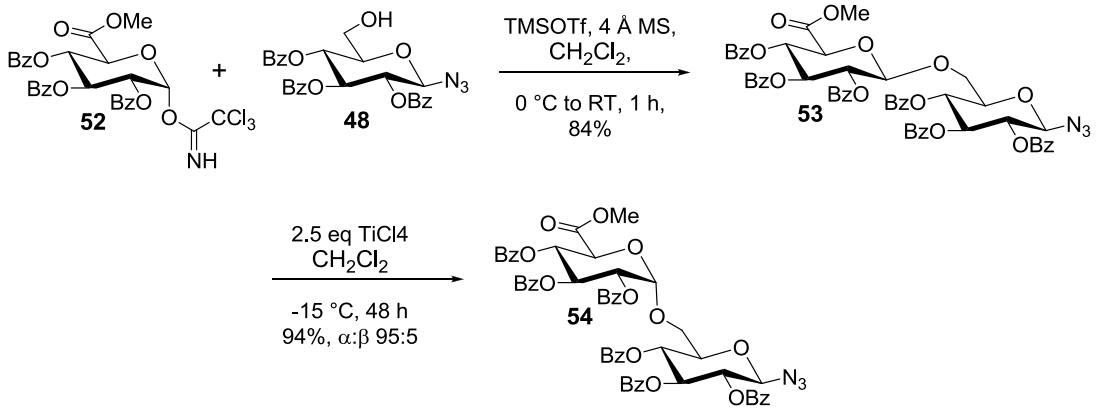
Scheme 49: Synthesis of acceptor 48

Donor **52** was prepared via a similar route from **41**, resulting in intermediate **50** which was oxidized with TEMPO/BAIB and subsequent base mediated esterification gave **51**. Removal of the anomeric allyl protecting group with $PdCl_2$, followed by DBU catalysed synthesis of trichloroacetimidate **52** in 28% yield from **41**.



Scheme 50: Synthesis of trichloroacetimidate donor 52

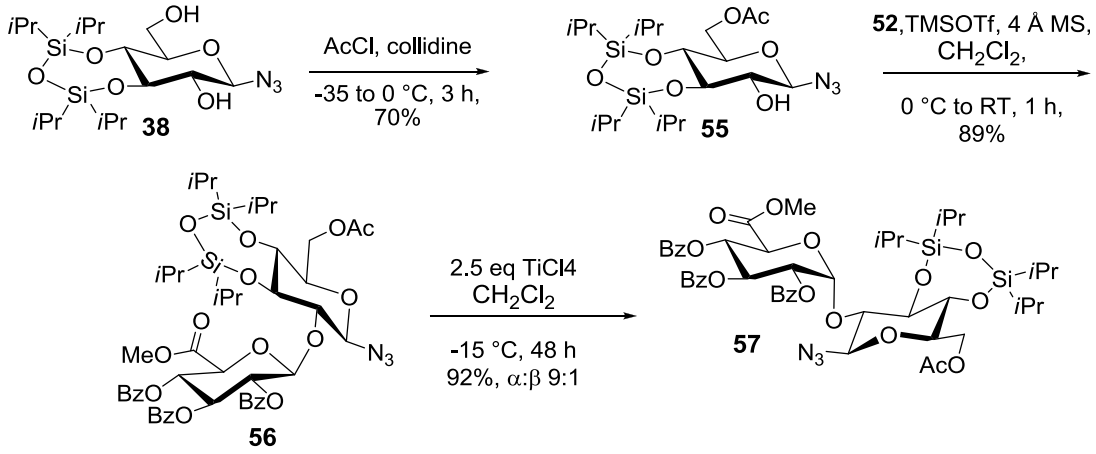
The glycosylation reaction went smoothly to give **53** in good yield. Treatment of **53** with the conditions optimised in Chapter 2, gratifyingly gave **54** in high yield and selectivity. No side products were observed in the ^{1}H NMR following the workup and the mixture was merely passed through a silica plug to remove any remaining $TiCl_4$ associated residues.



Scheme 51: Synthesis and anomerisation of 53

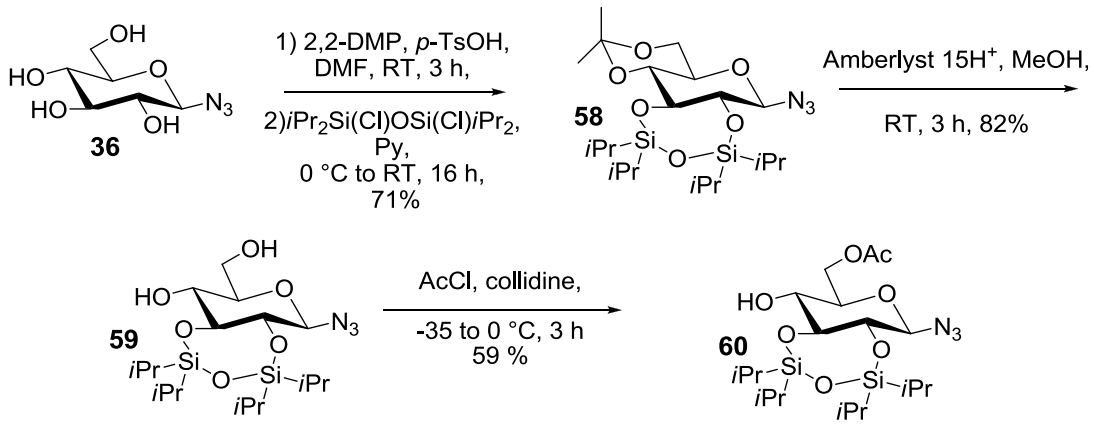
Next the anomerisation of a secondary linkage was investigated. The oxygen atom in such linkages is less electron rich than the corresponding oxygen in a primary linkage, which should have a bearing on the anomerisation reaction. Taking intermediate **38** and treating it AcCl in collidine at -35 °C for 3 hours, resulted in selective acetylation at the primary alcohol in 70% yield[204]. The TMSOTf mediated glycosylation of **55** and **52** gave disaccharide **56** in 89% yield. Compound **56** underwent anomerisation to give **57** in high selectivity and yield. This result not only showed the anomerisation of a secondary glycosyl linkage but also showed that the reaction could be carried out in the presence of disiloxane groups. Seeing as benzyl

ethers and analogues protecting groups are labile under such Lewis acidic conditions, this is important as it expands the protecting group strategies which may be applied under these anomerisation conditions. It is also important to note that the siloxane protecting group may enhance the anomerisation reaction, as it would be less electron withdrawing than acyl protecting groups.



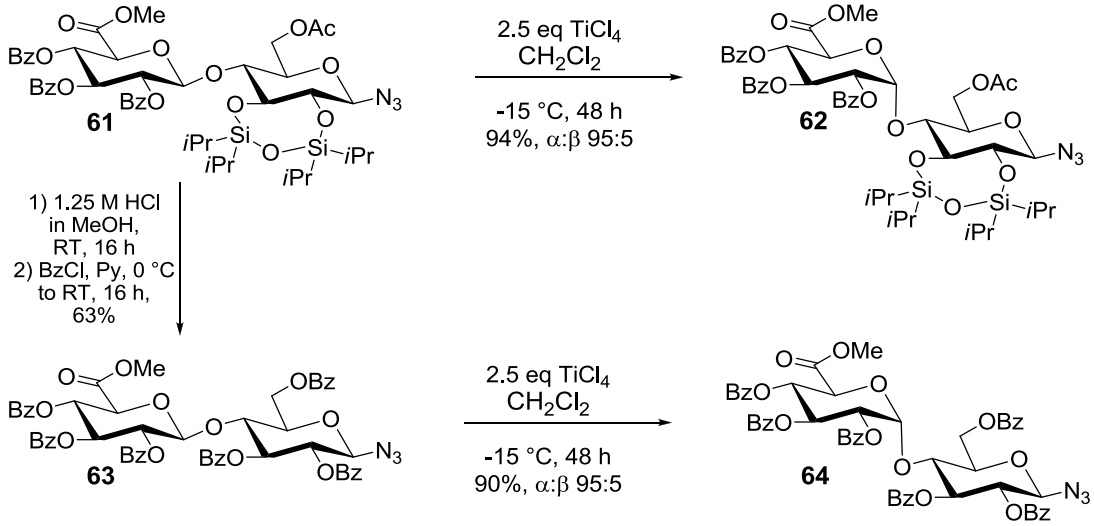
Scheme 52: Synthesis and anomerisation of 56

Attention then turned to the synthesis of the 1,4-linked disaccharides **61** and **63**. The glycosyl acceptor was prepared form **36**, beginning with the selective introduction of a 6,4-isoprorpylidene was achieved with 2,2-DMP and catalytic *p*-TsOH in DMF. Treatment of the 2,3-diol with TIPDSCl$_2$ in pyridine gave **58** in 71% yield over the two steps. Initial attempts to selectively remove the isopropylidene with catalytic *p*-TsOH or CSA or dowex® 50WX8 H+-resin in methanol resulted in mixtures of desired product, a compound lacking the isopropylidene with the disiloxane being partially cleaved and predominantly the fully deprotected compound. It has previously been shown that amberlyst® 15 hydrogen form can remove an isopropylidene from an acid sensitive substrate[205], however initial trials with amberlyst® 15 hydrogen form also resulted in a mixture of compounds. Both resins are strongly acidic however the amberlyst® resin can be dried by azeotropic removal of water with toluene. Further drying on high vacuum, followed by addition to a solution of 58 in MeOH gave the desired product in 46% yield as the major product along with other partially and fully deprotected compounds. It was found that newly purchased resin further increase the yield to 82%. With **59** in hand, a regioselective acylation was once again applied to give **60**.



Scheme 53: Synthesis of acceptor 60

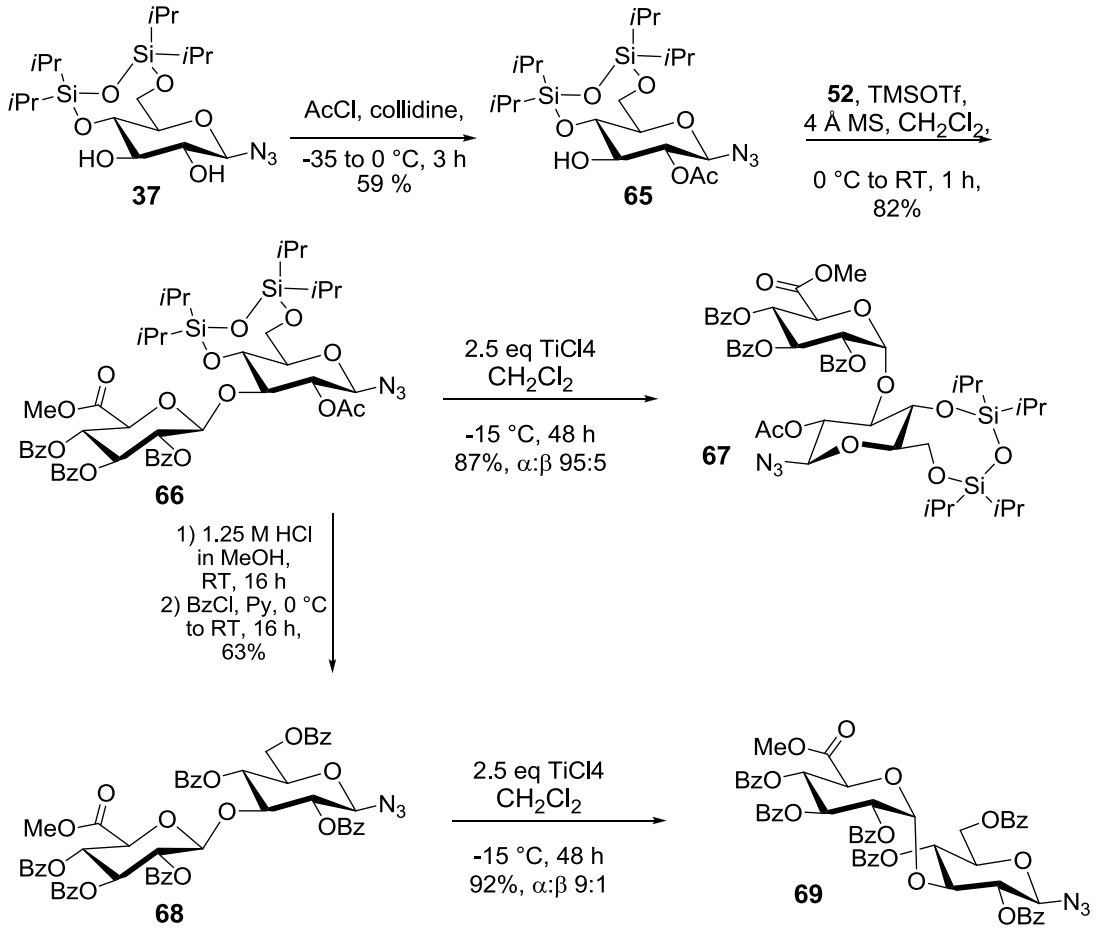
Disaccharide **61** was formed in 66% yield by reacting **60** with trichloroacetimidate **52** in the presence of TMSOTf. Anomerisation of **61** gave **62** in high yield and selectivity. The acetate and disiloxane protecting groups were then removed using methanolic HCl and the resulting triol intermediate was treated with benzoyl chloride in pyridine to give **63** in 54% yield. Subjecting **63** to the anomerisation conditions satisfyingly gave **64** in high yield and selectivity. This was a significant result as anomerisation reactions with such electronically deficient systems have not resulted in high stereoselectivities.



Scheme 54: Anomerisation of disaccharides 61 and 63

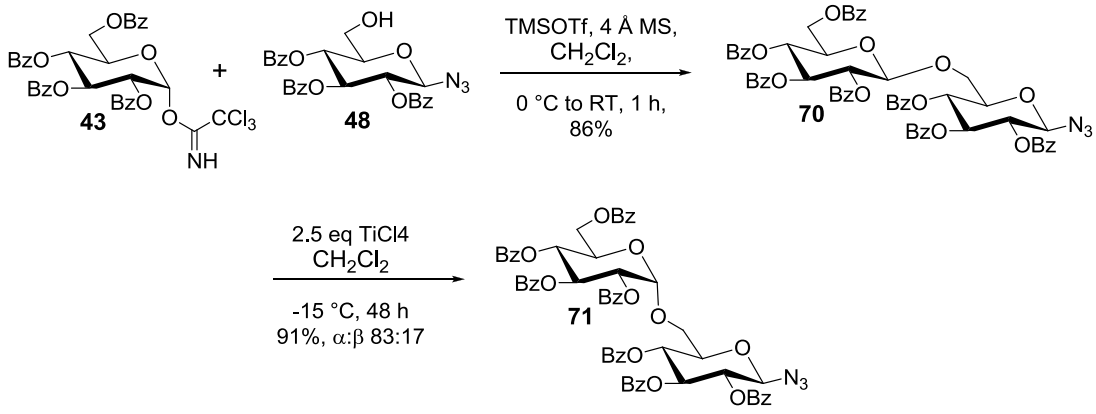
The synthesis of the 1,3-disaccharide involved the preparation of acceptor **65** from intermediate **37** where 2-OH was regioselectivly protected using AcCl in collidine at -35 °C and allowing the reaction to come slowly to room temperature. The greater nucleophilicity of the 2-OH, as well as possible steric hindrance at the 3-

OH due to the *iso*-propyl substituents of the disiloxane protecting group, result in the selective introduction of the acyl group [204,206]. Subsequent glycosylation of acceptor **65** and donor **52** gave disaccharide **66** in good yield. Again the anomerisation went smoothly to give **67**. The protecting groups on **66** were then manipulated to give **68** in 54% yield. Treating **68** with $TiCl_4$ as previously described gave **69** in high yield and selectivity. It is of interest to note that attempts to anomerise an acetylated derivative of **68** were unsuccessful.



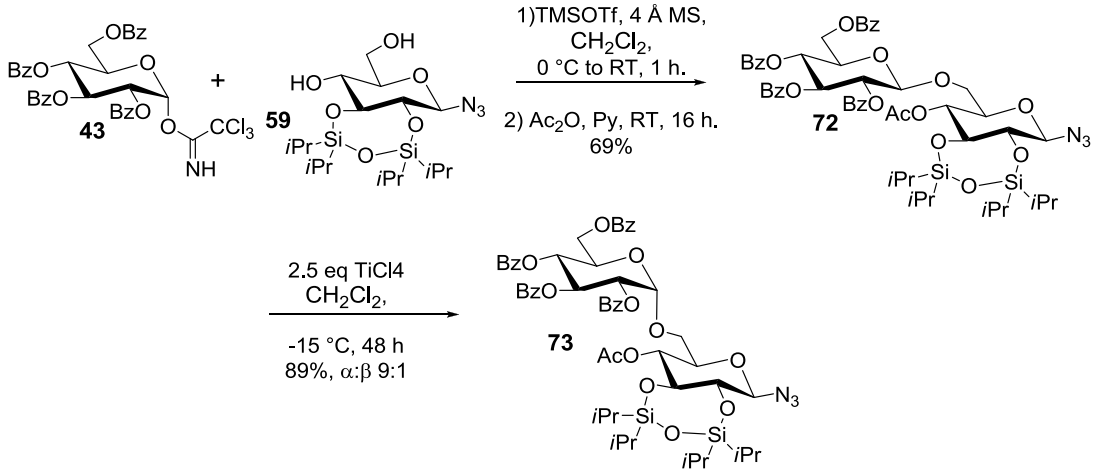
Scheme 55: Synthesis and anomerisation of 66 and 68

The success of the anomerisations discussed above, led us to investigate the anomerisation of analogous compounds lacking the ester functionality. Compound **70** was prepared form acceptor **48** and donor **43** in the presence of catalytic TMSOTf. Although the anomerisation resulted in an α-favourable anomeric mixture, the selectivity was moderate relative to the selectivity achieved for the methyl ester containing derivative **53**.



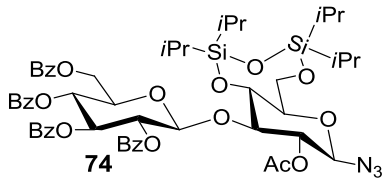
Scheme 56: Synthesis and anomerisation of 70

It was thought that the reactivity of the disaccharide towards anomerisation may be increased by adding the disiloxane protecting group. Coupling **59** and donor **43** followed by acetyl protection of 4-OH gave disaccharide **72**. Gratifyingly **72** anomerised to give **73** in 89% yield with a α:β of 9:1. The higher selectivity seen here due to the addition of the disiloxane is intriguing and may be useful in future studies with similar substrates.



Scheme 57: Anomerisation of disaccharide bearing a disiloxane

Disaccharide **74**, which contains a secondary linkage, was prepared to investigate this effect further. Unfortunately no anomerisation occurred and the starting material was recovered when $TiCl_4$ was applied.



74

Figure 13: Secondary linked disaccharide

3.5 Summary and conclusions.

The results obtained from the disaccharide anomerisation study represent a novel method for the regioselective anomerisation of disaccharides with high selectivities and yields being achieved. The anomerisation of such deactivated substrates shows the potential of the method and its possible application in synthetic carbohydrate chemistry.

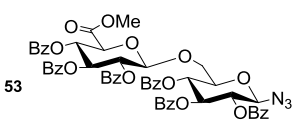
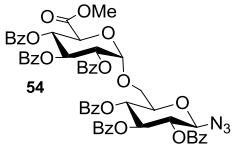
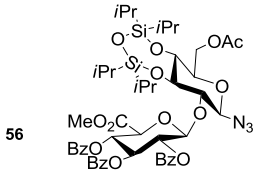
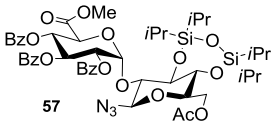
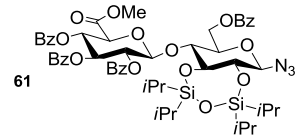
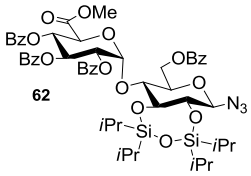
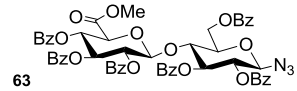
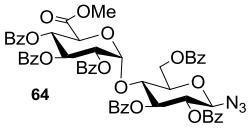
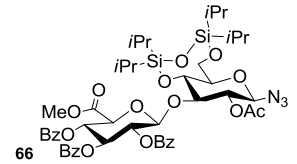
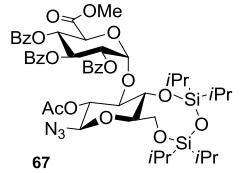
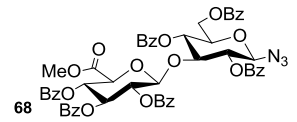
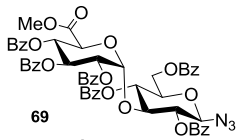
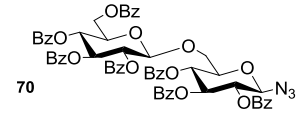
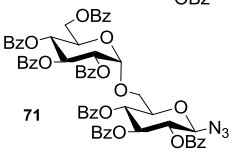
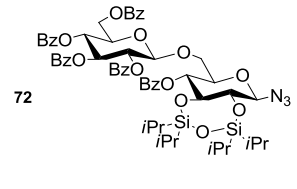
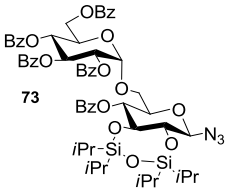
Substrate	Product	α:β	% Yield
 53	 54	95:5	94 %
 56	 57	9:1	92 %
 61	 62	95:5	94 %
 63	 64	95:5	90 %
 66	 67	95:5	87 %
 68	 69	9:1	92 %
 70	 71	83:17	91 %
 72	 73	9:1	89%

Table 5: Summary of disaccharide anomerisation study

The ester functionality enhances the reactivity of such substrates towards anomerisation which is agreement with previous studies[93,106,107]. The presence of this ester could potentially allow for site directed anomerisation in structures of greater complexity. While omission of this ester group would also further enhance this

methodology and although anomerisation occurred with compounds **70** and **72,** these compounds are 1,6-linked. The attempt to anomerise the analogous 1,4-linked compound was unsuccessful and even though this is disappointing, it reveals the boundaries of the current system, thus presenting a new challenge. Such challenges require the development of an improved promoter system and further studies to understand the effects of the protecting groups involved.

Chapter 4: The effects of acyl protecting groups on the rate of anomerisation

4.1 Introduction

In 1954, Reeves *et al*. observed a substantial rate increase in the anomerisation of substrates bearing benzoate protecting groups in comparison to the acetyl protected derivatives[95]. During the course of an investigation, probing the factors affecting the rate and the stereochemical outcome of anomerisation reactions, Murphy *et al*. quantified this difference in rate[93]. It was observed that the benzoate protected substrate anomerised at a rate five times greater than the corresponding acetyl protected compound. During the course of the investigation outlined in Chapter 3, the acetate protected derivative of compound **68** failed to anomerise, while compound **68**, which is benzoate protected, underwent anomerisation smoothly.

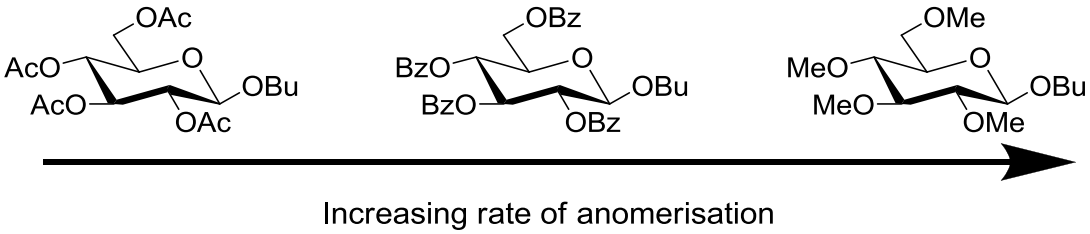


Figure 14: Trend observed by Murphy *et al*.

Such observations are counterintuitive, as the study of Koto *et al*. showed a benzyl ether protected carbohydrate reacts faster than the corresponding acetate protected compounds, which is presumably due to the electronic nature of the protecting groups[96]. This was ratified with the study involving *p*-chlorobenzyl ether carried out by Mukaiyama *et al*.[97]. Therefore, the factors affecting the rate of anomeriation are analogous to those affecting the activation of glycosyl donors[iii]. However, studies carried out by Wong *et al*. have shown that acetate protected thioglycosides are activated at a faster rate than the corresponding benzoate protected thioglycosides[207].

[iii]Note: Changing the conformation from $^4C_1$ to $^1C_4$ should in theory reverse the anomeric effect and therefore would not be useful in the anomerisation study discussed herein.

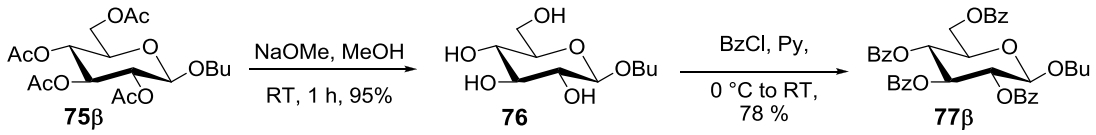
It is apparent from this that electronic effects, as usually described for carbohydrate systems, are likely not to be the cause of the rate increase seen with the benzoate protected compounds. Another possibility is that the effect is steric in nature. Although steric effects have been used to explain the stereochemical outcome of reactions (see Chapter 1), it is not evident from an extensive literature search that there are examples of steric effects increasing the rate of glycosyl donor activation or anomerisation reactions. However, this is a possible explanation for the rate increase in this case, as the steric interactions between the benzoate groups may reduce the entropy of the system. This could lead to preorganisation of chelating groups that are involved in chelation of the Lewis acid, and would lead to an increase in the rate of anomerisation[208–211].

4.2 Objectives

To examine this hypothesis, there was an objective to prepare a library of compounds to study in more detail how the protecting groups affect the rate of anomerisation. As the goal of this research is to improve the anomerisation reaction, where possible attempts were to be made to further increase the rate of the anomerisation reaction based on the findings. Finally, if successful, the improved protecting group strategy would be applied to the anomerisation of substrates, analogous to those which have previously been unsuccessful (e.g. compound **74**).

4.3 Results and discussion

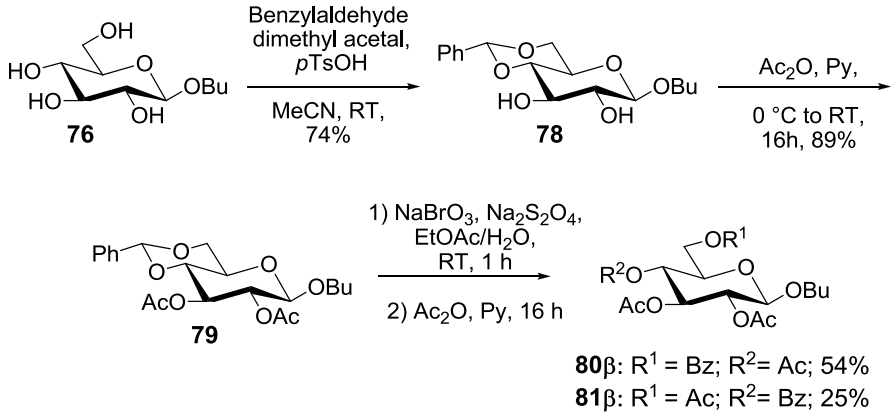
The study began with the synthesis of compounds **75β** and **77β**. Compound **75β** was prepared as previously described by Murphy *et al* [93]. Zemplén deacetylation of **75β** gave intermediate **76** in quantitative yield. Benzoylation of **76** with benzoyl chloride in pyridine gave **77β** in 78% yield.



Scheme 58: Preparation of 77β from 75β

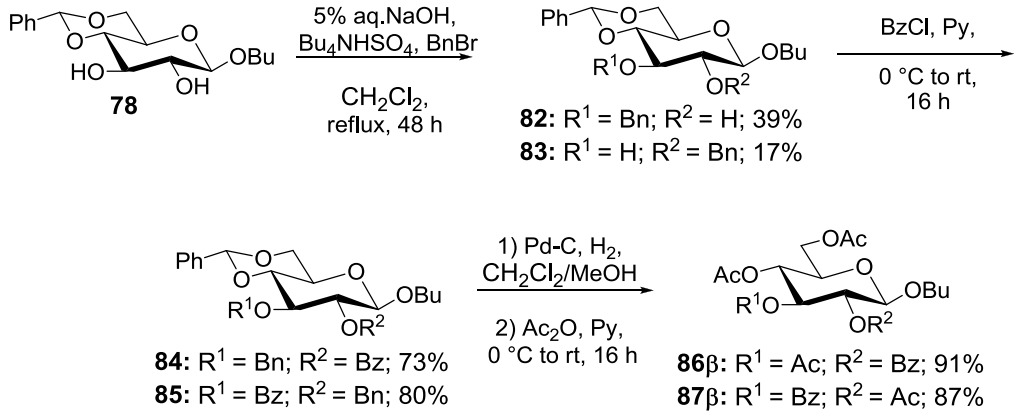
Attention then turned the preparation of monobenzoylated compounds **80β**, **81β**, **86β** and **87β**. These compounds were prepared so as to investigate and compare

the effect of the benzoate protection on the rate of anomerisation at each of the positions about the pyranose ring. The four compounds were prepared from intermediate **78**, which itself was prepared in 74% yield from **76**. Acetylation of the 4,6-benzylidine protected compound gave compound **79** in 89% yield. The oxidative cleavage of the benzylidene using $NaBrO_3$ and $Na_2S_2O_4$, under bi-phasic conditions, followed by acetylation, resulted in the formation a separable mixture, giving **80β** and **81β** in 79% total yield, with the ratio being 32:68 in favour of compound **80β**.



Scheme 59: Synthesis of compounds 80β and 81β

Benzylation of **78** under the biphasic alkali conditions previously reported by Oscarson *et al*. gave a mixture of compounds **82** and **83** (69:31 respectively) in 56% yield[212]. Benzoylation of the respective free hydroxyl groups gave compounds **84** and **85** in good yields. Hydrogenolysis of these intermediates, followed by acetylation with Ac_2O in pyridine gave **86β** and **87β** in 91% and 87% yields respectively.



Scheme 60: Preparation of compound 86β and 87β

With these compounds in hand, attention turned to the quantification of the rate of anomerisation for each substrate. Murphy *et al.* have previously shown that Lewis acid catalysed anomerisations generated straight line plots with use of the equation[93] which can be applied for equilibrium kinetics:

$$\ln\left(\frac{[A]_0 - [A]_e}{[A]_t - [A]_e}\right) = -(k_f + k_r)t$$

where $[A]_0$ is the initial concentration of the β-anomer, $[A]_e$ is the concentration of the β anomer at equilibrium, $[A]_t$ is the concentration of the β-anomer at a time t, k_f is the rate constant of the forward reaction (β → α) and K_r is the rate constant of the reverse reaction (α → β). Herein, k is used to represent $(k_f + k_r)$. The reactions were monitored by NMR and data obtained were found to give straight line plots according to the equilibrium rate law. Each reaction was carried out in triplicate and all plots had r^2 values of 0.97 or greater.

Examination of the relative rates showed a two fold rate increase for the fully benzoylated compound **77β** when compared to **75β**[iv]. Compound **80β** was the slowest of all the monobenzoylated compounds, none of which showed a major rate increase compared to the peracetylated compound. The reduction in rate for **80β** can be rationalised by the reduction of the electron density at saccharide C-6 position by the electron withdrawing benzoyl group thus reducing the rate of the anomerisation and it is in line with the study of Koto *et al*[96]. The rates obtained for compounds **81β** and **86β** are higher than **80β**, but less than the peracetylated compound. This may be due to the proximity of the benzoate groups to the site of chelation and/or the reaction centre and thus the reaction is less sensitive to the electron withdrawing effect of the benzoate groups in these derivatives.

The rate of anomerisation observed for compound **87β** conflicted this proposal as it anomerises the fastest of the monobenzoylated compounds, although it cannot alone be declared as the cause of the rate increase seen for **77β**. The rate observed for **87β** could be due to a number of phenomena, however two rational

[iv] Note: This anomerisation study was carried out using 1 equivalent of $SnCl_4$ rather than with the 0.5 equivalent of the promoter as carried out previously by Murphy *et al*. As a result the relative rates will vary as the rate of anomerisation does not have a linear relationship to the concentration of $SnCl_4$ used and the relationship also varies from substrate to substrate..

explanations can be proposed. Stabilisation by an acyl group has previously been proposed by Manabe *et al.*[104] and although acetate and benzoate groups both contain the required carbonyl functionality, the steric difference between the group may result in the carbonyl being orientated in a conformation which further enhances the this stabilisation, thus resulting in a faster anomerisation reaction.

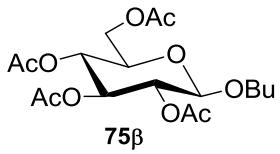
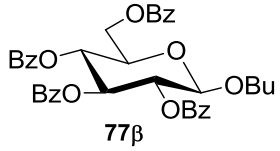
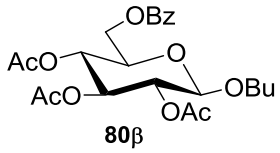
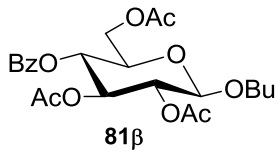
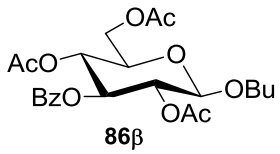
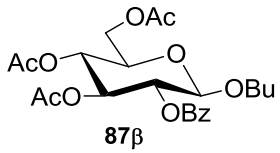
Substrate	$10^4(k_f + k_r)$ (s^{-1})	Relative Rate	α:β (Yield)
 **75β**	**7.6**	**1**	**9:1 (64%)**
 **77β**	**15.7**	**2.07**	**95:5 (72%)**
 **80β**	**6.0**	**0.79**	**92:8 (81%)**
 **81β**	**7.1**	**0.93**	**89:11 (76%)**
 **86β**	**7.2**	**0.95**	**93.7 (73%)**
 **87β**	**8.6**	**1.13**	**9:1 (61%)**

Table 6: Rate of anomerisation for series I compounds

Although this type of stabilisation has not been previously proposed in synthetic carbohydrate chemistry, cation-π interactions have been used to rationalise the

stabilisation of the transition state leading to the oxocarbenium ion in glycosyl hydrolases[213–218]. These interactions may not only be involved in anomerisation reactions but also in glycosylation reactions. The work of Wong *et al*. showed the relative rate of glycosylation of the 2-*O*-acetyl and 2-*O*-benzoyl protected compounds (**C** and **D**) to be faster for the 2-*O*-benzoyl compound, which could also be explained by a greater stabilisation of the transition state by the benzoate group[219].

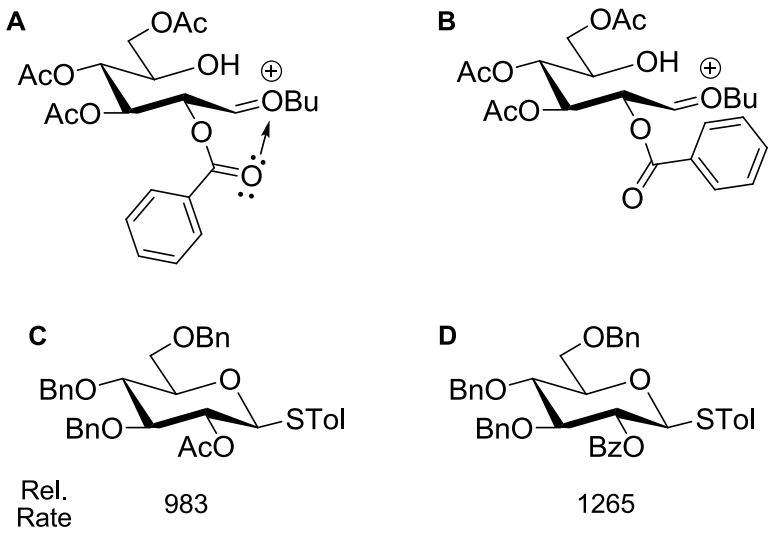
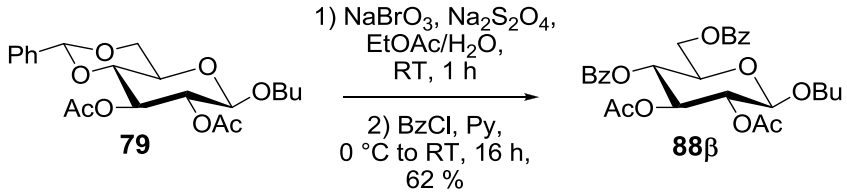


Figure 15: Oxocarbenium stabilisation by acyl groups

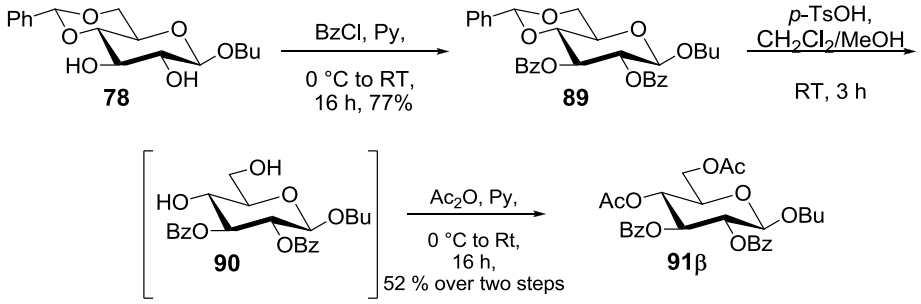
Attention next turned to the preparation of compounds bearing two or three benzoate groups. Compound **88β** was prepared from intermediate **79**, by applying the previously outlined oxidative benzylidene cleavage followed by benzoylation to give **88β** in 62% yield.



Scheme 61: Preparation of compound 88β

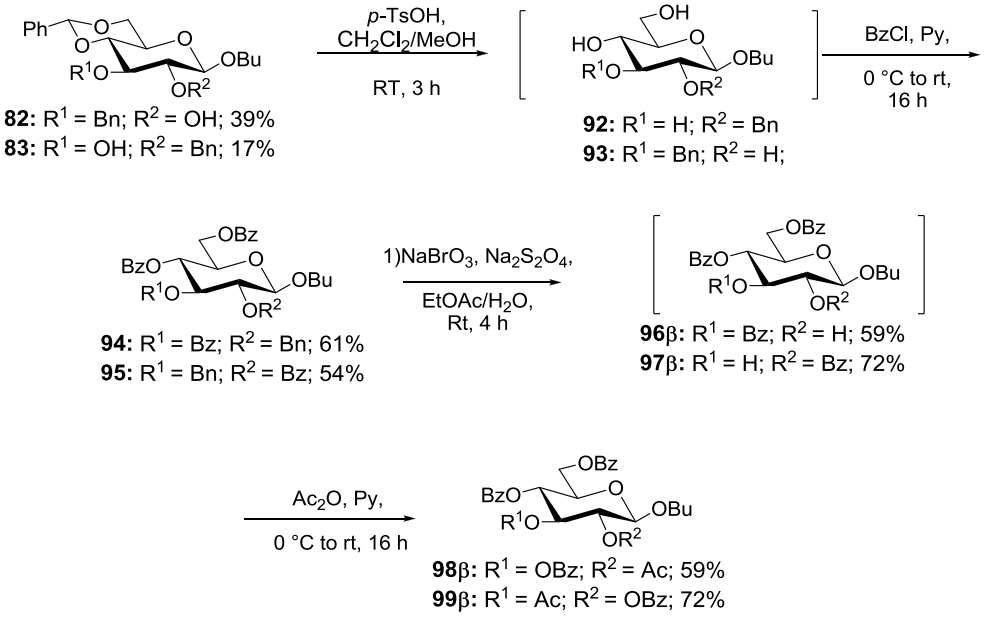
Compound **91β** was prepared from benzylidene intermediate **78** in 3 steps. Benzoylation of **78** with benzoyl chloride in pyridine gave intermediate **89**. Acid catalysed cleavage of the benzylidene acetal in a DCM/MeOH gave intermediate **90**

which was taken crude to the next step and was acetylated to give **91β** in 40% yield from **78.**



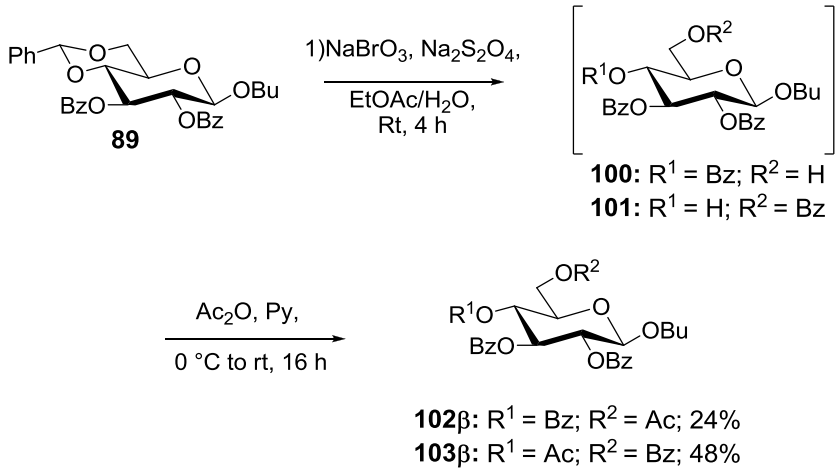
Scheme 62: Synthesis of compound 91β

The synthesis of compounds **98β** and **99β** was carried out in a similar manner from compounds **82** and **83** respectively. Acid catalysed cleavage of the benzylidene acetal as previously described followed by benzoylation gave compounds **94** and **95**. Oxidative cleavage of the benzyl ether protecting groups with $NaBrO_3$ and $Na_2S_2O_4$ went smoothly to give the monohydroxylated intermediates which were acetylated to give the desired substrates in good yield.



Scheme 63: Synthetic route to compounds 98β and 99β

Compounds **102β** and **103β** were prepared from benzylidene acetal **89** using the biphasic oxidative ring opening procedure previously described. Acetylation of intermediates **100** and **101** gave compounds **102β** and **103β** in moderate yield.



Scheme 64: Preparation of compounds 102β and 103β

Kinetic studies on the di- and tri benzoylated compounds did not result in any compound having a rate comparable or better than that of the fully benzoylated **77β** and as before only one compound anomerised at a faster rate than compound **75β**. The rate of anomerisation for compound **88β** is relatively slow. This was not surprising and the rationalisation applied to the rate observed for compound **80β** can also be applied here. Contrary to this compound **91β** has a less electron withdrawing acetate at C-6 but has the benzoate at C-2 that may be involved in the cation-PI interaction and this was the only dibenzoylated derivative to be faster than **77β**. Compound **98β** was the slowest in this series; the effect of the electron withdrawing benzoates at C-3, C-4 and C-6 seems to be additive and deactivate the saccharide towards anomerisation. .

When comparing rates of anomerisation of **98β** and **99β**, the proposal for a greater stabilisation by the benzoate group at C-2 can be again supported as **99β** shows a rate increase. The rate of anomerisation for compound **99β**, exemplified the effect of the benzoate at C-2 and although the rate increase is modest, in relative terms it is substantial. Compounds **102β** and **103β** elucidate the importance of the electronic nature of the protecting groups at C-4 and C-6. When compared with **91β,** which has acetate groups at these positions, it is evident that the electron

withdrawing nature of the benzoate groups result in a decrease in the rate of anomerisation.

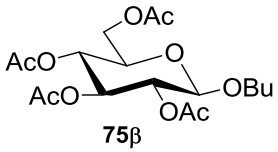
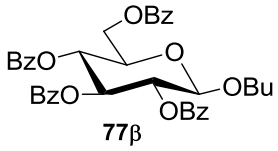
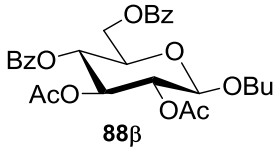
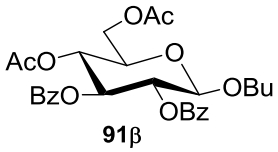
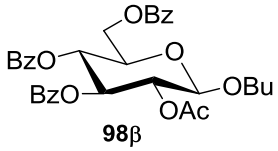
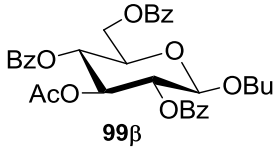
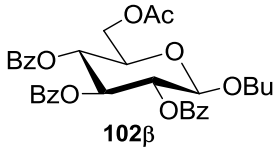
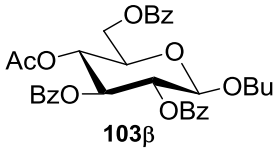
Substrate	$10^4(k_f + k_r)$ (s^{-1})	Relative Rate	α:β (Yield)
 **75β**	**7.6**	**1**	**9:1 (64%)**
 **77β**	**15.7**	**2.07**	**95:5 (72%)**
 **88β**	**4.6**	**0.61**	**92:8 (84%)**
 **91β**	**8.5**	**1.12**	**88:12 (61%)**
 **98β**	**3.7**	**0.49**	**9:1 (54%)**
 **99β**	**6.2**	**0.82**	**91:9 (67%)**
 **102β**	**6.6**	**0.87**	**9:1 (83%)**
 **103β**	**5.6**	**0.74**	**89:11 (70%)**

Table 7: Anomerisation of series II compounds

The twelve compounds which were thus far kinetically analysed have show consistently a rate enhancement by the benzoate group at C-2, but rate reductions for benzoates at C-3, C-4, C-6. On the basis of all the data, one might expect a rate reduction for **77β** but this compound is faster than expected. To further probe the cause of this rate increase for **77β** conformational analysis was carried out using NOE experiments and computational modeling.

The NOE experiments were used to calculate the distances between the protons at C-6 and the proton at C-4 for different compounds **75β**, **77β** and **98β**. The conformation about the C-5–C-6 bond is of particular interest in this instance, as it has been previously published that the oxygen bonded to C-6 and/or the oxygen of the carbonyl present in the protecting group may have a role to play in the chelation of the Lewis acid[93,96].

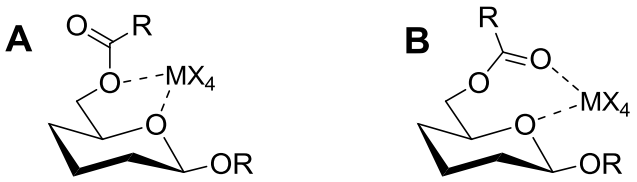


Figure 16: Possible sites of Lewis acid chelation

The gauche-gauche (gg), trans-gauche (tg) and gauche-trans (gt) conformations are depicted below (Figure) and it is evident from simple conformational analysis that the *gg* and the *gt* conformations will allow chelation occur, however the *tg* conformation will not. It has been shown that in the case where R= H, there was not a strong preference for one of these conformational isomers [220]. However increasing steric interactions have been shown to result in one or more of the conformers being disfavoured[221,222]. It is of interest to note that the effect of constraining these conformers have been carried out for glycoside hydrolysis[223,224], however the results cannot be correlated directly to the anomerisation, of interest herein, as hydrolysis and anomerisation have different mechanisms (i.e. endocyclic vs. exocyclic cleavage), hence a separate study would have to be carried out to investigate the effect of conformation between C-5 and C-6 on the rate of anomerisation.

It is important to note that due to rotation about the C-5–C-6 bond, the results obtained may reflect an average distance rather than actual distance between the proton at C-4 and the protons at C-6 The 2-D NOE spectra were acquired with

mixing times varying from 200 ms to 700 ms, thus allowing for a build up curve to be obtained by plotting the mixing times against the absolute NOE build-up (i.e., the peak areas of the cross peaks)[v]. A build up curve corresponding to the cross peak between H-1 and H-3 was also constructed, as this distance would be expected to be fixed if the $^4C_1$ conformation is fixed for each of the compounds; this distance was used as a reference distance.

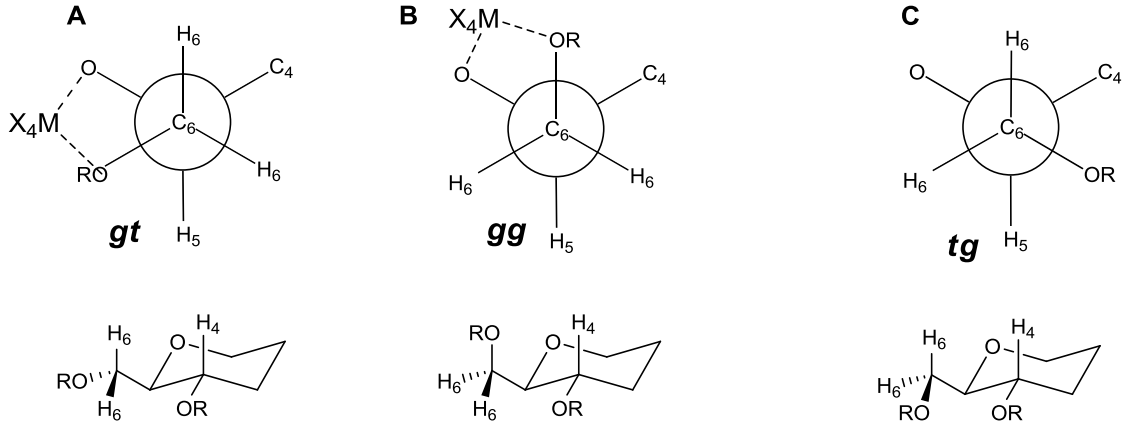


Figure 17: Possible conformations about the C-5–C-6 bond.

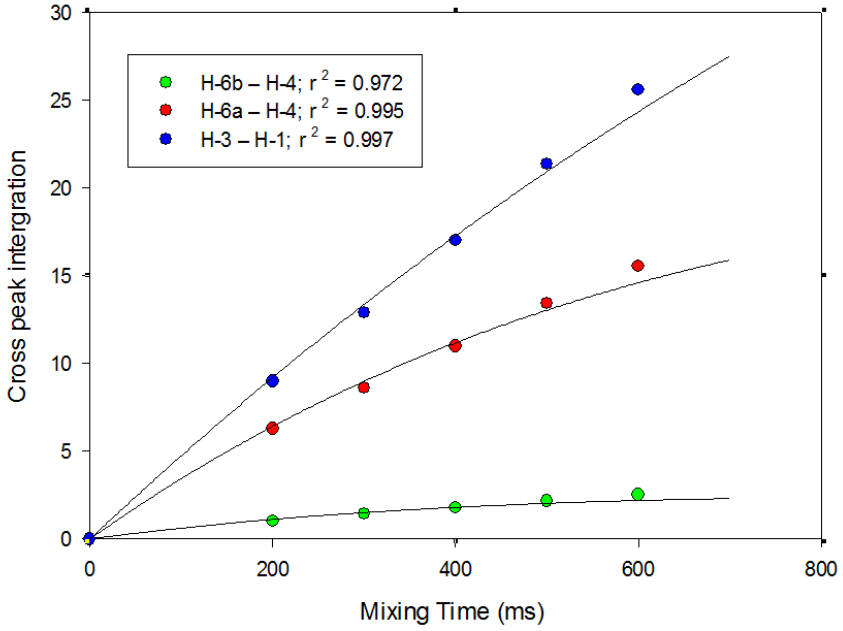


Figure 13: Build up curve for compound 75β[vii]

[v] The method to carry out this study was obtained from the PhD thesis of Dr. Jenifer Hendel[239]
[vii] For the build up curves of other compounds see appendix 2.

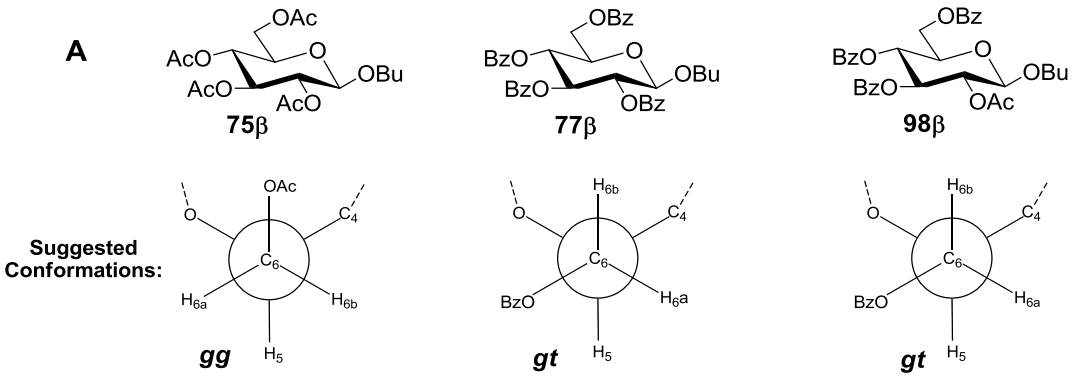
The data points of the build up curve were then fitted to the following equation[225,226]:

$$A_{cross}(\tau_m) = k_1(-e^{-k_2\tau_m} + e^{-k_3\tau_m})$$

In this equation A_{cross} is the area of the cross-peak, τ_m is the mixing time (milliseconds, ms) and k_{1-3} represent constants. The lines on the graphs were extrapolated to zero and the initial slope (at $\tau_m = 0$) was obtained. The distance between the hydrogen atoms was then calculated using the isolated spin-pair approximation, where the initial slope is proportional to the inverse distance (r^6). Using a known distance between the two reference protons and the initial slope from the corresponding build-up curve, the distance between the protons at protons at C-6 and the proton at H-4 could be calculated using the following equation[225,226]:

$$r_{unknown}^6 = slope_{reference} \times (r_{reference}^6/slope_{unknown})$$

The calculated distances provide evidence that conformation about the C-5–C-6 bond was different for compounds bearing a benzoate at position six compared to the compounds which had an acetate at this position. These distances suggested that compound **75β** is in *gg* conformation, while compounds **77β** and **98β** are in the *gt* conformation. In the *gt* conformation, the ring oxygen is in close proximity to O-6 and the oxygen of the benzoate group. Although this may have an effect on the rate of anomerisation it was not in agreement with the experimental findings for compound **98β**, hence computational studies were carried out to investigate the energy differences between each conformation for the three compounds studied.



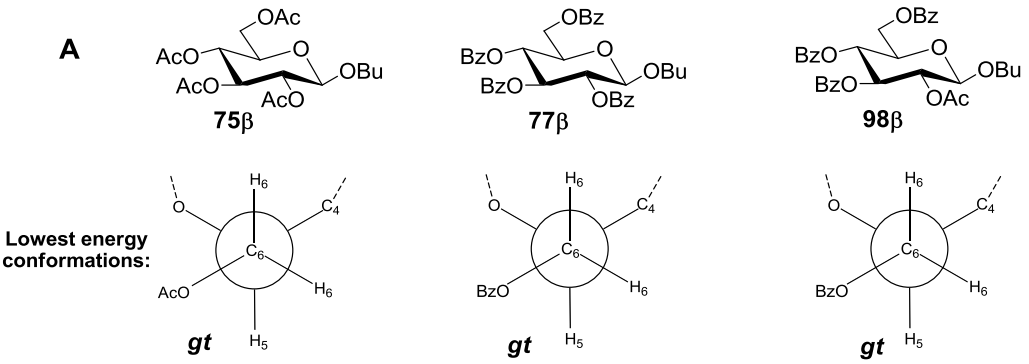
Substrate	Dist. H_{6a} to H_4	Dist. H_{6b} to H_4
75β	3.45 Å	2.62 Å
77β	2.78 Å	2.70 Å
98β	2.80 Å	2.69Å

Figure 19: Distances calculated by NOE experiments

Computational studies were carried out using *Macromodel*^{TM} as part of the *Schroedinger Programme*^{TM} in an attempt to rationalise the results obtained from the NOE experiments[227,228]. The force field used was OPLS-AA (Optimized Potentials for Liquid Simulations-All Atom)[229] and the calculations were carried out under solvent free conditions. Compounds were first minimized and subsequently conformational searches were carried out where structures with a ΔE of >10 kcal mol^{-1} relative to the lowest energy minimized structure being retained in the search.

Each of the compounds investigated showed a preference for the *gt* conformation, with the *gg* conformation being the next lowest energy conformation. It is interesting to note the *tg* conformation was not observed within the energy parameter where structures were retained in the search. Although the distances calculated by the NOE experiments and the molecular modelling to not correlate, the distances observed in the NOE experiments for compound **77β** and **98β** could only occur in a *gt* conformation.

A



B

Substrate	Computationally determined distances		Distances determined by NOE experiments	
	H_{6a} to H_4	H_{6b} to H_4	H_{6a} to H_4	H_{6b} to H_4
75β	3.13 Å	2.55 Å	3.45 Å	2.62 Å
77β	3.41 Å	2.36 Å	2.78 Å	2.70 Å
98β	3.07 Å	2.57 Å	2.80 Å	2.69 Å

Figure 20: Computational conformational studies and distances determined by modelling and NOE experiments

Further computational analysis of the conformations about the C5-C-6 bond were carried out using dihedral driving, in an attempt to evaluate the rotational restrictions present for each compound. Comparing the two compounds of similar structure **77β** and **98β** gives an interesting insight into the conformational differences. The two compounds have a similar profiles going between the *gg* and *gt* conformations, showing a preference for the *gt* conformation, while it is evident that compound **77β** disfavours the *tg* conformation. Compound **75β** shows little preference for the *gg* or *gt* conformation and as expected from previous calculations the *tg* conformation occurs at a higher energy and although the energy barrier to this conformation is higher than that calculated going from the *gg* to the *gt* or vice versa, it is not substantial when compared to the barrier observed for compound **77β**.

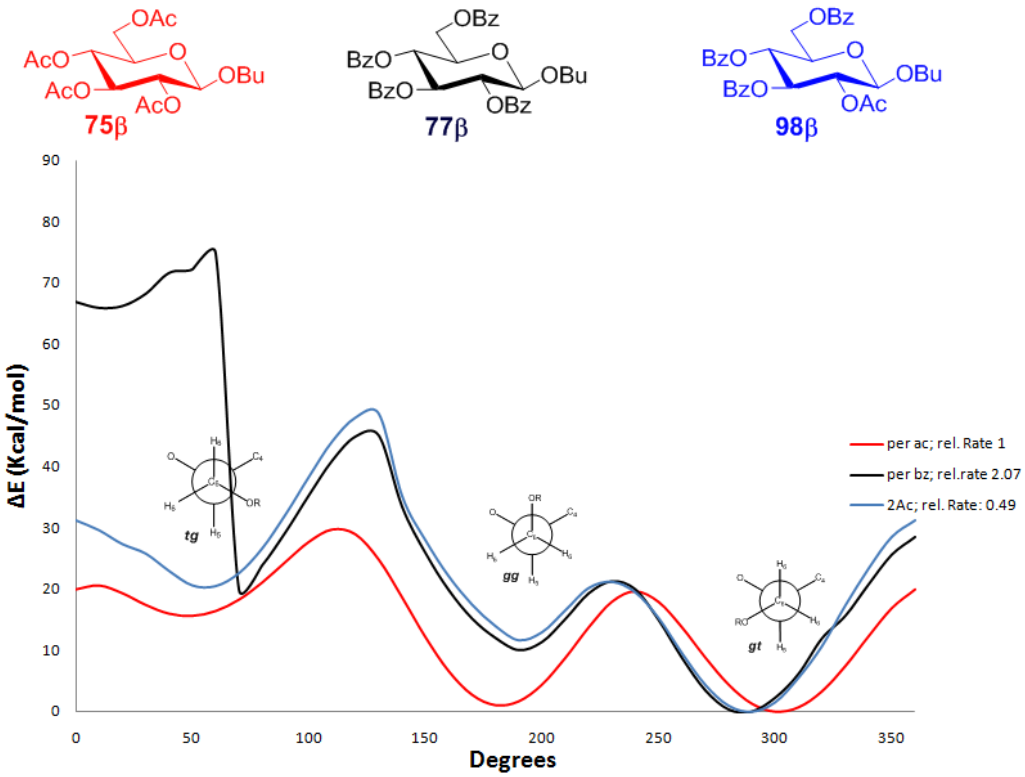
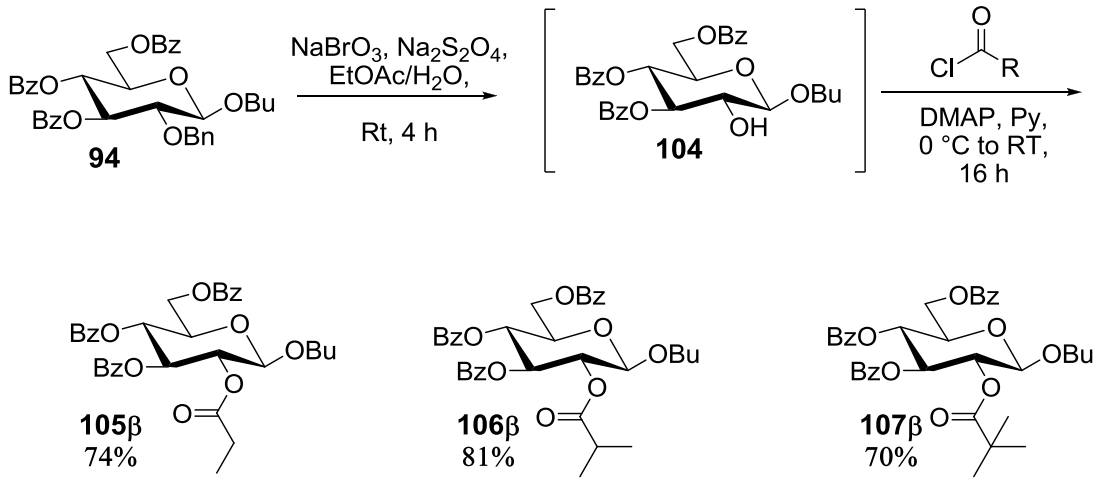


Figure 21: Dihedral driving analysis.

Leading on from these conformational analysis studies, it was considered that having four benzoyl groups on the saccharide could lead to enhanced steric interaction that could influence preorganisation about the C-5 to C-6 bond and increase in anomerisation rate. It was decided to vary the nature of the acyl group at C-2 to try to gain insight as to whether a steric effect was involved in the reaction. Compounds **105β**, **106β** and **107β** were thus prepared from compound **94**, using the previously outlined for oxidative removal of the benzyl ether, giving intermediate **104** which was used directly in the next step and reacted with the three corresponding acid chlorides.



Scheme 65: Preparation of 2-*O*-acyl compounds

Kinetic studies on these compounds proved to be revealing, as the rate of anomerisation increased as the electron withdrawing ability of the substituents decreased and as the size of the protecting group increased. Although it is interesting to note that compound **77β** does not follow this electronic trend. It was attempted to correlate the data to the Taft equation, however due to the small sample size and the slight variation in the functionality of the substrates, it was felt the results obtained may not truly reflect the effect of sterics and electronics on the rate of anomerisation.

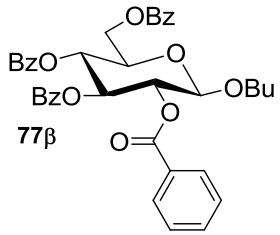
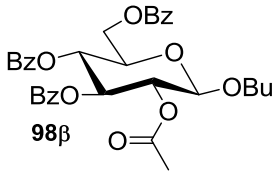
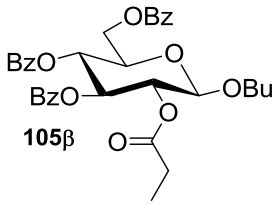
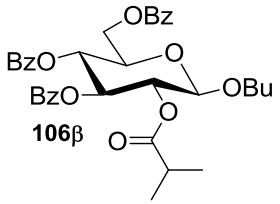
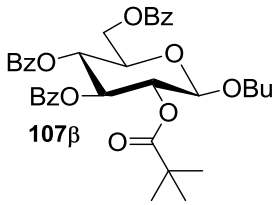
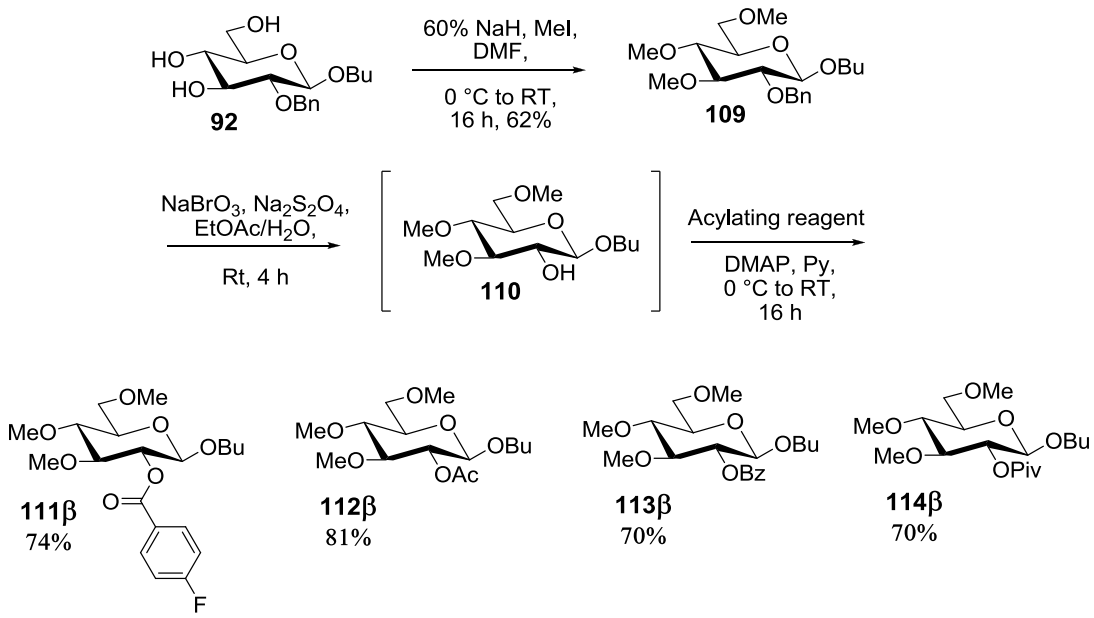
Substrate	$10^4(k_f + k_r)$ (s^{-1})	Relative Rate	α:β (Yield)
 **77β**	**15.7**	**2.07**	**95:5 (72%)**
 **98β**	**3.7**	**0.49**	**9:1 (84)**
 **105β**	**4.1**	**0.53**	**94:6 (66%)**
 **106β**	**5.5**	**0.72**	**92:8 (48%)**
 **107β**	**9.9**	**1.3**	**95:5 (89%)**

Table 8: Rate of anomerisation for series III compounds

In an attempt to investigate further the other factors which may be in play, such as the proposed cation-π interaction, compounds **108β**, **111β**, **112β**, **113β** and **114β** were prepared so as to vary the cation-π-interactions and effects due to protecting groups other than position C-2. Compound **108** was prepared as previously described by Murphy *et al.* from compound **76**[93]**.** The 2-*O*-acyl compounds were prepared from intermediate **92**, which was treated with NaH and methyl iodide to give compound **109**. As previously described, the benzyl ether was removed and acylation of the hydroxyl-containing intermediate gave the desired compounds in good yields, after purification by chromatography.



Scheme 66: Preparation of compound 111β to 114β

Anomerisation studies on these compounds resulted in compound **113β** being faster than its acetylated counterpart **112β**. Interestingly compound **114β** is faster than **113β** showing that electronics could also play an important role at the C-2 position, where the pivalate is more electron donating and leads to an increase in rate compared to the benzoate. This comparison does not however correlate to the rates observed for previously discussed compounds **77β** and **107β** where the 2-*O*-benzoyl protected compound is seen to be faster than the 2-*O*-pivoyl protected compound indicating that the benzoate at C-3, 4 and 6 play a role in the difference observed.

Compound **111β** was prepared in order to try to directly investigate the proposed cation-π interaction. Dougherty *et al*. have previously published that a fluorine substituted benzene has a lesser cation-π interaction than benzene[230]. It is also important to note that according to the Taft polar substituent constant and Hammet σ and σ^+ vaules a *p*-fluorophenyl substituent and a phenyl substituent are electronically comparible[231,232]. Interesting the rate observed for compound **111β** was the lowest in this series of compounds by a significant amount and provides further evidence that a cation-π interaction plays a role in the stabilisation of a carbocation in the transition state for the anomerisation reaction.

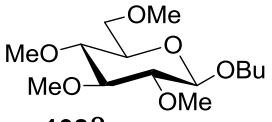
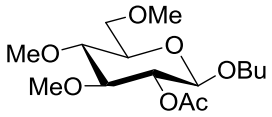
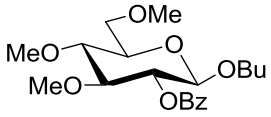
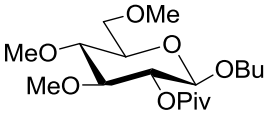
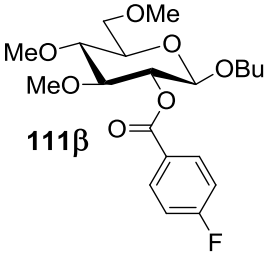
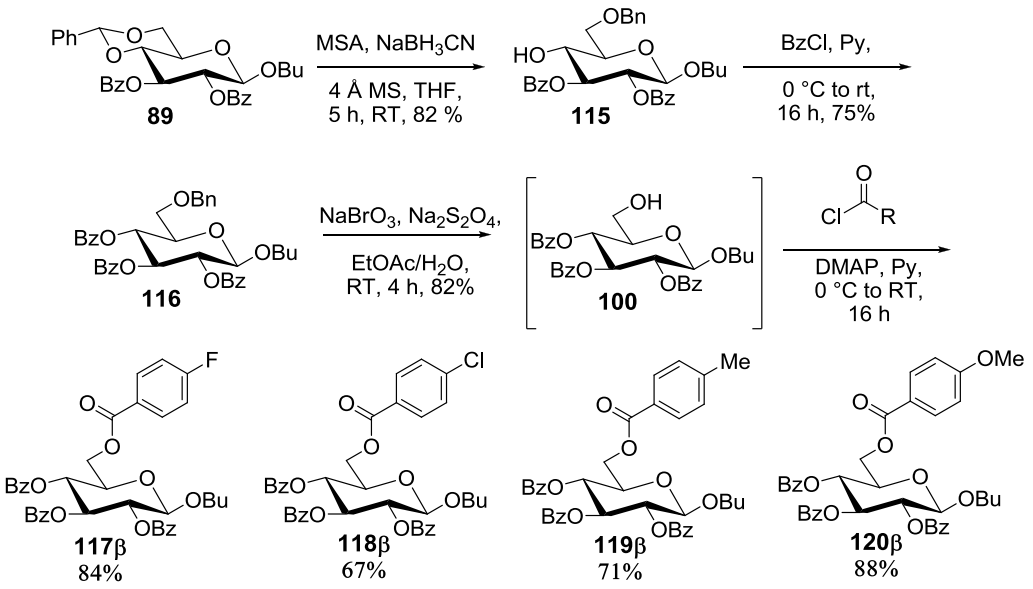
Substrate	$10^4(k_f + k_r)$ (s^{-1})	Relative Rate	α:β (Yield)
 **108β**	**4676.0**	**615.3**	**96:4 (72%)**
 **112β**	**3088.3**	**406.4**	**92:8 (74%)**
 **113β**	**4088.4**	**537.9**	**95:5 (71%)**
 **114β**	**4386.0**	**577.1**	**94:6 (86%)**
 **111β**	**1854.7**	**244.0**	**95:5 (52%)**

Table 9: Rate of anomerisation for series IV compounds

Next attention was turned to studying the effect of modification at the C-6 position as it was felt that decreasing the electron withdrawing ability of the ester protecting group would further increase the rate of anomerisation. A series of compounds were prepared which had benzoate protecting groups at C-2, 3 and 4 and a variety of substituted benzoates at C-6. The compounds were prepared from compound **89** which was treated with MSA and $NaBH_3CN$, resulting in the regioselective opening of the benzylidene acetal to give **115**[233].Benzoylation of the resulting monohydroxy intermediate gave **116**. Oxidative removal of the benzyl ether followed by acylation with a variety of acid chlorides in pyridine gave the desired library of compounds in good yields.



Scheme 67: Synthesis of compound 117β to 120β

The anomerisation studies carried out under these compounds gave interesting results. All of these compounds anomerised more slowly than perbenzoylated**77β** and no trend was clear for this series of compounds. It could be the case that there may be an interaction between the phenyl rings of the benzoate groups and that by changing the electrostatics of a single benzoate this interaction is disrupted. NOE experiments and computational studies carried out on compounds **119β** and **120β** give analogous results to the results obtained for compound **77β**. Interestingly, overlapping these three structures resulted in a slight variation in the conformation of the benzoate groups at positions four and six and the change can be correlated to the rates observed. Conformational calculation for compounds **117β** and **118β** were then carried out and the lowest energy conformations found were also overlayed, further illustrating this conformational difference.

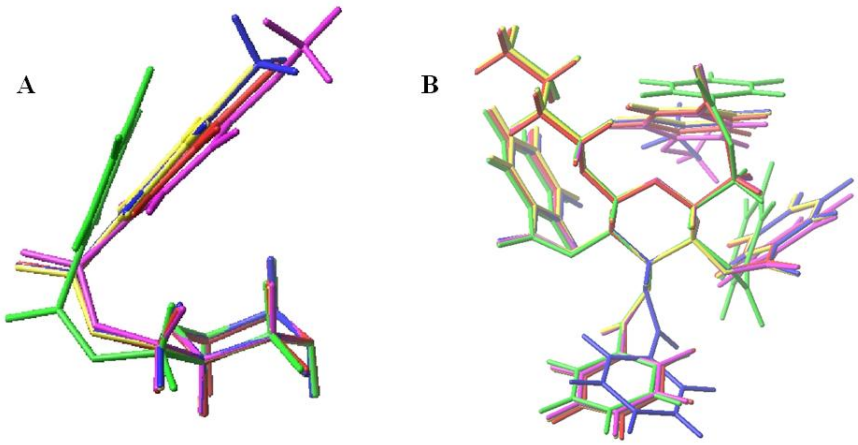


Figure 22: A) conformational change at C-6; B) overall conformational change

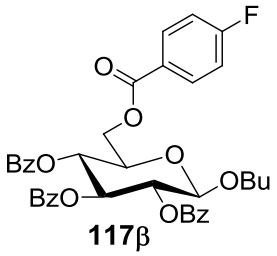
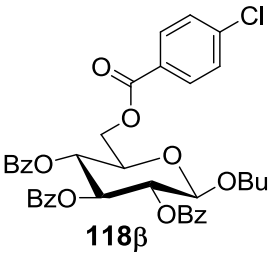
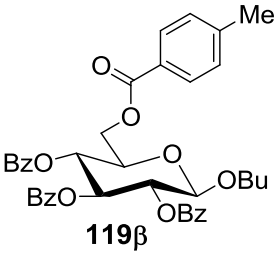
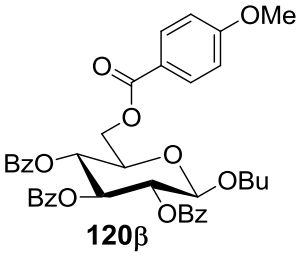
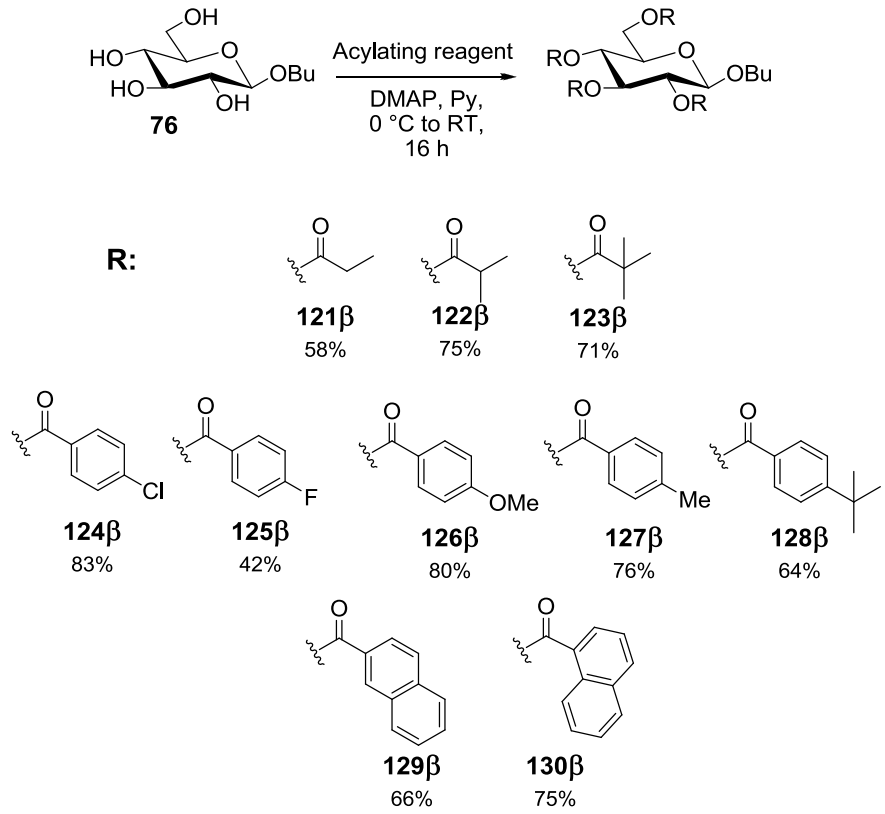
Substrate	$10^4(k_f + k_r)$ (s^{-1})	Relative Rate	α:β (Yield)
 **117β**	**5.8**	**0.76**	**85:15 (62%)**
 **118β**	**8.20**	**1.08**	**93:7 (73%)**
 **119β**	**6.9**	**0.91**	**90:1 (41%)**
 **120β**	**10.4**	**1.37**	**96:4 (66%)**

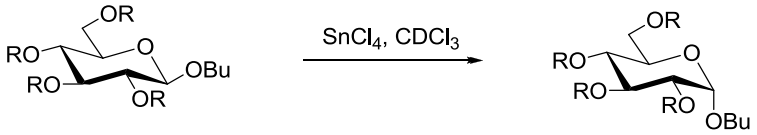
Table 10: Rate of anomerisation for series V compounds

It was thought that the reduction in rate observed with the substituted benzoyl compound could be overcome by changing the protecting groups so that all positions have the same protecting group, as is the case with compound **77β**. Aromatic and aliphatic protecting groups were investigated and were prepared from intermediate **76** under similar conditions to those used to prepared compound **77β**.



Scheme 68: Synthesis of compound 121β to 130β

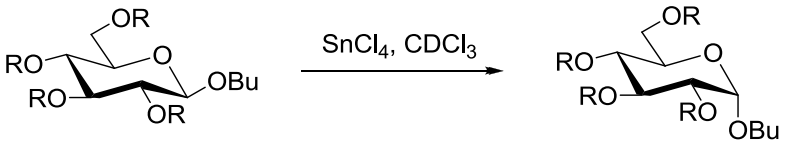
The anomerisation of the aliphatic ester protecting groups gave results which followed the trends seen for the compounds in series **III** (compounds **105β** to **107β**). The rates obtained for compounds **121β** to **123β** do not compare to the rate obtained for compound **77β**, thus once again indicating that both steric and electronic effects impact the rate of anomerisation.



No.	R	$10^4(k_f + k_r)$ (s^{-1})	Relative Rate	α:β (Yield)
121β		8.3	1.09	90:10 (66%)
122β		9.4	1.24	92:8 (76%)
123β		10.1	1.33	95:5 (81%)

Table 11: Rates of anomerisation for series VI compounds

The anomerisation studies carried out on the compounds bearing aromatic ester groups provided interesting results. The two *p*-halogen substituted compounds were particularly slow and this may be due to the ability of the halogen atoms to weaken cation-π interactions[230]. The rate of anomerisation for compounds **126β**, **127β** and **128β** was high and this is the first time a rate faster than that observed for **77β** has been achieved. It is evident that the rate increase observed is largely due to electronics, although attempts to graph the logarithm of the relative rates (i.e. $\log(k_s/k_{77\beta})$) against the Taft electronic parameters and Hammett values (both σ and σ^+ values) did not result in a straight line plots (include in the table Taft and Hammett parameters).



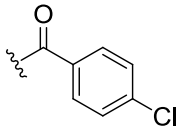
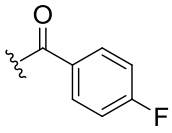
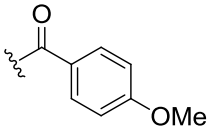
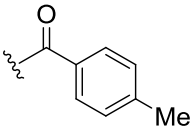
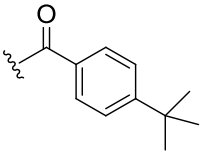
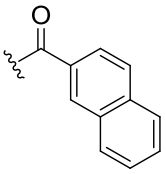
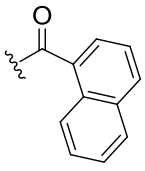
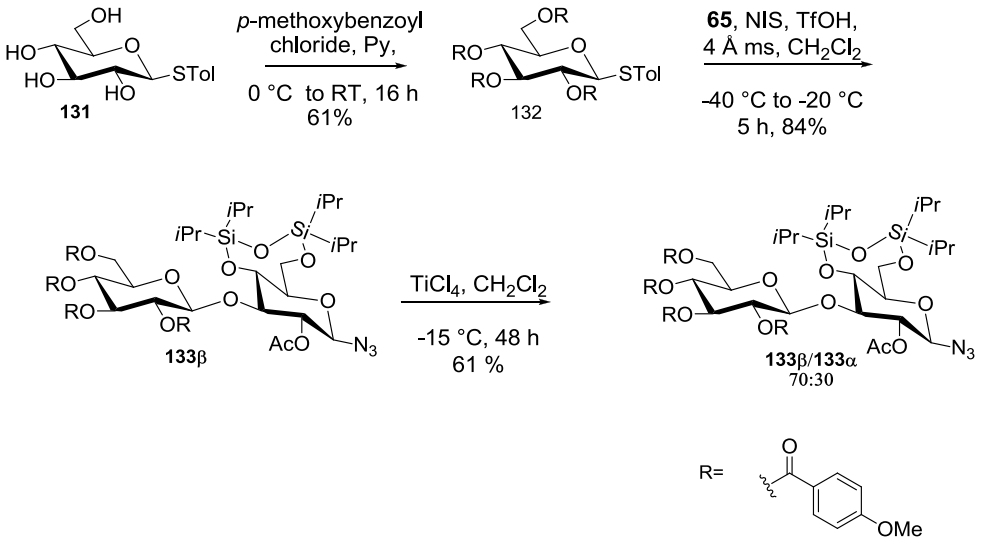
No.	R	$10^4(k_f + k_r)$ (s^{-1})	Relative Rate	α:β
124β		6.2	0.82	95:5
125β		7.2	0.95	90:10
126β		31.1	4.09	95:5
127β		27.9	3.67	92:8
128β		27.0	3.55	94:6
129β		12.5	1.64	90:1
130β		21.6	2.84	95:5

Table 12: Rates of anomerisation for series VII compounds

Compounds **129β** and **130β** gave conflicting results, however the pKa value for the corresponding carboxylic acids also vary substantially [viii]. The pKa for 1-napthanoic acid would suggest that the 1-napthoyl group is electron withdrawing and hence the rate of anomerisation should be extremely slow for compound **129β**, however the relative rate is still greater than 1. This can be attributed to steric interactions and the cation-π interaction at C-2 which stabilises the transition state leading to the endocyclic intermediate. The pKa value for 2-napthanoic acid is slightly lower than that of benzoic acid, thus one would expect the rate to be faster than that observed for **130β** and **77β** and this is the case. This result further illustrates the importance of steric interaction is anomerisation reactions of this type.

Having observed a substantial rate increase with the *p*-methoxybenzoate protecting groups, it was deemed worthwhile preparing a disaccharide analogous to compound **74**, which had *p*-methoxybenzoate protecting groups instead of benzoate protecting groups. It was thought that rate enhancement could occur in this case, as previous studies with compound **74** starting material was fully recovered. Disccharide **133** was prepared from known compound **131** using *p*-methoxybenzoyl chloride in pyridine. The coupling of donor **132** with acceptor **65** was carried out with NIS and TfOH and gave the desired disaccharide in 84% yield. The anomerisation of compound **133β** did not result in an α-favourable mixture. However it is promising that the anomerisation occurs to some extent.



Scheme 69: Synthesis and anomerisation of compound 133β

[viii] pKa value: 1-napthanoic acid = 3.7; 2-napthanoic acid = 4.17; benzoic acid = 4.19; acetic acid = 4.76.

4.4 Conclusions

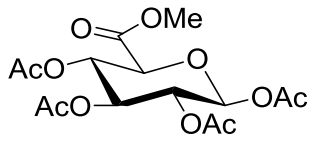
In conclusion the rate of anomerisation has been quantified for 34 substrates in a attempt to elucidate the effect of benzoate protecting groups and to try expand the anomerisation of disaccharide substrates to non-uronic acid derivatives. The data obtained shows that the rate of anomerisation is affected by both the steric and electronic properties of the protecting groups. It is also evident that the rate observed for compound **77β** is due to a steric effect and the benzoate groups must be present at all positions for this to occur. There is also an unexpected rate increase for a benzoate at C-2, which was further investigated using a 4-fluorobenzate. The involvement of this effect in the rate observed for compound **77β** is however unclear and further investigations need to be carried out to elucidate this effect. It is again clear from the study carried out with the substituted benzoate and napthoyl protected compounds (**124β** – **130β**) that the anomerisation reaction is affected by both the steric and electronic properties of the protecting groups. The attempt to apply the 4-methoxybenzoate groups to disaccharide anomerisation did not result in the desired outcome, however it shows the limitations of the system and the need to find a better protecting group strategy and/or an improved promoter system. It is evident from this study that further alterations to the protecting group strategy may be enough to bring about the desired α-slectivity.

Chapter 5: Experimental data

General Experimental Conditions:

Optical rotations were determined at the sodium D line at 20°C using a Schmidt and Haensch UniPol L1000. NMR spectra were recorded with a 500 MHz or 600 MHz Varian spectrometer. Chemical shifts are reported relative to internal Me_4Si in $CDCl_3$ (δ 0.0) or HOD in D_2O (δ 4.79) for ^1H and Me_4Si in $CDCl_3$ (δ 0.0) or $CDCl_3$ (δ 77.0) for ^{13}C. ^1H NMR signals were assigned with the aid of COSY and ^{13}C NMR signals were assigned with the aid of DEPT, gHSQCAD and/or gHMBCAD. Coupling constants are reported in hertz. The IR spectra were recorded as thin films using a PerkinElmer Spectrum 100 FT-IR Spectrometer with an ATR attachment. High resolution mass spectra were recorded using a Waters LCT Premier XE (ESI-TOF instrument). Silica gel (pore size 60 Å, particle size 40-60 μm 230-400 mesh particle size) was purchased from Sigma-Aldrich. Dichloromethane, THF and DMF reaction solvents were obtained from a Pure Solv™ Solvent Purification System. Acetone and acetonitrile solvents (Chromatsolv for HPLC grade, >99.9%) and anhydrous pyridine were obtained from Sigma-Aldrich. 1M $TiCl_4$ in CH_2Cl_2 was purchased from Sigma Aldrich.

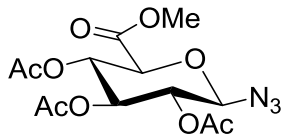
Chapter 2 experimental procedures:



Methyl 1,2,3,4-tetra-*O*-acetyl-β-D-glucopyranopyranuronate (2)[93]

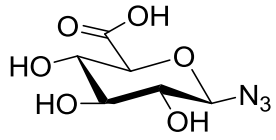
Triethylamine (0.15 mL) was added to a suspension of D-Glucurono-6,3-lactone (10 g, 56.8 mmol) in anhydrous methanol (150 mL).The reaction was stirred overnight. The solvent was evaporated and the resulting foam was used without further purification. The foam was taken up in acetic anhydride (50 mL) and sodium acetate (5 g, 61 mmol) was added. The resulting suspension was stirred for 4 days at room temperature. The reaction was poured onto ice water (300 mL) and stirred overnight. The resulting precipitate was filtered, washed with water and recrystallised with

ethanol to give **2** as a white solid (8.1 g, 38%); $[\alpha]_D$ +9.31 (*c* 1.5, $CHCl_3$); ^1H NMR (500 MHz, $CDCl_3$) δ 5.76 (d, ^3J (H,H) = 7.8, 1H; H-1), 5.30 (apt. t^3J (H,H) = 9.2, 1H; H-3), 5.23 (apt. t, ^3J (H,H) = 9.5, 1H; H-4), 5.13 (apt. t, ^3J (H,H) = 8.4, 1H; H-2), 4.17 (d, ^3J (H,H) =9.6, 1H; H-5), 3.73 (s, 3H; CO_2CH_3), 2.11 (s, 3H; $COCH_3$), 2.03 (s, 6H; 2 x $COCH_3$, overlapping peaks), 2.02 (s, 3H; $COCH_3$); ^{13}C NMR (126 MHz, $CDCl_3$) δ 169.9 (CO_2CH_3), 169.4, 169.1, 168.8, 166.8 (4 x $COCH_3$), 91.3 (C-1), 73.0 (C-5), 71.8 (C-3), 70.1 (C-2), 68.9 (C-4), 53.0 (CO_2CH_3), 20.7, 20.5, 20.5, 20.4 (4 x $COCH_3$). [α]D +9.31° (*c* 1.5, $CHCl_3$); IR (film) cm^{-1}: 2956, 1752, 1443, 1372, 1203, 1038; ESI-HRMS calcd for $C_{15}H_{20}O_{11}Na$ 399.0903, found m/z 399.0887 $[M+Na]^+$.



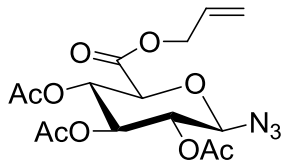
Methyl 2,3,4-tri-*O*-acetyl-β-D-glucopyranosyluronate azide (3)[187]

Compound **2** (4g, 10.6 mmol) was dissolved in DCM (25 mL) and cooled using an ice bath. $TMSN_3$ (4.18 mL, 31.8 mmol) and $SnCl_4$ (0.62 mL, 5.3 mmol) were added and the resulting solution was stirred overnight at room temperature. The reaction mixture was diluted with CH_2Cl_2 (25 mL) and was washed twice with 1M $KHSO_4$ (50 mL x 2), satd Aq. $NaHCO_3$ (50 mL), brine (50 mL), dried over anhydrous $NaSO_4$, filtered and the solvent was removed under reduced pressure. This residue was recrystallised from ethanol to yield **3** as a white solid (2.6 g, 69 %); $[\alpha]_D$ -39.5 (*c* 1.0, $CHCl_3$); ^1H NMR (500 MHz, $CDCl_3$) δ 5.31 – 5.19 (m, 2H; H-2, H-4, overlapping peaks), 4.96 (apt. t, ^3J (H,H) = 9.0 Hz, 1H; H-3); 4.71 (d, ^3J (H,H) = 8.7 Hz, 1H; H-1), 4.12 (d, ^3J (H,H) = 9.5 Hz, 1H; H-5), 3.78 (s, 3H; CO_2CH_3), 2.07 (s, 3H; $COCH_3$), 2.03 (s, 3H; $COCH_3$), 2.02 (s, 3H; $COCH_3$); ^{13}C NMR (126 MHz, $CDCl_3$) δ 170.1, 169.4, 169.2 (3 x $COCH_3$), 166.6 ($COOCH_3$), 88.2 (C-1), 74.4 (C-5), 72.0 (C-4), 70.6 (C-3), 69.1 (C-2), 53.2 (CO_2CH_3), 20.7 (2 x $COCH_3$), 20.6 ($COCH_3$); IR (film) cm^{-1}: 2959, 2123, 1755, 1439, 1371, 1241, 1203; ES-HRMS calcd for $C_{13}H_{21}O_9N_4$ 377.1309, found m/z 377.1326 $[M+NH_4]^+$.



Methyl 1-azido-1-deoxy-β-D-glucopyranosyluronate (5)[108]

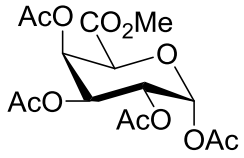
Azide **3** (1 g, 2.8 mmol) was added to LiOH (100 mL, 0.1 M) in MeOH-H2O-THF (5:2:1) and cooled to 0 °C and stirred for 16 h and allowed to attain room temp. dowex® 50WX8 H^+-resin was then added and then filtration and evaporation gave the unprotected azide (0.57 g, 93%) which was used in the next step without further purification; $[\alpha]_D$ +9.3 (*c* 0.2, CH_3OH); ^{1}H NMR (500 MHz, D_2O) δ 4.76 (d, 1H; ^3J (H,H) = 8.8 Hz; H-1), 3.81 (d, ^3J (H,H) = 9.4 Hz, 1H; H-5), 3.58 – 3.48 (m, 2H; H-3, H-4, overlapping signals), 3.31 (apt t, ^3J (H,H) = 8.7 Hz, 1H; H-2); ^{13}C NMR (126 MHz, D_2O): δ 175.2 (*C*O_2H), 89.9 (C-1), 77.6 (C-5), 75.5 (C-4), 72.5 (C-2), 71.4 (C-3); IR (film) cm^{-1}: 3239 (OH), 2120 (N_3), 1607 (C=O), 1419, 11243, 1056, 1027; ESI-HRMS calcd for $C_6H_9N_3O_6Na$ 242.0389, found *m/z* 242.0394 $[M+Na]^+$.



Allyl 2,3,4-tri-*O*-acetyl-1-azido-1-deoxy-β-D-glucopyranuronate (6)[234]

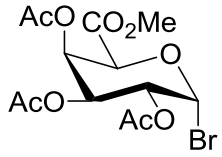
Sodium hydrogen carbonate (0.23 g, 2.7 mmol) and allyl iodide (0.25 mL, 2.7 mmol) were, respectively, added to intermediate **5** (0.5 g, 2.3 mmol) in DMF (5 mL). The mixture was then stirred for 16 h at room temp and then cooled to 0 °C. DMAP (0.03 g, 0.2 mmol) and Ac_2O (1.1 mL, 11.5 mmol) were added and the resulting mixture was stirred for 16 h. The resulting suspension was diluted with EtOAc (30 mL), washed with 1M HCl (2 x 30 mL), $NaHCO_3$ (30 mL), brine (30 mL), dried over Na_2SO_4, filtered and the solvent was removed under diminished pressure. Flash chromatography of the residue (petroleum ether-EtOAc 1:1) gave **6** (0.74 g, 71%) as a white solid; $[\alpha]_D$ -18.8 (*c* 2.85, CH_2Cl_2); ^{1}H NMR (500 MHz, $CDCl_3$): δ 5.90 (ddt, ^3J (H,H) = 16.8, 10.2, 6.0 Hz, 1H; -CH_2*CH*=CH_2), 5.36 (dq, ^3J (H,H) = 16.8 Hz, ^2J (H,H) = 1.2 Hz, 1H; CH_2CH=*CH*$_2$), 5.31–5.22 (m, 3H; overlapping peaks; -CH_2CH=*CH*$_2$, H-3, H-4), 4.99–4.93 (m, 1H; H-2), 4.71 (d, ^3J (*H,H)* = 8.7, 1H Hz; H-1), 4.64 (qd, ^2J (H,H)= -13.0 Hz, ^3J (H,H) = 6.0 Hz, 2H; *CH*$_2$CHCH$_2$), 2.07 (s, 3H; CO*CH*$_3$), 2.02 (s, 3H; CO*CH*$_3$), 2.00 (s, 3H; CO*CH*$_3$); ^{13}C NMR (126 MHz, $CDCl_3$): δ = 169.9, 169.2, 169.1 (each *C*OCH$_3$), 165.7 (*C*O_2CH$_2$CHCH$_2$), 130.9 (-CH_2*CH*=CH_2), 119.6 (-CH_2CH=*C*H$_2$), 88.0 (C-1), 74.3 (C-5), 71.9 (C-3), 70.4 (C-2), 69.0 (C-4), 66.8 (-*C*H$_2$CHCH$_2$), 20.5 (2s, each CO*CH*$_3$, overlapping peaks); IR

(film) cm^{-1}: 2965, 2120, 1751, 1733 1373, 1242, 1206, 1085, 1050, 1034. ESI-HRMS calcd for $C_{15}H_{19}O_9N_3Na$ 408.1019, found *m/z* 408.1039 $[M+Na]^+$.



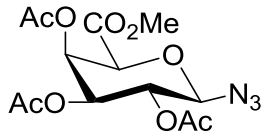
Methyl 1,2,3,4-tetra-*O*-acetyl-β-D-galactopyranuronate (9)[106]

Perchloric acid (0.05 mL) was added slowly to Ac_2O (15 mL) at 0 °C. D-Galacturonic acid (2.5 g, 11.8 mmol) was then added and the mixture was stirred at 0 °C for 30 min and at room temp for a further 3 h. At this point the reaction was cooled to 0 °C and MeOH was slowly added. The mixture was partitioned between CH_2Cl_2 (50 mL) and H_2O (50 mL). The layers were separated and the aq layer was extracted with CH_2CH_2 (2 x 25 mL). The combined organic portions were washed with water (50 mL), brine (50 mL), dried over Na_2SO_4, filtered and the solvent was removed under diminished pressure. The resulting residue was taken up in DMF (25 mL) and then $NaHCO_3$ (1.2 g, 14.2 mmol) and methyl iodide (0.88 mL, 14.2 mmol) were added and the mixture was stirred for 16 h before being diluted with EtOAc (50 mL) and H_2O (50 mL). The layers were separated and the aq layer was extracted with EtOAc (2 x 25 mL). The combined organic layer were washed with 1M aq HCl (50 mL), $NaHCO_3$ (50 mL), brine (50 mL), dried over Na_2SO_4, filtered and the solvent was removed under diminished pressure. Flash chromatography of the residue (petroleum ether-EtOAc 1:1) gave the acetylated intermediate (3.0 g, 71%) as a white solid; $[\alpha]_D$ +137.9 (*c* 0.5, CH_2Cl_2); ^{1}H NMR (500 MHz, $CDCl_3$) δ 6.51 (d, ^3J (H,H) = 2.6 Hz, 1H; H-1), 5.84 – 5.78 (m, 1H; H-4), 5.41 – 5.35 (m, 2H; H-3, H-2, overlapping peaks), 4.74 (d, ^3J (H,H) = 1.4 Hz, 1H; H-5), 3.75 (s, 3H; CO_2CH_3), 2.14 (s, 3H; $COCH_3$), 2.11 (s, 3H; $COCH_3$), 2.01 (s, 6H; 2 x $COCH_3$, overlapping peaks); ^{13}C NMR (126 MHz, $CDCl_3$) δ 170.0, 169.7, 168.4 (4 x $COCH_3$, overlapping peaks), 166.5 (CO_2CH_3), 89.6 (C-1), 70.7 (C-5), 68.6 (C-4), 67.0 (C-2), 66.0 (C-3), 52.8 (CO_2CH_3), 20.8, 20.6, 20.5 (2s) (4 x ($COCH_3$); IR (film) cm^{-1}: 2984, 1770, 1746, 1440, 137, 1252, 1207. ESI-HRMS calcd for $C_{15}H_{20}O_{11}Na$ 399.0903, found *m/z* 399.0897 $[M+Na]^+$.



Methyl 2,3,4-tri-*O*-acetyl-1-bromo-1-deoxy-α-D-galactopyranuronate (10)[93]

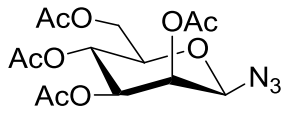
Compound **9** (2.5 g, 6.6 mmol) was dissolved in CH_2Cl_2 (25 mL) and the mixture was cooled using an ice bath. To this was added 33% HBr in AcOH (25 mL) and the mixture was allowed to attain room temp and stirred overnight. The mixture was then diluted with CH_2Cl_2 (50 mL), poured onto iced water (50 mL), the layers were separated and the aq layer washed with further CH_2Cl_2 (25 mL). The combined organic extracts were washed with ice water (100 mL), satd aq $NaHCO_3$ (50 mL), brine (50 mL), dried over Na_2SO_4, filtered and the solvent was removed under diminished pressure. The title compound **10** was obtained as a white foam (2.14 g, 81%) and was used in the next step without further purification; ^{1}H NMR (500 MHz, $CDCl_3$): δ 6.76 (d, ^3J (H,H) = 3.9 Hz, 1H; H-1), 5.82 (dd, ^3J (H,H) = 3.4, 1.7 Hz, 1H; H-4), 5.47 – 5.41 (m, 1H; H-3), 5.09 (dd, ^3J (H,H) = 10.7, 3.8 Hz, 1H; H-2), 4.87 (1H; d, ^3J (H,H) = 1.2 Hz; H-5), 3.76 (s, 3H; CO_2CH_3), 2.10 (s, 7H; 2 x $COCH_3$), 2.01 (s, 3H; $COCH_3$); ^{13}C NMR (126 MHz, $CDCl_3$): δ 169.8, 169.6, 169.4 (3 x $COCH_3$), 165.8 (CO_2CH_3), 87.2 (C-1), 72.4 (C-5), 67.9 (C-4), 67.6 (C-3), 67.2 (C-2), 53.0 (CO_2CH_3), 20.7, 20.5, 20.4 (3 x $COCH_3$); IR (film) cm^{-1}: 2992, 2957, 1755, 1372, 1220, 1093, 1013.



Methyl 2,3,4-tri-*O*-acetyl-1-azido-1-deoxy-β-D-galactopyranuronate (11)[187]

The bromide **10** (0.25 g, 0.63 mmol) and NaN_3 (0.41 g, 6.3 mmol) were placed in a Biotage microwave vial and then DMF (2.5 mL) was added and the vial sealed and the resulting suspension was placed in an ultrasonic bath and then sonicated for 15-20 min . The vial was opened and the solution was poured on H_2O (15 mL) and extracted twice with EtOAc (15 mL). The combined organic extracts were washed with H_2O (40 mL), brine (40 mL), dried over Na_2SO_4, filtered and the solvent was removed under diminished pressure. Flash chromatography of the residue (petroleum ether-EtOAc 1:1) gave **11** (0.21 g, 92%) as a white solid; $[\alpha]_D$ 16.3 (c 0.6, CH_2Cl_2); ^{1}H NMR (500 MHz, $CDCl_3$): δ 5.74 (dd, ^3J (H,H) = 3.5, 1.4 Hz, 1H; H-4), 5.19 (dd,

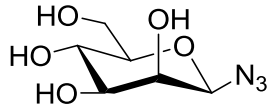
^3J (H,H) = 10.4, 8.8 Hz, 1H; H-2), 5.09 (dd, ^3J (H,H) = 10.4, 3.5 Hz, 1H; H-3), 4.67 (d, ^3J (H,H) = 8.8 Hz, 1H; H-1), 4.39 (d, ^3J (H,H) = 1.4 Hz, 1H; H-5), 3.78 (s, 3H; CO_2CH_3), 2.13 (s, 3H; $COCH_3$), 2.09 (s, 3H; $COCH_3$), 2.00 (s, 3H; $COCH_3$). ^{13}C NMR (126 MHz, $CDCl_3$): δ 170.1 (CO_2CH_3), 169.8, 169.4, 165.9 (3 x $COCH_3$), 88.6 (C-1), 74.2 (C-5), 70.5 (C-3), 68.1 (C-4), 67.8 (C-2), 53.1 (CO_2CH_3), 20.8, 20.7 (2s) (3 x $COCH_3$); IR (film) cm^{-1}: 2980, 2119, 1771, 1737, 1273, 1239, 1210, 1051; ESI-HRMS calcd for $C_{13}H_{17}O_9N_3Na$ 382.0862, found *m/z* 382.0866 $[M+Na]^+$.



2,3,4,6-Tetra-*O*-acetyl-β-D-mannopyranosyl azide (14)[169]

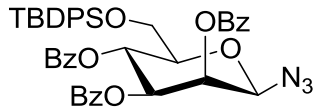
Penta-*O*-acetyl-α-D-mannose (3 g, 7.7 mmol) was dissolved in CH_2Cl_2 (80 mL), I_2 (2.74 g, 10.8 mmol) was added followed by the slow addition of Et_3SiH (1.72 mL, 10.8 mmol; **warning exothermic**). The reaction was heated at reflux for 20 min and was then cooled to room temp, diluted with CH_2Cl_2 (80 mL) and washed with satd aq $NaHCO_3$ (150 mL) containing 10% $Na_2S_2O_3$. The aq phase was further extracted with CH_2Cl_2 (50 mL) and the combined organic extracts were dried over Na_2SO_4, filtered and the solvent was removed under diminished pressure. The residual glycosyl iodide was taken up in CH_2Cl_2 (60 mL) and tetrabutylammonium azide (3.3 g, 11.6 mmol) was added. The reaction mixture was stirred overnight before diluting with CH_2Cl_2 (50 mL) and extracting with 1M HCl (100 mL). The aq phase was further washed with CH_2Cl_2 (30 mL) and the combined organic extracts were dried over Na_2SO_4, filtered and the solvent was removed under diminished pressure. Flash chromatography of the residue (petroleum ether-EtOAc 1:1) gave **14** (2.1 g, 64%) as a white solid; $[\alpha]_D$ -70.6 (*c* 0.3, CH_2Cl_2); ^{1}H NMR (500 MHz, $CDCl_3$) δ 5.44 (dd, ^3J (H,H) = 3.3, 1.3 Hz, 1H; H-2), 5.26 (apt t, ^3J (H,H) = 10.0 Hz, 1H; H-4), 5.04 (dd, ^3J (H,H) = 10.1, 3.3 Hz, 1H; H-3), 4.73 (d , ^3J (H,H) = 1.3 Hz, 1H; H-1), 4.28 (dd, ^2J (H,H) = -12.4 Hz, ^3J (H,H) = 5.7 Hz, 1H; H-6a), 4.20 (dd, ^2J (H, H) = -12.4 Hz, ^3J (H,H) = 2.5 Hz, 1H; H-6b), 3.76 (ddd, ^3J (H,H) = 10.0, 5.7, 2.5 Hz, 1H; H-5), 2.20 (s, 3H; $COCH_3$), 2.11 (s, 3H; $COCH_3$), 2.05 (s, 3H; $COCH_3$), 1.99 (s, 3H; $COCH_3$); ^{13}C NMR (126 MHz, $CDCl_3$) δ 170.6, 169.9 (2s), 169.5 (each $COCH_3$), 85.1 (C-1), 74.6 (C-5), 70.9 (C-3), 69.2 (C-2), 65.3 (C-4), 62.3 (C-6), 20.7, 20.6, 20.5 (each

CO*CH*$_3$); IR (film) cm^{-1}: 2115, 1744, 1366, 1238, 1209, 1038; ESI-HRMS calcd for $C_6H_{15}N_4O_5$ 391.1465, found *m/z* 391.1469 $[M+NH_4]^+$.



β-D-mannopyranosyl azide (15)

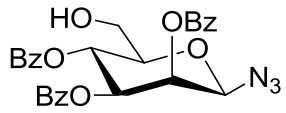
Azide **14** (1.8 g, 4.8 mmol) was taken up in MeOH (20 mL) and NaOMe (0.05 g, 0.96 mmol) was added and the mixture stirred for 1 h. Dowex® 50WX8 H^+-resin (500 mg) was then added and the resulting suspension was stirred until the solution was neutral. This was then filtered and the solvent was removed to give the deprotected intermediate (0.93 g, 94%) as a white solid; $[\alpha]_D$ -42.6 (*c* 0.2, CH_3OH); ^{1}H NMR (500 MHz, D_2O) δ 4.87 (d, ^3J (H,H) = 1.1 Hz, 1H; H-1), 3.03 (dd, ^3J (H,H) = 3.2, 1.1 Hz, 1H; H-2), 3.96 (dd, ^2J (H,H) = -12.3 Hz, ^3J (H,H) = 2.2 Hz, 1H; H-6a), 3.77 (dd, ^2J (H,H) = -12.3 Hz, ^3J (H,H) = 6.4 Hz, 1H; H-6b), 3.67 (dd, ^3J (H,H) = 9.7, 3.2 Hz, 1H; H-3), 3.61 (apt t, ^3J (H,H) = 9.6 Hz, 1H; H-4), 3.49 (ddd, ^3J (H,H) = 9.5, 6.4, 2.2 Hz, 1H; H-5); ^{13}C NMR (126 MHz, D_2O) δ 87.2 (C-1), 78.3 (C-5), 72.7 (C-3), 71.0 (C-2), 66.4 (C-4), 60.9 (C-6); IR (film) cm^{-1}: 3332, 2886, 2113, 1739, 1370, 1243, 1053, 1008; ESI-HRMS calcd for $C_8H_{13}N_3O_6Na$ 228.0596, found *m/z* 228.0600 $[M+Na]^+$.



6-*O*-*tert*-Butyldiphenylsilyl-2,3,4-tri-*O*-benzoyl-β-D-mannopyranosyl azide (16)

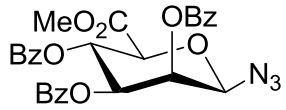
Compound 15 (0.9 g, 4.4 mmol) was dissolved in pyridine (50 mL) and the resulting solution was cooled over an ice bath. TBDPSCl (1.36 mL, 5.3 mmol) was then added in a drop-wise manner and the reaction mixture was allowed to attain room temp and was stirred overnight. The resulting suspension was again cooled using an ice bath and benzoyl chloride (1.12 mL, 9.7 mmol) was added slowly and the mixture was allowed to warm to room temp and was stirred overnight. Methanol (5 mL) was then added and the resulting slurry was diluted with EtOAc (50 mL), washed twice with 1M HCl (50 mL), satd aq $NaHCO_3$ (50 mL), brine (50 mL), dried over Na_2SO_4, filtered and the solvent was removed under diminished pressure. Flash chromatography of the residue (petroleum ether-EtOAc, 7:3) gave 16 (2.53 g, 76%)

as a foam; $[\alpha]_D$ -19.5 (*c* 0.1, CH_2Cl_2); ^{1}H NMR (500 MHz, $CDCl_3$) δ 8.15-7.13 (ms, 25H; Ar-H), 6.26 (apt t, ^3J (H,H) = 10.0 Hz, 1H; H-4), 5.96 (dd, ^3J (H,H) = 3.2, 1.3 Hz, 1H; H-2), 5.56 (dd, ^3J (H,H) = 10.3, 3.2 Hz, 1H; H-3), 5.00 (d, ^3J (H,H) = 1.3 Hz, 1H; H-1), 3.99–3.88 (m, 3H; H-6a, H-6b, H-5, overlapping peaks), 1.12 (s, 9H; C(CH_3)$_3$); ^{13}C NMR (126 MHz, $CDCl_3$): δ 165.7, 165.4, 164.9 (each *C*OPh), 135.7, 135.5 (5 x Ar-CH, overlapping peaks), 133.5 133.3 (2s), 132.6 (5 x Ar-C), 130.2, 129.8, 129.7 (2s), 129.6, 129.3, 129.0, 128.8, 128.6, 128.5, 128.3, 127.8, 127.6 (20 x Ar-CH, overlapping peaks), 85.4 (C-1), 77.4 (C-5), 72.4 (C-3), 70.3 (C-2), 65.4 (C-4), 61.8 (C-6), 26.5 (C(CH_3)$_3$, overlapping peaks), 19.2 (*C*(CH_3)$_3$); IR (film) cm^{-1}: 2931, 2119, 1729, 1452, 1259, 1092, 1025; ESI-HRMS calcd for $C_{43}H_{41}N_3O_8SiNa$ 778.2561, found *m/z* 778.2553 $[M+Na]^+$.



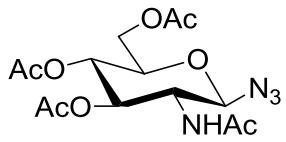
2,3,4-tri-*O*-benzoyl-β-D-mannopyranosyl azide (17)

The TPDPS derivative **16** (2.5 g, 3.3 mmol) was dissolved in THF (25 mL) and the mixture cooled over an ice bath. Acetic acid (0.38 mL, 6.6 mmol) was added followed by 1M TBAF in THF (6.6 mL, 6.6 mmol). The mixture was allowed to attain room temp and stirred for 16 h. Silica was then added and the solvent was removed to adsorb the residue onto silica gel. This was directly subjected to flash chromatography (petroleum ether-EtOAc 3:2) to give the primary alcohol intermediate (1.38 g, 81%) as a white solid; $[\alpha]_D$ -6.2 (*c* 0.06, CH_2Cl_2); ^{1}H NMR (500 MHz, $CDCl_3$) δ 8.14 –7.14 (m, 15H; aromatic H), 5.93 (dd, ^3J (H,H) = 3.3, 1.3 Hz, 1H; H-2), 5.81 (apt t, ^3J (H,H) = 9.9 Hz, 1H; H-4), 5.68 (dd, ^3J (H,H) = 10.1, 3.3 Hz, 1H; H-3), 5.07 (d, ^3J (H,H) = 1.3 Hz, 1H; H-1), 4.02–3.80 (m, 3H; overlapping H-6a, H-6b, H-5); ^{13}C NMR (126 MHz, $CDCl_3$) δ 166.1, 165.5, 165.3 (3 x *C*OPh), 133.8, 133.7, 133.4, 130.1, 129.8, 129.7 (9 x Ar-CH, overlapping peaks), 128.9 (Ar-C), 128.7 (2s) (2 x Ar-CH, Ar-C, overlapping peaks), 128.6 (2 x Ar-CH, overlapping peaks), 128.5 (2s) (2 x Ar-CH, Ar-C, overlapping peaks), 128.3 (2 x Ar-CH, overlapping peaks), 85.7 (C-1), 77.2 (C-5), 71.5 (C-3), 70.0 (C-2), 66.4 (C-4), 61.4 (C-6); IR (film) cm^{-1}: 3514, 2118, 1721, 1452, 1248, 1090, 1026; ESI-HRMS calcd for $C_{27}H_{23}N_3O_8Na$ 660.1389, found *m/z* 660.1397 $[M+Na]^+$.



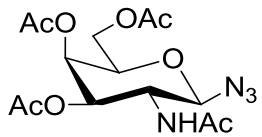
Methyl 1-azido-2,3,4-tri-*O*-benzoyl-1-deoxy-β-D-mannopyranuronate (18)

Alcohol **17** (1.3 g, 2.5 mmol) was taken up in MeCN-H_2O (3:1, 50 mL) and then BAIB (8.05 g, 25.0 mmol) and TEMPO (0.04 g, 0.25 mmol) were added and the mixture stirred for 5 h and the solvent was then evaporated under diminished pressure. The resulting residue was taken up in CH_2Cl_2 (50 mL) and washed with 10% $Na_2S_2O_3$ (50 mL), 1M HCl (50 mL), brine (50 mL), dried over Na_2SO_4, filtered and the solvent was removed under diminished pressure. The residue was dissolved in DMF (50 mL), $NaHCO_3$ (0.32 g, 3.75 mmol) and methyl iodide (0.23 mL, 3.75 mmol) were added. The mixture was stirred overnight before being diluted with EtOAc (50 mL) and H_2O (50 mL). The layers were separated and the aq layer was extracted with further EtOAc (2 x 20 mL). The combined organic extracts were washed with 1M HCl (50 mL), H_2O (50 mL), brine (50 mL), dried over Na_2SO_4, filtered and the solvent removed. Flash chromatography of the residue (petroleum ether-EtOAc 7:3) gave **18** (0.33 g, 24%) as a white solid; $[\alpha]_D$ 144.2 (c 0.85, CH_2Cl_2); ^{1}H NMR (500 MHz, $CDCl_3$): δ = 8.10 (dd, ^3J (H,H) = 8.4, 1.4 Hz, 2H; Ar-H), 7.95 (dd, ^3J (H,H) = 8.4, 1.4 Hz, 2H; Ar-H), 7.83 (dd, ^3J (H,H) = 8.4, 1.4 Hz, 2H; Ar-H), 7.65 – 7.61 (m, 1H; Ar-H), 7.57 – 7.44 (m, 4H; Ar-H, overlapping peaks), 7.39 (t, ^3J (H,H) = 7.9 Hz, 2H; Ar-H), 7.29 (t, ^3J (H,H) = 7.8 Hz, 2H; Ar-H), 5.97 (apt t, ^3J (H,H) = 9.3 Hz, 1H; H-4), 5.92 (dd, ^3J (H,H) = 3.3, 1.6 Hz, 1H; H-2), 5.67 (dd, ^3J (H,H) = 9.6, 3.3 Hz, 1H; H-3), 5.18 (d, ^3J (H,H) = 1.6 Hz, 1H; H-1), 4.45 (d, ^3J (H,H) = 9.2 Hz, 1H; H-5), 3.74 (s, 3H; CO_2CH_3); ^{13}C NMR (126 MHz, $CDCl_3$) δ 167.0 (CO_2CH_3), 165.5 (2s), 165.3 (3 x *C*OPh), 133.9, 133.7, 133.6, 130.3, 130.0 (2s) (12 x Ar-CH, overlapping peaks), 128.9 (2s) (2 x Ar-C), 128.8 (2 x Ar-CH, overlapping peaks), 128.7 (2s) (Ar-C, 2 xAr-CH, overlapping peaks), 128.5 (2 x Ar-CH, overlapping peaks), 86.0 (C-1), 74.8 (C-5), 70.8 (C-3), 69.2 (C-2), 67.3 (C-4), 53.2 (CO_2CH_3); IR (film) cm^{-1}: 2954, 2125, 1731, 1455, 1376, 1259 1104, 998; ESI-HRMS calcd for $C_{28}H_{23}O_9N_3Na$ 568.1332, found *m/z* 568.1339 $[M+Na]^+$.



2-Acetamido-3,4,6-tri-*O*-Acetyl-2-deoxy-β-D-glucopyranosyl azide (22)[235]

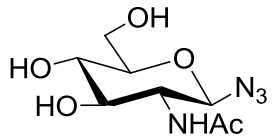
Pentaacetyl-D-glucosamine (3 g, 7.7 mmol) was suspended in CH_2Cl_2 (30 mL) and cooled to 0 °C. A 33% solution of HBr in AcOH (30 mL) was added and the reaction mixture was stirred for 5 h, keeping the reaction on ice. The reaction was then diluted with CH_2Cl_2 (50 mL) and poured onto ice (100 mL). The layers were separated and the aq layer was washed with a further portion of CH_2Cl_2 (30 mL). The combined organic extracts were washed with ice (100 mL), satd aq $NaHCO_3$ (100 mL), brine (100 mL), dried over Na_2SO_4, filtered and the solvent was removed under diminished pressure to give **9**. Freshly prepared **9** was dissolved in CH_2Cl_2 (30 mL) and tetrabutylammonium azide (4.38 g, 15.4 mmol) was added. The reaction mixture was stirred overnight and the solvent was removed under diminished pressure. Flash chromatography of the residue (EtOAc) gave the intermediate azide (1.55 g, 54%) as a white solid; $[\alpha]_D$ -49.8 (*c* 0.15, CH_2Cl_2); ^{1}H NMR (500 MHz, $CDCl_3$): δ 5.66 (d, ^3J (H,H) = 8.9 Hz, 1H; N*H*COCH$_3$), 5.24 (dd, ^3J (H,H) = 10.6, 9.4 Hz, 1H; H-3), 5.10 (dd, ^3J (H,H) = 10.1, 9.4 Hz, 1H; H-4), 4.76 (d, ^3J (H,H) = 9.2 Hz, 1H; H-1), 4.27 (dd, ^2J (H,H) = -12.4 Hz, ^3J (H,H) = 4.9 Hz, 1H; H-6a), 4.16 (dd, ^2J (H,H) = -12.4 Hz, ^3J (H,H) = 2.3 Hz, 1H; H-6b), 3.91 (apt dt, ^3J (H,H) = 10.6, 9.2 Hz, 1H; H-2), 3.79 (ddd, ^3J (H,H) = 10.1, 4.9, 2.3 Hz, 1H; H-5), 2.10 (s, 3H; CO*C*H$_3$), 2.04 (s, 3H; CO*C*H$_3$), 2.03 (s, 3H; NHCO*C*H$_3$), 1.98 (s, 3H; CO*C*H$_3$); ^{13}C NMR (126 MHz, $CDCl_3$): δ 171.0, 170.6, 170.3 (each *C*OCH$_3$), 169.2 (NH*C*OCH$_3$), 88.4 (C-1), 74.0 (C-5), 72.1 (C-3), 68.0 (C-4), 61.8 (C-6), 54.2 (C-2), 23.2 (NHCO*C*H$_3$), 20.7, 20.6 (2s) (3 x CO*C*H$_3$); IR (film) cm^{-1}: 3334, 2959, 2141, 2105, 1740, 1659, 1371, 1224, 1034; ESI-HRMS calcd for $C_{14}H_{20}N_4O_8Na$ 395.1179, found *m/z* 395.1187 $[M+Na]^+$.



2-Acetamido-3,4,6-tri-*O*-Acetyl-2-deoxy-β-D-galactopyranosyl azide (23)[157]

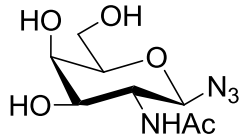
Reaction of pentaacetyl-D-galactosamine (3 g, 7.7 mmol) as described above for the corresponding glucosamine **22,** gave the intermediate azide **23** (1.7 g, 59%) as a white solid; $[\alpha]_D$ -30.5 (*c* 0.04, CH_2Cl_2); ^{1}H NMR (500 MHz, $CDCl_3$): δ 5.56 (d, ^3J (H,H) = 8.8 Hz, 1H; N*H*COCH$_3$), 5.38 (dd, ^3J (H,H) = 3.3, 1.1 Hz, 1H; H-4), 5.24 (dd, ^3J (H,H) = 11.1, 3.3 Hz, 1H; H-3), 4.79 (d, ^3J (H,H) = 9.2 Hz, 1H; H-1), 4.19 –

4.13 (m, 2H; H-6a, H-6b, overlapping peaks), 4.07 – 3.97 (m, 2H; H-5, H-2, overlapping peaks), 2.16 (s, 3H; NHCO*CH*$_3$), 2.06 (s, 3H; CO*CH*$_3$), 2.01 (s, 3H; CO*CH*$_3$), 1.99 (s, 3H; CO*CH*$_3$); ^{13}C NMR (126 MHz, $CDCl_3$) δ 170.5, 170.4 (3 x *C*OCH$_3$), 170.1 (NH*C*OCH$_3$), 88.7 (C-1), 72.8 (C-5), 69.7 (C-3), 66.5 (C-4), 61.4 (C-6), 50.8 (C-2), 23.4 (NHCO*CH*$_3$), 20.7, 20.6 (2s) (3 x CO*CH*$_3$); IR (film) cm^{-1}: 3267, 2932, 2113, 1723, 1549, 1315, 1240, 1061; ESI-HRMS calcd for $C_{14}H_{20}N_4O_8Na$ 395.1179, found *m/z* 395.1184 $[M+Na]^+$.



2-Acetamido-2-deoxy-β-D-glucopyranosyl azide (24)[236]

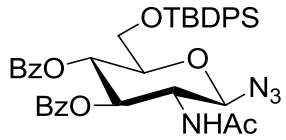
This intermediate (1.5 g, 4.0 mmol) was dissolved in MeOH (20 mL) and NaOMe (0.04 g, 0.8 mmol) was added. The reaction was quenched after 1 h by the addition of Dowex® 50WX8 H^+-resin (50 mg). The reaction was filtered and the solvent was removed to give the unprotected GlcNAc derivative (0.89 g, 91%) as a white solid; $[\alpha]_D$ -21.9 (*c* 0.07, CH_3OH); ^{1}H-NMR (500 MHz, D_2O): δ 4.78 (d, ^3J (H,H) = 9.4 Hz, 1H; H-1), 3.95 (dd, ^2J (H, H) = -12.5 Hz, ^3J (H,H) = 2.2 Hz, 1H; H-6a), 3.79 (dd, ^2J (H,H) = -12.5 Hz, ^3J (H,H) = 5.5 Hz, 1H; H-6b), 3.73 (dd, ^3J (H,H) = 10.2, 9.4 Hz, 1H; H-2), 3.62 – 3.57 (m, 1H; H-3), 3.57 – 3.34 (m, 1H; H-5), 3.50 (dd, ^3J (H,H) = 9.8, 8.7 Hz, 1H; H-4), 2.08 (s, 3H; NHCO*CH*$_3$); ^{13}C NMR (126 MHz, D_2O) δ 174.7 (NH*C*OCH$_3$), 88.6 (C-1), 77.8 (C-5), 73.6 (C-3), 69.4 (C-4), 60.5 (C-6), 55.0 (C-2), 22.0 (NHCO*C*H$_3$); IR (film) cm^{-1}: 3266, 2920, 2112, 1737, 1544, 1373, 1235, 1034; ESI-HRMS calcd for $C_8H_{15}N_4O_5$ 233.1012, found *m/z* 233.1019$[M+H]^+$.



2-Acetamido-2-deoxy-β-D-galactopyranosyl azide (25)[157]

Treatment of this azide (1.65 g, 4.4 mmol) as described above for the corresponding GlcNAc derivative with MeOH (20 mL) and NaOMe (0.05 g, 0.9 mmol) gave the unprotected GalNAc azide **25** (0.93 g, 86%) as a white solid; $[\alpha]_D$ -145.2 (*c* 0.04, CH_3OH); ^{1}H NMR (500 MHz, D_2O): δ 4.68 (d, ^3J (H,H) = 9.3 Hz, 1H; H-1), 3.99 (dd, ^3J (H,H) = 3.1, 0.8 Hz, 1H; H-4), 3.94 (dd, ^3J (H,H) = 10.7, 9.3 Hz, 1H; H-2),

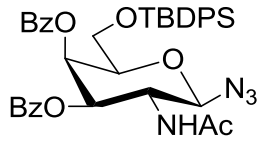
3.85 – 3.75 (m, 4H; H-6a, H-6b, H-5, H-3, overlapping peaks), 2.07 (s, 3H; NHCO*CH*$_3$); ^{13}C NMR (126 MHz, D_2O): δ 174.9 (NH*C*OCH$_3$), 89.0 (C-1), 77.2 (C-5), 70.7 (C-3), 67.6 (C-4), 60.9 (C-6), 51.7 (C-2), 22.1 (NHCO*CH*$_3$); IR (film) cm^{-1}: 3329, 2907, 2095, 1639, 1553, 1429, 1326, 1226, 1018; ESI-HRMS calcd for $C_8H_{14}N_4O_5Na$ 269.0862, found *m/z* 269.0851 $[M+Na]^+$.



2-Acetamido-6-*O*-*tert*-butyldiphenylsilyl-3,4-di-*O*-benzoyl-2-deoxy-β-D-glucopyranosyl azide (26)

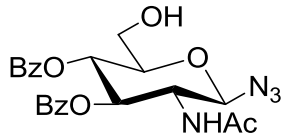
This polyhydroxylated intermediate (0.84 g, 3.4 mmol) was taken up in pyridine (15 mL) and the resulting solution was cooled using an ice bath. TBDPSCl (1.1 mL, 4.1 mmol) was added dropwise and the mixture was allowed to attain room temp and stirred for 16 h. The resulting suspension was cooled using an ice bath and benzoyl chloride (0.87 mL, 7.5 mmol) was added slowly. The reaction mixture was allowed to warm to room temp and was then stirred for 16 h after which time MeOH (~5 mL) was added. The resulting slurry was diluted with EtOAc (50 mL), washed with 1M HCl (2 x 25 mL), satd aq $NaHCO_3$ (50 mL), brine (50 mL), dried over Na_2SO_4, filtered and the solvent was removed under diminished pressure. Flash chromatography of the residue (petroleum ether-EtOAc 6:4) gave 11 (1.8 g, 76%) as a white foam; $[\alpha]_D$ -51.2 (*c* 0.13, CH_2Cl_2); ^{1}H NMR (500 MHz, $CDCl_3$) δ 7.98 – 7.91 (m, 2H; Ar-H), 7.90 – 7.83 (m, 2H; Ar-H), 7.75 – 7.68 (m, 2H; Ar-H), 7.61 – 7.45 (m, 4H; Ar-H), 7.42 – 7.32 (m, 6H; Ar-H), 7.18 (dd, ^3J (H,H) = 8.1, 7.0 Hz, 2H; Ar-H), 5.82 – 5.70 (m, 2H; H-4, N*H*COCH$_3$, overlapping peaks), 5.59 (dd, ^3J (H,H) = 10.7, 9.6 Hz, 1H; H-3), 4.76 (d, ^3J (H,H) = 9.2 Hz, 1H; H-1), 4.25 (apt dt, ^3J (H,H) = 10.7, 9.2 Hz, 1H; H-2), 3.91–3.78 (m, 3H; H-6a, H-6b, H-5, overlapping peaks), 1.91 (s, 3H; NHCO*CH*$_3$), 1.04 (s, 9H; C(*CH*$_3$)$_3$); ^{13}C NMR (126 MHz, $CDCl_3$): δ 170.5 (NH*C*OCH$_3$), 167.1, 164.8 (2 x *C*OPh), 135.6, 135.5, 133.6, 133.5, 133.3 (6 x Ar-CH, overlapping peaks), 132.9, 132.8 (2 x Ar-C), 130.0, 129.7 (2s), 129.6, 128.5 (2s) (6 x Ar-CH, overlapping peaks) (Ar-C, 2 x Ar-CH, overlapping peaks), 128.4 (2s) (Ar-C, 2 x Ar-CH, overlapping peaks), 127.7, 127.6 (4 x Ar-CH, overlapping peaks), 88.6 (C-1), 77.1 (C-5), 73.2 (C-3), 68.3 (C-4), 62.2 (C-6), 54.6 (C-2), 26.6 (C(*CH*$_3$)$_3$, overlapping peaks), 23.3 (NHCO*CH*$_3$), 19.2 (*C*(CH$_3$)$_3$); IR (film) cm^{-1}:

3268, 2931, 2113, 1725, 1657, 1548, 1240, 1061; ESI-HRMS calcd for $C_{38}H_{40}N_4O_7SiNa$ 701.2533, found *m/z* 701.2540 $[M+Na]^+$.



2-Acetamido-6-*O*-*tert*-butyldiphenylsilyl-3,4-di-*O*-benzoyl-2-deoxy-β-D-galactopyranosyl azide (27)

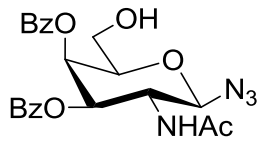
Intermediate **25** (0.9 g, 3.7 mmol) was reacted with pyridine (15 mL) and TBDPSCl (1.14 mL, 4.4 mmol) and then benzoyl chloride (0.93 mL, 8.0 mmol) as described above gave after chromatography (petroleum ether-EtOAc, 6:4) the title compound **27** (1.79 g, 70%) as a white foam; $[\alpha]_D$ +32.7 (*c* 0.1, CH_2Cl_2); ^{1}H NMR (500 MHz, $CDCl_3$) δ 8.07 – 8.02 (m, 2H; Ar-H), 7.87 – 7.83 (m, 2H; Ar-H), 7.66 – 7.60 (m, 3H; Ar-H), 7.54 – 7.47 (m, 5H; Ar-H), 7.42 – 7.28 (m, 5H; Ar-H), 7.11 (t, ^3J (H,H) = 7.6 Hz, 2H; Ar-H), 6.00 – 5.94 (m, 1H; H-3), 5.64 – 5.57 (m, 2H; H-4, N*H*COCH$_3$, overlapping peaks), 4.80 (d, ^3J (H,H) = 9.2 Hz, 1H; H-1), 4.33 (apt dt, ^3J (H,H) = 11.1, 9.0 Hz, 1H; H-2), 4.06 (ddd, ^3J (H,H) = 7.4, 6.1, 1.2 Hz, 1H; H-5), 3.86 – 3.75 (m, 2H; H-6a, H-6b, overlapping peaks), 1.89 (s, 3H; NHCO*CH*$_3$), 0.99 (s, 9H; C(*CH*$_3$)$_3$); ^{13}C NMR (126 MHz, $CDCl_3$): δ 170.5 (NH*C*OCH$_3$), 166.4, 165.3 (2 x *C*OPh), 135.5, 135.4, 133.5 (2s) , 133.4 (6 x Ar-CH, overlapping peaks),, 132.7, 132.5 (2 x Ar-C), 129.9 (2s), 129.8, 129.7 (6 x Ar-CH, overlapping peaks), 129.4, 128.8 (2 x Ar-C), 128.6, 128.4, 127.8, 127.6 (8 x Ar-CH, overlapping peaks), 89.0 (C-1), 75.7 (C-5), 71.0 (C-4), 67.1 (C-3), 61.1 (C-6), 51.4 (C-2), 26.6 (C(*CH*$_3$)$_3$, overlapping peaks), 23.3 (NHCO*CH*$_3$), 19.0 (*C*(CH$_3$)$_3$); IR (film): cm^{-1}: 3994, 2860, 2115, 1722, 1657, 1272, 1106, 1068; ESI-HRMS calcd for $C_{38}H_{40}N_4O_7SiNa$ 701.2533, found *m/z* 701.2525$[M+Na]^+$.



2-Acetamido-3,4-di-*O*-benzoyl-2-deoxy-β-D-glucopyranosyl azide (28)

The TPDPS derivative **26** (0.75 g, 1.1 mmol) was dissolved in THF (15 mL) and HF-pyridine (5 mL) was added slowly. The reaction mixture was then stirred overnight before dilution with EtOAc (50 mL) and careful addition of the mixture to

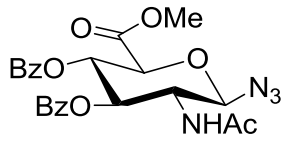
satd aq $NaHCO_3$ (100 mL). The resulting biphasic mixture was separated and the organic phase washed with further satd aq $NaHCO_3$ (50 mL), 1M HCl (50 mL), brine (50 mL), dried over Na_2SO_4, filtered and the solvent was removed under diminished pressure. Flash chromatography of the residue (petroleum ether-EtOAc 3:7) gave the intermediate alcohol (0.45 g, 89%) as a white foam; $[\alpha]_D$ -22.7 (c 0.05, CH_2Cl_2); ^{1}H NMR (500 MHz, $CDCl_3$) δ 7.91 (ddd, ^3J (H,H) = 8.5, 3.9, 1.4 Hz, 1H; Ar-H), 7.56 – 7.44 (m, 2H; Ar-H), 7.35 (ddd, ^3J (H,H) = 8.8, 7.5, 1.5 Hz, 1H; Ar-H), 5.94 (d, ^3J (H,H) = 8.9 Hz, 1H; N*H*COCH$_3$), 5.78 (dd, ^3J (H,H) = 10.7, 9.4 Hz, 1H; H-3), 5.51 (apt t, ^3J (H,H) = 9.7 Hz, 1H; H-4), 4.97 (d, ^3J (H,H) = 9.3 Hz, 1H; H-1), 4.16 (apt dt, ^3J (H,H) = 10.7, 8.9 Hz, 1H; H-2), 3.93 – 3.81 (m, 2H; H-5, H-6a, overlapping peaks), 3.80 – 3.64 (m, 1H; H-6b), 1.89 (s, 3H; NHCO*C*H$_3$); ^{13}C NMR (126 MHz, $CDCl_3$): δ 170.6 (NH*C*OCH$_3$), 166.7, 165.9 (2 x*C*OPh), 133.7 (2s) (2 x Ar-CH), 129.8 (4 x Ar-CH, overlapping peaks), 128.5 (2s) (4 x Ar-CH, Ar-C, overlapping peaks) , 128.4 (Ar-C), 88.7 (C-1), 76.7 (C-5), 72.4 (C-3), 69.0 (C-4), 61.2 (C-6), 54.6 (C-2), 23.2 (NHCO*C*H$_3$); IR (film) cm^{-1}: 3274, 2965, 2115, 1720, 1451, 1260, 1069, 1024; ESI-HRMS calcd for $C_{22}H_{22}N_4O_7Na$ 477.1386, found *m/z* 477.1384 $[M+Na]^+$.



2-Acetamido-3,4-di-*O*-benzoyl-2-deoxy-β-D-galactopyranosyl azide (29)

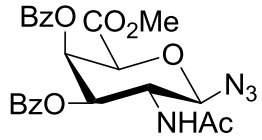
Treatment of the TBDPS derivative **27** (0.75 g, 1.1 mmol) in THF (15 mL) with HF-pyridine (5 mL) as described for **26** gave the primary alcohol intermediate (0.46 g, 93%) as a white foam; $[\alpha]_D$ +68.2 (*c* 0.2, CH_2Cl_2); ^{1}H NMR (500 MHz, $CDCl_3$): δ 8.14– 7.28 (m, 10H; Ar-H), 5.80 (d, ^3J (H,H) = 9.0 Hz, 1H; N*H*COCH$_3$), 5.77 – 5.73 (m, 1H; H-4), 5.58 (dd, ^3J (H,H) = 11.1, 3.3 Hz, 1H; H-3), 4.86 (d, ^3J (H,H) = 9.2 Hz, 1H; H-1), 4.51 (apt dt, ^3J (H,H) = 11.1, 9.0 Hz, 1H; H-2), 4.05 (td, ^3J (H,H) = 6.7, 1.0 Hz, 1H; H-5), 3.84 (apt dt, ^2J (H,H) = -11.5 Hz, ^3J (H,H) 5.3 Hz, 1H; H-6a), 3.69 – 3.61 (m, 1H; H-6b), 1.92 (s, 3H; NHCO*C*H$_3$); ^{13}C NMR (126 MHz, $CDCl_3$): δ 170.6 (NH*C*OCH$_3$), 166.7, 166.2 (2 x *C*OPh), 134.0, 133.7, 130.1, 129.8, 128.8 (6 x Ar-CH, overlapping peaks), 128.6 (2s) (2 x Ar-C), 128.5 (4 x Ar-CH, overlapping peaks), 89.1 (C-1), 76.0 (C-5), 70.8 (C-3), 68.2 (C-4), 60.5 (C-6), 51.2 (C-2), 23.3

(NHCO*CH*$_3$); IR (film) cm^{-1}: 3286, 2929, 2114, 1722, 1660, 1249, 1093, 1025; ESI-HRMS calcd for $C_{22}H_{22}N_4O_7Na$ 477.1386, found *m/z* 477.1392 $[M+Na]^+$.



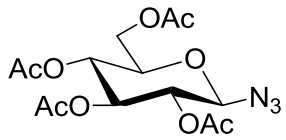
Methyl 2-acetamido-1-azido-1,2-dideoxy-3,4-di-*O*-benzoyl-β-D-glucopyranuronate (30)

Compound **28** (0.4 g, 0.9 mmol) was dissolved in MeCN-H_2O (10 mL, 3:1) and TEMPO (0.14 g, 0.09 mmol) and BAIB (0.72 g, 2.3 mmol) were added. The mixture was stirred for 5 h at which point 10% $Na_2S_2O_3$ (5 mL) was added and the mixture concentrated. The resulting slurry was dissolved in EtOAc (25 mL) and extracted with 1M HCl (25 mL), dried over Na_2SO_4, filtered and the solvent was removed under diminished pressure. The residue was taken up in MeOH (10 mL) and *p*-TsOH.H_2O (0.35 g, 0.2 mmol) was added. The mixture was stirred for 16 h and triethylamine (0.5 mL) was added and the the solvent was removed under diminished pressure. Flash chromatography of the residue (petroleum ether-EtOAc 6:4) gave **30** (0.2 g, 47%) as a white foam; [α]D 58.7 (c 0.9, CH_2Cl_2); ^{1}H NMR (500 MHz, $CDCl_3$) δ = 7.94 (dd, ^3J (H,H) = 8.2, 1.4 Hz, 2H; Ar-H), 7.88 (dd, ^3J (H,H) = 8.3, 1.4 Hz, 2H; Ar-H), 7.55 – 7.47 (m, 2H; Ar-H), 7.40 – 7.36 (m, 2H; Ar-H), 7.33 (dd, ^3J (H,H) = 8.5, 7.1 Hz, 2H; Ar-H), 5.89 (d, ^3J (H,H) = 8.7 Hz, 1H; N*H*COCH$_3$), 5.83 (dd, ^3J (H,H) = 10.3, 9.3 Hz, 1H; H-3), 5.66 (apt t, ^3J (H,H) = 9.5 Hz, 1H; H-4), 5.12 (d, ^3J (H,H) = 8.9 Hz, 1H; H-1), 4.41 (d, ^3J (H,H) = 9.7 Hz, 1H; H-5), 4.09 (apt dt, ^3J (H,H) = 10.3, 8.7 Hz, 1H; H-2), 3.68 (s, 3H; CO_2CH_3), 1.92 (s, 3H; NHCO*CH*$_3$); ^{13}C NMR (126 MHz, $CDCl_3$): δ 170.6 (NH*C*OCH$_3$), 166.8 (*C*O$_2$CH$_3$), 166.4, 165.1 (2 x *C*OPh), 133.7, 133.5 (2 x Ar-CH), 129.9, 129.7 (4 x Ar-CH, overlapping peaks), 128.6 (Ar-C), 128.5 (2 x Ar-CH, overlapping peaks), 128.4 (2 x Ar-CH, Ar-C, overlapping peaks), 88.6 (C-1), 74.4 (C-5), 71.5 (C-3), 69.7 (C-4), 54.4 (C-2), 53.0 (CO_2CH_3), 23.2 (CO*CH*$_3$); IR (film) cm-1: 2954, 2113, 1721, 1451, 1247, 1096, 1069, 1026; ESI-HRMS calcd for $C_{23}H_{22}O_8N_4Na$ 505.1335, found *m/z* 505.1354 $[M+Na]^+$.



Methyl 2-acetamido-1-azido-1,2-dideoxy-3,4-di-*O*-benzoyl-β-D-glucopyranuronate (31)

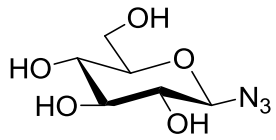
Intermediate **29** (0.4 g, 0.9 mmol) was taken up in MeCN-H_2O (10 mL, 3:1) was reacted with TEMPO (0.14 g, 0.09 mmol) and BAIB (0.72 g, 2.3 mmol) and the resulting carboxylic acid treated with *p*-TsOH.H_2O (0.35 g, 0.2 mmol) in MeOH (10 mL) as described above to give **31** (0.22 g, 51%) as a white foam; $[\alpha]_D$ 39.3 (*c* 0.6, CH_2Cl_2); ^{1}H NMR (500 MHz, $CDCl_3$) δ = 7.92 -7.37 (ms, 10H; Ar-H), 6.11 (dd, ^3J (H,H) = 3.5, 1.4 Hz, 1H; H-4), 5.82 – 5.76 (m, 2H; N*H*COCH$_3$, H-3, overlapping peaks), 5.14 (d, ^3J (H,H) = 9.0 Hz, 1H; H-1), 4.67 (d, ^3J (H,H) = 1.4 Hz, 1H; H-5), 4.23 (dt, ^3J (H,H) = 11.0, 9.0 Hz, 1H; H-2), 3.72 (s, 3H; CO_2CH_3), 1.91 (s, 3H; NHCO*CH*$_3$); ^{13}C-NMR (126 MHz, $CDCl_3$): δ 170.7 (NH*C*OCH$_3$), 166.2, 165.9 (2 x *C*OPh), 165.1 (*C*O$_2$CH$_3$), 133.7, 133.6, 130.0, 129.8 (6 x Ar-CH, overlapping peaks), 128.8 (Ar-C), 128.6 (2 x Ar-CH, Ar-C, overlapping peaks), 128.5 (2 x Ar-CH, overlapping peaks), 88.7 (C-1), 74.4 (C-5), 69.8 (C-3), 68.6 (C-4), 52.9 (CO_2CH_3), 51.3 (C-2), 23.3 (NHCO*CH*$_3$); IR (film) cm^{-1}: 2956, 2117, 1725, 1665, 1451, 1248, 1092, 1067, 1025; ESI-HRMS calcd for $C_{23}H_{22}O_8N_4Na$ 505.1335, found *m/z* 505.1340 $[M+Na]^+$.



2,3,4,6-tetra-*O*-acetyl-β-D-glucopyranosyl azide (35)[127]

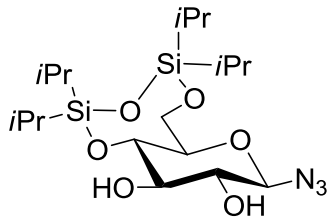
Glucose pentaacetate (10 g, 25.6 mmole) was taken up in CH_2Cl_2 (80 ml) and cooled using an ice bath. $TMSN_3$ (5.1 ml, 38.4 mmole) was added, followed by drop wise addition of $SnCl_4$ (1.5 ml, 12.8 mmole). The reaction mixture was allowed to come slowly to room temperature overnight. The resulting solution was diluted with CH_2Cl_2 (100 ml) and washed twice with 1M $KHSO_4$ (100 ml), satd Aq $NaHCO_3$ (100 ml), brine (100 ml), dried over anhydrous $NaSO_4$, filtered and the solvent was removed under reduced pressure. This residue was recrystallised from ethanol to yield **35** (7.7 g, 81 %) as a white solid; $[\alpha]_D$ -31.9 (*c* 0.28, CH_2Cl_2); ^{1}H NMR (500 MHz, $CDCl_3$) δ 5.22 (apt. t, ^3J (H,H) = 9.5 Hz, 1H; H-3), 5.11 (apt. t, ^3J (H,H) = 9.7

Hz, 1H; H-4), 4.96 (dd, ^{3}J (H,H) = 9.5, 8.8 Hz, 1H; H-2), 4.65 (d, ^{3}J (H,H) = 8.8 Hz, 1H; H-1), 4.27 (dd, ^{2}J (H,H) = -12.5, ^{3}J (H,H) = 4.8 Hz, 1H; H-6a), 4.17 (dd, ^{2}J (H,H) = -12.5, ^{3}J (H,H) = 2.3 Hz, 1H; H-6b), 3.79 (ddd, ^{3}J (H,H) = 10.1, 4.8, 2.3 Hz, 1H; H-5), 2.10 (s, 3H; CO*CH*$_3$), 2.08 (s, 3H; CO*CH*$_3$), 2.03 (s, 3H; CO*CH*$_3$), 2.01 (s, 3H; CO*CH*$_3$). ^{13}C NMR (126 MHz, $CDCl_3$) δ 170.6, 170.1, 169.3, 169.2 (4 x *C*OCH$_3$), 87.9 (C-1), 74.0 (C-5), 72.6 (C-3), 70.6 (C-2), 67.9 (C-4), 61.6 (C-6), 20.7, 20.6, 20.5 (4 x CO*CH*$_3$, overlapping peaks); IR (film) cm^{-1}: 2909, 2117, 1753, 1368, 1209, 1036; ES-HRMS calcd for $C_{14}H_{19}N_3O_9Na$ 396.1019, found m/z 396.1023 $[M+Na]^+$.



β-D-glucopyranosyl azide (36)[237]

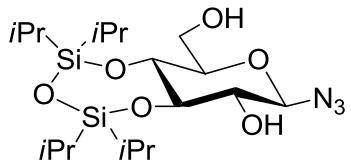
Sodium methoxide (0.2 g, 4.0 mmol) was added to the azide **35** (7.5 g, 20.1 mmol) in MeOH (50 mL) and the mixture was stirred for 1 h and then Dowex® 50WX8 H^+-resin (500 mg) was added and the resulting suspension stirred until the *p*H was 7. This mixture was then filtered and the solvent was removed under diminished pressure to give β-D-glucopyranosyl azide (3.92 g, 95%) as a white solid; $[\alpha]_D$ -31.0 (*c* 0.3, CH_3OH); ^{1}H-NMR (500 MHz, D_2O): δ 4.75 (d, ^{3}J (H,H) = 8.8 Hz, 1H; H-1), 3.93 (dd, ^{2}J (H,H) = -12.4 Hz, ^{3}J (H,H) = 2.2 Hz, 1H; H-6a), 3.75 (dd, ^{2}J (H,H) = -12.4 Hz, ^{3}J (H,H) = 5.7 Hz, 1H; H-6b), 3.57 – 3.49 (m, 2H; H-5, H-3, overlapping peaks), 3.41 (apt t, ^{3}J (H,H) = 9.0 Hz, 1H; H-4), 3.27 (apt t, ^{3}J (H,H) = 9.0 Hz, 1H; H-2); ^{13}C-NMR (126 MHz, D_2O): δ 90.9 (C-1), 79.0 (C-5), 76.9 (C-3), 73.6 (C-2), 69.9 (C-4), 61.4 (C-6); IR (film) cm^{-1}: 3303, 2881, 2125, 1472, 1377, 1263, 1064; ESI-HRMS calcd for $C_6H_{12}N_3O_5$ 206.0777, found *m/z* 206.0772 $[M+H]^+$.



4,6-*O*-(1,1,3,3-Tetraisopropyl-1,3-disiloxanediyl)-β-D-glucopyranosyl azide (37).

To a solultion of **36** (3.5 g, 17.1 mmol) in pyridine (50 mL) at 0°C was added 1,3-

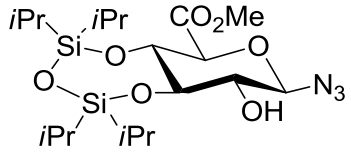
dichloro-1,1,3,3-tetraisopropyldisiloxane (0.99 mL, 20.5 mmol) and the mixture was allowed to warm to room temp and was then stirred for 5 h at which point MeOH (1 mL) was added and the solvent removed under diminished pressure. The resulting residue was taken up in EtOAc (50 mL) and washed with 1M HCl (50 mL), $NaHCO_3$ (50 mL), brine (50 mL), then dried over Na_2SO_4, filtered and the solvent removed under diminished pressure. Flash chromatography of the residue (petroleum ether-EtOAc, 7:3) gave **37** (4.7 g, 61%) as a white solid; $[\alpha]_D$ -80.7 (*c* 0.20, CH_2Cl_2); ^{1}H NMR (500 MHz, $CDCl_3$): δ 4.58 (d, ^3J (H,H) = 8.6 Hz, 1H; H-1), 4.09 (dd, ^2J (H,H) = 12.7 Hz, ^3J (H,H) = 2.1 Hz, 1H; H-6a), 4.00 (dd, ^2J (H,H) = 12.7 Hz, ^3J (H,H) = 1.5 Hz, 1H; H-6b), 3.83 (apt t, ^3J (H,H) = 9.1 Hz, 1H; H-4), 3.60 (apt t, ^3J (H,H) = 9.1 Hz, 1H; H-3), 3.34 – 3.26 (m, 2H; H-5, H-2, overlapping peaks), 2.56 (s, 2H; 2 x OH), 1.25 – 0.89 (m, 28H; 4 x C*H*(CH_3)$_2$, overlapping peaks); ^{13}C NMR (126 MHz, $CDCl_3$): δ 90.8 (C-1), 78.7 (C-5), 76.5 (C-3), 73.5 (C-2), 68.8 (C-4), 60.6 (C-6), 17.4, 17.3, 17.2 (3s), 17.1 (2s) (8 x CH(*C*H_3)$_2$, overlapping peaks), 13.6, 13.2, 12.5 (2s) (4 x C*H*(CH_3)$_2$, overlapping peaks); IR (film) cm^{-1}: 3420, 2868, 2115, 1465, 1248, 1025; ESI-HRMS calcd for $C_{18}H_{37}N_3O_6Si_2Na$ 442.2349, found *m/z* 442.2352 $[M+Na]^+$.



3,4-*O*-(1,1,3,3-Tetraisopropyl-1,3-disiloxanediyl)-β-D-glucopyranosyl azide (38)

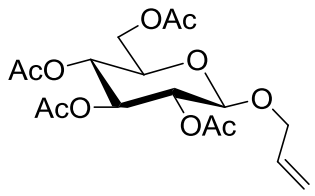
To a solution of diol **37** (2 g, 4.45 mmol), in DMF (25 mL), *p*-TsOH.H_2O (0.17 g, 0.9 mmol) was added and the mixture stirred at room temp for 5 h and it was then diluted with EtOAc (50 mL), washed with H_2O (2 x 25 mL), satd aq $NaHCO_3$ (50 mL), brine (50 mL), dried over Na_2SO_4, filtered and the solvent was removed under diminished pressure. Flash chromatography of the residue (petroleum ether-EtOAc 8:2) gave the 3,4-protected intermediate (1.87 g, 94%) as a clear oil; $[\alpha]_D$ -4.8 (*c* 0.17, CH_2Cl_2); ^{1}H NMR (500 MHz, $CDCl_3$) δ = 4.60 (d, ^3J (H,H) = 8.6 Hz, 1H; H-1), 3.93 (ddd, ^2J (H,H) = -12.0 Hz, ^3J (H,H) = 6.3, 2.2 Hz, 1H; H-6a), 3.77 (ddd, ^2J (H,H) = -12.0 Hz, ^3J (H,H) = 7.2, 4.9 Hz, 1H; H-6b), 3.73 – 3.64 (m, 2H; H-4, H-3, overlapping peaks), 3.45 (ddd, ^3J (H,H) = 8.9, 4.9, 2.8 Hz, 1H; H-5), 3.38 (apt td, ^3J (H,H) = 8.6, 2.2 Hz, 1H; H-2), 2.44 (d, ^3J (H,H) = 2.3 Hz, 1H; OH), 1.93 (apt t, ^3J

(H,H) = 6.8 Hz, 1H; OH), 1.16 – 0.86 (m, 28H; 4 x C*H*(CH_3)$_2$, overlapping peaks); ^{13}C NMR (126 MHz, $CDCl_3$) δ 89.5 (C-1), 79.8 (C-3), 78.4 (C-5), 73.9 (C-2), 72.1 (C-4), 61.9 (C-6), 17.3 (3s), 17.2 (2s), 17.1 (8 x CH(CH_3)$_2$, overlapping peaks), 12.9, 12.8, 12.1 (2s) (4 x *CH*(CH_3)$_2$, overlapping peaks); IR (film) cm^{-1}: 3349, 2868, 2114, 1464, 1248, 1052, 987; ESI-HRMS calcd for $C_{18}H_{37}N_3O_6Si_2Na$ 442.2349, found *m/z* 442.2356 [M+Na]$^+$.



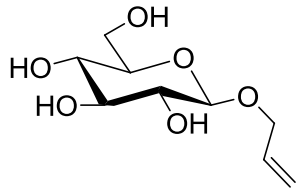
Methyl 1-azido-1-deoxy-3,4-*O*-(1,1,3,3-tetraisopropyl-1,3-disiloxanediyl)-β-D-glucopyranuronate (39)

Intermediate **38** (1.8 g, 4.0 mmol) was dissolved in MeCN-H_2O (60 mL, 3:1) and BAIB (3.24 g, 10.1 mmol) and TEMPO (0.06 g, 0.4 mmol) were added and the mixture was stirred for 5 h. Work-up as described above for the TEMPO-BAIB oxidation gave the carboxylic acid, which when treated in DMF (25 mL) with $NaHCO_3$ (0.5 g, 6.0 mmol) and methyl iodide (0.37 mL, 6.0 mmol) as described above gave **39** (0.97 g, 51%) as a clear oil after chromatography (petroleum ether-EtOAc 9:1); [α]D -3.6° (c 0.06, CH_2Cl_2); ^{1}H NMR (500 MHz, $CDCl_3$): δ = 4.61 (d, ^3J (H,H) = 8.7 Hz, 1H; H-1), 3.96 – 3.90 (m, 2H; H-5, H-4, overlapping peaks), 3.78 (s, 3H; O*CH*$_3$), 3.68 (ddd, ^3J (H,H) = 8.5, 6.4, 1.9 Hz, 1H; H-3), 3.45 (td, ^3J (H,H) = 8.7, 1.9 Hz, 1H; H-2), 2.43 (d, ^3J (H,H) = 2.4 Hz, 1H; OH), 1.29–0.46 (m, 28H; 4 x C*H*(CH_3)$_2$, overlapping peaks); ^{13}C NMR (126 MHz, $CDCl_3$): δ 168.2 (*C*O_2CH_3), 89.9 (C-1), 79.3 (C-3), 77.4 (C-5), 73.7 (C-4), 73.4 (C-2), 52.4 (CO_2*CH*$_3$), 17.3, 17.2 (4s), 17.1, 17.0 (2s) (8 x CH(CH_3)$_2$, overlapping peaks), 12.9, 12.8, 12.2, 12.1 (4 x *CH*(CH_3)$_2$, overlapping peaks); IR (film) cm^{-1}: 3441, 2867, 2125, 1785, 1736, 1464, 1251, 1081, 987; ESI-HRMS calcd for $C_{19}H_{37}N_3O_7Si_2Na$ 498.2068, found *m/z* 498.2074 [M+Na]$^+$.



Allyl 2,3,4,6-tetra-*O*-acetyl-β-D-glucopyranoside (40)[238]

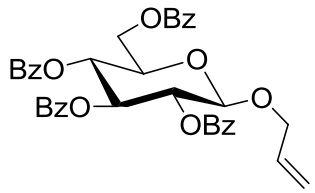
Glucose pentaacetate (15 g, 38.4 mmol) was taken up in CH_2Cl_2 (80 ml) and cooled using an ice bath. To the resulting solution was added allyl alcohol (6.5 ml, 96.0 mmol) and $BF_3{\cdot}OEt_2$ (23.7 ml, 192.0 mmol) and the reaction mixture was allowed to come to room temperature and stir overnight. The solution was diluted with CH_2Cl_2 (150 ml) and poured slowly onto satd aq $NaHCO_3$ (250 ml). The biphasic mixture was separated and the organic layer washed with a further portion of satd aq $NaHCO_3$ (250 ml), brine (250 ml), dried over Na_2SO_4, filtered and concentrated .The crude product was purified via flash chromatography (petroleum ether-EtOAc 6:4) to **40** (9.1 g, 61%) as a white solid; [α]D -28.3° (c 0.1, CH_2Cl_2); ^{1}H NMR (500 MHz, $CDCl_3$) δ 5.84 (dddd, ^3J (H,H) = 17.3, 10.4, 6.1, 4.9 Hz, 1H, CH_2CHCH_2), 5.27 (dq, ^3J (H,H) = 17.3, ^4J (H,H) = 1.7 Hz, 1H; CH_2CHCH_2), 5.24 – 5.16 (m, 2H, H-3; CH_2CHCH_2, overlapping peaks), 5.09 (dd, ^3J (H,H) = 10.0, 9.3 Hz, 1H; H-4), 5.02 (dd, ^3J (H,H) = 9.6, 7.9 Hz, 1H; H-2), 4.55 (d, ^3J (H,H) = 7.9 Hz, 1H; H-1), 4.33 (ddt, ^2J (H,H) = -13.2, ^3J (H,H) = 4.9, ^4J (H,H) =1.7 Hz, 1H; CH_2CHCH_2), 4.26 (dd, ^2J (H,H) = -12.3, ^3J (H,H) = 4.8 Hz, 1H; H-6a), 4.14 (dd, ^2J (H,H) = 12.3, ^3J (H,H) = 2.5 Hz, 1H; H-6b), 4.09 (ddt, ^2J (*H,H)* = -13.2, ^3J (H,H) = 6.1, ^4J (H,H) = 1.4 Hz, 1H; CH_2CHCH_2), 3.68 (ddd, ^3J (H,H) = 10.0, 4.8, 2.5 Hz, 1H; H-5), 2.08 (s, 3H; $COCH_3$), 2.04 (s, 3H; $COCH_3$), 2.02 (s, 3H; $COCH_3$), 2.00 (s, 3H; $COCH_3$); ^{13}C NMR (126 MHz, $CDCl_3$) δ 170.6, 170.3, 169.4, 169.3 (4 x $COCH_3$), 133.3 (CH_2CHCH_2), 117.6 (CH_2CHCH_2), 99.5 (C-1), 72.8 (C-3), 71.7 (C-5), 71.3 (C-2), 70.0 (CH_2CHCH_2), 68.4 (C-4), 61.9 (C-6), 20.7, 20.7, 20.6, 20.6 (4 x $COCH_3$); IR (film) cm^{-1}: 2951, 1738, 1445, 1369, 1208, 1031; ES-HRMS calcd for $C_{17}H_{25}O_{10}$ 389.1448, found m/z 389.1456 $[M+H]^+$.



Allyl β-D-glucopyranoside (41)[238]

Compound **40** (9 g, 23.2 mmole) was taken up in MeOH (50 ml) and NaOMe (0.25 g, 4.6 mmole) was added. The reaction was followed by TLC and apon completion dowex® 50WX8 H^+-resin (500mg) was added and the resulting suspension was stirred until the solution was neutralised. This was then filtered and evaporated to give **41** (4.4 g, 87%) as a white solid; $[\alpha]_D$ -35.0 (*c* 0.2, CH_3OH); ^{1}H NMR (500

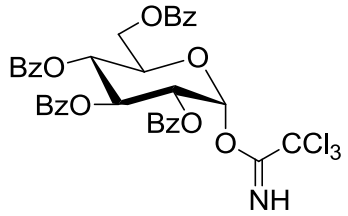
MHz, D_2O) δ 5.85 (dddd, ^3J (H,H) =17.0, 10.5, 6.3, 5.5 Hz, 1H; CH_2CHCH_2), 5.25 (dq, ^3J (H,H) =17.0, ^4J (H,H) = 1.5 Hz, 1H; CH_2CHCH_2), 5.15 (dq, ^3J (H,H) =10.5, ^4J (H,H) = 1.5 Hz, 1H; CH_2CHCH_2), 4.37 (d, ^3J (H,H) = 8.0 Hz, 1H; H-1), 4.26 (ddt, ^2J (H,H) =12.7, ^3J (H,H) = 5.5, ^4J (H,H) = 1.4 Hz, 1H; CH_2CHCH_2), 4.09 (ddt, ^2J (H,H) = -12.7, ^3J (H,H) =6.3, ^4J (H,H) = 1.4 Hz, 1H; CH_2CHCH_2), 3.78 (dd, ^2J (H,H) = -12.3, ^3J (H,H) =2.2 Hz, 1H; H-6a), 3.58 (dd, ^2J (H,H) = -12.3, ^3J (H,H) = 6.0 Hz, 1H; H-6b), 3.35 (apt. t,^3J (H,H) = 9.2 Hz, 1H; H-3), 3.33 – 3.29 (m, 1H; H-5), 3.25 (dd, ^3J (H,H) = 9.9, 8.9 Hz, 1H; H-4), 3.15 (dd, ^3J (H,H) = 9.3, 8.0 Hz, 1H; H-2);^{13}C NMR (126 MHz, D_2O) δ 133.2 (CH_2CHCH_2), 118.7 (CH_2CHCH_2), 101.1 (C-1), 75.8 (C-5), 75.7 (C-3), 73.0 (C-2), 70.5 (CH_2CHCH_2), 69.6 (C-4), 60.7 (C-6); IR (film) cm^{-1}: 3295, 2915, 1664, 1458, 1365, 1109, 1073, 1022; ES-HRMS calcd for $C_9H_{16}O_6Na$ 243.0845, found m/z 243.0852 $[M+Na]^+$.



Allyl 2,3,4,6-tetra-*O*-benzoyl-β-D-glucopyranoside (42)

Intermediate **41** (4.4g, 20.0 mmole) was taken up in pyridine and cooled using an ice bath. BzCl (20.43 ml, 175.8 mmole) was added slowly via a dropping funnel. The reaction mixture was allowed to attain room temperature and stir over night, before quenching with MeOH. The resulting slurry was diluted with EtOAc (100 ml), washed twice with 1M HCl (100 ml), satd aq $NaHCO_3$ (100 ml), brine (100 ml), dried over Na_2SO_4, filtered and concentrated. The resulting residue was purified via flash chromatography (petroleum ether-EtOAc 8:2) to **42** (10.3 g, 81%) as a white solid; $[\alpha]_D$ +19.4 (*c* 0.2, CH_2Cl_2); ^{1}H NMR (500 MHz, $CDCl_3$) δ 8.04 – 8.01 (m, 2H; Ar-H), 7.98 – 7.95 (m, 2H; Ar-H), 7.91 – 7.88 (m, 2H; Ar-H), 7.85 – 7.81 (m, 2H; Ar-H), 7.57 – 7.47 (m, 3H; Ar-H), 7.43 – 7.38 (m, 4H; Ar-H), 7.37 – 7.32 (m, 2H; Ar-H), 7.30 – 7.26 (m, 2H; Ar-H), 5.91 (apt. t, ^3J (H,H) = 9.6 Hz, 1H; H-3), 5.80 (dddd, ^3J (H,H) = 17.0, 10.4, 6.3, 4.9 Hz, 1H; CH_2CHCH_2), 5.68 (apt. t, ^3J (H,H) = 9.7 Hz, 1H; H-4), 5.56 (dd, ^3J (H,H) = 9.7, 7.8 Hz, 1H; H-2), 5.22 (dq, ^3J (H,H) =17.0, ^4J (H,H) = 1.6 Hz, 1H; CH_2CHCH_2), 5.12 (dq, ^3J (H,H) =10.4, ^4J (H,H) = 1.6 Hz, 1H; CH_2CHCH_2), 4.90 (d, ^3J (H,H) = 7.8 Hz, 1H; H-1), 4.64 (dd, ^2J (H,H) = -12.1, ^3J (H,H) = 3.2 Hz, 1H; H-6a), 4.51 (dd, ^2J (H,H) = -12.1, ^3J (H,H) = 5.4 Hz,

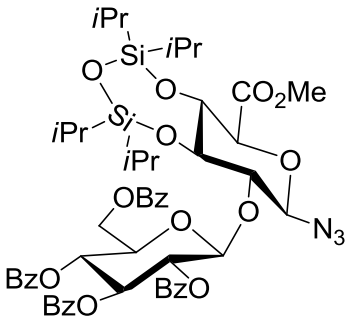
1H; H-6b), 4.38 – 4.33 (m, 1H; CH_2CHCH_2), 4.20 – 4.13 (m, 2H; CH_2CHCH_2, H-5, overlapping peaks); ^{13}C NMR (126 MHz, $CDCl_3$) δ 166.1, 165.8, 165.2, 165.1 (4 x *C*OPh), 133.4 (Ar-CH), 133.3 (CH_2CHCH_2), 133.2, 133.2, 133.1, 129.8, 129.8, 129.7, 129.7, 129.6 (14 x Ar-CH, overlapping peaks), 129.3, 128.8, 128.8, 128.4 (4 x Ar-C), 128.4, 128.3, 128.3 (5 x Ar-CH, overlapping peaks), 117.9 (CH_2CHCH_2), 99.8 (C-1), 72.9 (C-3), 72.2 (C-5), 71.9 (C-2), 70.1 (CH_2CHCH_2), 69.8 (C-4), 63.2 (C-6); IR (film) cm^{-1}: 3072, 1729, 1451 1249, 1090, 1026; ES-HRMS calcd for $C_{37}H_{36}NO_{10}$ 653.2261, found m/z 653.22644 $[M+NH_4]^+$.



2,3,4,6-tetra-O-benzoyl-1-(2,2,2--trichloro-1-iminoethoxy)-α-D-glucopyranoside (43)[93]

Compound **42** (10 g, 15.7 mmole) was taken up in MeOH/ CH_2Cl_2 (50 ml, 3:1) and $PdCl_2$ (0.56 g, 3.1 mmole) was added. The reaction mixture was stirred over night, before filtration through celite and concentration to give the crude product which was purified via flash chromatography (petroleum ether-EtOAc 6:4).The resulting hemiacetal (6.4 g, 10.7 mmole) was taken up in CH_2Cl_2 (50 ml) and cooled using an ice bath. To this was added trichloroacetonitrile (10.75 ml, 107.3 mmole) and catalytic DBU (0.25 ml). The reaction was followed by TLC and upon consumption of the starting material the solution was concentrated to ~10 ml. This was directly purified via flash chromatography (petroleum ether-EtOAc 7:3, 0.1% Et_3N) to **43** (6.7 g, 76 % over 2 steps) as a white solid; $[\alpha]_D$ +78.8 (*c* 0.2, CH_2Cl_2); ^1H NMR (500 MHz, $CDCl_3$) δ 8.64 (s, 1H; NH), 8.07 – 8.00 (m, 2H; Ar-H), 7.96 (ddd, ^3J (H,H) = 8.5, 4.9, 1.6 Hz, 4H; Ar-H), 7.87 (dd, ^3J (H,H) = 7.9, 1.7 Hz, 2H; Ar- H), 7.59 – 7.47 (m, 3H; Ar-H), 7.43 (td, ^3J (H,H) = 7.4, 5.5 Hz, 3H; Ar-H), 7.37 (d, ^3J (H,H) = 7.8 Hz, 4H; Ar-H), 7.30 (t, ^3J (H,H) = 7.8 Hz, 2H; Ar-H), 6.84 (d, ^3J (H,H) = 3.7 Hz, 1H; H-1), 6.28 (apt. t, ^3J (H,H) = 10.0 Hz, 1H; H-3), 5.82 (apt. t, ^3J (H,H) = 10.0 Hz, 1H; H-4), 5.63 (dd ^3J (H,H) = 10.2, 3.7 Hz, 1H; H-2), 4.67 – 4.60 (m, 2H; H-5, H-6a, overlapping peaks), 4.49 (dd, ^2J (H,H) = -12.5, ^3J (H,H) = 5.2 Hz, 1H; H-6b); ^{13}C NMR (126 MHz, $CDCl_3$) δ 166.0, 165.6, 165.4, 165.2 (4 x *C*OPh), 160.5

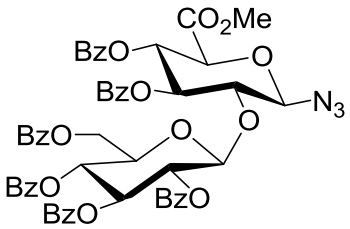
(*C*(NH)CCl_3) 133.5, 133.3, 133.1, 129.9, 129.8, 129.7 (14 x Ar-CH, overlapping peaks), 129.6, 128.8, 128.6 (4 x ArC, overlapping peaks), 128.5, 128.4, 128.4, 128.3 (6 x Ar-CH, overlapping peaks), 93.1 (C-1), 70.7 (C-2, C-5, overlapping peaks), 70.2 (C-3), 68.7 (C-4), 62.5 (C-6); IR (film) cm^{-1}: 334, 1723, 1452, 1248, 1091, 1025,



Methyl 2-*O*-(2,3,4,6-tetra-*O*-benzoyl-β-D-glucopyranosyl)-1-azido-1-deoxy-3,4-*O*-(1,1,3,3-tetraisopropyl-1,3-disiloxanediyl)-β-D-glucopyranuronate (44)

To a flame dried flask, containing freshly activated 4 Å molecular sieves (0.6 g), was added **39** (0.25 g, 0.5 mmol), **43** (0.58 g, 0.8 mmol) and CH_2Cl_2 (6 mL). The resulting suspension was stirred at room temp for 30 min before cooling to 0 °C using an ice bath. TMSOTf (0.029 mL, 0.16 mmol) was then added and the reaction mixture was allowed to attain room temp over 1 h. Triethylamine (0.25 mL) was added, the mixture filtered and the solvent was removed under diminished pressure. Flash chromatography of the residue (petroleum ether-EtOAc 8:2) gave **44** (0.35 g, 67%) as a white foam; $[\alpha]_D$ -22.6 (*c* 0.07, CH_2Cl_2); ^{1}H NMR (500 MHz, $CDCl_3$) δ 8.06 – 8.01 (m, 2H; Ar-H), 7.91 (ddd, ^3J (H,H) = 8.5, 4.0, 1.3 Hz, 4H; Ar-H), 7.82 – 7.71 (m, 2H; Ar-H), 7.57 – 7.52 (m, 1H; Ar-H), 7.50 (dd, ^3J (H,H) = 8.3, 6.7 Hz, 2H; Ar-H), 7.41 (apt q, ^3J (H,H) = 7.8 Hz, 3H; Ar-H), 7.35 (td, ^3J (H,H) = 7.7, 4.2 Hz, 4H; Ar-H), 7.28 – 7.22 (m, 1H; Ar-H), 5.85 (apt t, ^3J (H,H) = 9.5 Hz, 1H; H-3), 5.73 (apt t, ^3J (H,H) = 9.6 Hz, 1H; H-4), 5.58 (dd, ^3J (H,H) = 9.6, 7.7 Hz, 1H; H-2), 5.35 (d, ^3J (H,H) = 7.7 Hz, 1H; H-1), 4.71 (dd, ^2J (H,H) = -12.1 Hz, ^3J (H,H) = 3.2 Hz, 1H; H-6a), 4.57 – 4.47 (m, 2H; H-1', H6-b, overlapping peaks), 4.11 (ddd, ^3J (H,H) = 10.0, 5.2, 3.2 Hz, 1H; H-5), 3.93 (apt t, ^3J (H,H) = 8.5 Hz, 1H; H-2'), 3.89 – 3.79 (m, 3H; H-3', H-4', H-5', overlapping peaks), 3.75 (s, 3H; OCH_3), 1.06-0.68 (m, 28H; 4 x CH(CH_3)$_2$, overlapping peaks); ^{13}C-NMR (126 MHz, $CDCl_3$): δ 168.1 (CO_2CH_3), 166.1, 165.8, 165.1 (2s) (4 x *C*OPh), 133.4, 133.2 (2s), 133.1, 129.9, 129.8, 129.7 (12 x Ar-CH, overlapping peaks), 129.6, 129.2, 128.8, 128.0 (4 x Ar-

C), 128.4 (2s), 128.3, 128.2 (8 x Ar-CH, overlapping peaks), 100.0 (C-1), 88.4 (C-1'), 79.7 (C-3'), 77.2 (C-5'), 76.4 (C-2'), 74.0 (C-4'), 73.1 (C-3), 72.5 (C-2), 72.3 (C-5), 69.6 (C-4), 62.9 (C-6), 52.4 (CO_2CH_3), 17.5, 17.4, 17.2 (2s), 17.1, 17.0 (2s) (8 x $CH(CH_3)_2$, overlapping peaks), 12.8, 12.7, 12.3, 12.2 (4 x $CH(CH_3)_2$, overlapping peaks); IR (film) cm^{-1}: 2946, 2119, 1728, 1452, 1249, 1089, 986. ESI-HRMS calcd for $C_{53}H_{63}N_3O_{16}Si_2Na$ 1076.3645, found *m/z* 1076.3652 $[M+Na]^+$.



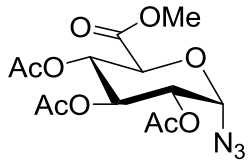
Methyl 1-azido-1-deoxy-2-*O*-(2,3,4,6-tetra-*O*-benzoyl-β-D-glucopyranosyl)-3,4-di-*O*-benzoyl-β-D-glucopyranosuronate (45)

Disaccharide **44** (0.2 g, 0.19 mmol) was added to 1.25 M HCl in methanol (10 mL) at 0 °C and the resulting solution was allowed to attain room temp and stirred for 16 h. The mixture was cooled using an ice bath, diluted with MeOH (20 mL) and $NaHCO_3$ was then added. The resulting slurry was concentrated to dryness and the residue suspended in pyridine and cooled using an ice bath. Benzoyl chloride (0.13 mL, 1.1 mmol) was then added and the mixture allowed to warm to room temp and was stirred for a further 16 h. Methanol (0.5 mL) was added and the mixture diluted with EtOAc (10 mL). This was washed with 1M HCl (2 x 5 mL), satd aq $NaHCO_3$ (10 mL), brine (10 mL), and then dried over Na_2SO_4, filtered and the solvent was removed under diminished pressure. Flash chromatography of the residue (petroleum ether-EtOAc, 6:4) gave **45** (0.12 g, 63%) as a glassy solid; $[\alpha]_D$ -12.2 (c 0.35, CH_2Cl_2); ^{1}H NMR (500 MHz, $CDCl_3$): δ 8.11 (dd, *J* = 8.3, 1.5 Hz, 2H; Ar-H), 8.06 (dd, *J* = 8.4, 1.4 Hz, 2H; Ar-H), 7.86 (dd, *J* = 8.4, 1.4 Hz, 2H; Ar-H), 7.78 (dd, *J* = 8.3, 1.4 Hz, 2H; Ar-H), 7.71 (dd, ^3J (H,H) = 8.4, 1.4 Hz, 2H; Ar-H), 7.65 (dd, ^3J (H,H) = 8.3, 1.4 Hz, 2H; Ar-H), 7.60 (dd, ^3J (H,H) = 8.2, 1.4 Hz, 2H; Ar-H), 7.58 – 7.41 (m, 6H; Ar-H), 7.40 – 7.36 (m, 1H; Ar-H), 7.35 – 7.28 (m, 5H; Ar-H), 7.21 (td, ^3J (H,H) = 7.9, 6.4 Hz, 4H; Ar-H), 5.76 – 5.64 (m, 3H; H-3, H-3', H-4, overlapping peaks), 5.55–5.48 (m, 2H; H-4', H-2', overlapping peaks), 5.07 (d, ^3J (H,H) = 7.8 Hz, 1H; H-1'), 4.90 (d, ^3J (H,H) = 7.7 Hz, 1H; H-1), 4.71 (dd, ^2J (H,H) = -12.2 Hz, ^3J (H,H) 3.1Hz, 1H; H-6a), 4.54 (dd, ^2J (H,H) = -12.2 Hz, ^3J (H,H) 4.6Hz, 1H; H-

6b), 4.26 (d, ^3J (H,H) = 9.2 Hz, 1H; H-5'), 4.16 (ddd, ^3J (H,H) = 9.5, 4.6, 3.1 Hz, 1H; H-5), 4.10 (apt t, ^3J (H,H) = 8.2 Hz, 1H; H-2), 3.66 (s, 3H; OCH_3); ^{13}C NMR (126 MHz, $CDCl_3$): δ 166.9 (CO_2CH_3), 166.1, 165.7, 165.0, 165.0, 164.8 (6 x COPh, overlapping peaks), 133.7, 133.4 (2s), 133.2 (2s), 132.9 , 130.2, 129.8, 129.7 (2s), 129.6 (18 x Ar-CH, overlapping peaks), 129.5, 129.2, 128.9, 128.8 128.7, 128.6 (6 x Ar-C, overlapping peaks) 128.5 (2s), 128.4 (2s) 128.2, 128.1 (12 x Ar-CH, overlapping peaks), 100.9 (C-1'), 88.8 (C-1), 77.1 (C-2), 74.7 (C-5'), 73.6 (C-3), 72.8 (C-3'), 72.3 (C-5), 71.9 (C-2'), 69.6 (C-4), 69.3 (C-4'), 62.7 (C-6), 52.9 (CO_2CH_3); IR (film) cm^{-1}: 2953, 2120, 1726, 1684, 1452, 1248, 1091, 1067, 1026; ESI-HRMS calcd for $C_{55}H_{45}O_{17}N_3Na$ 1042.2647, found *m/z* 1042.2671 $[M+Na]^+$.

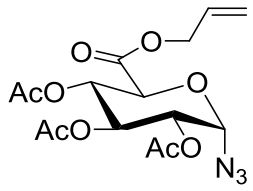
General procedure for the anomerisation reactions using $TiCl_4$:

The β-anomer (1 eq) was added to a flame dried round bottomed flask and anhydrous CH_2Cl_2 (10 mL per g of substrate) was added. The flask was then cooled on an ice bath and 2.5 eq $TiCl_4$ (1.0 M in CH_2Cl_2) was added dropwise. The flask was then left to stand in a freezer (-15 to -18 °C) for 48-72 h. The mixture was diluted with CH_2Cl_2 and washed with NH_4Cl (1.0 M, 10 mL). The aq layer was extracted with CH_2Cl_2 and the combined organic layers were washed with satd aq $NaHCO_3$ and brine. The organic layer was dried over Na_2SO_4, filtered through silica gel and the solvent removed to give the products.



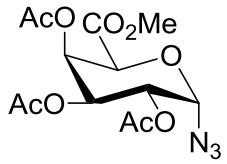
Methyl 2,3,4-tri-*O*-acetyl-α-D-glucopyranosyluronate azide (4)

$[\alpha]_D$ -129.0 (*c* 1.15, CH_2Cl_2); ^{1}H NMR (500 MHz, $CDCl_3$) δ 5.67 (d, ^3J (H,H) = 4.2, 1H; H-1), 5.42 (apt. t, ^3J (H,H) = 9.6, 1H; H-3), 5.15 (apt. t, ^3J (H,H) = 9.6, 1H; H-4), 4.96 (dd, ^3J (H,H) = 9.9, 4.2, 1H; H-2), 4.48 (d, ^3J (H,H) = 9.9, 1H; H-5), 3.76 (s, 3H, CO_2CH_3), 2.10 (s, 3H; $COCH_3$), 2.04 (s, 3H; $COCH_3$), 2.03 (s, 3H; $COCH_3$); ^{13}C NMR (126 MHz, $CDCl_3$) δ 169.8, 169.6, 169.4 (3 x $COCH_3$), 167.4 (CO_2CH_3), 86.1 (C-1), 69.9 (C-3), 69.7 (C-4), 69.0 (C-2), 68.6 (C-5), 53.0 (CO_2CH_3), 20.6, 20.5, 20.5 (3 x $COCH_3$); IR (film) cm^{-1}: 2956, 2120, 1728, 1687, 1452, 1246, 1091, 1067, 1026; ES-HRMS calcd for $C_{13}H_{17}O_9N_3Na$ 382.0862, found m/z 382.0867 $[M+Na]^+$.



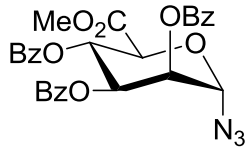
Allyl 2,3,4-tri-*O*-acetyl-1-azido-1-deoxy-α-D-glucopyranuronate (7)

$[\alpha]_D$ 127.8 (*c* 1.2, CH_2Cl_2); ^{1}H-NMR (500 MHz, $CDCl_3$) δ 5.90 (ddt, ^3J (H,H) = 17.0, 10.4, 6.0 Hz, 1H; -CH_2CHCH_2), 5.68 (d, ^3J (H,H) = 4.2 Hz, 1H; H-1), 5.42 (apt t, ^3J (H,H) = 9.6 Hz, 1H; H-3), 5.36 (dd, ^3J (H,H) = 17.0 Hz, ^2J (H,H) = -1.4 Hz, 1H; -$CH_2CH{=}CH_2$), 5.30 (dd, ^3J (H,H) = 10.4 Hz, ^2J (H,H) = -1.4 Hz 1H; -CH_2CHCH_2), 5.16 (apt t, ^3J (H,H) = 9.6 Hz, 1H; H-4), 4.96 (dd, ^3J (H,H) = 10.2, 4.2 Hz, 1H; H-2), 4.70–4.56 (m, 2H; -CH_2CHCH_2), 4.50 (d, ^3J (H,H) = 9.9 Hz, 1H; H-5), 2.10 (s, 3H; $COCH_3$), 2.02 (s, 3H; $COCH_3$), 2.01 (s, 3H; $COCH_3$); ^{13}C NMR (126 MHz, $CDCl_3$) δ 169.9, 169.8, 169.6 (3 x $COCH_3$), 166.8 ($CO_2CH_2CHCH_2$), 131.1 (-CH_2CHCH_2), 119.9 (-CH_2CHCH_2), 86.3 (C-1), 70.1 (C-5), 69.8 (C-2), 69.1 (C-4), 68.9 (C-3), 67.0 (-CH_2CHCH_2), 20.8, 20.7, 20.7 (3 x $COCH_3$); IR (film) cm^{-1}: 2955, 2113, 1721, 1451, 1247, 1093, 1069, 1026. ESI-HRMS calcd for $C_{15}H_{19}O_9N_3Na$ 408.1019, found *m/z* 408.1031 $[M+Na]^+$.



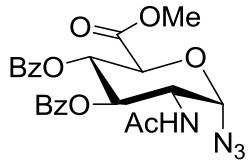
Methyl 2,3,4-tri-*O*-acetyl-1-azido-1-deoxy-α-D-galactopyranuronate (12)

[α]D 178.3 (c 3.3, CH_2Cl_2); ^{1}H NMR (500 MHz, $CDCl_3$) δ 5.77 (d, ^3J (H,H) = 3.8 Hz, 1H; H-1), 5.76 (dd, ^3J (H,H) = 3.1, 1.6 Hz, 1H; H-4), 5.40 – 5.13 (m, 2H; H-2, H-3, overlapping peaks), 4.77 (d, ^3J (H,H) = 1.6 Hz, 1H; H-5), 3.77 (s, 3H; CO_2Me), 2.11 (s, 3H; $COCH_3$), 2.10 (s, 3H; $COCH_3$), 2.00 (s, 3H; $COCH_3$); ^{13}C NMR (126 MHz, $CDCl_3$) δ 170.0, 169.7, 169.6 (3 x $COCH_3$), 166.6 (CO_2CH_3), 87.0 (C-1), 70.1 (C-5), 68.6 (C-4), 66.9, 66.8 (C-2, C-3), 52.8 (CO_2CH_3), 20.6 (2s) 20.5 (3 x $COCH_3$); $[\alpha]_D$ 178.3 (c 3.3, CH_2Cl_2); IR (film) cm^{-1}: 2962, 2114, 1767, 1743, 1368, 1250, 1211, 1173, 1056; ESI-HRMS calcd for $C_{13}H_{17}O_9N_3Na$ 382.0862, found *m/z* 382.0863 $[M+Na]^+$.



Methyl 1-azido-2,3,4-tri-*O*-benzoyl-1-deoxy-α-D-mannopyranuronate (19)

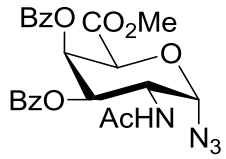
$[\alpha]_D$ - 48.5 (*c* 0.8, CH_2Cl_2); ^{1}H NMR (500 MHz, $CDCl_3$) δ = 8.04 (td, ^3J (H,H) = 8.2, 1.4 Hz, 4H; Ar-H), 7.91 (dd, ^3J (H,H) = 8.3, 1.4 Hz, 2H; Ar-H), 7.62 – 7.56 (m, 2H; Ar-H), 7.53 (ddd, ^3J (H,H) = 7.6, 6.7, 1.4 Hz, 1H; Ar-H), 7.45 (td, ^3J (H,H) = 7.9, 2.4 Hz, 4H; Ar-H), 7.38 (t, ^3J (H,H) = 7.9 Hz, 2H; Ar-H), 5.96 – 5.91 (m, 1H; H-4), 5.89 – 5.84 (m, 2H; H-1, H-3, overlapping peaks), 5.59 (dd, ^3J (H,H) = 4.8, 3.2 Hz, 1H; H-2), 4.84 (d, ^3J (H,H) = 6.6 Hz, 1H; H-5), 3.64 (s, 3H; CO_2CH_3); ^{13}C NMR (126 MHz, $CDCl_3$): δ 167.8 (CO_2CH_3), 165.2, 165.2, 164.9 (3 x *C*OPh), 133.7, 133.7, 133.7, 129.9, 129.9, 129.8 (9 xAr-CH, overlapping peaks), 128.8, 128.7 (2 x Ar-C), 128.6 (2s) (Ar-C, 4 x Ar-CH, overlapping peaks), 128.5 (2 x Ar-CH, overlapping peaks), 86.0 (C-1), 72.1 (C-5), 69.0 (C-2), 68.4 (H-3), 68.1 (C-4), 52.8 (CO_2CH_3; IR (film) cm^{-1}: 2955, 2120, 1726, 1452, 1244, 1091, 1069, 1026; ESI-HRMS calcd for $C_{28}H_{23}O_9N_3Na$ 568.1332, found *m/z* 568.1327 $[M+Na]^+$.



Methyl 2-acetamido-1-azido-3,4-di-*O*-benzoyl-1,2-dideoxy-α-D-glucopyranuronate azide (32)

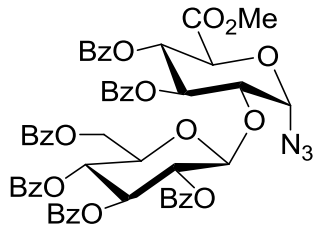
$[\alpha]_D$ 75.6 (*c* 1.7, CH_2Cl_2); ^{1}H NMR (500 MHz, $CDCl_3$): δ = 7.92 (ddd, ^3J (H,H) = 8.5, 5.1, 1.4 Hz, 4H; Ar-H), 7.55 – 7.49 (m, 2H; Ar-H), 7.37 (td, ^3J (H,H) = 7.7, 3.9 Hz, 4H; Ar-H), 6.03 (d, ^3J (H,H) = 8.5 Hz, 1H; N*H*COCH$_3$), 5.74 (d, ^3J (H,H) = 3.9 Hz, 1H; H-1), 5.66 – 5.61 (apt t, ^3J (H,H) = 9.3 Hz, 1H; H-4), 5.60 – 5.55 (apt t, ^3J (H,H) = 10.3 Hz, 1H; H-3), 4.70 (d, ^3J (H,H) = 9.5 Hz, 1H; H-5), 4.60 (ddd, ^3J (H,H) = 10.3, 8.5, 4.1 Hz, 1H; H-2), 3.67 (s, 3H; CO_2CH_3), 1.91 (s, 3H; NHCOCH_3); ^{13}C NMR (126 MHz, $CDCl_3$): δ 170.1 (NH*C*OCH$_3$), 167.4 (CO_2CH_3), 167.0, 165.1 (2 x *C*OPh), 133.8, 133.6, 129.9, 129.7 (6 x Ar-CH, overlapping peaks), 128.7 (Ar-C) 128.5 (2s) (4 x Ar-CH, overlapping peaks) 128.34 (Ar-C), 88.0 (C-1), 70.5 (C-5), 70.0 (C-4), 69.3 (C-2), 53.0 (CO_2CH_3), 51.5 (C-2), 23.0 (NHCOCH_3); IR

(film) cm^{-1}: 2955, 2116, 1726, 1664, 1452, 1248, 1093, 1069, 1026; ESI-HRMS calcd for $C_{23}H_{22}O_8N_4Na$ 505.1335, found *m/z* 505.1339 $[M+Na]^+$.



Methyl 2-acetamido-1-azido-3,4-di-*O*-benzoyl-1,2-dideoxy-α-D-galactopyranuronate (33)

$[\alpha]_D$ 64.1 (*c* 1.15, CH_2Cl_2); ^1H NMR (500 MHz, $CDCl_3$): δ = 8.05 (dd, ^3J (H,H) = 8.3, 1.4 Hz, 2H; Ar-H), 7.84 (dd, ^3J (H,H) = 8.3, 1.3 Hz, 2H; Ar-H), 7.63 – 7.58 (m, 1H; Ar-H), 7.55 – 7.50 (m, 1H; Ar-H), 7.49 – 7.45 (m, 2H ,Ar-H), 7.34 (t, ^3J (H,H) = 7.8 Hz, 2H; Ar-H), 6.11 (dd, ^3J (H,H) = 3.4, 1.5 Hz, 1H; H-4), 5.84 (d, ^3J (H,H) = 4.0 Hz, 1H; H-1), 5.73 (d, ^3J (H,H) = 8.7 Hz, 1H; N*H*$COCH_3$), 5.48 (dd, ^3J (H,H) = 11.3, 3.4 Hz, 1H; H-3), 4.94 (d, ^3J (H,H) = 1.5 Hz, 1H; H-5), 4.89 (ddd, ^3J (H,H) = 11.3, 8.7, 4.1 Hz, 1H; H-2), 3.72 (s, 3H; CO_2CH_3), 1.92 (s, 3H; NHCOCH_3); ^{13}C NMR (126 MHz, $CDCl_3$) δ 170.2 (NH*C*OCH_3), 166.7 (*C*O_2CH_3), 166.5, 165.2 (2 x *C*OPh), 133.7 (2s), 130.0, 129.9 (6 x Ar-CH, overlapping peaks), 128.8 (Ar-C), 128.6 (2s) (2 x Ar-CH, Ar-C,overlapping peaks), 128.5 (Ar-C, overlapping peaks), 88.9 (C-1), 70.6 (C-5), 68.7 (C-4), 68.1 (C-3), 52.9 (CO_2CH_3), 47.7 (C-2), 23.2 (NHCOCH_3); IR (film) cm^{-1}: 2923, 2123, 1755, 1451, 1247, 1093, 1024; ESI-HRMS calcd for $C_{23}H_{22}O_8N_4Na$ 505.1335, found *m/z* 505.1346 $[M+Na]^+$.

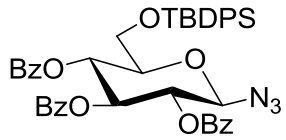


Methyl 1-azido-1-deoxy-2-*O*-(2,3,4,6-tetra-*O*-benzoyl-β-D-glucopyranosyl)-3,4-di-*O*-benzoyl-α-D-glucopyranuronate (46)

$[\alpha]_D$ 6.1 (*c* 0.6, CH_2Cl_2); ^1H NMR (500 MHz, $CDCl_3$): δ = 8.09 (dt, ^3J (H,H) = 7.0, 1.4 Hz, 2H; Ar-H), 7.90 (dd, ^3J (H,H) = 8.3, 1.4 Hz, 2H; Ar-H), 7.83 (dd, ^3J (H,H) = 8.4, 1.4 Hz, 2H; Ar-H), 7.73 (dd, ^3J (H,H) = 8.4, 1.4 Hz, 2H; Ar-H), 7.60 (t, ^3J (H,H) = 7.5 Hz, 1H; Ar-H), 7.55 (dd, ^3J (H,H) = 8.3, 1.5 Hz, 2H; Ar-H), 7.49 (qd, ^3J (H,H) = 8.7, 7.4 Hz, 4H; Ar-H), 7.42 (dd, ^3J (H,H) = 8.4, 1.4 Hz, 2H; Ar-H), 7.41 – 7.28

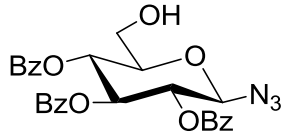
(m, 7H; Ar-H), 7.22 (t, ^{3}J (H,H) = 7.9 Hz, 2H; Ar-H), 7.12 (t, ^{3}J (H,H) = 7.8 Hz, 2H; Ar-H), 7.05 (t, ^{3}J (H,H) = 7.8 Hz, 2H; Ar-H), 5.93 (d, ^{3}J (H,H) = 4.1 Hz, 1H; H-1'), 5.87 – 5.78 (m, 2H; H-2', H-3, overlapping peaks), 5.68 (apt t, ^{3}J (H,H) = 9.7 Hz, 1H; H-3'), 5.52 (dd, ^{3}J (H,H) = 9.9, 7.8 Hz, 1H; H-2), 5.41 (apt t, ^{3}J (H,H) = 9.9 Hz, 1H; H-4'), 5.00 (d, ^{3}J (H,H) = 7.9 Hz, 1H; H-1), 4.82 (dd, ^{2}J (H,H) = -12.3 Hz, ^{3}J (H,H) = 2.8 Hz, 1H; H-6a), 4.60 (d, ^{3}J (H,H) J = 10.1 Hz, 1H; H-5'), 4.41 (dd, ^{2}J (H,H) J = -12.3 Hz, ^{3}J (H,H) = 4.8 Hz, 1H; H-6b), 4.21 – 4.12 (m, 2H; H-4, H-5, overlapping peaks), 3.63 (s, 3H; CO_2CH_3); ^{13}C NMR (126 MHz, $CDCl_3$): δ 167.9 (CO_2CH_3), 166.2, 165.8, 165.4, 165.2, 164.8, 164.7 (6 x *C*OPh, overlapping peaks), 133.7, 133.5, 133.4, 133.0, 132.8, 130.0 (2s), 129.9, 129.8, 129.6 (18 x Ar-CH, overlapping peaks), 129.5 (2s) (2 x Ar-CH, Ar-C, overlapping peaks), 128.8 (2s) (2 x Ar-c), 128.7 (4s) (2 x Ar-CH, 3 x Ar-C, overlapping peaks), 128.6, 128.5, 128.4, 128.3, 128.2 (10 x Ar-CH, overlapping peaks), 102.4 (C-1), 88.6 (C-1'), 78.3 (C-5), 72.9 (C-4), 72.6 (C-3), 71.7 (C-2), 70.2 (C-4'), 70.1 (C-2'), 70.0 (C-5'), 69.2 (C-3'), 62.3 (C-6'), 53.0 (CO_2CH_3); IR (film) cm^{-1}: 2925, 2124, 1725, 1452, 1258, 1089, 1067, 1025; ESI-HRMS calcd for $C_{55}H_{45}O_{17}N_3Na$ 1042.2647, found *m/z* 1042.2658 $[M+Na]^+$.

Chapter 3 experimental procedures:



6-*O*-*tert*-Butyldiphenylsilyl-2,3,4-tri-*O*-benzoyl-β-D-mannopyranosyl azide (47)

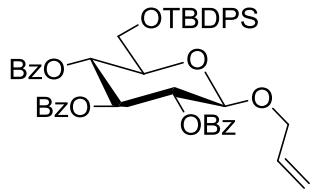
Azide **36** (1 g, 4.87 mmol) was reacted with TBDPSCl (1.5 mL, 5.85 mmol) in pyridine and then benzoyl chloride (3.73 mL, 32.14 mmol) as described above to give the silylated intermediate (1.99 g, 54%) as a foam; $[\alpha]_D$ -25.9 (*c* 0.41, CH_2Cl_2); ^{1}H NMR (500 MHz, $CDCl_3$): δ 7.99 – 7.94 (m, 2H; Ar-H), 7.91 – 7.86 (m, 2H; Ar-H), 7.86 – 7.81 (m, 2H; Ar-H), 7.74 – 7.69 (m, 2H; Ar-H), 7.61 – 7.56 (m, 2H; Ar-H), 7.56 – 7.50 (m, 2H; Ar-H), 7.45 – 7.34 (m, 7H; Ar-H), 7.34 – 7.27 (m, 3H; Ar-H), 7.23 – 7.18 (m, 2H; Ar-H), 5.86 (apt t, ^3J (H,H) = 9.7 Hz, 1H; H-3), 5.75 (apt t, ^3J (H,H) = 9.7 Hz, 1H; H-4), 5.47 (dd, ^3J (H,H) = 9.7, 8.8 Hz, 1H; H-2), 4.87 (d, ^3J (H,H) = 8.8 Hz, 1H; H-1), 3.96 – 3.84 (m, 3H; H-6a, H-6b, H-5, overlapping peaks), 1.06 (s, 9H; C(CH_3)$_3$); ^{13}C NMR (126 MHz, $CDCl_3$): δ 165.8, 165.1, 164.8 (3 x *C*OPh), 135.6, 135.5, 133.4, 133.3, 133.2 (7 x Ar-CH, overlapping peaks), 132.9, 132.8 (2 x Ar-C), 129.9, 129.8, 129.8, 129.7, 129.6 (8 x Ar-CH, overlapping peaks), 129.0, 128.8, 128.7 (3 x Ar-C), 128.4, 128.4, 128.3, 127.7, 127.6 (10 x Ar-CH, overlapping peaks), 88.1 (C-1), 77.3 (C-5), 73.1 (C-3), 71.5 (C-2), 68.5 (C-4), 62.3 (C-6), 26.6 (C(CH_3)$_3$), 19.2 (*C*(CH_3)$_3$); IR (film) cm^{-1}:3071, 2858, 2116, 1731, 1451, 1245, 1088, 1068; ESI-HRMS calcd for $C_{43}H_{42}N_3O_8Si$ 756.2736, found *m/z* 756.2742 $[M+H]^+$.



2,3,4-Tri-*O*-benzoyl-β-D-glucopyranosyl azide (48)

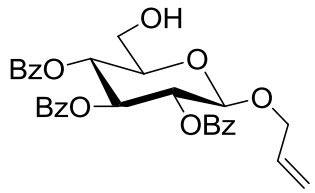
Compound **47** (1.89 g, 2.50 mmol) was taken up in THF (50 mL) was cooled over ice and AcOH (0.29 mL, 5.03 mmol) and 1.0 M TBAF in THF (5.03 mL, 5.03 mmol) added and the mixture stirred for 16 h. The product was adsorbed onto silica gel and flash chromatography (petroleum ether-EtOAc 3:2) gave 29 (1.02 g, 79%) as

a white solid; $[\alpha]_D$ +88.1 (*c* 0.2, CH_2Cl_2); ^{1}H NMR (500 MHz, $CDCl_3$) δ = 7.95 (td, ^3J (H,H) = 8.2, 1.4 Hz, 4H; Ar-H), 7.83 (dd, ^3J (H,H) = 8.3, 1.4 Hz, 2H; Ar-H), 7.54 (tdd, ^3J (H,H) = 6.7, 4.8, 1.3 Hz, 2H; Ar-H), 7.45 – 7.35 (m, 5H; Ar-H), 7.28 (t, ^3J (H,H) = 7.8 Hz, 2H; Ar-H), 5.96 (apt t, ^3J (H,H) = 9.8 Hz, 1H; H-3), 5.54 (apt t, ^3J (H,H) = 9.8 Hz, 1H; H-4), 5.47 (dd, ^3J (H,H) = 9.8, 8.8 Hz, 1H; H-2), 4.96 (d, ^3J (H,H) = 8.8 Hz, 1H; H-1), 3.96 – 3.86 (m, 2H; H-5, H-6a, overlapping peaks), 3.77 (dt, ^2J (H,H) = -13.2 Hz, ^3J (H,H) = 4.8 Hz, 1H; H-6b), 2.60 (dd, ^3J (H,H) = 8.8, 5.6 Hz, 1H; OH); ^{13}C NMR (126 MHz, $CDCl_3$): δ 166.0, 165.7, 165.0 (3 x *C*OPh), 133.8, 133.5, 133.4, 130.0, 129.9, 129.7 (9 x Ar-CH, overlapping peaks), 128.7, 128.6 (2 x Ar-C), 128.5, 128.4 (4 x Ar-CH, overlapping peaks), 128.3 (2s) (Ar-C, 2 x Ar-CH, overlapping peaks), 88.4 (C-1), 77.0 (C-5), 72.6 (C-3), 71.2 (C-2), 69.0 (C-4), 61.1 (C-6); IR (film) cm^{-1}: 3491, 2122, 1723, 1450, 1244, 1088; ESI-HRMS calcd for $C_{27}H_{27}NO_8Na$ 399.0903, found *m/z* 399.0887 $[M+Na]^+$.



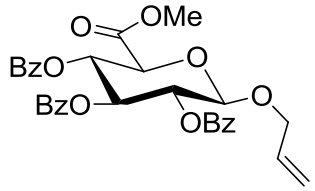
Allyl 6-*O*-*tert*-butyldiphenylsilyl-2,3,4-tri-*O*-benzoyl-β-D-glucopyranoside (49) Intermediate **41** (10 g, 45.4 mmol) was reacted with pyridine (100 mL), TBDPSCl (14.1 mL, 54.5 mmol) and benzoyl chloride (34.82 mL, 299.7 mmol) as described previously to give **49** (27.3 g, 78%) as a foam; $[\alpha]_D$ -21.1 (*c* 0.1, CH_2Cl_2); ^{1}H NMR (500 MHz, $CDCl_3$) δ 7.99 – 7.94 (m, 1H), 7.88 – 7.81 (m, 2H; Ar-H), 7.71 – 7.67 (m, 4H; Ar-H), 7.62 – 7.58 (m, 2H; Ar-H), 7.54 – 7.48 (m, 2H; Ar-H), 7.44 – 7.27 (m, 9H; Ar-H), 7.25 – 7.21 (m, 2H; Ar-H), 5.88 – 5.78 (m, 2H; CH_2*CH*CH_2, C-3, overlapping peaks), 5.62 (apt t, ^3J (H,H) = 9.2 Hz, 1H; H-4), 5.53 (dd, ^3J (H,H) = 9.7, 7.9 Hz, 1H; H-2), 5.25 (dq, ^3J (H,H) = 17.3 Hz, ^2J (H,H) -1.7 Hz, 1H; CH_2CH*C*H_2), 5.15 (dq, ^3J (H,H) = 10.5 Hz, ^2J (H,H) 1.4 Hz, 1H; CH_2CH=*C*H_2), 4.85 (d, ^3J (H,H) = 7.9 Hz, 1H; H-1), 4.38 (ddt, ^2J (H,H) = -13.3 Hz, ^3J (H,H) = 4.8, 1.7 Hz, 1H; *C*H_2CH=CH_2), 4.17 (ddt, ^2J (H,H) = -13.3 Hz, ^3J (H,H) = 6.3, 1.4 Hz, 1H; *C*H_2CH=CH_2), 3.90 – 3.82 (m, 2H; H-5, H-6a, H-6b, overlapping peaks), 1.04 (s, 9H; C(*C*H_3)$_3$); ^{13}C NMR (126 MHz, $CDCl_3$) δ 165.9, 165.0 (3 x *C*OPh, overlapping peaks), 135.6, 135.5 (4 x Ar-CH, overlapping peaks), 133.6 (CH_2*C*H=CH_2), 133.2 (2 x Ar-CH), 133.1 (2s) (Ar-C, 2 x Ar-CH, overlapping peaks), 133.0 (Ar-C), 129.8

(2s), 129.7, 129.6 (2s) (6 x Ar-CH, overlapping peaks), 129.5, 129.2, 129.0 (3 x Ar-C),128.3 (2s), 128.2, 127.6 (2s) (11 x Ar-CH, overlapping peaks), 117.6 ($CH_2CH\mathit{CH_2}$), 99.7 (C-1), 75.2 (C-5), 73.4 (C-3), 72.0 (C-2), 69.6 ($\mathit{CH_2}CH=CH_2$), 69.3 (C-4), 62.8 (C-6), 26.6 ($C(\mathit{CH_3})_3$, overlapping peaks), 19.2 ($\mathit{C}(CH_3)_3$); IR (film) cm^{-1}: 3071, 2857, 1729, 1451, 1259, 1091, 1026; ESI-HRMS calcd for $C_{46}H_{46}O_9SiNa$ 793.2809, found *m/z* 793.2798 $[M+Na]^+$.

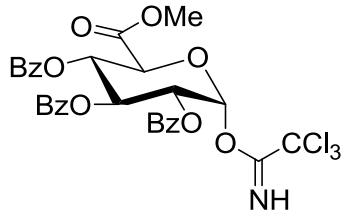


Allyl 2,3,4-tri-*O*-benzoyl-β-D-glucopyranoside (50)

The TBDPS derivative **49** (27.0 g, 35.0 mmol) was dissolved in THF (250 mL) and the resulting solution was cooled using an ice bath. To this AcOH (4 mL, 70.0 mmol) and 1M TBAF in THF (70 mL, 70.0mmol) were added. The mixture was allowed to attain room temp and was stirred for 16 h and the product adsorbed on silica gel. Flash chromatography (petroleum ether-EtOAc 3:2) gave the intermediate alcohol (14.4 g, 77%) as a white solid; $[\alpha]_D$ -23.0 (*c* 0.2, CH_2Cl_2); ^{1}H NMR (500 MHz, $CDCl_3$) δ 7.95 (apt tt, ^3J (H,H) = 7.3, 1.4 Hz, 4H; Ar-H), 7.89 – 7.81 (m, 2H; Ar-H), 7.59 – 7.47 (m, 2H; Ar-H), 7.46 – 7.35 (m, 5H; Ar-H), 7.31 – 7.26 (m, 2H; Ar-H), 5.93 (apt t, ^3J (H,H) = 9.7 Hz, 1H; H-3), 5.81 (dddd, ^3J (H,H) = 17.0, 10.7, 6.1, 5.0 Hz, 1H; $CH_2\mathit{CH}CH_2$), 5.60 – 5.39 (m, 2H; H-2, H-4, overlapping peaks), 5.26 (dq, ^3J (H,H) = 17.0 Hz, ^2J (H,H) = -1.4 Hz, 1H; $CH_2CH\mathit{CH_2}$), 5.15 (dq, ^3J (H,H) = 10.7 Hz, ^2J (H,H) = -1.4 Hz, 1H; $CH_2CH\mathit{CH_2}$), 4.89 (d, ^3J (H,H) = 7.9 Hz, 1H; H-1), 4.39 (ddt, ^2J (H,H) = -13.3 Hz, ^3J (H,H) = 5.0, 1.6 Hz, 1H; $\mathit{CH_2}CHCH_2$), 4.19 (ddt, ^2J (H,H) = -13.3 Hz, ^3J (H,H) = 6.1, 1.4 Hz, 1H; $\mathit{CH_2}CHCH_2$), 3.86 (ddd, ^2J (H,H) = -12.4 Hz, ^3J (H,H) = 8.8, 1.9 Hz, 1H; H-6a), 3.83 – 3.68 (m, 2H; H-6b, H-5), 2.55 (dd, ^3J (H,H) = 8.8, 5.3 Hz, 1H; OH); ^{13}C NMR (126 MHz, $CDCl_3$) δ 166.0, 165.8, 165.0 (3 x *C*OPh), 133.7 (Ar-CH, overlapping peaks), 133.4 ($CH_2\mathit{CH}CH_2$), 133.2 (2s) (2 x Ar-CH), 129.9, 129.8, 129.7 (6 x Ar-CH, overlapping peaks), 129.3, 128.8, 128.6 (3 x Ar-C), 128.5, 128.3 (2s) (6 x Ar-CH), 117.7 ($CH_2CH\mathit{CH_2}$), 100.0 (C-1), 74.6 (C-5), 72.8 (C-3), 71.8 (C-4), 70.2 ($\mathit{CH_2}CHCH_2$), 69.6 (C-2), 61.4 (C-6); IR (film) cm^{-1}: 3380, 2955, 1722, 1451, 1252, 1066, 1026; ESI-HRMS calcd for $C_{30}H_{28}O_9Na$ 555.1631, found *m/z* 555.1637 $[M+Na]^+$.

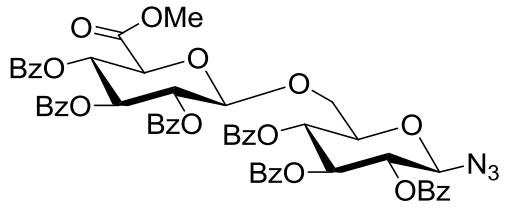


1-*O*-Allyl-2,3,4-tri-*O*-benzoyl-β-D-glucopyranosiduronic acid, methyl ester (51) Intermediate **50** (14 g, 26.3 mmol) in MeCN-H_2O (100 mL, 3:1) was oxidised, using BAIB (21.17 g ,65.7 mmol) and TEMPO (0.4 g, 2.6 mmol), and the resulting acid was esterified in DMF (80 mL) using $NaHCO_3$ (3.3 g, 39.5 mmol) and methyl iodide (2.5 mL, 39.5 mmol) as described above to give **51** (8.7 g, 59%) as a foam; $[\alpha]_D$ -40.0 (*c* 0.07, CH_2Cl_2); ^{1}H NMR (500 MHz, $CDCl_3$): δ 7.98 – 7.92 (m, 4H; Ar-H), 7.90 – 7.83 (m, 2H; Ar-H), 7.52 (dddd, ^3J (H,H) = 7.6, 4.9, 2.4, 1.3 Hz, 2H; Ar-H), 7.47 – 7.43 (m, 1H; Ar-H), 7.38 (dddd, ^3J (H,H) = 8.2, 6.2, 3.5, 1.7 Hz, 4H; Ar-H), 7.33 – 7.28 (m, 2H; Ar-H), 5.90 (apt t, ^3J (H,H) = 9.3 Hz, 1H; H-3), 5.80 (dddd, ^3J (H,H) = 17.0, 10.5, 6.4, 4.7 Hz, 1H; CH_2CHCH_2), 5.71 (apt t, ^3J (H,H) = 9.4 Hz, 1H; H-4), 5.57 (dd, ^3J (H,H) = 9.3, 7.3 Hz, 1H; H-2), 5.26 (dq, ^3J (H,H) = 17.0 Hz, ^2J (H,H) = -1.6 Hz, 1H; CH_2CHCH_2), 5.16 (dq, ^3J (H,H) = 10.5 Hz, ^3J (H,H) = 1.4 Hz, 1H; CH_2CHCH_2), 4.92 (d, ^3J (H,H) = 7.3 Hz, 1H; H-1), 4.42 (ddt, ^2J (H,H) = -13.2 Hz , ^3J (H,H) = 4.8, 1.6 Hz, 1H; $CH_2CH=CH_2$), 4.35 (d, ^3J (H,H) = 9.4 Hz, 1H), 4.17 (ddt, ^2J (H,H) = -13.2 Hz, ^3J (H,H) = 6.4, 1.4 Hz, 1H; $CH_2CH=CH_2$), 3.70 (s, 3H; CO_2CH_3); ^{13}C NMR (126 MHz, $CDCl_3$): δ 167.4 (CO_2CH_3), 165.6, 165.2, 165.0 (3 x *C*OPh), 133.4, 133.3, 133.2 (3 x Ar-CH), 133.1 ($CH_2CH=CH_2$), 129.8 (3s) (6 x Ar-CH, overlapping peaks), 129.2, 128.7, 128.5 (3 x Ar-C), 128.4 (2s), 128.3 (6 x Ar-CH, overlapping peaks), 118.0 ($CH_2CH=CH_2$), 99.6 (C-1), 72.9 (C-5), 72.0 (C-3), 71.5 (C-2), 70.2 (CH_2CHCH_2), 70.1 (C-4), 52.9 (CO_2CH_3); IR (film) cm^{-1}: 3068, 1761, 1726, 1451, 1250, 1088; ESI-HRMS calcd for $C_{31}H_{32}NO_{10}$ 578.2026, found *m/z* 578.2031 $[M+NH_4]^+$.



2,3,4-Tri-*O*-benzoyl-1-deoxy-1-(2,2,2-trichloro-1-iminoethoxy)-D-glucopyranuronate, methyl ester (52) [93]

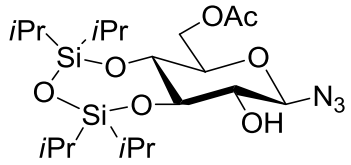
The allyl glycoside **51**(8.5 g, 15.1 mmol) was dissolved in MeOH-CH_2Cl_2 (60 mL, 3:1) and $PdCl_2$ (0.54 g, 3.0 mmol) was added and the mixture was stirred for 16 h at room temp. The resulting suspension was filtered through celite and the solvent was removed to give a foam. Flash chromatography (petroleum ether-EtOAc 6:4) gave the hemiacetal (5.6 g, 10.8 mmol). This intermediate was dissolved in CH_2Cl_2 (50 mL) and cooled on an ice bath and trichloroacetonitrile (10.8 mL, 107.6 mmol) and DBU (0.5 mL) were added. The mixture was stirred for 5 h and was directly subjected to flash chromatography (petroleum ether-EtOAc 7:3, 0.1% Et_3N) to give **52** (6.95 g, 69%) as a white foam; $[\alpha]_D$ +44.4 (*c* 0.18, CH_2Cl_2); ^{1}H NMR (500 MHz, $CDCl_3$): δ 8.68 (s, 1H; N*H*), 8.00 – 7.93 (m, 4H; Ar-H), 7.92 – 7.85 (m, 2H; Ar-H), 7.58 – 7.49 (m, 2H; Ar-H), 7.46 (ddt, ^3J (H,H) = 8.7, 7.2, 1.3 Hz, 1H; Ar-H), 7.42 – 7.30 (m, 5H; Ar-H), 6.91 (d, ^3J (H,H) = 3.6 Hz, 1H; H-1), 6.29 (apt t, ^3J (H,H) = 9.9 Hz, 1H; H-3), 5.76 (apt t, ^3J (H,H) = 9.9 Hz, 1H; H-4), 5.63 (dd, ^3J (H,H) = 10.1, 3.6 Hz, 1H; H-2), 4.77 (d, ^3J (H,H) = 10.5 Hz, 1H; H-5), 3.69 (s, 3H; CO_2CH_3); ^{13}C NMR (126 MHz, $CDCl_3$): δ 167.2 (CO_2CH_3), 165.5, 165.2 (3 x *C*OPh, overlapping peaks), 160.3 (O*C*(NH)CCl_3), 133.6 (2s), 133.4, 129.9 (2s), 129.7 (9 x Ar-CH, overlapping peaks), 128.7, 128.6 (2 x Ar-C), 128.5 (2 x Ar-CH, overlapping peaks), 128.4 (2s) (4 x Ar-CH, Ar-C, overlapping peaks), 92.9 (C-1), 70.9 (C-5), 70.2 (C-2), 69.6 (C-4), 69.3 (C-3), 53.0 (CO_2CH_3); IR (film) cm^{-1}: 3068, 1728, 1451, 1278, 1092, 1025.



2,3,4-Tri-*O*-benzoyl-6-*O*-(2,3,4-tri-*O*-benzoyl-5-*S*-(methoxycarbonyl)-β-D-xylopyranosyl)-β-D-glucopyranosyl azide (53)

The glycosidation of acceptor **48** (0.2 g, 0.39 mmol) and donor **52** (0.43 g, 0.58 mmol) was carried out as previously described to give **53** (0.33 g, 84%) as a white solid; $[\alpha]_D$ -10.1 (*c* 0.75, CH_2Cl_2); ^{1}H NMR (500 MHz, $CDCl_3$): δ = 8.06 – 7.97 (m, 2H), 7.98 – 7.90 (m, 4H), 7.90 – 7.85 (m, 4H), 7.79 – 7.74 (m, 2H), 7.52 (t, ^3J (H,H)

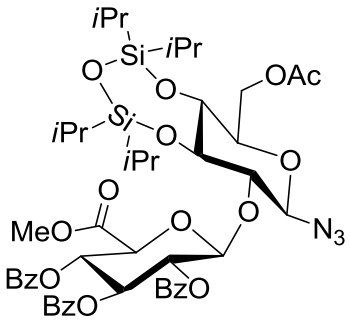
= 7.5 Hz, 4H), 7.48 – 7.34 (m, 10H), 7.31 (t, ^3J (H,H) = 7.7 Hz, 2H), 7.29 – 7.24 (m, 3H), 5.91 (apt t, ^3J (H,H) = 9.2 Hz, 1H; H-3'), 5.79 (apt t, ^3J (H,H) = 9.6 Hz, 1H; H-3), 5.68 (apt t, ^3J (H,H) = 9.3 Hz, 1H; H-4'), 5.54 (dd, ^3J (H,H) = 9.3, 7.1 Hz, 1H; H-2'), 5.38 (apt t, ^3J (H,H) = 9.8 Hz, 1H; H-4), 5.35 (apt t, ^3J (H,H) = 9.3 Hz, 1H; H-2), 5.04 (d, ^3J (H,H) = 7.3 Hz, 1H; H-1), 4.65 (d, ^3J (H,H) = 8.8 Hz, 1H; H-1'), 4.35 (d, ^3J (H,H) = 9.4 Hz, 1H; H-5'), 4.13 (dd, ^2J (H,H) = -12.0 Hz, ^3J (H,H) = 1.9 Hz, 1H; H-6a), 4.06 (ddd, ^3J (H,H) = 9.8, 7.4, 1.9 Hz, 1H; H-5), 3.90 (dd, ^2J (H,H) = -12.0 Hz, ^3J (H,H) = 7.4 Hz, 1H; H-6b), 3.66 (s, 3H; CO_2CH_3); ^{13}C NMR (126 MHz, $CDCl_3$): δ 167.4 (CO_2CH_3), 165.7, 165.7, 165.4, 165.3, 165.2, 165.1 (6 x *C*OPh), 133.8, 133.6, 133.6, 133.5 , 130.0, 130.0, 130.0, 129.9 (18 x Ar-CH, overlapping peaks), 129.3, 128.9, 128.9, 128.9, 128.7 (5 x Ar-C), 128.6, 128.6 (8 x Ar-CH, Ar-C, overlapping peaks), 128.5, 128.4 (4 x Ar-CH, overlapping peaks), 101.6 (C-1), 88.0 (C-1'), 76.6 (C-5), 73.0 (C-5'), 72.8 (C-3), 72.0 (C-3'), 71.6 (C-2'), 71.4 (C-2), 70.1 (C-4'), 69.2 (C-4), 68.8 (C-6), 53.0 (CO_2CH_3); IR (film) cm^{-1}: 2956, 2120, 1727, 1452, 1245, 1087, 1067, 1026; ESI-HRMS calcd for $C_{55}H_{45}O_{17}N_3Na$ 1042.2647, found *m/z* 1042.2656 $[M+Na]^+$.



6-*O*-acetyl-3,4-*O*-(1,1,3,3-tetraisopropyl-1,3-disiloxanediyl)-β-D-glucopyranosyl azide (55)

A solution of **38** (0.75 g, 1.7 mmol) in collidine (5 mL) was cooled to -35 °C. To this was added freshly distilled AcCl (0.13 mL, 1.84 mmol) and the reaction mixture was allowed attain room temp. Methanol was added and the solvent was removed under diminished pressure. Flash chromatography of the residue (petroleum ether-EtOAc 9:1) gave **26** (0.58 g, 70%) as a white solid; $[\alpha]_D$ -23.0 (*c* 0.18, CH_2Cl_2); ^{1}H NMR (500 MHz, $CDCl_3$): δ = 4.56 (d, ^3J (H,H) = 8.7 Hz, 1H; H-1), 4.44 (dd, ^2J (H,H) = 12.0 Hz, ^3J (H,H) = 2.1 Hz, 1H; H-6a), 4.20 (dd, ^2J (H,H) = 12.0 Hz, ^3J (H,H) = 5.2 Hz, 1H; H-6b), 3.74 – 3.67 (m, 1H; H-4), 3.67 – 3.62 (m, 1H; H-3), 3.56 (ddd, ^3J (H,H) = 9.3, 5.3, 2.1 Hz, 1H; H-5), 3.40 (apt t, ^3J (H,H) = 8.7 Hz, 1H; H-2), 2.44 (d, ^3J (H,H) = 2.6 Hz, 1H; OH), 2.09 (s, 3H; $CO\mathit{CH}_3$), 1.12 – 0.93 (m, 28H; 4 x $CH(CH_3)_2$, overlapping peaks); ^{13}C NMR (126 MHz, $CDCl_3$): δ 170.7 ($OCOCH_3$),

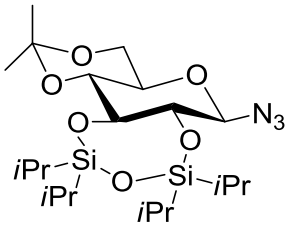
89.6 (C-1), 79.7 (C-3), 76.1 (C-5), 73.7 (C-2), 72.2 (C-4), 62.9 (C-6), 20.9, 17.3 (3s), 17.2 (3s), 17.1 (8 x CH(*CH*$_3$)$_2$, overlapping peaks), 12.8, 12.7, 12.1 (2s) (4 x *CH*(CH$_3$)$_2$, overlapping peaks); IR (film) cm^{-1}: 3504, 2947, 2868, 2114, 1725, 1463, 1250, 1028, 980; ESI-HRMS calcd for $C_{20}H_{39}N_3O_7Si_2Na$ 512.224, found *m/z* 512.2229 $[M+Na]^+$.



2-*O*-(2,3,4-Tri-*O*-benzoyl-5-*S*-(methoxycarbonyl)-β-D-xylopyranosyl)-3,4-*O*-(1,1,3,3-tetraisopropyl-1,3-disiloxanediyl)-6-O-acetyl-β-D-glucopyranosyl azide (56)

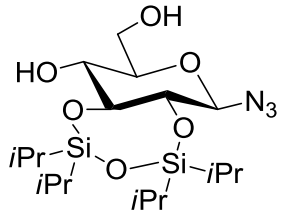
Glycosidation with acceptor **55** (0.5 g, 1.0 mmol) and donor **52** (0.91 g, 1.2 mmol) as described above gave **56** (0.88 g, 89%) as a foam; $[\alpha]_D$ -4.0 (*c* 1.0, $CHCl_3$); ^{1}H NMR (500 MHz, $CDCl_3$): δ = 7.91 (ddt, ^3J (H,H) = 17.1, 7.0, 1.4 Hz, 4H; Ar-H), 7.81 (dd, ^3J (H,H) = 8.4, 1.4 Hz, 2H; Ar-H), 7.54 – 7.48 (m, 2H; Ar-H), 7.44 – 7.33 (m, 5H; Ar-H), 7.28 (d, ^3J (H,H) = 7.8 Hz, 2H; Ar-H), 5.84 (apt t, ^3J (H,H) = 9.2 Hz, 1H; H-3'), 5.78 (apt t, ^3J (H,H) = 9.5 Hz, 1H; H-4'), 5.58 (dd, ^3J (H,H) = 9.0, 7.6 Hz, 1H; H-2'), 5.34 (d, ^3J (H,H) = 7.5 Hz, 1H; H-1'), 4.54 (d, ^3J (H,H) = 8.1 Hz, 1H; H-1), 4.44 (dd, ^2J (H,H) = -12.0 Hz, ^3J (H,H) = 2.2 Hz, 1H; H-6a), 4.33 (d, ^3J (H,H) = 9.6 Hz, 1H; H-5'), 4.14 (dd, ^2J (H,H) = -12.0 Hz, ^3J (H,H) = 5.1 Hz, 1H; H-6b), 3.87 – 3.82 (m, 1H; H-2), 3.79 (apt t, ^3J (H,H) = 8.5 Hz, 1H; H-3), 3.73 (s, 3H; CO_2CH_3), 3.71 – 3.63 (m, 1H; H-4), 3.49 (ddd, ^3J (H,H) = 9.5, 5.1, 2.1 H-z, 1H; H-5), 2.08 (s, 3H; $COCH_3$), 1.08 – 0.72 (m, 28H; 4 x CH(*CH*$_3$)$_2$, overlapping peaks); ^{13}C NMR (126 MHz, $CDCl_3$): δ 170.7 (*C*OCH_3), 167.0 (*C*O_2CH_3), 165.7, 165.0 (2s), (3 x *C*OPh), 133.4, 133.3 (2s)129.9, 129.8, 129.7 (9 x Ar-CH, overlapping peaks), 129.2, 128.8, 128.6 (3 x Ar-C), 128.4, 128.3, 128.2 (6 x Ar-CH, overlapping peaks), 100.2 (C-1'), 88.4 (C-1), 79.8 (C-3), 78.0 (C-2), 75.6 (C-5), 73.1 (C-5'), 72.6 (C-3'), 72.5 (C-4), 72.1 (C-2'), 70.1 (C-4'), 62.8 (C-6), 53.0 (CO_2CH_3), 20.9 ($COCH_3$), 17.5 (2s) 17.4, 17.3, 17.2 (3s)17.1 (8 x CH(*CH*$_3$)$_2$, overlapping peaks), 12.8, 12.7, 12.3 (2s) (4

x *CH*(CH_3)$_2$, overlapping peaks); IR (film) cm^{-1}: 3073, 2952, 2120, 1727, 1686, 1452, 1248, 1091, 1067, 1026; ESI-HRMS calcd for $C_{48}H_{61}O_{16}N_3Si_2Na$ 1014.3488, found *m/z* 1014.3491 $[M+Na]^+$.



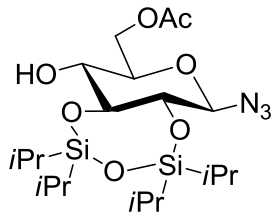
4,6-*O*-isopropylidene-2,3-*O*-(1,1,2,2-tetraisopropyl-1,3-disiloxanediyl)-2-*O*-acetyl-β-D-glucopyranosyl azide (58)

Azide **36** (1.5 g, 7.3 mmol) was dissolved in DMF (15 mL) and 2,2-dimethoxypropane (1.78 mL, 14.6 mmol) and *p*-toluenesulfonic acid (0.14 g, 0.73 mmol) were added and the reaction mixture was stirred at room temp for 3 h. Triethylamine (1 mL) was added and the solvent was removed and the residue dissolved in pyridine (15 mL) and the mixture cooled over ice. 1,3-Dichloro-1,1,3,3-tetraisopropyldisiloxane (2.88 g, 9.13 mmol) was added and the mixture stirred for 16 h at room temp. Methanol (1 mL) was added followed by EtOAc (50 mL) and this layer was washed with 1M HCl (2 x 50 mL), satd aq $NaHCO_3$ (50 mL), brine (50 mL), dried over Na_2SO_4, filtered and the solvent was removed under diminished pressure. Flash chromatography of the residue (petroleum ether-EtOAc 95:5) gave the protected intermediate (2.53 g, 71%) as a clear oil; $[\alpha]_D$ +78.8 (*c* 0.25, CH_2Cl_2); ^{1}H NMR (500 MHz, $CDCl_3$) δ 4.57 (d, ^3J (H,H) = 8.2 Hz, 1H; H-1), 3.95 (dd, ^2J (H,H) = -10.8 Hz, ^3J (H,H) = 5.3 Hz, 1H; H-6a), 3.75 (apt t, ^2J (H,H) = 10.5 Hz, 1H; H-6b), 3.68 (dd, ^3J (H,H) = 8.9, 7.9 Hz, 1H; H-3), 3.55 – 3.49 (m, 2H; H-2, H-4, overlapping peaks), 3.32 (td, ^3J (H,H) = 10.0, 5.3 Hz, 1H; H-5), 1.47 (s, 3H; C(CH_3)$_2$), 1.38 (s, 3H; C(CH_3)$_2$), 1.13–0.99 (m, 28H; 4 x C*H*(CH_3)$_2$, overlapping peaks); ^{13}C NMR (126 MHz, $CDCl_3$) δ 99.5 (*C*(CH_3)$_2$), 91.3 (C-1), 78.1 (C-2), 76.6 (C-3), 72.7 (C-4), 69.5 (C-5), 62.0 (C-6), 28.9, 19.0 (C(*C*H_3)$_2$), 17.3, 17.2, 17.1 (2s), 17.0, 16.8 (8 x CH(CH_3)$_2$, overlapping peaks), 12.9, 12.8, 12.2, 12.0 (4 x *CH*(CH_3)$_2$, overlapping peaks); IR (film) cm^{-1}: 2945, 2867, 2115, 1738, 1465, 1064, 983; ESI-HRMS calcd for $C_{21}H_{42}N_3O_6Si_2$ 488.7451, found *m/z* 488.7458 $[M+H]^+$.



2,3-*O*-(1,1,3,3-Tetraisopropyl-1,3-disiloxanediyl)-β-D-glucopyranosyl azide (59)

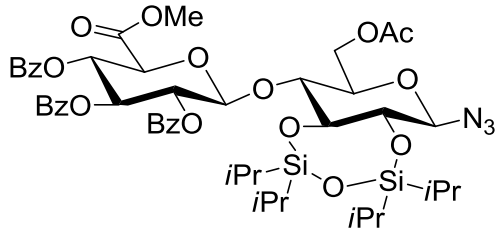
Intermediate **58** (2.5 g, 5.1 mmol) was dissolved in MeOH and amberlyst® 15 H^+ (3.0 g) was added and the mixture stirred for 5 h. The resin was filtered off and the solvent was removed and flash chromatography of the residue (petroleum ether-EtOAc, 8:2) gave the required 2,3-O-silylated intermediate (1.88 g, 82%) as a wax; $[\alpha]_D$ -18.0 (*c* 0.11, CH_2Cl_2); ^{1}H NMR (500 MHz, $CDCl_3$) δ 4.61 (d, ^3J (H,H) = 8.1 Hz, 1H; H-1), 3.95 (dd, ^2J (H,H) = -12.1 Hz, ^3J (H,H) = 3.1 Hz, 1H; H-6a), 3.81 (dd, ^2J (H,H) = -12.1 Hz, ^3J (H,H) = 4.7 Hz, 1H; H-6b), 3.66 (apt t, ^3J (H,H) = 8.5 Hz, 1H; H-3), 3.55 (apt td, ^3J (H,H) = 9.2, 8.6, 1.4 Hz, 1H; H-4), 3.51 – 3.45 (m, 2H; H-5, H-2, overlapping peaks), 2.45 (d, ^3J (H,H) = 2.2 Hz, 1H; OH), 2.04 (s, 1H; OH), 1.12 – 0.99 (m, 28H; 4 x C*H*(C*H*$_3$)$_2$, overlapping peaks); ^{13}C NMR (126 MHz, $CDCl_3$) δ 90.8 (C-1), 80.1 (C-3), 76.9 (C-5) 76.5 (C-2), 70.6 (C-4), 62.3 (C-6), 17.4, 17.2 (3s) 17.1, 17.0 (8 x CH(*C*H$_3$)$_2$, overlapping peaks), 12.8 (2s), 12.1, 12.4 (4 x *C*H(CH$_3$)$_2$, overlapping peaks); IR (film) cm^{-1}: 3372, 2945, 2868, 2117, 1738, 1464, 1143, 1036, 986; ESI-HRMS calcd for $C_{18}H_{37}N_3O_6Si_2Na$ 442.2349, found *m/z* 442.2354 $[M+Na]^+$.



2,3-*O*-(1,1,3,3-Tetraisopropyl-1,3-disiloxanediyl)-6-*O*-acetyl-β-D-glucopyranosyl azide (60)

Compound **59** (1.5 g, 3.35 mmol) was reacted with freshly distilled AcCl (0.26 mL, 3.69 mmol) in collidine (7.5 mL) as previously described and gave **60** (0.97 g, 59%) after flash chromatography (petroleum ether-EtOAc 9:1); $[\alpha]_D$ -25.6 (*c* 0.25, CH_2Cl_2); ^{1}H NMR (500 MHz, $CDCl_3$) δ 4.57 (d, ^3J (H,H) = 8.2 Hz, 1H; H-1), 4.42 (dd, ^2J (H,H) = -12.2 Hz, ^3J (H,H) = 2.2 Hz, 1H; H-6a), 4.30 (dd, ^2J (H,H) = -12.2 Hz, ^3J (H,H) = 5.4 Hz, 1H; H-6b), 3.64 (apt t, ^3J (H,H) = 8.6 Hz, 1H; H-3), 3.59

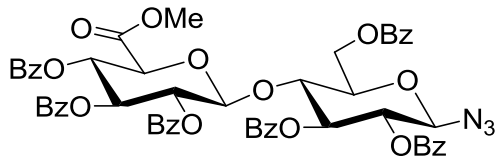
(ddd, ^3J (H,H) = 9.7, 5.4, 2.2 Hz, 1H; H-5), 3.49 (apt t, ^3J (H,H) = 8.4 Hz, 1H; H-2), 3.44 (ddd, ^3J (H,H) = 9.7, 8.6, 2.2 Hz, 1H; H-4), 2.48 (d, ^3J (H,H) = 2.2 Hz, 1H; OH), 2.11 (s, 3H; COCH_3), 1.11 – 1.03 (m, 28H; 4 x CH(CH_3)$_2$, overlapping peaks); ^{13}C NMR (126 MHz, $CDCl_3$): δ 171.1 (COCH$_3$), 90.8 (C-1), 80.0 (C-3), 76.4 (C-2), 75.1 (C-5), 70.2 (C-4), 63.1 (C-6), 20.9 (COCH_3), 17.3, 17.2 (3s), 17.1, 17.0 (8 x CH(CH_3)$_2$, overlapping peaks), 12.8 (2s), 12.1 (2s), 12.1 (4 x CH(CH$_3$)$_2$, overlapping peaks); IR (film) cm^{-1}: 3484, 2946, 2869, 2116, 1736, 1464, 1245, 1149, 1039, 985; ESI-HRMS calcd for $C_{20}H_{39}N_3O_7Si_2Na$ 512.224, found *m/z* 512.2219[M+Na]$^+$.



2,3-*O*-(1,1,3,3-Tetraisopropyl-1,3-disiloxanediyl)-4-*O*-(2,3,4-tri-*O*-benzoyl-5-*S*-(methoxycarbonyl)-β-D-xylopyranosyl)-6-*O*-acetyl-β-D-glucopyranosyl azide (61)

Glycosidation of **60** (0.5 g, 1.02 mmol) with donor **52** (1.13 g, 1.53 mmol) as previously described gave **61** (0.67 g, 66%) after chromatography (petroleum ether-EtOAc 8:2) as a glass; $[\alpha]_D$ -75.3 (*c* 0.3, CH_2Cl_2); ^{1}H NMR (500 MHz, $CHCl_3$) δ = 7.98 – 7.90 (m, 4H; Ar-H), 7.86 – 7.81 (m, 2H; Ar-H), 7.58 – 7.51 (m, 2H; Ar-H), 7.48 – 7.36 (m, 6H; Ar-H), 7.30 (t, ^3J (H,H) = 7.8 Hz, 2H; Ar-H), 5.84 (apt t, ^3J (H,H) = 9.5 Hz, 1H; H-3'), 5.69 (apt t, ^3J (H,H) = 9.6 Hz, 1H; H-4'), 5.50 (dd, ^3J (H,H) = 9.6, 7.8 Hz, 1H; H-2'), 4.92 (d, ^3J (H,H) = 7.8 Hz, 1H; H-1'), 4.47 (d, ^3J (H,H) = 8.3 Hz, 1H; H-1), 4.35 (dd, ^2J (H,H) = -12.2 Hz, ^3J (H,H) = 2.0 Hz, 1H; H-6a), 4.28 (d, ^3J (H,H) = 9.7 Hz, 1H; H-5'), 4.14 (dd, ^3J (H,H) = -12.2 Hz, ^3J (H,H) = 4.9 HZ, 1H; H-6b), 3.80 (apt t, ^3J (H,H) = 8.4 Hz, 1H; H-3), 3.76 – 3.69 (m, 4H; CO_2CH_3, H-4, overlapping peaks), 3.49 (apt t, ^3J (H,H) = 8.3 Hz, 1H; H-2), 3.42 (ddd, ^3J (H,H) = 10.0, 4.9, 2.0 Hz, 1H; H-5), 2.03 (s, 3H; COCH_3), 1.23 – 1.04 (m, 28H; 4 x CH(CH_3)$_2$, overlapping peaks); ^{13}C NMR (126 MHz, $CDCl_3$): δ 170.3 (COCH$_3$), 166.5 (COCH$_3$), 165.5, 164.9, 164.6 (3 x COPh), 133.5, 133.4, 133.3, 129.8 (2s) (9 x Ar-CH, overlapping peaks), 128.7, 128.6 (3 x Ar-C, overlapping peaks), 128.5, 128.4, 128.3 (6 x Ar-CH, overlapping peaks), 100.9 (C-1'), 90.5 (C-1), 77.8 (C-3), 77.1 (C-4), 74.6 (C-5), 73.7 (C-5'), 72.3 (C-3'), 71.8 (C-2'), 70.2 (C-

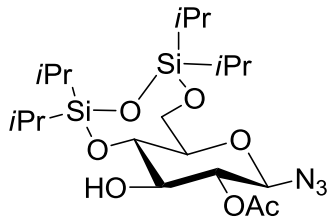
4'), 61.9 (C-6), 52.8 (CO_2CH_3), 29.7, 20.8, 17.4, 17.3, 17.2 (2s), 17.1 (2s), 17.0 (8 x $CH(CH_3)_2$, overlapping peaks), 12.8 (2s), 12.1, 11.6 (4 x $CH(CH_3)_2$, overlapping peaks); IR (film) cm^{-1}: 3072, 2955, 2118, 1728, 1691, 1451, 1248, 1090, 1067, 1025; ESI-HRMS calcd for $C_{48}H_{61}O_{16}N_3Si_2Na$ 1014.3488, found *m/z* 1014.3469 $[M+Na]^+$.



2,3,6-Tri-*O*-benzoyl-4-*O*-(2,3,4-tri-*O*-benzoyl-5-*S*-(methoxycarbonyl)-β-D-xylopyranosyl)-β-D-glucopyranosyl azide (63)

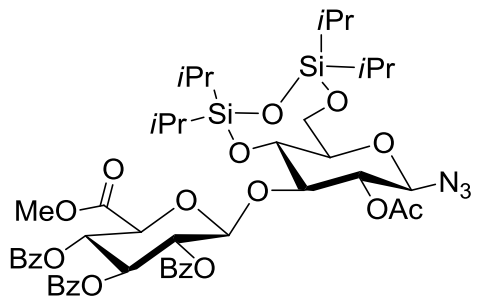
Disaccharide **31** (0.3 g, 0.3 mmol) was added to 1.25 M HCl in methanol (10 mL) at 0 °C and the resulting solution was allowed to attain room temp and stirred for 16 h. The reaction mixture was cooled over an ice bath, diluted with MeOH (20 mL) and $NaHCO_3$ was added. The resulting slurry was concentrated to dryness and the residue suspended in pyridine and cooled over an ice bath. BzCl (0.21 mL, 1.8 mmol) was then added and the reaction mixture was allowed to warm to room temp and was stirred overnight. Methanol (0.5 mL) was added and the mixture diluted with EtOAc (10 mL). This layer was washed with 1M HCl (2 x 5 mL), satd aq $NaHCO_3$ (10 mL), brine (10 mL), dried over Na_2SO_4, filtered and the solvent was removed under diminished pressure. Flash chromatography of the residue (petroleum ether-EtOAc 6:4) gave **63** (0.17 g, 63%) as a glass; $[\alpha]_D$ 56.6 (*c* 1.15, CH_2Cl_2); ^1H NMR (500 MHz, $CDCl_3$) δ = 8.02 – 7.98 (m, 2H; Ar-H), 7.89 (dd, ^3J (H,H) = 8.3, 1.4 Hz, 2H; Ar-H), 7.76 – 7.72 (m, 4H; Ar-H), 7.62 (dd, ^3J (H,H) = 8.4, 1.4 Hz, 2H; Ar-H), 7.58 (dd, ^3J (H,H) = 8.3, 1.4 Hz, 2H; Ar-H), 7.55 – 7.45 (m, 3H; Ar-H), 7.45 – 7.33 (m, 7H; Ar-H), 7.29 – 7.17 (m, 8H; Ar-H), 5.78 – 5.67 (m, 3H ,H-3, H-4', H-3', overlapping peaks), 5.54 – 5.48 (m, 2H; H-2', H4', overlapping peaks), 5.07 (d, ^3J (H,H) = 7.6 Hz, 1H; H-1'), 4.87 (d, ^3J (H,H) = 8.0 Hz, 1H; H-1), 4.57 (dd, ^2J (H,H) = -12.4 Hz, ^3J (H,H) = 3.0 Hz, 1H; H-6a), 4.41 (dd, ^2J (H,H) = -12.4 Hz, ^3J (H,H) = 5.1 Hz, 1H; H-6b), 4.35 (d, ^3J (H,H) = 9.1 Hz, 1H; H-5'), 4.12 – 4.07 (m, 2H; H-5, H-2, overlapping peaks), 3.73 (s, 3H; CO_2CH_3); ^{13}C NMR (126 MHz, $CDCl_3$) δ 166.7 (CO_2CH_3), 166.0, 165.5, 165.1, 165.0, 164.9, 164.7 (6 x *C*OPh), 133.4 (2s), 133.3, 133.1, 132.9, 129.8 (2s), 129.7 (3s), 129.6 (18 x Ar-CH, overlapping peaks), 129.5, 128.8, 128.7, 128.5 (3s) (6 x Ar-C), 128.4 (2s), 128.3

(2s), 128.2, 128.1 (12 x Ar-CH, overlapping peaks), 100.8 (C-1'), 88.8 (C-1), 77.7 (C-2), 73.9 (C-5 & C-3, overlapping peaks), 73.0 (C-5'), 72.2 (C-3'), 71.6 (C-2'), 70.0 (C-4'), 69.0 (C-4), 62.8 C-6), 53.0 (CO_2CH_3); IR (film) cm^{-1}: 2945, 2867, 2120, 1724, 1452, 1248, 1092, 1066, 1027, 986, 702; ESI-HRMS calcd for $C_{55}H_{45}O_{17}N_3Na$ 1042.2647, found *m/z* 1042.2631 $[M+Na]^+$.



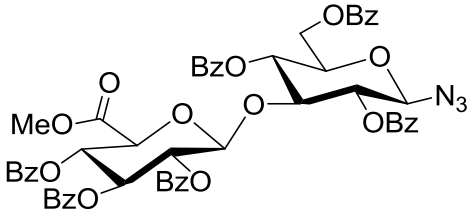
2-*O*-Acetyl-4,6-*O*-(1,1,3,3-tetraisopropyl-1,3-disiloxanediyl)-β-D-glucopyranosyl azide (65)

A solution of **37** (0.5 g, 1.1 mmol) in collidine (2.5 mL) was cooled to -35 °C. To this was added freshly distilled AcCl (0.087 mL, 1.23 mmol) and the reaction mixture was allowed to attain room temp and stirred for 16 h. MeOH was added and the solvent was removed and flash chromatography of the residue (petroleum ether-EtOAc 9:1) gave the 2-*O*-acetylated intermediate (0.42 g, 78%); $[\alpha]_D$ -21.8 (*c* 0.1, CH_2Cl_2); ^1H NMR (500 MHz, $CDCl_3$) δ 4.92 – 4.84 (m, 1H; H-2), 4.53 (d, ^3J (H,H) = 9.0 Hz, 1H; H-1), 3.99 – 3.91 (m, 1H; H-6a), 3.82 – 3.71 (m, 3H; H-6b, H-4, H-3, overlapping peaks), 3.45 (dddd, ^3J (H,H) = 7.9, 5.2, 2.8, 1.3 Hz, 1H; H-5), 2.09 (s, 3H; $CO\mathit{CH_3}$), 1.98 – 1.91 (m, 1H; OH), 1.13 – 0.89 (m, 28H; 4 x $C\mathit{H}(C\mathit{H_3})_2$, overlapping peaks); ^{13}C NMR (126 MHz, $CDCl_3$): δ 169.2 ($\mathit{C}OCH_3$), 87.9 (C-1), 78.4 (C-5), 77.3 (C-4), 72.7 (C-3), 72.5 (C-2), 61.9 (C-6), 20.6 ($CO\mathit{CH_3}$), 17.2 (2s), 17.1 (4s) (8 x $CH(\mathit{CH_3})_2$, overlapping peaks), 12.8 (2s), 12.1, 12.0 (4 x $\mathit{CH}(CH_3)_2$, overlapping peaks); IR (film) cm^{-1}: 3533, 2943, 2866, 2121, 1729, 1462, 1243, 980; ESI-HRMS calcd for $C_{20}H_{39}N_3O_7Si_2Na$ 512.224, found *m/z* 512.2232 $[M+Na]^+$.



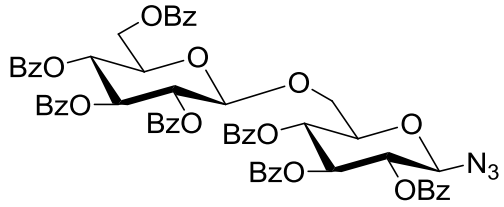
2-*O*-Acetyl-3-*O*-(2,3,4-tri-O-benzoyl-5-*S*-(methoxycarbonyl)-β-D-xylopyranosyl)-4,6-*O*-(1,1,3,3-tetraisopropyl-1,3-disiloxanediyl)-β-D-glucopyranosyl azide (66)

Glycosidation of intermediate **65** (0.4 g, 0.8 mmol) with **52** (0.91 g, 1.2 mmol) gave **66** (0.65 g, 82%) after chromatography (petroleum ether-EtOAc 8:2) as a foam; $[\alpha]_D$ -24.1 (*c* 0.1, CH_2Cl_2); ^{1}H NMR (500 MHz, $CDCl_3$): δ = 7.98 (dd, ^3J (H,H) = 8.3, 1.4 Hz, 2H; Ar-H), 7.93 (dd, ^3J (H,H) = 8.4, 1.4 Hz, 2H; Ar-H), 7.86 (dd, ^3J (H,H) = 8.3, 1.4 Hz, 2H; Ar-H), 7.51 (dd, ^3J (H,H) = 7.5, 3.6 Hz, 2H; Ar-H), 7.47 – 7.42 (m, 1H), 7.38 (q, ^3J (*H,H)* = 7.9 Hz, 4H; Ar-H), 7.30 (t, ^3J (H,H) = 7.8 Hz, 2H; Ar-H), 5.89 (apt t, ^3J (H,H) = 9.3 Hz, 1H; H-3'), 5.71 (apt t, ^3J (H,H) = 9.4 Hz, 1H; H-4'), 5.53 (dd, ^3J (H,H) = 9.3, 7.4 Hz, 1H; H-2'), 5.09 (d, ^3J (H,H) = 7.4 Hz, 1H; H-1'), 4.83 (t, ^3J (H,H) = 9.0 Hz, 1H; H-2), 4.36 (d, ^3J (H,H) = 9.5 Hz, 1H; H-5), 4.28 – 4.19 (m, 2H; H-6a, H-1, overlapping peaks), 3.85 (dd, ^2J (H,H) = -12.2 Hz, ^3J (H,H) = 7.3 Hz, 1H; H-6b), 3.70 (s, 3H; CO_2CH_3), 3.63 (dd, ^3J (H,H)= 9.1, 7.7 Hz, 1H; H-3), 3.59 – 3.49 (m, 2H; H-5, H-4, overlapping peaks), 2.06 (s, 3H; $COCH_3$), 1.09 – 0.94 (m, 28H; 4 x $CH(CH_3)_2$, overlapping peaks); ^{13}C NMR (126 MHz, $CDCl_3$) δ 169.3 ($COCH_3$), 167.5 (CO_2CH_3), 165.7, 165.3, 165.2 (3 x *C*OPh), 133.6, 133.4, 130.0, 129.9 (9 x Ar-CH, overlapping peaks), 129.4, 129.0, 128.9 (3 x Ar-C), 128.6 (2s), 128.5 (6 x Ar-CH, overlapping peaks), 101.7 (C-1'), 87.6 (C-1), 79.0 (C-5), 77.4 (C-3), 73.3 (C-4), 73.0 (C-5'), 72.6 (C-2), 72.3 (C-3'), 71.8 (C-2'), 70.3 (C-4'), 69.0 (C-6), 53.0 (CO_2CH_3), 20.8 ($COCH_3$), 17.6, 17.5, 17.3 (4s), 17.2 (8 x $CH(CH_3)_2$, overlapping peaks), 12.9, 12.8, 12.3, 12.2 (4 x $CH(CH_3)_2$, overlapping peaks); IR (film) cm^{-1}: 2948, 2868, 2118, 1732, 1452, 1248, 1223, 1092, 1068, 1041, 1027, 984; ESI-HRMS calcd for $C_{48}H_{61}O_{16}N_3Si_2Na$ 1014.3488, found *m/z* 1014.3533 $[M+Na]^+$.



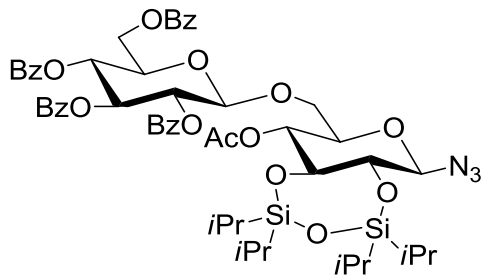
2,4,6-Tri-*O*-benzoyl-3-*O*-(2,3,4-tri-*O*-benzoyl-5-*S*-(methoxycarbonyl)-β-D-xylopyranosyl)-β-D-glucopyranosyl azide (68)

Disaccharide **66** (0.25 g, 0.252 mmol) was added to 1.25 M HCl in methanol (10 mL) at 0 °C and the resulting solution was allowed to attain room temp and stirred for 16 h. The reaction mixture was cooled over an ice bath, diluted with MeOH (20 mL) and $NaHCO_3$ was added. The resulting slurry was concentrated to dryness and the residue suspended in pyridine and cooled over an ice bath. BzCl (0.18 mL, 1.5 mmol) was then added and the reaction mixture was allowed to warm to room temp and was stirred overnight. Methanol (0.5 mL) was added and the mixture diluted with EtOAc (10 mL). This layer was washed with 1M HCl (2 x 5 mL), satd aq $NaHCO_3$ (10 mL), brine (10 mL), dried over Na_2SO_4, filtered and the solvent was removed under diminished pressure. Flash chromatography of the residue (petroleum ether-EtOAc 6:4) gave **68**(0.15 g, 63%) as a glass; $[\alpha]_D$ -15.6 (*c* 1.25, CH_2Cl_2); ^{1}H NMR (500 MHz, $CDCl_3$): δ = 8.00 (dd, ^3J (H,H) = 8.4, 1.4 Hz, 2H; Ar-H), 7.95 – 7.90 (m, 4H; Ar-H), 7.88 (ddd, ^3J (H,H) = 8.4, 3.0, 1.4 Hz, 4H; Ar-H), 7.79 – 7.75 (m, 2H; Ar-H), 7.55 – 7.50 (m, 4H; Ar-H), 7.48 – 7.27 (m, 14H; Ar-H), 5.91 (apt t, ^3J (H,H) = 9.3 Hz, 1H; H-3'), 5.79 (apt t, ^3J (H,H) = 9.6 Hz, 1H; H-3), 5.68 (apt t, ^3J (H,H) = 9.3 Hz, 1H; H-4'), 5.54 (dd, ^3J (H,H) = 9.2, 7.3 Hz, 1H; H-2'), 5.38 (apt t, ^3J (H,H) = 9.8 Hz, 1H; H-2), 5.35 (dd, ^3J (H,H) = 9.7, 8.7 Hz, 1H; H-4), 5.04 (d, ^3J (H,H) = 7.3 Hz, 1H; H-1'), 4.65 (d, ^3J (H,H) = 8.8 Hz, 1H; H-1), 4.35 (d, ^3J (H,H) = 9.4 Hz, 1H; H-5'), 4.13 (dd, ^2J (H,H) = -12.0 Hz, ^3J (H,H) = 1.9 Hz, 1H; H-6a), 4.06 (ddd, ^3J (H,H) = 9.7, 7.6, 1.9 Hz, 1H; H-5), 3.90 (dd, ^2J (H,H) = -12.0 Hz, ^3J (H,H) = 7.6 Hz, 1H; H-6b), 3.66 (s, 3H; CO_2CH_3); ^{13}C NMR (126 MHz, $CDCl_3$) δ 167.2 (CO_2CH_3), 165.6, 165.5, 165.3, 165.2, 165.0, 164.9 (6 x *C*OPh), 133.6, 133.5, 133.4, 133.3, 129.9 (2s), 129.8 (2s), 129.7 (18 x Ar-CH, overlapping peaks), 129.1, 128.8, 128.7 (2s), 128.6 (5 x Ar-C, overlapping peaks), 128.5, 128.4 (2s) (8 x Ar-CH, Ar-C, overlapping peaks), 128.3 (2s) (4 x Ar-CH, overlapping peaks), 101.5 (C-1'), 87.8 (C-1), 76.5 (C-5), 72.8 (C-5'), 72.6 (C-3), 71.8 (C-3'), 71.5 (C-2'), 71.2 (C-2), 70.0 (C-4'), 69.1 (C-4), 68.6 (C-6), 52.9 (CO_2CH_3); IR (film) cm^{-1}: 2956, 2120, 1714, 1451, 1247, 1088, 1068, 1026; ESI-HRMS calcd for $C_{55}H_{45}O_{17}N_3Na$ 1042.2647, found *m*/*z* 1042.2646 $[M+Na]^+$.



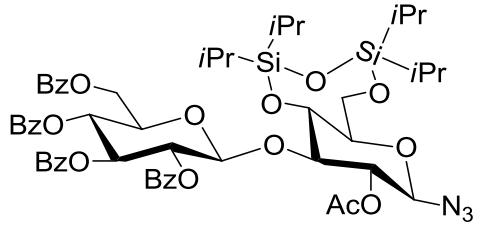
2,3,4-Tri-*O*-benzoyl-6-*O*-(2,3,4,6-tetra-*O*-benzoyl-β-D-glucopyranosyl)-β-D-glucopyranosyl azide (70)

Glycosidation of intermediate **43** (0.5 g, 0.67 mmol) with **48** (0.23 g, 0.45 mmol) gave **70** (0.42 g, 86%) after chromatography (Cyclohexane-EtOAc 8:2) as a foam; ; $[\alpha]_D$ 8.0 (*c* 0.1, CH_2Cl_2); ^{1}H NMR (500 MHz, $CDCl_3$): δ 8.01 (t, ^3J (H,H) =8.4, 4H; Ar-*H*), 7.90 (dd, ^3J (H,H) =14.7, 7.7, 4H; Ar-*H*), 7.86 – 7.79 (m, 4H; Ar-*H*), 7.76 (d, ^3J (H,H) =7.4, 2H; Ar-*H*), 7.57 – 7.46 (m, 5H; Ar-*H*), 7.46 – 7.34 (m, 11H; Ar-*H*), 7.32 – 7.22 (m, 5H; Ar-*H*), 5.90 (apt. t, ^3J (H,H) =9.6, 1H; H-3'), 5.78 (apt. t, ^3J (H,H) =9.6, 1H; H-3), 5.64 (apt. t, ^3J (H,H) =9.7, 1H; H-4'), 5.52 (dd, ^3J (H,H) =9.8, 7.8, 1H; H-2'), 5.38 – 5.30 (m, 2H; H-2, H-4, overlapping peaks), 5.00 (d, ^3J (H,H) =7.9, 1H; H-1'), 4.66 – 4.56 (m, 2H; H-6a', H-1, overlapping peaks) 4.44 (dd, ^2J (H,H) = -12.1, ^3J (H,H) = 4.9, 1H; H-6b'), 4.13 (ddd, ^3J (H,H) =9.6, 4.7, 2.9, 1H; H-5'), 4.09 – 4.00 (m, 2H; H-6^a, H-5, overlapping peaks), 3.90 (dd, ^2J (H,H) =11.8, ^3J (H,H) = 7.2, 1H; H-6b); ^{13}C NMR (126 MHz, $CDCl_3$): δ 166.1, 165.7, 165.5, 165.2, 165.1, 164.9 (7 x *C*OPh, overlapping peaks), 133.6, 133.5, 133.4, 133.3, 133.2, 133.1, 129.9, 129.8, 129.7 (14 x Ar-*C*H, overlapping peaks), 129.5, 129.2, 128.8, 128.7, 128.6 (7 x Ar-*C*, overlapping peaks), 128.4, 128.3 (14 x Ar-*C*H, overlapping peaks), 101.6 (C-1'), 87.8 (C-1), 76.5 (C-5), 72.7 (C-3'), 72.6 (C-3), 72.3 (C-5'), 71.8 (C-2'), 71.2 (C-2), 69.5 (C-4'), 69.2 (C-4), 68.3 (C-6), 62.9 (C-6'); ESI-HRMS calcd for $C_{55}H_{45}O_{17}N_3Na$ 1042.2647, found *m/z* 1042.2653 $[M+Na]^+$.



2,3-*O*-(1,1,3,3-tetraisopropyl-1,3-disiloxanediyl)-4-*O*-benzoyl-6-*O*-(2,3,4,6-tetra-*O*-benzoyl-β-D-glucopyranosyl)-β-D-glucopyranosyl azide (72)

Glycosidation of intermediate **43** (0.5 g, 0.67 mmol) with **59** (0.3 g, 0.67 mmol) followed by acetylation of the crude product with Ac_2O (250 µl) in pyridine (5 ml) gave **72** (0.5 g, 69%) after chromatography (cyclohexane-EtOAc 8:2) as a glassy solid; $[\alpha]_D$ 6.7 (*c* 0.1, CH_2Cl_2); ^{1}H NMR (500 MHz, $CDCl_3$): δ 8.07 – 7.93 (m, 4H; Ar-*H*), 7.90 (d, ^3J (H,H) =7.6, 2H; Ar-*H*), 7.83 (d, ^3J (H,H) =7.6, 2H; Ar-*H*), 7.59 – 7.45 (m, 4H; Ar-*H*), 7.41 (dt, ^3J (H,H) =10.1, 7.6, 4H; Ar-*H*), 7.34 (t, ^3J (H,H) =7.7, 2H; Ar-*H*), 7.31 – 7.24 (m, 2H; Ar-*H*), 5.90 (apt. t, ^3J (H,H) =9.6, 1H; H-3'), 5.67 (apt. t, ^3J (H,H) =9.7, 1H; H-4'), 5.51 (dd, ^3J (H,H) =9.8, 7.9, 1H; H-2'), 4.99 (d, ^3J (H,H) =7.9, 1H; H-1'), 4.72 (apt. t, ^3J (H,H) =9.7, 1H; H-4), 4.64 (dd, ^2J (H,H) = -12.2, ^3J (H,H) = 3.1, 1H; H-6a'), 4.47 (dd, ^2J (H,H) = -12.2, ^3J (H,H) = 5.0, 1H; H-6b'), 4.25 (d, ^3J (H,H) =8.2, 1H; H-1), 4.14 (ddd, ^3J (H,H) =10.0, 5.1, 3.1, 1H; H-5'), 3.89 (dd, ^2J (H,H) =11.9, ^3J (H,H) = 2.0, 1H; H-6), 3.71 (dd, ^2J (H,H) =12.0, ^3J (H,H) = 7.8, 1H; H-6), 3.65 – 3.52 (m, 2H; H-3,H-5, overlapping peaks), 3.43 (apt. t, ^3J (H,H) =8.4, 1H; H-2), 1.99 (s, 3H; COC*H*$_3$), 1.24 – 0.83 (m, 28H; 4 x C*H*(C*H*$_3$)$_2$, overlapping peaks); ^{13}C NMR (126 MHz, $CDCl_3$): δ 169.5 (*C*OCH$_3$), 166.1, 165.7, 165.2 (4 x *C*OPh, overlapping peaks), 133.4, 133.2, 133.1, 129.8, 129.7 (12 x Ar-*C*H, overlapping peaks), 129.6, 129.3, 128.8 (4 x Ar-*C*, overlapping peaks), 128.4, 128.3 (8 x Ar-*C*H,overlapping peaks), 101.5 (C-1'), 89.9 (C-1), 77.2 (C-3), 76.9 (C-2), 76.0 (C-5), 72.8 (C-3'), 72.3 (C-5'), 71.8 (C-2), 70.3 (C-4), 69.6 (C-4'), 68.6 (C-6), 63.0 (C-6'), 20.6 (CO*C*H$_3$), 17.1, 16.9 (8 x CH(*C*H$_3$)$_2$, overlapping peaks), 12.8, 12.7, 12.0 (4 x *C*H(CH$_3$)$_2$, overlapping peaks); ESI-HRMS calcd for $C_{59}H_{67}O_{17}N_3Na$ 1129.4060, found *m/z* 1129.4068 $[M+Na]^+$.



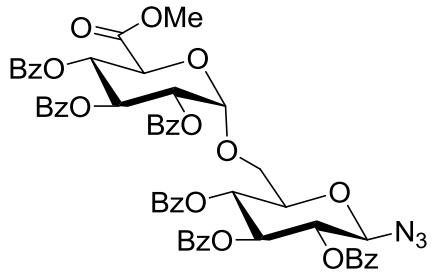
2-*O*-acetyl-3-*O*-(2,3,4,6-tetra-*O*-benzoyl-β-D-glucopyranosyl)-4,6-*O*-(1,1,3,3-tetraisopropyl-1,3-disiloxanediyl)-β-D-glucopyranosyl azide (74)

$[\alpha]_D$ 6.1 (*c* 0.1, CH_2Cl_2); ^{1}H NMR (500 MHz, $CDCl_3$): δ 8.03 (d, ^3J (H,H) =7.7, 2H; Ar-*H*), 7.98 (d, ^3J (H,H) =7.7, 2H; Ar-*H*), 7.90 (d, ^3J (H,H) =7.7, 2H; Ar-*H*), 7.83 (d, ^3J (H,H) =7.6, 2H; Ar-*H*), 7.52 (dq, ^3J (H,H) =21.7, 7.5, 4H; Ar-*H*), 7.44 – 7.27 (m, 8H; Ar-*H*), 5.90 (apt. t, ^3J (H,H) =9.6, 1H; H-3'), 5.69 (apt. t, ^3J (H,H) =9.7, 1H; H-

4'), 5.53 (dd, ^3J (H,H) =9.7, 7.8, 1H; H-2'), 5.07 (d, ^3J (H,H) =7.8, 1H; H-1'), 4.81 (apt. t, ^3J (H,H) =9.1, 1H; H-2), 4.63 (dd, ^2J (H,H) = -12.1, ^3J (H,H) = 3.2, 1H; H-6a'), 4.52 (dd, ^2J (H,H) = -12.2, ^3J (H,H) = 5.0, 1H; H-6b'), 4.24 – 4.06 (m, 3H; H-1, H-6a, H-5', overlappping peaks), 3.79 (dd, ^2J (H,H) = -12.0, ^3J (H,H) = 7.8, 1H; H-6b), 3.61 (t, ^3J (H,H) =8.7, 1H; H-3), 3.52 (dd, ^3J (H,H) =9.6, 7.8, 1H; H-5), 3.48 – 3.43 (m, 1H; H-4), 2.06 (s, 3H; COCH_3), 1.18 – 0.82 (m, 28H; 4 x CH(CH_3)$_2$, overlapping peaks); ^{13}C NMR (126 MHz, $CDCl_3$): δ 169.1 (*C*OCH$_3$), 166.1, 165.2, 165.1 (4 x *C*OPh, overlapping peaks), 133.4, 133.2, 133.1, 129.8, 129.7 (12 x Ar-*C*H, overlapping peaks), 129.6, 129.3, 128.8 (4 x Ar-*C*, overlapping peaks), 128.4, 128.3 (8 x Ar-*C*H, overlapping peaks), 101.5 (C-1'), 87.3 (C-1), 78.7 (C-4), 77.2 (C-3), 73.3 (C-5), 72.9 (C-3'), 72.4 (C-2), 72.2 (C-2'), 71.9 (C-5'), 69.6 (C-4'), 68.5 (C-6), 63.1 (C-6'), 20.6 (CO*C*H$_3$), 17.3, 17.2, 17.1, 17.0 (8 x CH(*C*H$_3$)$_2$, overlapping peaks), 12.7, 12.1, 12.0 (4 x *C*H(CH$_3$)$_2$, overlapping peaks); ESI-HRMS calcd for $C_{54}H_{65}N_3O_{16}Si_2Na$ 1090.3801, found *m/z* 1090.3811 $[M+Na]^+$.

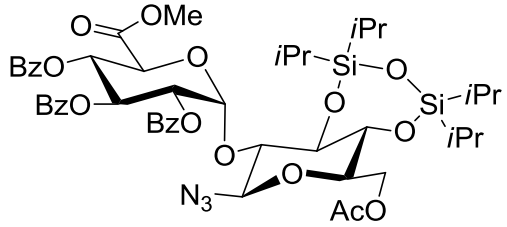
General procedure for the anomerisation reactions using $TiCl_4$:

The β-anomer (1 eq) was added to a flame dried round bottomed flask and anhydrous CH_2Cl_2 (10 mL per g of substrate) was added. The flask was then cooled on an ice bath and 2.5 eq $TiCl_4$ (1.0 M in CH_2Cl_2) was added dropwise. The flask was then left to stand in a freezer (-15 to -18 °C) for 48-72 h. The mixture was diluted with CH_2Cl_2 and washed with NH_4Cl (1.0 M, 10 mL). The aq layer was extracted with CH_2Cl_2 and the combined organic layers were washed with satd aq $NaHCO_3$ and brine. The organic layer was dried over Na_2SO_4, filtered through silica gel and the solvent removed to give the products.



2,3,4-Tri-*O*-benzoyl-6-*O*-(2,3,4-tri-*O*-benzoyl-5-*S*-(methoxycarbonyl)-α-D-xylopyranosyl)-β-D-glucopyranosyl azide (54)

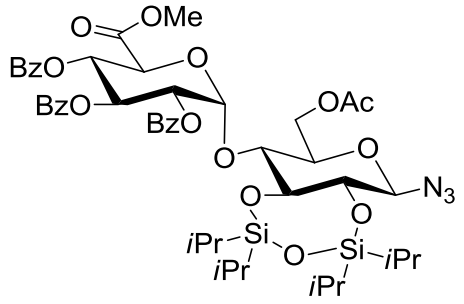
$[\alpha]_D$ 44.9 (*c* 1.1, CH_2Cl_2); ^{1}H NMR (500 MHz, $CDCl_3$) δ = 8.13 – 8.02 (m, 2H; Ar-H), 8.00 (dd, ^3J (H,H) = 8.5, 1.5 Hz, 2H; Ar-H), 7.96 (d, ^3J (H,H) = 6.9 Hz, 2H; Ar-H), 7.91 (ddd, ^3J (H,H) = 8.2, 3.7, 1.4 Hz, 4H; Ar-H), 7.81 (dd, ^3J (H,H) = 8.3, 1.5 Hz, 2H; Ar-H), 7.55 – 7.27 (m, 17H; Ar-H), 6.29 (apt t, ^3J (H,H) = 9.8 Hz, 1H; H-3'), 5.88 (apt t, ^3J (H,H) = 9.7 Hz, 1H; H-3), 5.68 (apt t, ^3J (H,H) = 9.8 Hz, 1H; H-4'), 5.60 (apt t, ^3J (H,H) = 9.8 Hz, 1H; H-4), 5.51 (d, ^3J (H,H) = 3.6 Hz, 1H; H-1'), 5.40 – 5.31 (m, 2H; H-2, H-2', overlapping peaks), 4.90 (d, ^3J (H,H) = 8.8 Hz, 1H; H-1), 4.74 (d, ^3J (H,H) = 10.1 Hz, 1H; H-5'), 4.16 – 4.02 (m, 2H; H-5, H-6a, overlapping peaks), 3.80 (dd, ^2J (H,H) = -11.5 Hz, ^3J (H,H) = 1.9 Hz, 1H; H-6b), 3.60 (s, 3H; CO_2CH_3); ^{13}C NMR (126 MHz, $CDCl_3$): δ 168.3 (CO_2CH_3), 165.9, 165.8, 165.7, 165.5, 165.2, 165.0 (6 x *C*OPh), 133.7 (2s), 133.6, 133.5, 133.3, 130.1 (2s), 130.0, 129.9 (2s) (18 x Ar-CH, overlapping peaks), 129.2, 129.1, 129.0, 128.9 (4 x Ar-C), 128.7 (2s) (2 x Ar-CH, Ar-C, overlapping peaks) , 128.6 (2s) (4 x Ar-CH, Ar-C, overlapping peaks), 128.5 (2s), 128.4 (6 x Ar-CH, overlapping peaks), 96.4 (C-1'), 88.2 (C-1), 75.5 (C-5), 72.9 (C-3), 71.5 (C-2), 71.3 (C-2'), 70.2 (C-4') 69.9 (C-3'), 68.9 (C-4), 68.6 (C-5'), 67.0 (C-6), 52.9 (CO_2CH_3); IR (film) cm^{-1}: 2955, 2924, 2118, 1726, 1451, 1248, 1090, 1067, 1025; ESI-HRMS calcd for $C_{55}H_{45}O_{17}N_3Na$ 1042.2647, found *m/z* 1042.2649 $[M+Na]^+$.



2-*O*-(2,3,4-Tri-*O*-benzoyl-5-*S*-(methoxycarbonyl)-α-D-xylopyranosyl)-3,4-*O*-(1,1,3,3-tetraisopropyl-1,3-disiloxanediyl)-6-*O*-acetyl-β-D-glucopyranosyl azide (57)

$[\alpha]_D$ 48.0 (*c* 0.35, CH_2Cl_2); ^{1}H-NMR (500 MHz, $CDCl_3$) δ = 8.00 (dd, ^3J (H,H) = 8.3, 1.5 Hz, 2H; Ar-H), 7.96 – 7.91 (m, 2H; Ar-H), 7.88 (dd, ^3J (H,H) = 8.3, 1.5 Hz, 2H; Ar-H), 7.57 – 7.49 (m, 1H; Ar-H), 7.46 – 7.37 (m, 5H; Ar-H), 7.30 (t, ^3J (H,H) = 7.7 Hz, 2H; Ar-H), 6.21 (apt t, ^3J (H,H) = 10.1 Hz, 1H; H-3'), 6.08 (d, ^3J (H,H) = 3.7 Hz, 1H; H-1'), 5.65 (apt t, ^3J (H,H) = 10.0 Hz, 1H; H-4'), 5.35 (dd, ^3J (H,H) = 10.4, 3.7 Hz, 1H; H-2'), 4.94 (d, ^3J (H,H) = 10.3 Hz, 1H; H-5'), 4.49 (d, ^3J (H,H) = 8.7 Hz, 1H; H-1), 4.40 (dd, ^2J (H,H) = -12.0 Hz, ^3J (H,H) = 2.2 Hz, 1H; H-6a), 4.15

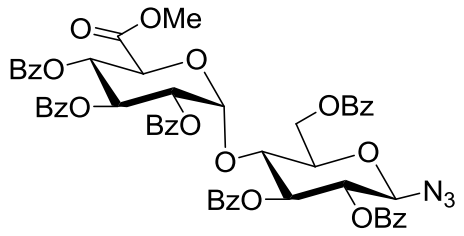
(dd, ^2J (H,H) = -12.0 Hz, ^3J (H,H) = 5.0 Hz, 1H; H-6b), 3.87 (apt t, ^3J (H,H) = 8.7 Hz, 1H; H-3), 3.73 (apt t, ^3J (H,H) = 8.9 Hz, 1H; H-4), 3.64 (s, 3H; CO_2CH_3), 3.56 (apt t, ^3J (H,H) = 8.8 Hz, 1H; H-2), 3.51 (dq, ^3J (H,H) = 7.3, 3.0, 2.5 Hz, 1H; H-5), 2.05 (s, 3H; $COCH_3$), 1.45 – 0.75 (m, 28H; 4 x $CH(CH_3)_2$, overlapping peaks); ^{13}C NMR (126 MHz, $CDCl_3$): δ 170.7 ($COCH_3$), 168.2 (CO_2CH_3), 165.6, 165.4, 165.3 (3 x *C*OPh), 133.4 (2s) , 133.2, 129.8, 129.7 (9 x Ar-CH, overlapping peaks),129.1, 129.0, 128.9 (3 x Ar-C) 128.5, 128.4, 128.3 (6 x Ar-CH, overlapping peaks), 94.9 (C-1'), 89.7 (C-1), 78.0 (C-3), 76.9 (C-2), 75.7 (C-5), 72.7 (C-4), 71.0 (C-2'), 70.0 (C-4'), 69.0 (C-3'), 68.6 (C-5'), 62.7 (C-6), 52.7 (CO_2CH_3), 29.7 ($COCH_3$), 20.8, 17.5 (2s), 17.4, 17.3, 17.2 (2s), 17.1 (2s) (8 x $CH(CH_3)_2$, overlapping peaks), 12.9, 12.7, 12.2, 11.4 (4 x $CH(CH_3)_2$, overlapping peaks); IR (film) cm^{-1}: 3072, 2953, 2120, 1727, 1452, 1248, 1091, 1067, 1026; ESI-HRMS calcd for $C_{48}H_{61}O_{16}N_3Si_2Na$ 1014.3488, found *m/z* 1014.3494 $[M+Na]^+$.



2,3-*O*-(1,1,3,3-Tetraisopropyl-1,3-disiloxanediyl)-4-*O*-(2,3,4-tri-*O*-benzoyl-5-*S*-(methoxycarbonyl)-α-D-xylopyranosyl)-6-*O*-acetyl-β-D-glucopyranosyl azide (62)

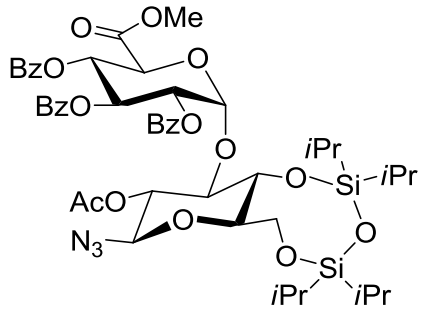
$[\alpha]_D$ 29.0 (*c* 0.2, CH_2Cl_2); ^{1}H NMR (500 MHz, $CDCl_3$): δ = 8.05 (dd, ^3J (H,H) = 8.2, 1.4 Hz, 2H; Ar-H), 7.94 – 7.89 (m, 4H; Ar-H), 7.58 – 7.53 (m, 2H; Ar-H), 7.51 – 7.46 (m, 1H; Ar-H), 7.43 – 7.36 (m, 4H; Ar-H), 7.26 (m, 2H; Ar-H), 5.99 (d, ^3J (H,H) = 2.4 Hz, 1H; H-1'), 5.81 (apt t, ^3J (H,H) = 5.5 Hz, 1H; H-3'), 5.65 (apt t, ^3J (H,H) = 4.9 Hz, 1H; H-4'), 5.46 (dd, ^3J (H,H) = 5.9, 2.4 Hz, 1H; H-2'), 4.77 (d, ^3J (H,H) = 4.7 Hz, 1H; H-5'), 4.60 (dd, ^2J (H,H) = -12.2 Hz, ^3J (H,H) = 2.3 Hz, 1H; H-6a), 4.53 (d, ^3J (H,H) = 8.2 Hz, 1H; H-1), 4.40 (dd, ^2J (H,H) = -12.2 Hz, ^3J (H,H) = 5.0 Hz, 1H; H-6b), 4.04 (dd, ^3J (H,H) = 9.9, 8.6 Hz, 1H; H-4), 3.87 (apt t, ^3J (H,H) = 8.6 Hz, 1H; H-3), 3.65 – 3.59 (m, 4H; CO_2CH_3, H-5, overlapping peaks), 3.53 (apt t, ^3J (H,H) = 8.4 Hz, 1H; H-2), 2.06 (s, 3H; $COCH_3$), 1.17 – 0.83 (m, 28H; 4 x $CH(CH_3)_2$, overlapping peaks); ^{13}C NMR (126 MHz, $CDCl_3$): δ 170.7 ($COCH_3$), 168.4 ($COCH_3$), 165.4, 165.2 (3 x *C*OPh, overlapping peaks), 133.7, 133.4, 130.1,

130.0, 129.8 (9 x Ar-CH, overlapping peaks), 199.3 128.8, 128.6 (3 x Ar-C) 128.4, 128.4, 128.3 (6 x Ar-CH, overlapping peaks), 94.6 (C-1'), 90.5 (C-1), 80.3 (C-3), 76.7 (C-2), 74.4 (C-5), 74.2 (C-4) 72.3 (C-5'), 68.6 (H-3'), 68.2 (H-4'), 67.4 (H-2') 63.0 (C-6), 52.6 (CO_2CH_3), 20.8 ($COCH_3$), 17.3 (2s), 17.2 (2s), 17.1, 16.9 (8 x $CH(CH_3)_2$, overlapping peaks), 12.9, 12.7, 12.1, 12.0 (4 x $CH(CH_3)_2$, overlapping peaks); IR (film) cm^{-1}: 2927, 2868, 2118, 1729, 1452, 1246, 1091, 1068, 1026, 988; ESI-HRMS calcd for $C_{48}H_{61}O_{16}N_3Si_2Na$ 1014.3488, found *m/z* 1014.3467 $[M+Na]^+$.



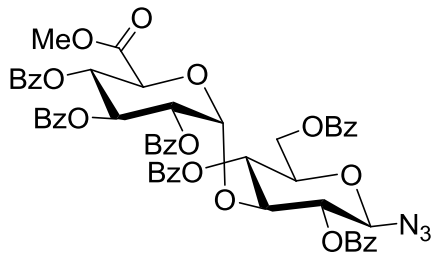
2,3,6-Tri-*O*-benzoyl-4-*O*-(2,3,4-tri-*O*-benzoyl-5-*S*-(methoxycarbonyl)-α-D-xylopyranosyl)-β-D-glucopyranosyl azide (64)

$[\alpha]_D$ 65.3 (*c* 0.15, CH_2Cl_2); ^{1}H NMR (500 MHz, $CDCl_3$) δ = 8.07 – 8.02 (m, 2H; Ar-H), 8.01 – 7.98 (m, 2H; Ar-H), 7.97 – 7.94 (m, 2H; Ar-H), 7.91 (ddd, ^3J (H,H) = 8.5, 3.9, 1.4 Hz, 4H; Ar-H), 7.83 – 7.79 (m, 2H; Ar-H), 7.55 – 7.27 (m, 17H; Ar-H), 6.28 (apt t, ^3J (H,H) = 9.8 Hz, 1H; H-3'), 5.87 (apt t, ^3J (H,H) = 9.7 Hz, 1H; H-3), 5.67 (apt t, ^3J (H,H) = 9.8 Hz, 1H; H-4'), 5.59 (apt t, ^3J (H,H) = 9.7 Hz, 1H; H-4), 5.50 (d, ^3J (H,H) = 3.7 Hz, 1H; H-1'), 5.38 – 5.32 (m, 2H; H-2, H-2', overlapping peaks), 4.89 (d, ^3J (H,H) = 8.8 Hz, 1H; H-1), 4.73 (d, ^3J (H,H) = 10.1 Hz, 1H; H-5'), 4.10 (ddd, ^3J (H,H) = 9.8, 6.3, 1.7 Hz, 1H; H-5), 4.05 (dd, ^2J (H,H) = -11.3 Hz, ^3J (H,H) = 6.4 Hz, 1H; H-6a), 3.79 (dd, ^2J (H,H) = -11.3 Hz, ^3J (H,H) = 1.7 Hz, 1H; H-6b), 3.60 (s, 3H; CO_2CH_3); ^{13}C NMR (126 MHz, $CDCl_3$): δ 168.1 (CO_2CH_3), 165.7 (2s) , 165.6, 165.4, 165.0, 164.8 (6 x *C*OPh), 133.6, 133.5 (2s), 133.3, 133.2, 130.0, 129.9 (2s), 129.8 (2s) (18 x Ar-CH, overlapping peaks), 129.1, 128.9, 128.8 (2s), 128.6 (5 x Ar-C), 128.5 (2s) (2x Ar-CH, Ar-C, overlapping peaks), 128.4(2s), 128.3 (2s) (10 x Ar-CH, overlapping peaks), 96.3 (C-1'), 88.1 (C-1), 75.4 (C-5), 72.8 (C-3), 71.3 (C-2), 71.2 (C-2'), 70.0 (C4'), 69.8 (C-3'), 68.8 (C-4), 68.4 (C-5'), 66.8 (C-6), 52.8 (CO_2CH_3); IR (film) cm^{-1}: 2952, 2119, 1725, 1452, 1247, 1091, 1067, 1026, 704; ESI-HRMS calcd for $C_{55}H_{45}O_{17}N_3Na$ 1042.2647, found *m/z* 1042.2665 $[M+Na]^+$.



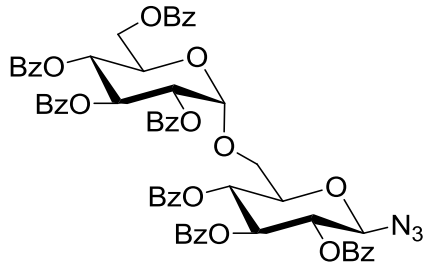
2-*O*-Acetyl-3-*O*-(2,3,4-tri-*O*-benzoyl-5-*S*-(methoxycarbonyl)-α-D-xylopyranosyl)-4,6-*O*-(1,1,3,3-tetraisopropyl-1,3-disiloxanediyl)-β-D-glucopyranosyl azide (67)

$[\alpha]_D$ -9.7 (*c* 0.35, CH_2Cl_2); ^{1}H NMR (500 MHz, $CDCl_3$) δ = 8.00 (dd, ^3J (H,H) = 8.2, 1.4 Hz, 2H; Ar-H), 7.95 (dd, ^3J (H,H) = 8.3, 1.4 Hz, 2H; Ar-H), 7.90 (dd, ^3J (H,H) = 8.3, 1.4 Hz, 2H; Ar-H), 7.54 – 7.49 (m, 2H; Ar-H), 7.46 – 7.36 (m, 5H; Ar-H), 7.31 (t, ^3J (H,H) = 7.7 Hz, 2H; Ar-H), 6.19 (apt t, ^3J (H,H) = 9.9 Hz, 1H; H-3'), 5.68 – 5.62 (m, 2H; H-1', H-4', overlapping peaks), 5.32 (dd, ^3J (H,H) = 10.1, 3.7 Hz, 1H; H-2), 4.68 (d, ^3J (H,H) = 10.1 Hz, 1H; H-5'), 4.56 (apt t, ^3J (H,H) = 8.8 Hz, 1H; H-2), 4.43 (d, ^3J (H,H) = 9.0 Hz, 1H; H-1), 4.01 – 3.98 (m, 2H; H-6a, H-6b, overlapping peaks), 3.71 – 3.63 (m, 5H; CO_2CH_3, H-3, H-4, overlapping peaks), 3.53 – 3.46 (m, 1H; H-5) 2.05 (s, 3H; $COCH_3$), 1.22 – 0.94 (m, 28H; 4 x $CH(CH_3)_2$, overlapping peaks); ^{13}C NMR (126 MHz, $CDCl_3$) δ 168.9 ($COCH_3$), 168.4 (CO_2CH_3), 165.7 (2s), 165.5 (3 x *C*OPh), 133.6, 133.5, 133.3, 130.0, 129.9 (9 x Ar-CH, overlapping peaks), 129.2, 129.0, 128.9 (3 x Ar-C), 128.7, 128.5 (2s) (6 x Ar-CH, overlapping peaks), 96.6 (C-1'), 87.9 (C-1), 77.9 (C-5), 77.6 (C-4), 72.5 (C-2), 72.4 (C-3), 71.6 (C-2'), 70.3 (C-4), 69.8 (C-3'), 68.7 (C-5), 65.9 (C-6), 53.0 (CO_2CH_3), 20.8 ($COCH_3$), 17.4 (4s), 17.3 (2s) (8 x $CH(CH_3)_2$, overlapping peaks), 12.9, 12.8, 12.3, 12.2 (4 x $CH(CH_3)_2$, overlapping peaks); IR (film) cm^{-1}: 2925, 2867, 2117, 1731, 1452, 1260, 1095, 1067, 1041, 983; ESI-HRMS calcd for $C_{48}H_{61}O_{16}N_3Si_2Na$ 1014.3488, found *m/z* 1014.3492 $[M+Na]^+$.



2,4,6-Tri-*O*-benzoyl-3-*O*-(2,3,4-tri-*O*-benzoyl-5-*S*-(methoxycarbonyl)-α-D-xylopyranosyl)-β-D-glucopyranosyl azide (69)

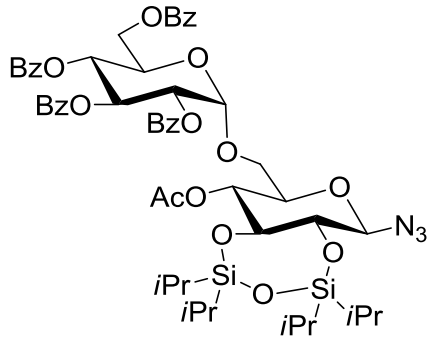
$[\alpha]_D$ 40.2 (*c* 0.95, CH_2Cl_2); ^{1}H NMR (500 MHz, $CDCl_3$): δ 8.15 – 8.10 (m, 2H; Ar-H), 8.08 – 8.03 (m, 2H; Ar-H), 8.02 – 7.98 (m, 2H; Ar-H), 7.97 – 7.94 (m, 2H; Ar-H), 7.94 – 7.89 (m, 3H Ar-H), 7.83 – 7.77 (m, 2H; Ar-H), 7.64 – 7.60 (m, 1H; Ar-H), 7.56 – 7.27 (m, 19H; Ar-H), 6.29 (apt t, ^3J (H,H) = 9.8 Hz, 1H; H-3'), 5.88 (apt t, ^3J (H,H) = 9.7 Hz, 1H; H-3), 5.68 (apt t, ^3J (H,H) = 9.8 Hz, 1H; H-4'), 5.59 (apt t, ^3J (H,H) = 9.8 Hz, 1H; H-4), 5.51 (d, ^3J (H,H) = 3.7 Hz, 1H; H-1'), 5.40 – 5.30 (m, 2H; H-2, H-2', overlapping peaks), 4.90 (d, ^3J (H,H) = 8.8 Hz, 1H; H-1), 4.74 (d, ^3J (H,H) = 10.1 Hz, 1H; H-5'), 4.11 (ddd, ^3J (H,H) = 9.6, 6.4, 1.7 Hz, 1H; H-5), 4.05 (dd, ^2J (H,H) = -11.3 Hz, ^3J (H,H) = 6.4 Hz, 1H; H-6a), 3.79 (d, ^2J (H,H) = -11.3 Hz, ^3J (H,H) = 1.7 Hz, 1H; H-6b), 3.60 (s, 3H; CO_2CH_3); ^{13}C NMR (126 MHz, $CDCl_3$): δ 168.1 (CO_2CH_3), 165.7 (2s), 165.6, 165.4, 165.0, 164.8 (6 x *C*OPh), 133.7, 133.6, 133.5 (2s), 133.3, 133.2, 130.2, 130.0 (2s), 129.9, 129.8 (2s) (18 x Ar-CH, overlapping peaks), 129.1, 128.9, 128.8 (2s), 128.6 (5 x Ar-C), 128.5 (3s) (4 x Ar-CH, Ar-C, overlapping peaks), 128.4 (2s), 128.3 (2s) (8 x Ar-CH, overlapping peaks), 96.3 (C-1'), 88.1 (C-1), 75.4 (C-5), 72.8 (C-3), 71.3 (C-3'), 71.2 (C-4'), 70.0 (C-2'), 69.8 (C-2), 68.8 (C-4), 68.4 (C-5'), 66.8 (C-6), 52.8 (CO_2CH_3); IR (film) cm^{-1}: 2957, 2924, 2119, 1724, 1452, 1248, 1090, 1067, 1025; ESI-HRMS calcd for $C_{55}H_{45}O_{17}N_3Na$ 1042.2647, found *m/z* 1042.2653 $[M+Na]^+$.



2,3,4-Tri-*O*-benzoyl-6-*O*-(2,3,4,6-tetra-*O*-benzoyl-α-D-glucopyranosyl)-β-D-glucopyranosyl azide (71)

$[\alpha]_D$ 27.7 (*c* 0.8, CH_2Cl_2); ^{1}H NMR (500 MHz, $CDCl_3$): δ 8.09 (d, ^3J (H,H) =7.7, 2H; Ar-*H*), 8.04 (d, ^3J (H,H) =7.4, 2H; Ar-*H*), 7.99 – 7.94 (m, 2H; Ar-*H*), 7.93 – 7.88 (m, 4H; Ar-*H*), 7.80 (d, ^3J (H,H) =8.0, 1H; Ar-*H*), 7.55 – 7.27 (m, 24H; Ar-*H*), 6.26 (apt. t, ^3J (H,H) =9.8, 1H; H-3'), 5.84 (apt. t, ^3J (H,H) =9.6, 1H; H-3), 5.68 (apt. t, ^3J (H,H) =9.8, 1H; H-4'), 5.45 – 5.39 (m, 2H; H-4, H-1', overlapping peaks), 5.35 (dd, ^3J

(H,H) =10.0, 3.9, 1H; H-2'), 5.24 (apt. t, ^{3}J (H,H) =9.3, 1H; H-2), 4.98 (d, ^{3}J (H,H) =8.8, 1H; H-1), 4.72 – 4.51 (m, 2H; H-6a', H-5', overlapping peaks), 4.40 (dd, ^{2}J (H,H) = -12.3, ^{3}J (H,H) =5.7, 1H; H-6b'), 4.17 – 3.99 (m, 2H; H-6a, H-5, overlapping peaks), 3.73 (dd, ^{2}J (H,H) = -11.5, ^{3}J (H,H) = 1.7, 1H; H-6b); ^{13}C NMR (126 MHz, $CDCl_3$): δ 166.0, 165.8, 165.7, 165.3, 165.1, 164.8 (7 x *C*OPh, overlapping peaks), 133.6, 133.4, 133.1, 130.0, 130.0, 129.9, 129.8, 129.7 (21 x Ar-*C*H, overlapping peaks), 129.2, 128.9, 128.8, 128.6 (7 x Ar-*C*, overlapping peaks), 128.5, 128.4, 128.3, 128.3 (14 x Ar-*C*H, overlapping peaks), 95.8 (C-1'), 87.9 (C-1), 75.4 (C-5), 72.8 (C-3), 71.8 (C-2'), 71.2 (C-2), 70.6 (C-3'), 69.2 (C-4'), 68.9 (C-4), 68.1 (C-5'), 66.2 (C-6), 62.7 (C-6'); ESI-HRMS calcd for $C_{55}H_{45}O_{17}N_3Na$ 1042.2647, found *m/z* 1042.2653 $[M+Na]^+$.



2,3-*O*-(1,1,3,3-tetraisopropyl-1,3-disiloxanediyl)-4-*O*-benzoyl-6-*O*-(2,3,4,6-tetra-*O*-benzoyl-α-D-glucopyranosyl)-β-D-glucopyranosyl azide (73)

$[\alpha]_D$ 31.2 (*c* 0.6, CH_2Cl_2); ^{1}H NMR (500 MHz, $CDCl_3$): δ 8.08 (d, ^{3}J (H,H) =7.7, 2H; Ar-*H*), 8.02 (d, ^{3}J (H,H) =7.8, 2H; Ar-*H*), 7.95 (d, ^{3}J (H,H) =7.7, 2H; Ar-*H*), 7.87 (d, ^{3}J (H,H) =7.8, 2H; Ar-*H*), 7.59 – 7.26 (m, 12H; Ar-*H*), 6.21 (apt. t, ^{3}J (H,H) =9.8, 1H; H-3'), 5.67 (apt. t, ^{3}J (H,H) =9.9, 1H; H-4'), 5.37 (d, ^{3}J (H,H) =3.8, 1H; H-1'), 5.30 (dd, ^{3}J (H,H) =10.1, 3.8, 1H; H-2), 4.81 (apt. t, ^{3}J (H,H) =9.7, 1H; H-4), 4.70 – 4.53 (m, 3H; H-6a', H-5', H-1, overlapping peaks), 4.41 (dd, ^{2}J (H,H) = -11.9, ^{3}J (H,H) = 5.5, 1H; H-6b'), 3.90 (dd, ^{2}J (H,H) = -11.1, ^{3}J (H,H) = 7.7, 1H), 3.78 – 3.64 (m, 2H; H-5, H-3), 3.58 (dd, ^{2}J (H,H) = -11.1, ^{3}J (H,H) = 2.0, 1H; H-6b), 3.29 (apt. t, ^{3}J (H,H) =8.4, 1H; H-2), 2.03 (s, 3H; COC*H*$_3$), 1.16 – 0.91 (m, 28H; 4 x C*H*(C*H*$_3$)$_2$, overlapping peaks); ^{13}C NMR (126 MHz, $CDCl_3$): δ 169.3 (*C*OCH$_3$), 166.0, 165.8, 165.7, 165.3 (4 x *C*OPh), 133.4, 133.3, 133.1, 133.0, 130.0, 129.9 (8 x Ar-*C*H, overlapping peaks), 129.8 (Ar-*C*, 2 x Ar-*C*H,overlapping peaks), 129.7 (4 x Ar-*C*H,

overlapping peaks), 129.2, 129.0, 128.8 (3 x Ar-*C*), 128.4, 128.3 (4 x Ar-*C*H, overlapping peaks), 95.4 (C-1'), 89.9 (C-1), 77.5 (C-5), 76.5 (C-2), 74.5 (C-3), 72.0 (C-2'), 70.6 (C-3'), 70.3 (C-4), 69.2 (C-4'), 67.9 (C-5'), 66.8 (C-6), 62.8 (C-6'), 20.7 (CO*C*H_3), 17.2, 17.1, 16.9 (8 x CH(*C*H_3)$_2$, overlapping peaks), 12.8, 12.6, 12.0 (4 x *C*H(CH_3)$_2$, overlapping peaks); ESI-HRMS calcd for $C_{59}H_{67}O_{17}N_3Na$ 1129.4060, found *m*/*z* 1129.4062 $[M+Na]^+$.

Chapter 4 experimental procedures:

General Procedures:

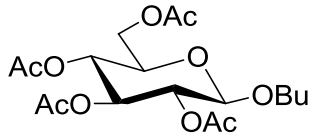
1. Acylation

A solution of the substrate (1 eq) in pyridine (5 mL/0.25 g) was cooled using an ice bath and to this was added DMAP[9] (0.1 eq) followed by the slow addition of the acylation agent. The reaction mixture was allowed attain room temperature and was stirred overnight before being quched by the addition of MeOH. The resulting solution was concentrated, diluted with EtOAc, washed twice with 1M HCl, satd aq $NaHCO_3$, brine, dried over Na_2SO_4, filtered and the solvent was removed under diminished pressure. Flash chromatography of the residue (cyclohexane-EtOAc 8:2 to 6:4) gave the desired compound.

2. Oxidative removal of benzyl ethers or opening of benzylidene acetals followed by acylation.

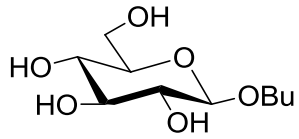
To a solution of the substrate in EtOAc (1 mL per 0.05 g) was added a solution of $NaBrO_3$ (3 eq) in H_2O (1mL per 0.05 g). The biphasic mixture was stirred vigourisly and to this was added a solution of 85% $Na_2S_2O_4$ (3 eq) in H_2O (1 mL per 20 mg) in a dropwise manner. The reaction was followed by TLC and upon consumption of the starting material, the reaction was quenched with a 1M aq $Na_2S_2O_3$ (0.5 mL) was added. The layers were separated and the orgainic layer was dried over Na_2SO_4, filtered and solvent was removed under diminished pressure. The resulting residue was taken up in pyridine and cooled using an ice bath. To this solution was added DMAP (0.1 eq) followed by the slow addition of the acylating agent (2.5 eq). The reaction was allowed to attain room temperature and was stirred overnight before being quenched by the addition of MeOH. The resulting solution was diluted with EtOAc, washed twice with 1M HCl, satd aq $NaHCO_3$, brine, dried over Na_2SO_4, filtered and solvent was reomoved under diminished pressure. Flash chromatography of the residue (cyclohexane-EtOAc 8:2 to 6:4) gave the desired compound(s).

[9] The addition of DMAP is optional and in some cases was omitted.



Butyl 2,3,4,6-tetra-*O*-acetyl-β-D-glucopyranoside (75β)[93]

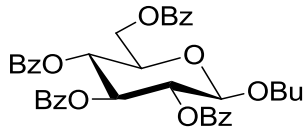
$[\alpha]_D$ -23.6 (*c* 0.2, CH_2Cl_2); ^{1}H NMR (500 MHz, $CDCl_3$): δ 5.19 (apt. t, ^3J (H,H) = 9.5, 1H; H-3), 5.07 (apt. t, ^3J (H,H) = 9.8, 1H; H-4), 4.97 (dd, ^3J (H,H) = 9.7, 7.9, 1H; H-2), 4.48 (d, ^3J (H,H) = 8.0, 1H; H-1), 4.25 (dd, ^2J (H,H) = -12.2, ^3J (H,H) = 4.8, 1H; H-6a), 4.12 (dd, ^2J (H,H) = -12.2, ^3J (H,H) = 2.4, 1H; H-6b), 3.87 (dt, ^2J (H,H) = -9.7, ^3J (H,H) = 6.3, 1H; C*H*H), 3.68 (ddd, ^{3}J (H,H) = 10.0, 4.7, 2.5, 1H; H-5), 3.47 (dt, ^2J (H,H) = -9.7, ^3J (H,H) = 6.8, 1H; C*H*H), 2.07 (s, 3H; COCH_3), 2.03 (s, 3H; COCH_3), 2.01 (s, 3H; COCH_3), 1.99 (s, 3H; COCH_3), 1.60 – 1.45 (m, 2H; CH_2), 1.43 – 1.27 (m, 2H; CH_2), 0.89 (t, ^3J (H,H) = 7.4, 3H; CH_3);^{13}C NMR (126 MHz, $CDCl_3$): δ 170.7, 170.3, 169.4, 169.3 (4 x *C*OCH_3), 100.8 (C-1), 72.8 (C-5), 71.7 (C-2), 71.3 (C-2), 69.9 (*C*H_2), 68.5 (C-4), 62.0 (C-6), 31.4 (*C*H_2), 20.7, 20.6 (4 x CO*C*H_3, overlapping peaks), 18.9 (*C*H_2), 13.7 (*C*H_3); IR (film) cm^{-1}:2961, 2875, 1747, 1725, 1374, 1265, 1238, 1224, 1097, 1029, 903, 716, 612; ESI-HRMS calcd for $C_{18}H_{32}O_{10}N$ 422.2026, found *m/z* 422.2024 $[M+NH_4]^+$.



Butyl β-D-glucopyranoside (76)[93]

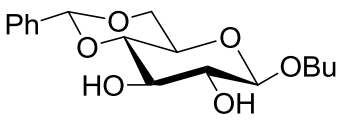
75β (11.4 g, 28.2 mmole) was taken up in anhydrous MeOH (150 mL) and NaOMe was added. The reaction was followed by TLC and apon consumption of the starting material Dowex® 50WX8 H^+-resin (1 g) was added and the mixture was stirred until the solution was neutralised. The resulting mixture was then filtered and solvent was evaporated under diminished pressure to give **76** (6.33 g) in 96 % yield; $[\alpha]_D$ -5.3 (*c* 0.2, CH_2Cl_2); ^{1}H NMR (500 MHz, D_2O): δ 4.32 (d, ^3J (H,H) = 8.0, 1H; H-1), 3.86 – 3.69 (m, 2H; H-6a, C*H*H, overlapping peaks), 3.64 – 3.49 (m, 2H; H-6a, C*H*H, overlapping peaks), 3.41 – 3.27 (m, 2H; H-3, H-5, overplapping peaks), 3.28 – 3.17 (m, 1H, H-4), 3.12 (dd, ^3J (H,H) = 9.4, 7.9, 1H; H-2), 1.56 – 1.39 (m, 2H; CH_2), 1.31 – 1.13 (m, 2H; CH_2), 0.77 (t, ^3J (H,H) = 7.4, 3H; CH_3); ^{13}C NMR (126 MHz, D_2O): δ 102.1 (C-1), 75.8 (C-3, C-5, overlapping peaks), 73.1 (C-2), 70.3 (*C*H_2), 69.6 (C-4), 60.7 (C-6), 30.8 (*C*H_2), 18.4 (*C*H_2), 13.0 (*C*H_3); IR (film) cm^{-1}: 3368, 3243, 2966,

2871, 1754, 178, 1376, 1209, 1066, 1034, 749; ESI-HRMS calcd for $C_{10}H_{20}O_6Na$ 259.1158, found *m/z* 259.1151 $[M+Na]^+$.



Butyl 2,3,4,6-tetra-*O*-benzoyl-β-D-glucopyranoside (77β)[93]

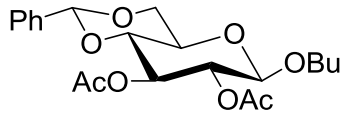
76 (1 g, 4.23 mmol) was subjected to general procedure 1, using Benzoyl chloride as the acylating agent. Purification by flash chromatography (cyclohexane-EtOAc 8:2) gave **77β** (2.15 g, 78%) as a foam; $[\alpha]_D$ 14.6 (*c* 0.5, CH_2Cl_2); ^{1}H NMR (500 MHz, $CDCl_3$): δ 8.01 (d, ^3J (H,H) = 7.7, 1H; Ar-H), 7.95 (d, ^3J (H,H) = 7.7, 1H; Ar-H), 7.90 (d, ^3J (H,H) = 7.8, 1H; Ar-H), 7.83 (d, ^3J (H,H) = 7.7, 1H; Ar-H), 7.51 (dq, ^3J (H,H) = 21.4, 7.5, 2H; Ar-H), 7.40 (dq, ^3J (H,H) = 15.9, 7.8, 3H; Ar-H), 7.34 (t, ^3J (H,H) = 7.7, 1H; Ar-H), 7.28 (t, ^3J (H,H) = 7.7, 1H; Ar-H), 5.90 (apt. t, ^3J (H,H) = 9.6, 1H; H-3), 5.67 (apt. t, ^3J (H,H) = 9.7, 1H; H-4), 5.52 (dd, 9.7, 7.9, 1H; H-2), 4.83 (d, ^3J (H,H) = 7.8, 1H; H-1), 4.63 (dd, ^2J (*H,H*) = -12.2, ^3J (H,H) = 3.3, 1H; H-6a), 4.50 (dd, ^2J (H,H) = -12.1, ^3J (H,H) = 5.2, 1H; H-6b), 4.15 (ddd, ^3J (H,H) = 9.3, 5.2, 3.4, 1H; H-5), 3.91 (dt, ^2J (H,H) = -9.7, ^3J (H,H) = 6.3, 1H; C*H*H), 3.55 (dt, ^2J (H,H) = -9.7, ^3J (H,H) = 6.8, 1H; C*H*H), 1.56 – 1.45 (m, 2H; CH_2), 1.23 (m, 2H; CH_2), 0.74 (t, ^3J (*H,H*) = 7.4, 1H; CH_3); ^{3}C NMR (126 MHz, $CDCl_3$): δ 166.1, 165.8, 165.2, 165.1 (4 x *C*OPh), 133.4, 133.2, 133.1, 129.8, 129.7 (8 x Ar-*C*H, overlapping peaks), 129.6, 129.4, 128.8 (4 x Ar-*C*, overlapping peaks), 128.3, 128.2 (4 x Ar-*C*H, overlapping peaks), 102.3 (C-1), 72.9 (C-3), 72.1 (C-5), 71.9 (C-2), 70.0 (*C*H_2), 69.9 (C-4), 63.2 (C-6), 31.4 (*C*H_2), 18.9 (*C*H_2), 13.5 (*C*H_3); IR (film) cm^{-1}: 3337, 2960, 2875, 1724, 1602, 1451, 1260, 1118, 1091, 1066, 1026, 952, 704; ESI-HRMS calcd for $C_{38}H_{40}O_{10}N$ 670.2652, found *m/z* 670.2668 $[M+NH_4]^+$.



Butyl 4,6-*O*-benzylidene-β-D-glucopyranoside (78)

Compound **76** (13.2 g, 55.87 mmol) was taken up in MeCN (100 mL) and to this was added benzyaldehide dimethyl actel and catalytic *p*-TsOH.H_2O (0.5 g, 2.63 mmol). The reaction was stirred for 2 h, before triethylamine (0.22 mL, 3 mmol) was added. The resulting suspension was evapotated to dryness under diminished

pressure and purified by flash chromatography (CH_2Cl_2-MeOH 95:5) to give **78** (13.41 g, 74%) as a white solid; $[\alpha]_D$ -35.7 (*c* 0.2, CH_2Cl_2); ^{1}H NMR (500 MHz, CD_3OD): δ 7.49 (dd, ^3J (H,H) = 6.7, 2.8, 2H; Ar-*H*), 7.33 (dd, ^3J (H,H) = 5.1, 2.0, 3H; Ar-*H*), 5.57 (s, 1H; C*H*Ph), 4.27 (dd, ^3J (H,H) =10.4, 4.4, 1H; H-1), 4.27 (dd, ^2J (H,H) = -10.4, ^3J (H,H) = 4.4, 1H; H-6a), 3.84 (dt, ^2J (H,H) = -9.6, ^3J (H,H) =6.7, 1H; C*H*H), 3.76 (apt. t, ^3J (H,H) = 9.8, 1H, H-6b), 3.62 (apt. t, ^3J (H,H) =8.8, 1H; H-3), 3.57 (dt, ^2J (H,H) = -9.6, ^3J (H,H) = 6.6, 1H; C*H*H), 3.49 – 3.39 (m, 2H, H-4, H-5, overlapping peaks), 3.27 (d, ^3J (H,H) = 8.6, 1H; H-2), 1.67 – 1.53 (m, 2H; CH_2), 1.47 – 1.36 (m, 2H; CH_2), 0.93 (t, ^3J (H,H) =7.4, 3H; CH_3); ^{13}C NMR (126 MHz, CD_3OD): δ 137.7 (Ar-*C*) 128.5, 127.6, 126.1 (5 x Ar-*C*H, overlapping peaks), 103.6 (C-1), 101.5 (*C*HPh), 80.9 (C-4), 74.6 (C-2), 73.3 (C-3), 69.4 (*C*H_2), 68.3 (C-6), 66.1 (C-5), 31.5 (*C*H_2), 18.8 (*C*H_2), 12.7 (*C*H_3); IR (film) cm^{-1}: 3995, 3370, 2931, 2875, 1725, 1695, 1452, 1262, 1177, 1088, 1067, 980, 950, 751, 701; ESI-HRMS calcd for $C_{17}H_{25}O_{10}$ 325.1621, found *m/z* 325.1657 $[M+H]^+$.



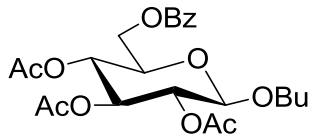
Butyl 2,3-di-*O*-acetyl-4,6-O-benzylidene-β-D-glucopyranoside (79)

78 (1 g, 3.08 mmol) was subjected to general procedure 1, using acetic anhydride as the acylating reagent. Purification by flash chromatography (cyclohexane-EtOAc 8:2) gave **79** (1.12g, 89%) as a white solid; $[\alpha]_D$ 6.7 (*c* 0.3, CH_2Cl_2); ^{1}H NMR (500 MHz, $CDCl_3$): δ 7.50 – 7.38 (m, 2H; Ar-*H*), 7.39 – 7.32 (m, 3H; Ar-*H*), 5.50 (s, 1H; C*H*Ph), 5.31 (apt. t, ^3J (H,H) =9.3, 1H; H-3), 4.99 (dd, ^3J (H,H) =9.4, 7.9, 1H; H-2), 4.57 (d, ^3J (H,H) =8.0, 1H; H-1), 4.36 (dd, ^2J (H,H) = -10.6, ^3J (H,H) =5.0, 1H; H-6a), 3.87 (dt, ^2J (H,H) = -9.6, ^3J (H,H) = 6.3, 1H; C*H*H), 3.80 (apt.t, ^3J (H,H) =10.3, 1H; H-6b), 3.69 (apt. t, ^3J (H,H) =9.6, 1H; H-4), 3.58 – 3.46 (m, 2H; C*H*H, H-5, overlaping peaks), 2.05 (s, 3H; COCH_3), 2.04 (s, 3H; COCH_3), 1.64 – 1.50 (m, 2H; CH_2), 1.42 – 1.29 (m, 2H; CH_2), 0.90 (t, ^3J (*H,H)* =7.4, 3H; CH_3); ^{13}C NMR (126 MHz, $CDCl_3$): δ 170.2, 169.5 (2 x *C*OCH_3), 136.8 (Ar-*C*), 129.1, 128.2, 126.1 (5 x Ar-*C*H, overlapping peaks), 101.4 (C-1, *C*HPh, overlapping peaks), 78.4 (C-4), 72.3 (C-2), 71.8 (C-2), 70.1 (C-3), 68.6 (*C*H_2), 66.3 (C-5), 31.4 (*C*H_2), 20.8, 20.7 (2 x CO*C*H_3), 18.9 (*C*H_2), 13.7 (*C*H_3); IR (film) cm^{-1}: 2961, 2876, 1733, 1371, 1240,

1177, 1087, 1057, 1027, 992, 966, 904, 762, 696; ESI-HRMS calcd for $C_{21}H_{28}O_8Na$ 431.1682, found *m/z* 431.1667 $[M+Na]^+$.

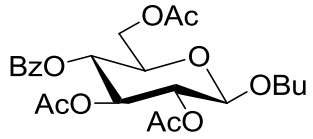
Preparation of compounds **80β** and **81β.**

79 (1g, 2.45 mmol) was subjected to the conditions outlined in general procedure 2, using acetic anhydride as the acylating reagent. Purification by flash chromatography (cyclohexane-EtOAc 8:2) gave compounds **80β** (0.617 g, 54%) and **81β** (0.285 g, 25%).



Butyl 2,3,4-tri-*O*-acetyl-6-*O*-benzoyl- β -D-glucopyranoside (80β)

$[\alpha]_D$ -12.5 (*c* 1.6, CH_2Cl_2); ^{1}H NMR (500 MHz, $CDCl_3$): δ 8.05 (dd, ^3J (H,H) = 8.5, 1.3, 2H; Ar-H), 7.63 – 7.53 (m, 1H; Ar-H), 7.48 – 7.42 (m, 2H; Ar-H), 5.24 (apt. t, ^3J (H,H) = 9.4, 1H; H-3), 5.18 (apt. t, ^3J (H,H) = 9.6, 1H; H-4), 5.01 (dd, ^3J (H,H) = 9.4, 8.0, 1H; H-2), 4.53 (d, ^3J (H,H) = 8.0, 1H; H-1), 4.51 (dd, ^2J (H,H) = -12.2, ^3J (H,H) = 2.7, 1H; H-6a), 4.38 (dd, ^2J (H,H) = -12.0, ^3J (H,H) = 4.8, 1H; H-6b), 3.90 – 3.77 (m, 2H; H-5, C*H*H, overlapping peaks), 3.49 (dt, ^2J (H,H) = 9.6, ^3J (H,H) = 6.7, 1H; C*H*H), 2.04 (s, 3H; COCH_3), 2.01 (s, 6H; 2 x COCH_3, overlapping peaks), 1.61 – 1.47 (m, 2H; CH_2), 1.39 – 1.19 (m, 2H; CH_2), 0.88 (t, ^3J (H,H) = 7.4, 3H; CH_3); ^{13}C NMR (126 MHz, $CDCl_3$): δ 170.3, 169.3 (3 x *C*OCH$_3$, overlapping peaks), 166.2 (*C*OPh), 133.2, 129.7 (3 x Ar-*C*H, overlapping peaks), 129.6 (Ar-*C*), 128.4 (Ar-*C*H, overlapping peaks), 100.8 (C-1), 72.9 (C-3), 71.7 (C-5), 71.4 (C-2), 69.9 (*C*H$_2$), 68.9 (C-4), 62.7 (C-6), 31.4 (*C*H$_2$), 20.6 (3 x CO*C*H$_3$), 18.9 (*C*H$_2$), 13.7 (*C*H$_3$). IR (film) cm^{-1}: 2963, 2874, 1731, 1368, 1241, 1175, 1089, 1060, 1025, 1001, 950, 901, 759; ESI-HRMS calcd for $C_{23}H_{34}O_{10}N$ 484.2183, found *m/z* 484.2189 $[M+NH_4]^+$.

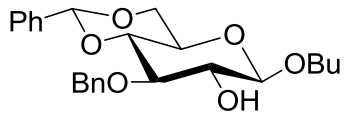


Butyl 2,3,6-tri-*O*-acetyl-4-*O*-benzoyl- β -D-glucopyranoside (81β)

$[\alpha]_D$ -64.3 (*c* 0.9, CH_2Cl_2); ^{1}H NMR (500 MHz, $CDCl_3$): δ 7.99 – 7.94 (m, 2H, Ar-H), 7.59 – 7.55 (m, 1H; Ar-H), 7.47 – 7.41 (m, 2H; Ar-H), 5.41 (apt. t, ^3J (H,H) = 9.5 Hz, 1H; H-3), 5.34 (apt. t, ^3J (H,H) = 9.6 Hz, 1H; H-4), 5.05 (dd, ^3J (H,H) = 9.5, 7.9 Hz, 1H; H-2), 4.57 (d, ^3J (H,H) =7.9 Hz, 1H; H-1), 4.25 (dd, ^2J (H,H) = -12.2, ^3J (H,H) =5.0 Hz, 1H; H-6a), 4.19 (dd, ^2J (H,H) = -12.2, ^3J (H,H) = 3.2 Hz, 1H; H-6b), 3.90 (dt, ^2J (H,H) = -9.6, ^3J (H,H) = 6.3 Hz, 1H; C*H*H), 3.83 (ddd, *J* = 9.8, 5.0, 3.2 Hz, 1H; H-5), 3.52 (dt, ^2J (H,H) = -9.7, ^3J (H,H) = 6.7 Hz, 1H; C*H*H), 2.05 (s, 3H; COCH_3), 2.00 (s, 3H; COCH_3), 1.90 (s, 3H; COCH_3), 1.64 – 1.51 (m, 2H; CH_2), 1.42 – 1.31 (m, 2H; CH_2), 0.91 (t, ^3J (H,H) =7.4 Hz, 3H; CH_3); ^{13}C NMR (126 MHz, $CDCl_3$): δ 170.6, 170.2, 169.3 (3 x *C*OCH_3), 165.1 (*C*OPh), 133.6, 129.8 (2s, 3 x Ar-*C*H, overlapping peaks), 128.8 (Ar-*C*), 128.6 (Ar-*C*H, overlapping peaks), 100.92 (C-1), 72.6 (C-3), 71.8 (C-5), 71.5 (C-2), 69.9 (*C*H_2), 69.4 (C-4), 62.5 (C-6), 31.4(*C*H_2), 20.6, 20.5 (3 x CO*C*H_3, overlapping peaks), 19.0 (*C*H_2), 13.7 (*C*H_3); IR (film) cm^{-1}: 2964, 2880, 1735, 1373, 1241, 1178, 1083, 1059, 1031, 987, 962, 900, 761; ESI-HRMS calcd for $C_{23}H_{34}O_8N$ 484.2183, found *m/z* 484.2184 $[M+NH_4]^+$.

Preperation of compounds **82** and **83.**

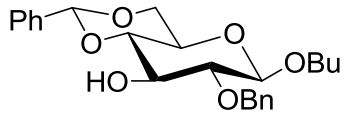
Compound **78** (5.6 g, 17.26 mmole) was taken up in CH_2Cl_2 (90 mL) and to this was added TBAHS (0.586 g, 1.73 mmole) and a 5% aq solution of NaOH (45mL). The mixture was refluxed for 48 h, allowed to cool to room temperature and the reaction was quenched by the addition of a 1 M HCl solution. The biphasic mixture was extracted with CH_2Cl_2 twice and the resulting organic solution was dried over Na_2SO_4, filtered and solvent was removed under diminished pressure. The resulting residue was purified by flash chromatography (toluene-acetone 9:1) allowing for separation of the products to give compounds **82** (2.75 g, 39%) and **83** (1.21 g, 17%).



Butyl 3-*O*-benzyl-4,6-O-benzylidene-β-D-glucopyranoside (82)

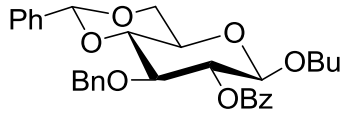
$[\alpha]_D$ -18.7 (*c* 0.1, CH_2Cl_2); ^{1}H NMR (500 MHz, $CDCl_3$): δ 7.51 – 7.46 (m, 2H; Ar-*H*), 7.42 – 7.34 (m, 5H; Ar-*H*), 7.34 – 7.27 (m, 3H; Ar-*H*), 5.57 (s, 1H; C*H*Ph), 4.96 (d, ^2J (H,H) = -11.7, 1H; C*H*HPh), 4.81 (d, ^2J (H,H) = -11.7, 1H; C*H*HPh), 4.39 (d,

^{3}J (H,H) = 7.7, 1H; H-1), 4.35 (dd, ^{2}J (H,H) = -10.5, ^{3}J (H,H) = 4.9, 1H; H-6a), 3.90 (dt, ^{2}J (H,H) = -9.5, ^{3}J (H,H) =6.8, 1H; C*H*H), 3.80 (apt. t, ^{3}J (H,H) = 10.3, 1H; H-6b), 3.71 (apt. t, ^{3}J (H,H) = 9.1, 1H; H-4), 3.66 (apt. t, ^{3}J (H,H) =8.8, 1H; H-3), 3.59 – 3.54 (m, 2H; C*H*H, H-2), 3.44 (td, ^{3}J (H,H) =9.4, 5.0, 1H; H-5), 2.40 (d, ^{3}J (H,H) =2.2, 1H; O*H*), 1.63 (dq, ^{3}J (H,H) =9.0, 6.9, 2H; CH_2), 1.39 (h, ^{3}J (H,H) =7.4, 2H; CH_2), 0.93 (t, ^{3}J (H,H) =7.4, 3H; CH_3); ^{13}C NMR (126 MHz, $CDCl_3$): δ 138.4, 137.3 (2 x Ar-*C*), 129.0, 128.4, 128.2, 128.0, 127.7, 126.0 (10 x Ar-*C*H, overlapping peaks), 103.3 (C-1), 101.2 (*C*HPh), 81.4 (C-4), 80.2 (C-3), 74.5 (*C*H_2Ph), 74.4 (C-2), 70.2 (*C*H_2), 68.7 (C-6), 66.4 (C-5), 31.6 (*C*H_2), 19.1(*C*H_2), 13.8 (*C*H_3); IR (film) cm^{-1}: 3065, 2961, 1723, 1452, 1260, 1088, 1067, 1026, 1002, 853, 706;ESI-HRMS calcd for $C_{24}H_{31}O_6$ 415.2121, found *m/z* 415.2122 $[M+H]^+$.



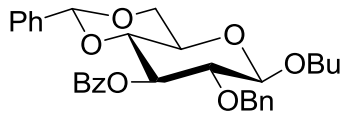
Butyl 2-*O*-benzyl-4,6-O-benzylidene-β-D-glucopyranoside (83)

$[\alpha]_D$ -12.1 (*c* 0.1, CH_2Cl_2); ^{1}H NMR (500 MHz, $CDCl_3$): δ 7.52 – 7.45 (m, 2H; Ar-*H*), 7.41 – 7.33 (m, 6H; Ar-*H*), 7.33 – 7.29 (m, 1H; Ar-*H*), 5.52 (s, 1H; C*H*Ph), 4.96 (d, ^{2}J (H,H) = -11.4, 1H; C*H*HPh), 4.73 (d, ^{2}J (H,H) = -11.4, 1H; C*H*HPh), 4.51 (d, ^{3}J (H,H) = 7.7, 1H; H-1), 4.34 (dd, ^{2}J (H,H) = -10.5, ^{3}J (H,H) =5.0, 1H; H-6a), 3.94 (dt, ^{2}J (H,H) =9.5, ^{3}J (H,H) = 6.6, 1H; C*H*H), 3.83 (td, ^{3}J (H,H) =9.1, 2.2, 1H; H-3), 3.78 (apt. t, ^{3}J (H,H) = 10.3, 1H; H-6b), 3.61 – 3.51 (m, 2H; C*H*H, H-4, overlapping peaks), 3.42 (td, ^{3}J (H,H) = 9.7, 5.0, 1H; H-5), 3.37 – 3.31 (m, 1H; H-2), 2.47 (d, ^{3}J (H,H) = 2.2, 1H; O*H*), 1.65 (dq, ^{3}J (H,H) = 15.3, 6.9, 2H; CH_2), 1.43 (dq, ^{3}J (H,H) = 15.0, 7.3, 2H; CH_2), 0.94 (t, ^{3}J (H,H) = 7.4, 3H; CH_3); ^{13}C NMR (126 MHz, $CDCl_3$): δ 138.2, 137.0 (2 x Ar-C), 129.2, 128.5, 128.3, 128.1, 127.9, 126.3 (10 x Ar-*C*H, overlapping peaks), 103.8 (C-1), 101.7 (*C*HPh), 81.8 (C-2), 80.4 (C-4), 74.7 (*C*H-$_2$Ph), 73.1 (C-3), 70.2 (*C*H_2), 68.7 (C-6), 66.1 (C-5), 31.8 (*C*H_2), 19.3(*C*H_2), 13.8 (*C*H_3); IR (film) cm^{-1}: 3498, 3065, 2958, 2931, 2875, 1457, 1386, 1375, 1274, 1180, 1101, 1085, 1051, 981, 965, 909, 920, 851, 794, 731, 695; ESI-HRMS calcd for $C_{24}H_{31}O_6$ 415.2121, found *m/z* 415.2126 $[M+H]^+$.



Butyl 2-*O*-benzoyl-3-*O*-benzyl-4,6-O-benzylidene- β -D-glucopyranoside (84)

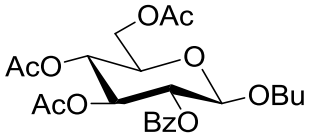
82 (2.5g, 6.03 mmol) was subjected to the conditions outlined in general procedure 1, using benzoyl chloride as the acylating reagent. Purification by flash chromatography (cyclohexane-EtOAc 9:1) gave **84** (2.28 g, 73%) as a white solid; $[\alpha]_D$ -31.5. (*c* 1.3, CH_2Cl_2); ^{1}H NMR (500 MHz, $CDCl_3$): δ 8.00 (dd, ^3J (H,H) =8.3, 1.4, 2H; Ar-*H*), 7.64 – 7.54 (m, 1H; Ar-*H*), 7.54 – 7.49 (m, 2H; Ar-*H*), 7.46 (d, ^3J (H,H) =6.8, 1H; Ar-*H*), 7.43 – 7.37 (m, 3H; Ar-*H*), 7.19 – 7.12 (m, 3H; Ar-*H*), 7.11 – 7.04 (m, 2H; Ar-*H*), 5.62 (s, 1H; C*H*HPh), 5.32 – 5.22 (m, 1H; H-2), 4.83 (d, ^2J (H,H) = -12.1, 1H; C*H*HPh), 4.70 (d, ^2J (H,H) = -12.1, 1H; C*H*HPh), 4.59 (d, ^3J (H,H) =7.9, 1H; H-1), 4.39 (dd, ^2J (H,H) = -10.5, ^3J (H,H) = 5.0, 1H; H-6a), 3.91 – 3.79 (m, 4H; H6b, H-4, H-3, C*H*H, overlapping peaks), 3.51 (dt, ^3J (H,H) =9.7, 4.7, 1H; H-5), 3.45 (dt, ^2J (H,H) = -9.8, ^3J (H,H) =6.8, 1H; C*H*H), 1.53 – 1.37 (m, 2H; CH_2), 1.27 – 1.12 (m, 2H; CH_2), 0.71 (t, ^3J (H,H) =7.4, 3H; CH_3); ^{13}C NMR (126 MHz, $CDCl_3$): δ 165.1 (*C*OPh), 137.9, 137.2 (2 x Ar-*C*), 133.0 (Ar-*C*H), 129.9 (Ar-*C*), 129.8, 129.0, 128.3, 128.1, 128.0, 127.5, 126.0 (14 x Ar-*C*H, overlapping peaks), 101.8 (C-1), 101.3 (*C*HPh), 81.7 (C-4), 77.9 (C-3), 73.9 (*C*H_2Ph), 73.5 (C-2), 70.0 (*C*H_2), 68.8 (C-6), 66.3 (C-5), 31.4 (*C*H_2), 18.8 (*C*H_2), 13.5 (*C*H_2); IR (film) cm^{-1}: 3493, 3065, 2958, 2875, 1498, 1457, 1374, 1274, 1180, 1101, 1085, 1051, 981, 965, 909, 920, 696; ESI-HRMS calcd for $C_{31}H_{38}O_7$ 536.2648, found *m/z* 536.2643 $[M+NH_4]^+$.



Butyl 2-*O*-benzyl-3-*O*-benzoyl-4,6-O-benzylidene-β-D-glucopyranoside (85)

To a solution of **83** (1 g, 2.4 mmol) was subjected to the conditions outlined in general procedure 1, using benzoyl chloride as the acylating reagent. Purification by flash chromatography (cyclohexane-EtOAc 9:1) gave **85** (1.0 g, 80%) as a white solid; $[\alpha]_D$ -33.3 (*c* 1.6, CH_2Cl_2); ^{1}H NMR (500 MHz, $CDCl_3$): δ 7.98 (d, ^3J (H,H) =7.6, 2H; Ar-*H*), 7.56 (t, ^3J (H,H) =7.4, 1H; Ar-*H*), 7.50 – 7.39 (m, 3H; Ar-*H*), 7.35 – 7.26 (m, 3H; Ar-*H*), 7.20 – 7.05 (m, 4H; Ar-*H*), 5.58 (apt. t, ^3J (H,H) =9.4, 1H), 5.47 (s, 1H; C*H*HPh), 4.82 (d, ^2J (H,H) = -11.5, 1H; C*H*HPh), 4.71 – 4.63 (m, 1H; C*H*HPh, H-1,overlapping peaks), 4.38 (dd, ^2J (H,H) = -10.5, ^3J (H,H) = 4.9, 1H; H-6a), 3.98 (dt, ^2J (H,H) = -9.5, ^3J (H,H) = 6.5, 1H; C*H*H), 3.81 (apt. t, ^3J (H,H) =10.3,

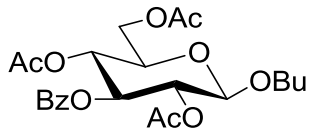
1H; H-6b), 3.73 (apt. t, ^{3}J (H,H) =9.5, 1H; H-4), 3.68 – 3.50 (m, 3H; C*H*H, H-5, H-2), 1.79 – 1.61 (m, 2H; CH_2), 1.51 – 1.42 (m, 2H; CH_2), 0.96 (t, ^{3}J (H,H) =7.4, 3H; CH_3); ^{13}C NMR (126 MHz, $CDCl_3$): δ 165.5 (*C*OPh), 137.6, 136.9 (2 x Ar-*C*), 132.9 (Ar-*C*H), 130.0 (Ar-*C*), 129.8, 128.9, 128.2, 128.1, 127.6, 126.1 (14 x Ar-*C*H, overlapping peaks), 104.2 (C-1), 101.3 (*C*HPh), 79.3 (C-3), 78.9 (C-4), 74.3 (*C*H_2Ph), 73.2 (C-3), 70.3 (*C*H_2), 68.8 (C-6), 66.2 (C-5), 31.8 (*C*H_2), 19.3 (*C*H_2), 13.8 (*C*H_3); IR (film) cm^{-1}: 3037, 2959, 2933, 2864, 1719, 1268, 1085, 1068, 991, 960, 696; ESI-HRMS calcd for $C_{31}H_{38}O_7$ 536.2648, found *m/z* 536.2657 $[M+NH_4]^+$.



Butyl 2-O-benzoyl-4,6,3-tri-*O*-acetyl-β-D-glucopyranoside (86β)

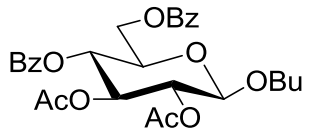
84 (0.5 g, 0.96 mmol) was taken up in CH_2Cl_2/MeOH (1:1, 20 mL) and placed under a N_2 atmosphere before adding catalytic 20% Pd-C. H_2 gas was then bubbled through the systema and the resulting mixture was stirred overnight under an atmosphere of H_2 (balloon). The H_2 atmosphere was then replaced with N_2, filtered and solvent was evaporated under diminished pressure. The resulting residue was taken up in pyridine (5 mL) and cooled using and ice bath. To this was added Ac_2O (0.225 mL, 2.4 mmol) and the solution was stirred overnight before being diluted with EtOAc (30 mL), washed twice with 1M HCl (50 mL), satd aq $NaHCO_3$ (50 mL), brine (50 mL), dried over Na_2SO_4, filtered and the solventwas removed under diminished pressure. Flash chromatography of the redisue (cyclohexane-EtOAc 7:3) gave **86β** (0.41 g, 91%) as a white solid; $[\alpha]_D$ -9.5 (*c* 2.5 CH_2Cl_2); ^{1}H NMR (500 MHz, $CDCl_3$): δ 8.07 – 7.91 (m, 2H; Ar-H), 7.65 – 7.53 (m, 1H; Ar-H), 7.50 – 7.39 (m, 1H; Ar-H), 5.40 (apt. t, ^{3}J (H,H) = 9.6 Hz, 1H; H-3), 5.26 (dd, ^{3}J (H,H) =9.8, 7.9 Hz, 1H; H-2), 5.17 (apt. t, ^{3}J (H,H) = 9.7 Hz, 1H; H-4), 4.63 (d, ^{3}J (H,H) =7.9 Hz, 1H; H-1), 4.31 (dd, ^{2}J (H,H) = -12.2, ^{3}J (H,H) = 4.8 Hz, 1H; H6a), 4.18 (dd, ^{2}J (H,H) = -12.2, ^{3}J (H,H) = 2.5 Hz, 1H; H-6b), 3.88 (dt, ^{2}J (H,H) = -9.7, ^{3}J (H,H) = 6.3 Hz, 1H; C*H*H), 3.77 (ddd, *J* = 10.0, 4.8, 2.5 Hz, 1H; H-5), 3.49 (dt, ^{2}J (H,H) = 9.7, ^{3}J (H,H) = 6.7 Hz, 1H; C*H*H), 2.11 (s, 3H; CO*C*H_3), 2.04 (s, 3H; CO*C*H_3), 1.93 (s, 3H; CO*C*H_3), 1.56 – 1.41 (m, 2H,; CH_2), 1.31 – 1.14 (m, 2H; CH_2), 0.74 (t, ^{3}J (H,H) =7.4 Hz, 3H; CH_3); ^{13}C NMR (126 MHz, $CDCl_3$): δ 170.7, 170.3, 169.4 (3 x *C*OCH_3), 165.0 (*C*OPh), 133.3, 129.7 (Ar-*C*H, overlapping peaks), 129.4 (Ar-*C*), 128.4 (Ar-*C*H),

101.1 (C-1), 72.7 (C-3), 71.9 (C-5), 71.7 (C-2), 70.0 (*C*H_2), 68.6 (C-4), 62.1 (C-6), 31.3 (*C*H_2), 20.8, 20.6, 20.6 (3 x CO*C*H_3), 18.8 (*C*H_2), 13.5 (*C*H_3); IR (film) cm^{-1}: 2961, 1746, 1237, 1029, 715, 612; ESI-HRMS calcd for $C_{23}H_{34}O_8N$ 484.2183, found *m/z* 484.2185 $[M+NH_4]^+$.



Butyl 2,4,6-tri-*O*-acetyl-3-*O*-benzoyl- β -D-glucopyranoside (87β)

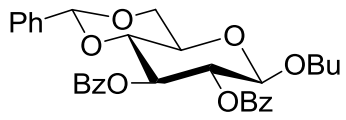
Prepared using the procedure previously described to prepare compound **86β** starting with **85** (0.5 g, 0.96 mmol) to give **87β** (0.39 g, 87%) as a viscous oil; $[\alpha]_D$ 27.22 (*c* 1.2, CH_2Cl_2); ^{1}H NMR (500 MHz, $CDCl_3$): δ 8.04 – 7.83 (m, 2H; Ar-*H*), 7.60 – 7.52 (m, 1H; Ar-*H*), 7.43 (apt. t, ^3J (H,H) =7.8, 2H; Ar-*H*), 5.47 (d, ^3J (H,H) =9.6, 1H; H-3), 5.26 (apt.t, ^3J (H,H) =9.8, 1H; H-4), 5.15 (dd, ^3J (H,H) =9.8, 8.0, 1H; H-2), 4.58 (d, ^3J (H,H) =8.0, 1H; H-1), 4.30 (dd, ^2J (H,H) = -12.3, ^3J (H,H) = 4.8, 1H; H-6a), 4.17 (dd, ^2J (H,H) = -12.3, ^3J (H,H) = 2.4, 1H; H-6b), 3.90 (dt, ^2J (H,H) = -9.7, ^3J (H,H) = 6.3, 1H; C*H*H), 3.78 (ddd, ^3J (H,H) = 9.9, 4.8, 2.5, 1H; H-5), 3.52 (dt, ^2J (H,H) = -9.6, ^3J (H,H) =6.8, 1H; C*H*H), 2.10 (s, 3H; COC*H*$_3$), 1.95 (s, 3H; COC*H*$_3$), 1.92 (s, 3H; COC*H*$_3$), 1.64 – 1.48 (m, 2H; C*H*$_2$), 1.44 – 1.26 (m, 2H; C*H*$_2$), 0.91 (t, ^3J (H,H) =7.4, 3H; C*H*$_3$); ^{13}C NMR (126 MHz, $CDCl_3$): δ 170.7, 169.3, 169.2 (3 x *C*OCH$_3$), 165.9 (*C*OPh), 133.5, 129.8 (3 x Ar-*C*H, overlapping peaks), 128.9 (Ar-*C*), 128.5 (Ar-*C*H, overlapping peaks), 100.9 (C-1), 73.3 (C-3), 71.8 (C-5), 71.3 (C-2), 69.9 (*C*H_2), 68.4 (C-4), 62.0 (C-6), 31.4 (*C*H_2), 20.8, 20.6, 20.5 (3 x CO*C*H_3), 18.9 (*C*H_2), 13.7 (*C*H_3). IR (film) cm^{-1}: 2962, 1742, 1267, 1092, 1028, 896, 708, 522; ESI-HRMS calcd for $C_{23}H_{30}O_{10}Na$ 489.1737, found *m/z* 489.1741 $[M+Na]^+$.



Butyl 2,3-di-*O*-acetyl-4,6-di-*O*-benzoyl- β -D-glucopyranoside (88β)

79 (0.5g, 1.22 mmole) was subjected to the conditions outlined in general procedure 2, using benzoyl chloride as the acylating reagent. Purification by flash chromatography (cyclohexane-EtOAc 7:3) gave **88β** (0.40 g, 62%) as a foam; $[\alpha]_D$ 11.7 (*c* 0.1, CH_2Cl_2); ^{1}H NMR (500 MHz, $CDCl_3$): δ 8.01 – 7.90 (m, 4H; Ar-*H*),

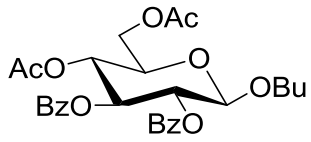
7.64 – 7.50 (m, 2H; Ar-*H*), 7.44 – 7.35 (m, 4H; Ar-*H*), 5.51 – 5.41 (m, 2H; H-3,H-4, overlapping peaks), 5.15 – 5.00 (m, 1H; H-3), 4.61 (d, ^{3}J (H,H) =8.0, 1H; H-1), 4.56 (dd, ^{2}J (H,H) = -12.1, ^{3}J (H,H) = 3.3, 1H; H-6a), 4.42 (dd, ^{2}J (H,H) = -12.1, ^{3}J (H,H) = 5.2, 1H; H-6b), 4.04 – 3.94 (m, 1H; H-5), 3.88 (dt, ^{2}J (H,H) = -9.7, ^{3}J (H,H) = 6.3, 1H; C*H*H), 3.51 (dt, ^{2}J (H,H) = -9.6, ^{3}J (H,H) =6.7, 1H; C*H*H), 2.06 (s, 3H; COCH_3), 1.91 (s, 3H; COCH_3), 1.61 – 1.53 (m, 2H; CH_2), 1.44 – 1.26 (m, 2H; CH_2), 0.89 (t, ^{3}J (H,H) =7.4, 3H; CH_3); ^{13}C NMR (126 MHz, $CDCl_3$): δ 170.2, 169.4 (2 x *C*OCH$_3$), 166.1, 165.1 (2 x *C*OPh), 133.5, 133.1, 129.8, 129.7 (6 x Ar-*C*H, overlapping peaks), 129.6, 128.8 (2 x Ar-*C*), 128.5, 128.3 (4 x Ar-*C*H, overlapping peaks), 100.9 (C-1), 72.6 (C-3), 71.9 (C-5), 71.5 (C-2), 69.9 (*C*H$_2$), 69.7 (C-4), 63.1 (C-6), 31.4 (*C*H$_2$), 20.7, 20.5 (2 x CO*C*H$_3$), 18.9 (*C*H$_2$), 13.7 (*C*H$_3$). IR (film) cm^{-1}: 2967, 1754, 1277, 1213, 1071, 764, 706 ; ESI-HRMS calcd for $C_{28}H_{36}O_{10}N$ 546.2339, found *m/z* 546.2343 $[M+NH_4]^+$.



Butyl 2,3-di-*O*-benzyl-4,6-O-benzylidene-β-D-glucopyranoside (89)

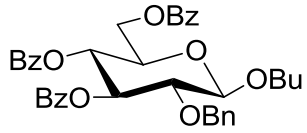
78 (1.22 g, 5.16 mmole) was subjected to the conditions outlined in general procedure 1, using benzoyl as the acylating reagent. Purification by flash chromatography (cyclohexane-EtOAc 8:2) gave **89** (2.12 g, 77%) as a foam; $[\alpha]_D$ 39.6 (*c* 0.6, CH_2Cl_2); ^{1}H NMR (500 MHz, $CDCl_3$): δ 7.96 (d, ^{3}J (H,H) =7.6, 3H; Ar-*H*), 7.49 (dd, ^{3}J (H,H) =12.9, 7.1, 2H; Ar-*H*), 7.44 – 7.28 (m, 10H; Ar-*H*), 5.78 (apt. t, ^{3}J (H,H) =9.6, 1H; H-3) 5.55 (s, 1H; C*H*Ph), 5.49 – 5.43 (m, 1H; H-2), 4.79 (d, ^{3}J (H,H) =7.8, 1H; H-1), 4.44 (dd, ^{2}J (H,H) = -10.6, ^{3}J (H,H) = 4.9, 1H; H-6a), 3.97 – 3.83 (m, 3H; H-6b, H-4, *CH*H), 3.70 (td, ^{3}J (H,H) =9.7, 4.9, 1H; H-5), 3.53 (dt, ^{2}J (H,H) = -9.7, ^{3}J (H,H) = 6.7, 1H; C*H*H), 1.49 – 1.42 (m, 1H; CH_2), 1.33 – 1.17 (m, 2H; CH_2), 0.74 (t, ^{3}J (H,H) =7.4, 3H; CH_3); ^{13}C NMR (126 MHz, $CDCl_3$): δ 165.6, 165.2 (2 x *C*OPh), 136.8, 133.1, 133.0, 129.8, 129.7 (7 x Ar-*C*H, overlapping peaks), 129.4, 129.0, (3 x Ar-*C*, overlapping peaks), 128.3, 128.2, 126.1 (8x Ar-*C*H, overlapping peaks), 101.8 (C-1), 101.4 (*C*HPh), 78.9 (C-4), 72.5 (C-2), 72.1 (C-3), 70.2 (*C*H$_2$), 68.7 (C-6), 66.6 (C-5), 31.4 (*C*H$_2$), 18.8 (*C*H$_2$), 13.5 (*C*H$_3$). IR (film) cm^{-1}: 336, 2966, 2880, 1733, 1717, 1451, 1290, 1259, 1092, 1071, 1028, 987, 954,

847, 765, 709; ESI-HRMS calcd for $C_{31}H_{32}O_8Na$ 555.1995, found *m/z* 555.2003 $[M+Na]^+$.



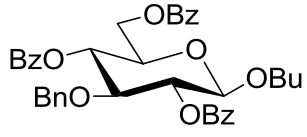
Butyl 2,3-di-*O*-benzoyl-4,6-di-*O*-acetyl- β -D-glucopyranoside (91β)

To a solution of **89** (2.0 g, 3.76 mmole) in CH_2Cl_2/MeOH (1:1, 10 mL) was added *p*-TsOH.H_2O (0.71 g, 3.76 mmol) and the reaction was stirred at room temperature until the starting material had been consumed, at which point the reaction was neutralised by the addition of triethylamine (0.75 mL, 5.6 mmole). The resulting solution was evaporated to dryness and the residue was taken up in pyridine (10 mL) and cooled using an ice bath. To this was added Ac_2O (1.3 mL, 15.04 mmol) and the reaction was allowed to attain room temperature and stir over night before being diluted with diluted with EtOAc (30 mL), washed twice with 1M HCl (50 mL), satd aq $NaHCO_3$ (50 mL), brine (50 mL), dried over Na_2SO_4, filtered and solvent was removed under diminished pressure. The resulting residue was purified by flash chromatography (cyclohexane-EtOAc 6:4) to give **91β** (1.03g, 52 %) as a white solid; $[\alpha]_D$ 2.7 (*c* 0.2, CH_2Cl_2); ^{1}H NMR (500 MHz, $CDCl_3$): δ 7.92 (dd, ^3J (H,H) =12.6, 7.7, 4H; Ar-*H*), 7.50 (td, ^3J (H,H) =7.3, 4.1, 2H; Ar-*H*), 7.37 (q, ^3J (H,H) =7.5, 4H; Ar-*H*), 5.65 (apt. t, ^3J (H,H) =9.7, 1H; H-3), 5.53 – 5.37 (m, 1H; H-2), 5.34 (apt. t, ^3J (H,H) =9.7, 1H; H-3), 4.71 (d, ^3J (H,H) =7.9, 1H; H-1), 4.34 (dd,^2J (H,H) = -12.4, ^3J (H,H) =4.5, 1H; H-6a), 4.21 (dd, ^2J (H,H) = -12.3, ^3J (H,H) = 2.5, 1H; H-6b), 3.96 – 3.77 (m, 2H; H-5, C*H*H, overlapping peaks), 3.51 (dt, ^2J (H,H) = -9.7, ^3J (H,H) =6.7, 1H; C*H*H), 2.12 (s, 3H; COC*H*$_3$), 1.94 (s, 3H; COC*H*$_3$), 1.49 (ddd, ^3J (H,H) =21.9, 10.6, 6.4, 2H; C*H*$_2$), 1.32 – 1.02 (m, 2H; C*H*$_2$), 0.74 (t, ^3J (H,H) =7.4, 3H; C*H*$_3$); ^{13}C NMR (126 MHz, $CDCl_3$): δ 170.7, 169.4 (2x *C*OCH$_3$), 165.8, 165.0 (2 x *C*OPh), 133.3, 133.1, 129.8, 129.7 (6 x Ar-*C*H, overlapping peaks), 129.4, 128.8 (2 x Ar-*C*), 128.4, 128.3 (4 x Ar-*C*H, overlapping peaks), 101.2 (C-1), 73.1 (C-3), 71.9 (C-4), 71.7 (C-5), 70.0 (*C*H$_2$), 68.6 (C-4), 62.1 (C-6), 31.3 (*C*H$_2$), 20.8, 20.5 (2 x CO*C*H$_3$), 18.8 (*C*H$_2$), 13.5 (*C*H$_3$); IR (film) cm^{-1}: 2965, 1721, 1369, 1277, 1222, 1089, 1055, 1028, 973, 707, 617; ESI-HRMS calcd for $C_{28}H_{36}O_{10}N$ 546.2339, found *m/z* 546.2337$[M+NH_4]^+$.



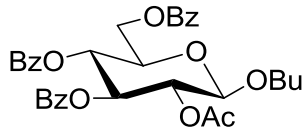
Butyl 2-O-benzyl-3,4,6-tri-*O*-benzoyl-β -D-glucopyranoside (94)

To a solution of **82** (1.7 g, 4.10 mmol) in CH_2Cl_2/MeOH (1:1, 20 mL) was added *p*-TsOH.H_2O (0.78 g, 4.10 mmol) and the reaction was stirred at room temperature until the starting material had been consumed, at which point the reaction was neutralised by the addition of triethylamine (0.7 mL, 4.92 mmol). The resulting solution was evapoted to dryness and the residue was taken up in pyridine and cooled using an ice bath. To this was added BzCl (0.95 mL, 8.20 mmol) and the reaction was allowed to attain room temperature and stir over night before being diluted with diluted with EtOAc (50 mL), washed twice with 1M HCl (100 mL), satd aq $NaHCO_3$ (100 mL), brine (100 mL), dried over Na_2SO_4, filtered and solvent was removed under diminished pressure. The resulting residue was purified via flash chromatography (cyclohexane-EtOAc 8:3) to give **94** (1.60 g, 61 %) as a foam.; $[\alpha]_D$ 4.5 (*c* 0.2, CH_2Cl_2); ^{1}H NMR (500 MHz, $CDCl_3$): δ 8.01 – 7.94 (m, 2H; Ar-*H*), 7.59 – 7.43 (m, 3H; Ar-*H*), 7.34 (dt, ^3J (H,H) =25.1, 7.9, 6H; Ar-*H*), 7.19 – 7.03 (m, 5H; Ar-*H*), 5.68 (apt. t, ^3J (H,H) =9.6, 1H; H-3), 5.47 (apt. t, ^3J (H,H) =9.8, 1H; H-2), 4.83 (d, ^2J (H,H) = -11.7, 1H; C*H*HPh), 4.67 (d, ^3J=7.7, 1H; H-1), 4.66 (d, ^2J (H,H) = -11.7, 1H; C*H*HPh), 4.56 (dd, ^2J (H,H) = -12.0, ^3J (H,H) = 3.3, 1H; H-6a), 4.45 (dd, ^2J (H,H) = -12.0, ^3J (H,H) = 5.7, 1H; H-6b), 4.05 – 3.95 (m, 2H; H-5, C*H*H, overlapping peaks), 3.67 – 3.56 (m, 2H; H-4, C*H*H, overlapping peaks), 1.74 – 1.59 (m, 2H; CH_2), 1.50 – 1.37 (m, 2H; CH_2), 0.94 (t, ^3J (H,H) =7.4, 3H; CH_3); ^{13}C NMR (126 MHz, $CDCl_3$): δ 166.1, 165.7, 165.4 (3 x *C*OPh), 137.6 (Ar-*C*), 133.3, 133.0 , 129.8, 129.8, 129.7(9 x Ar-*C*H, overlapping peaks), 129.5, 128.9, (3 x Ar-*C*, overlapping peaks), 128.3, 128.2 , 128.1, 127.6(11 x Ar-*C*H, overlapping peaks), 103.8 (C-1), 78.5 (C-4), 74.1 (*C*H_2Ph), 73.9 (C-3), 71.8 (C-5), 70.1 (C-2), 70.0 (*C*H_2), 63.5 (C-6), 31.7 (*C*H_2), 19.2 (*C*H_2), 13.8 (*C*H_3); IR (film) cm^{-1}: 3341, 2974, 2876, 1724, 1263, 1117, 1091, 1068, 1028, 705 ESI-HRMS calcd for $C_{38}H_{38}O_9Na$ 661.2414, found *m/z* 661.2408 $[M+Na]^+$.



Butyl 2,4,6-tri-*O*-benzoyl-3-O-benzyl- β -D-glucopyranoside (95β)

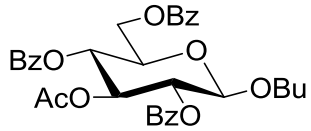
Prepared using the procedue for the preperation of compound **94**, starting from **82** (2.0 g, 4.82 mmol) giving **95β** (1.66 g, 54 %) as a foam; $[\alpha]_D$ 6.1 (*c* 0.3, CH_2Cl_2); ^{1}H NMR (500 MHz, $CDCl_3$): δ 8.05 – 7.97 (m, 2H; Ar-*H*), 7.60 – 7.55 (m, 4H; Ar-*H*), 7.54 – 7.50 (m, 2H; Ar-*H*), 7.47 – 7.44 (m, 1H; Ar-*H*), 7.44 – 7.40 (m, 2H; Ar-*H*), 7.37 (t, ^3J (H,H) =7.7, 2H; Ar-*H*), 7.07 – 7.01 (m, 1H; Ar-*H*), 6.98 (m, 4H; Ar-*H*), 5.57 (apt. t, ^3J (H,H) =9.5, 1H; H-4), 5.43 – 5.33 (m, 1H; H-2), 4.67 (d, ^3J (H,H) =7.8, 1H; H-1), 4.62 – 4.55 (m, 3H; H-6a, C*HH*Ph, overlapping peaks), 4.42 (dd, ^2J (H,H) = -12.0, ^3J (H,H) = 5.5, 1H; H-6b), 4.07 (apt.t, ^3J (H,H) =9.1, 1H; H-3), 3.99 (ddd, ^3J (H,H) =9.3, 5.5, 3.4, 1H; H-5), 3.86 (dt, ^2J (H,H) =9.8, ^3J (H,H) = 6.3, 1H; C*H*H), 3.48 (dt, ^2J (H,H) = -9.8, ^3J (H,H) = 6.7, 1H; C*H*H), 1.61 – 1.40 (m, 1H; C*H*-$_2$), 1.29 – 1.14 (m, 1H; CH_2), 0.72 (t, ^3J (H,H) =7.5, 1H; CH_3); ^{13}C NMR (126 MHz, $CDCl_3$): δ 166.2, 165.0, 164.9 (*C*OPh), 137.2 (Ar-*C*), 133.4, 133.1, 133.0 (3 x Ar-*C*H), 129.8 (Ar-*C*, 2 x Ar-*C*H, overlapping peaks), 129.7, 129.7 (Ar-*C*, 4 x Ar-*C*H, overlapping peaks) 129.3 (Ar-*C*), 128.4, 128.3, 128.1, 128.0, 127.6 (11 x Ar-*C*H, overlapping peaks), 101.2 (C-1), 79.4 (C-3), 73.8 (*C*H_2Ph), 73.5 (C-2), 72.1 (C-5), 71.2 (C-4), 69.7 (*C*H_2), 63.5 (C-6), 31.4 (*C*H_2), 18.9(*C*H_2), 13.5(*C*H_3); IR (film) cm^{-1}: 3336, 2960, 2875, 1724, 1260, 1118, 1090, 1065, 1026, 703; ESI-HRMS calcd for $C_{38}H_{38}O_9Na$ 661.2414, found *m/z* 661.2435 $[M+Na]^+$.



Butyl 2-*O*-acetyl-3,4,6-tri-*O*-benzoyl- β -D-glucopyranoside (98β)

94 (1.5g, 2.35 mmol) was subjected to the conditions outlined in general procedure 2, using acetic anhydride as the acylating reagent. Purification by flash chromatography (cyclohexane-EtOAc 7:3) gave **98β** (0.81 g, 59%) as a foam; $[\alpha]_D$ 5.2 (*c* 0.1, CH_2Cl_2); ^{1}H NMR (500 MHz, $CDCl_3$): δ 8.00 (dd, ^3J (H,H) =8.1, 1.4, 2H; Ar-*H*), 7.89 (td, ^3J (H,H) =8.1, 1.4, 4H; Ar-*H*), 7.57 – 7.45 (m, 3H; Ar-*H*), 7.42 – 7.30 (m, 7H; Ar-*H*), 5.70 (apt. t, ^3J (H,H) =9.6, 1H; H-3), 5.59 (apt. t, ^3J (H,H) =9.7, 1H; H-4), 5.25 (dd, ^3J (H,H) =9.7, 7.9, 1H; H-2), 4.70 (d, ^3J (H,H) =7.9, 1H; H-1), 4.60 (dd, ^2J (H,H) =12.1, ^3J (H,H) =3.3, 1H; H-6a), 4.46 (dd, ^2J (H,H) =12.1, ^3J (H,H) = 5.3, 1H; H-6b), 4.07 (ddd, ^3J (H,H) = 9.8, 5.3, 3.3, 1H; H-5), 3.91 (dt, ^2J (H,H) = -9.6, ^3J (H,H) =6.4, 1H; C*H*H), 3.55 (dt, ^2J (H,H) = -9.6, ^3J (H,H) =6.7, 1H;

C*H*H), 1.97 (s, 3H; COC*H*$_3$), 1.67 – 1.49 (m, 2H; C*H*$_2$), 1.44 – 1.28 (m, 2H; C*H*$_2$), 0.90 (t, ^3J (H,H) =7.4, 3H; C*H*$_{20}$); ^{13}C NMR (126 MHz, $CDCl_3$): δ 169.3 (*C*OCH$_3$), 166.1, 165.8, 165.2 (3 x *C*OPh), 133.4, 133.3, 133.1, 129.8, 129.7 (9 x Ar-*C*H, overlapping peak), 129.6, 128.9, 128.8 (3 x Ar-*C*), 128.4, 128.3 (6 x Ar-*C*H, overlapping peaks), 101.0 (C-1), 73.1 (C-3), 72.0 (C-5), 71.5 (C-2), 69.9 (C-4), 69.8 (*C*H$_2$), 63.2 (C-6), 31.4 (*C*H$_2$), 20.6 (CO*C*H$_3$), 19.0 (*C*H$_2$), 13.7 (*C*H$_3$); IR (film) cm^{-1}: 2963, 1714, 1265, 1218, 1091, 1026, 706; ESI-HRMS calcd for $C_{33}H_{38}O_{10}N$ 608.2496, found *m/z* 608.2490 $[M+NH_4]^+$.

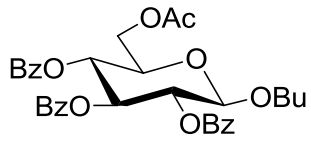


Butyl 2,4,6-tri-*O*-benzoyl-3-*O*-acetyl- β -D-glucopyranoside (99β)

95 (1.5g, 2.35 mmol) was subjected to the conditions outlined in general procedure 2, using acetic anhydride as the acylating reagent. Purification by flash chromatography (cyclohexane-EtOAc 7:3) gave **98β** (0.97 g, 72%) as a foam; $[\alpha]_D$ 12.71 (*c* 0.2, CH_2Cl_2); ^{1}H NMR (500 MHz, $CDCl_3$): δ 8.04 – 7.91 (m, 5H; Ar-*H*), 7.64 – 7.47 (m, 4H; Ar-*H*), 7.51 – 7.27 (m, 6H; Ar-*H*), 5.65 (apt.t, ^3J (H,H) =9.6, 1H; H-3), 5.51 (apt. t, ^3J (H,H) =9.7, 1H; H-4), 5.36 (dd, ^3J (H,H) =9.7, 7.9, 1H; H-2), 4.74 (d, ^3J (H,H) =7.9, 1H; H-1), 4.60 (dd, ^2J (H,H) = -12.0, ^3J (H,H) = 3.3, 1H; H-6a), 4.46 (dd, ^2J (H,H) = -12.1, ^3J (H,H) =5.3, 1H; H-6b), 4.06 (ddd, ^3J (H,H) =10.0, 5.2, 3.3, 1H; H-5), 3.88 (dt, ^2J (H,H) = -9.6, ^3J (H,H) = 6.3, 1H; C*H*H), 3.51 (dt, ^2J (H,H) = -9.8, ^3J (H,H) =6.7, 1H; C*H*H), 1.83 (s, 3H); COC*H*$_3$), 1.59 – 1.39 (m, 2H; C*H*$_2$), 1.34 – 1.16 (m, 2H; C*H*$_2$), 0.74 (t, ^3J (H,H) =7.4, 3H; C*H*$_3$); ^{13}C NMR (126 MHz, $CDCl_3$): δ 170.1 (*C*OCH$_3$), 166.1, 165.2, 165.0 (3 x *C*OPh), 133.5, 133.3, 133.1, 129.8, 129.8, 129.7 (9 x Ar-*C*H, overlapping peaks), 129.6 129.4, 128.8 (3 x Ar-*C*), 128.5 , 128.4, 128.3 (6 x Ar-*C*H., overlapping peaks), 101.2 (C-1), 72.4 (C-3), 72.1 (C-5), 71.9 (C-2), 70.0 (*C*H$_2$), 69.8 (C-4), 63.2 (C-6), 31.3 (*C*H$_2$), 20.5 (COCH$_3$), 18.8 (*C*H$_2$), 13.5 (*C*H$_2$); IR (film) cm^{-1}: 2960, 1716, 1452, 1263, 1215, 1090, 1068, 1026, 974, 706; ESI-HRMS calcd for $C_{33}H_{38}O_{10}N$ 608.2496, found *m/z* 608.2495 $[M+NH_4]^+$.

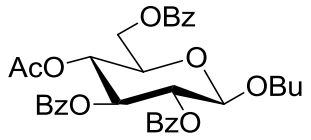
Preparation of compounds **102β** and **103β**:

To a solution of **89** (1.5 g, 2.8 mmol) was subjected to the conditions outlined in general procedure 2, using acetic anhydride as the acylating reagent. Purification by flash chromatography (cyclohexane-EtOAc 8:2) gave compounds **102β** (0.4 g, 24 %) and **103β** (0.8 g, 48%);



Butyl 2,3,4-tri-*O*-benzoyl-6-*O*-acetyl- β -D-glucopyranoside (102β)

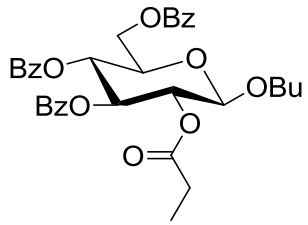
$[\alpha]_D$ 15.9 (*c* 0.2, CH_2Cl_2); ^{1}H NMR (500 MHz, $CDCl_3$): δ 7.95 (dd, ^3J (H,H) = 7.8, 1.7, 2H; Ar-H), 7.91 (dd, ^3J (H,H) = 8.0, 1.5, 2H; Ar-H), 7.86 – 7.80 (m, 2H; Ar-H), 7.55 – 7.48 (m, 2H; Ar-H), 7.45 – 7.40 (m, 1H; Ar-H), 7.37 (td, ^3J (H,H) = 7.7, 4.5, 5H; Ar-H), 7.28 (apt. t, ^3J (H,H) = 7.9, 2H; Ar-H), 5.86 (apt. t, ^3J (H,H) = 9.6, 1H; H-3), 5.58 (apt. t, ^3J (H,H) = 9.7, 1H; H-4), 5.49 (dd, ^3J (H,H) = 9.7, 7.8, 1H; H-2), 4.79 (d, ^3J (H,H) = 7.8, 1H; H-1), 4.33 (dd, ^2J (H,H) = -12.1, ^3J (H,H) = 4.9, 1H; H-6a), 4.27 (dd, ^2J (H,H) = 12.1, ^3J (H,H) = 3.1, 1H; H-6b), 4.00 (ddd, ^3J (H,H) = 9.8, 5.0, 3.1, 1H; H-5), 3.93 (dt, ^2J (*H,H)* = -9.7, ^3J (H,H) = 6.4, 1H; C*H*H), 3.55 (dt, ^2J (*H,H)* = -9.7, ^3J (H,H) = 6.7, 1H; C*H*H), 2.04 (s, 2H; COCH_3), 1.59 – 1.45 (m, 2H; CH_2), 1.32 – 1.17 (m, 2H; CH_2), 0.76 (t, ^3J (H,H) = 7.4, 3H; CH_3); ^{13}C NMR (126 MHz, $CDCl_3$): δ 170.6 (*C*OCH$_3$), 165.8, 165.2 (3 x *C*OPh, overlapping peaks), 133.4, 133.2, 133.1, 129.8, 129.7, 129.7 (9 x Ar-*C*H, overlapping peaks), 129.4, 128.8 (3 x Ar-*C*, overlapping peaks), 128.4, 128.3, 128.3 (6 x Ar-*C*H, overlapping peaks), 101.3 (C-1), 72.9 (C-3), 72.0 (C-5), 71.9 (C-2), 70.1 (*C*H$_2$), 69.5 (C-4), 62.6 (C-6), 31.4 (*C*H$_2$), 20.7 (CO*C*H$_3$). 18.9 (*C*H$_2$), 13.6 (*C*H$_3$); IR (film) cm^{-1}: 2945, 1730, 1226, 1067, 1025, 705; ESI-HRMS calcd for $C_{33}H_{34}O_{10}Na$ 613.2050, found *m/z* 613.2048 $[M+Na]^+$.



Butyl 2,3,6-tri-*O*-benzoyl-4-*O*-acetyl- β -D-glucopyranoside (103β)

$[\alpha]_D$ 9.4 (*c* 0.4, CH_2Cl_2); ^{1}H NMR (500 MHz, $CDCl_3$): δ 8.16 – 8.01 (m, 2H; Ar-*H*), 7.93 (ddd, ^3J (H,H) = 13.6, 8.4, 1.4, 4H; Ar-*H*), 7.67 – 7.55 (m, 1H; Ar-*H*), 7.56 – 7.44 (m, 4H; Ar-*H*), 7.44 – 7.30 (m, 4H; Ar-*H*), 5.69 (apt. t, ^3J (H,H) = 9.6, 1H; H-

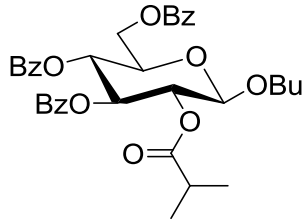
3), 5.48 – 5.37 (m, 2H; H-2, H-4, overlapping peaks), 4.76 (d, ^{3}J (H,H) = 7.9, 1H; H-1), 4.59 (dd, ^{2}J (H,H) = -12.1, ^{3}J (H,H) = 2.7, 1H; H-6a), 4.46 (dd, ^{2}J (H,H) = -12.1, ^{3}J (H,H) = 5.1, 1H; H-6b), 4.01 (ddd, ^{3}J (H,H) = 10.0, 5.1, 2.8, 1H; H-5), 3.89 (dt, ^{2}J (H,H) = -9.7, ^{3}J (H,H) = 6.3, 1H; C*H*H), 3.52 (dt, ^{2}J (*H,H)* = -9.7, ^{3}J (*H,H)* = 6.7, 1H; C*H*H), 1.93 (s, 3H; COCH_3), 1.58 – 1.40 (m, 2H; CH_2), 1.43 – 1.12 (m, 2H; CH_2), 0.73 (t, ^{3}J (*H,H)* = 7.4, 3H; CH_3).; ^{13}C NMR (126 MHz, $CDCl_3$): δ 169.4 (*C*OCH_3), 166.2, 165.8, 165.0 (3 x *C*OPh), 133.3, 133.2, 133.1, 129.8, 129.7 (9 x Ar-*C*H, overlapping peaks),129.6, 129.4, 128.9 (3 x Ar-*C*), 128.4, 128.4, 128.3 (6 x Ar-CH, overlapping peaks), 101.2 (C-1), 73.2 (C-3), 72.0 (C-5), 71.8 (C-2), 70.0 (*C*H_2) 69.0 (C-4), 62.9 (C-6), 31.3 (*C*H_2), 20.6 (CO*C*H_3), 18.8 (*C*H_2), 13.5 (*C*H_3); IR (film) cm^{-1}: 2960, 1730, 1450, 1286, 1101, 981, 661; ESI-HRMS calcd for $C_{33}H_{38}O_{10}N$ 608.2496, found *m/z* 608.2496 $[M+NH_4]^+$.



Butyl 2-propionyl-3,4,6-tri-*O*-benzoyl-β-D-glucopyranoside (105β)

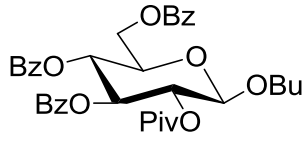
94 (0.25 g, 0.39 mmol) was subjected to the conditions outlined in general procedure 3, using propionyl chloride as the acylating reagent. Purification by flash chromatography (cyclohexane-EtOAc 7:2) gave **105β** (0.175 g, 74%) as a foam; $[\alpha]_D$ 37.8 (*c* 0.1, CH_2Cl_2); ^{1}H NMR (500 MHz, $CDCl_3$): δ 8.00 (d, ^{3}J (H,H) = 7.7, 2H; Ar-*H*), 7.90 (dd, ^{3}J (H,H) = 7.5, 2.0, 4H; Ar-*H*), 7.51 (dt, ^{3}J (H,H) = 21.8, 7.5, 3H; Ar-*H*), 7.45 – 7.32 (m, 6H; Ar-*H*), 5.71 (apt. t, ^{3}J (H,H) = 9.7, 1H; H-3), 5.60 (apt. t, ^{3}J (H,H) = 9.7, 1H; H-4), 5.38 – 5.22 (m, 1H; H-2), 4.71 (d, ^{3}J (H,H) = 7.9, 1H; H-1), 4.60 (dd, ^{2}J (H,H) = -12.2, ^{3}J (H,H) = 3.3, 1H; H-6a), 4.47 (dd, ^{2}J (H,H) = -12.2, ^{3}J (H,H) = 5.2, 1H; H-6b), 4.08 (ddd, ^{3}J (H,H) = 9.3, 5.3, 3.4, 1H; H-5), 3.91 (dt, ^{2}J (H,H) = -9.6, ^{3}J (H,H) = 6.4, 1H; C*H*H), 3.55 (dt, ^{2}J (H,H) = -9.7, ^{3}J (H,H) = 6.9, 1H; C*H*H), 2.24 (qd, ^{3}J (H,H) = 7.8, 5.7, 2H, CH_2), 1.67 – 1.50 (m, 2H; CH_2), 1.35 (dp, *J*=13.7, 6.8, 2H; CH_2), 0.99 (t, ^{3}J (H,H) = 7.6, 3H; CH_3), 0.90 (t, ^{3}J (H,H) = 7.4, 3H; CH_3); ^{13}C NMR (126 MHz, $CDCl_3$): δ 172.8 (*C*OCH_2CH_3), 166.1, 165.8, 165.2 (3 x *C*OPh), 133.4, 133.3, 133.1, 129.8, 129.7 (9 x Ar-*C*H, overlapping peaks), 129.6, 128.9, 128.8 (3 x Ar-*C*), 128.4, 128.3 (6 x Ar-*C*, overlapping peaks), 101.0

(C-1), 73.1 (C-3), 72.1 (C-5), 71.3 (C-2), 69.9 (*C*H_2), 69.8 (C-4), 63.2 (C-6), 31.4 (*C*H_2), 27.4 (*C*H_2), 19.0 (*C*H_2), 13.7 (*C*H_3), 9.0 (*C*H_3). ESI-HRMS calcd for $C_{34}H_{35}O_{10}Na$ 627.2206, found *m/z* 627.2214$[M+Na]^+$.



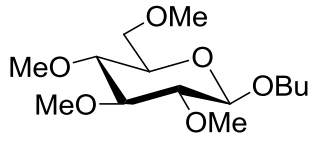
Butyl 2-*O*-isobutyryl-3,4,6-tri-*O*-benzoyl-β-D-glucopyranoside (106β)

94 (0.25 g, 0.39 mmol) was subjected to the conditions outlined in general procedure 3, using isobutyryl chloride as the acylating reagent. Purification by flash chromatography (cyclohexane-EtOAc 7:2) gave **106β** (0.195 g, 81%) as a foam; $[\alpha]_D$ 2.8 (*c* 0.2, CH_2Cl_2); ^{1}H NMR (500 MHz, $CDCl_3$): δ 8.08 – 7.98 (m, 2H; Ar-*H*), 7.89 (ddd, ^3J (H,H) =8.1, 4.3, 1.5, 4H; Ar-*H*), 7.59 – 7.47 (m, 3H; Ar-*H*), 7.41 – 7.32 (m, 6H; Ar- *H*), 5.73 (apt. t, ^3J (H,H) = 9.7, 1H; H-3), 5.60 (apt. t, ^3J (H,H) =9.7, 1H; H-4), 5.28 (dd, ^3J (H,H) =9.8, 7.9, 1H; H-2), 4.71 (d, ^3J (H,H) =7.9, 1H; H-1), 4.60 (dd, ^2J (H,H) = -12.1, ^3J (H,H) = 3.3, 1H; H-6a), 4.48 (dd, ^2J (H,H) = -12.0, ^3J (H,H) = 5.3, 1H; H-6b), 4.08 (ddd, ^3J (H,H) =9.2, 5.3, 3.3, 1H); H-5, 3.91 (dt, ^2J (H,H) = -9.6, ^3J (H,H) = 6.3, 1H; C*H*H), 3.54 (dt, ^2J (H,H) = -9.6, ^3J (H,H) = 6.8, 1H; C*H*H), 2.47 (p, ^3J (H,H) =7.0, 1H; C*H*$(CH_3)_2$), 1.62 – 1.49 (m, 2H; CH_2), 1.35 (ddt, ^3J (H,H) =14.1, 8.9, 7.0, 2H. CH_2), 1.05 (d, ^3J (H,H) =7.0, 3H; CH_3), 0.96 (d, ^3J (H,H) =7.0, 3H; CH_3), 0.89 (t, ^3J (H,H) =7.4, 3H; CH_3). ^{13}C NMR (126 MHz, $CDCl_3$): δ 175.4 (*C*OCH$(CH_3)_2$), 166.1, 165.8, 165.2 (3 x *C*OPh), 133.4, 133.3, 133.0, 129.8, 129.8, 129.7 (9 x Ar-*C*H, overlapping peaks), 129.6, 128.9, 128.8 (3 x Ar-*C*), 128.4, 128.3 (6 x Ar-*C*H, overlapping peaks), 101.1 (C-1), 73.0 (C-3), 72.1 (C-5), 71.0 (C-2), 69.9 (*C*H_2), 69.8 (C-4), 63.3 (C-6), 33.9 (*C*H$(CH_3)_2$), 31.5 (*C*H_2), 19.0 (*C*H_2), 18.7 (2 x *C*H_3, overlapping peaks), 13.7 (*C*H_3); IR (film) cm^{-1}: 33336, 2971, 2933, 2875, 1741, 1727, 1716, 1453, 1273, 1100, 1070, 1049, 1055, 975, 951, 708; ESI-HRMS calcd for $C_{35}H_{38}O_{10}Na$ 641.2363, found *m/z* 641.2333 $[M+Na]^+$.



Butyl 2-*O*-pivaloyl-3,4,6-tri-*O*-benzoyl-β-D-glucopyranoside (107β)

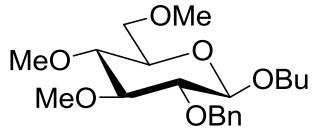
94 (0.25 g, 0.39 mmol) was subjected to the conditions outlined in general procedure 3, using trimethyl acetyl chloride as the acylating reagent. Purification by flash chromatography (cyclohexane-EtOAc 7:2) gave **106β** (0.172 g, 70%) as a foam; $[\alpha]_D$ 8.43 (*c* 0.2, CH_2Cl_2); ^{1}H NMR (500 MHz, $CDCl_3$): δ 8.10 – 7.95 (m, 2H; Ar-*H*), 7.89 (t, ^3J (H,H) =7.6, 4H; Ar-*H*), 7.67 – 7.37 (m, 3H; Ar-*H*), 7.42 – 7.33 (m, 6H; Ar-*H*), 5.75 (apt. t, ^3J (H,H) =9.7, 1H; H-3), 5.59 (apt. t, ^3J (H,H) =9.7, 1H; H-4), 5.27 (dd, ^3J (H,H) =9.9, 7.9, 1H; H-2), 4.71 (d, ^3J (H,H) =7.9, 1H; H-1), 4.60 (dd, ^2J (H,H) = -12.1, ^3J (H,H) =3.3, 1H; H-6a), 4.48 (dd, ^2J (H,H) = -12.1, ^3J (H,H) = 5.3, 1H; H-6b), 4.08 (ddd, ^3J (H,H) =9.2, 5.3, 3.3, 1H; H-5), 3.91 (dt, ^2J (H,H) = -9.6, ^3J (H,H) =6.4, 1H; C*H*H), 3.54 (dt, ^2J (H,H) = -9.7, ^3J (H,H) =6.8, 1H; C*H*H), 1.66 – 1.51 (m, 2H, CH_2), 1.44 – 1.26 (m, 2H; CH_2), 1.05 (s, 9H; 3 x CH_3, overlapping peaks), 0.89 (t, ^3J (H,H) =7.4, 1H; CH_3); ^{13}C NMR (126 MHz, $CDCl_3$): δ 176.6 (*C*OC$(CH_3)_3$), 166.1, 165.8, 165.2 (3 x *C*OPh), 133.4, 133.3, 133.0, 129.8, 129.7 (9 x Ar-*C*H, overlapping peaks), 128.9, 128.8 (3 x Ar-*C*, overlapping peaks), 128.4, 128.3 (6 x Ar-*C*H, overlapping peaks), 101.2 (C-1), 73.0 (C-3), 72.1 (C-5), 71.0 (C-2), 69.9 (C-4), 69.8 (*C*H_2), 63.3 (C-6), 38.7 (*C*$(CH_3)_3$), 31.5 (*C*H_2), 26.8 (3 x *C*H_3, overlapping peaks), 19.0 (*C*H_2), 13.7 (*C*H_3); ESI-HRMS calcd for $C_{36}H_{40}O_{10}Na$ 655.2519, found *m/z* 655.2529 $[M+Na]^+$.



Butyl 2,3,4,6-tetra-*O*-methyl-β-D-glucopyranoside (108β)[93]

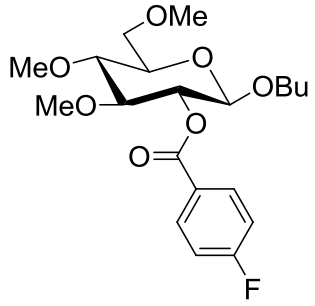
76 (0.5 g, 2.11 mmol) was taken up in DMF (10 mL) and cooled using an ice bath. To this was added 60% NaH (0.65 g, 16.93 mmol) and the rection mixture was stirred for 1 h, at which point MeI (1.05 mL, 16.93 mmo) was added. The resulting suspension was stirred over night before being diluted with Et_2O (10 mL) washed twice with 1M HCl (20 mL), satd aq $NaHCO_3$ (20 mL), brine (20 mL), dried over Na_2SO_4, filtered and the solvent was evaporated under diminished pressure. The resulting residue was purified via flash chromatography (cyclohexane-EtOAc 1:1) to give **108β** (0.32 g, 53%) as clear oil; $[\alpha]_D$ -18.7 (*c* 0.3, CH_2Cl_2); ^{1}H NMR (500 MHz, $CDCl_3$): δ 4.20 (d, ^3J (H,H) =7.5, 1H; H-1), 3.90 (dt, ^3J (H,H) =9.5, ^3J (H,H) = 6.4, 1H; C*H*H), 3.65 – 3.59 (m, 4H; H-6a, OCH_3, overlapping peaks)3.56 (s, 3H; OCH_3),

3.54 (dd, ^{2}J (H,H) = 10.7, ^{3}J (H,H) = 4.9, 1H; H-6b), 3.51 (s, 3H; OCH_3), 3.46 (dt, ^{2}J (H,H) = 9.5, ^{3}J (H,H) = 6.8, 1H; C*H*H), 3.25 (ddd, ^{3}J (H,H) = 9.4, 4.9, 2.0, 1H; H-5), 3.18 – 3.09 (m, 2H; H-3, H-4, overlapping peaks), 2.97 (td, ^{3}J (H,H) = 7.7, 1.4, 1H; H-2), 1.65 – 1.51 (m, 2H; CH_2), 1.45 – 1.31 (m, 2H; CH_2), 0.91 (t, ^{3}J (H,H) = 7.4, 3H; CH_3); ^{13}C NMR (126 MHz, $CDCl_3$): δ 103.4 (C-1), 86.4 (C-3), 83.8 (C-2), 79.5 (C-4), 74.6 (C-5), 71.4 (C-6), 69.7 (*C*H_2), 60.8, 60.4, 59.3 (4 x O*C*H_3), 31.7 (*C*H_2), 19.2 (*C*H_2), 13.8 (*C*H_3); IR (film) cm^{-1} : 3935, 2834, 1461, 1372, 1098; ESI-HRMS calcd for $C_{14}H_{28}O_6Na$ 315.1784, found *m/z* 345.1791 $[M+Na]^+$.



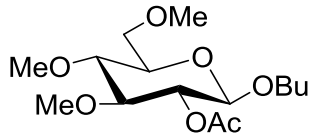
Butyl 2-*O*-benzyl-3,4,6-tri-*O*-methyl-β-D-glucopyranoside (109)

92 (1.5 g, 4.6 mmol) was subjected to the procedure used to prepare compound **108.** The resulting crude product was purified via flash chromatography (cyclohexane-EtOAc 7:3) to give **109** (1.05 g, 62%) as clear oil; $[\alpha]_D$ -4.6(*c* 0.1, CH_2Cl_2); ^{1}H NMR (500 MHz, $CDCl_3$): δ 7.39 – 7.29 (m, 4H; Ar-*H*), 7.30 – 7.21 (m, 1H; Ar-*H*), 4.89 (d, ^{2}J *(H,H)* = -11.0, 1H; C*H*HPh), 4.68 (d, ^{2}J *(H,H)* = -11.1, 1H; C*H*HPh), 4.31 (d, ^{3}J (H,H) =7.3, 1H; H-1), 3.93 (dt, ^{2}J (H,H) = -9.5, ^{3}J (H,H) = 6.4, 1H; C*H*H), 3.68 – 3.61 (m, 4H; H-6a, OCH_3, overlapping peaks), 3.59 – 3.47 (m, 4H; H-6b, C*H*H, OCH_3, overlapping peaks), 3.40 (s, 3H; OCH_3), 3.29 – 3.21 (m, 3H, 3 x C*H*), 3.14 (dd, ^{3}J *(H,H)* =9.8, 8.3, 1H; C*H*), 1.69 – 1.56 (m, 2H; CH_2), 1.46 – 1.30 (m, 2H; CH_2), 0.92 (t, ^{3}J (H,H) =7.4, 3H; CH_3); ^{13}C NMR (126 MHz, $CDCl_3$): δ 138.6 (Ar-*C*), 128.3, 128.1, 127.6 (5 x Ar-*C*H, overlapping peaks), 103.5 (C-1), 86.5 (*C*H), 81.9 (*C*H), 79.6 (*C*H), 74.7 (*C*H_2Ph), 74.6 (*C*H), 71.4 (C-6), 69.7 (*C*H_2), 61.1, 60.4, 59.3 (3 x O*C*H_3), 31.8 (CH_2), 19.3 (*C*H_2), 13.9 (*C*H_3); IR (film) cm^{-1} : 3961, 2846, 1420, 1381, 1088, 710; ESI-HRMS calcd for $C_{20}H_{35}O_6N$ 386.2543, found *m/z* 386.2548$[M+NH_4]^+$.



Butyl 2-*O*-(4-fluorobenzoyl)-3,4,6-tri-*O*-methyl-β-D-glucopyranoside (111β)

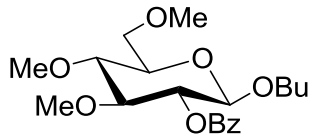
109 (0.15 g, 0.41 mmol) was subjected to the conditions outlined in general procedure 3, using 4-fluorobenzoyl chloride as the acylating reagent. Purification by flash chromatography (cyclohexane-EtOAc 6:4) gave **111β** (0.121 g, 74%) as a white solid; $[\alpha]_D$ -33.7 (*c* 0.5, CH_2Cl_2); ^{1}H NMR (500 MHz, $CDCl_3$): δ 8.13 – 8.00 (m, 2H; Ar-*H*), 7.15 – 7.05 (m, 2H; Ar-*H*), 5.09 (dd, ^3J (H,H) =9.5, 8.0, 1H; H-2), 4.45 (d, ^3J (H,H) =7.9, 1H; H-1), 3.85 (dt, ^2J (H,H) = -9.7, ^3J (H,H) = 6.3, 1H; C*HH*), 3.67 (dd, ^2J (H,H) = -10.7, ^3J (H,H) =2.0, 1H; H-6a), 3.61 (dd, ^3J (H,H) =10.7, ^3J (H,H) = 4.7, 1H; H-6b), 3.55 (s, 3H; OCH_3) 3.48 (s, 3H; OCH_3), 3.45 – 3.36 (m, 6H; OCH_3, H-5, H-2, C*H*H), 3.35 – 3.21 (m, 1H; H-4), 1.43 – 1.33 (m, 2H; CH_2), 1.27 – 1.11 (m, 2H; CH_2), 0.71 (t, ^3J (H,H) =7.4, 3H; CH_3). ^{13}C NMR (126 MHz, $CDCl_3$): δ 165.78(d, ^1J (C,F) =254.0; Ar*C*F), 164.2 (*C*OC_6H_4F) 132.2(d, ^3J (C,F) =9.0; 2 x Ar-*CH*,overlapping peaks), 126.4 (d, ^4J (C,F) =3.1; Ar*C*), 115.5 (d, ^2J (C,F) =21.9; 2 x Ar-*C*H, overlapping peaks). 101.0 (C-1), 84.8 (C-3), 79.3 (C-4), 75.1 (C-5), 73.7 (C-2), 71.3 (C-6), 69.4 (*C*H_2), 60.5, 60.3, 59.4 (3 x O*C*H_3), 31.4 (*C*H_2), 18.9 (*C*H_2), 13.6 (CH_3); IR (film) cm^{-1} 3517, 1260, 1088, 1055, 720; ESI-HRMS calcd for $C_{20}H_{29}O_7FNa$ 423.1795, found *m/z* 423.1799 $[M+Na]^+$.



Butyl 2-*O*-acetyl-3,4,6-tri-*O*-methyl-β-D-glucopyranoside (112β)

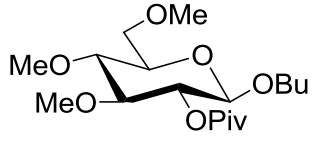
109 (0.15 g, 0.41 mmol) was subjected to the conditions outlined in general procedure 3, using acetic anhydride as the acylating reagent. Purification by flash chromatography (cyclohexane-EtOAc 6:4) gave **112β** (0.106 g, 81%) as a clear oil; $[\alpha]_D$ -194 (*c* 0.6, CH_2Cl_2); ^{1}H NMR (500 MHz, $CDCl_3$): δ 4.84 (dd, ^3J (H,H) =9.3, 7.9, 1H; H-2), 4.30 (d, ^3J (H,H) =8.0, 1H; H-1), 3.85 (dt, ^3J (H,H) =9.7, ^3J (H,H) =6.2, 1H; C*H*H), 3.64 (dd, ^2J (H,H) = -10.8, ^3J (H,H) = 2.0, 1H; H-6a), 3.57 (dd, ^2J

(H,H) = -10.8, ^{3}J (H,H) = 4.8, 1H; H-6b), 3.53 (s, 3H; OCH_3), 3.51 (s, 3H; OCH_3), 3.45 – 3.39 (m, 4H; OCH_3, CHH, overlapping peaks), 3.36 – 3.19 (m, 3H; H-3, H-4, H-5, overlapping peaks), 2.08 (s, 3H; COCH_3), 1.58 – 1.43 (m, 2H; CH_2), 1.39 – 1.27 (m, 2H; CH_2), 0.88 (t, ^{3}J (H,H) =7.4, 3H; CH_3); ^{13}C NMR (126 MHz, $CDCl_3$): δ 169.5 (*C*OCH$_3$), 100.9 (C-1), 84.6 (C-3), 79.3 (C-4), 75.0 (C-4), 73.0 (C-2), 71.3 (*C*H$_2$), 69.3 (C-6), 60.4, 60.1, 59.4 (3 x O*C*H$_3$, overlapping peaks), 31.4 (CO*C*H$_3$), 20.9 (*C*H$_2$), 19.0 (*C*H$_2$), 13.7 (*C*H$_3$); IR (film) cm^{-1} 3511, 3256, 2928, 1725, 1268, 1091, 1062, 712, 520; ESI-HRMS calcd for $C_{15}H_{28}O_7Na$ 343.1733, found *m/z* 343.1741[M+Na]$^{+}$.



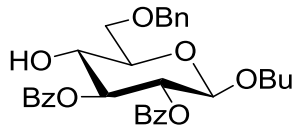
Butyl 2-*O*-benzoyl-3,4,6-tri-*O*-methyl-β-D-glucopyranoside (113β)

109 (0.15 g, 0.41 mmol) was subjected to the conditions outlined in general procedure 3 with benzoyl chloride being using as the acylating reagent. Purification by flash chromatography (cyclohexane-EtOAc 6:4) gave **113β** (0.110 g, 70%) as a clear oil; $[\alpha]_D$ -23.3 (*c* 0.1, CH_2Cl_2); ^{1}H NMR (500 MHz, $CDCl_3$): δ 8.11 – 7.92 (m, 2H; Ar-*H*), 7.57 (tt, ^{3}J (H,H) =7.0, 1.4, 1H; Ar-*H*), 7.45 (t, ^{3}J (H,H) =7.8, 2H; Ar-*H*), 5.12 (dd, ^{3}J (H,H) =9.5, 8.0, 1H; H-2), 4.46 (d, ^{3}J (H,H) =8.0, 1H; H-1), 3.85 (dt, ^{2}J (H,H) = -9.7, ^{3}J (H,H) = 6.3, 1H; CHH), 3.68 (dd, ^{2}J (H,H) = -10.7, ^{3}J (H,H) = 2.0, 1H; H-6a), 3.61 (dd, ^{2}J (H,H) = -10.7, ^{3}J (H,H) = 4.8, 1H; H-6b), 3.55 (s, 3H; OCH_3), 3.49 (s, 3H; OCH_3), 3.47 – 3.37 (m, 6H; OCH_3, H-5, H-3, CHH, overlapping peaks), 3.35 – 3.28 (m, 1H; H-4), 1.51 – 1.34 (m, 2H; CH_2), 1.27 – 1.10 (m, 2H; CH_2), 0.71 (t, ^{3}J (H,H) =7.4, 3H; CH_3); ^{13}C NMR (126 MHz, $CDCl_3$): δ 165.2 (*C*OPh), 132.9 (Ar-*C*H), 132.9 (Ar-*C*) 129.7, 128.3 (4 x Ar-*C*H, overlapping peaks), 101.1 (C-1), 84.9 (C-3), 79.3 (C-4), 75.1 (C-5), 73.7 (C-2), 71.4 (C-6), 69.5 (*C*H$_2$), 60.5, 60.3, 59.4 (3 x O*C*H$_3$), 31.4 (*C*H$_2$), 18.9 (*C*H$_2$), 13.6 (*C*H$_3$); IR (film) cm^{-1} 3515, 2933, 1726, 1266, 1059, 710, 519; ESI-HRMS calcd for $C_{20}H_{30}O_7Na$ 405.1889, found *m/z* 405.1892 [M+Na]$^{+}$.



Butyl 2-*O*-pivaloyl-3,4,6-tri-*O*-methyl-β-D-glucopyranoside (114β)

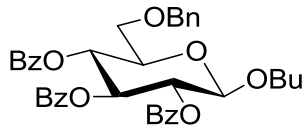
109 (0.15 g, 0.41 mmol) was subjected to the conditions outlined in general procedure 3, uisng trimethyl actyl chloride as the acylating reagent. Purification via flash chromatography (cyclohexane-EtOAc 6:4) gave **114β** (0.104 g, 70%) as a waxy solid; $[\alpha]_D$ -25.6 (*c* 0.2, CH_2Cl_2); ^{1}H NMR (500 MHz, $CDCl_3$): δ 4.84 (apt.t, ^3J (H,H) =8.5, 1H; H-2), 4.31 (d, ^3J (H,H) =8.0, 1H; H-1), 3.83 (dt, ^2J (H,H) =9.4, ^3J (H,H) = 6.4, 1H; C*H*H) 3.64 (dd, ^2J (H,H) = -10.7, ^3J (H,H) = 2.0, 1H; H-6a), 3.58 (dd, ^2J (H,H) = -10.7, ^3J (H,H) = 4.8, 1H; H-6b), 3.53 (s, 3H; OCH_3), 3.50 (s, 3H; OCH_3), 3.43 – 3.36 (m, 4H; OCH_3, C*H*H, overlapping peaks), 3.35 – 3.31 (m, 1H; H-5), 3.30 – 3.20 (m, 2H; H-3, H-4, overlapping peaks), 1.56 – 1.42 (m, 2H; CH_2), 1.37 – 1.25 (m, 1H, CH_2), 1.22 (s, 9H; 3 x CH_3, overlapping peaks), 0.90 – 0.84 (m, 3H; CH_3); ^{13}C NMR (126 MHz, $CDCl_3$): δ 176.7 (*C*OC$(CH_3)_3$), 101.1 (C-1), 84.8 (C-3), 79.6 (C-4), 74.9 (C-5), 72.5 (C-2), 71.3 (C-6), 69.3 (*C*H_2), 60.4, 60.2, 59.4 (3 x O*C*H_3), 38.7 (*C*$(CH_3)_3$), 31.6 (*C*H_2), 27.1 (3 x *C*H_3, overlapping peaks), 19.1 (*C*H_2), 13.8 (*C*H_2); IR (film) cm^{-1} 3516, 2940, 1727, 1267, 1089, 1060, 711, 540; ESI-HRMS calcd for $C_{18}H_{34}O_7Na$ 385.2202, found *m/z* 385.2209$[M+Na]^+$.



Butyl 2,3-di-*O*-benzoyl-6-*O*-benzyl-β-D-glucopyranoside (115)

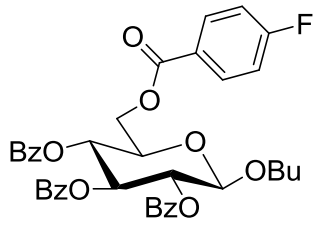
89 (10g, 18.8 mmole) was taken up in anhydrous THF (150 mL) and to this was added 4 Å molecular sieves (10 g) and $NaBH_3CN$ (8.26 g, 131.44 mmole). The resulting suspension was stirred for 30 min before MSA (8.53 mL, 131.44 mmole) was slowly added (WARNING: gas evolution). After 5 h the reaction was quenched with triethylamine (25 mL). The suspension was filtered and evaporated before being taken up in EtOAc, washed satd aq $NaHCO_3$ (200 mL), brine (200 mL), dried over Na_2SO_4, filtered and the solvent was removed under deminised pressure. Flash chromatography of the residue (cyclohexane-EtOAc 8:2) gave **115** (8.04 g, 82%) as white solid; $[\alpha]_D$ 14.4(*c* 0.6, CH_2Cl_2); ^{1}H NMR (500 MHz, $CDCl_3$): δ 7.96 (dd, ^3J (H,H) =15.5, 7.8, 4H; Ar-*H*), 7.50 (td, ^3J (H,H) =7.4, 5.4,2H; Ar-*H*), 7.48 – 7.27 (m, 7H; Ar-*H*), 5.55 – 5.25 (m, 2H; H-2, H-3, overlapping peaks), 4.87 – 4.49 (m, 2H; C-1, C*HH*Ph, overlapping peaks), 3.95 (apt. t, ^3J (H,H) =9.1, 1H; H-4), 3.89 (dt, ^2J (H,H) = -10.1, ^3J (H,H) = 6.4, 1H; C*H*H), 3.87 – 3.84 (m, 1H; H-6a, H-6b,

overlapping peaks), 3.69 (dt, ^{3}J (H,H) =9.5, 4.7, 1H; H-5), 3.50 (dt, ^{2}J (H,H) = -9.7, ^{3}J (H,H) =6.7, 1H; C*H*H), 1.49 (ddtd, *J*=25.8, 13.9, 7.3, 1.6, 2H; *CH*$_2$), 1.27 – 1.05 (m, 2H; C*H*$_2$), 0.79 – 0.66 (m, 3H; C*H*$_3$); ^{13}C NMR (126 MHz, $CDCl_3$): δ 167.2, 165.2 (2 x *C*OPh), 137.6 (Ar-*C*), 133.4, 133.0, 130.0,129.9 (6 x Ar-*C*H, overlapping peaks) 129.7, 129.5 (2 x Ar-*C*), 129.1, 128.5, 128.4, 128.3, 127.8 (9 x Ar-*C*H, overlapping peaks), 101.1 (C-1), 76.7 (C-3), 74.5 (C-5), 73.8 (*C*H$_2$Ph), 71.5 (C-2), 71.3 (C-4), 70.2 (C-6), 69.8 (*C*H$_2$), 31.4 (*C*H$_2$), 18.9 (*C*H$_2$), 13.6 (*C*H$_3$) IR (film) cm^{-1}: 3494, 2951, 1760, 1585, 1451, 1266, 1089, 1059, 1027, 999, 710; ESI-HRMS calcd for $C_{31}H_{34}O_8Na$ 557.2151, found *m/z* 557.2150 $[M+Na]^+$.



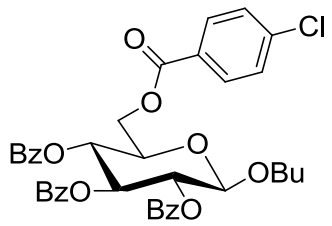
Butyl 2,3,4-tri-*O*-benzoyl-6-*O*-benzyl-β-D-glucopyranoside (116)

115 (8.0 g, 14.96 mmol) was acylated with benzoyl chloride using the conditions outlined in general procedure 1. Purification by flash chromatography (cyclohexane-EtOAc 8:2) gave **116** (7.166 g, 75%) as a foam; $[\alpha]_D$ 6.1 (*c* 0.1, CH_2Cl_2); ^{1}H NMR (500 MHz, $CDCl_3$): δ 8.16 – 8.03 (m, 2H; Ar-*H*), 8.02 – 7.89 (m, 4H; Ar-*H*), 7.60 (t, ^{3}J (H,H) =7.5, 1H; Ar-*H*), 7.49 (q, ^{3}J (H,H) =7.3, 4H; Ar-*H*), 7.42 – 7.33 (m, 4H; Ar-*H*), 7.13 – 7.05 (m, 5H; Ar-*H*), 5.77 (apt. t, ^{3}J (H,H) =9.4, 1H; H-4), 5.38 (dd, ^{3}J (H,H) =9.9, 7.9, 1H; H-2), 4.71 (d, ^{3}J (H,H) =7.9, 1H; H-1), 4.65 (dd, ^{2}J (H,H) = -11.9, ^{3}J (H,H) = 2.2, 1H; H-6a), 4.62 – 4.51 (m, 3H; H-6b, C*HH*Ph, overlapping peaks), 3.96 (apt. t, ^{3}J (H,H) =9.3, 1H; H-3), 3.91 – 3.80 (m, 2H; H-5, C*H*H, overlapping peaks), 3.49 (dt, ^{2}J (H,H) = -9.7, ^{3}J (H,H) = 6.8, 1H; C*H*H), 1.56 – 1.36 (m, 2H; C*H*$_2$), 1.29 – 1.00 (m, 2H; C*H*$_2$), 0.88 – 0.60 (m, 3H; C*H*$_3$); ^{13}C NMR (126 MHz, $CDCl_3$): δ 166.2, 165.7, 165.3 (3 x *C*OPh), 136.7 (Ar-*C*), 133.2, 133.2, 133.0 (3 x Ar-*C*H), 129.8 (Ar-*C*, 3 x Ar-*C*H, overlapping peaks), 129.7 (2 x Ar-*C*H, overlapping peaks), 129.5, 129.3 (2 x Ar-*C*), 128.4, 128.4, 128.3, 128.0 (12 x Ar-*C*H, overlapping peaks), 101.2 (C-1), 76.0 (C-3), 75.2 (C-4), 74.8 (*C*H$_2$Ph), 73.3 (C-5), 72.1 (C-2), 69.9 (*C*H$_2$), 63.2 (C-6), 31.4 (*C*H$_2$), 18.8 (*C*H$_2$), 13.5 (*C*H$_3$); IR (film) cm^{-1}: 3490, 3066, 2959, 2874, 1725, 1602, 1452, 1258, 1088, 1067, 1026, 981, 910, 704; ESI-HRMS calcd for $C_{38}H_{38}O_9Na$ 661.2414, found *m/z* 608.2417 $[M+Na]^+$.



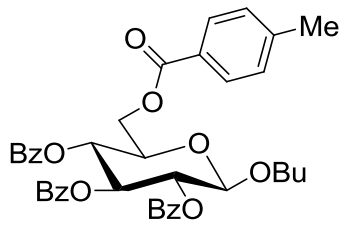
Butyl 2,3,4-tri-*O*-benzoyl-6-*O*-(4-fluorobenzoyl)-β-D-glucopyranoside (117β)

116 (0.25 g, 0.39 mmol) was subjected to the conditions outlined in general procedure 3, uisng 4-fluorobenzoyl chloride as the acylating reagent Purification via flash chromatography (cyclohexane-EtOAc 8:2) gave **117β** (0.22 g, 84%) as a foam; $[\alpha]_D$ 9.2 (*c* 0.2, CH_2Cl_2); ^{1}H NMR (500 MHz, $CDCl_3$): δ 8.05 – 8.00 (m, 2H; Ar-*H*), 7.99 – 7.93 (m, 2H; Ar-*H*), 7.91 – 7.86 (m, 2H; Ar-*H*), 7.86 – 7.80 (m, 2H; Ar-*H*), 7.54 – 7.47 (m, 2H; Ar-*H*), 7.46 – 7.27 (m, 7H; Ar-*H*), 7.19 – 6.88 (m, 2H; Ar-*H*), 5.89 (apt. t, ^3J (H,H) =9.6, 1H; H-3), 5.67 (apt. t, ^3J (H,H) =9.7, 1H; H-4), 5.51 (dd, ^3J (H,H) =9.8, 7.8, 1H; H-2), 4.83 (d, ^3J (H,H) =7.8, 1H; H-1), 4.62 (dd, ^2J (H,H) = -12.1, ^3J (H,H) = 3.4, 1H; H-6a), 4.50 (dd, ^2J (H,H) = -12.0, ^3J (H,H) = 4.9, 1H; H-6b), 4.14 (ddd, ^3J (H,H) = 9.9, 4.9, 3.4, 1H; H-5), 3.91 (dt, ^2J (H,H) = -9.7, ^3J (H,H) = 6.4, 1H; C*H*H), 3.55 (dt, ^2J (H,H) = -9.7, ^3J (H,H) = 6.7, 1H; C*H*H), 1.62 – 1.35 (m, 2H; CH_2), 1.30 – 1.16 (m, 2H; CH_2), 0.74 (t, ^3J (H,H) =7.4, 1H; CH_3); ^{13}C NMR (126 MHz, $CDCl_3$): δ 166.49 (d, ^1J (*C,F)* =128.5; Ar-*C*F), 165.8, 165.1 (3 x *C*OPh, overlapping peaks) 164.8 (*C*OC_6H_4F), 133.4, 133.2, 133.1 (3 x Ar-*C*H), 132.29 (d, ^3J (*C,F)* =9.5; 2 Ar-*C*H, overlapping peaks), 129.8, 129.7, 129.7 (6 x Ar-*C*H, overlapping peaks), 129.4, 128.8, (3 x Ar-*C*, overlapping peaks), 128.4, 128.3 (6 Ar-*C*H, overlapping peaks), 125.84 (d, ^4J (*C,F)* =3.0; Ar-*C*), 115.49 (d, ^2J (*C,F)* =22.0; 2 x Ar-*C*H, overlapping peaks), 101.3 (C-1), 72.9 (C-3), 72.0 (C-2), 71.9 (C-5), 70.1 (*C*H_2), 69.8 (C-4), 63.3 (C-6), 31.4 (*C*H_2), 18.9 (*C*H_2), 13.5 (*C*H_3); IR (film) cm^{-1}: 2959, 1722, 1451, 1260, 1091, 1066, 1026, 704; ESI-HRMS calcd for $C_{38}H_{35}O_{10}NaF$ 693.2112, found *m/z* 693.2113 $[M+Na]^+$.



Butyl 2,3,4-tri-*O*-benzoyl-6-*O*-(4-chlorobenzoyl)-β-D-glucopyranoside (118β)

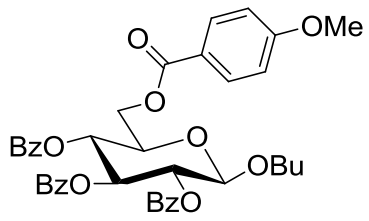
116 (0.25 g, 0.39 mmol) was subjected to the conditions outlined in general procedure 3, using 4-chlorobenzoyl chloride as the acylating agent. Purification by flash chromatography (cyclohexane-EtOAc 8:2) gave **118β** (0.180 g, 67%) as a foam; $[\alpha]_D$ 11.8 (*c* 0.1, CH_2Cl_2); ^{1}H NMR (500 MHz, $CDCl_3$): δ 7.99 – 7.92 (m, 4H; Ar-*H*), 7.89 (dd, ^3J (H,H) = 8.3, 1.3, 2H; Ar-*H*), 7.83 (dd, ^3J (H,H) = 8.3, 1.4, 2H; Ar-*H*), 7.51 (dt, ^3J (H,H) = 8.9, 7.4, 2H; Ar-*H*), 7.46 – 7.32 (m, 7H; Ar-*H*), 7.29 (t, ^3J (H,H) = 7.9, 2H; Ar-*H*), 5.90 (apt. t, ^3J (H,H) = 9.7, 1H; H-3), 5.67 (apt. t, ^3J (H,H) = 9.7, 1H; H-4), 5.52 (dd, ^3J (H,H) = 9.8, 7.8, 1H; H-2), 4.84 (d, ^3J (H,H) = 7.8, 1H; H-1), 4.63 (dd, ^2J (H,H) = -12.1, ^3J (H,H) = 3.5, 1H; H-6a), 4.51 (dd, ^2J (H,H) = -12.1, ^3J (H,H) = 5.0, 1H; H-6b), 4.14 (ddd, ^3J (H,H) = 9.9, 4.9, 3.4, 1H; H-5), 3.91 (dt, ^2J (H,H) = -9.7, ^3J (H,H) = 6.3, 1H; C*H*H), 3.55 (dt, ^2J (H,H) = -9.7, ^3J (H,H) = 6.7, 1H; C*H*H), 1.60 – 1.44 (m, 2H; CH_2), 1.29 – 1.19 (m, 2H; CH_2), 0.75 (t, ^3J (H,H) = 7.4, 3H; CH_3); ^{13}C NMR (126 MHz, $CDCl_3$): δ 165.8 (*C*OC_6H_4Cl), 165.3, 165.2, 165.1 (3 x *C*OPh),139.6 (Ar-*C*Cl) 133.4, 133.2, 133.1, 131.1, 129.8, 129.7 (11 x Ar*C*H, overlapping peaks), 129.4, 128.8 (3 x Ar-*C*), 128.7, 128.4, 128.3, 128.3 (8 x Ar-*C*H, overlapping peaks), 128.0 (Ar-*C*H), 101.3 (C-1), 72.9 (C-3), 72.0 (C-2), 71.9 (C-5), 70.1 (*C*H_2), 69.8 (C-4), 63.4 (C-6), 31.4 (*C*H_2), 18.9 (*C*H_2), 13.5 (*C*H_3); IR (film) cm^{-1}: 2961, 1708, 1604, 1249, 1166, 1088, 1025, 845, 766; ESI-HRMS calcd for $C_{38}H_{35}O_{10}NaCl$ 709.1816, found *m/z* 709.1822 $[M+Na]^+$.



Butyl 2,3,4-tri-*O*-benzoyl-6-*O*-(4-methylbenzoyl)-β-D-glucopyranoside (119β)

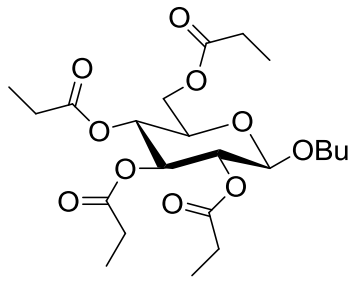
116 (0.25 g, 0.39 mmol) was subjected to the conditions oultlined in general procedure 3, using 4-methylbenzoyl chlorde as the acylating reagent. Purification via flash chromatography (cyclohexane-EtOAc 8:2) gave **119β** (0.185 g, 71%) as a foam; $[\alpha]_D$ 2.1 (*c* 0.1, CH_2Cl_2); ^{1}H NMR (500 MHz, $CDCl_3$): δ 7.96 (dd, ^3J (H,H) = 8.1, 1.4, 2H; Ar-*H*), 7.90 (dd, ^3J (H,H) = 7.9, 3.6, 4H; Ar-*H*), 7.86 – 7.79 (m, 2H; Ar-*H*), 7.56 – 7.47 (m, 2H; Ar-*H*), 7.44 – 7.29 (m, 7H; Ar-*H*), 7.19 (d, ^3J (H,H) = 7.9, 2H; Ar-*H*), 5.90 (apt. t, ^3J (H,H) = 9.7, 1H; H-3), 5.66 (apt. t, ^3J (H,H) = 9.7, 1H; H-4), 5.52 (dd, ^3J (H,H) = 9.8, 7.8, 1H; H-2), 4.83 (d, ^3J (H,H) = 7.8, 1H; H-1), 4.62

(dd, ^{2}J (H,H) = -12.0, ^{3}J (H,H) = 3.3, 1H; H-6a), 4.49 (dd, ^{2}J (H,H) = -12.1, ^{3}J (H,H) = 5.4, 1H; H-6b), 4.15 (ddd, ^{3}J (H,H) = 9.2, 5.4, 3.4, 1H; H-5), 3.92 (dt, ^{2}J (H,H) = -9.8, ^{3}J (H,H) = 6.3, 1H; C*H*H), 3.55 (dt, ^{2}J (H,H) = -9.8, ^{3}J (H,H) = 6.7, 1H; C*H*H), 2.40 (s, 3H; CH_3), 1.64 – 1.38 (m, 2H; CH_2), 1.34 – 1.18 (m, 2H; CH_2), 0.75 (t, ^{3}J (H,H) = 7.4, 3H; CH_3); ^{13}C NMR (126 MHz, $CDCl_3$): δ 166.2 (*C*OC_6H_4(CH_3)), 165.8, 165.2, 165.1 (3 x *C*OPh), 143.8 (Ar-*C*(CH_3)), 133.3, 133.2, 133.1, 129.8, 129.7 (11 x Ar-*C*H, overlapping peaks), 129.4 (Ar-*C*), 129.0 (2 x Ar-*C*H, overlapping peaks), 128.9, 128.8 (2 x Ar*C*), 128.4, 128.3, 128.3 (6 x Ar*C*H, overlapping peaks), 126.9 (Ar-*C*), 101.3 (C-1), 73.0 (C-3), 72.2 (C-5), 72.0 (C-2), 70.0 (*C*H_2), 69.9 (C-4), 63.1 (C-6), 31.4 (*C*H_2), 21.7 (*C*H_3), 18.9 (*C*H_2), 13.5 (*C*H_3); IR (film) cm^{-1}: 2978, 1187, 1649, 1501, 1212, 1166, 1069, 1045, 1012, 751; ESI-HRMS calcd for $C_{39}H_{38}O_{10}Na$ 689.2363, found *m/z* 689.2361 $[M+Na]^+$.



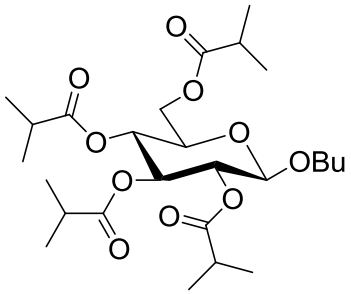
Butyl 2,3,4-tri-*O*-benzoyl-6-*O*-(4-methoxylbenzoyl)-β-D-glucopyranoside (120β) **116** (0.25 g, 0.39 mmol) was subjected to the conditions outlined in general procedure 3 uisng 4-methoxybenzoyl chloride as the acylating reagent. Purification via flash chromatography (cyclohexane-EtOAc 8:2) gave **120β** (0.234 g, 88%) as a foam; $[\alpha]_D$ 12.1 (*c* 0.2, CH_2Cl_2); ^{1}H NMR (500 MHz, $CDCl_3$): δ 8.00 – 7.94 (m, 4H; Ar-*H*), 7.89 (dd, ^{3}J (H,H) =8.4, 1.4,2H; Ar-*H*), 7.83 (dd, ^{3}J (H,H) =8.2, 1.4, 2H; Ar-*H*), 7.54 – 7.45 (m, 2H; Ar-*H*), 7.44 – 7.24 (m, 7H; Ar-*H*), 6.86 (d, ^{3}J (H,H) =8.8, 2H; Ar-*H*), 5.89 (apt. t, ^{3}J (H,H) =9.6, 1H; H-3), 5.67 (apt. t, ^{3}J (H,H) =9.7, 1H; H-4), 5.51 (dd, ^{3}J (H,H) =9.7, 7.9, 1H; H-2), 4.83 (d, ^{3}J (H,H) =7.8, 1H; H-1), 4.61 (dd, ^{3}J (H,H) = -12.0, ^{3}J (H,H) = 3.3, 1H; H-6a), 4.47 (dd, ^{2}J (H,H) = -12.0, ^{3}J (H,H) = 5.2, 1H; H-6b), 4.14 (ddd, ^{3}J (H,H) =9.9, 5.2, 3.3, 1H; H-5), 3.91 (dt, ^{3}J (H,H) =9.7, 6.3, 1H; C*H*H), 3.85 (s, 3H; OCH_3), 3.55 (dt, ^{3}J (H,H) =9.8, ^{3}J (H,H) = 6.7, 1H; C*H*H), 1.51 (qdd, ^{3}J (H,H) =13.7, 8.5, 6.7, 2H; CH_2), 1.32 – 1.13 (m, 2H; CH_2), 0.74 (t, ^{3}J (H,H) =7.4, 3H; CH_3); ^{13}C NMR (126 MHz, $CDCl_3$): δ 165.8 (*C*OPh, *C*OC_6H_4(OCH_3), overlapping peaks), 165.2 , 165.1 (2 x *C*OPh), 163.4 (Ar-*C*(OCH_3), 133.3, 133.2, 133.1, 131.8, 129.8, 129.7 (11 x Ar-*C*H, overlapping peaks), 129.4,

128.9 (3 x Ar-*C*, overlapping peaks), 128.4, 128.3, 128.3 (6 x Ar-*C*H, overlapping peaks), 122.0 (Ar-*C*), 113.6 (2 x Ar-*C*H, overlapping peaks), 101.3 (C-1), 73.0 (C-3), 72.2 (C-5), 72.0 (C-2), 70.0 (C-4), 69.9 (*C*H_2), 63.0 (C-5), 55.4 (O*C*H_3), 31.4 (*C*H_2), 18.9 (*C*H_2), 13.5 (*C*H_3); IR (film) cm^{-1}: 2961, 1718, 1604, 1551, 1248, 1166, 1088, 1025, 844, 764, 695; ESI-HRMS calcd for $C_{39}H_{38}O_{11}Na$ 705.2312, found *m/z* 705.2310 $[M+Na]^+$.



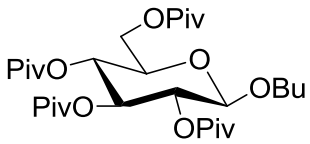
Butyl 2,3,4,6-tetra-*O*-propionyl-β-D-glucopyranoside (121β)

76 (0.25g, 1.06 mmol) was acylated using propionyl chloride under the conditions outlined in general procedure 1. Purified via flash chromatography (cyclohexane-EtOAc 7:3) to give **121β** (0.283 g, 58%) as a clear oil; $[\alpha]_D$ -8.7 (*c* 0.1, CH_2Cl_2); ^{1}H NMR (500 MHz, $CDCl_3$): δ 5.22 (apt. t, ^3J (H,H) = 9.5, 1H; H-3), 5.10 (apt. t, ^3J (H,H) = 9.7, 1H; H-4), 5.00 (dd, ^3J (H,H) = 9.6, 8.0, 1H; H-2), 4.49 (d, ^3J (H,H) =7.9, 1H; H-1), 4.25 (dd, ^2J (H,H) = -12.3, ^3J (H,H) = 5.0, 1H; H-6a), 4.14 (dd, ^2J (H,H) = -12.2, ^3J (H,H) = 2.4, 1H; H-6b), 3.86 (dt, ^2J (H,H) = 9.6, ^3J (H,H) = 6.3, 1H; C*H*H), 3.69 (ddd, *J*=9.9, 4.9, 2.4, 1H; H-5), 3.47 (dt, ^2J (H,H) = -9.7, ^3J (H,H) = 6.8, 1H; C*H*H), 2.43 – 2.32 (m, 2H; CH_2), 2.32 – 2.18 (m, 6H; 6 x CH_2, overlapping peaks), 1.54 (dddd, ^3J (H,H) = 19.8, 15.1, 11.2, 7.0, 2H; CH_2), 1.32 (dq, ^3J (H,H) = 15.2, 6.8, 6.4, 2H; CH_2), 1.16 – 1.02 (m, 12H; 4 x CH_3, overlapping peaks), 0.89 (t, ^3J (H,H) =7.4, 3H; CH_3); ^{13}C NMR (126 MHz, $CDCl_3$): δ 174.1, 173.7, 172.8, 172.7 (4 x *C*OCH_2CH_3), 100.9 (C-1), 72.7 (C-3), 71.9 (C-5), 71.2 (C-2), 69.8 (*C*H_2), 68.3 (C-4), 61.9 (C-6), 31.4 (*C*H_2), 27.4 (4 x *C*H_2, overlapping peaks) , 18.9 (*C*H_2), 13.7 (*C*H_3),9.1, 9.0, 8.9 (4 x *C*H_3, overlapping peaks); IR (film) cm^{-1}: 2964, 1724, 1604, 1511, 1251, 1166, 1092, 1068, 1026, 845, 765, 707; ESI-HRMS calcd for $C_{22}H_{36}O_{10}Na$ 483.2206, found *m/z* 483.2209 $[M+Na]^+$.



Butyl 2,3,4,6-tetra-*O*-isobutyryl-β-D-glucopyranoside (122β)

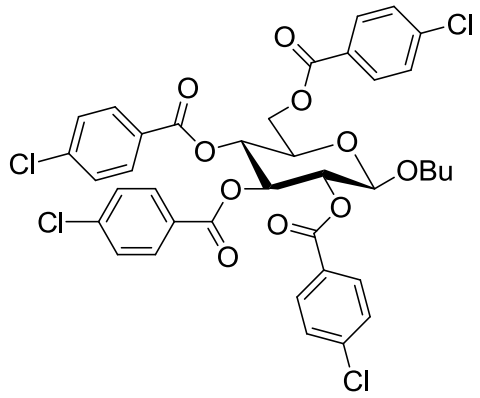
76 (0.25g, 1.06 mmol) was acylated using isobutyryl chloride under the conditions outlined in general procedure 1. Purification via flash chromatography (cyclohexane-EtOAc 7:3) gave **122β** (0.41 g, 75%) as a clear oil; $[\alpha]_D$ -9.2 (*c* 0.2, CH_2Cl_2); ^{1}H NMR (500 MHz, $CDCl_3$): δ 5.25 (apt. t, ^3J (H,H) =9.6, 1H; H-3), 5.10 (apt. t, ^3J (H,H) =9.7, 1H; H-4), 5.00 (dd, ^3J (H,H) =9.7, 8.0, 1H; H-2), 4.49 (d, ^3J (H,H) =8.0, 1H; H-1), 4.26 – 4.10 (m, 2H; H-6), 3.85 (dt, ^2J (H,H) = -9.5, ^3J (H,H) = 6.3, 1H; C*H*H), 3.75 – 3.63 (m, 1H; H-5), 3.46 (dt, ^2J (H,H) = -9.7, ^3J (H,H) = 6.8, 1H; C*H*H), 2.59 (p, ^3J (H,H) =7.0, 1H; C*H*$(CH_3)_2$), 2.55 – 2.39 (m, 3H; 3 x C*H*$(CH_3)_2$, overlapping peaks), 1.59 – 1.45 (m, 2H; CH_2), 1.41 – 1.26 (m, 2H; CH_2), 1.17 (d, ^3J (H,H) =2.7, 3H; CH_3), 1.16 (d, ^3J (H,H) =2.6, 3H; CH_3), 1.14 – 1.00 (m, 18H; 6 x CH_3,overlapping peaks), 0.88 (t, ^3J (H,H) =7.4, 3H; CH_3); ^{13}C NMR (126 MHz, $CDCl_3$): δ 176.7, 176.1, 175.2, 175.2 (4 x *C*OCH$(CH_3)_2$), 101.0 (C-1), 72.3 (C-3), 72.1 (C-5), 71.0 (C-2), 69.7 (*C*H_2), 68.1 (C-4), 61.9 (C-6), 33.9, 33.8 (4 x *C*H$(CH_3)_2$, overlapping peaks), 31.4 (*C*H_2), 19.0, 18.9, 18.8, 18.7 (*C*H_2, 8 x *C*H_3, overlapping peaks), 13.7 (*C*H_3); IR (film) cm^{-1}: 2970, 1726, 1256, 1091, 1027, 847, 709; ESI-HRMS calcd for $C_{26}H_{44}O_{10}Na$ 539.2832, found *m/z* 539.2825 $[M+Na]^+$.



Butyl 2,3,4,6-tetra-*O*-pivaloyl-β-D-glucopyranoside (123β)

76 (0.25g, 1.06 mmol) was acylated using trimethyl acetyl chloride under the conditions outlined in general procedure 1. Purification via flash chromatography (cyclohexane-EtOAc 7:3) gave **123β** (0.43 g, 71%) as a clear oil; $[\alpha]_D$ -4.6 (*c* 0.1, CH_2Cl_2); ^{1}H NMR (500 MHz, $CDCl_3$): δ 5.30 (apt. t, ^3J (H,H) = 9.5, 1H; H-3), 5.08 (apt. t, ^3J (H,H) = 9.7, 1H; H-3), 5.00 (dd, ^3J (H,H) = 9.6, 8.0, 1H; H-2), 4.48 (d, ^3J

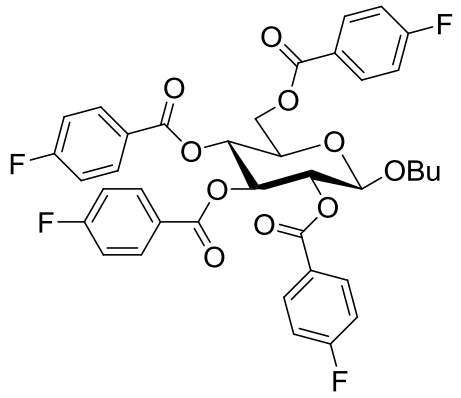
(H,H) = 7.9, 1H; H-1), 4.21 (dd, ^{2}J (H,H) = -12.1, ^{3}J (H,H) = 1.9, 1H; H-6a), 4.04 (dd, ^{2}J (H,H) = -12.2, ^{3}J (H,H) = 6.0, 1H; H-6b), 3.82 (dt, ^{2}J (H,H) = -9.6, ^{3}J (H,H) = 6.6, 1H; C*H*H), 3.71 (ddd, ^{3}J (H,H) = 10.0, 6.1, 1.9, 1H; H-5), 3.44 (dt, ^{2}J (H,H) = -9.4, ^{3}J (H,H) = 6.8, 1H; C*H*H), 1.53 (dp, ^{3}J (H,H) = 8.1, 6.6, 2H; CH_2), 1.37 – 1.27 (m, 2H; CH_2), 1.21 (s, 9H; C$(CH_3)_3$), 1.14 (s, 18H; C$(CH_3)_3$), 1.10 (s, 9H C$(CH_3)_3$), 0.88 (t, ^{3}J (H,H) = 7.4, 3H; CH_3); ^{13}C NMR (126 MHz, $CDCl_3$): δ 178.1, 177.2, 176.5, 176.4 (4 x *C*OC$(CH_3)_3$), 101.0 (C-1), 72.3 (C-3), 72.2 (C-5), 71.2 (C-2), 69.5 (*C*H_2), 68.2 (C-4), 62.1 (C-6), 38.7 (4 x *C*$(CH_3)_3$, overlapping peaks), 31.5 (*C*H_2), 27.1, 27.0 (12 x *C*H_3, overlapping peaks), 19.0 (*C*H_2), 13.7 (*C*H_3); IR (film) cm^{-1}: 2963, 1721, 1604, 1512, 1250, 1167, 1091, 1068, 1026, 845, 766; ESI-HRMS calcd for $C_{30}H_{52}O_{10}Na$ 595.3458, found *m/z* 595.3467 $[M+Na]^+$.



Butyl 2,3,4,6-tetra-*O*-(4-chlorobenzoyl)-β-D-glucopyranoside (124β)

76 (0.25g, 1.06 mmol) was acylated using 4-chlorobenzoyl chloride under the conditions outlined in general procedure 1. Purification via flash chromatography (cyclohexane-EtOAc 7:3) gave **124β** (0.695 g, 83%) as a clear oil; $[\alpha]_D$ 4.9 (*c* 0.1, CH_2Cl_2); ^{1}H NMR (500 MHz, $CDCl_3$): δ 7.96 – 7.90 (m, 2H; Ar-*H*), 7.88 (d, ^{3}J (H,H) =6.7, 2H; Ar-*H*), 7.79 (dd, ^{3}J (H,H) =7.7, 1.0, 2H; Ar-*H*), 7.77 – 7.71 (m, 2H; Ar-*H*), 7.41 – 7.33 (m, 2H; Ar-*H*), 7.34 – 7.30 (m, 2H; Ar-*H)*, 7.30 – 7.21 (m, 2H; Ar-*H*), 5.81 (apt. t, ^{3}J (H,H) =9.7, 1H; H-3), 5.61 (apt.t, ^{3}J (H,H) =9.7, 1H; H-4), 5.46 (dd, ^{3}J (H,H) =9.8, 7.8, 1H; H-2), 4.81 (d, ^{3}J (H,H) =7.8, 1H; H-1), 4.60 (dd, ^{2}J (H,H) = -12.2, ^{3}J (H,H) = 3.4, 1H; H-6a), 4.49 (dd, ^{2}J (H,H) = -12.1, ^{3}J (H,H) = 4.9, 1H; H-6b), 4.12 (ddd, ^{3}J (H,H) =9.9, 4.9, 3.4, 1H; H-5), 3.91 (dt, ^{2}J (H,H) = -9.8, ^{3}J (H,H) = 6.4, 1H; C*H*H), 3.54 (dt, ^{2}J (H,H) = -9.7, ^{3}J (H,H) = 6.7, 1H; C*H*H), 1.54 – 1.46 (m, 2H; CH_2), 1.32 – 1.17 (m, 2H; CH_2), 0.76 (t, ^{3}J (H,H) =7.4, 3H; CH_3); ^{13}C NMR (126 MHz, $CDCl_3$): δ 165.2, 164.9, 164.3, 164.2 (4 x *C*OC_6H_4Cl), 140.2, 140.0,

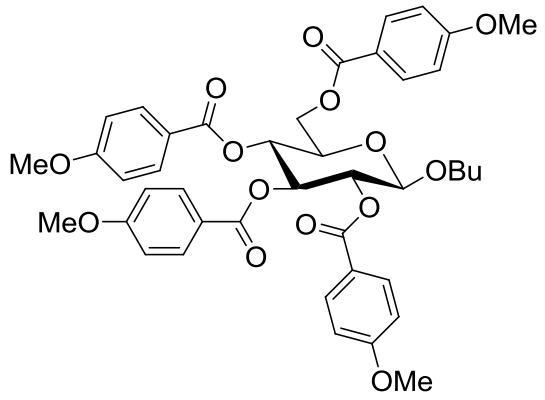
139.8, 139.7 (4 x Ar-*C*Cl), 131.1 (8 x Ar-*C*H, overlapping peaks), 128.8, 128.7 (8 x Ar-*C*H, overlapping peaks), 127.9, 127.6, 127.0 (4 x Ar-*C*, overlapping peaks), 101.1 (C-1), 73.2 (C-3), 72.0 (C-2), 71.8 (C-5), 70.1 (*C*H_2), 69.9 (C-4), 63.2 (C-6), 31.3 (*C*H_2,) 18.8 (*C*H_2), 13.5 (*C*H_3); IR (film) cm^{-1}: 2964, 1722, 1604, 1511, 1250, 1166, 1068, 1091, 1026, 845, 765; ESI-HRMS calcd for $C_{38}H_{32}O_{10}Cl_4Na$ 811.0647, found *m/z* 811.0653 $[M+Na]^+$.



Butyl 2,3,4,6-tetra-*O*-(4-flourobenzoyl)-β-D-glucopyranoside (125β)

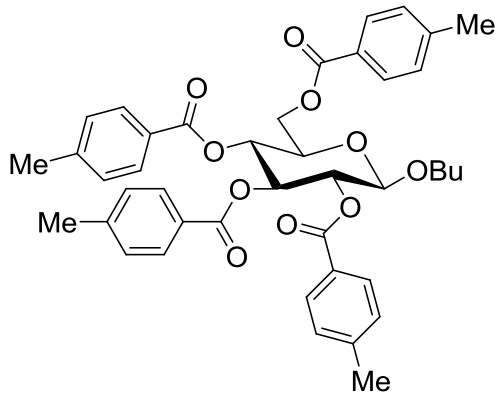
76 (0.25g, 1.06 mmol) was acylated using 4 flurorbenzoyl chloride under the conditions outlined in general procedure 1. Purification via flash chromatography (cyclohexane-EtOAc 7:3) gave **125β** (0.32g, 42%) as a clear oil; $[\alpha]_D$ 26.8 (*c* 0.4, CH_2Cl_2); ^{1}H NMR (500 MHz, $CDCl_3$): δ 8.06 – 8.00 (m, 2H; Ar-*H*), 8.00 – 7.93 (m, 2H; Ar-*H*), 7.93 – 7.87 (m, 2H; Ar-*H*), 7.87 – 7.80 (m, 2H; Ar-*H*), 7.12 – 6.90 (m, 8H; Ar-*H*), 5.82 (apt. t, ^3J (H,H) =9.7, 1H; H-3), 5.62 (apt. t, ^3J (H,H) =9.7, 1H; H-4), 5.47 (dd, ^3J (H,H) =9.8, 7.8, 1H; H-2), 4.81 (d, ^3J (H,H) =7.9, 1H; H-1), 4.62 (dd, ^2J (H,H) = -12.1, ^3J (H,H) = 3.2, 1H; H-6a), 4.48 (dd, ^2J (H,H) = -12.1, ^3J (H,H) = 5.0, 1H; H-6b), 4.12 (ddd, ^3J (H,H) =9.9, 5.0, 3.3, 1H; H-5), 3.91 (dt, ^2J (H,H) = -9.7, ^3J (H,H) =6.3, 1H; C*H*H), 3.54 (dt, ^2J (H,H) = -9.7, ^3J (H,H) =6.7, 1H; C*H*H), 1.60 – 1.41 (m, 2H; CH_2), 1.31 – 1.12 (m, 2H; CH_2), 0.75 (t, ^3J (H,H) =7.4, 1H; CH_3). ^{13}C NMR (126 MHz, $CDCl_3$): δ 167.8 – 164.6 (m; 4 x Ar-*C*F, *2 x* *C*OC_6H_4F, overlapping peaks), 164.2, 164.1 (2 x *C*OC_6H_4F), 132.44 – 132.2 (m; 4 x Ar-*C*H, overlapping peaks), 125.7 (d, ^4J (C,F) =2.9; Ar-*C*), 125.5(d, ^4J (C,F) =3.0; Ar-*C*), , 124.9 (d, ^4J (C,F) =2.9; Ar-*C*), 124.9 (d, ^4J (C,F) =2.8; Ar-*C*), , 124.8 (d, ^4J (C,F) =2.9; Ar-*C*), 115.7 (m; 4 x Ar-*C*H, overlapping peaks), 101.2 (C-1), 73.1 (C-3), 71.9 (C-5, C-2, overlapping peaks), 70.1 (*C*H_2), 69.8 (C-4), 63.1 (C-6), 31.3 (*C*H_2), 18.8 (*C*H_2), 13.5

(CH_3). IR (film) cm^{-1}: 2965, 1718, 11254, 1090, 1026, 707; ESI-HRMS calcd for $C_{38}H_{32}O_{10}F_4Na$ 747.1829, found *m/z* 747.1833 $[M+Na]^+$.



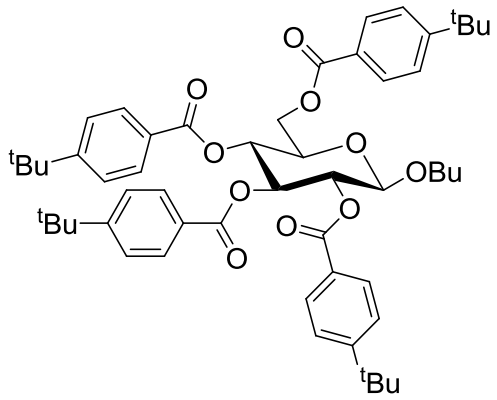
Butyl 2,3,4,6-tetra-*O*-(4-methoxybenzoyl)-β-D-glucopyranoside (126β)

76 (0.25g, 1.06 mmol) was acylated using 4-methoxybenzoyl chloride under the conditions outlined in general procedure 1. Purification by flash chromatography (cyclohexane-EtOAc 7:3) gave **126β** (0.655 g, 80%) as a clear oil; $[\alpha]_D$ 17.1 (*c* 0.2, CH_2Cl_2); ^1H NMR (500 MHz, $CDCl_3$): δ 7.95 (d, ^3J (H,H) = 8.7, 2H; Ar-*H*), 7.93 – 7.90 (m, 2H; Ar-*H*), 7.86 – 7.82 (m, 2H; Ar-*H*), 7.81 – 7.76 (m, 2H; Ar-*H*), 6.87 – 6.82 (m, 4H; Ar-*H*), 6.81 – 6.78 (m, 2H; Ar-*H*), 6.77 – 6.70 (m, 2H; Ar-*H*), 5.81 (apt. t, ^3J (H,H) =9.7, 1H; H-3), 5.59 (apt.t, ^3J (H,H) =9.7, 1H; H-4), 5.45 (dd, ^3J (H,H) =9.8, 7.8, 1H; H-2), 4.79 (d, ^3J (H,H) =7.7, 1Hl; H-1), 4.58 (dd, ^2J (H,H) = -11.9, ^3J (H,H) = 3.4, 1H; H-6a), 4.45 (dd, ^2J (H,H) = -12.1, ^3J (H,H) = 5.3, 1H; H-6b), 4.10 (ddd, ^3J (H,H) =9.3, 5.3, 3.4, 1H; H-5), 3.89 (dt, ^2J (H,H) = -9.7, ^3J (H,H) = 6.3, 1H; C*H*H), 3.84 (s, 3H; OCH_3), 3.81 (s, 3H; OCH_3), 3.79 (s, 3H; OCH_3), 3.75 (s, 3H; OCH_3), 3.53 (dt, ^2J (H,H) = -9.8, ^3J (H,H) = 6.8, 1H; C*H*H), 1.57 – 1.43 (m, 2H; CH_2), 1.29 – 1.17 (m, 2H; CH_2), 0.75 (t, ^3J (H,H) =7.4, 3H; CH_3); ^{13}C NMR (126 MHz, $CDCl_3$): δ 165.9, 165.4, 164.8(4 x *C*OC_6H_4(OCH_3), overlapping peaks), 163.6, 163.4 (4 X Ar-*C*(OCH_3), 131.9, 131.8 (8 x Ar-*C*H,overlapping peaks), 122.1, 121.8, 121.3 (4 x Ar-*C*, overlapping peaks), 113.6, 113.5 (8 x Ar-*C*H,overlapping peaks), 101.4 (C-1), 72.7 (C-3), 72.2 (C-2), 71.7 (C-5), 69.9 (*C*H_2), 69.7 (C-4), 63.2 (C-6), 55.4, 55.3 (4 x O*C*H_3, overlapping peaks), 31.4 (*C*H_2), 18.9 (*C*H_2), 13.6 (*C*H_3); IR (film) cm^{-1}: 2960, 1717, 1604, 1511, 1248, 1087, 1025, 844, 764; ESI-HRMS calcd for $C_{42}H_{48}O_{14}N$ 790.3075, found *m/z* 790.3080 $[M+NH_4]^+$.



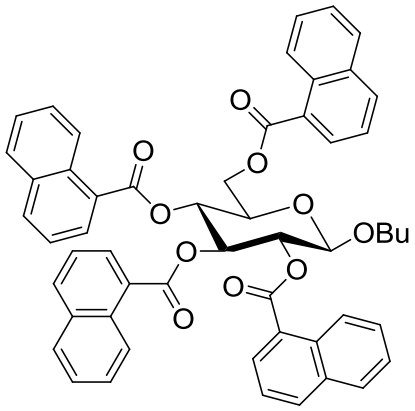
Butyl 2,3,4,6-tetra-*O*-(4-methylbenzoyl)-β-D-glucopyranoside (127β)

76 (0.25g, 1.06 mmol) was acylated using 4-methylbenzoyl chloride under the conditions outlined in general procedure 1. Purification via flash chromatography (cyclohexane-EtOAc 7:3) gave **127β** (0.571 g, 76%) as a clear oil; $[\alpha]_D$ 35.2 (*c* 1.2, CH_2Cl_2); ^{1}H NMR (500 MHz, $CDCl_3$): δ 7.92 – 7.87 (m, 2H; Ar-*H*), 7.86 – 7.83 (m, 2H; Ar-*H*),7.78 (d, ^3J (H,H) =8.2, 2H; Ar-*H*), 7.74 – 7.70 (m, 2H; Ar-*H*), 7.17 (t, ^3J (H,H) =8.7, 4H; Ar-*H*), 7.12 (d, ^3J (H,H) =8.0, 2H; Ar-*H*), 7.06 (d, ^3J (H,H) =8.0, 2H; Ar-*H*), 5.87 (apt. t, ^3J (H,H) =9.7, 1H; H-3), 5.62 (apt.t, ^3J (H,H) =9.7, 1H; H-4), 5.49 (dd, ^3J (H,H) =9.8, 7.9, 1H; H-2), 4.81 (d, ^3J (H,H) =7.8, 1H; H-1), 4.60 (dd, ^2J (H,H) = -12.1, ^3J (H,H) = 3.3, 1H; H-6a), 4.47 (dd, ^2J (H,H) = -12.1, ^3J (H,H) = 5.5, 1H; H-6b), 4.13 (ddd, ^3J (H,H) =9.3, 5.5, 3.3, 1H; H-5), 3.90 (dt, ^2J (H,H) = -9.7, ^3J (H,H) =6.4, 1H; C*H*H), 3.54 (dt, ^2J (H,H) = -9.8, ^3J (H,H) = 6.8, 1H; C*H*H), 2.39 (s, 3H; CH_3), 2.35 (s, 3H; CH_3), 2.33 (s, 3H; CH_3), 2.28 (s, 3H; CH_3), 1.50 (dddt, ^3J (H,H) = 24.6, 13.9, 8.5, 6.8, 2H; CH_2), 1.29 – 1.13 (m, 2H; CH_2), 0.75 (d, ^3J (H,H) = 7.4, 2H; CH_3); ^{13}C NMR (126 MHz, $CDCl_3$): δ 166.2, 165.8, 165.2, 165.1 (4 x *C*O$C_6H_4(CH_3)$), 144.1, 143.8, 143.7(4 x Ar-*C*(CH_3) overlapping peaks), 129.9, 129.8, 129.7 (8 x Ar-*C*H, overlapping peaks), 129.0, 128.9 (8 x Ar-*C*H, overlapping peaks), 126.9, 126.7, 126.2, 126.1 (4 x Ar*C*), 101.3 (C-1), 72.7 (C-3), 72.2 (C-5), 71.8 (C-2), 70.0 (*C*H_2), 69.7 (C-4), 63.2 (C-6), 31.4 (*C*H_2), 21.7, 21.6 (4 x *C*H_3, overlapping peaks), 18.9(*C*H_2), 13.6 (*C*H_3); IR (film) cm^{-1}: 2966, 1722, 1609, 1582, 11376, 1231, 1061, 1021, 789, 695; ESI-HRMS calcd for $C_{42}H_{44}O_{10}Na$ 731.2832, found *m/z* 731.2820 $[M+Na]^+$.



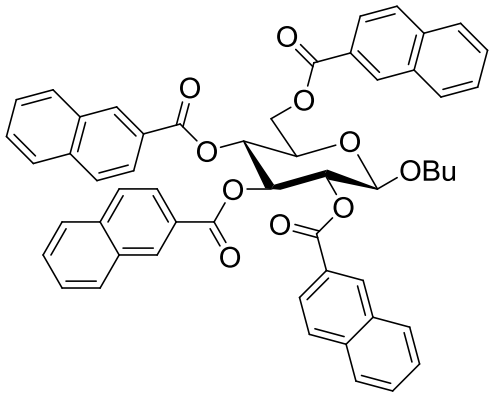
Butyl 2,3,4,6-tetra-*O*-(4-*tert*-butylbenzoyl)-β-D-glucopyranoside (128β)

76 (0.25g, 1.06 mmol) was acylated using 4-*tert*-butylbenzoyl chloride under the conditions outlined in general procedure 1. Purification via flash chromatography (cyclohexane-EtOAc 7:3) gave **128β** (0.595 g, 64%) as a clear oil; $[\alpha]_D$ 34.2 (*c* 0.4, CH_2Cl_2); ^{1}H NMR (500 MHz, $CDCl_3$): δ 7.99 – 7.92 (m, 2H; Ar-*H*), 7.91 – 7.83 (m, 4H; Ar-*H*), 7.82 – 7.74 (m, 2H; Ar-*H*), 7.45 – 7.35 (m, 6H; Ar-*H*), 7.33 – 7.28 (m, 2H; Ar-*H*), 5.87 (apt. t, ^3J (H,H) =9.6, 1H; H-3), 5.63 (apt. t, ^3J (H,H) =9.7, 1H; H-4), 5.49 (dd, ^3J (H,H) =9.7, 7.8, 1H; H-2), 4.80 (d, ^3J (H,H) =7.8, 1H; H-1), 4.62 (dd, ^2J (H,H) = -12.1, ^3J (H,H) = 2.9, 1H; H-6a), 4.44 (dd, ^2J (H,H) = -12.1, ^3J (H,H) = 5.5, 1H; H-6b), 4.11 (ddd, ^3J (H,H) =9.9, 5.5, 3.0, 1H; H-5), 3.88 (dt, ^2J (H,H) = -9.8, ^3J (H,H) = 6.4, 1H; C*H*H), 3.53 (dt, ^2J (H,H) = -9.8, ^3J (H,H) = 6.8, 1H; C*H*H), 1.59 – 1.42 (m, 2H, CH_2), 1.33 (s, 9H; C$(CH_3)_3$), 1.31 – 1.28 (m, 18H; C$(CH_3)_3$), 1.28 – 1.13 (m, 11H; C$(CH_3)_3$, CH_2, overlapping peaks), 0.73 (t, ^3J (H,H) = 7.4, 3H; CH_3); ^{13}C NMR (126 MHz, $CDCl_3$): δ 166.2, 165.8, 165.2, 165.0 (4 x $COC_6H_4(^tBu)$), 157.0, 156.7 (4 x Ar-$C(^tBu)$, overlapping peaks), 129.8, 129.7, 129.6 (8 x Ar-*C*H, ovrlapping peaks), 126.9, 126.7, 126.2, 126.1 (4 x Ar-*C*), 125.3, 125.2 (8 x Ar-*C*H, overlapping peaks), 101.3 (C-1), 72.8 (C-3), 72.4 (C-5), 71.8 (C-2), 69.9 (CH_2), 69.6 (C-4), 63.1 (C-6), 35.1, 35.0 (4 x $C(CH_3)_3$, overlapping peaks), 31.4 (CH_2), 31.1, 31.0 (12 x CH_3, overlapping peaks), 18.9 (CH_2), 13.6 (CH_3); ESI-HRMS calcd for $C_{54}H_{68}O_{10}Na$ 899.4710, found *m/z* 899.4714 $[M+Na]^+$.



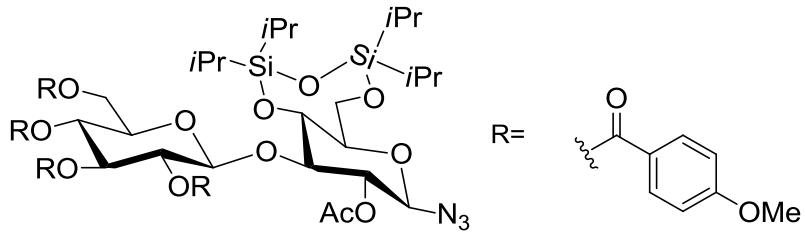
Butyl 2,3,4,6-tetra-*O*-(1-napthoyl)-β-D-glucopyranoside (129β)

76 (0.25 g, 1.06 mmol) was acylated using 1-naphthoyl chloride under the conditions outlined in general procedure 1. Purification via flash chromatography (cyclohexane-EtOAc 7:3) gave **129β** (0.6 g, 67%) as a clear oil; $[\alpha]_D$ 25.8 (*c* 0.7, CH_2Cl_2); ^{1}H NMR (500 MHz, $CDCl_3$): δ 8.92 (d, ^3J (H,H) =8.6, 1H; Ar-*H*), 8.70 – 8.61 (m, 2H; Ar-*H*), 8.46 (d, ^3J (H,H) =8.7, 1H; Ar-*H*), 8.25 (dd, ^3J (H,H) =7.3, 1.3, 1H; Ar-*H*), 8.19 (dd, ^3J (H,H) =7.3, 1.2, 1H; Ar-H), 8.13 – 8.07 (m, 2H; Ar-*H*), 7.97 (d, ^3J (H,H) =8.2, 2H; Ar-H), 7.93 (d, ^3J (H,H) =8.2, 1H; Ar-*H*), 7.90 – 7.81 (m, 3H; Ar-H), 7.77 (dd, ^3J (H,H) =7.9, 1.3, 1H; Ar-*H*), 7.71 (d, ^3J (H,H) =8.2, 1H; Ar-*H*), 7.59 (ddd, ^3J (H,H) =8.5, 6.8, 1.4, 1H; Ar-*H*), 7.52 (ddd, ^3J (H,H) =8.4, 7.0, 1.3, 1H; Ar-*H*), 7.49 – 7.29 (m, 9H; Ar-*H*), 7.19 (ddd, ^3J (H,H) =8.3, 6.9, 1.4, 1H; Ar-*H*), 6.18 (apt. t, ^3J (H,H) =9.6, 1H; H-3), 5.92 (apt. t, ^3J (H,H) =9.7, 1H; H-4), 5.76 (dd, ^3J (H,H) =9.8, 7.9, 1H; H-2), 4.99 (d, ^3J (H,H) =7.9, 1H; H-1), 4.78 (d, ^3J (H,H) =4.3, 2H; H-6), 4.33 (dt, ^3J (H,H) =9.2, 4.3, 1H; H-5), 4.04 (dt, ^2J (H,H) = -9.5, 6.4, 1H; C*H*H), 3.63 (dt, ^2J (H,H) = -9.5, ^3J (H,H) = 6.7, 1H; C*H*H), 1.69 – 1.47 (m,2H; CH_2), 1.31 (dddd, ^3J (H,H) =16.3, 14.2, 11.0, 6.9, 2H; CH_3), 0.76 (t, ^3J (H,H) =7.4, 3H; CH_3); ^{13}C NMR (126 MHz, $CDCl_3$): δ 167.0, 166.7, 166.0, 165.8 (4 x *C*OAr), 133.9 (Ar-*C*H, overlapping peaks), 133.7, 133.6 (4 x Ar-*C*, overlapping peaks), 133.5, 133.4, (3 x Ar-*C*H, overlapping peaks), 131.3, 131.1 (4 x Ar-*C*, overlapping peaks), 130.7, 130.5, 129.8, 128.5, 128.3, 127.9, 127.7, 127.5 (12 x Ar-*C*H, overlapping peaks), 126.7, 126.4 (3x Ar-*C*, overlapping peaks), 126.2, 126.1, 126.0, 125.8, 125.7, 125.6 (6 x Ar-*C*H), 125.5 (Ar-*C*), 125.4, 125.1, 124.6, 124.4, 124.3 (6 x Ar-*C*H, overlapping peaks) , 101.4 (C-1), 73.0 (C-3), 72.3 (C-5), 72.1 (C-2), 70.1 (*C*H_2), 69.9 (C-4), 63.4 (C-6), 31.5 (*C*H_2), 19.0 (*C*H_2), 13.6 (*C*H_3); ESI-HRMS calcd for $C_{54}H_{44}O_{10}Na$ 875.2832, found *m/z* 875.2859 $[M+Na]^+$.



Butyl 2,3,4,6-tetra-*O*-(2-napthoyl)-β-D-glucopyranoside (130β)

76 (0.25g, 1.06 mmol) was acylated using 2-naphthoyl chloride under the conditions outlined in general procedure 1. Purification via flash chromatography (cyclohexane-EtOAc 7:3) gave **130β** (0.68 g, 75%) as a clear oil; $[\alpha]_D$ 18.4 (*c* 0.5, CH_2Cl_2); ^{1}H NMR (500 MHz, $CDCl_3$): δ 8.54 (dd, ^3J (H,H) =8.3, 1.6, 2H; Ar-*H*), 8.44 (dd, ^3J (H,H) =25.0, 1.6, 2H; Ar-*H*), 7.99 (ddd, ^3J (H,H) =15.5, 8.6, 1.7, 2H; Ar-*H*), 7.92 – 7.85 (m, 2H; Ar-*H*), 7.85 – 7.76 (m, 6H; Ar-*H*), 7.75 – 7.62 (m, 6H), 7.59 – 7.38 (m, 8H; Ar-*H*), 6.11 (apt. t, ^3J (H,H) =9.6, 1H; H-3), 5.85 (apt. t, ^3J (H,H) =9.6, 1H; H-4), 5.69 (dd, ^3J (H,H) =9.7, 7.8, 1H; H-2), 4.99 (d, ^3J (H,H) =7.8, 1H; H-1), 4.75 (dd, ^2J (H,H) = -11.9, ^3J (H,H) = 3.9, 1H; H-6a), 4.69 (dd, ^2J (H,H) = -11.9, ^3J (H,H) = 5.1, 1H; H-6b), 4.34 (dt, ^3J (H,H) =9.5, 4.6, 1H; H-5), 3.99 (dt, ^2J (H,H) = -9.8, ^3J (H,H) = 6.4, 1H; C*H*H), 3.62 (dt, ^2J (H,H) = -9.9, ^3J (H,H) = 6.8, 1H; C*H*H), 1.65 – 1.47 (m, 2H; CH_2), 1.32 – 1.18 (m, 2H; CH_2), 0.73 (t, ^3J (H,H) =7.4, 3H; CH_3); ^{13}C NMR (126 MHz, $CDCl_3$): δ 166.3, 166.1, 165.4, 165.3 (4 x *C*OAr), 135.6, 135.5, 135.5, 132.3, 132.3, 132.2, 132.2 (8 x Ar-*C*, overlapping peaks), 131.6, 131.6, 131.4, 131.3, 129.4, 129.4, 129.3, 128.4, 128.3, 128.3, 128.2, 128.2, 128.1, 128.1, 127.7 , 127.6, 127.6, 127.5 (22 x Ar-*C*H, overlapping peaks), 126.8 (Ar-*C*), 126.6 (Ar-*C*, 2 x Ar-*C*H, overlapping peaks), 126.5, 126.0 (2 x Ar-*C*, overlapping peaks), 125.2, 125.1, 125.0 (4 x Ar-*C*H, overlapping peaks), 101.4 (C-1), 73.2 (C-3), 72.2 (C-2), 72.1 (C-5), 70.5 (C-4), 70.1 (*C*H_2), 63.8 (C-6), 31.4 (*C*H_2), 18.9 (*C*H_2), 13.6 (*C*H_3); IR (film) cm^{-1}: 2961, 1718, 1604, 1511, 1248, 1167, 1068, 1025, 766, 706; ESI-HRMS calcd for $C_{54}H_{44}O_{10}Na$ 875.2832, found *m/z* 875.2841$[M+Na]^+$.

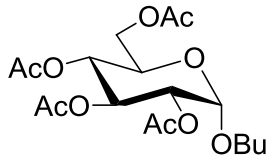


2-*O*-acetyl-3-*O*-(2,3,4,6-tetra-*O*-(4-methoxybenzoyl)-β-D-glucopyranosyl)-4,6-*O*-(1,1,3,3-tetraisopropyl-1,3-disiloxanediyl)-β-D-glucopyranosyl azide (133β).

$[\alpha]_D$ 29.0 (*c* 0.2, CH_2Cl_2); ^{1}H NMR (500 MHz, $CDCl_3$): δ 7.95 (dd, ^3J (H,H) =14.8, 8.6, 4H; Ar-*H*), 7.84 (d, ^3J (H,H) =8.6, 2H; Ar-*H*), 7.78 (d, ^3J (H,H) =8.6, 2H; Ar-*H*), 6.87 (t, ^3J (H,H) =7.9, 4H; Ar-*H*), 6.79 (d, ^3J (H,H) =8.6, 2H; Ar-*H*), 6.74 (d, ^3J (H,H) =8.6, 2H; Ar-*H*), 5.82 (apt. t, ^3J (H,H) =9.7, 1H; H-3'), 5.61 (apt. t, ^3J (H,H) =9.7, 1H; H-4'), 5.49 – 5.42 (m, 1H; H-2'), 5.03 (d, ^3J (H,H) =7.8, 1H; H-1'), 4.80 (d, ^3J (H,H) =9.2, 1H; H-2), 4.58 (dd, ^3J (H,H) =12.2, ^3J (H,H) =3.3, 1H; H-6a'), 4.47 (dd, ^3J (H,H) =12.1, ^3J (H,H) = 5.1, 1H; H-6b'), 4.23 (d, ^3J (H,H) =9.0, 1H; H-1), 4.19 (d, ^3J (H,H) =11.9, 1H; H-6a), 4.12 (dt, ^3J (H,H) =9.1, 4.1, 1H; H-5'), 3.85 (s, 3H; OCH_3), 3.82 (s, 3H; OCH_3), 3.80 (s, 3H; OCH_3), 3.79 – 3.74 (m, 4H, OCH_3, H-6b, overlapping peaks), 3.61 (apt. t, ^3J (H,H) =8.7, 1H; H-3), 3.52 (apt. t, ^3J (H,H) =8.7, 1H; H-5), 3.44 (apt. t, ^3J (H,H) =8.9, 1H; H-4), 2.06 (s, 3H, COCH_3), 1.07 – 0.85 (m, 28H; 4 x C*H*(CH_3)$_2$, overlapping peaks); ^{13}C NMR (126 MHz, $CDCl_3$): δ 169.1 (*C*OCH_3), 165.8, 165.3, 164.8 (4 x *C*OC_6H_4(OCH_3), overlapping peaks), 163.6, 163.5, 163.4 (4 x Ar-*C*(OCH_3), overlapping peaks), 131.9, 131.8 (4 x Ar-*C*H, overlapping peaks), 122.1, 121.8, 121.3, 121.2 (4 x Ar-*C*, overlapping peaks), 113.6, 113.5 (4 x Ar-*C*H, overlapping peaks), 101.6 (C-1'), 87.3 (C-1), 78.8 (C-5), 77.2 (C-3), 73.3 (C-4), 72.6 (C-3), 72.5 (C-2), 72.3 (C-5'), 71.7 (C-2'), 69.5 (C-4'), 68.4 (C-6), 63.0 (C-6'), 55.3 (4 x OCH_3, overlapping peaks), 20.6 (CO*C*H_3), 17.3 , 17.1 (8 x CH(*C*H_3)$_2$, overlapping peaks), 12.6, 12.1, 12.0 (4 x *C*H(CH$_3$)$_2$, overlapping peaks)

General procedure for the anomerisation of kinetic substrates.

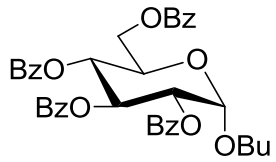
To a solution of the substrate (0.064 mmol) in $CDCl_3$ (0.65 mL) in an NMR tube, was added a freshly prepared solution of $SnCl_4$ in $CDCl_3$ (0.2 mL of 0.32M, 0.064 mmol). The solution was mixed thoroughly and the reaction was then monitored by ^1H NMR at 25 °C. Once equilibrium had been reached the solution was diluted with DCM (1 mL) and washed twice with 1M $KHSO_4$ (1 mL), satd aq $NaHCO_3$ (1 mL), brine (1 mL), dried over anhydrous $NaSO_4$, filtered and the solvent was removed under reduced pressure. The resulting residue was taken up in CH_2Cl_2 and passed through a short column of silica for further purification, followed by evaporation of the solvent under diminished pressure which gave the desired compound. (Note: All glass wear (NMR tube, volumetrics, syringes etc) were oven dried before use. The samples where dried on a high vacuum line for at least 24 hr prior to use. CDCl3 was distilled using phosphorus pentoxide and was analyzed before use for water content. ^{31}P NMR was also run to insure there was no phosphoric acid present. A fresh solution of SnCl4 was prepared for each kinetic run. As regards the plots themselves the same three peaks were integrated at each time interval. Each substrate was run at least three times. In some cases (e.g. compounds **75β** and **77β**) the substrate was run multiple times at random intervals during the study to ensure the quality of the solvent and the SnCl4 solutions were consistent).



Butyl 2,3,4,6-tetra-*O*-acetyl-α-D-glucopyranoside (75α)[93]

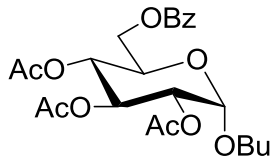
$[\alpha]_D$ 49.1 (*c* 0.5, CH_2Cl_2); ^1H NMR (500 MHz, $CDCl_3$): δ 5.48 (d, ^3J (H,H) =10.0, 1H; H-3), 5.12 – 4.96 (m, 2H; H-1, H-4, overlapping peaks), 4.84 (dd, ^3J (H,H) =10.2, 3.7, 1H; H-2), 4.25 (dd, ^2J (H,H) = -12.3, ^3J (H,H) = 4.6, 1H; H-6a), 4.09 (dd, ^2J (H,H) = -12.3, ^3J (H,H) = 2.4, 1H; H-6b), 4.01 (ddd, ^3J (H,H) =10.3, 4.7, 2.3, 1H; H-5), 3.68 (dt, ^2J (H,H) = -9.9, ^3J (H,H) =6.5, 1H; C*H*H), 3.43 (dt, ^2J (H,H) = -9.9, ^3J (H,H) =6.5, 1H; C*H*H), 2.09 (s, 3H; COCH_3), 2.02 (s, 3H; COCH_3), 2.01 (s, 6H; 2 x COCH_3, overlapping peaks), 1.58 (dq, ^3J (H,H) = 8.1, 6.3, 2H; CH_2), 1.43 – 1.34 (m, 2H; CH_2), 0.93 (t, ^3J (H,H) =7.4, 3H; CH_3); ^{13}C NMR (126 MHz, $CDCl_3$): δ 170.6, 170.2, 170.1 169.6 (4 x *C*OCH$_3$), 95.6 (C-1), 70.9 (C-2), 70.2 (c-3), 68.6 (C-4), 68.4

(CH_2), 67.1 (C-5), 62.0 (C-6), 31.3 (CH_2), 20.7, 20.6 (4 x COCH_3, overlapping peaks), 19.2 (CH_2), 13.7 (CH_3); IR (film) cm^{-1}: 3367, 3241, 2967, 2872, 1753, 1738, 1376, 1209, 1067, 1034, 906, 748; ESI-HRMS calcd for $C_{18}H_{32}O_{10}N$ 422.2026, found *m/z* 422.2031$[M+NH_4]^+$.



Butyl 2,3,4,6-tetra-*O*-benzoyl- β -D-glucopyranoside (77α)[93]

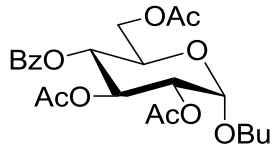
$[\alpha]_D$ 101.7 (*c* 0.8, CH_2Cl_2); ^{1}H NMR (500 MHz, $CDCl_3$): δ 8.05 (dd, ^3J (H,H) = 8.0, 1.5, 2H; Ar-H), 8.00 – 7.97 (m, 2H; Ar-H), 7.96 – 7.92 (m, 2H; Ar-H), 7.87 (dd, ^3J (*H,H)* = 8.3, 1.4, 2H; Ar-H), 7.57 – 7.54 (m, 1H; Ar-H), 7.53 – 7.48 (m, 2H; Ar-H), 7.45 – 7.34 (m, 8H; Ar-H), 7.29 (t, ^3J (H,H) =7.8, 2H; Ar-H), 6.19 (t, ^3J (H,H) =9.8, 1H; H-3), 5.67 (t, ^3J (H,H) =9.7, 1H; H-4), 5.34 (d, ^3J (H,H) =3.7, 1H; H-1), 5.30 (dd, ^3J (H,H) =10.1, 3.7, 1H; H-2), 4.72 – 4.54 (m, 1H; H-6a), 4.52 – 4.41 (m, 2H; H-6a, H-5, overlapping peaks), 3.80 (dt, ^2J (H,H) = -9.9, ^3J (H,H) = 6.5, 1H; C*H*H), 3.49 (dt, ^2J (H,H) = -9.9, ^3J (H,H) =6.6, 1H; C*H*H), 1.60 (dtd, ^3J (*H,H)* =13.6, 6.9, 4.2, 2H; CH_2), 1.34 (m, 2H; CH_2), 0.83 (t, ^3J (H,H) =7.4, 3H; CH_3); ^{13}C NMR (126 MHz, $CDCl_3$): δ 166.2, 165.8, 165.3 (4 x *C*OPh, overlapping peaks), 133.4, 133.3, 133.1, 129.9, 129.7 (8 x Ar-*C*H, overlapping peaks), 129.2, 129.1, 128.9 (4 x Ar-*C*, overlapping peaks), 128.4, 128.2 (4 x Ar-*C*H, overlapping peaks), 96.0 (C-1), 72.0 (C-2), 70.6 (C-3), 69.6 (C-4), 68.7 (CH_2), 67.7 (C-5), 63.1 (C-6), 31.3 (CH_2), 19.2 (CH_2), 13.7 (CH_3); IR (film) cm^{-1}: 3369, 2958, 1720, 1450, 1260, 1091, 1067, 1026, 705; ESI-HRMS calcd for $C_{38}H_{40}O_{10}N$ 670.2652, found *m/z* 670.2651 $[M+NH_4]^+$.



Butyl 2,3,4-tri-*O*-acetyl-6-*O*-benzoyl-α-D-glucopyranoside (80α)

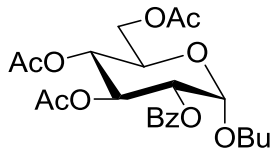
$[\alpha]_D$ 10.0 (*c* 0.3, CH_2Cl_2); ^{1}H NMR (500 MHz, $CDCl_3$): δ 8.05 (d, ^3J (H,H) = 7.6, 1H; Ar-H), 7.57 (t, ^3J (H,H) = 7.4, 1H; Ar-H), 7.45 (apt. t, ^3J (H,H) =7.7, 1H; Ar-H), 5.52 (apt. t, ^3J (H,H) =9.8, 1H; H-3), 5.15 (apt. t, ^3J (H,H) = 9.8, 1H; H-4), 5.07 (d, ^3J (H,H) =3.7, 1H; H-1), 4.87 (dd, ^3J (H,H) =10.2, 3.8, 1H; H-2), 4.47 (dd, ^2J (H,H) = -12.2, ^3J (H,H) = 2.4, 1H; H-6a), 4.37 (dd, ^2J (H,H) = -12.2, ^3J (H,H) = 5.1, 1H; H-

6b), 4.16 (ddd, ^{3}J (H,H) = 10.2, 5.1, 2.4, 1H; H-5), 3.71 (dt, ^{2}J (H,H) = -9.8, ^{3}J (H,H) = 6.6, 1H; C*H*H), 3.44 (dt, ^{2}J (H,H) = -9.8, ^{3}J (H,H) = 6.6, 1H; C*H*H), 2.06 (s, 3H; COCH_3), 2.03 (s, 3H; COCH_3), 2.02 (s, 2H; COCH_3), 1.64 – 1.54 (m, 2H; CH_2), 1.43 – 1.30 (m, 2H; CH_2), 0.91 (t, ^{3}J (H,H) = 7.4, 1H; CH_3); ^{13}C NMR (126 MHz, $CDCl_3$): δ 170.2, 170.1, 169.6 (3 x *C*OCH$_3$), 166.2 (*C*OPh), 133.2, 129.7 (3 x Ar-*C*H, overlapping peaks), 129.6 (Ar-*C*), 128.4 (2 x Ar-*C*H, overlapping peaks), 95.6 (C-1), 71.0 (C-2), 70.3 (C-3), 69.0(C-4), 68.4 (*C*H$_2$), 67.2 (C-5), 62.6 (C-6), 31.3 (*C*H$_2$), 20.7, 20.6 (CO*C*H$_3$, overlapping peaks), 19.2 (*C*H$_2$), 13.7 (*C*H$_3$); IR (film) cm^{-1}: 2959, 2880, 1735, 1374, 1239, 1181, 1084, 1055, 1030, 990, 976, 906, 763, 697; ESI-HRMS calcd for $C_{23}H_{30}O_{10}Na$ 489.1737, found *m/z* 489.1740 $[M+Na]^+$.



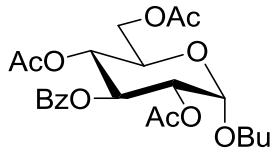
Butyl 2,3,6-tri-O-acetyl-4-O-benzoyl-α-D-glucopyranoside (81α)

$[\alpha]_D$ 5.9 (*c* 0.6, CH_2Cl_2); ^{1}H NMR (500 MHz, $CDCl_3$): δ 7.99 (dd, ^{3}J (H,H) =8.2, 1.4, 2H; Ar-*H*), 7.66 – 7.56 (m, 1H; Ar-*H*), 7.46 (t, ^{3}J (H,H) =7.8, 2H; Ar-*H*), 5.72 (apt. t, ^{3}J (H,H) =9.8, 1H; H-3), 5.30 (apt.t, ^{3}J (H,H) =9.8, 1H; H-4), 5.15 (d, ^{3}J (H,H) =3.7, 1H; H-1), 4.92 (dd, ^{3}J (H,H) =10.2, 3.7, 1H; H-2), 4.29 (dd, ^{2}J (H,H) = -12.3, ^{3}J (H,H) = 4.8, 1H; H-6a), 4.22 (dd, ^{2}J (H,H) = -12.3, ^{3}J (H,H) =2.8, 1H; H-6b), 4.16 (ddd, *J*=10.1, 4.8, 2.7, 1H; H-5), 3.74 (dt, ^{2}J (H,H) = -9.9, ^{3}J (H,H) =6.5, 1H; C*H*H), 3.49 (dt, ^{2}J (H,H) = -9.9, ^{3}J (H,H) = 6.6, 1H; C*H*H), 2.16 (s, 3H; COCH_3), 2.12 (s, 3H; COCH_3), 1.97 (s, 3H; COCH_3), 1.67 – 1.58 (m, 2H; CH_2), 1.46 – 1.34 (m, 2H; CH_2), 0.96 (t, ^{3}J (H,H) =7.4, 3H; CH_3); ^{13}C NMR (126 MHz, $CDCl_3$): δ 173.1 , 171.4, 171.2 (3 x *C*OCH$_3$), 165.5 (*C*OPh), 133.9, 130.0, 128.7 (5 x Ar-*C*H, overlapping peaks), 128.5 (Ar-*C*), 95.5 (C-1), 71.4 (C-2), 70.5 (C-3), 69.3 (C-4), 68.7 (*C*H$_2$), 67.1 (C-5), 63.5 (C-6), 31.3 (*C*H$_2$), 20.9, 20.8 (3 x CO*C*H$_3$), 19.2 (*C*H$_2$), 13.8 (*C*H$_3$); IR (film) cm^{-1}: 2963, 2880, 1730, 1367, 1241, 1173, 1084, 1054, 1026, 990, 969, 901, 761, 699; ESI-HRMS calcd for $C_{23}H_{34}O_8N$ 484.2183, found *m/z* 484.2191$[M+NH_4]^+$.



Butyl 2-O-benzoyl-4,6,3-tri-*O*-acetyl-α-D-glucopyranoside (86α)

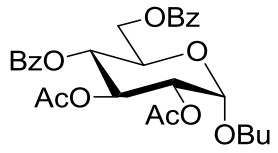
$[\alpha]_D$ 11.5 (*c* 0.5, CH_2Cl_2); ^{1}H NMR (500 MHz, $CDCl_3$): δ 8.08 – 7.95 (m, 2H; Ar-*H*), 7.59 – 7.53 (m, 1H; Ar-*H*), 7.44 (t, ^3J (H,H) =7.8, 2H; Ar-*H*), 5.77 – 5.60 (m, 1H; H-3), 5.21 (d, ^3J (H,H) =3.8, 1H, H-1), 5.14 (apt. t, ^3J (H,H) =9.8, 1H; H-4), 5.05 (dd, ^3J (H,H) =10.4, 4.0, 1H; H-2), 4.29 (dd, ^2J (H,H) = -12.3, ^3J (H,H) = 4.6, 1H; H-6a), 4.15 – 4.11 (m, 1H, H-6b), 4.08 (ddd, ^3J (H,H) =10.1, 4.6, 2.3, 1H; H-5), 3.70 (dt, ^2J (H,H) = -9.8, ^3J (H,H) =6.4, 1H; C*H*H), 3.42 (dt, ^2J (H,H) = -9.9, ^3J (H,H) = 6.4, 1H; C*H*H), 2.11 (s, 3H; COC*H*$_3$), 2.05 (s, 3H; COC*H*$_3$), 1.95 (s, 3H; COC*H*$_3$), 1.56 – 1.49 (m, 2H; C*H*$_2$), 1.31 (h, ^3J (H,H) =7.4, 2H; C*H*$_2$), 0.82 (t, ^3J (H,H) =7.4, 3H; C*H*$_3$); ^{13}C NMR (126 MHz, $CDCl_3$): δ 170.7, 170.2, 169.6 (3 x *C*OCH$_3$), 165.7 (*C*OPh), 133.4, 129.8 (3 x Ar-*C*H, overlapping peaks), 129.1 (Ar-*C*), 128.5 (2 x Ar-*C*H, overlapping peaks), 95.8 (C-1), 71.6 (C-2), 70.2 (C-3), 68.6 (C-4), 68.5 (*C*H$_2$), 67.3 (C-5), 62.0 (C-6), 31.3 (*C*H$_2$), 20.7 (3 x CO*C*H$_3$), overlapping peaks), 19.1 (*C*H$_2$), 13.6 (*C*H$_3$); IR (film) cm^{-1}: 2874, 1725, 1229, 1116, 704; ESI-HRMS calcd for $C_{23}H_{30}O_{10}Na$ 489.1737, found *m/z* 489.1735 $[M+Na]^+$.



Butyl 2,4,6-tri-*O*-acetyl-3-*O*-benzoyl-α-D-glucopyranoside (87α)

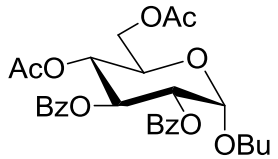
$[\alpha]_D$ 2.6 (*c* 0.1, CH_2Cl_2); ^{1}H NMR (500 MHz, $CDCl_3$): δ 7.98 (d, ^3J (H,H) =7.3, 2H; Ar-*H*), 7.61 – 7.54 (m, 1H; Ar-*H*), 7.43 (apt. t, ^3J (H,H) =7.8, 2H; Ar-*H*), 5.75 (apt. t, ^3J (H,H) =9.9, 1H; H-3), 5.29 – 5.16 (m, 1H; H-4), 5.10 (d, ^3J (H,H) =3.7, 1H; H-1), 5.04 (dd, ^3J (H,H) =10.2, 3.7, 1H; H-2), 4.28 (dd, ^2J (H,H) =12.2, ^3J (H,H) = 4.6, 1H; H-6a), 4.17 – 4.02 (m, 2H; H-6b, H-5 , overlapping peaks), 3.73 (dt, ^2J (H,H) = -9.8, ^3J (H,H) = 6.6, 1H; C*H*H), 3.47 (dt, ^2J (H,H) = -9.7, ^3J (H,H) = 6.5, 1H; C*H*H), 2.11 (s, 3H; COC*H*$_3$), 1.97 (s, 3H; COC*H*$_3$), 1.93 (s, 3H; COC*H*$_3$), 1.68 – 1.56 (m, 2H; C*H*$_2$), 1.41 (qd, ^3J (H,H) =7.2, 2.4, 2H; C*H*$_2$), 0.94 (t, ^3J (H,H) =7.4, 3H; C*H*$_3$); ^{13}C NMR (126 MHz, $CDCl_3$): δ 170.7, 169.5 (3 x *C*OCH$_3$, overlapping peaks), 165.9 (*C*OPh), 133.4, 129.8 (3 x Ar-*C*H, overlapping peaks), 129.1 (Ar-*C*), 128.5 (2 x Ar-*C*H, overlapping peaks), 95.9 (C-1), 71.0 (C-2), 70.7 (C-3), 68.5 (C-4, *C*H$_2$, overlapping peaks), 67.4 (C-5), 62.0 (C-6), 31.3 (*C*H$_2$), 20.8, 20.6, 20.5 (3 x COC*H*$_3$), 19.2 (*C*H$_2$), 13.8(*C*H$_3$); IR (film) cm^{-1}: 2875, 1723, 1451, 1369, 1213,

1069, 686, 547; ESI-HRMS calcd for $C_{23}H_{34}O_8N$ 484.2183, found *m/z* 484.2189 $[M+NH_4]^+$.



Butyl 2,3-di-*O*-acetyl-4,6-di-*O*-benzoyl- β -D-glucopyranoside (88α)

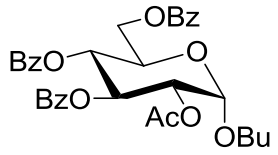
$[\alpha]_D$ 60.6 (*c* 0.3, CH_2Cl_2); ^{1}H NMR (500 MHz, $CDCl_3$): δ 8.00 (ddd, *J*=7.7, 6.0, 1.5, 4H; Ar-*H*), 7.64 – 7.49 (m, 2H; ArH), 7.41 (dd, ^3J (H,H) =14.9, 7.5, 4H; Ar-*H*), 5.75 (apt. t, ^3J (H,H) =9.9, 1H; H-3), 5.41 (apt.t, ^3J (H,H) =9.8, 1H; H-4), 5.16 (d, ^3J (H,H) =3.7, 1H; H-1), 4.95 (dd, ^3J (H,H) =10.2, 3.7, 1H; H-2), 4.54 (dd, ^2J (H,H) = -12.2, ^3J (H,H) = 3.0, 1H; H-6a), 4.42 (dd, ^2J (H,H) = -12.2, ^3J (H,H) = 5.4, 1H; H-6b), 4.31 (ddd, ^3J (H,H) =10.1, 5.3, 2.9, 1H; H-5), 3.76 (dt, ^2J (H,H) = -9.9, ^3J (H,H) = 6.6, 1H; C*H*H), 3.49 (dt, ^2J (H,H) = -9.8, ^3J (H,H) = 6.7, 1H; C*H*H), 2.13 (s, 3H; COCH_3), 1.97 (s, 2H; COCH_3), 1.69 – 1.57 (m, 2H; CH_2), 1.39 (dt, ^3J (H,H) =15.0, 7.4, 2H; CH_2), 0.93 (t, ^3J (H,H) =7.4, 3H; CH_3); ^{13}C NMR (126 MHz, $CDCl_3$): δ 171.4 (2 x *C*OCH$_3$, overlapping peaks), 166.5, 165.6 (2 x *C*OPh), 133.8, 133.3, 130.0, 129.8 (5 x Ar-*C*H, overlapping peaks), 129.3 (Ar-*C*), 128.6 (2 x Ar-*C*H overlapping peaks), 128.5 (Ar-*C*), 128.4 (2 x Ar-*C*H, overlapping peaks), 95.5 (C-1), 71.5 (C-2), 70.6 (C-3), 69.7 (C-4), 68.6 (*C*H$_2$), 67.4 (C-5), 63.3 (C-6), 31.3 (*C*H$_2$), 20.8 (2 x CO*C*H$_3$, overlapping peaks), 19.2 (*C*H$_2$), 13.8 (*C*H$_3$); IR (film) cm^{-1}: 2878, 1716, 1232, 1182, 1034, 899, 750, 680 ;ESI-HRMS calcd for $C_{28}H_{36}O_{10}N$ 546.2339, found *m/z* 546.2341$[M+NH_4]^+$.



Butyl 2,3-di-*O*-benzoyl-4,6-di-*O*-acetyl-α-D-glucopyranoside (91α)

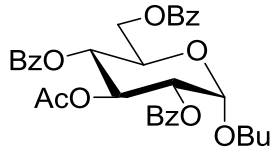
$[\alpha]_D$ 15.2 (*c* 0.2, CH_2Cl_2); ^{1}H NMR (500 MHz, $CDCl_3$): δ 7.95 (td, ^3J (H,H) =8.1, 1.4, 4H; Ar-*H*), 7.55 – 7.47 (m, 2H; Ar-*H*), 7.38 (t, ^3J (H,H) =7.6, 4H; Ar-*H*), 5.99 (apt. t, ^3J (H,H) =9.8, 1H; H-3), 5.34 (apt. t, ^3J (H,H) =9.9, 1H; H-3), 5.29 (d, ^3J (H,H) =3.6, 1H; H-1), 5.23 (dd, ^3J (H,H) =10.2, 3.7, 1H; H-2), 4.39 (dd, ^2J (H,H) = -12.4, ^3J (H,H) = 4.5, 1H; H-6a), 4.26 (dd, ^2J (H,H) = -12.3, ^3J (H,H) = 2.3, 1H; H-

6b), 4.20 (ddd, ^{3}J (H,H) =10.3, 4.4, 2.4, 1H; H-5), 3.75 (dt, ^{2}J (H,H) = -9.8, ^{3}J (H,H) = 6.4, 1H; C*H*H), 3.48 (dt, ^{2}J (H,H) = -9.8, ^{3}J (H,H) = 6.5, 1H; C*H*H), 2.27 (s, 3H; COCH_3), 2.02 (s, 3H; COCH_3), 1.63 – 1.51 (m, 2H; CH_2), 1.35 (q, ^{3}J (H,H) =7.4, 2H; CH_2), 0.84 (t, ^{3}J (H,H) =7.4, 3H; CH_3); ^{13}C NMR (126 MHz, $CDCl_3$): δ 173.8, 171.2 (2 x *C*OCH$_3$), 166.1, 166.0 (2 x *C*OPh), 133.6, 129.9, 129.8 (6 x Ar-*C*H, overlapping peaks), 128.8, 128.7 (2 x Ar-*C*), 128.5, 128.4 (2 x Ar-*C*H), 96.0 (C-1), 71.8 (C-2), 70.7 (C-3), 69.0 (C-4), 68.9 (*C*H$_2$), 67.1 (C-5), 63.4 (C-6), 31.3 (*C*H$_2$), 21.1, 20.8 (2 x CO*C*H$_3$), 19.2 (*C*H$_2$), 13.7 (*C*H$_3$); IR (film) cm^{-1}: 2932, 1717, 1265, 1171, 1069, 1037, 918, 856, 685; ESI-HRMS calcd for $C_{28}H_{36}O_{10}N$ 546.2339, found *m/z* 546.2352 $[M+NH_4]^+$.



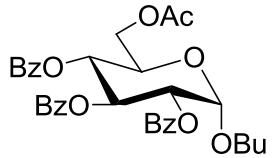
Butyl 2-*O*-acetyl-3,4,6-tri-*O*-benzoyl-β-D-glucopyranoside (98α)

$[\alpha]_D$ 36.42 (*c* 0.1, CH_2Cl_2); ^{1}H NMR (500 MHz, $CDCl_3$): δ 8.03 (dd, ^{3}J (H,H) =8.2, 1.3, 2H; Ar-*H*), 7.91 (td, ^{3}J (H,H) =8.1, 1.4, 4H; Ar-*H*), 7.59 – 7.52 (m, 1H; Ar-*H*), 7.52 – 7.46 (m, H; Ar-*H*), 7.43 – 7.39 (m, 2H; Ar-*H*), 7.35 (td, ^{3}J (H,H) =7.8, 2.9, 4H; Ar-*H*), 5.99 (apt. t, ^{3}J (H,H) =9.8, 1H; H-3), 5.57 (apt. t, ^{3}J (H,H) =9.8, 1H; H-4), 5.21 – 5.02 (m, 2H; H-1, H-2, overlapping peaks), 4.56 (dd, ^{2}J (H,H) = -12.0, ^{3}J (H,H) = 2.8, 1H; H-6a), 4.43 (dd, ^{2}J (H,H) = -12.0, ^{3}J (H,H) = 5.3, 1H; H-6b), 4.38 (ddd, ^{3}J (H,H) =10.2, 5.3, 2.7, 1H; H-5), 3.79 (dt, ^{2}J (H,H) = -9.8, ^{3}J (H,H) = 6.6, 1H; C*H*H), 3.51 (dt, ^{2}J (H,H) = -9.8, ^{3}J (H,H) =6.6, 1H; C*H*H), 1.98 (s, 3H; COCH_3), 1.64 (dt, ^{3}J (H,H) =8.7, 6.7, 2H; CH_2), 1.42 (p, ^{3}J (H,H) =7.5, 2H; CH_2), 0.94 (t, ^{3}J (H,H) =7.4, 2H; CH_3); ^{13}C NMR (126 MHz, $CDCl_3$): δ 170.3 (*C*OCH$_3$), 166.1, 165.6, 165.3 (3 x *C*OPh), 133.3, 133.2, 133.1, 129.9, 129.7, 129.7 (9 xAr-*C*H, overlapping peaks), 129.2, 128.9, 128.4 (3 x Ar-*C*), 128.3 (6 x Ar-*C*H, overlapping peaks), 95.8 (C-1), 71.2 (C-2), 70.5 (C-3), 69.7 (C-4), 68.5 (*C*H$_2$), 67.7 (C-5), 63.0 (C-6), 31.3 (*C*H$_2$), 20.6 (CO*C*H$_3$), 19.2 (*C*H$_2$), 13.8 (*C*H$_3$); IR (film) cm^{-1}: 2875, 1757, 1492, 1265, 1178, 1068, 964 686; ESI-HRMS calcd for $C_{33}H_{38}O_{10}N$ 608.2496, found *m/z* 608.2500 $[M+NH_4]^+$.



Butyl 2,4,6-tri-*O*-benzoyl-3-*O*-acetyl-α-D-glucopyranoside (99α)

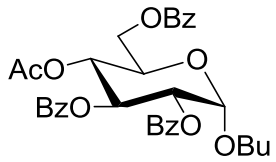
$[\alpha]_D$ 25.4 (*c* 0.1, CH_2Cl_2); ^{1}H NMR (500 MHz, $CDCl_3$): δ 8.08 – 7.88 (m, 5H; Ar-*H*), 7.62 – 7.51 (m, 3H; Ar-*H*), 7.50 – 7.37 (m, 7H; Ar-*H*), 5.94 (apt. t, ^3J (H,H) =9.9, 1H; H-3), 5.49 (apt. t, ^3J (H,H) =9.8, 1H; H-4), 5.28 (d, ^3J (H,H) =3.8, 1H; H-1), 5.14 (dd, ^2J (H,H) = -10.2, ^3J (H,H) = 3.8, 1H; H-2), 4.56 (dd, ^2J (H,H) = -12.1, ^3J (H,H) = 2.8, 1H; H-6a), 4.47 – 4.40 (m, 1H; H-6b), 4.37 (ddd, ^3J (H,H) =10.2, 5.3, 2.8, 1H; H-5), 3.76 (dt, ^2J (H,H) = -9.8, ^3J (H,H) = 6.5, 1H; C*H*H), 3.46 (dt, ^2J (H,H) = -9.8, ^3J (H,H) =6.6, 1H; C*H*H), 1.86 (s, 3H; COCH_3), 1.66 – 1.50 (m, 2H; CH_2), 1.32 (m, 2H; CH_2), 0.81 (t, ^3J (H,H) =7.4, 1H; CH_3); ^{13}C NMR (126 MHz, $CDCl_3$): δ 170.1 (*C*OCH$_3$), 166.1, 165.7, 165.3 (3 x *C*OPh), 133.5, 133.4, 133.1, 129.9, 129.9, 129.7 (9 x Ar-*C*H, overlapping peaks), 129.1, 128.9 (3 x Ar-*C*, overlapping peaks), 128.5, 128.5, 128.3 (6 x Ar*C*H, overlapping peaks), 95.8 (C-1), 71.8 (C-2), 70.0 (C-3), 69.7 (C-4), 68.6 (*C*H$_2$), 67.6 (C-5), 63.1 (C-6), 31.3 (*C*H$_2$), 20.6 (CO*C*H$_3$), 19.2 (*C*H$_2$), 13.6 (*C*H$_3$); IR (film) cm^{-1}: 2874, 1757, 1584, 1376, 1176, 1010, 892, 617; ESI-HRMS calcd for $C_{33}H_{38}O_{10}N$ 608.2496, found *m/z* 608.2491$[M+NH_4]^+$.



Butyl 2,3,4-tri-*O*-benzoyl-6-*O*-acetyl-α-D-glucopyranoside (102α)

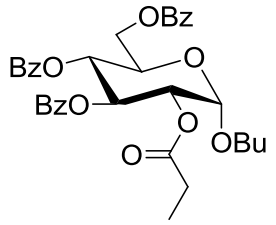
$[\alpha]_D$ 24.8 (*c* 0.3, CH_2Cl_2); ^{1}H NMR (500 MHz, $CDCl_3$): δ 8.01 – 7.90 (m, 4H; Ar-*H*), 7.90 – 7.82 (m, 2H; Ar-*H*), 7.51 (t, ^3J (H,H) = 7.4, 2H; Ar-*H*), 7.44 – 7.35 (m, 4H; Ar-*H*), 7.29 (t, ^3J (H,H) = 7.8, 2H; Ar-*H*), 6.15 (apt.t, ^3J (H,H) = 9.8, 1H; H-3), 5.58 (apt. t, ^3J (H,H) = 9.5, 1H; H-3), 5.33 (d, ^3J (H,H) = 3.8, 1H; H-1), 5.27 (dd, ^3J (H,H) = 10.2, 3.8, 1H; H-2), 4.34 – 4.28C*H*H), 2.08 (s, 3H; COCH_3), 1.62 – 1.52 (m, H, CH_2), 1.37 (q, ^3J (*H,H)* = 7.5, 1H; CH_2), 0.86 (t, ^3J (H,H) = 7.4, 4H; CH_3); ^{13}C NMR (126 MHz, $CDCl_3$): δ 170.3 (*C*OCH$_3$), 166.1, 165.6, 165.3 (3 x *C*OPh), 133.3, 133.2, 133.1, 129.9, 129.7, 129.7 (9 xAr-*C*H, overlapping peaks), 129.2, 128.8, 128.6 (3 x Ar-*C*), 128.3 (6 x Ar-*C*H, overlapping peaks), 95.8 (C-1), 71.2 (C-3), 70.5 (C-4), 69.7 (C-2), 68.5 (*C*H$_2$), 67.7 (C-5), 63.0 (C-6), 31.3 (*C*H$_2$), 20.6 (CO*C*H$_3$), 19.2

(CH_2), 13.8 (CH_3); IR (film) cm^{-1}: 2957, 1726, 1451, 1282, 1091, 977, 685; ESI-HRMS calcd for $C_{33}H_{34}O_{10}Na$ 613.2050, found *m/z* 613.2045 $[M+Na]^+$.



Butyl 2,3,6-tri-*O*-benzoyl-4-*O*-acetyl-α-D-glucopyranoside (103α)

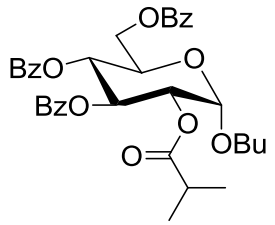
$[\alpha]_D$ 23.3 (*c* 0.1, CH_2Cl_2); ^1H NMR (500 MHz, $CDCl_3$): δ 8.10 (dd, ^3J (H,H) = 8.3, 1.4, 2H; Ar-*H*), 8.01 – 7.89 (m, 4H; Ar-*H*), 7.62 – 7.57 (m, 1H; Ar-*H*), 7.55 – 7.45 (m, 4H; Ar-*H*), 7.45 – 7.33 (m, 4H; Ar-*H*), 6.00 (apt. t, ^3J (H,H) = 9.8, 1H; H-3), 5.42 (apt. t, ^3J (H,H) = 9.9, 1H; H-4), 5.29 (d, *J*=3.7, 1H; H-1), 5.22 (dd, ^3J (H,H) = 10.2, 3.7, 1H; H-2), 4.54 (dd, ^2J (H,H) = -12.2, ^3J (H,H) = 2.5, 1H; H-6a), 4.45 (dd, ^2J (H,H) = -12.2, ^3J (H,H) = 5.0, H1; H-6b), 4.31 (ddd, ^3J (H,H) = 10.3, 5.0, 2.4, 1H; H-5), 3.76 (dt, ^2J (H,H) = -9.8, ^3J (H,H) = 6.5, 1H; C*H*H), 3.47 (dt, ^2J (H,H) = -9.8, ^3J (H,H) = 6.6, 1H; C*H*H), 1.96 (s, 3H; COCH_3), 1.62 – 1.51 (m, 2H; CH_2), 1.33 (h, ^3J (H,H) = 7.4, 1H; CH_2), 0.82 (t, ^3J (H,H) = 7.4, 1H; CH_3); ^{13}C NMR (126 MHz, $CDCl_3$): δ 169.5 (*C*OCH$_3$), 166.2, 165.8 (3 x *C*OPh, overlapping peaks), 133.3, 133.2, 129.9 (5 x Ar-*C*H, overlapping peaks), 129.7 (Ar-*C*, 4 x Ar-*C*H, overlapping peaks), 129.2, 129.1 (2 x Ar-*C*), 128.4 (6 x Ar-*C*H, overlapping peaks) 95.9 (C-1), 71.9 (C-2), 70.8 (C-3), 68.8 (C-4), 68.6 (*C*H$_2$), 67.6 (C-5), 62.8 (C-6), 31.3 (*C*H$_2$), 20.6 (CO*C*H$_3$), 19.2 (*C*H$_2$), 13.6 (*C*H$_3$); IR (film) cm^{-1}: 2964, 1721, 1447, 1277, 1087, 983, 670; ESI-HRMS calcd for $C_{33}H_{34}O_{10}Na$ 613.2050, found *m/z* 613.2061 $[M+Na]^+$.



Butyl 2-*O*-propionyl-3,4,6-tri-*O*-benzoyl-α-D-glucopyranoside (105α)

$[\alpha]_D$ 97.7 (*c* 0.5, CH_2Cl_2); ^1H NMR (500 MHz, $CDCl_3$): δ 8.06 – 7.94 (m, 2H; Ar-*H*), 7.95 – 7.87 (m, 4H; Ar-*H*), 7.54 (t, ^3J (H,H) = 7.5, 1H; Ar-*H*), 7.49 (td, ^3J (H,H) =7.4, 4.6, 2H; Ar-*H*), 7.41 (t, ^3J (H,H) = 7.6, 2H; Ar-*H*), 7.35 (t, ^3J (H,H) = 7.7, 4H; Ar-*H*), 5.99 (apt. t, ^3J (H,H) = 9.8, 1H; H-3), 5.57 (apt. t, ^3J (H,H) = 9.9, 1H; C-4),

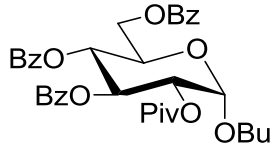
5.25 – 5.04 (m, 2H; H-1, H-2), 4.56 (dd, ^2J (H,H) = -12.1, ^3J (H,H) = 2.8, 1H; H-6a), 4.44 (dd, ^2J (H,H) = -12.0, ^3J (H,H) = 5.4, 1H; H-6b), 4.38 (ddd, ^3J (H,H) = 10.2, 5.3, 2.8, 1H; H-5), 3.78 (dt, ^2J (H,H) = -9.8, ^3J (H,H) = 6.6, 1H; C*H*H), 3.50 (dt, ^2J (H,H) = -9.8, ^3J (H,H) = 6.6, 1H; C*H*H), 2.37 – 2.16 (m, 2H; CH_2), 1.64 (dq, ^3J (H,H) = 8.8, 6.8, 2H; CH_2), 1.41 (h, ^3J (H,H) = 7.4, 2H; CH_2), 0.99 (t, ^3J (H,H) = 7.6, 3H; CH_3), 0.93 (t, ^3J (H,H) = 7.4, 3H; CH_3); ^{13}C NMR (126 MHz, $CDCl_3$): δ 173.8 (*C*OCH_2CH_3), 166.1, 165.6, 165.3(3 x *C*OPh), 133.3, 133.2, 133.1, 129.9 (5 x Ar-*C*H, overlapping peaks), 129.7 (Ar-*C*, 4 x Ar-*C*H, overlapping peaks), 129.2, 128.9 (2 x Ar-*C*), 128.4, 128.3 (6 x Ar-*C*H, overlapping peaks), 95.9 (C-1), 71.1 (C-2), 70.6 (C-3), 69.7 (C-4), 68.5 (*C*H_2), 67.7 (C-5), 63.1 (C-6), 31.3 (*C*H_2), 27.4 (*C*H_2), 19.2 (*C*H_2), 13.8(*C*H_3), 8.9 (*C*H_3) ESI-HRMS calcd for $C_{34}H_{35}O_{10}Na$ 627.2206, found *m/z* 627.2192 $[M+Na]^+$.



Butyl 2-*O*-isobutyryl-3,4,6-tri-*O*-benzoyl-β-D-glucopyranoside (106α)

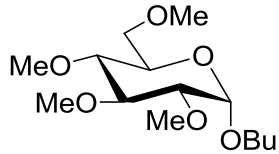
$[\alpha]_D$ 24.7 (*c* 0.4, CH_2Cl_2); ^{1}H NMR (500 MHz, $CDCl_3$): δ 8.06 – 8.01 (m, 2H; Ar-*H*), 7.91 (ddd, ^3J (H,H) =18.3, 8.4, 1.4, 4H; Ar-*H*), 7.57 – 7.52 (m, 1H; Ar-*H*), 7.52 – 7.45 (m, 2H; Ar-*H*), 7.45 – 7.36 (m, 2H; Ar-*H*), 7.37 – 7.33 (m, 4H; Ar-*H*), 6.01 (apt. t, ^3J (H,H) =9.8, 1H; H-3), 5.58 (apt. t, ^3J (H,H) =9.8, 1H; H-4), 5.15 (d, ^3J (H,H) =3.8, 1H; H-1), 5.11 (dd, ^3J (H,H) =10.1, 3.7, 1H; H-2), 4.56 (dd, ^2J (H,H) = -12.1, ^3J (H,H) = 2.8, 1H; H-6a), 4.44 (dd, ^2J (H,H) = -12.1, ^3J (H,H) = 5.3, 1H; H-6b), 4.38 (ddd, ^3J (H,H) =10.2, 5.4, 2.8, 1H; H-5), 3.78 (dt, ^2J (H,H) =9.8, ^3J (H,H) = 6.6, 1H; C*H*H), 3.49 (dt, ^2J (H,H) =9.8, ^3J (H,H) =6.7, 1H; C*H*H), 2.48 (dt, ^2J (H,H) =14.0, ^3J (H,H) = 7.0, 1H; C*H*$(CH_3)_2$), 1.68 – 1.60 (m, 2H; CH_2), 1.46 – 1.38 (m, 2H; CH_2), 1.04 (d, ^3J (H,H) =7.0, 3H; CH_3), 0.97 (d, ^3J (H,H) =7.0, 3H; CH_3), 0.93 (t, ^3J (H,H) =7.4, 3H; CH_3); ^{13}C NMR (126 MHz, $CDCl_3$): δ 176.4 (*C*O$CH(CH_3)_2$), 166.1, 165.6, 165.3(3 x *C*OPh), 133.3, 133.1, 133.0, 129.9, 129.7 (9 x Ar-*C*H, overlapping peaks), 129.2, 128.9 (3 x Ar-*C*, overlapping peaks), 128.4(6 x Ar-*C*H, overlapping peaks), 95.9 (C-1), 71.0 (C-2), 70.6 (C-3), 69.7 (C-4), 68.5 (*C*H_2), 67.7 (C-5), 63.1 (C-6), 33.8 (*C*$H(CH_3)_2$), 31.4 (*C*H_2), 19.2 (*C*H_2), 18.7 (*C*H_3), 18.6(*C*H_3),

13.8(CH_3); IR (film) cm^{-1} 3294, 3001, 2920, 2865, 1758, 1731, 1709, 1443, 1268, 1093, 1065, 1038, 932, 754; ESI-HRMS calcd for $C_{35}H_{38}O_{10}Na$ 641.2363, found *m/z* 641.2360 $[M+Na]^+$.



Butyl 2-*O*-pivaloyl-3,4,6-tri-*O*-benzoyl-α-D-glucopyranoside (107α)

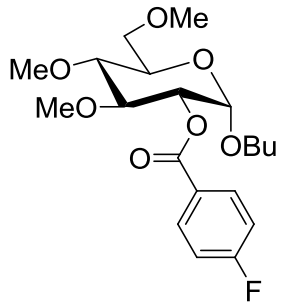
$[\alpha]_D$ 34.4 (*c* 0.5, CH_2Cl_2);^{1}H NMR (500 MHz, $CDCl_3$): δ 8.03 (d, ^3J (H,H) =7.5, 2H; Ar-*H*), 7.93 (d, ^3J (H,H) =8.0, 2H; Ar-*H*), 7.89 (d, ^3J (H,H) =8.1, 4H; Ar-*H*), 7.48 (td, ^3J (H,H) =7.5, 7.0, 2.8, 2H; Ar-*H*), 7.40 – 7.34 (m, 5H; Ar-*H*), 6.04 (apt. t, ^3J (H,H) =9.9, 1H; H-3), 5.59 (apt. t, ^3J (H,H) =9.9, 1H; H-4), 5.16 (d, ^3J (H,H) =3.7, 1H; H-1), 5.06 (dd, ^3J (H,H) =10.2, 3.8, 1H; H-2), 4.57 (dd, ^2J (H,H) = -12.1, ^3J (H,H) =2.9, 1H; H-6a), 4.44 (dd, ^2J (H,H) = -12.1, ^3J (H,H) = 5.4, 1H; H-6b), 4.39 (ddd, ^3J (H,H) =10.3, 5.3, 2.9, 1H; H-5), 3.78 (dt, ^2J (H,H) = -9.8, ^3J (H,H) =6.4, 1H; C*H*H), 3.47 (dt, ^2J (H,H) = -9.9, ^3J (H,H) = 6.7, 1H; C*H*H), 1.66 – 1.52 (m, 2H; CH_2), 1.46 – 1.34 (m, 2H; CH_2), 1.05 (s, 9H; 3 x CH_3, overlapping peaks), 0.93 (t, ^3J (H,H) =7.4, 3H; CH_3); ^{13}C NMR (126 MHz, $CDCl_3$): δ 178.1 (*C*OC(CH_3)$_3$), 165.8, 165.1 (3 x x*C*OPh, overlapping peaks), 133.4, 133.2, 133.1, 129.8, 129.7, 129.7 (9 x Ar-*C*H, overlapping peaks), 129.4, 128.8 (3 x Ar-*C*, overlapping peaks), 128.4, 128.3 (6 x Ar-*C*H, overlapping peaks), 101.2 (C-1), 73.0 (C-3), 72.3 (C-4), 71.9 (C-2), 69.8 (*C*H_2), 69.6 (C-5), 62.6 (C-6), 38.8 (CO*C*(CH_3)$_3$), 31.4 (*C*H_2), 27.1 (COC(*C*H_3)$_3$, overlapping peaks), 18.9 (*C*H_2), 13.5 (*C*H_3); ESI-HRMS calcd for $C_{36}H_{44}O_{10}N$ 650.2960, found *m/z* 650.2951 $[M+NH_4]^+$.



Butyl 2,3,4,6-tetra-*O*-methyl-α-D-glucopyranoside (108α)[93]

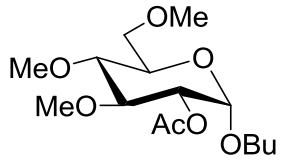
$[\alpha]_D$ 53.9 (*c* 0.1, CH_2Cl_2); ^{1}H NMR (500 MHz, $CDCl_3$): δ 4.91 (d, ^3J (H,H) =3.6, 1H; H-1), 3.68 – 3.55 (m, 6H; H-6, C*H*, OCH_3, C*H*H overlapping peaks), 3.55 – 3.49 (m, 4H; C*H*H, OCH_3, overlapping peaks), 3.49 – 3.45 (m, 5H; C-6b, C*H* OCH_3, overlapping peaks), 3.40 (s, 3H; OCH_3, overlapping peaks), 3.21 – 3.16 (m, 2H; C-2, C*H*, overlapping peaks), 1.69 – 1.50 (m, 2H; CH_2), 1.46 – 1.22 (m, 2H; CH_2), 0.90

(t, ^{3}J (H,H) =7.4, 3H; CH_3).; ^{13}C NMR (126 MHz, $CDCl_3$): δ 96.2 (C-1), 83.3 (C-2), 81.7 (*C*H), 79.6 (*C*H), 71.1 (*C*H_2), 69.8(*C*H), 67.7 (C-6), 60.8, 60.4, 59.2, 58.7 (4 x O*C*H_3), 31.4 (*C*H_2), 19.4 (*C*H_2), 13.8(*C*H_3). IR (film) cm^{-1} : 3937, 2843, 1450, 1381, 1092; ESI-HRMS calcd for $C_{14}H_{29}O_6$ 385.2202, found *m/z* 385.2209$[M+H]^+$.



Butyl 2-*O*-(4-flourobenzoyl)-3,4,6-tri-*O*-methyl-α-D-glucopyranoside (111α)

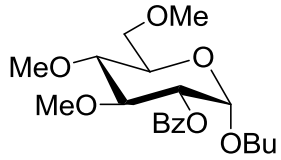
$[\alpha]_D$ 22.0 (*c* 0.2, CH_2Cl_2); 8.10 (dd, ^{3}J (H,H) =8.4, 1.2, 2H; Ar-*H*), 7.60 – 7.53 (m, 2H; Ar-*H*), 5.11 (d, ^{3}J (H,H) =3.6, 1H; H-1), 4.90 – 4.84 (m, 1H; H-2), 3.77 - 3.70 (m, 2H, 2 x C*H*, overlapping peaks), 3.69 – 3.60 (m, 3H; H-6a, H-6b, C*H*H, overlapping peaks), 3.61 (s, 3H; OCH_3), 3.54 (s, 3H; OCH_3), 3.43 (s, 3H; OCH_3), 3.40 (dt, ^{2}J (H,H) =10.0, ^{3}J (H,H) = 6.8, 1H; C*H*H), 3.6 (apt t, ^{3}J (H,H) =9.8, 1H; C*H*) 1.49 (dq, ^{2}J (H,H) =8.2, ^{3}J (H,H) = 6.6, 2H; CH_2), 1.34 – 1.27 (m, 2H; CH_2), 0.84 (t, ^{3}J *(H,H)* =7.3, 3H;CH_3); ^{13}C NMR (126 MHz, $CDCl_3$): δ 167.1 (d, ^{1}J (C,F) =254.0; Ar*C*F), 165.6 (*C*OC_6H_4F) 135.1(d, ^{3}J (C,F) =9.0; 2 x Ar*CH*,overlapping peaks), 128.1 (d, ^{4}J (C,F) =3.1; Ar*C*), 114.9 (d, ^{2}J (C,F) =21.9; 2 x Ar-*C*H, overlapping peaks). 96.4 (C-1), 85.1 (C-2), 80.2 (C-3), 75.1 (C-5), 74.7 (C-4), 71.8 (C-6), 70.4 (*C*H_2), 60.8, 60.6, 59.9 (3 x O*C*H_3), 31.3 (*C*H_2), 18.9 (*C*H_2), 13.6 (CH_3); ESI-HRMS calcd for $C_{20}H_{31}O_7F$ 401.1976, found *m/z* 401.1970 $[M+H]^+$.



Butyl 2-*O*-acetyl-3,4,6-tri-*O*-methyl-α-D-glucopyranoside (112α)

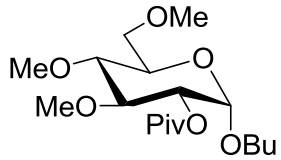
$[\alpha]_D$ 13.3 (*c* 0.1, CH_2Cl_2); ^{1}H NMR (500 MHz, $CDCl_3$): δ 4.97 (d, ^{3}J (H,H) =3.8, 1H; H-1), 4.69 (dd, ^{3}J (H,H) =10.0, 3.7, 1H; H-2), 3.72 – 3.46 (m, 10H; H-6a, H-6b, 2 x C*H*, C*H*H, 2 x OCH_3, ovverlapping peaks), 3.47 – 3.36 (m, 4H; C*H*H, OCH_3, overpapping peaks), 3.25 (apt. t, ^{3}J (H,H) =9.5, 1H; C*H*), 2.10 (s, 3H; COCH_3), 1.54 (d, ^{3}J (H,H) =8.2, 2H; CH_2), 1.36 (dtd, ^{3}J (H,H) =10.6, 7.7, 4.2, 2H; CH_2), 0.91 (t, ^{3}J

(H,H) =7.3, 3H; CH_3); ^{13}C NMR (126 MHz, $CDCl_3$): δ 170.3 (*C*OCH$_3$), 95.8 (C-1), 81.4 (C*H)*, 79.5 (*C*H), 73.5 (*C*H), 71. (C-6), 70.0 (*C*-H), 67.8 (*C*H$_2$), 60.7, 60.5, 59.2 (3 x O*C*H$_3$), 31.4 (*C*H$_2$), 21.0 (CO*C*H$_3$), 19.3 (*C*H$_2$), 13.8 (*C*H$_3$); IR (film) cm^{-1} 3511, 3260, 2940, 1730, 1268, 1089, 1057, 708; ESI-HRMS calcd for $C_{15}H_{28}O_7Na$ 343.1733, found *m/z* 343.1730[M+Na]$^+$.



Butyl 2-*O*-benzoyl-3,4,6-tri-*O*-methyl-α-D-glucopyranoside (113α)

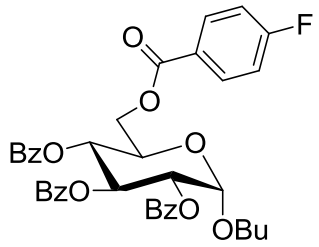
[α]$_D$ 4.8 (*c* 0.1, CH_2Cl_2); ^{1}H NMR (500 MHz, $CDCl_3$): δ 8.08 (dd, ^3J (H,H) =8.2, 1.4, 2H; Ar-*H*), 7.60 – 7.53 (m, 1H; Ar-*H*), 7.45 (t, ^3J (H,H) =7.7, 2H; Ar-*H*), 5.09 (d, ^3J (H,H) =3.7, 1H; H-1), 4.95 (dd, ^3J (H,H) =10.0, 3.8, 1H; H-2), 3.77 (apt. t, ^3J (H,H) =9.5, 1H; H-3), 3.73 (ddd, ^3J (H,H) =10.1, 4.0, 2.1, 1H; H-5), 3.69 – 3.60 (m, 4H; H-6a, H-6b, C*H*H, overlapping peaks), 3.58 (s, 3H; OCH_3), 3.57 (s, 3H; OCH_3), 3.43 (s, 3H; OCH_3), 3.37 (dt, ^2J (H,H) =10.1, ^3J (H,H) = 6.6, 1H; C*H*H), 3.33 (apt t, ^3J (H,H) =9.6, 1H; H-4) 1.51 (dq, ^2J (H,H) =8.2, ^3J (H,H) = 6.6, 2H; CH_2), 1.36 – 1.29 (m, 2H; CH_2), 0.82 (t, ^3J *(H,H)* =7.4, 3H;CH_3); ^{13}C NMR (126 MHz, $CDCl_3$): δ 165.9 (*C*OPh), 133.1 (Ar-*C*H), 130.0 (Ar-*C*), 129.7, 128.4 (4 x Ar-*C*H, overlapping peaks), 96.1 (C-1), 81.7 (C-3), 79.5 (C-4), 73.9 (C-2), 71.1 (C-6), 70.0 (C-5), 67.9 (*C*H$_2$), 60.8, 60.6, 59.3 (3 x O*C*H$_3$), 31.4 (*C*H$_2$), 19.2 (*C*H$_2$), 13.7 (*C*H$_3$); IR (film) cm^{-1} 3254, 2930, 1728, 1314, 1179, 1088, 1027, 960, 687, 547; ESI-HRMS calcd for $C_{20}H_{30}O_7Na$ 405.1889, found *m/z* 405.1898[M+Na]$^+$.



Butyl 2-*O*-pivaloyl-3,4,6-tri-*O*-methyl-α-D-glucopyranoside (114α)

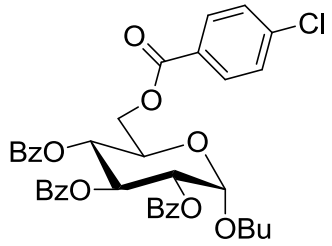
[α]$_D$ 15.8 (*c* 0.1, CH_2Cl_2); ^{1}H NMR (500 MHz, $CDCl_3$): δ 4.96 (d, ^3J (H,H) =4.2, 1H; H-1), 4.65 – 4.53 (m, 1H; H-2), 3.67 – 3.57 (m, 5H; 2 x C*H*, H-6a, H-6b, C*H*H, overlapping peaks), 3.56 (s, 3H; OCH_3), 3.54 (s, 3H; *OCH$_3$*), 3.40 (s, 3H; OCH_3), 3.37 – 3.29 (m, 1H; C*H*H), 3.27 – 3.22 (m, 1H; C*H*), 1.51 (dt, ^3J (H,H) =8.1, 6.7, 2H; CH_2), 1.35 (qd, ^3J (H,H) =7.5, 1.5, 2H; CH_2), 1.22 (s, 9H; 3 x CH_3, overlapping peaks), 0.89 (td, ^3J (H,H) =7.3, 1.5, 3H; CH_3); ^{13}C NMR (126 MHz, $CDCl_3$): δ 177.8

(*C*OC(CH$_3$)$_3$), 95.8 (C-1), 81.6 (*C*H), 79.5 (*C*H), 73.3 (*C*H), 71.0 (C-6), 69.9 (*C*H), 67.7 (*C*H$_2$), 60.8, 60.5, 59.2 (3 x O*C*H$_3$), 38.7 (CO*C*(CH$_3$)$_3$), 31.5 (*C*H$_2$), 27.1 (3x *C*H$_3$, overlapping peaks), 19.3 (*C*H$_2$), 13.8 (*CH$_3$*); IR (film) cm^{-1} 3516, 1731, 1264, 1085, 1056, 715, 539; ESI-HRMS calcd for $C_{18}H_{34}O_7Na$ 385.2202, found *m/z* 385.2213 [M+Na]$^+$.



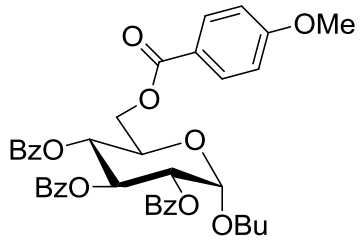
Butyl 2,3,4-tri-*O*-benzoyl-6-*O*-(4-fluorobenzoyl)-α-D-glucopyranoside (117α)

[α]$_D$ 23.3 (*c* 0.1, CH_2Cl_2); ^{1}H NMR (500 MHz, $CDCl_3$): δ 8.09 – 8.02 (m, 2H; Ar-*H*), 8.00 – 7.97 (m, 2H; Ar-*H*), 7.94 (d, ^3J (H,H) = 7.7, 2H; Ar-*H*), 7.87 (d, ^3J (H,H) = 7.8, 2H; Ar-*H*), 7.51 (td, ^3J (H,H) = 7.3, 5.3, 2H; Ar-*H*), 7.46 – 7.33 (m, 5H; Ar-*H*), 7.29 (t, ^3J (H,H) = 7.7, 2H; Ar-*H*), 7.09 (t, ^3J (H,H) = 8.6, 2H; Ar-*H*), 6.19 (apt. t, ^3J (H,H) = 9.8, 1H; H-3), 5.67 (apt. t, ^3J (H,H) = 9.8, 1H; H-3), 5.34 (d, ^3J (H,H) = 3.8, 1H; H-1), 5.30 (dd, ^3J (H,H) = 10.1, 3.7, 1H; H-2), 4.67 – 4.56 (m, 1H; H-6a), 4.52 – 4.40 (m, 2H; H-6b, H-5), 3.79 (dt, ^2J (H,H) = -9.9, ^3J (H,H) = 6.5, 1H; C*H*H), 3.50 (dt, ^2J (H,H) = -9.9, ^3J (H,H) = 6.6, 1H; C*H*H), 1.66 – 1.56 (m, 2H; C*H$_2$*), 1.35 (h, ^3J (H,H) = 7.4, 2H; C*H$_2$*), 0.84 (t, 7.4, 2H); ^{13}C NMR (126 MHz, $CDCl_3$): δ 166.3 (d, ^1J (C,F) =131.6; Ar-*C*F), 165.8, 165.3, 165.2 (3 x *C*OPh), 164.8 (*C*OC$_6$H$_4$F), 133.4, 133.3, 133.1(3 x Ar-*C*H), 132.3 (d, ^3J (C,F) =9.5; 2 x ArCH, overlapping peaks), 129.9, 129.8, 129.7 (6 x Ar-*C*H, overlapping peaks), 129.2, 129.0, 128.9 (3 x Ar-*C*), 128.4, 128.3 (6 x Ar-*C*H, overlapping peaks), 125.9 (d, ^4J (C,F) =2.8; Ar-*C*), 115.5 (d, ^2J (C,F) =22.0; 2 x Ar-*C*H, overlapping peaks), 96.0 (C-1), 72.0 (C-2), 70.5 (C-3), 69.6 (C-4), 68.7 (*C*H$_2$), 67.6 (C-5), 63.2 (C-6), 31.3 (*C*H$_2$), 19.2 (*C*H$_2$), 13.7 (*C*H$_3$); IR (film) cm^{-1}: 2960, 1721, 1602, 1259, 1089, 1067, 1026, 706; ESI-HRMS calcd for $C_{38}H_{35}O_{10}NaF$ 693.2112, found *m/z* 693.2124 [M+Na]$^+$.



Butyl 2,3,4-tri-*O*-benzoyl-6-*O*-(4-chlorobenzoyl)-α-D-glucopyranoside (118α)

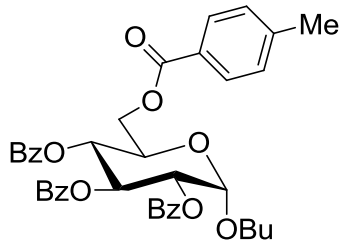
$[\alpha]_D$ 37.8 (*c* 0.1, CH_2Cl_2); ^{1}H NMR (500 MHz, $CDCl_3$): δ 8.01 – 7.96 (m, 3H; Ar-*H*), 7.95 – 7.91 (m, 2H; Ar-*H*), 7.91 – 7.81 (m, 2H; Ar-*H*), 7.50 (dd, *J*=7.4, 5.2, 2H; Ar-*H*), 7.45 – 7.33 (m, 10H; Ar*H*), 6.20 (apt. t, ^3J (H,H) = 9.8, 1H; H-3), 5.68 (apt. t, ^3J (H,H) = 9.6, 1H; H-4), 5.34 (d, ^3J (H,H) = 3.7, 1H; H-1), 5.30 (dd, ^3J (H,H) = 10.1, 3.7, 1H; H-2), 4.60 (dd, ^2J (H,H) = -11.7, ^3J (H,H) = 2.5, 1H; H-6a), 4.53 – 4.35 (m, 2H; H-6b, H-5, overlapping peaks), 3.80 (dt, ^2J (H,H) = -10.0, ^3J (H,H) = 6.5, 1H; C*H*H), 3.50 (dt, ^2J (H,H) = -9.9, ^3J (H,H) = 6.6, 1H; C*H*H), 1.71 – 1.52 (m, 2H; CH_2), 1.35 (q, ^3J (H,H) = 7.5, 1H; CH_2), 0.84 (t, ^3J (H,H) = 7.4, 3H; CH_3). ^{13}C NMR (126 MHz, $CDCl_3$): δ 165.8 (*C*OC_6H_4Cl, *C*OPh, overlapping peaks), 165.8, 165.3 (2 x *C*OPh), 139.6, 133.4, 133.3, 133.1, 129.9, 129.8, 129.7 (11 x Ar-*C*H, overlapping peaks), 129.2, 129.0, 128.8 (3 x Ar-C), 128.7, 128.4, 128.3 (8 x Ar-*C*H, overlapping peaks), 128.1 (Ar-*C*), 96.0 (C-1), 72.0 (C-2), 70.5 (C-3), 69.6 (C-4), 68.7 (*C*H_2), 67.6 (C-5), 63.3 (C-6), 31.3 (*C*H_2), 19.2 (*C*H_2), 13.7 (*C*H_3); IR (film) cm^{-1}: 2973, 1743, 1582, 1511, 1421, 1269, 1034, 1011, 789; ESI-HRMS calcd for $C_{38}H_{35}O_{10}NaCl$ 709.1816, found *m*/*z* 709.1817 $[M+Na]^+$.



Butyl 2,3,4-tri-*O*-benzoyl-6-*O*-(4-methoxylbenzoyl)-α-D-glucopyranoside (120α)

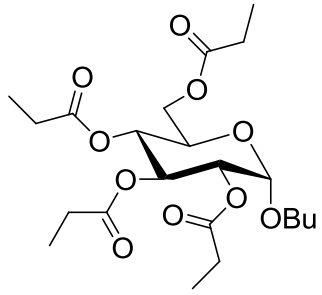
$[\alpha]_D$ 35.1 (*c* 0.1, CH_2Cl_2); ^{1}H NMR (500 MHz, $CDCl_3$): δ 8.03 – 7.96 (m, 4H; Ar-*H*), 7.96 – 7.90 (m, 2H; Ar-*H*), 7.89 – 7.83 (m, 2H; Ar-*H*), 7.50 (q, ^3J (H,H) = 7.6, 2H; Ar-*H*), 7.46 – 7.40 (m, 1H; Ar-*H*), 7.37 (dd, ^3J (H,H) = 14.8, 7.5, 4H; Ar-*H*), 7.29 (t, ^3J (H,H) = 7.7, 2H; Ar-*H*), 6.93 – 6.69 (m, 2H; Ar-*H*), 6.18 (apt. t, ^3J (H,H) = 9.9, 1H; H-3), 5.67 (apt. t, ^3J (H,H) = 9.7, 1H; H-4), 5.34 (d, ^3J (H,H) = 3.7, 1H; H-1), 5.29 (dd, ^3J (H,H) = 10.1, 3.7, 1H; H-2), 4.62 – 4.51 (m, 1H; H-6a), 4.47 – 4.38 (m, 2H; H-6b, H-5, overlapping peaks), 3.85 (s, 3H; OCH_3), 3.80 (dt, ^2J (H,H) = -9.9, ^3J (H,H) =6.4, 1H; C*H*H), 3.49 (dt, ^2J (H,H) = -9.9, ^3J (H,H) = 6.6, 1H; C*H*H), 1.67 – 1.53 (m, 2H; CH_2), 1.35 (q, ^3J (H,H) =7.5, 2H; CH_2), 0.83 (t, ^3J (H,H) =7.4, 3H; CH_3); ^{13}C NMR (126 MHz, $CDCl_3$): δ 165.9 (*C*OPh), 165.8 (*C*OPh, *C*OC_6H_4(OCH_3), overlapping peaks), 165.3 (*C*OPh), 163.5 (Ar-*C*(OCH_3)), 133.3, 133.1, 131.8, 129.9, 129.7 (11 x Ar-*C*H, overapping peaks), 129.2, 129.1, 128.9 (3 x Ar*C*), 128.4, 128.2 (6 x Ar-*C*H, overlapping peaks), 122.1 (Ar-*C*), 113.6 (2 x Ar-*C*H,

overlapping peaks), 96.0 (C-1), 72.1 (C-2), 70.6 (C-3), 69.6 (C-4), 68.6 (*C*H_2), 67.8 (C-5), 62.8 (C-6), 55.4 (O*C*H_3), 31.3 (*C*H_2), 19.2 (*C*H_2), 13.7 (*C*H_3); IR (film) cm^{-1}: 2962, 1117, 1604, 1511, 1248, 1166, 1088, 1069, 1025, 845, 765, 694; ESI-HRMS calcd for $C_{39}H_{38}O_{11}Na$ 705.2312, found *m/z* 705.2318 $[M+Na]^+$.



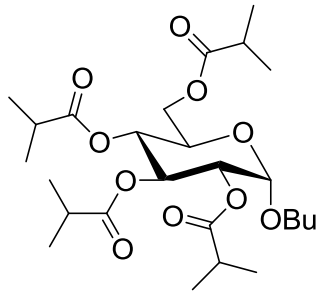
Butyl 2,3,4-tri-*O*-benzoyl-6-*O*-(4-methylbenzoyl)-α-D-glucopyranoside (119α)

$[\alpha]_D$ 19.6 (*c* 0.1, CH_2Cl_2); ^{1}H NMR (500 MHz, $CDCl_3$): δ 8.02 – 7.95 (m, 2H; Ar-*H*), 7.96 – 7.90 (m, 4H; Ar-*H*), 7.87 (dd, ^3J (H,H) = 8.3, 1.4, 2H; Ar-*H*), 7.55 – 7.47 (m, 2H; Ar-*H*), 7.39 (ddt, ^3J (H,H) = 20.6, 13.0, 7.6, 5H; Ar-*H*), 7.29 (t, ^3J (H,H) = 7.7, 2H; Ar-*H*), 7.21 (d, ^3J (H,H) = 7.9, 2H; Ar-*H*), 6.18 (apt. t, ^3J (H,H) = 9.8, 1H; H-3), 5.66 (apt. t, ^3J (H,H) = 9.6, 1H; H-4), 5.34 (d, ^3J (H,H) = 3.7, 1H; H-1), 5.29 (dd, ^3J (H,H) = 10.1, 3.8, 1H; H-2), 4.60 – 4.55 (m, 1H; H-6a), 4.49 – 4.40 (m, 2H; H-6b, H-5, overlapping peaks), 3.80 (dt, ^2J (H,H) = 9.9, ^3J (H,H) = 6.5, 1H; C*H*H), 3.49 (dt, ^2J (H,H) = 9.9, ^3J (H,H) = 6.6, 1H; C*H*H), 2.40 (s, 3H; CH_3), 1.64 – 1.55 (m, 2H; CH_2), 1.35 (p, ^3J (H,H) = 7.4, 2H; CH_2), 0.83 (t, ^3J (H,H) = 7.4, 3H; CH_3); ^{13}C NMR (126 MHz, $CDCl_3$): δ 166.2 (*C*OC_6H_4(CH_3)), 165.8, 165.3 (3 x *C*OPh, overlapping peaks), 143.8 (Ar-*C*(CH_3)), 133.3, 133.3, 133.0, 129.9, 129.7, 129.7 (11 x Ar-*C*H, overlapping peaks), 129.2 (Ar-*C*), 129.1 (2 x Ar-*C*H, Ar-*C*, overlapping peaks), 128.9 (Ar-*C*), 128.4, 128.2(6 x Ar-*C*H, overlapping peaks) , 127.0 (Ar*C*), 95.9 (C-1), 72.1 (C-2), 70.6 (C-3), 69.6 (C-4), 68.6 (*C*H_2), 67.8 (C-5), 62.9 (C-6), 31.3 (*C*H_2), 21.7 (*C*H_3), 19.2 (*C*H_2), 13.7 (*C*H_3); IR (film) cm^{-1}: 3007, 1725, 1594, 1538, 1217, 1141, 1037, 1020, 864, 786, 681; ESI-HRMS calcd for $C_{39}H_{38}O_{10}Na$ 689.2363, found *m/z* 689.2374 $[M+Na]^+$.



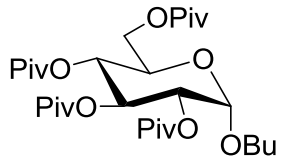
Butyl 2,3,4,6-tetra-*O*-propionyl-α-D-glucopyranoside (121α)

$[\alpha]_D$ 15.2 (*c* 0.1, CH_2Cl_2); ^{1}H NMR (500 MHz, $CDCl_3$): δ 5.50 (apt. t, ^3J (H,H) =9.8, 1H; H-3), 5.13 – 5.01 (m, 2H; H-1, H-4), 4.86 (dd, ^3J (H,H) =10.2, 3.8, 1H; H-2), 4.25 (dd, ^2J (H,H) = -12.3, ^3J (H,H) =4.8, 1H; H-6a), 4.10 (dd, ^2J (H,H) = -12.3, ^3J (H,H) =2.2, 1H; H-6b), 4.02 (ddd, ^3J (H,H) =10.2, 4.8, 2.2, 1H; H-5), 3.68 (dt, ^3J (H,H) =9.9, 6.5, 1H; C*H*H), 3.42 (dt, ^3J (H,H) =9.9, 6.5, 1H; C*H*H), 2.43 – 2.15 (m, 8H; 4 x CH_2), 1.64 – 1.32 (m, 2H; CH_2), 1.48 – 1.09 (m, 2H; CH_2), 1.16 – 0.98 (m, 12H; 4 x CH_3), 0.92 (t, ^3J (H,H) =7.4, 3H; CH_3); ^{13}C NMR (126 MHz, $CDCl_3$): δ 174.1, 173.6, 173.5, 173.0 (4 x *C*OCH_2CH_3), 95.7 (C-1), 70.9(C-2), 70.1 (C-3), 68.4 (C-4), 68.3 (*C*H_2), 67.3 (C-5), 61.9 (C-6), 31.3(*C*H_2), 27.5, 27.4, 27.3 (4 x *C*H_2, overlapping peaks), 19.2 (*C*H_2), 13.7 (*C*H_2), 9.2, 9.0 (4 x *C*H_3, overlapping peaks); IR (film) cm^{-1}: 2961, 1722, 1065, 1250, 1166, 1094, 1098, 1028, 789, 695; ESI-HRMS calcd for $C_{22}H_{36}O_{10}Na$ 483.2206, found *m/z* 483.2215 $[M+Na]^+$.



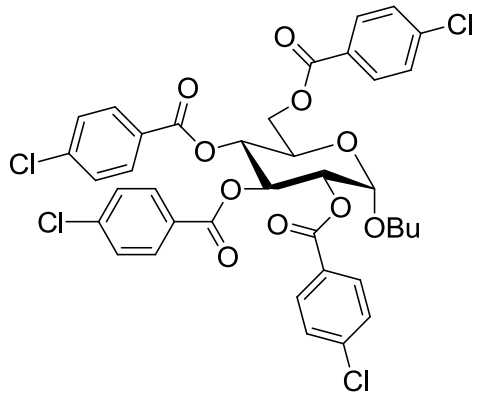
Butyl 2,3,4,6-tetra-*O*-isobutyryl-α-D-glucopyranoside (122α)

$[\alpha]_D$ 19.8 (*c* 0.3, CH_2Cl_2); ^{1}H NMR (500 MHz, $CDCl_3$): δ 5.54 (apt. t, ^3J (H,H) =9.8, 1H; H-3), 5.08 (apt. t, ^3J (H,H) =9.9, 1H; H-3), 5.05 (d, ^3J (H,H) =3.8, 1H; H-1), 4.84 (dd, ^3J (H,H) =10.2, 3.8, 1H; H-2), 4.17 (dd, ^2J (H,H) = -12.2, ^3J (H,H) = 5.1, 1H; H-6a), 4.11 (dd, ^2J (H,H) = -12.4, ^3J (H,H) = 2.1, 1H; H-6b), 4.02 (ddd, ^3J (H,H) =10.3, 5.0, 2.1, 1H; H-5), 3.68 (dt, ^2J (H,H) = -9.8, ^3J (H,H) = 6.5, 1H; C*H*H), 3.40 (dt, ^2J (H,H) = -9.8, ^3J (H,H) = 6.6, 1H; C*H*H), 2.59 (p, ^3J (H,H) =7.0, 1H; C*H*), 2.55 – 2.42 (m, 3H; 3 x C*H*, overlapping peaks), 1.62 – 1.32 (m, 2H; CH_2), 1.43 – 1.15 (m, 2H; CH_2), 1.23 – 1.15 (m, 6H, 2 x CH_3, overlapping peaks), 1.15 – 1.03 (m, 18H; 6 x CH_3, overlapping peaks), 0.92 (t, ^3J (H,H) =7.4, 3H; CH_3); ^{13}C NMR (126 MHz, $CDCl_3$): δ 176.7, 176.2, 175.9, 175.4 (4 x *C*O$CH(CH_3)_2$), 95.6 (C-1), 71.0 (C-2), 69.7 (C-3), 68.3 (C-4), 68.0 (*C*H_2), 67.5 (C-5), 61.8 (C-6), 33.9, 33.8 (4 x CO*C*$H(CH_3)_2$, overlapping peaks), 31.3 (*C*H_2), 19.2 (4 x *C*H_3, overlapping peaks), 18.9 (*C*H_2, 2 x *C*H_3, overlapping peaks), 18.8 (2 x *C*H_3, overlapping peaks), 13.7 (*C*H_3); IR (film) cm^{-1}: 2987, 1768, 1606,m 1453, 1167, 1068, 891, 759, 636; ESI-HRMS calcd for $C_{26}H_{44}O_{10}Na$ 539.2832, found *m/z* 539.2836 $[M+Na]^+$.



Butyl 2,3,4,6-tetra-*O*-pivaloyl-α-D-glucopyranoside (123α)

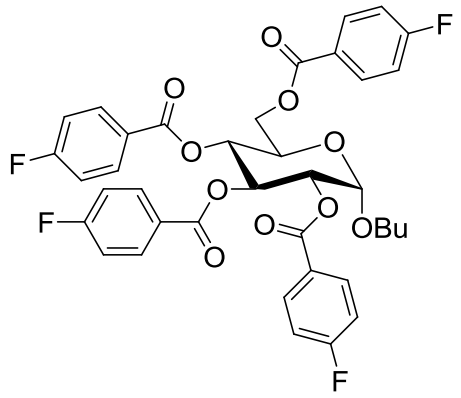
$[\alpha]_D$ 11.8 (*c* 0.1, CH_2Cl_2); ^{1}H NMR (500 MHz, $CDCl_3$): δ 5.55 (apt. t, ^3J (H,H) = 9.7, 1H; H-3), 5.11 – 4.98 (m, 2H; H-1, H-4, overlapping peaks), 4.78 (dd, ^3J (H,H) = 10.0, 3.8, 1H; H-2), 4.14 (dd, ^2J (H,H) = -12.2, ^3J (H,H) = 1.9, 1H; H-6a), 4.08 – 3.99 (m, 2H; H-6b, H-5, overlapping peaks), 3.67 (dt, ^2J (H,H) = -9.7, ^3J (H,H) = 6.4, 1H, C*H*H), 3.36 (dt, ^2J (H,H) = -9.8, ^3J (H,H) = 6.7, 1H; C*H*H), 1.62 – 1.49 (m, 2H; CH_2), 1.42 – 1.31 (m, 2H; CH_2), 1.21 (s, 9H; C$(CH_3)_3$), 1.15 (s, 19H; 2 x C$(CH_3)_3$), 1.12 (s, 9H; C$(CH_3)_3$). 0.91 (t, ^3J (H,H) = 7.4, 3H; CH_3); ^{13}C NMR (126 MHz, $CDCl_3$): δ 178.0, 177.7, 177.0, 176.6 (4 x *C*OC$(CH_3)_3$), 95.4 (C-1), 71.3 (C-2), 69.7 (C-3), 68.1 (*C*H_2), 68.0 (C-4), 67.5 (C-5), 62.0 (C-6), 38.8, 38.7 (4 x *C*$(CH_3)_3$, overlapping peaks), 31.4(*C*H_2) , 27.2, 27.1, 27.0 (12 x *C*H_3, overlapping peaks), 19.2 (*C*H_2), 13.7 (*C*H_3); IR (film) cm^{-1}: 2961, 1718, 1600, 1514, 1253, 1169, 1094, 1070, 1023, 891, 788; ESI-HRMS calcd for $C_{30}H_{52}O_{10}Na$ 595.3458, found *m/z* 595.3459 $[M+Na]^+$.



Butyl 2,3,4,6-tetra-*O*-(4-chlorobenzoyl)-α-D-glucopyranoside (124α)

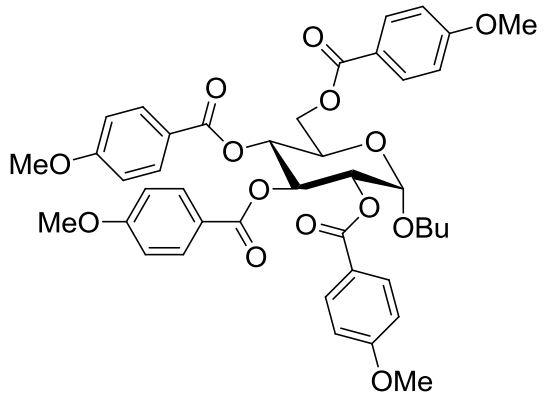
$[\alpha]_D$ 56.3 (*c* 0.8, CH_2Cl_2); ^{1}H NMR (500 MHz, $CDCl_3$): δ 8.00 – 7.93 (m, 2H; Ar-*H*), 7.93 – 7.88 (m, 2H; Ar-*H*), 7.87 – 7.81 (m, 2H; Ar-*H*), 7.81 – 7.75 (m, 2H; Ar-*H*), 7.42 – 7.22 (m, 8H; Ar-*H*), 6.10 (apt. t, ^3J (H,H) =9.8, 1H; H-3), 5.61 (apt.t, ^3J (H,H) =9.7, 1H; H-4), 5.39 – 5.16 (m, 2H; H-1, H-2, overlapping peaks), 4.57 (dd, ^2J (H,H) = -11.8, ^3J (H,H) = 2.6, 1H; H-6a), 4.52 – 4.35 (m, 2H; H-6b, H-5), 3.79 (dt, ^2J (H,H) = -9.8, ^3J (H,H) =6.4, 1H; C*H*H), 3.49 (dt, ^2J (H,H) = -9.9, ^3J (H,H) = 6.6, 1H; C*H*H), 1.67 – 1.56 (m, 2H; CH_2), 1.35 (h, ^3J (H,H) =7.4, 2H; CH_2), 0.85 (t, ^3J (H,H) =7.3, 3H; CH_3); ^{13}C NMR (126 MHz, $CDCl_3$): δ 165.2, 164.9, 164.8, 164.4 (4 x

*C*OC$_6$H$_4$Cl), 140.2, 140.1, 139.9, 139.7 (4 x Ar-*C*Cl), 131.2, 131.1, 131.0 (8 x Ar-*C*H, overlapping peaks), 128.8 (8 x Ar-*C*H, overlapping peaks),128.0, 127.3, 127.1 (4 x Ar-*C*, overlapping peaks), 95.9 (C-1), 71.9 (C-2), 70.8 (C-3), 69.7 (C-4), 68.7 (*C*H$_2$), 67.5 (C-5), 63.1 (C-6), 31.3 (*C*H$_2$), 19.2 (*C*H$_2$), 13.7 (*C*H$_3$); IR (film) cm^{-1}: 2961, 1720, 1607, 1509, 1253, 1161, 1096, 1066, 1029, 891, 789; ESI-HRMS calcd for $C_{38}H_{32}O_{10}Cl_4Na$ 811.0647, found *m/z* 811.0651 $[M+Na]^+$.



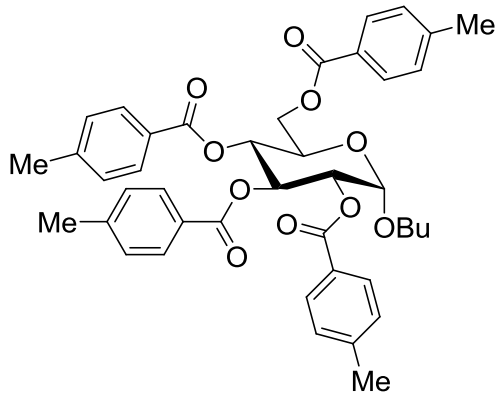
Butyl 2,3,4,6-tetra-*O*-(4-flourobenzoyl)-α-D-glucopyranoside (125α)

$[\alpha]_D$ 78.9 (*c* 0.5, CH_2Cl_2); ^{1}H NMR (500 MHz, $CDCl_3$): δ 8.09 – 8.03 (m, 2H; Ar-*H*), 8.02 – 7.96 (m, 2H; Ar-*H*), 7.94 (dd, ^3J (H,H) =8.6, 5.4, 2H; Ar-*H*), 7.87 (dd, ^3J (H,H) =8.7, 5.5, 2H; Ar-*H*), 7.14 – 7.00 (m, 6H; Ar-*H*), 6.96 (t, ^3J (H,H) =8.5, 2H; Ar-*H*), 6.12 (apt. t, ^3J (H,H) =9.8, 1H; H-3), 5.63 (apt.t, ^3J (H,H) =9.7, 1H; H-4), 5.35 – 5.24 (m, 2H; H-1, H-2), 4.63 – 4.53 (m, 1H; H-6a), 4.51 – 4.37 (m, 2H; H-6b, H-5, overlapping peaks), 3.79 (dt, ^2J (H,H) = -9.9, ^3J (H,H) =6.5, 1H; C*H*H), 3.50 (dt, ^2J (H,H) = -9.8, ^3J (H,H) = 6.6, 1H; C*H*H), 1.68 – 1.42 (m, 2H; CH_2), 1.35 (h, ^3J (H,H) =7.4, 2H; CH_2), 0.84 (t, ^3J (H,H) =7.4, 3H; CH_3); ^{13}C NMR (126 MHz, $CDCl_3$): δ167.40 – 164.53 (m; 4 x Ar-*C*F, 2 x *C*OC$_6$H$_4$F, overlapping peaks), 164.3 (*C*OC$_6$H$_4$F), 133.30 – 131.33 (m; 4 x Ar-*C*H, overlapping peaks), 115.78 – 115.35 (m; 4 x Ar-*C*H, overlapping peaks), 96.0 (C-1), 71.9 (C-2), 70.8 (C-3), 69.6 (C-4), 68.7 (*C*H$_2$), 67.6 (C-5), 63.0 (C-6), 31.3 (*C*H$_2$), 19.2 (*C*H$_2$), 13.6 (*C*H$_3$); IR (film) cm^{-1}: 2974, 1724, 1603, 1267, 1153, 1068, 759; ESI-HRMS calcd for $C_{38}H_{32}O_{10}F_4Na$ 747.1829, found *m/z* 747.1838 $[M+Na]^+$.



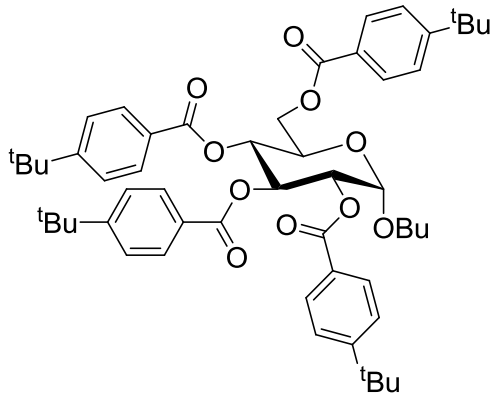
Butyl 2,3,4,6-tetra-*O*-(4-methoxybenzoyl)-α-D-glucopyranoside (126α)

$[\alpha]_D$ 101.9 (*c* 1.8, CH_2Cl_2); ^{1}H NMR (500 MHz, $CDCl_3$): δ 8.02 – 7.97 (m, 2H; Ar-*H*), 7.96 – 7.92 (m, 2H; Ar-*H*), 7.90 – 7.87 (m, 2H; Ar-*H*), 7.86 – 7.80 (m, 2H; Ar-*H*), 6.92 – 6.87 (m, 2H; Ar-*H*), 6.86 – 6.83 (m, 2H; Ar-*H*), 6.83 – 6.80 (m, 2H; Ar-*H*), 6.78 – 6.73 (m, 2H; Ar-*H*), 6.11 (apt. t, ^3J (H,H) =9.8, 1H; H-3), 5.60 (apt. t, ^3J (H,H) =9.5, 1H; H-4), 5.31 (d, ^3J (H,H) =3.7, 1H; H-1), 5.23 (dd, ^3J (H,H) =10.2, 3.7, 1H; H-2), 4.59 – 4.53 (m, 1H; H-6a), 4.45 – 4.38 (m, 2H; H-6b, H-5, overlapping peaks), 3.85 (s, 3H; OC*H*$_3$), 3.81 (s, 3H; OC*H*$_3$), 3.80 (s, 3H; OC*H*$_3$), 3.80 – 3.77 (m, 1H; C*H*H), 3.75 (s, 3H; OC*H*$_3$), 3.48 (dt, ^2J (H,H) = -9.8, ^3J (H,H) = 6.6, 1H; C*H*H), 1.65 – 1.54 (m, 2H; C*H*$_2$), 1.34 (h, ^3J (H,H) =7.4, 2H; C*H*$_2$), 0.84 (t, ^3J (H,H) =7.4, 3H; C*H*$_3$); ^{13}C NMR (126 MHz, $CDCl_3$): δ 165.9, 165.6, 165.4, 165.0 (4 x *C*OC$_6$H$_4$(OCH$_3$) 163.6, 163.4 (4 X Ar-*C*(OCH$_3$), overlapping peaks), 132.0, 131.8 (8 x Ar-*C*H,overlapping peaks), 122.2, 121.7, 121.5, 121.4 (4 x Ar-*C*, overlapping peaks), 113.6, 113.5 (8 x Ar-*C*H,overlapping peaks), 96.1 (C-1), 71.9 (C-2), 70.3 (C-3), 69.5 (C-4), 68.5 (*C*H$_2$), 67.8 (C-5), 63.0 (C-6), 55.4, 55.3 (4 x O*C*H$_3$, overlapping peaks), 31.3 (*C*H$_2$), 19.2 (*C*H$_2$), 13.7 (*C*H$_3$); IR (film) cm^{-1}: 2987, 1691, 1615, 1524, 1256, 1060, 1021, 857, 766; ESI-HRMS calcd for $C_{42}H_{44}O_{14}Na$ 795.2629, found *m/z* 795.2633 $[M+Na]^+$.



Butyl 2,3,4,6-tetra-*O*-(4-methylbenzoyl)-α-D-glucopyranoside (127α)

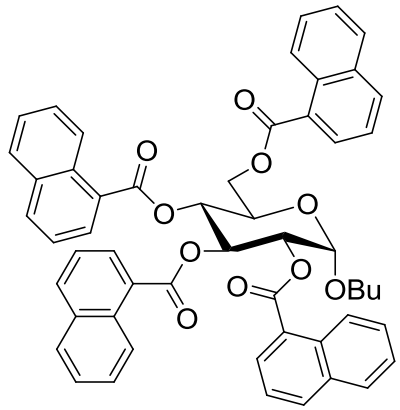
$[\alpha]_D$ 98.1 (*c* 0.9, CH_2Cl_2); ^{1}H NMR (500 MHz, $CDCl_3$): δ 7.99 – 7.89 (m, 2H; Ar-*H*), 7.90 – 7.83 (m, 2H; Ar-*H*), 7.84 – 7.80 (m, 2H; Ar-*H*), 7.78 – 7.74 (m, 2H; Ar-*H*), 7.24 – 7.20 (m, 2H; Ar-*H*), 7.18 – 7.12 (m, 4H; Ar-*H*), 7.11 – 7.06 (m, 2H; Ar-*H*) 6.15 (apt. t, ^3J (H,H) =9.9, 1H; H-3), 5.61 (apt. t, ^3J (H,H) = 9.7, 1H; H-4), 5.32 (d, ^3J (H,H) =3.8, 1H; H-1), 5.25 (dd, ^3J (H,H) =10.1, 3.7, 1H; H-2), 4.63 – 4.53 (m, 1H; H-6a), 4.50 – 4.37 (m, 2H; H-6b, H-5, overlapping peaks), 3.78 (dt, ^2J (H,H) = -9.8, ^3J (H,H) = 6.5, 1H; C*H*H), 3.47 (dt, ^2J (H,H) = -9.9, ^3J (H,H) = 6.6, 1H; C*H*H), 2.40 (s, 3H; CH_3), 2.35 (s, 3H; CH_3), 2.35 (s, 3H; CH_3), 2.29 (s, 3H; CH_3), 1.67 – 1.52 (m, 2H; CH_2), 1.34 (q, ^3J (H,H) =7.4, 2H; CH_2), 0.83 (t, ^3J (H,H) =7.4, 1H; CH_3); ^{13}C NMR (126 MHz, $CDCl_3$): δ 166.2, 165.9, 165.8, 165.3 (4 x *C*O$C_6H_4(CH_3)$), 144.0, 143.7(4 x Ar-*C*(CH_3) overlapping peaks), 129.9, 129.7, 129.1, 129.0, 128.9(16 x Ar-*C*H, overlapping peaks), 127.0, 126.5, 126.4, 126.2 (4 x Ar*C*), 96.0 (C-1), 72.0 (C-2), 70.3 (C-3), 69.5 (C-4), 68.6 (*C*H_2), 67.8 (C-5), 63.0 (C-6), 31.3 (*C*H_2), 21.7, 21.6(4 x *C*H_3, overlapping peaks), 19.2(*C*H_2), 13.7 (*C*H_3); IR (film) cm^{-1}: 2962, 1718, 1604, 1511, 1249, 1167, 1088, 1068, 1025, 845, 766; ESI-HRMS calcd for $C_{42}H_{44}O_{10}Na$ 731.2832, found *m/z* 731.2830 $[M+Na]^+$.



Butyl 2,3,4,6-tetra-*O*-(4-*tert*-butylbenzoyl)-α-D-glucopyranoside (128α)

$[\alpha]_D$ 133.4 (*c* 1.2, CH_2Cl_2); ^{1}H NMR (500 MHz, $CDCl_3$): δ 8.02 – 7.93 (m, 2H; Ar-*H*), 7.94 – 7.87 (m, 4H; Ar-*H*), 7.83 (d, ^3J (H,H) =8.5, 2H; Ar-*H*), 7.47 – 7.43 (m, 2H; Ar-*H*), 7.43 – 7.36 (m, 4H; Ar-*H*), 7.34 – 7.29 (m, 2H; Ar-*H*), 6.17 (apt. t, ^3J (H,H) =9.8, 1H; H-3), 5.66 (apt. t, ^3J (H,H) =9.4, 1H; H-4), 5.32 (d, ^3J (H,H) =3.7, 1H; H-1), 5.27 (dd, ^3J (H,H) =10.2, 3.8, 1H; H-2), 4.64 – 4.53 (m, 1H; H-6a), 4.48 – 4.35 (m, 2H; H-6b, H-5, overlapping peaks), 3.78 (dt, ^2J (H,H) = -9.8, ^3J (H,H) = 6.6, 1H; C*H*H), 3.48 (dt, ^2J (H,H) = -9.8, ^3J (H,H) =6.6, 1H; C*H*H), 1.65 – 1.54 (m, 2H; CH_2), 1.37 – 1.32 (m,11H; C$(CH_3)_3$, CH_2, overlapping peaks), 1.30 (s, 18H; 2 x

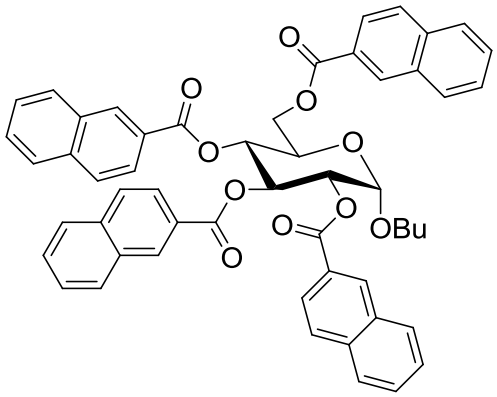
C*(CH₃)₃*, overlapping peaks), 1.25 (s, 9H; C*(CH₃)₃*), 0.83 (t, ^{3}J (H,H) =7.4, 1H; C*H₃*); ^{13}C NMR (126 MHz, $CDCl_3$): δ 166.2, 165.8, 165.7, 165.3 (4 x *C*OC$_6$H$_4$(^{t}Bu)), 157.0, 156.9, 156.7, 156.6 (4 x Ar-*C*(^{t}Bu), overlapping peaks), 129.8, 129.6 (8 x Ar-*C*H, ovrlapping peaks), 127.0, 126.6, 126.4, 126.2 (4 x Ar-*C*), 125.3, 125.2 (8 x Ar-*C*H, ovrlapping peaks), 96.0 (C-1), 72.0 (C-2), 70.4 (C-3), 69.4 (C-4), 68.6 (*C*H$_2$), 67.9 (C-5), 62.9 (C-6), 35.1, 35.0 (4 x *C*(CH$_3$)$_3$, overlapping peaks), 31.4 (*C*H$_2$), 31.1, 31.0 (12 x *C*H$_3$, overlapping peaks), 19.2 (*C*H$_2$), 13.7 (*C*H$_3$); ESI-HRMS calcd for $C_{54}H_{68}O_{10}Na$ 899.4710, found *m/z* 899.4719$[M+Na]^+$.



Butyl 2,3,4,6-tetra-*O*-(1-napthoyl)-α-D-glucopyranoside (129α)

$[\alpha]_D$ 18.4 (*c* 0.5, CH_2Cl_2); ^{1}H NMR (500 MHz, $CDCl_3$): δ 8.97 (d, ^{3}J (H,H) =8.6, 1H; Ar-*H*), 8.93 (d, ^{3}J (H,H) =8.5, 1H; Ar-*H*), 8.73 (d, ^{3}J (H,H) =8.3, 1H; Ar-*H*), 8.51 (d, ^{3}J (H,H) =8.7, 1H; Ar-*H*), 8.37 – 8.19 (m, 2H; Ar-*H*), 8.07 – 7.92 (m, 4H; Ar-*H*), 7.92 – 7.78 (m, 3H; Ar-*H*), 7.71 (d, ^{3}J (H,H) =8.1, 1H; Ar-*H*), 7.65 – 7.59 (m, 1H; Ar-*H*), 7.58 – 7.14 (m, 12H; Ar-*H*), 6.49 (ddd, ^{3}J (H,H) =11.2, 9.6, 1.6, 1H; H-4), 5.95 (apt. t, *J*=9.9, 1H; H-3), 5.61 – 5.46 (m, 2H; H-1, H-2, overlapping peaks), 4.78 – 4.73 (m, 2H; H-6), 4.65 (dt, ^{3}J (H,H) =10.2, 4.0, 1H; H-5), 3.96 – 3.84 (m, 1H; C*H*H), 3.60 (dt, ^{2}J (H,H) = -9.8, ^{3}J (H,H) = 6.6, 1H; C*H*H), 1.66 (dt, ^{3}J (H,H) =8.9, 6.5, 2H; C*H₂*), 1.43 – 1.33 (m, 2H; C*H₂*), 0.84 (t, ^{3}J (H,H) =7.4, H; C*H₃*); ^{13}C NMR (126 MHz, $CDCl_3$): δ 167.0, 166.7, 166.6, 166.0 (4 x *C*OAr), 134.0, 133.9 (2 x Ar-*C*H), 133.8, 133.7 (3 x Ar-*C*, overlapping peaks), 133.6 (Ar-*C*H), 133.5 (Ar-*C*), 133.3 (Ar-*C*H), 131.4, 131.3, 131.2, 131.0 (4 x Ar-*C*), 130.6, 130.6, 129.9, 128.5, 128.4, 128.3, 127.9, 127.8, 127.5 (10 x Ar-*C*H, overlapping peaks), 126.5, 126.4 (3 x Ar-*C*), 126.2, 126.2, 126.0, 125.8, 125.6 (6 x Ar-*C*H, overlapping peaks), 125.6 (2 x

Ar-*C*, Ar-*C*H, overlapping peaks), 125.5, 125.2, 124.5, 124.5, 124.4 (6 x Ar-*C*H, overlapping peaks), 96.2 (C-1), 72.1 (C-2), 70.6 (C-3), 69.7 (C-4), 68.8 (*C*H_2), 67.9 (C-5), 63.3 (C-6), 31.5 (*C*H_2), 19.3 (*C*H_2), 13.7 (*C*H_3); ESI-HRMS calcd for $C_{54}H_{44}O_{10}Na$ 875.2832, found *m/z* 875.2838 $[M+Na]^+$.



Butyl 2,3,4,6-tetra-*O*-(2-napthoyl)-α-D-glucopyranoside (130α)

$[\alpha]_D$ 164.2 (*c* 1.6, CH_2Cl_2); ^{1}H NMR (500 MHz, $CDCl_3$): δ 8.57 (dd, ^3J (H,H) =11.3, 2.9, 2H; Ar-*H*), 8.01 (ddd, ^3J (H,H) =16.2, 8.5, 1.7, 2H; Ar-*H*), 7.94 (dd, ^3J (H,H) =8.7, 1.8, 1H; Ar-*H*), 7.92 – 7.86 (m, 2H; ArI), 7.82 (dd, ^3J (H,H) =10.5, 8.2, 2H; Ar-*H*), 7.76 (td, ^3J (H,H) =8.9, 8.4, 3.3, 4H; Ar-*H*), 7.69 (t, ^3J (H,H) =8.1, 3H; Ar-*H*), 7.62 (dd, ^3J (H,H) =8.4, 4.6, 3H; Ar-*H*), 7.55 – 7.35 (m, 9; Ar-*H*), 6.46 (apt. t, ^3J (H,H) =9.8, 1H; H-3), 5.91 (apt. t, ^3J (H,H) =9.6, 1H; H-4), 5.57 (dd, ^3J (H,H) =10.2, 3.7, 1H; H-2), 5.51 (d, ^3J (H,H) =3.8, 1H; H-1), 4.86 – 4.60 (m, 3H; H-6a, H-6b, H-5, overlapping peaks), 3.93 (dt, ^2J (H,H) = -9.9, ^3J (H,H) = 6.5, 1H; C*H*H), 3.61 (dt, ^2J (H,H) = -9.9, ^3J (H,H) = 6.6, 1H; C*H*H), 1.78 – 1.61 (m, 2H; CH_2), 1.41 (q, ^3J (H,H) =7.4, 2H; CH_2), 0.86 (t, ^3J (H,H) =7.4, 3H; CH_3); ^{13}C NMR (126 MHz, $CDCl_3$): δ 167.1, 166.5, 166.4, 166.2 (4 x *C*OAr), 135.6, 132.3, 132.2, 132.0, 131.9, 131.6 (12 x Ar-*C*, overlapping peaks), 129.5, 129.4, 128.6, 128.4, 128.3, 128.2, 127.6, 127.5, 126.7, 126.6, 126.5, 126.4, 126.0, 125.7, 125.1, 125.0 (28 x Ar-*C*H, overlapping peaks), 96.1 (C-1), 72.3 (C-2), 71.1 (C-3), 70.5 (C-4), 68.9 (*C*H_2), 67.8 (C-5), 64.1 (C-6), 31.4 (*C*H_2), 19.3 (*C*H_2), 13.7 (*C*H_3); IR (film) cm^{-1}: 2967, 1718, 1605, 1582, 1510, 1376, 1239, 1168, 1088, 1021, 802, 695; ESI-HRMS calcd for $C_{54}H_{44}O_{10}Na$ 875.2832, found *m/z* 875.2830 $[M+Na]^+$.

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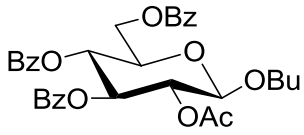
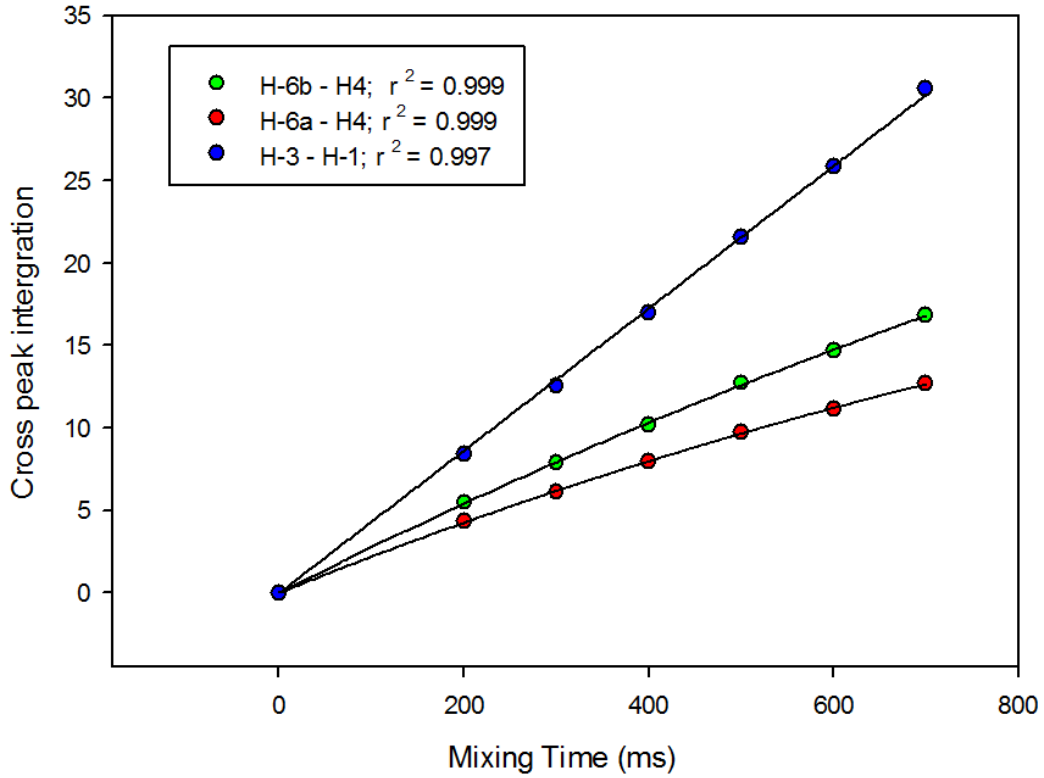
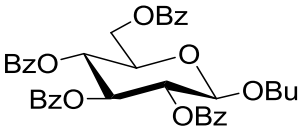
Appendix 1: NOE build up curves

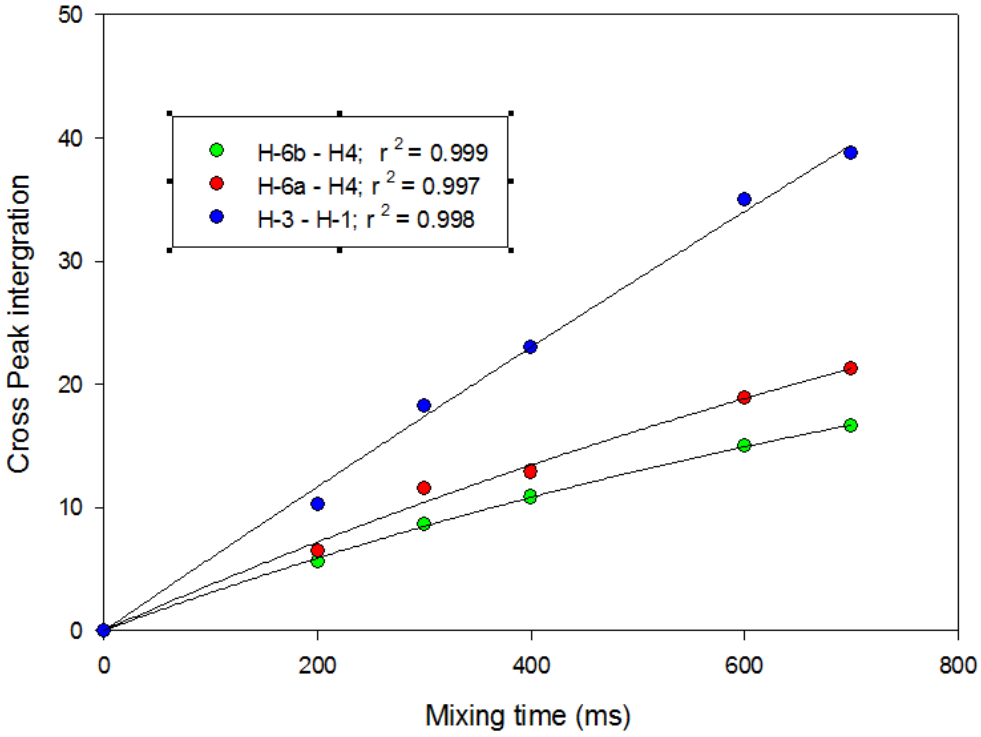




cross peak intergrations

mixing time	H6a->H-4	H-6b>H-4	H-3->H1
0.0000	0.0000	0.0000	0.0000
200.0000	4.3200	5.5000	8.4000
300.0000	6.1100	7.8800	12.5200
400.0000	7.9600	10.2000	17.0100
500.0000	9.7500	12.7300	21.5900
600.0000	11.1700	14.7200	25.8800
700.0000	12.6600	16.8100	30.6000





cross peak intergrations

Mixing time	H6a->H4	H6b-> H4	H-5->H3
0.0000	0.0000	0.0000	0.0000
200.0000	5.5900	6.4400	10.2400
300.0000	8.6300	11.5200	18.1900
400.0000	10.8000	12.8700	22.9400
600.0000	15.0000	18.8700	34.9700
700.0000	16.5800	21.2500	38.7200