Syntheses of *C*- and *N*-nucleosides from 1-aza-2-azoniaallene and 1,3-diaza-2-azoniaallene salts

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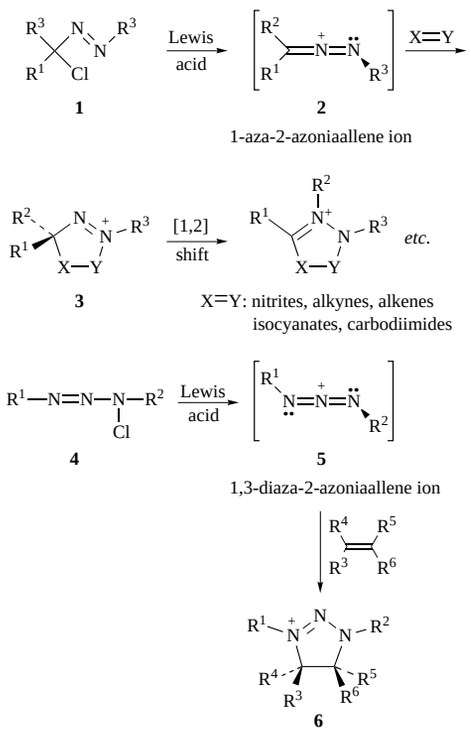
***C*-Nucleosides are prepared by cycloaddition of 1-aza-2-azoniaallene salts 2 and 1,3-diaza-2-azoniaallene salts 5 to the triple bonds of a glycosylalkyne and of glycosyl cyanides. Thus, the glucosylalkyne 7 reacts with salts 5 to give the 4-glucosyl-1,2,3-triazolium salt 8. From the galactosyl cyanide 9, the ribofuranosyl cyanide 13, and several 1-aza-2-azoniaallene salts 2 the glycosyl-1,2,4-triazoles 11, 15, 17 are obtained. Deacylation affords the free *C*-nucleosides 12, 16, 18. Cycloaddition to the C=S double bond of the glucosyl isothiocyanate 19 furnishes glucosylimino-1,3,4-thiaziazoles 20–22. A new method for the preparation of the isothiocyanate 19 is described.**

The chemistry of *N*-nucleosides, the building constituents of DNA and RNA and the basis of many biologically active compounds, has been extensively reviewed.[1,2] Since 1957, when pseudouridine [5-(β-D-ribofuranosyl)uracil] was first isolated from yeast DNA,[3] the chemistry and biochemistry of naturally occurring and non-biogenic *C*-nucleosides has become a field of broad interest.[1,4–9] A recent review on *C*-nucleosides comprises more than a thousand references.[6]

Recently, we described syntheses of the two new heterocumulenic cations **2** and **5**. 1-Aza-2-azoniaallene ions **2** were found to undergo cycloaddition to the multiple bonds of alkenes, alkynes, isocyanates, carbodiimides, and nitriles to furnish pyrazolium ions **3**, which in most cases undergo spontaneous successive transformations.[10–16] 1,3-Diaza-2-azoniaallene ions **5** (obtained from thiazenes **4**) were reported to form 4,5-dihydro-1,2,3-triazolium ions **6** with alkenes[17,18] (Scheme 1). We wondered whether these cycloadditions could be applied to syntheses of *C*- and *N*-nucleosides. Here we report our first results.



Scheme 1

Results and discussion

The alkyne **7** is readily prepared by reaction of phenylethynylmagnesium bromide with 2,3,4,6-tetra-*O*-α-D-glucopyranosyl bromide.[19] There seems to be only a single report on 1,3-dipolar cycloaddition of compound **7**, describing addition of diazomethane across the triple bond to afford a glucosylpyrazole.[20]

No reactions could be achieved between alkyne **7** and several 1-aza-2-azoniaallene salts **2**. However, when compound **7** was subjected to reaction with the 1,3-diaza-2-azoniaallene salt **5** ($R^1 = R^2 = 2,4,6\text{-}Cl_3C_6H_2$)[17] prepared *in situ* from the chlorotriazene **4** ($R^1 = R^2 = 2,4,6\text{-}Cl_3C_6H_2$) the triazolium salt **8** was isolated in 76% yield (Scheme 2). *C*-Glucosyl-1,2,3-triazoles seem to be unreported in the literature.[6] Also, cycloadditions of 1,3-diaza-2-azoniaallene cations **5** to alkynes have not been reported before. This reaction is currently under close investigation.

C-Nucleosides are frequently prepared from glycosyl cyanides.[6] 1-Aza-2-azoniaallene salts react especially smoothly with nitriles,[10] so we tried cycloadditions of salts **2** to the nitrile groups of the *C*-glycosides **9** and **13**. Crystalline cyanogalactoside **9**, easily accessible from acetylated galactose,[21] reacted with chloride **1a** and antimony pentachloride to afford the crystalline triazolium salt **11a** in 75% yield (Scheme 2). At −60 °C, chloride **1a** and antimony pentachloride give the heteroallene **2a** as an orange precipitate. At ~−30 °C dissolution of the precipitate and a colour change to brown indicated reaction with the nitrile **9**. At temperatures above −30 °C the primarily formed product **10a** furnished the end product **11a** by [1,2] migration of a methyl group.[10,13] The *C*-nucleoside **11b** was prepared correspondingly (84%). However, in this case the intermediate **10b** lost a molecule of isobutene to give a protonated triazole, from which the nucleoside **11b** was obtained by treatment with aq. sodium hydrogen carbonate.[10,12] With sodium methoxide in methanol compound **11b** was transformed into the crystalline free nucleoside **12b** (77%). Thus cumulenes **2** with R^2 = *tert*-butyl can be used to prepare electrically neutral 2-unsubstituted 1,2,4-triazoles.[10,12]

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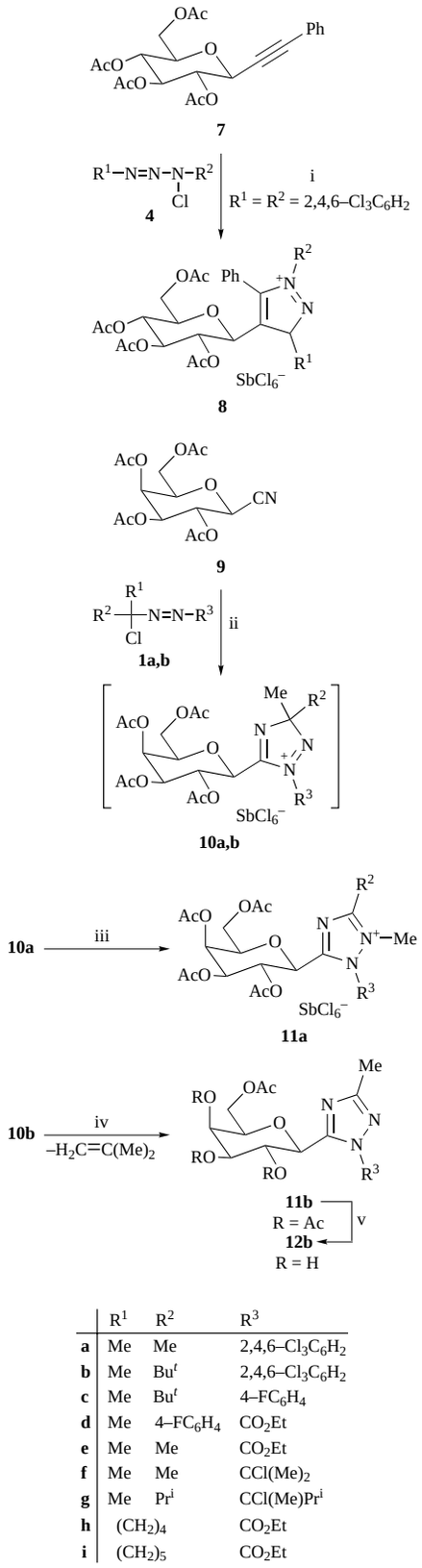
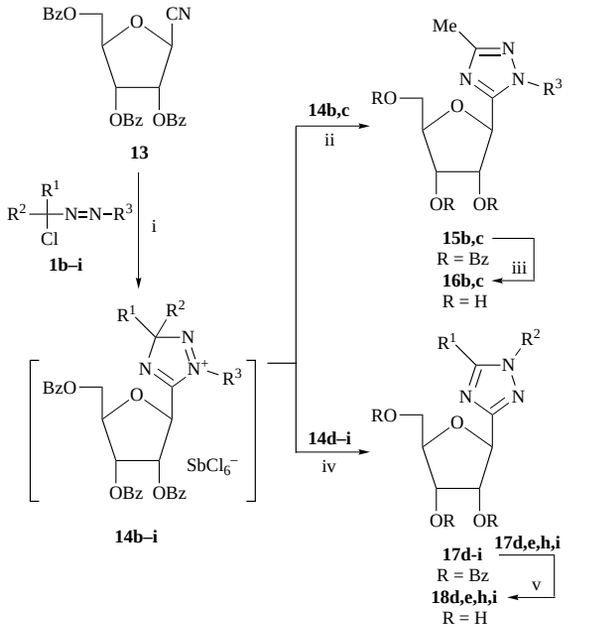


	R^1	R^2	R^3
a	Me	Me	2,4,6–$Cl_3C_6H_2$
b	Me	Bu^t	2,4,6–$Cl_3C_6H_2$
c	Me	Bu^t	4–FC_6H_4
d	Me	4–FC_6H_4	CO_2Et
e	Me	Me	CO_2Et
f	Me	Me	$CCl(Me)_2$
g	Me	Pr^i	$CCl(Me)Pr^i$
h	$(CH_2)_4$		CO_2Et
i	$(CH_2)_5$		CO_2Et

Scheme 2 *Reagents and conditions:* i, $SbCl_5$, CH_2Cl_2, −60 to 0 °C, 2.5 h (76%); ii, $SbCl_5$, CH_2Cl_2, −60 to 23 °C, 7 h; iii (75%); iv, aq. $NaHCO_3$ (84%); v, NaOMe, MeOH, 23 °C, 3 h (77%)

While 1,2,4-triazole *C*-galactosides seem to be unreported, a few 1,2,4-triazole *C*-ribofuranosides are documented.[22–27] These compounds were prepared as analogues of the synthetic *N*-nucleoside ribavirin (1-β-D-ribofuranosyl-1,2,4-triazole-3-carboxamide), which found clinical application because of its broad spectrum of activity against both DNA and RNA viruses. However, all *C*-analogues of ribavirin synthesized so far seem to be devoid of any significant biological activity.

Notwithstanding these negative results we directed efforts into syntheses of new *C*-ribofuranosyl-1,2,4-triazoles starting from the nitrile **13** (Scheme 3).[21]



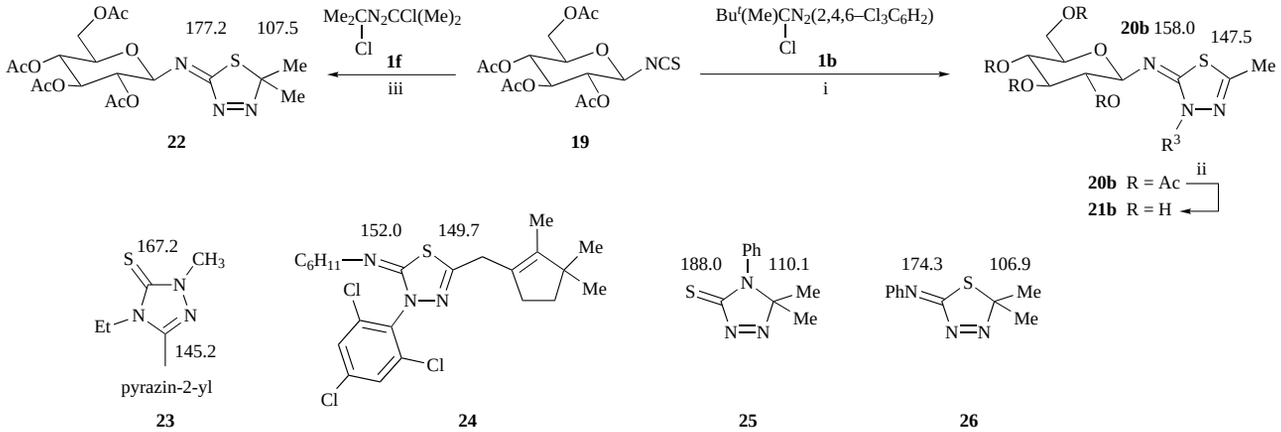
Scheme 3 *Reagents and conditions:* i, $SbCl_5$, CH_2Cl_2, −60 to 23 °C, 7 h; ii, aq. $NaHCO_3$, 23 °C (resp. 48%, 84%); iii, NaOMe, MeOH, 23 °C, 3 h (resp. 84%, 51%); iv, aq. $NaHCO_3$, 23 °C (43–77%); v, NaOMe, MeOH, 23 °C, 3 h (61–74%)

No reaction could be induced between nitrile **13** and the 1,3-diaza-2-azoniaallene salt **5** ($R^1 = R^2 = 2,4,6\text{-}Cl_3C_6H_2$). However, the 1-aza-2-azoniaallene salts **2b**,**c**, formed as reactive intermediates from the (chloroalkyl)azo compounds **1b**,**c** with antimony pentachloride, afforded the triazolyl ribosides **15b**,**c**, and, after deblocking, the neutral nucleosides **16b**,**c** in moderate yields. Heterocumulenes **2** were found to react with the nitrile **13** generally more sluggishly than with simple nitriles such as acetonitrile or benzonitrile. In order to compensate for some decomposition of salt **2** competing with cycloaddition to nitrile **13** the (chloroalkyl)azo compounds **1** had to be applied in up to four-fold molecular excess.

For unknown reasons no transformation could be induced between compounds **13** and **2a** although salt **2a** is sterically less encumbered than its analogue **2b**.

Another group of 2-unsubstituted 1,2,4-triazoles (compounds **17d**–**i**) can be prepared from nitriles and salts **2** with $R^3 = CO_2Et$ or $R^3 = CClR^4R^5$ (Scheme 3).[12,16] The moisture-sensitive iminium salts **14** were directly subjected to hydrolysis with aq. hydrogen carbonate to furnish the triazoles **17d**–**i** in moderate yields. The nucleoside **17e** (= **17f**) was obtained from both (chloroalkyl)azo compounds **1e** and **1f** in comparable yields (57 and 54%). However, allenes prepared from compound **1** with $R^3 = CClR^4R^5$ are more reactive than those with $R^3 = CO_2Et$.[16] Therefore, for the preparation of compound **17e** only a small excess of substrate **1f** was required, leading to a cleaner product as compared with the reaction with substrate **1e**. Debenzoylation of compounds **17d**,**e**,**h**,**i** furnished the ribosides **18d**,**e**,**h**,**i**.

The glucopyranosyl isothiocyanate **19** was first prepared by Fischer from tetra-*O*-acetyl-α-D-glucopyranosyl bromide and silver thiocyanate.[28] All later methods recommended for the preparation of compound **19** are variants of Fischer's procedure.[29–33] We have found that penta-*O*-acetyl-D-glucopyranose reacts with trimethylsilyl isothiocyanate in the presence of tin tetrachloride to furnish the pure β-form **19** in reproducible yields of 75–85%.



Scheme 4 *Reagents and conditions:* i, $SbCl_5$, CH_2Cl_2, −60 to 23 °C, 7 h, aq. $NaHCO_3$, 23 °C (85%); ii, NaOMe, MeOH, 23 °C, 3 h (71%); iii, $SbCl_5$, CH_2Cl_2, −60 to 23 °C, 7 h, aq. $NaHCO_3$, 23 °C (63%); the figures are ^{13}C NMR shifts

While isothiocyanate **19** did not react with the 1,3-diaza-2-azoniaallene ion **5** ($R^1 = R^2 = 2,4,6\text{-}Cl_3C_6H_2$), a crystalline product **20b** was isolated (85%) from the reaction mixture of compound **19** and the 1-aza-2-azoniaallene salt **1b** (Scheme 4). Reactions of heterocumulenes **2** with isothiocyanates have not yet been described. Cycloaddition could have occurred either across the C=S double bond of compound **19** to give the 2,3-dihydro-1,3,4-thiadiazole **20b** (*cf.* structure **24**) or across the C=N double bond with formation of an isomeric 4,5-dihydro-1*H*-1,3,4-triazole-5-thione (*cf.* structure **23**). For the exocyclic (C-2) and endocyclic (C-5) C=N carbon atoms of the thiadiazole **24** (constitution secured by X-ray structural analysis) ^{13}C chemical shifts of δ_C 152.0 and 149.7 ($CDCl_3$) were observed.[34] L'abbé *et al.* reported values in the range 151–164 ppm for C-2 and of 149–155 ppm for C-5 for several thiadiazoles of type **24**.[35,36] On the other hand, for triazole-5-thiones of type **23** ^{13}C chemical shifts close to δ_C 168 and of δ_C 145–160 were reported for C=S (C-5) and C=N (C-3), respectively.[37–40] According to these data ^{13}C NMR shifts of δ_C 158.0 and 147.5 ($CDCl_3$) observed for compound **20b** may be assigned to C-2, -5 of the thiadiazole shown in Scheme 4. Deblocking of compound **20b** with sodium in methanol afforded the nucleoside **21b** (71%).

The crystalline thiadiazole nucleoside **22** was obtained (45%) from substrates **19** and **1f**. Again, arguments in favour of a 2,5-dihydro-1,3,4-thiadiazole structure and against an isomeric 4,5-dihydro-3*H*-1,2,4-triazole-3-thione rest on the ^{13}C NMR spectra. For the thiadiazole **26** (X-ray structural analysis)[34] the ^{13}C NMR shifts given in Scheme 4 were observed, while for several triazoles **25** C=S shifts close to δ_C 188 and shifts of the saturated ring carbon (C-5) of δ_C 109–110 were found.[34,41] Accordingly, compound **22** is a thiadiazole.

In conclusion, cycloadditions of readily accessible 1-aza-2-azoniaallene salts **2** and 1,3-diaza-2-azoniaallene salts **5** provide a new method for the preparation of *C*- as well as of *N*-nucleosides.

Experimental

Solvents were dried by standard methods. Cycloadditions were carried with exclusion of moisture. IR spectra: Perkin-Elmer FTIR 1600. ^1H and ^{13}C NMR spectra: Bruker AC-250 and WM-250 spectrometers; internal reference $SiMe_4$; δ-scale; *J*-values are given in Hz. Optical rotations: Perkin-Elmer 241 polarimeter; $[\alpha]_D$-values are in units of 10^{-1} deg cm^2 g^{-1}.

3,3-Dimethylbutan-2-one 4-fluorophenylhydrazone

A mixture of 4-fluorophenylhydrazine hydrochloride (1.63 g, 10 mmol), 3,3-dimethylbutan-2-one (2.02 g, 20 mmol) and NaOAc (0.82 g, 10 mmol) in EtOH (30 ml) was boiled under reflux for 8 h. The solvent was evaporated off and the residue was extracted with $CHCl_3$ (3 × 20 ml). The combined organic extracts were diluted with $CHCl_3$ (40 ml), filtered with added decolorizing charcoal, and evaporated *in vacuo* to furnish the *title hydrazone* as an orange oil (1.91 g, 92%) (Found: C, 69.25; H, 7.82; N, 13.35. $C_{12}H_{17}FN_2$ requires C, 69.20; H, 8.23; N, 13.45%); $\nu_{max}(CCl_4)/cm^{-1}$ 1607 and 1709; δ_H(250 MHz; $CDCl_3$) 1.16 (9 H) and 1.80 (3 H) (CH_3) and 6.89–7.03 (m, ArH); δ_C(62.9 MHz; $CDCl_3$) 10.6 and 27.8 (3 C) (CH_3), 38.5 (C), 113.9 (d, *J* 7, *o*-C), 115.6 (d, *J* 22, *m*-C), 142.8 (d, *J* 2, *ipso*-C), 156.9 (d, *J* 236, *p*-C) and 152.7 (C=N).

Ethyl 3-[1-(4-fluorophenyl)ethylidene]carbazate

A mixture of 4-fluoroacetophenone (13.81 g, 100 mmol) and ethyl carbazate (10.41 g, 100 mmol) in EtOH (80 ml) containing AcOH (1 ml) was boiled under reflux for 5 h. Crystallization at −15 °C and washing with a small amount of cold EtOH afforded the *title compound* as a crystalline powder (20.40 g, 91%); mp 121–122 °C (Found: C, 59.09; H, 5.86; N, 12.54. $C_{11}H_{13}FN_2O_2$ requires C, 58.93; H, 5.84; N, 12.49%); $\nu_{max}(CCl_4)/cm^{-1}$ 1702, 1723 and 1761; δ_H(250 MHz; $CDCl_3$) 1.34 (t, *J* 7.1) and 2.21 (together CH_3), 4.21 (q, *J* 7.1, CH_2), 7.01 (m, 2 H) and 7.72 (m, 2 H) (ArH) and 8.49 (br, NH); δ_C(62.9 MHz; $CDCl_3$) 13.1 and 14.6 (CH_3), 62.0 (CH_2), 115.3 (d, *J* 22, *m*-C), 128.2 (d, *J* 8, *o*-C), 134.4 (d, *J* 3, *i*-C), 163.5 (d, *J* 248, *p*-C), 147.7 (C=N) and 154.6 (br, C=O).

Ethyl 3-isopropylidenecarbazate

A solution of ethyl carbazate (10.41 g, 100 mmol) in acetone (40 ml) was boiled under reflux for 2 h. Evaporation of excess of acetone afforded the *title ester* as a powder (13.99 g, 98%); mp 68–69 °C (Found: C, 50.02; H, 8.36; N, 19.93. $C_6H_{12}N_2O_2$ requires C, 49.98; H, 8.39; N, 19.43%); $\nu_{max}(CCl_4)/cm^{-1}$ 1710 and 1760; δ_H(250 MHz; $CDCl_3$) 1.32 (t, *J* 7.0), 1.87 and 2.04 (CH_3), 4.27 (q, *J* 7.0, CH_2) and 7.99 (br, NH); δ_C(62.9 MHz; $CDCl_3$) 4.6, 16.3 and 25.4 (CH_3), 61.8 (CH_2), 151.0 and 154.4 (C=O and C=N).

(1-Chloro-1,2,2-trimethylpropyl)azo-(4-fluorobenzene) 1c

At −20 °C, with exclusion of light, *tert*-butyl hypochlorite[42] (1.63 g, 15 mmol) was added dropwise to a solution of 3,3-dimethylbutan-2-one 4-fluorophenylhydrazone (2.07 g, 10 mmol) in $CHCl_3$ (20 ml). After stirring of the mixture at 0 °C for 3 h the solvent was evaporated off to afford the title azo compound as a red oil (2.38 g, 98%), which was used without further purification; $\nu_{max}(CCl_4)/cm^{-1}$ 1597; δ_H(250 MHz; $CDCl_3$) 1.20 (9 H) and 1.84 (CH_3), 7.13 (m, 2 H) and 7.80 (m, 2 H) (ArH); δ_C(62.9 MHz; $CDCl_3$) 24.5, 26.2 (3 C) (CH_3), 41.1, 103.5 (C), 116.0 (d, *J* 23, *m*-C), 125.0 (d, *J* 9, *o*-C), 147.7 (d, *J* 3, *i*-C) and 164.4 (d, *J* 252, *p*-C).

Ethyl [1-chloro-1-(4-fluorophenyl)ethyl]azocarboxylate 1d
At −20 °C, with exclusion of light, *tert*-butyl hypochlorite (1.63 g, 15 mmol) was added dropwise to a solution of ethyl [1-(4-fluorophenyl)ethylidene]carbazate (2.24 g, 10 mmol) in $CHCl_3$ (10 ml). After stirring of the mixture at 0 °C for 3 h the solvent was evaporated off to afford compound **1d** as an orange oil (2.56 g, 99%), which was used without further purification; $\nu_{max}(CCl_4)/cm^{-1}$ 1610 and 1771; δ_H(250 MHz; $CDCl_3$) 1.42 (t, *J* 7.1) and 2.23 (CH_3), 4.47 (q, *J* 7.1, CH_2), 7.09 (m, 2 H) and 7.52 (m, 2 H) (ArH); δ_C(62.9 MHz; $CDCl_3$) 14.1 and 29.3 (CH_3), 65.1 (CH_2), 94.6 (C), 115.7 (d, *J* 12, *m*-C), 128.7 (d, *J* 8, *o*-C), 135.4 (d, *J* 4, *i*-C), 162.9 (d, *J* 249, *p*-C) and 161.6 (C=O).

Ethyl (1-chloro-1-methylethyl)azocarboxylate 1e
From ethyl 3-isopropylidenecarbazate (1.44 g, 10 mmol) as described for analogue **1d**. Title compound was obtained as a yellow-orange oil (1.64 g, 92%), which was used without further purification; $\nu_{max}(CCl_4)/cm^{-1}$ 1771; δ_H(250 MHz; $CDCl_3$) 1.43 (t, *J* 7.1) and 1.91 (6 H) (CH_3), 4.46 (q, *J* 7.1, CH_2); δ_C(62.9 MHz; $CDCl_3$) 14.1 and 29.7 (2 C) (CH_3), 64.9 (CH_2), 93.2 (C) and 161.6 (C=O).

5-Phenyl-4-(2,3,4,6-tetra-*O*-acetyl-β-D-glucopyranosyl)-1,3-bis-(2,4,6-trichlorophenyl)-1,2,3-triazolium hexachloroantimonate 8
A solution of $SbCl_5$ (2.99 g, 10 mmol) in CH_2Cl_2 (20 ml) was added dropwise to a cold (−60 °C) suspension of chloride **4** ($R^1 = R^2 = 2,4,6\text{-}Cl_3C_6H_2$)[17] (4.38 g, 10 mmol) and alkyne **7**[19] (4.32 g, 10 mmol) in CH_2Cl_2 (40 ml). The colour of the mixture changed from yellow to red. The mixture was stirred at between −60 and −30 °C for 2 h, then at 0 °C for 30 min. On slow addition of Et_2O (100 ml) some 2,4,6-trichlorobenzenediazonium hexachloroantimonate (1.14 g, 21%) precipitated. Filtration, and evaporation of the filtrate, afforded a brown residue, which was dissolved in CH_2Cl_2 (16 ml). Slow addition of Et_2O (160 ml) to the red solution furnished the *salt* **8** as a precipitate (8.92 g, 76%); mp 188–190 °C (decomp.) (Found: C, 34.78; H, 2.50; N, 3.52. $C_{34}H_{28}Cl_{12}N_3O_9Sb$ requires C, 34.91; H, 2.41; N, 3.59%); $[a]_D^{25}$ −61.8 (*c* 1.0, $CHCl_3$); $\nu_{max}(CH_2Cl_2)/cm^{-1}$ 1759; δ_H(250 MHz; $CDCl_3$) 1.76, 1.91, 1.98 and 2.10 (CH_3), 4.06 (d, *J* 12.9, H-6′), 4.40 (m, H-5′, -6′), 4.84 (t, *J* 9.6, H-4′), 5.00–5.31 (m, H-1′–3′) and 7.62–7.84 (ArH); δ_C(62.9 MHz; $CDCl_3$) 20.4, 20.5, 20.7 and 20.8 (CH_3), 61.2, 66.5, 70.3, 70.7, 73.3 and 77.0 (CH), 119.1–145.9 (15 signals, aryl, =C), 169.2, 169.3, 169.6 and 170.1 (C=O).

Preparation of acylated glycosyl-1*H*-1,2,4-triazolium hexachloroantimonates. General procedure
A solution of $SbCl_5$ (10–40 mmol) in CH_2Cl_2 (4–20 ml) was added dropwise to a stirred, cold (−60 °C) solution of the glycosyl cyanide **9** or **13** (10 mmol) and the required (chloroalkyl)azo compound **1** (10–40 mmol) in CH_2Cl_2 (10–50 ml). After stirring of the mixture at −60 °C for 2 h, then between −60 and 0 °C for 2 h, then at 0 °C for 2 h, and finally at 23 °C for 1 h, water (200 ml) and $NaHCO_3$ (33.61 g, 400 mmol) were added. Vigorous shaking, filtration, separation of the organic phase, extraction of the aqueous phase with $CHCl_3$ (3 × 60 ml), drying of the combined organic extracts over Na_2SO_4, and evaporation of the mixture afforded the product, which was purified by crystallization or by column chromatography (300 g of SiO_2; eluent $CHCl_3$).

2,3-Dimethyl-5-(2,3,4,6-tetra-*O*-acetyl-β-D-galactopyranosyl)-1-(2,4,6-trichlorophenyl)-1*H*-1,2,4-triazolium hexachloroantimonate 11a
From $SbCl_5$ (2.99 g, 10 mmol) in CH_2Cl_2 (20 ml) nitrile **9**[21,43] (3.57 g, 10 mmol) and compound **1a**[10,44] (2.86 g, 10 mmol) in CH_2Cl_2 (50 ml). After the mixture had been stirred the solvent was evaporated off. The yellow residue was dissolved in warm CH_2Cl_2 (20 ml). Filtration, addition of Et_2O (10 ml) to the filtrate, and crystallization at −15 °C afforded *title compound* **11a** as a powder (7.02 g, 75%); mp 135–137 °C (Found: C, 30.55; H, 2.81; N, 4.31. $C_{24}H_{27}Cl_9N_3O_9Sb$ requires C, 30.59; H, 2.89; N, 4.46%); $[a]_D^{22}$ −45; $[a]_{578}^{22}$ −47 (*c* 1.1, $CHCl_3$); $\nu_{max}(CH_2Cl_2)/cm^{-1}$ 1757; δ_H(250 MHz; $CDCl_3$) 1.99, 2.05, 2.10, 2.14, 3.00 and 4.01 (CH_3), 3.49 (dd, *J* 7.5 and 11.7) and 3.80 (dd, *J* 4.6 and 11.7) (H_2-6′), 4.06 (m, H-5′), 4.95 (d, *J* 9.9, H-1′), 5.17 (dd, *J* 3.1 and 10.1, H-3′), 5.39 (d, *J* 2.9, H-4′), 5.58 (t, *J* 10.0, H-2′) and 7.73 (dd, *J* 2.1, ArH); δ_C(62.9 MHz; $CDCl_3$) 14.5, 20.5, 20.6, 20.7, 20.9 and 35.3 (CH_3), 61.4, 66.3, 67.0, 70.8, 72.8 and 75.2 (C-1′–6′), 124.9, 129.8, 130.3, 135.5, 136.3 and 142.2 (aryl), 157.2 and 160.9 (C=N) and 169.5, 169.6, 169.7 and 170.2 (C=O).

3-Methyl-5-(2,3,4,6-tetra-*O*-acetyl-β-D-galactopyranosyl)-1-(2,4,6-trichlorophenyl)-1*H*-1,2,4-triazole 11b
From $SbCl_5$ (7.50 g, 25 mmol) in CH_2Cl_2 (10 ml), nitrile **9** (8.93 g, 25 mmol) and chloride **1b**[12] (8.20 g, 25 mmol) in CH_2Cl_2 (25 ml). After the mixture had been stirred the solvent was decanted from a dark brown oil, which was dissolved in $CHCl_3$ (150 ml). The solution was shaken with water (100 ml). Separation of the phases, extraction of the aqueous phase with $CHCl_3$ (2 × 50 ml), drying of the combined organic extracts and evaporation of the solution afforded an oil, which was dissolved in MeCN (150 ml). The solution was cooled to −20 °C and aq. $NaHCO_3$ (17.80 g, 200 mmol in 80 ml) was added. After stirring of the mixture at −10 °C for 2 h, then at between −10 and 23 °C for 3 h, MeCN was removed under reduced pressure and the aqueous solution was extracted with $CHCl_3$ (80 ml). Work-up furnished a yellow powder, which was crystallized at −15 °C from CH_2Cl_2 (7 ml)–pentane (20 ml) to give *title compound* **11b** as a powder (12.33 g, 84%); mp 129–131 °C (Found: C, 46.69; H, 4.22; N, 7.16. $C_{23}H_{24}Cl_3N_3O_9$ requires C, 46.60; H, 4.08; N, 7.09%); $[a]_D^{22}$ −16; $[a]_{578}^{22}$ −16 (*c* 1.0, $CHCl_3$); $\nu_{max}(CCl_4)/cm^{-1}$ 1759; δ_H(250 MHz; $CDCl_3$) 1.99, 2.01, 2.02, 2.14 and 2.45 (CH_3), 3.79 (m, H-5′, H_2-6′), 4.54 (d, *J* 9.9, H-1′), 5.07 (dd, *J* 3.2 and 10.1, H-3′), 5.38 (d, *J* 3.2, H-4′), 5.70 (t, *J* 10.0, H-2′) and 7.48 (dd, *J* 2.2, ArH); δ_C(62.9 MHz; $CDCl_3$) 14.0, 20.5, 20.6 and 20.8 (CH_3), 61.6, 67.0, 67.3, 71.7, 72.8 and 74.7 (C-1′–6′), 128.3, 128.4, 133.0, 135.3, 135.5 and 136.7 (aryl), 152.1 and 162.1 (C=N), 169.1, 170.0, 170.1 and 170.2 (C=O).

5-(β-D-Galactopyranosyl)-3-methyl-1-(2,4,6-trichlorophenyl)-1*H*-1,2,4-triazole 12b
A solution of sodium (0.46 g, 20 mmol) and tetraacetate **11b** (5.93 g, 10 mmol) in MeOH (100 ml) was stirred at 23 °C for 3 h. Neutralization with Amberlite 120 (H^+ form) and evaporation of the solution afforded a yellow foam, which was dissolved in water (60 ml). Extraction with Et_2O (2 × 60 ml) and evaporation of the aqueous solution furnished a powder, which was crystallized from MeOH (2 ml) to give *title compound* **12b** as a pale brown crystalline powder (3.27 g, 77%); mp 218–220 °C (Found: C, 42.63; H, 3.80; N, 9.93. $C_{15}H_{16}Cl_3N_3O_5$ requires C, 42.42; H, 3.80; N, 9.90%); $[a]_D^{22}$ +19; $[a]_{578}^{22}$ +21 (*c* 0.9, MeOH); ν_{max}(Nujol)/cm^{-1} 1528; δ_H(250 MHz; CD_3SOCD_3) 2.34 (CH_3), 3.20–3.43 (m, 4 H), 3.67 (br m, 1 H), 3.88 (m, 2 H), 4.38 (m, 2 × OH), 4.75 (d, *J* 5.5, OH), 4.84 (d, *J* 4.3, OH) and 7.93 (ArH); δ_C(62.9 MHz; CD_3SOCD_3) 13.6 (CH_3), 59.7, 67.8, 68.6, 73.4, 74.2 and 79.1 (C-1′–6′), 128.6, 128.7, 132.0, 134.5, 134.7, 135.7, 155.4 and 160.3 (aryl, C-3, -5).

3-Methyl-5-(2,3,5-tri-*O*-benzoyl-β-D-ribofuranosyl)-1-(2,4,6-trichlorophenyl)-1*H*-1,2,4-triazole 15b
From $SbCl_5$ (5.98 g, 20 mmol) in CH_2Cl_2 (20 ml) and a mixture of nitrile **13**[21] (4.72 g, 10 mmol) and chloride **1b**[12] (6.56 g, 20 mmol) in CH_2Cl_2 (40 ml). Chromatography on silica gel (240 g), first with $CHCl_3$–light petroleum (distillation range 60–80 °C) (3:2), and then with $CHCl_3$ as eluent, afforded *title compound* **15b** as a pale yellow crystalline powder (3.39 g, 48%); mp 65–66 °C (Found: C, 59.18; H, 3.83; N, 6.14. $C_{35}H_{26}Cl_3N_3O_7$ requires C, 59.46; H, 3.71; N, 5.95%); $[a]_D^{23}$ +9; $[a]_{578}^{23}$ +10 (*c* 1.1,

$CHCl_3$); $\nu_{max}(CCl_4)/cm^{-1}$ 1742; δ_H(250 MHz; $CDCl_3$) 2.45 (CH_3), 4.44 (dd, *J* 5.2 and 11.9, H-5′), 4.59 (m, H-4′, -5′), 5.21 (d, *J* 4.3, H-1′), 5.97 (t, *J* 5.5, H-3′), 6.20 (dd, *J* 4.6 and 5.2, H-2′) and 7.26–8.08 (ArH); δ_C(62.9 MHz; $CDCl_3$) 14.0 (CH_3), 64.2, 72.5, 75.1, 75.4, 80.3 (C-1′–5′), 153.8 and 162.2 (C=N), 165.0, 165.2 and 166.1 (C=O).

1-(4-Fluorophenyl)-3-methyl-5-(2,3,5-tri-*O*-benzoyl-β-D-ribofuranosyl)-1*H*-1,2,4-triazole 15c

From $SbCl_5$ (4.19 g, 14 mmol) in CH_2Cl_2 (15 ml) and a mixture of nitrile **13** (4.72 g, 10 mmol) and chloride **1c** (3.40 g, 14 mmol) in CH_2Cl_2 (50 ml). Purification by column chromatography afforded *title compound* **15c** as a pale brown crystalline powder (5.22 g, 84%); mp 59–61 °C (Found: C, 67.42; H, 4.31; N, 6.97. $C_{35}H_{28}FN_3O_7$ requires C, 67.62; H, 4.54; N, 6.76%); $[\alpha]_D^{23}$ +7; $[\alpha]_{578}^{23}$ +8 (*c* 1.1, $CHCl_3$); $\nu_{max}(CCl_4)/cm^{-1}$ 1734; δ_H(250 MHz; $CDCl_3$) 2.37 (CH_3), 4.54–4.80 (m, H-4′, H_2-5′), 5.19 (d, *J* 3.1, H-1′), 6.21 (t, $J \approx 5.3$, H-3′), 6.28 (dd, $J \approx 3.1$ and 5.3, H-2′) and 7.12–8.09 (ArH); δ_C(62.9 MHz; $CDCl_3$) 13.8 (CH_3), 63.7, 72.8, 74.8, 75.4 and 80.2 (C-1′–5′), 116.4 (d, *J* 23, *m*-aryl), 127.0 (d, *J* 9, *o*-aryl), 162.6 (d, *J* 249, *p*-aryl), 151.8 and 160.9 (C=N), 165.2, 165.3 and 166.2 (C=O).

3-Methyl-5-(β-D-ribofuranosyl)-1-(2,4,6-trichlorophenyl)-1*H*-1,2,4-triazole 16b

At 23 °C a solution of **15b** (5.42 g, 10 mmol) and sodium (0.46 g, 20 mmol) in MeOH (200 ml) was stirred for 3 h. Neutralization with 0.5 M HCl, evaporation of the solution, dissolution of the residue in water (80 ml)–Et_2O (80 ml), separation of the phases, extraction of the aqueous phase with Et_2O (80 ml), and evaporation of the aqueous phase afforded an oil, which was purified by column chromatography on silica gel (130 g), first with $CHCl_3$, finally with $CHCl_3$–MeOH (9 : 1) as eluent. Work-up afforded *title compound* **16b** as a pale yellow oil, which slowly solidified to give a pale yellow powder (3.32 g, 84%); mp 144–146 °C (Found: C, 43.34; H, 3.93; N, 10.61. $C_{14}H_{14}Cl_3N_3O_4$ requires C, 42.61; H, 3.58; N, 10.65%); $[\alpha]_D^{23}$ −20; $[\alpha]_{578}^{23}$ −21 (*c* 0.5, MeOH); ν_{max}(Nujol)/cm^{-1} 1538 and 1559; δ_H(250 MHz; CD_3SOCD_3; 303 K) 2.34 (CH_3), 3.27 (m, H_2-5′), 3.72 (q, $J \approx 4.9$, H-4′), 3.88 (q, $J \approx 5.0$, H-3′), 4.22 (q, $J \approx 5.8$, H-2′), 4.45 (d, *J* 5.7, H-1′), 4.62 (t, *J* 5.5, OH-5′), 4.96 (d, *J* 5.4, OH-3′), 5.17 (d, *J* 6.3, OH-2′) and 7.96 (ArH); δ_C(62.9 MHz; CD_3SOCD_3; 303 K) 13.5 (CH_3), 61.8, 71.4, 74.6, 75.7 and 85.1 (C-1′–5′), 128.8, 131.8, 134.1, 134.6 and 136.1 (aryl), 156.3 and 160.7 (C=N).

1-(4-Fluorophenyl)-3-methyl-5-(β-D-ribofuranosyl)-1*H*-1,2,4-triazole hydrate 16c

A solution of tribenzoate **15c** (6.22 g, 10 mmol) in MeOH (200 ml) and conc. aq. NH_3 (200 ml) was kept at 23 °C for 20 h. The solvent was evaporated off and the oily residue was purified by column chromatography [SiO_2 (300 g); $CHCl_3$, then $CHCl_3$–MeOH (95 : 5) as eluent] to afford a foam, which was dissolved in water (50 ml). Repeated extraction with Et_2O to remove small amounts of benzamide, and evaporation of water, afforded *title compound* **16c** as a resin (1.58 g, 51%) (Found: C, 51.57; H, 5.59; N, 12.70. $C_{14}H_{16}FN_3O_4 \cdot H_2O$ requires C, 51.36; H, 5.54; N, 12.84%); $[\alpha]_D^{23}$ −35; $[\alpha]_{578}^{23}$ −38 (*c* 0.96, MeOH); $\nu_{max}(CHCl_3)$/cm^{-1} 1602; δ_H(250 MHz; CD_3SOCD_3) 2.32 (CH_3), 3.43 (m, H_2-5′), 3.82 (q, $J \approx 4.4$, H-4′), 4.02 (q, $J \approx 4.5$, H-3′), 4.44 (q, $J \approx 6.1$, H-2′), 4.55 (d, *J* 6.1, H-1′), 4.80 (t, $J \approx 5.7$, OH-5′), 5.02 (d, *J* 4.8, OH-3′), 5.17 (d, *J* 6.3, OH-2′) and 7.39–7.64 (ArH); δ_C(62.9 MHz; CD_3SOCD_3) 13.5 (CH_3), 62.0, 71.4, 74.0, 74.4 and 85.8 (C-1′–5′), 116.4 (d, *J* 23, *m*-C), 126.8 (d, *J* 9, *o*-C), 133.0 (d, *J* 3, *i*-C), 161.8 (d, *J* 246, *p*-C), 153.8 and 159.5 (C=N).

1-(4-Fluorophenyl)-5-methyl-3-(2,3,5-tri-*O*-benzoyl-β-D-ribofuranosyl)-1*H*-1,2,4-triazole 17d

From $SbCl_5$ (8.97 g, 30 mmol) in CH_2Cl_2 (30 ml) and a mixture of nitrile **13** (4.72 g, 10 mmol) and chloride **1d** (7.76 g, 30 mmol) in CH_2Cl_2 (40 ml). After stirring of the mixture the solvent was removed. The dark brown residue was dissolved in MeCN (30 ml). After cooling of the mixture to 0 °C, water (100 ml) and $NaHCO_3$ (25.20 g, 300 mmol) were added slowly. The mixture was stirred at 23 °C for 30 min and filtered. MeCN was removed *in vacuo*, and the aqueous phase was extracted with $CHCl_3$ (3 × 60 ml). The combined organic extracts were washed with water (3 × 30 ml), dried over Na_2SO_4, and evaporated. The orange-brown residue was purified by flash chromatography (140 g silica gel; $CHCl_3$ as eluent) to afford *title compound* **17d** as a foam (4.76 g, 77%) (Found: C, 67.52; H, 4.62; N, 6.72. $C_{35}H_{28}FN_3O_7$ requires C, 67.63; H, 4.54; N, 6.76%); $[\alpha]_D^{23}$ −32; $[\alpha]_{578}^{23}$ −35 (*c* 1.0, $CHCl_3$); $\nu_{max}(CCl_4)/cm^{-1}$ 1738; δ_H(250 MHz; $CDCl_3$) 2.45 (CH_3), 4.64–4.85 (m, H-4′, H_2-5′), 5.49 (d, *J* 4.2, H-1′), 6.14 (m, H-2′, -3′) and 7.13–8.16 (ArH); δ_C(62.9 MHz; $CDCl_3$) 13.1 (CH_3), 64.4, 72.9, 75.3, 77.7 and 79.9 (C 1′–5′), 116.4 (d, *J* 23.6, *m*-aryl), 153.5 and 160.3 (C=N), 162.4 (d, *J* 250, *p*-aryl), 165.2, 165.3 and 166.3 (C=O).

1,5-Dimethyl-3-(2,3,5-tri-*O*-benzoyl-β-D-ribofuranosyl)-1*H*-1,2,4-triazole 17e

(**a**) From $SbCl_5$ (5.98 g, 20 mmol) in CH_2Cl_2 (20 ml) and nitrile **13** (4.72 g, 10 mmol) and chloride **1e** (3.57 g, 20 mmol) in CH_2Cl_2 (20 ml). The resulting brown oil solidified after addition of Et_2O (40 ml) to afford a brown powder (3.30 g, 61%). Crystallization at −15 °C from MeOH (14 ml) furnished, after work-up of the mother liquor, the *title compound* **17e** as a pale yellow powder (3.08 g, 57%); mp 131–133 °C (Found: C, 66.61; H, 5.19; N, 7.65. $C_{30}H_{27}N_3O_7$ requires C, 66.53; H, 5.03; N, 7.76%); $[\alpha]_D^{23}$ −28; $[\alpha]_{578}^{23}$ −29 (*c* 0.9, $CHCl_3$); $\nu_{max}(CCl_4)/cm^{-1}$ 1739; δ_H(250 MHz; $CDCl_3$) 2.39 and 3.73 (CH_3), 4.60–4.81 (3 H), 5.38 (d, *J* 1.4, H-1′), 6.05 (m, 2 H) and 7.27–8.58 (m, 15 H, Ph); δ_C(62.9 MHz; $CDCl_3$) 11.9, 35.2 (CH_3), 64.4, 72.9, 75.3, 77.8, 79.8 (C1′–5′), 153.3, 159.3 (C=N), 165.3, 165.4 and 166.3 (C=O).

(**b**) From $SbCl_5$ (3.74 g, 12.5 mmol) in CH_2Cl_2 (20 ml) and a mixture of nitrile **13** (4.72 g, 10 mmol) and chloride **1f**[45,46] (2.29 g, 12.5 mmol) in CH_2Cl_2 (30 ml). The product was precipitated from the reaction mixture by addition of pentane (300 ml). The precipitate was dissolved in MeCN (70 ml). After cooling of the mixture to 0 °C, water (200 ml) and $NaHCO_3$ (10.50 g, 125 mmol) were added. The mixture was stirred at 23 °C for 2 h. The organic phase was separated and the aqueous phase was extracted with MeCN (3 × 100 ml). The combined organic phases were evaporated and the residue was dissolved in CH_2Cl_2 (100 ml). Filtration with added decolorizing charcoal and evaporation of the solution afforded a red foam (3.03 g, 56%), which was crystallized from MeOH (10 ml) to give the *title compound* **17e** as a pale yellow crystalline powder (2.93 g, 54%); mp 130–132 °C; $[\alpha]_D^{23}$ −27; $[\alpha]_{578}^{23}$ −30 (*c* 1.0, $CHCl_3$).

1-Isopropyl-5-methyl-3-(2,3,5-tri-*O*-benzoyl-β-D-ribofuranosyl)-1*H*-1,2,4-triazole 17g

From $SbCl_5$ (3.74 g, 12.5 mmol) in CH_2Cl_2 (20 ml) and a mixture of nitrile **13** (4.72 g, 10 mmol) and chloride **1g**[47,48] (2.99 g, 12.5 mmol) in CH_2Cl_2 (80 ml). After completion of the reaction the solvent was evaporated off and the red residue was dissolved in MeCN (40 ml). Cooling to 0 °C, addition of water (200 ml) and $NaHCO_3$ (10.50 g, 125 mmol), stirring at 23 °C for 6 h, concentration of the solution to a volume of ~100 ml, extraction with CH_2Cl_2 (3 × 60 ml), and work-up of the combined organic phases afforded a yellow foam, which was purified by flash chromatography with CH_2Cl_2 as eluent to furnish a foam (2.85 g, 50%). Crystallization at −15 °C from EtOH (10 ml) afforded *title compound* **17g** as prisms (2.11 g, 37%); mp 97–99 °C (Found: C, 67.39; H, 5.62; N, 7.08. $C_{32}H_{31}N_3O_7$ requires C, 67.48; H, 5.49; N, 7.38%); $[\alpha]_D^{23}$ −30; $[\alpha]_{578}^{23}$ −32 (*c* 0.9, $CHCl_3$); $\nu_{max}(CCl_4)/cm^{-1}$ 1731; δ_H(250 MHz; $CDCl_3$) 1.45 (d, *J* 6.6, 6 H), 2.43 (CH_3), 4.41 (sept, *J* 6.6, CH), 4.73 (m, H-4′, H_2-5′), 5.43 (d, $J \approx 4,3$, H-1′), 6.07 (m, H-2′, -3′) and 7.27–8.15 (Ph); δ_C(62.9

MHz; $CDCl_3$) 11.9, 22.18 and 22.22 (CH_3), 50.3 (CH), 64.6, 73.0, 75.3, 77.7 and 79.8 (C-1′–5′), 151.7 and 158.8 (C=N), 165.3, 165.4 and 166.3 (C=O).

5,6,7,8-Tetrahydro-2-(2,3,5-tri-*O*-benzoyl-β-D-ribofuranosyl)-1,2,4-triazolo[1,5-*a*]pyridine 17h

From $SbCl_5$ (11.96 g, 40 mmol) in CH_2Cl_2 (40 ml) and a mixture of nitrile **13** (4.72 g, 10 mmol) and chloride **1h**[12] (8.19 g, 40 mmol) in CH_2Cl_2 (50 ml). After stirring of the mixture the solvent was removed. The dark brown residue was dissolved in MeCN (50 ml). After cooling of the mixture to 0 °C, water (60 ml) and $NaHCO_3$ (26.89 g, 320 mmol) were added. The mixture was stirred at 23 °C for 30 min and filtered. MeCN was removed *in vacuo*, and the aqueous phase was extracted with $CHCl_3$ (3 × 60 ml). The combined organic extracts were washed with water (3 × 30 ml), dried over Na_2SO_4 and evaporated. The dark brown residue was purified by flash chromatography (100 g silica gel; $CHCl_3$ as eluent) to afford a foam (3.58 g, 63%), which slowly crystallized from MeOH to give *title compound* **17h** as a crystalline powder; mp 126–127 °C (Found: C, 67.80; H, 5.23; N, 7.42. $C_{32}H_{29}N_3O_7$ requires C, 67.72; H, 5.15; N, 7.40%); $[\alpha]_D^{23}$ −34; $[\alpha]_{578}^{23}$ −36 (*c* 0.9, $CHCl_3$); $\nu_{max}(CCl_4)/cm^{-1}$ 1732; δ_H(250 MHz; $CDCl_3$) 1.98 (m, 4 H), 2.87 (t, *J* 6.1), 4.08 (t, *J* 6.0) (each CH_2), 4.73 (m, H-4′, H_2-5′), 5.43 (m, *J* ≈ 3.8, H-1′), 6.06 (m, H-2′, -3′) and 7.27–8.16 (Ph); δ_C(62.9, MHz; $CDCl_3$) 20.4, 22.8, 23.7 and 47.0 (CH_2), 64.5, 72.9, 75.4, 78.0 and 79.7 (C-1′–5′), 153.6 and 159.9 (C=N), 165.2, 165.3 and 166.3 (C=O).

6,7,8,9-Tetrahydro-2-(2,3,5-tri-*O*-benzoyl-β-D-ribofuranosyl)-5*H*-1,2,4-triazolo[1,5-*a*]azepine 17i

From $SbCl_5$ (11.96 g, 40 mmol) in CH_2Cl_2 (60 ml) and a mixture of nitrile **13** (4.72 g, 10 mmol) and chloride **1i**[12] (8.75 g, 40 mmol) in CH_2Cl_2 (30 ml). Column chromatography afforded a yellow oil, which was crystallized from MeOH (10 ml) to afford the *title compound* **17i** as a crystalline powder (2.50 g, 43%); mp 127–128 °C (Found: C, 68.17; H, 5.35; N, 7.26. $C_{33}H_{31}N_3O_7$ requires C, 68.14; H, 5.37; N, 7.23%); $[\alpha]_D^{23}$ −32; $[\alpha]_{578}^{23}$ −34 (*c* 1.0, $CHCl_3$); $\nu_{max}(CHCl_3)/cm^{-1}$ 1726; δ_H(250 MHz; $CDCl_3$) 1.79 (m, 6 H), 2.90 (m, 2 H) and 4.17 (m, 2 H) (5 × CH_2), 4.75 (m, H-4′, H_2-5′), 5.40 (br, H-1′), 6.05 (m, H-2′, -3′) and 7.28–8.14 (Ph); δ_C(62.9 MHz; $CDCl_3$), 24.8, 27.3, 27.5, 30.3 and 51.3 (CH_2), 64.4, 72.8, 75.4, 77.9 and 79.7 (C-1′–5′), 158.2 and 158.3 (C=N), 165.2, 165.3 and 166.3 (C=O).

1-(4-Fluorophenyl)-5-methyl-3-(β-D-ribofuranosyl)-1*H*-1,2,4-triazole 18d

From tribenzoate **17d** (6.22 g, 10 mmol) as described for analogue **16b**. After neutralization and evaporation of the solution the dark brown residue was extracted with MeOH (150 ml). Filtration and evaporation of the solution furnished a brown foam, which was suspended in water (150 ml). Extraction with Et_2O (2 × 70 ml), then with Et_2O–$CHCl_3$ (5:1) (70 ml), filtration of the aqueous solution with added decolorizing charcoal, and evaporation of the solution afforded *title compound* **18d** as a crystalline powder (2.23 g, 72%); mp 83–86 °C (Found: C, 54.21; H, 5.27; N, 13.67. $C_{14}H_{16}FN_3O_4$ requires C, 54.37; H, 5.21; N, 13.59%); $[\alpha]_D^{23}$ −26; $[\alpha]_{578}^{23}$ −27 (*c* 1.0, MeOH); ν_{max}(Nujol)/cm^{-1} 1608; δ_H(250 MHz; CD_3SOCD_3) 2.44 (CH_3), 3.53 (m, H_2-5′), 3.85 (q, *J* 4.9, H-4′), 4.04 (q, *J* 5.2, H-3′), 4.26 (q, *J* 5.5, H-2′), 4.68 (d, *J* 5.2, H-1′), 4.76 (t, *J* ≈ 6.1, OH-5′), 4.95 (d, *J* 5.5, OH-3′), 5.09 (d, *J* 6.1, OH-2′) and 7.38–7.67 (ArH); δ_C(62.9 MHz; CD_3SOCD_3) 12.6 (CH_3), 62.2, 71.4, 74.6, 77.9 and 84.8 (C-1′–5′), 116.3 (d, *J* 23, *m*-C), 126.8 (d, *J* 9, *o*-C), 133.4 (d, *J* 3, *i*-C), 161.5 (d, *J* 246, *p*-C), 152.9 and 161.6 (C=N).

1,5-Dimethyl-3-(β-D-ribofuranosyl)-1*H*-1,2,4-triazole 18e

From tribenzoate **17e** (5.42 g, 10 mmol) as described for analogue **16b**. Purification of the oily product by column chromatography [80 g SiO_2; eluent MeOH–$CHCl_3$ (5:95) followed by MeOH–$CHCl_3$ (10:90)] afforded *title compound* **18e** as a powder (1.40 g, 61%); mp 126–128 °C (Found: C, 47.10; H, 6.66; N, 18.30. $C_9H_{15}N_3O_4$ requires C, 47.15; H, 6.60; N, 18.33%); $[\alpha]_D^{23}$ −31; $[\alpha]_{578}^{23}$ −32 (*c* 1.0 in MeOH); ν_{max}(Nujol)/cm^{-1} 1516; δ_H(250 MHz; CD_3SOCD_3) 2.35 and 3.72 (CH_3), 3.49 (m, H_2-5′), 3.80 (q, *J* ≈ 4.9, H-4′), 3.99 (q, *J* ≈ 5.2, H-3′), 4.15 (q, *J* ≈ 5.5, H-2′), 4.56 (d, *J* 5.3, H-1′), 4.74 (dd, *J* 4.9 and 6.5, OH-5′), 4.83 (d, *J* 5.5, OH-3′) and 4.93 (d, *J* 6.0, OH-2′); δ_C(62.9 MHz; CD_3SOCD_3) 11.2 and 34.7 (CH_3), 62.2, 71.3, 74.6, 78.0 and 84.6 (C-1′–5′), 152.6 and 160.4 (C=N).

5,6,7,8-Tetrahydro-2-(β-D-ribofuranosyl)-1,2,4-triazolo[1,5-*a*]-pyridine 18h

From tribenzoate **17h** (5.68 g, 10 mmol) as described for analogue **18d**. *Title compound* **18h** was obtained as a brownish crystalline powder (1.74 g, 68%); mp 92–94 °C (Found: C, 51.57; H, 6.80; N, 16.46. $C_{11}H_{17}N_3O_4$ requires C, 51.76; H, 6.71; N, 16.46%); $[\alpha]_D^{23}$ −29; $[\alpha]_{578}^{23}$ −30 (*c* 1.0, MeOH); ν_{max}(Nujol)/cm^{-1} 1533; δ_H(250 MHz; CD_3SOCD_3) 1.91 (m, 4 H), 2.77 (t, *J* ≈ 5.9, 2 H), 3.46 (m, H_2-5′), 3.81 (q, *J* ≈ 4.6, H 4′), 4.04 (m, CH_2, H-3′), 4.17 (q, *J* ≈ 5.4, H-2′), 4.59 (d, *J* 5.4, H-1′), 4.82 (t, *J* ≈ 5.2, OH-5′), 4.93 (d, *J* 5.3, OH-3′) and 5.04 (d, *J* 5.9, OH-2′); δ_C(62.9 MHz; CD_3SOCD_3) 19.7, 22.2, 22.9 and 46.3 (CH_2), 62.2, 71.3, 74.7, 78.1 and 8.47 (C-1′–5′), 152.6 and 161.0 (C=N).

6,7,8,9-Tetrahydro-2-(β-D-ribofuranosyl)-5*H*-1,2,4-triazolo-[1,5-*a*]azepine 18i

From tribenzoate **17i** (5.82 g, 10 mmol) as described for analogue **16b**. Column chromatographic purification [250 g SiO_2; eluent $CHCl_3$, followed by $CHCl_3$–MeOH (95:5) and $CHCl_3$–MeOH (90:10)] afforded *title compound* **18i** as a pale brown crystalline powder (1.99 g, 74%); mp 123–124 °C (Found: C, 53.22; H, 7.11; N, 15.61. $C_{12}H_{19}N_3O_4$ requires C, 53.52; H, 7.11; N, 15.61%); $[\alpha]_D^{23}$ −30; $[\alpha]_{578}^{23}$ −31 (*c* 1.2, MeOH); ν_{max}(Nujol)/cm^{-1} 1523; δ_H(250 MHz; CD_3SOCD_3; 303 K) 1.60, 1.70, 1.81, 2.86 and 4.19 (m, CH_2), 3.48 (m, H_2-5′), 3.79 (q, *J* 4.6, H-4′), 3.97 (q, *J* 5.2, H-3′), 4.17 (q, *J* ≈ 5.5, H-2′), 4.54 (d, *J* 5.5, H-1′), 4.75 (dd, *J* 5.2 and 6.1, OH-5′), 4.84 (d, *J* 5.2, OH-3′) and 4.94 (d, *J* 6.1, OH-2′); δ_C(62.9 MHz; CD_3SOCD_3; 303 K) 24.5, 26.4, 27.0, 29.3 and 50.2 (CH_2), 62.2, 71.2, 74.5, 78.0 and 84.7 (C-1′–5), 157.3 and 159.4 (C=N).

2,3,4,6-Tetra-*O*-acetyl-β-D-glucopyranosyl isothiocyanate 19

A solution of 1,2,3,4,6-penta-*O*-acetyl-α-D-glucopyranose (3.90 g, 10 mmol), trimethylsilyl isothiocyanate[49] (1.31 g, 10 mmol), and distilled $SnCl_4$ (2.61 g, 10 mmol) in CH_2Cl_2 (60 ml) was boiled under reflux for 12 h. After addition of further trimethylsilyl isothiocyanate (0.66 g, 5 mmol) and $SnCl_4$ (2.61 g, 10 mmol) the mixture was boiled for another 12 h. After neutralization by shaking with water (50 ml) and excess of $NaHCO_3$, filtration and separation of the organic phase, the aqueous phase was extracted with CH_2Cl_2 (2 × 25 ml). Drying of the combined organic phases over Na_2SO_4, filtration with added decolorizing coal, and evaporation of the solution afforded a greenish crystalline powder, which was recrystallized at 5 °C from Et_2O (24 ml) to furnish the *title isothiocyanate* **19** as a crystalline powder (3.51 g, 81%); mp 113–114 °C; $[\alpha]_D^{293}$ +5.1 (*c* 1.0, $CHCl_3$) {lit.,[50] mp 112–113 °C; $[\alpha]_D^{293}$ +4.4 (in $CHCl_3$)}; $\nu_{max}(CCl_4)/cm^{-1}$ 1752 (C=O) and 2020 (NCS); δ_H(250 MHz; $CDCl_3$) 2.02, 2.03 and 2.11 (6 H) (CH_3), 3.76 (m, H-5), 4.19 (m, $J_{6,6'}$ 12.5, $J_{6,5}$ 2.4, $J_{5,6'}$ 4.7, H_2-6′) and 5.01–5.25 (m, H-1–4); δ_C(62.9 MHz; $CDCl_3$) 20.5 and 20.7 (CH_3), 61.6, 67.7, 71.9, 72.5, 74.1 and 83.5 (C-1–6), 144.3 (NCS), 169.0, 169.2, 170.1 and 170.5 (C=O).

2,3-Dihydro-5-methyl-2-(2,3,4,6-tetra-*O*-acetyl-β-D-gluco-pyranosylimino)-3-(2,4,6-trichlorophenyl)-1,3,4-triadiazole 20b

From $SbCl_5$ (8.97 g, 30 mmol) in CH_2Cl_3 (30 ml) and a mixture of compound **19** (3.89 g, 10 mmol) and chloride **1b** (12.78 g, 30

mmol) in CH_2Cl_2 (40 ml) in the manner described for compound **17d**. Flash chromatography afforded a foam, which crystallized from hot CCl_4 (30 ml) to afford pale yellow prisms (5.31 g, 85%); mp 126–128 °C (Found: C, 44.16; H, 3.91; N, 6.69. $C_{23}H_{24}Cl_3N_3O_9S$ requires C, 44.21; H, 3.87; N, 6.72%); $[a]_D^{23}$ +14; $[a]_{578}^{23}$ +15 (*c* 0.9, $CHCl_3$); $\nu_{max}(CCl_4)/cm^{-1}$ 1761 and 1635; δ_H(250 MHz; $CDCl_3$) 1.88, 1.98, 2.02, 2.08 and 2.43 (CH_3), 3.79 (m, H-5′), 4.16 (dd, *J* 2.4 and 12.3), 4.27 (dd, *J* 4.9 and 12.2) (together H_2-6′), 4.49 (d, *J* 8.8, H-1′), 4.97 (t, *J* 9.2, H-2′), 5.10 (t, *J* 9.5, H-4′), 5.23 (t, *J* 9.4, H-3′) and 7.43 (dd, *J* 2.2, ArH); δ_C(62.9 MHz; $CDCl_3$) 17.4 and 20.6 (2 C), 20.7 and 20.8 (CH_3), 62.2, 68.6, 72.5, 73.4, 73.6 and 91.2 (C-1′–6′), 128.5, 128.9, 133.1, 135.9, 136.0 and 136.5 (aryl), 147.5 and 158.0 (C=N, C=S), 168.9, 169.3, 170.3 and 170.6 (C=O).

2-(β-D-Glucopyranosylimino)-2,3-dihydro-5-methyl-3-(2,4,6-trichlorophenyl)-1,3,4-thiadiazole 21b

From tetraacetate **20b** (6.25 g, 10 mmol) as described for analogue **16b**. The oily product was purified by flash chromatography [560 g SiO_2; eluent $CHCl_3$–MeOH (19 : 1)]. Work-up afforded *title compound* **21b** as a crystalline powder (3.24 g, 71%); mp 91–94 °C (Found: C, 39.21; H, 3.67; N, 9.11. $C_{15}H_{16}Cl_3N_3O_5S$ requires C, 39.45; H, 3.53; N, 9.20%); $[a]_D^{23}$ +19; $[a]_{578}^{23}$ +20 (*c* 1.0, MeOH); ν_{max}(Nujol)/cm^{-1} 1620; δ_H(250 MHz; CD_3SOCD_3; 303 K) 2.39 (CH_3), 2.93–3.72 (m, H-2′–6′), 3.96 (d, *J* 8.2, H-1′), 4.44 (t, *J* 5.6, OH-6′), 4.68 (d, *J* 5.2, OH-2′), 4.86 (m, OH-3′, -4′) and 7.86 (ArH); δ_C(62.9 MHz; CD_3SOCD_3; 303 K) 16.9 (CH_3), 60.9, 69.9, 75.1, 77.4, 78.5 and 94.3 (C-1′–6′), 128.7, 128.8, 133.4, 135.0, 135.5 and 135.6 (aryl), 147.5 and 156.0 (C=N, C=S).

2,5-Dihydro-2,2-dimethyl-5-(2,3,4,6-tetra-*O*-acetyl-β-D-glucopyranosylimino)-1,3,4-thiadiazole 22

From $SbCl_5$ (8.97 g, 30 mmol) in CH_2Cl_2 (30 ml) and a mixture of compound **19** (3.89 g, 10 mmol) and chloride **1f** (5.49 g, 30 mmol) in CH_2Cl_2 (20 ml) as described for analogue **17d**. After removal of MeCN the aqueous phase was extracted with CH_2Cl_2 (2 × 30 ml). Drying of the combined organic phases, filtration with added decolorizing charcoal, and evaporation of the solution afforded an orange oil, which was crystallized at −15 °C from CH_2Cl_2 (10 ml)–Et_2O (30 ml) to give a pale orange powder (2.88 g, 63%). Recrystallization at −15 °C from CCl_4 (200 ml) furnished *title compound* **22** as a crystalline powder (2.08 g, 45%); mp 73–75 °C (Found: C, 46.75; H, 5.52; N, 8.88. $C_{18}H_{25}N_3O_9S$ requires C, 47.05; H, 5.48; N, 9.15%); $[a]_D^{23}$ −19; $[a]_{578}^{23}$ −19 (*c* 1.0, $CHCl_3$); $\nu_{max}(CH_2Cl_2)/cm^{-1}$ 1757 and 1646; δ_H(250 MHz; $CDCl_3$) 1.83, 1.84, 2.00, 2.02, 2.06 and 2.10 (CH_3), 3.88 (m, H-5′), 4.22 (dd, *J* 2.6 and 12.4), 4.27 (dd, *J* 4.8 and 12.4) (H_2-6′), 4.90 (d, *J* 8.6, H-1′), 5.19 (t, $J \approx 9.2$), 5.26 (t, $J \approx 8.7$) and 5.36 (t, $J \approx 9.4$) (H-2′, -3′, -4′); δ_C(62.9 MHz; $CDCl_3$) 20.6, 20.7, 20.8, 27.9 and 28.1 (CH_3), 62.0, 68.3, 71.7, 73.4, 74.0 and 89.7 (C-1′–6′), 107.5 (NCN), 169.1, 169.4, 170.3, 170.6 (C=O) and 177.2 (C=N).

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