

Synthesis of biolabile thioalkyl-protected phosphates from an easily accessible phosphotriester precursor

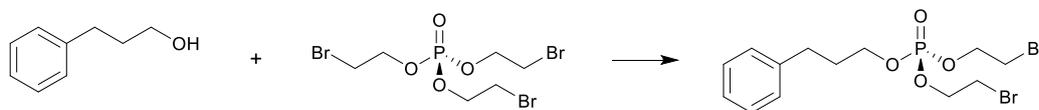
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Tabulated reaction optimisation data

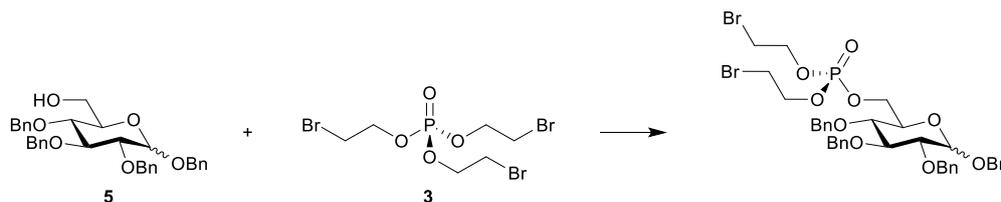
Table S1. Reaction optimisation with 3-phenylpropanol as a model substrate: variation of preactivation time



| Run | Phosphate equiv. | Tf ₂ O equiv. | Time (min.) Step i ^a | Pyridine equiv. | Time (min.) Step ii ^a | Substrate equiv. | Time (hours) Step iii ^a | Yield (%) |
|----------|------------------|--------------------------|---------------------------------|-----------------|----------------------------------|------------------|------------------------------------|-----------|
| Original | 1.0 | 1.5 | 1 | 2.0 | 10 | 2.0 | 1 | 17 |
| 1 | 1.0 | 1.5 | 5 | 2.0 | 10 | 2.0 | 1 | 37 |
| 2 | 1.0 | 1.5 | 10 | 2.0 | 10 | 2.0 | 1 | 51 |
| 3 | 1.0 | 1.5 | 20 | 2.0 | 10 | 2.0 | 1 | 45 |
| 4 | 1.0 | 1.5 | 30 | 2.0 | 10 | 2.0 | 1 | 43 |
| 5 | 1.0 | 1.5 | 10 | 2.0 | 20 | 2.0 | 1 | 42 |
| 6 | 1.0 | 1.5 | 10 | 2.0 | 30 | 2.0 | 1 | 36 |

^aReaction conditions: i) tri(2-bromoethyl)phosphate, Tf₂O, CH₂Cl₂, RT, 1-30 min. (as indicated), ii) pyridine, RT, 10-30 min. (as indicated), iii) 3-phenylpropanol, RT, 1 hr.

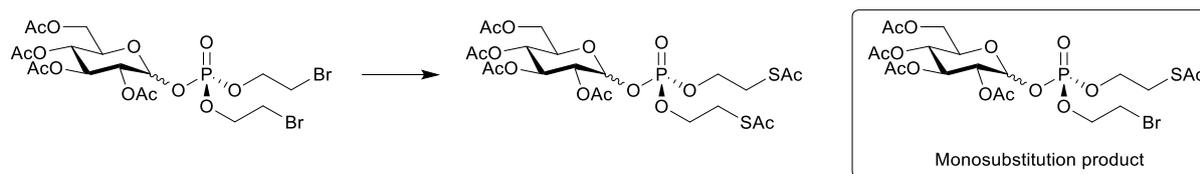
Table S2. Reaction optimisation with 1,2,3,4-tetra-O-benzylglucopyranose: variation of reaction time



| Run | Phosphate equiv. | Tf ₂ O equiv. | Time (min.) Step i ^a | Pyridine equiv. | Time (min.) Step ii ^a | Substrate equiv. | Time (hours) Step iii ^a | Yield (%) |
|----------|------------------|--------------------------|---------------------------------|-----------------|----------------------------------|------------------|------------------------------------|-----------|
| Original | 1.0 | 1.5 | 1 | 2.0 | 10 | 2.0 | 0.5 | 13 |
| 1 | 1.0 | 1.5 | 10 | 2.0 | 10 | 2.0 | 0.5 | 31 |
| 2 | 1.0 | 1.5 | 10 | 2.0 | 10 | 2.0 | 1 | 51 |
| 3 | 1.0 | 1.5 | 10 | 2.0 | 10 | 2.0 | 1.5 | 62 |
| 4 | 1.0 | 1.5 | 10 | 2.0 | 10 | 2.0 | 2 | 42 |
| 5 | 1.0 | 1.5 | 10 | 2.0 | 10 | 2.0 | 3 | 40 |
| 6 | 1.0 | 1.5 | 10 | 2.0 | 10 | 2.0 | 4 | 41 |

^aReaction conditions: i) **3**, Tf₂O, CH₂Cl₂, RT, 10 min., ii) pyridine, RT, 10 min., iii) **5**, RT, 0.5-4 hrs. (as indicated). Optimised conditions are highlighted in blue; these were used for all subsequent reactions.

Table S3. Screening of different solvents for the thioacetate substitution step



| Run | Anhydrous Solvent | Yield (%) |
|-----|-------------------|--|
| A | Distilled acetone | 0 |
| B | Acetonitrile | 53* |
| C | Tetrahydrofuran | Product + Monosubstitution + Degradation |
| D | Dichloromethane | Product + Monosubstitution |
| E | DMF | 42* |
| F | Pyridine | 72 |

Reaction conditions: KSAC in specified solvents, RT, overnight. Solvents that were screened include distilled acetone (A), anhydrous acetonitrile (B), anhydrous tetrahydrofuran (C), anhydrous dichloromethane (D), anhydrous dimethylformamide (E) and neat anhydrous pyridine (F). Optimised conditions are highlighted in blue; these were used for all subsequent reactions. *Yield calculated from NMR integrations.

Experimental evidence for the formation of oxazoline/oxazolinium ion species from GlcNAc-1-OH substrates

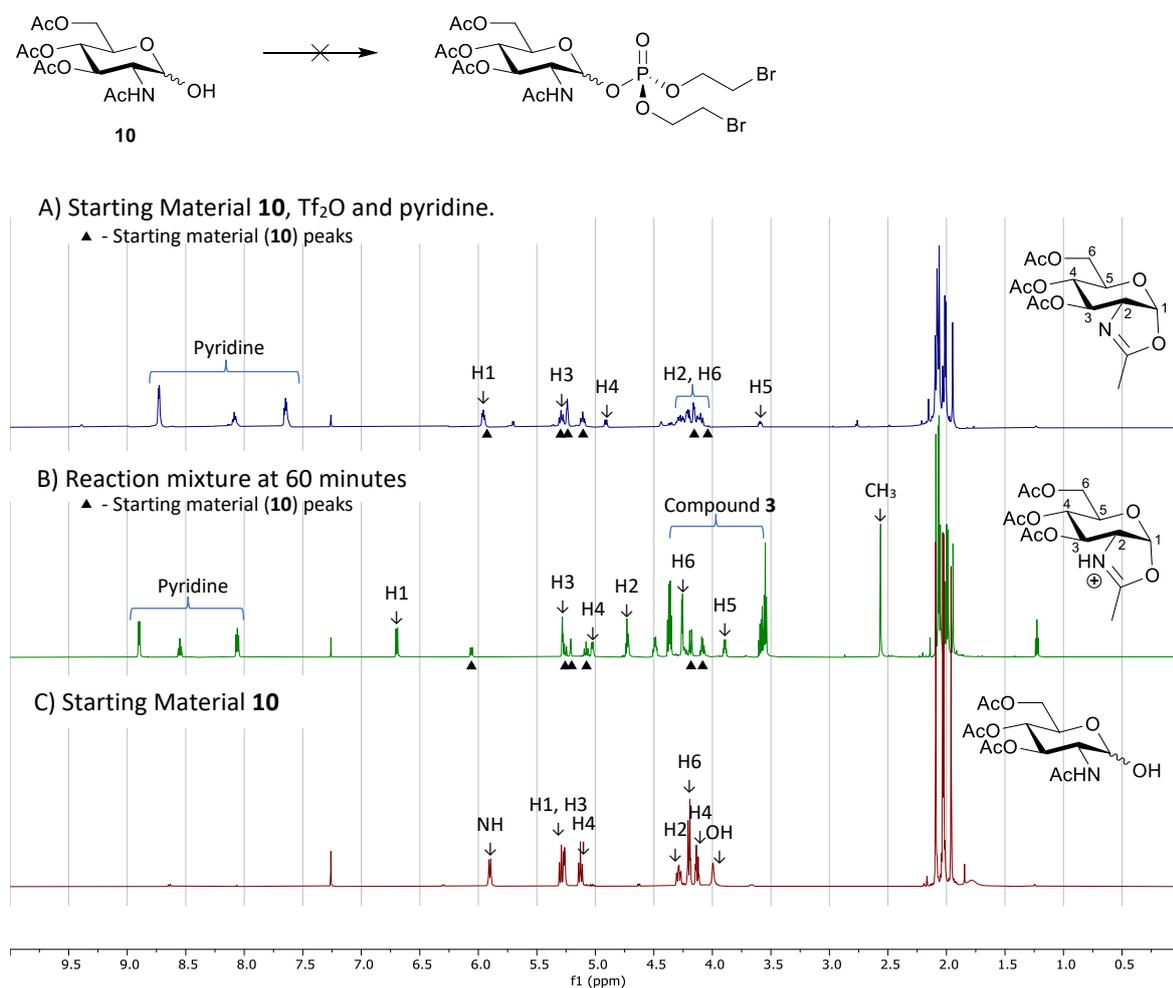


Figure S1. ¹H NMR studies on reaction progress with substrate **10**. All reactions were performed in CDCl₃ at RT. A) **10** was reacted with Tf₂O (1.5 equiv.) and pyridine (2 equiv.) in the absence of phosphotriester. Oxazoline peaks are labelled. B) **3** and **10** were reacted under the optimised reaction conditions (as in Table S2, entry 3). Oxazolinium ion peaks are labelled, showing characteristic downfield shifts in the H1, H2 and CH₃ peaks compared to those in (A) due to the deshielding effect of the positive charge. Note that this spectrum was taken at 60 minutes, however the same results were obtained after 5 minutes of reaction time. C) ¹H NMR spectrum of starting material **10** for reference.

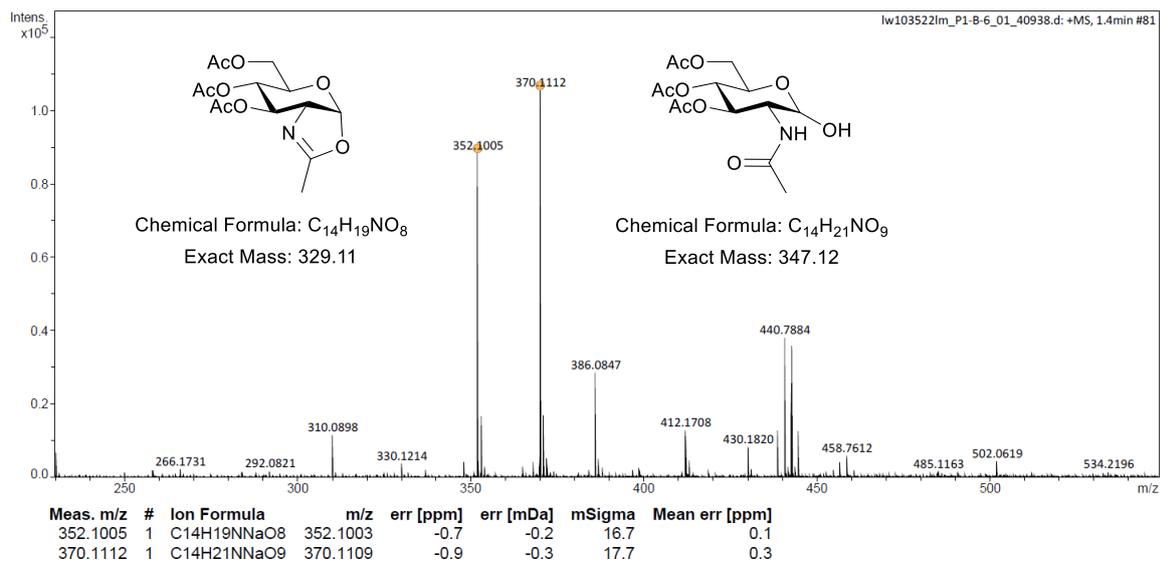


Figure S2. High resolution mass spectrometry data of the crude reaction mixture between **3** and **10** under the optimised reaction conditions, identifying the formation of the oxazoline (m/z 352.1 $[M+Na]^+$) along with unreacted **10** (m/z 370.1 $[M+Na]^+$).

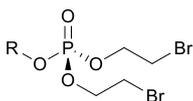
Experimental procedures

General

All reactions were conducted in oven-dried glassware under nitrogen atmosphere. Dry solvents were either freshly distilled (CH₂Cl₂, DMF, toluene, THF) or used directly from a SureSeal bottle (DCE, pyridine). Triflic anhydride was distilled over P₂O₅ prior to use and pyridine was used from a SureSeal bottle stored over molecular sieves. Flash column chromatography was run either manually with high purity 220-400 μm particle size silica (Sigma) or on an automated system (Teledyne, CombiFlash NextGen 300+) with 20 to 40 μm particle size silica (RediSep Rf Gold Normal-Phase Silica columns) as specified. Reactions and column fractions were monitored by TLC and visualised by UV and staining. For sugars, the staining consisted of charring with 10% H₂SO₄ in MeOH; for phosphate reactions a KMnO₄ stain was used; and for azido compounds the procedure involved initial reaction with 10% PPh₃ in CH₂Cl₂, followed by staining with ninhydrin. IR spectra were obtained by thin film ATR on a Perkin Elmer Spectrum 2 and [α]_D measurements were obtained on a Bellingham Stanley ADP400 polarimeter in the given solvent at specified concentration where C = 1 equals 10 mg/mL. ¹H and ¹³C NMR spectra were obtained either on a JEOL ECS400A spectrometer (400 and 100 MHz respectively) or a Bruker AVIIIHD600 spectrometer (600 and 150 MHz respectively). Structural assignments were corroborated by homo- and heteronuclear 2D NMR methods (COSY, HMQC and DEPT) where necessary. Chemical shifts are reported in parts per million (ppm, δ) relative to the solvent (CDCl₃, δ 7.26; CD₃OD, δ 3.31; D₂O, δ 4.79). ¹H NMR splitting patterns are designated as singlet (s), doublet (d), triplet (t), quartet (q), doublet of doublets (dd), doublet of doublets of doublets (ddd), doublet of triplets (dt), apparent triplet (ap. t), or multiplet (m). Coupling constants (*J*) are reported in Hertz (Hz). The integrals reported in the ¹H NMR peak list for mixtures of anomers were normalised so that the numbers of protons for each anomer are reported in whole integers. The actual anomeric ratios are also given and were determined from the relative integration of the respective anomeric proton peaks. Where indicated, yields of product within impure mixtures were calculated from the isolated mass based on the relatively peak ratios on ¹H NMR. Where one anomer is in a large excess, ¹³C NMR peaks may not be visible for the minor anomer and data are reported for the major anomer only.

Synthesis of phosphotriesters

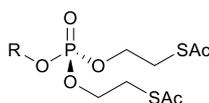
General procedure 1 – incorporation of the bis(2-bromoethyl) phosphate (step 1)



All starting materials were dried prior to use by co-evaporation with toluene (3x) and drying on a high vacuum manifold overnight.

To a stirring solution of tri-2-bromoethyl-phosphate **3** (1.0 equiv) in anhydrous CH₂Cl₂ (0.2 M) under N₂ was added freshly distilled Tf₂O (1.5 equiv). After stirring at RT for 10 minutes anhydrous pyridine (2.0 equiv) was added, and the mixture was stirred for 10 minutes. Then a solution of the starting alcohol (2.0 equiv) in CH₂Cl₂ (1.6 M, with Et₃N (2.0 equiv) where stated) was added. The reaction was stirred at RT for a further 1.5 hrs before the solvents were removed *in vacuo* and the residue dried onto silica. The crude product was purified by column chromatography with an appropriate solvent.

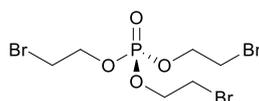
General procedure 2 – thioacetate substitution (step 2)



To a stirring solution of the appropriate bis(2-bromoethyl)-phosphate intermediate (1.0 equiv) in dry pyridine (0.1 M) was added KSAc (5.0 equiv). The resultant solution was left stirring for 18 hrs at RT before the precipitated KBr salt was removed through filtration. The resulting crude solution was dried onto silica, and the crude product was purified by column chromatography with an appropriate solvent.

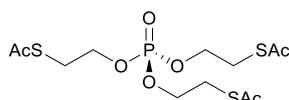
Note: it is possible to successfully complete steps 1 and 2 in one pot without purification of the bis-(2-bromoethyl)phosphate intermediate; in this case, the crude mixture obtained after step 1 is evaporated *in vacuo* and then directly dissolved in dry pyridine for step 2. This approach has proven helpful in cases where co-elution of products with unreacted phosphotriester **3** or by-product **4** is causing difficulties with purification, but it can lead to a slight drop in yield (e.g., from 61% to 53% for the reaction on **5**). It is also worth noting that unreacted substrate can usually be recovered, limiting the loss of valuable materials.

tris(2-bromoethyl)phosphate (**3**)



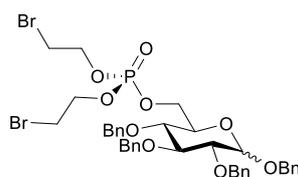
Under a N₂ atmosphere, POCl₃ (0.50 mL, 5.3 mmol, 1.0 equiv) was dissolved in dry CH₂Cl₂ (30 mL) at 0 °C. 2-Bromoethanol (1.9 mL, 27 mmol, 5.0 equiv) and triethylamine (5.2 mL, 37 mmol, 7.0 equiv) were added to the reaction mixture. The reaction was allowed to reach RT and stirred overnight. Upon completion, the triethylamine hydrochloride was precipitated out of the mixture by the addition of THF (40 mL). The salts were removed by filtration and the filtrate concentrated under vacuum. The crude mixture was purified by column chromatography (0-100% EtOAc/hexane) to yield the product tris(2-bromoethyl)-phosphate (**3**) as a clear oil (1.6 g, 3.8 mmol, 71%). **R_f** 0.58 (4:1 EtOAc/hexane) **HRMS (ESI)**: calculated for C₆H₁₂Br₃NaO₄P [M+Na]⁺ 438.7921, found 438.7916. **¹H NMR** (400 MHz, CDCl₃) δ_H 4.38 (dt, *J* = 8.2, 6.1 Hz, 6H, H₂COP), 3.57 (t, *J* = 6.1 Hz, 6H, H₂CBr). **¹³C NMR** (101 MHz, CDCl₃) δ_C 67.3 (d, COP), 29.5 (d, CBr). **³¹P NMR** (162 MHz, CDCl₃) δ_P -1.94. **IR** (V_{max}, film) 2967, 2885, 1455, 1422, 1270, 1235, 1064, 1004, 960, 944, 781, 572 cm⁻¹

tris(S-acyl-2-thioethyl)phosphate (**4**)



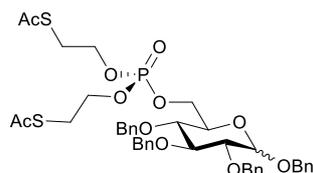
To a stirring solution of tris(2-bromoethyl)phosphate (**3**) (400 mg, 0.959 mmol, 1.00 equiv) in acetone (10 mL) was added KSAc (450 mg, 3.95 mmol, 4.12 equiv) and the resulting solution was allowed to stir for 24 hours at RT. The solvent was removed *in vacuo*, and the resulting residue was dissolved in CH₂Cl₂ (25 mL) and washed with H₂O (20 mL). The aqueous layer was extracted with CH₂Cl₂ (2 × 25 mL), and the organic layers were combined, dried over MgSO₄, filtered, and concentrated *in vacuo* to afford the crude product. The crude product was purified by automated flash column chromatography (0-100% EtOAc/hexane) to afford the title compound **4** as a pink oil (234 mg, 0.579 mmol, 60%). **HRMS (ESI)** Calculated for C₁₂H₂₁NaO₇PS₃ [M+Na]⁺ 427.0079, found 427.0088 **¹H NMR** (400 MHz, CDCl₃) δ_H 4.09 (dt, *J* = 7.4, 6.5 Hz, 6H, CH₂OP), 3.14 (t, 6H, CH₂SAc), 2.32 (s, 9H, CH₃). **¹³C NMR** (101 MHz, CDCl₃) δ_C 194.76 (C=O), 66.14 (d, *J* = 5.8 Hz, CH₂OP), 30.60 (CH₃), 29.21 (d, *J* = 7.2 Hz, CH₂SAc). **³¹P NMR** (162 MHz, CDCl₃) δ_P -1.59. **IR** (V_{max}, film) 2919, 2850, 1734, 1695, 1460, 1376, 1264, 1133, 1062, 1015, 956, 623 cm⁻¹

1,2,3,4-tetra-*O*-benzyl-6-bis(2-bromoethyl)phosphor- α,β -D-glucopyranoside (**7**) (optimised procedure)



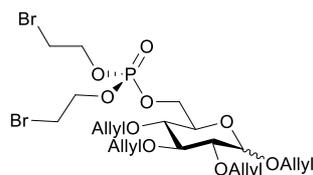
Following general procedure 1, the reaction was run with **3** on a 30 mg (72 μ mol) scale on 1,2,3,4-tetra-*O*-benzyl- α,β -D-glucopyranoside (**5**). The crude product was purified by automated flash column chromatography (0-60% EtOAc/hexane) to afford the title compound in a mixture of anomers (2:3 α : β) as a white solid (45 mg, 54 μ mol, 62%). **HRMS (ESI)** Calculated for $C_{38}H_{43}Br_2NaO_9P$ $[M+Na]^+$: 855.0904, found: 855.0945. **1H NMR** (400 MHz, $CDCl_3$) δ_H 7.51 – 7.27 (m, 40H, Aromatic H), 5.08 – 4.53 (m, 16H, CHPh), 4.81 (d, J = 3.8 Hz, 1H, α H1), 4.55 (d, J = 7.8 Hz, 1H, β H1), 4.48 – 4.19 (m, 8H, OCH_2CH_2Br , α/β H6, H6'), 4.08 (t, J = 9.2 Hz, 1H, α H3), 3.84 (ddt, J = 10.0, 4.0, 2.4 Hz, 1H, α H5), 3.68 (t, J = 8.9 Hz, 1H, β H3), 3.63 – 3.42 (m, 9H, CH_2Br , α H2, H4, β H2, H4, H5). **^{13}C NMR** (101 MHz, $CDCl_3$) δ_C 138.48, 138.34, 138.14, 138.07, 137.92, 137.28, 128.66, 128.62, 128.57, 128.52, 128.29, 128.09, 128.06, 128.00, 127.88, 127.85, 127.81, 102.55 (β C1), 95.67 (α C1), 84.56 (β C3), 82.29 (β C2), 81.97 (α C3), 79.98 (α C2), 77.46 (β C4), 77.24 (α C4), 75.86 (CH_2Ph), 75.23 (d, J = 7.8 Hz, β C5), 75.23 (CH_2Ph), 75.08, 73.60 (d, J = 7.8 Hz, α C5), 73.53, 73.21, 71.36, 69.50 (α C5), 67.08 (d, J = 6.0 Hz, CH_2CH_2Br), 67.03 (d, J = 5.9 Hz, CH_2CH_2Br), 67.03 (d, J = 5.9 Hz, β C6), 66.93 (d, J = 5.9 Hz, α C6), 29.67 (CH_2Br), 29.58, 29.48, 29.38. **^{31}P NMR** (162 MHz, $CDCl_3$) δ_P -1.31, -1.19. **IR** (V_{max} , film) 3031, 2885, 1421, 1453, 1360, 1273, 1012, 1067, 736, 698 cm^{-1}

1,2,3,4-tetra-*O*-benzyl-6-bis(SATE)phosphor- α,β -D-glucopyranoside (**6**)



Following general procedure 2, the reaction was run with **7** on a 30 mg (40 μ mol) scale. The crude product was purified by automated flash column chromatography (0-70% EtOAc/hexane) to afford the title compound **6** in a mixture of anomers (3:2 α : β) as a yellow oil (30 mg, 40 μ mol, quantitative). **HRMS (ESI)** Calculated for $C_{42}H_{49}NaO_{11}PS_2$ $[M+Na]^+$: 847.2346, found: 847.2380. **1H NMR** (400 MHz, $CDCl_3$) δ_H 7.44 – 7.27 (m, 40H, Aromatic H), 4.81 (d, J = 3.6 Hz, 1H, α H1), 5.05 – 4.515 (m, 16H, CHPh), 4.54 (d, J = 5.5 Hz, 1H, β H1), 4.38 (ddd, J = 11.1, 6.3, 1.8 Hz, 2H, α/β H6'), 4.24 (tdd, J = 11.1, 7.9, 3.3 Hz, 2H, α/β H6), 4.20 – 4.09 (m, 8H, OCH_2CH_2SAC), 4.06 (d, J = 9.4 Hz, 1H, α H3), 3.88 – 3.78 (m, 1H, α H5), 3.67 (t, J = 8.9 Hz, 1H, β H3), 3.63 – 3.45 (m, 5H, α H2, H4, β H2, H4, H5), 3.15 (qd, J = 6.6, 3.3 Hz, 8H, CH_2SAC), 2.31 (s, 2H, CH_3), 2.31 (s, 5H, CH_3), 2.30 (s, 5H, CH_3). **^{13}C NMR** (101 MHz, $CDCl_3$) δ_C 194.82, 138.51, 138.37, 138.17, 137.93, 137.32, 128.65, 128.59, 128.54, 128.50, 128.29, 128.12, 128.08, 128.05, 127.99, 127.95, 127.85, 127.82, 127.70, 102.50 (β C1), 95.57 (α C1), 84.58 (β C3), 82.30 (β C2), 81.97 (α C3), 80.04 (α C2), 77.37 (β C4), 77.26 (α C4), 75.85 (CH_2Ph), 75.31, 75.22, 75.06, 73.66 (β C5), 73.59 (CH_2Ph), 73.15, 66.25 (d, J = 6.0 Hz, α C6), 71.29, 66.66 (d, J = 4.4 Hz, β C6), 69.73 (α C5), 69.41 (CH_2Ph), 66.14 (d, J = 1.9 Hz), 66.18 (d, J = 1.3 Hz), 30.64, 29.33, 29.26. **^{31}P NMR** (162 MHz, $CDCl_3$) δ_P -0.94, -1.08.

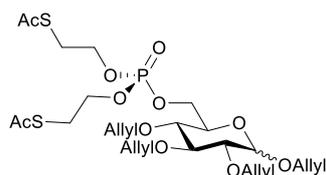
1,2,3,4-tetra-*O*-allyl-6-bis(2-bromoethyl)phosphor- α,β -D-glucopyranoside



Following general procedure 1, the reaction was run with **3** on a 30 mg (72 μ mol) scale on 1,2,3,4-tetra-*O*-acetyl- α,β -D-glucopyranoside (**8a**). The crude product was purified by automated flash column chromatography (0-60% EtOAc/hexane) to afford the title compound in a mixture of anomers (1:6 α : β) as a white solid (14 mg, 22 μ mol,

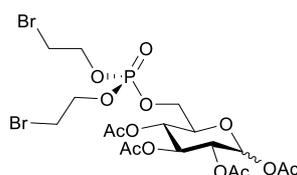
31%). **HRMS (ESI)** Calculated for $C_{22}H_{35}Br_2NaO_9P$ $[M+Na]^+$: 655.0278, found: 655.0301. **1H NMR** (400 MHz, $CDCl_3$) δ_H 6.03 – 5.78 (m, 8H, $CH=CH_2$), 5.36 – 5.22 (m, 4H, $CH=CH_2$), 5.22 – 5.13 (m, 4H, $CH=CH_2$), 4.44 – 4.28 (m, 22H, α H6, β H1, H5, H6', $OCH_2CH=CH$, CH_2CH_2Br), 4.28 – 4.04 (m, 8H, $OCH_2CH=CH_2$, α H6, β H6), 3.78 – 3.70 (m, 2H, α H3, H5), 3.60 – 3.46 (m, 8H, CH_2Br), 3.45 – 3.27 (m, 4H, α H2, H4, β H3, H4), 3.21 (dd, $J = 9.1, 7.8$ Hz, 1H, β H2). **^{13}C NMR** (101 MHz, $CDCl_3$) δ_C 135.12 ($CH=CH_2$), 135.04, 134.56, 133.90, 117.53 ($CH=CH_2$), 117.25, 117.12, 116.97, 102.47 (C1), 84.03 (C3), 81.57 (C2), 76.69 (C4), 74.56 (OCH_2CHCH_2), 73.94, 73.79, 73.47, 70.33 (C5), 67.12 (d, $J = 5.9$ Hz C6), 67.03 (d, $J = 5.9$ Hz, CH_2CH_2Br) 66.97 (d, $J = 5.9$ Hz, CH_2CH_2Br), 29.51 (CH_2Br), 29.43. **^{31}P NMR** (162 MHz, $CDCl_3$) δ_P -2.47. **IR** (V_{max} , film) 3088, 2894, 1736, 1647, 1456, 1426, 1348, 1270, 1067, 1009, 942 cm^{-1}

1,2,3,4-tetra-O-allyl-6-bis(SATE)phosphor- α,β -D-glucopyranoside



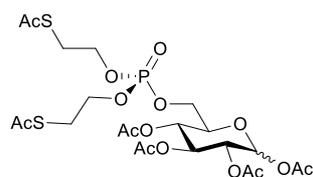
Following general procedure 2, the reaction was run with 1,2,3,4-tetra-O-allyl-6-bis(2-bromoethyl)-phosphor- α,β -D-glucopyranoside on an 8.0 mg (16 μ mol) scale. The crude product was purified by automated flash column chromatography (0-70% EtOAc/hexane) to afford the title compound in a mixture of anomers (3:7 $\alpha:\beta$) as a yellow oil (8.0 mg, 16 μ mol, quantitative) **HRMS (ESI)** Calculated for $C_{26}H_{41}NaO_{11}PS_2$ $[M+Na]^+$: 647.1726, found: 647.1720 **1H NMR** (400 MHz, $CDCl_3$) δ_H 6.00 – 5.83 (m, 4H, $CH=CH_2$), 5.33 – 5.23 (m, 4H, $CH=CH_2$), 5.23 – 5.11 (m, 4H, $CH=CH_2$), 4.90 (d, $J = 3.6$ Hz, 1H, α H1), 4.41 – 4.29 (m, 7H, α H6', β H1, β H6', $OCH_2CH=CH$), 4.24 (dddd, $J = 10.8, 8.5, 7.1, 5.4$ Hz, 4H, $OCH_2CH=CH$), 4.21 – 4.01 (m, 18H, $OCH_2CH=CH$, OCH_2CH_2SAc , α H6, β H6), 3.80 – 3.70 (m, 2H, α H3, α H5), 3.44 – 3.33 (m, 3H, α H4, β H3, β H5), 3.33 – 3.24 (m, 2H, α H2, β H4), 3.23 – 3.12 (m, 9H, CH_2SAc , β H2), 2.35 (t, $J = 1.3$ Hz, 12H, SAc). **^{13}C NMR** (101 MHz, $CDCl_3$) δ_C 194.84 (C=O SAc), 194.80 (C=O SAc), 135.36 ($OCH_2CH=CH_2$), 135.23, 135.15, 134.95, 134.81, 134.68, 134.03, 133.79, 118.32 ($OCH_2CH=CH_2$), 117.62, 117.50, 117.35, 117.26, 117.08, 116.93, 116.68, 102.50 (β C1), 95.81 (α C1), 84.15 (β C3), 81.67 (β C2), 81.50 (α C3), 79.52 (α C2), 76.88 (β C4), 74.58 ($OCH_2CH=CH_2$), 74.44, 74.06, 73.97, 73.81, 73.61, 73.57 (α C4), 72.46 ($OCH_2CH=CH_2$), 70.31 (β C5), 69.63 (d, $J = 8.3$ Hz, α C5), 68.35 ($OCH_2CH=CH_2$), 66.84 – 66.68 (m, α C6, β C6), 66.27 (d, $J = 5.8$ Hz, OCH_2CH_2SAc), 66.17 (d, $J = 6.8$ Hz, OCH_2CH_2SAc), 29.37 (CH_3), 29.32 (CH_3). **^{31}P NMR** (162 MHz, $CDCl_3$) δ_P -0.98, -1.17. **IR** (V_{max} , film) 2922, 2868, 1693, 1459, 1422, 1394, 1270, 1129, 1065, 1006, 957, 923, 776, 684, 622, 490 cm^{-1}

1,2,3,4-tetra-O-acetyl-6-bis-(2-bromoethyl)phosphor- α,β -D-glucopyranoside



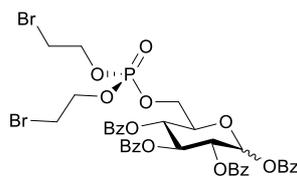
Following general procedure 1, the reaction was run with **3** on a 30 mg (72 μ mol) scale on 1,2,3,4-tetra-O-acetyl- α,β -D-glucopyranoside (**8b**) (3 equiv). The crude product was purified by automated flash column chromatography (0-60% EtOAc/hexane) to afford the title compound in a mixture of anomers (2:3 $\alpha:\beta$) as a clear oil (25 mg, 35 μ mol, 55%). **HRMS (ESI)** Calculated for $C_{18}H_{27}Br_2NaO_{13}P$ $[M+Na]^+$: 662.9448, found: 662.9445. **1H NMR** (400 MHz, $CDCl_3$) δ_H 6.33 (d, $J = 3.7$ Hz, 1H, α H1), 5.72 (d, $J = 8.3$ Hz, 1H, β H1), 5.48 (t, $J = 9.9$ Hz, 1H, α H3), 5.27 (t, $J = 10.6$ Hz, 1H, β H3), 5.18 – 5.05 (m, 3H, α H2, β α H2, H4), 4.56 – 4.47 (m, 1H, α H4), 4.41 – 4.27 (m, 8H, CHPh), 4.22 (ddd, $J = 11.5, 5.4, 2.3$ Hz, 1H, α H6'), 4.20 – 4.10 (m, 3H, α H6, β H6, H6'), 3.87 (ddd, $J = 8.0, 4.6, 2.0$ Hz, 1H, β CH-5), 3.73 (dt, $J = 11.5, 5.8$ Hz, 1H, α H5), 3.56 (dt, $J = 10.9, 6.8$ Hz, 8H, CH_2Br), 2.22 – 1.99 (m, 24H, CH_3). **^{13}C NMR** (101 MHz, $CDCl_3$) δ_C 169.61, 169.56, 169.54, 169.52, 91.61 (β C1), 88.90 (α C1), 72.95 (d, $J = 7.67$, β C5), 72.69 (β C3), 70.24 (α C5), 70.10 (β C2), 69.72 (α C3), 69.09 (α C2), 67.70 (β C4), 67.59 (α C4), 67.18 (d, $J = 5.75$, CH_2CH_2Br), 65.47 (d, $J = 5.75$, β C6), 65.34 (d, $J = 5.05$, α C6), 29.68, 29.59, 29.52, 29.47, 29.39, 29.34, 29.24, 20.88, 20.64, 20.55, 20.53, 20.43. **^{31}P NMR** (162 MHz, $CDCl_3$) δ_P -1.64, -1.75. **IR** (V_{max} , film) 2944, 2852, 1754, 1428, 1369, 1216, 1069, 1038, 1015, 942 cm^{-1}

1,2,3,4-tetra-*O*-acetyl-6-bis(SATE)phosphor- α,β -D-glucopyranoside



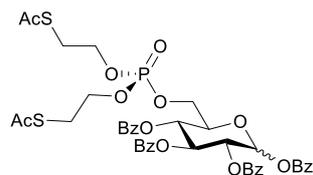
Following general procedure 2, the reaction was run with 1,2,3,4-tetra-*O*-acetyl-6-bis(2-bromoethyl)-phosphor- α,β -D-glucopyranoside on a 9.6 mg (15 μ mol) scale. The crude product was purified by automated flash column chromatography (0-70% EtOAc/hexane) to afford the title compound in a mixture of anomers (1:1 $\alpha:\beta$) as a yellow oil (5.1 mg, 8.1 μ mol, 54%). **HRMS (ESI)** Calculated for $C_{22}H_{33}NaO_{15}PS_2$ $[M+Na]^+$: 655.0891, found: 655.0900. **1H NMR** (400 MHz, $CDCl_3$) δ_H 6.33 (d, J = 3.8 Hz, 1H, α H1), 5.72 (d, J = 8.4 Hz, 1H, β H1), 5.47 (t, J = 9.9 Hz, 1H, α H3), 5.26 (t, J = 9.5 Hz, 1H, β H3), 5.19 – 5.05 (m, 3H, α H2, β H2, H4), 4.32 – 4.23 (m, 1H, α H6'), 4.22 – 4.06 (m, 11H, CH_2CH_2SAC , α H6, β H6), 3.91 – 3.81 (m, 1H, β H5), 3.71 (q, J = 4.9 Hz, 1H, α H5), 3.18 (td, J = 6.5, 3.5 Hz, 8H, CH_2CH_2SAC), 2.36 (s, 12H, SAC), 2.23 – 1.97 (m, 24H, OAc). **^{13}C NMR** (151 MHz, $CDCl_3$) δ_C 170.42, 170.25, 169.52, 169.35, 169.04, 91.78 (β C1), 89.11 (α C1), 73.29 (β C5), 72.92 (β C3), 70.51 (α C5), 70.32 (β C2), 70.00 (α C3), 69.28 (α C2), 67.93 (β C4), 67.86 (α C4), 66.46 – 66.35 (m, CH_2O), 65.37 – 65.46 (m, C6), 30.69, 29.85, 29.26, 21.02, 20.92, 20.76, 20.72, 20.70, 20.59. **^{31}P NMR** (162 MHz, $CDCl_3$) δ_P –1.35, –1.42. **IR** (V_{max} , film) 2964, 2923, 2848, 1754, 1693, 1429, 1368, 1247, 1213, 1016, 1133, 1017, 735, 713, 623, 546, 481 cm^{-1}

1,2,3,4-tetra-*O*-benzoyl-6-bis(2-bromoethyl)phosphore- α,β -D-glucopyranoside



Following general procedure 1, the reaction was run with **3** on a 15 mg (36 μ mol) scale on 1,2,3,4-tetra-*O*-benzoyl- α,β -D-glucopyranoside (**8c**). The crude product was purified by automated flash column chromatography (0-60% EtOAc/hexane) to afford the title compound in a mixture of anomers (1:1 $\alpha:\beta$) as a clear oil (6.1 mg, 14 μ mol, 39%). **HRMS (ESI)** Calculated for $C_{38}H_{35}Br_2NaO_{13}P$ $[M+Na]^+$: 911.0074, found: 911.0111 **1H NMR** (400 MHz, $CDCl_3$) δ_H 8.20 – 8.13 (m, 2H, Aromatic H), 8.08 – 8.01 (m, 2H, Aromatic H), 8.01 – 7.81 (m, 12H, Aromatic H), 7.62 – 7.33 (m, 16H, Aromatic H), 7.37 – 7.26 (m, 8H, Aromatic H), 6.83 (d, J = 3.7 Hz, 1H, α H1), 6.28 (d, J = 10.0 Hz, 1H, α H2), 6.25 (d, J = 8.2 Hz, 1H, β H1), 6.01 (t, J = 9.6 Hz, 1H, β H3), 5.83 (dd, J = 9.7, 8.0 Hz, 1H, β H2), 5.72 (t, J = 10.2 Hz, 1H, α H4), 5.68 – 5.60 (m, 2H, α H2 β H4), 4.55 – 4.46 (m, 1H, α H5), 4.43 – 4.22 (m, 12H, CH_2CH_2Br , α H6, β H5, H6), 3.54 – 3.41 (m, 8H, CH_2Br). **^{13}C NMR** (101 MHz, $CDCl_3$) δ_C 166.00, 165.76, 165.45, 165.27, 164.72, 134.15, 133.88, 133.68, 133.55, 130.34, 130.20, 130.06, 129.97, 129.94, 129.88, 128.99, 128.95, 128.77, 128.71, 128.67, 128.56, 128.52, 128.44, 92.72 (β C1), 89.97 (α C1), 73.84 (d, J = 6.9 Hz, β C5), 72.76 (β C3), 71.07 (d, J = 7.9 Hz, α C5), 70.78 (β C2), 70.45 (α C3), 70.37 (β C4), 68.65 (α C2), 68.42 (α C4), 67.16 – 67.39 (m, OCH_2CH_2Br), 65.97 (d, J = 4.8 Hz, α C6, β C6), 29.62 (CH_2Br), 29.47, 29.39. **^{31}P NMR** (162 MHz, $CDCl_3$) δ_P –1.89, –1.75. **IR** (V_{max} , film) 2961, 1731, 1582, 1452, 1257, 1067, 1012, 962, 709 cm^{-1}

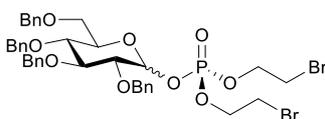
1,2,3,4-tetra-*O*-benzoyl-6-bis(SATE)phosphor- α,β -D-glucopyranoside



Following general procedure 2, the reaction was run with 1,2,3,4-tetra-*O*-benzoyl-6-bis(2-bromoethyl)-phosphor- α,β -D-glucopyranoside on a 12 mg (13 μ mol) scale. The crude product was purified by automated flash column chromatography (0-70% EtOAc/hexane) to afford the title compound in a mixture of anomers (1:1 $\alpha:\beta$)

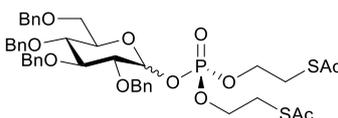
as a yellow oil (12 mg, 13 μmol , quantitative). **HRMS (ESI)** Calculated for $\text{C}_{42}\text{H}_{41}\text{NaO}_{15}\text{PS}_2$ $[\text{M}+\text{Na}]^+$: 903.1517, found: 903.1561. **$^1\text{H NMR}$** (400 MHz, CDCl_3) δ_{H} 8.19 – 7.28 (m, 40H, Aromatic H), 6.83 (d, $J = 3.8$ Hz, 1H, α H1), 6.32 – 6.21 (m, 2H, α H3 β H1), 6.01 (d, $J = 9.7$ Hz, 1H, β H3), 5.86 – 5.79 (m, 1H, β H2), 5.74 (t, $J = 9.9$ Hz, 1H, α H4), 5.70 – 5.61 (m, 2H, α H2 β H4), 4.54 – 4.45 (m, 1H, α H5), 4.37 – 4.20 (m, 5H, α H6, β H5, H6), 4.20 – 4.04 (m, 8H, $\text{OCH}_2\text{CH}_2\text{SAC}$), 3.23 – 3.03 (m, 8H, CH_2SAC), 2.23 – 2.39 (m, 12H, CH_3). **$^{13}\text{C NMR}$** (101 MHz, CDCl_3) δ_{C} 166.12, 166.02, 165.43, 165.23, 164.47, 134.10, 134.06, 133.80, 133.78, 133.63, 133.59, 133.51, 130.36, 130.20, 130.07, 130.06, 129.98, 129.96, 129.94, 129.89, 128.97, 128.74, 128.68, 128.67, 128.56, 128.53, 128.50, 92.74 (β C1), 90.04 (α C1), 73.82 (β C5), 72.87 (β C3), 71.15 (α C5), 70.85 (β C2), 70.49 (α C3, β C4), 68.73 (α C2), 68.44 (α C4), 66.26 (d, $J = 5.53$ Hz), 66.23 (d, $J = 4.42$ Hz), 65.62 (d, $J = 5.53$ Hz, β C6), 65.55 (d, $J = 5.53$ Hz, α C6), 30.65, 30.63, 30.60, 29.32, 29.30, 29.28, 29.25, 29.23. **$^{31}\text{P NMR}$** (162 MHz, CDCl_3) δ_{P} -1.62, -1.50. **IR** (V_{max} , film) 3073, 2964, 2922, 2852, 1731, 1652, 1253, 1066, 1015, 707 cm^{-1}

2,3,4,6-tetra-*O*-benzyl-1-bis(2-bromoethyl)phosphor- α,β -D-glucopyranoside



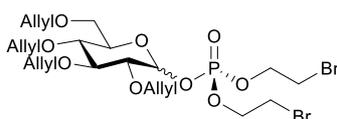
Following general procedure 1, the reaction was run with **3** on a 30 mg (72 μmol) scale on 2,3,4,6-tetra-*O*-benzyl- α,β -D-glucopyranose (**9a**). The crude product was purified by automated flash column chromatography (0-60% EtOAc/hexane) to afford the title product in a mixture of anomers ($\alpha:\beta$ 9:1) as a white solid (14 mg, 18 μmol , 26%). **HRMS (ESI)** Calculated for $\text{C}_{38}\text{H}_{43}\text{Br}_2\text{NaO}_9\text{P}$ $[\text{M}+\text{Na}]^+$: 855.0909, found: 855.0940. **$^1\text{H NMR}$** (400 MHz, CDCl_3) δ_{H} 7.47 – 7.07 (m, 20H, Aromatic H), 5.90 (dd, $J = 6.8, 3.2$ Hz, 1H, α H1), 5.26 – 5.17 (m, 1H, β H1), 5.04 – 4.44 (m, 8H, CHPh), 4.39 – 4.18 (m, 4H, $\text{CH}_2\text{CH}_2\text{Br}$), 4.06 – 3.87 (m, 2H, H3, H4), 3.77 – 3.62 (m, 4H, H2, H5, H6), 3.48 – 3.29 (m, 4H, CH_2Br). **$^{13}\text{C NMR}$** (101 MHz, CDCl_3) δ_{C} 138.49, 138.02, 137.82, 137.53, 128.64, 128.57, 128.52, 128.33, 128.19, 128.12, 128.10, 128.01, 127.97, 127.89, 96.22 (d, $J = 6.3$ Hz, C1), 81.15 (C3), 79.21 (d, $J = 8.1$ Hz, C2), 77.01 (C4), 75.83, 75.35, 73.66, 73.44, 72.85 (C5), 68.31 (C6), 67.11 (d, $J = 5.6$ Hz, $\text{OCH}_2\text{CH}_2\text{Br}$), 66.95 (d, $J = 4.8$ Hz, $\text{OCH}_2\text{CH}_2\text{Br}$), 29.39, 29.32. **IR** (V_{max} , film) 3363, 3030, 2880, 2916, 1735, 1496, 1452, 1416, 1212, 1071, 1017, 741, 695 cm^{-1} . $[\alpha]_{\text{D}}^{20} = +32.41$ (c=0.2, CH_2Cl_2)

2,3,4,6-tetra-*O*-benzyl-1-bis(SATE)phosphor- α,β -D-glucopyranoside



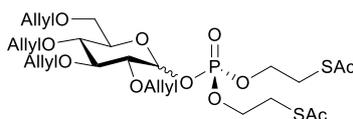
Following general procedure 2, the reaction was run with 2,3,4,6-tetra-*O*-benzyl-1-bis(2-bromoethyl)phosphor- α,β -D-glucopyranoside on a 7.0 mg (8.4 μmol) scale. The crude product was purified by manual flash column chromatography (20-50% EtOAc/hexane) to afford the title compound as the α -anomer as a yellow oil (5.4 mg, 6.5 μmol , 78%). **HRMS (ESI)** Calculated for $\text{C}_{42}\text{H}_{49}\text{NaO}_{11}\text{PS}_2$ $[\text{M}+\text{Na}]^+$: 847.2346, found: 847.2338. **$^1\text{H NMR}$** (400 MHz, CDCl_3) δ_{H} 7.41 – 7.27 (m, 18H, Aromatic H), 7.15 (dd, $J = 7.0, 2.5$ Hz, 2H, Aromatic H), 5.87 (dd, $J = 6.8, 3.2$ Hz, 1H, H1), 4.95 (d, $J = 10.8$ Hz, 1H, CHPh), 4.83 (dd, $J = 10.8, 6.8$ Hz, 2H, CHPh), 4.76 (d, $J = 11.3$ Hz, 1H, CHPh), 4.68 (d, $J = 11.3$ Hz, 1H, CHPh), 4.59 (d, $J = 11.9$ Hz, 1H, CHPh), 4.48 (t, $J = 11.9$ Hz, 2H, CHPh), 4.11 (dddd, $J = 12.8, 10.9, 7.6, 5.0$ Hz, 4H, $\text{OCH}_2\text{CH}_2\text{SAC}$), 4.03 – 3.86 (m, 2H, H3, H4), 3.79 – 3.50 (m, 4H, H2, H5, H6), 3.15 – 2.98 (m, 4H, CH_2SAC), 2.30 (d, $J = 4.0$ Hz, 6H, CH_3). **$^{13}\text{C NMR}$** (151 MHz, CDCl_3) δ_{C} 194.85, 138.65, 138.20, 137.94, 137.67, 128.62, 128.55, 128.30, 128.10 (d, $J = 2.8$ Hz), 128.07, 128.00, 127.92, 127.84, 95.97 (d, $J = 5.8$ Hz, C1), 81.25 (C3), 79.27 (d, $J = 7.4$ Hz, C2) 75.82 (CH_2Ph), 75.33, 73.66, 73.27, 72.78 (C5), 68.23 (C6), 66.30 (d, $J = 6.1$ Hz, $\text{CH}_2\text{CH}_2\text{SAC}$), 66.10 (d, $J = 6.1$ Hz, $\text{CH}_2\text{CH}_2\text{SAC}$), 30.65, 29.28 (d, $J = 7.5$ Hz), 29.25 (d, $J = 7.5$ Hz). **$^{31}\text{P NMR}$** (162 MHz, CDCl_3) δ_{P} -2.35. **IR** (V_{max} , film) 3031, 2923, 2852, 1743, 1693, 1497, 1454, 1268, 1068, 1015, 993, 737, 698, 623, 530 cm^{-1} . $[\alpha]_{\text{D}}^{20} = +9.89$ (c=0.46, CH_2Cl_2).

2,3,4,6-tetra-O-allyl-1-bis(2-bromoethyl)phosphor- α,β -D-glucopyranoside



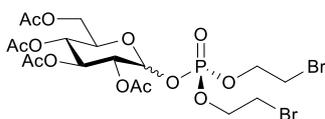
Following general procedure 1, the reaction was run with **3** on a 60 mg, (0.14 mmol) scale on 2,3,4,6-tetra-O-allyl- α,β -D-glucopyranose (**9b**). The crude product was purified by automated flash column chromatography (0-60% EtOAc/hexane) to afford the α -anomer of the title compound as a clear oil (18 mg, 28 μ mol, 20%). Note that this reaction did on separate occasions lead to $\alpha:\beta$ mixtures with the α -anomer in excess. **HRMS (ESI)** Calculated for $C_{22}H_{35}Br_2NaO_9P$ $[M+Na]^+$: 655.0278, found: 655.0291. **1H NMR** (400 MHz, $CDCl_3$) δ_H 6.01 – 5.85 (m, 4H, $CH=CH_2$), 5.81 (dd, $J = 6.8, 3.3$ Hz, 1H, H1), 5.36 – 5.23 (m, 4H, $CH=CH_2$), 5.23 – 5.11 (m, 4H, $CH=CH_2$), 4.42 – 4.30 (m, 5H, $OCH_2CH=CH_2$, OCH_2CH_2Br), 4.30 – 4.23 (m, 1H, $OCH_2CH=CH_2$), 4.23 – 4.18 (m, 1H, OCH_2CHCH_2), 4.18 – 4.09 (m, 2H, $OCH_2CH=CH_2$), 4.05 (ddt, $J = 12.8, 5.7, 1.4$ Hz, 1H, $OCH_2CH=CH_2$), 3.96 – 4.02 (m, 1H, OCH_2CHCH_2), 3.88 (dt, $J = 9.9, 3.0$ Hz, 1H, H5), 3.67 (t, $J = 9.7$ Hz, 1H, H3), 3.65 (d, $J = 3.0$ Hz, 2H, H6), 3.54 (dt, $J = 15.8, 6.4$ Hz, 4H, OCH_2CH_2Br), 3.47 (ap. t, $J = 9.9$ Hz, 1H, H4), 3.43 (dt, $J = 9.7, 3.2$ Hz, 1H, H2). **^{13}C NMR** (151 MHz, $CDCl_3$) δ_C : 135.29 ($OCH_2CH=CH_2$), 134.82, 134.52, 134.45, 117.98 ($OCH_2CH=CH_2$), 117.65, 117.17, 116.93, 96.51 (d, $J = 6.3$ Hz, C1), 80.64 (C3), 78.87 (d, $J = 7.3$ Hz, C2), 76.63 (C4), 74.48 ($OCH_2CH=CH_2$), 74.13, 72.82 (C5), 72.63 ($OCH_2CH=CH_2$), 72.51, 68.31 (C6), 67.05 (d, $J = 5.5$ Hz, OCH_2CH_2Br), 66.91 (d, $J = 4.8$ Hz, OCH_2CH_2Br), 29.37 (OCH_2CH_2Br), 29.32, 29.28, 29.23. **^{31}P NMR** (162 MHz, $CDCl_3$) δ_P –6.58. **IR** (V_{max} , film) 2920, 2853, 1737, 1538, 1455, 1376, 1260, 1096, 1820, 800 cm^{-1} . $[\alpha]_D^{20} = +6.32$ ($c=0.2$, CH_2Cl_2).

2,3,4,6-tetra-O-allyl-1-bis(SAc)phosphor- α,β -D-glucopyranoside



Following general procedure 2, the reaction was run with 2,3,4,6-tetra-O-benzoyl-1-bis(2-bromoethyl)-phosphor- α,β -D-glucopyranoside on a 1.8 mg (2.8 μ mol) scale. The crude product was purified by manual flash column chromatography (20-50% EtOAc/hexane) to afford the title compound in a mixture of anomers ($\alpha:\beta$ 3:1) as a yellow oil (1.3 mg, 2.0 μ mol, 72%). Note that the starting material for this reaction came from an independent replicate of the reaction described above and was a mixture of both anomers. **HRMS (ESI)** Calculated for $C_{26}H_{41}NaO_{11}PS_2$ $[M+Na]^+$: 647.1720, found: 647.1741. **1H NMR** (400 MHz, $CDCl_3$) δ_H 6.00 – 5.78 (m, 8H, $CH_2CH=CH_2$), 5.76 (dd, $J = 6.9, 3.3$ Hz, 1H, α H1), 5.32 – 5.20 (m, 4H, $CH=CH_2$), 5.18 – 5.12 (m, 8H, $CH=CH_2$), 5.00 (dd, $J = 7.8, 6.9$ Hz, 1H, β H1), 4.38 – 4.20 (m, 4H, $OCH_2CH=CH_2$), 4.20 – 4.06 (m, 12H, $OCH_2CH=CH_2$, CH_2CH_2SAc), 4.06 – 3.92 (m, 4H, $OCH_2CH=CH_2$), 3.83 (ddd, $J = 10.0, 3.4, 2.1$ Hz, 1H, α H5), 3.72 – 3.56 (m, 5H, α/β H6, β H2, H3, H5), 3.47 (dd, $J = 10.0, 9.3$ Hz, 1H, α H3), 3.43 – 3.36 (m, 2H, α H2, H4), 3.26 (t, $J = 7.5$ Hz, 1H, β H4), 3.21 – 3.11 (m, 8H, CH_2CH_2SAc), 2.33 (d, $J = 1.9$ Hz, 12H, CH_3). **^{13}C NMR** (101 MHz, $CDCl_3$) δ_C : 135.32 ($CH=CH_2$), 135.07, 134.87, 134.76, 134.54, 134.49, 117.83 ($CH=CH_2$), 117.57, 117.36, 117.17, 117.06, 116.82, 98.98 (d, $J = 6.7$ Hz, β C1), 96.12 (d, $J = 6.2$ Hz, α C1), 83.90 (β C3), 81.22 (d, $J = 8.5$ Hz, β C2), 80.66 (α C3), 78.81 (d, $J = 7.1$ Hz, α C2), 76.51 (α C4), 75.45 ($CH_2CH=CH_2$), 74.53, 74.44, 74.08, 73.96, 73.83, 72.63, 72.59 (α C5), 72.45, 72.30, 68.42 (β C6), 68.14 (α C6), 66.24 (d, $J = 5.7$ Hz, CH_2CH_2SAc), 66.02 (d, $J = 5.2$ Hz, CH_2CH_2SAc), 30.68 (CH_3), 29.34, 29.31, 29.26, 29.24, 29.20. **^{31}P NMR** (162 MHz, $CDCl_3$) δ_P –2.41. **IR** (V_{max} , film) 3079, 2922, 2867, 1693, 1461, 1421, 1355, 1270, 1065, 1009, 949, 622, 515 cm^{-1} .

2,3,4,6-tetra-O-acetyl-1-bis(2-bromoethyl)phosphor- α,β -D-glucopyranoside

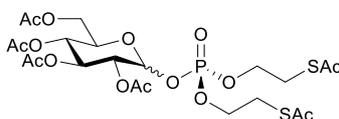


Following general procedure 1, the reaction was run with **3** on a 33 mg (80 μ mol) scale on 2,3,4,6-tetra-O-acetyl- α,β -D-glucopyranose (**9c**). The crude product was purified by automated flash column chromatography (20-90%

EtOAc/hexane) to afford the title compound in a mixture of anomers (α : β 1.2:1) as a white solid (17 mg, 26 μ mol, 33%). **HRMS (ESI)** Calculated for $C_{18}H_{27}Br_2NaO_{13}P$ $[M+Na]^+$: 662.9454, found: 662.9448. **1H NMR** (400 MHz, $CDCl_3$) δ_H 5.89 (dd, $J = 6.5, 3.2$ Hz, 1H, α H1), 5.49 (t, $J = 10.1$ Hz, 1H, α H3), 5.32 (t, $J = 7.5$ Hz, 1H, β H1), 5.25 – 5.08 (m, 4H, α H4, β H2, H3, H4), 5.03 (dt, $J = 10.1, 3.2$ Hz, 1H, H2), 4.44 – 4.29 (m, 8H, OCH_2CH_2Br , α H6, H6), 4.26 – 4.22 (m, 2H, α H6, β H6), 3.84 (dd, $J = 10.8, 2.7$ Hz, 1H, H5), 3.59 – 3.52 (m, 8H, CH_2Br), 2.10 (s, 8H, CH_3), 2.09 (s, 3H, CH_3), 2.04 (s, 6H, CH_3), 2.03 (s, 3H, CH_3), 2.01 (s, 2H, CH_3). **^{13}C NMR** (101 MHz, $CDCl_3$) δ_C 170.46 (C=O), 169.98, 169.35, 169.27, 96.41 (d, $J = 4.8$ Hz, C1), 72.79 (C3), 72.19 (C5), 71.03 (C2), 67.63 (C4), 67.31 (d, $J = 4.79$ Hz, OCH_2CH_2Br), 67.13 (d, $J = 5.8$ Hz, OCH_2CH_2Br), 61.31 (C6), 28.90 (OCH_2CH_2Br), 28.81, 28.70, 28.62, 20.74 (CH_3), 20.65, 20.54. **^{31}P NMR** (162 MHz, $CDCl_3$) δ_P -2.96 (α), -3.51 (β).

Large Scale: Following general procedure 1, the reaction was run with **3** on a 1.0 g (2.4 mmol) scale on 2,3,4,6-*tetra-O*-acetyl- α,β -D-glucopyranose (**9c**). The crude product was purified by automated flash column chromatography (20-90% EtOAc/hexane) to afford the title compound in a mixture of anomers (α : β 1.4:1) as a yellow oil (417 mg, 0.65 mmol, 28%).

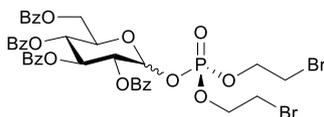
2,3,4,6-*tetra-O*-acetyl-1-*bis*(SATE)phosphor- α,β -D-glucopyranoside



Following general procedure 2, the reaction was run with 2,3,4,6-*tetra-O*-acetyl-1-*bis*(2-bromoethyl)-phosphor- α,β -D-glucopyranoside on a 17 mg (26 μ mol) scale. The crude product was purified by silica plug (80% EtOAc/hexane) to afford the title compound in a mixture of anomers (α : β 1.2:1) as a yellow oil (12 mg, 19 μ mol, 72%). **HRMS (ESI)** Calculated for $C_{22}H_{33}NaO_{15}PS_2$ $[M+Na]^+$: 655.0891, found: 655.0902. **1H NMR** (400 MHz, $CDCl_3$) δ_H 5.85 (dd, $J = 6.7, 3.4$ Hz, 1H, α H1), 5.47 (t, $J = 10.2$ Hz, 1H, α H3), 5.29 (t, $J = 7.5$ Hz, 1H, β H1), 5.21 – 5.17 (m, 1H, β H3), 5.15 – 5.06 (m, 3H, α H4, β H2, H4), 5.01 (dt, $J = 10.2, 3.1$ Hz, 1H, α H2), 4.29 – 4.09 (m, 12H, α/β H6, OCH_2CH_2SAc), 3.83 (ddd, $J = 10.0, 4.6, 2.3$ Hz, 1H, β H5), 3.55 (ap. tt, $J = 11.9, 6.1$ Hz, 1H, α H5), 3.22 – 3.12 (m, 8H, OCH_2CH_2SAc), 2.37 – 2.35 (m, 12H, CH_3), 2.11 – 2.00 (m, 24H, CH_3). **^{13}C NMR** (101 MHz, $CDCl_3$) δ_C 170.65, 170.16, 169.89, 169.52, 169.40, 96.4 (d, $J = 5.0$ Hz, β C1), 94.22 (d, $J = 5.0$ Hz, α C1), 72.66 (β C3), 72.28 (d, $J = 2.2$ Hz, α C3), 71.09 (d, $J = 9.63$ Hz, β C2), 69.70 (d, $J = 7.71$ Hz, α C2), 69.47 (β C5), 69.28 (α C5), 67.69 (α C4), 67.57 (β C4), 66.69 (d, $J = 6.2$ Hz, OCH_2CH_2SAc), 66.54 (d, $J = 5.6$ Hz, OCH_2CH_2SAc), 66.50 (d, $J = 5.48$ Hz, OCH_2CH_2SAc), 66.46 (d, $J = 6.08$ Hz, OCH_2CH_2SAc), 61.44 (α C6), 61.32 (β C6), 29.25 (CH_3 , SAc), 29.15, 29.12, 29.03, 20.85 (CH_3 , OAc), 20.78, 20.73, 20.70. **^{31}P NMR** (162 MHz, $CDCl_3$) δ_P -2.86. **IR** (V_{max} , film) 2960, 1747, 1694, 1429, 1367, 1216, 1032, 955, 735, 623 cm^{-1} .

Large Scale: Following general procedure 2, the reaction was run with 2,3,4,6-*tetra-O*-acetyl-1-*bis*(2-bromoethyl)-phosphate- α,β -D-glucopyranoside on a 417 mg (0.65 mmol) scale. The crude product was purified by silica plug (80% EtOAc/hexane) to afford the title compound in a mixture of anomers (α : β 1.2:1) as a yellow oil (372 mg, 0.59 mmol, 91%).

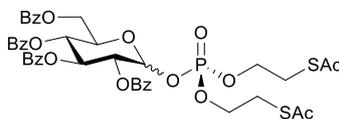
2,3,4,6-*tetra-O*-benzoyl-1-*bis*(2-bromoethyl)phosphor- α,β -D-glucopyranoside



Following general procedure 1, the reaction was run with **3** on a 30 mg (72 μ mol) scale on 2,3,4,6-*tetra-O*-benzoyl- α,β -D-glucopyranose (**9d**). The crude product was purified by automated flash column chromatography (0-60% EtOAc/hexane) to afford the title product in a mixture of anomers (α : β 5:1) as a clear oil (26 mg, 29 μ mol, 41%). **HRMS (ESI)** Calculated for $C_{38}H_{35}Br_2NaO_{13}P$ $[M+Na]^+$: 911.0074, found: 911.0109. **1H NMR** (400 MHz, $CDCl_3$) δ_H 8.12 – 7.80 (m, 16H, Aromatic H), 7.62 – 7.27 (m, 24H, Aromatic H), 6.24 – 6.16 (m, 2H, α H1, H3, β H1), 5.93 (t, $J = 9.4$ Hz, 1H, β H3), 5.78 (t, $J = 10.1$ Hz, 1H, α H4), 5.74 – 5.59 (m, 2H, β H2, H4), 5.43 (dt, $J = 10.1, 3.1$ Hz, 1H, α H2), 4.76 – 4.68 (m, 1H, α/β H5), 4.66 (dd, $J = 12.2, 3.3$ Hz, 1H, α H6'), 4.51 (dd, $J = 12.2, 4.6$ Hz, 1H, α H6), 4.47 – 4.35 (m, 2H, β H6, H6'), 4.36 – 4.15 (m, 8H, OCH_2CH_2Br), 3.35 (qdd, $J = 17.0, 8.6, 5.0$ Hz, 8H,

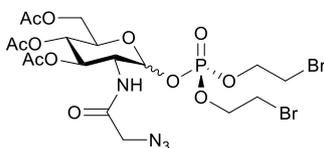
OCH₂CH₂Br). ¹³C NMR (α anomer) (101 MHz, CDCl₃) δ_c 166.15 (C=O), 165.83, 165.55, 165.27, 133.94, 133.77, 133.51, 133.44, 130.06, 129.91, 129.87, 129.62, 128.91, 128.78, 128.65, 128.51, 94.69 (d, *J* = 6.7 Hz, C1), 71.19 (d, *J* = 8.0 Hz, C2), 70.30 (C5), 69.60 (C3), 68.67 (C4), 67.40 (d, *J* = 4.4 Hz, OCH₂CH₂Br), 67.35 (d, *J* = 5.6 Hz, OCH₂CH₂Br), 62.58 (C6), 29.05 (OCH₂CH₂Br), 28.99, 28.92. ³¹P NMR (162 MHz, CDCl₃) δ_p -2.98, -3.44. IR (V_{max}, film) 3073, 2961, 2926, 2852, 1725, 1601, 1451, 1260, 1068, 1003, 959, 708 cm⁻¹

2,3,4,6-tetra-O-benzoyl-1-bis(SATE)phosphor-α,β-D-glucopyranoside



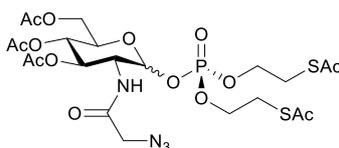
Following general procedure 2, the reaction was run with 2,3,4,6-tetra-O-benzoyl-1-bis(2-bromoethyl)-phosphor-α,β-D-glucopyranoside on a 24 mg (27 μmol) scale. The crude product was purified by manual flash column chromatography (20-50% EtOAc/hexane) to afford the title compound in a mixture of anomers (α:β 5:1) as a yellow oil (18 mg, 20 μmol, 74%). HRMS (ESI) Calculated for C₄₂H₄₁NaO₁₅PS₂ [M+Na]⁺: 903.1522, found; 903.1517. ¹H NMR (400 MHz, CDCl₃) δ_H 8.09 – 7.79 (m, 16H, Aromatic H), 7.61 – 7.25 (m, 24H, Aromatic H), 6.24 – 6.10 (m, 3H, α H1, H3, β H1), 5.91 (t, *J* = 9.6 Hz, 1H, β H3), 5.79 (t, *J* = 10.1 Hz, 1H, α H4), 5.75 – 5.59 (m, 2H, β H2, H4) 5.43 (dt, *J* = 10.1, 3.2 Hz, 1H, α H2), 4.69 (ddd, *J* = 10.1, 4.5, 2.8 Hz, 1H, α/β H5), 4.64 (dd, *J* = 12.2, 2.8 Hz, 1H, α H6), 4.55 – 4.43 (m, 2H, β H6, H6'), 4.51 (dd, *J* = 12.2, 4.5 Hz, 1H, α H6), 4.16 – 3.96 (m, 8H, OCH₂CH₂SAc), 3.02 (dt, *J* = 19.9, 6.4 Hz, 8H, OCH₂CH₂SAc), 2.32 (s, 3H, CH₃), 2.31 (s, 3H, CH₃). ¹³C NMR (101 MHz, CDCl₃) δ_c 166.18 (C=O), 165.79, 165.56, 165.25, 133.83, 133.71, 133.45, 133.37, 130.07, 129.92, 129.87, 128.99, 128.77, 128.73, 128.70, 128.61, 128.49, 94.51 (d, *J* = 5.8 Hz, C1), 71.11 (d, *J* = 8.0 Hz, C2), 70.14 (C5), 69.73 (C3), 68.67 (C4), 66.65 (d, *J* = 5.8 Hz, OCH₂CH₂SAc), 66.60 (d, *J* = 5.1 Hz, OCH₂CH₂SAc), 62.56 (C6), 30.64, (CH₃), 29.16 (OCH₂CH₂SAc), 29.09, 29.01. ³¹P NMR (162 MHz, CDCl₃) δ_p -2.87, -3.19. IR (V_{max}, film) 3064, 2959, 2972, 1727, 1694, 1452, 1264, 1092, 1069, 1025, 952, 707, 623, 484 cm⁻¹

3,4,6-tri-O-acetyl-2-azidoacetimido-1-bis(2-bromoethyl)-phosphor-α-D-glucosamine



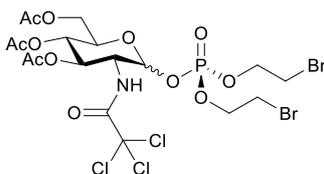
Following general procedure 1, the reaction was run with **3** on a 30 mg (72 μmol) scale on 3,4,6-tri-O-acetyl-2-azido-acetimido-α,β-D-glucosamine (**13**). The crude product was purified by manual flash column chromatography (0-8% MeOH/CH₂Cl₂) to afford the title compound as a clear oil (4.6 mg, 6.5 μmol, 9.0%). Similar yields were observed when running the reaction with or without Et₃N. HRMS (ESI) Calculated for C₁₈H₂₇Br₂N₄NaO₁₂P [M+Na]⁺: 702.9682, found: 702.9629. ¹H NMR (400 MHz, CDCl₃) δ_H 6.65 (d, *J* = 8.8 Hz, 1H, NH), 5.80 (dd, *J* = 5.9, 3.3 Hz, 1H, H1), 5.31 (dd, *J* = 10.6, 9.6 Hz, 1H, CH), 5.22 (t, *J* = 9.9 Hz, 1H), 4.46 – 4.37 (m, 5H, CH₂CH₂Br), 4.28 (dd, *J* = 12.4, 4.1 Hz, 1H), 4.25 – 4.20 (m, 1H, H6'), 4.16 – 4.12 (m, 1H, H6), 3.98 (d, *J* = 4.1 Hz, 2H, CH₂N₃), 3.58 (dtd, *J* = 12.9, 6.1, 0.9 Hz, 4H, CH₂CH₂Br), 2.11 (s, 3H, CH₃), 2.06 (s, 3H, CH₃), 2.05 (s, 3H, CH₃), 2.03 (s, 3H, CH₃).

3,4,6-tri-O-acetyl-2-azidoacetimido-1-bis(SATE)phosphor-α-D-glucosamine



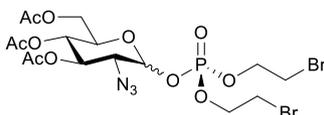
Following general procedure 2, the reaction was run with 3,4,6-tri-O-acetyl-2-azido-acetimido-1-bis(2-bromoethyl)phosphor-α-D-glucosamine on a 4.6 mg (6.5 μmol) scale. The crude product was analysed by ¹H NMR, and full conversion to the title compound was observed. Data were in accordance with literature values.¹

3,4,6-tri-*O*-acetyl-2-deoxy-2-trichloroacetamido-1-bis(2-bromoethyl)phosphor- α/β -D-glucopyranoside



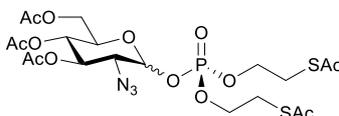
Following general procedure 1, the reaction was run with **3** on a 54 mg (130 μ mol) scale on 3,4,6-tri-*O*-acetyl-2-deoxy-2-trichloroacetamido- α/β -D-glucopyranose (**14**) in the presence of Et₃N (2.0 equiv). The crude product was purified by manual flash column chromatography (10-80% EtOAc/hexane) to afford the title compound in a mixture of anomers (4:1 α : β) (17 mg, 23 μ mol, 39%). **HRMS (ESI)** Calculated for C₁₈H₂₅Br₂Cl₃NaO₁₂P [M+Na]⁺: 763.8444, found: 763.8439. **¹H NMR α anomer** (400 MHz, CDCl₃) δ _H 7.10 (d, *J* = 8.6 Hz, 1H, NH), 5.85 (dd, *J* = 5.6, 3.3 Hz, 1H, H1), 5.37 (dd, *J* = 10.9, 9.7 Hz, 1H, H3), 5.24 (t, *J* = 9.7 Hz, 1H, H4), 4.44 – 4.36 (m, 4H, OCH₂CH₂Br), 4.35 – 4.25 (m, 3H, H2, H6), 4.23 (dd, *J* = 4.1, 2.2 Hz, 1H, H5), 4.14 (dd, *J* = 12.2, 2.0 Hz, 1H, H6'), 3.55 (td, *J* = 6.0, 3.9 Hz, 4H, OCH₂CH₂Br), 2.10 (s, 3H, CH₃), 2.05 (s, 3H, CH₃), 2.03 (s, 3H, CH₃). **¹³C NMR** (101 MHz, CDCl₃) δ _c 171.51, 170.64, 169.24, 162.30, 95.71, 91.79, 70.11, 69.59, 67.68, 66.98, 54.25 (d, *J* = 9.3 Hz), 29.27 (d, *J* = 4.6 Hz), 20.83, 20.67, 20.64.

3,4,6-tri-*O*-acetyl-2-azido-2-deoxy-1-bis(2-bromoethyl)phosphor-D-glucopyranoside



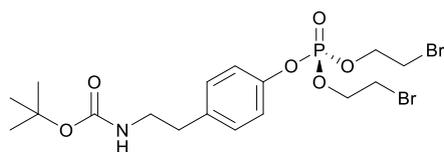
Following general procedure 1, the reaction was run with **3** on a 25 mg (60 μ mol) scale on 3,4,6-tri-*O*-acetyl-2-azido-2-deoxy-D-glucopyranose (**15**). The crude product was purified by manual flash column chromatography (20-80% EtOAc/hexane) to afford the title compound in a mixture of anomers (2.5:1 α : β) along with unreacted **3**. The yield was determined from peak integration on ¹H NMR (16 mg, 26 μ mol, 43%). **HRMS (ESI)** Calculated for C₁₆H₂₄Br₂N₃NaO₁₁P [M+Na]⁺: 645.9413 found: 645.9407. **¹H NMR α anomer** (400 MHz, CDCl₃) δ _H 5.85 (dd, *J* = 6.4, 3.3 Hz, 1H, H1), 5.45 (dd, *J* = 10.5, 9.3 Hz, 1H), 5.16 – 5.03 (m, 3H), 4.43 – 4.36 (m, 11H, OCH₂CH₂Br, unreacted **3**), 4.31 (dd, *J* = 12.6, 3.9 Hz, 1H), 4.23 – 4.19 (m, 2H), 4.11 (dd, *J* = 12.2, 2.2 Hz, 1H), 3.69b (dt, *J* = 10.4, 3.2 Hz, 1H), 3.60 – 3.54 (m, 11H, OCH₂CH₂Br, unreacted **3**), 2.10 (s, 3H, CH₃), 2.08 (s, 3H, CH₃), 2.05 (s, 3H, CH₃), 2.03 (s, 3H, CH₃). **¹³C NMR** (101 MHz, CDCl₃) δ _c 170.71, 170.52, 169.99, 169.81, 169.66, 101.37, 72.91, 70.55, 67.28, 61.17, 29.50, 29.44, 29.32, 20.73.

3,4,6-tri-*O*-acetyl-2-azido-2-deoxy-1-bis(SATE)phosphor-D-glucopyranoside



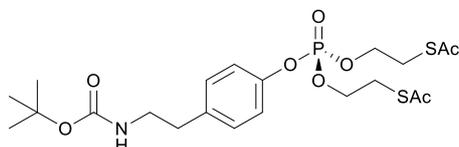
Following general procedure 2, the reaction was run with 3,4,6-tri-*O*-acetyl-2-azido-2-deoxy-1-bis(2-bromoethyl)phosphor-D-glucopyranoside on a 16 mg (26 μ mol) scale. The crude product was purified by manual column chromatography (0-100% EtOAc/hexane) to afford the title compound as a mixture of anomers (α : β 7:1) as a pale-yellow oil (14 mg, 22 μ mol, 83%). Data were in accordance with literature.¹

N-Boc-3-(bis(2-bromoethyl)phosphor)-tyramine



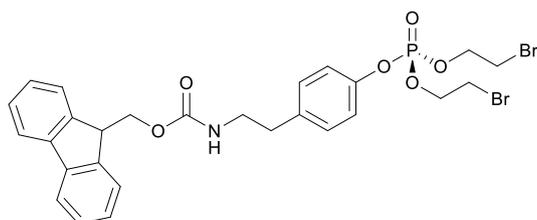
Following general procedure 1, the reaction was run with **3** on a 42 mg (0.10 mmol) scale on *N*-Boc-tyramine (**16**) in the presence of Et₃N (2.0 equiv). The crude product was purified by automated flash column chromatography (0-50% EtOAc/hexane) to afford the title compound with unreacted **3** as a clear oil. The crude mixture (16 mg, 30 μmol) was used without further purification. **HRMS (ESI)** Calculated for C₁₇H₂₅Br₂NNaO₆P [M+Na]⁺: 551.9762, found: 551.9757. **¹H NMR** (400 MHz, CDCl₃) δ_H 7.17 (s, 4H, Aromatic H), 4.53 (br s, 1H, NH), 4.46 – 4.36 (m, 5H, OCH₂CH₂Br), 3.57 – 3.51 (m, 5H, OCH₂CH₂Br), 3.35 (q, *J* = 6.7 Hz, 2H, CH₂), 2.78 (t, *J* = 7.1 Hz, 2H, CH₂), 1.43 (s, 9H, (CH₃)₃). **¹³C NMR** (101 MHz, CDCl₃) δ_C 153.51, 130.31, 125.13, 120.23 (d, *J* = 4.8 Hz), 67.70 (d, *J* = 5.8 Hz), 67.65, 29.20 (d, *J* = 7.6 Hz), 28.54.

N-Boc-3-(bis(SATE)phosphor)-tyramine



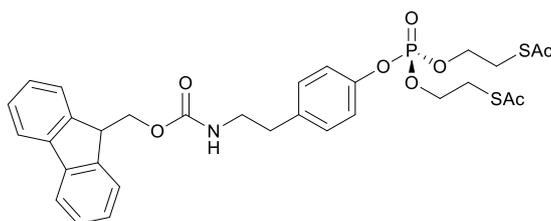
Following general procedure 2, the reaction was run with crude *N*-Boc-3-(bis(2-bromoethyl)phosphor)-tyramine on a 16 mg (30 μmol) scale. The crude product was purified by manual column chromatography (30-100% EtOAc/hexane) to afford the title compound as a colourless oil (9.6 mg, 18 μmol, 18% from **16**). **HRMS (ESI)** Calculated for C₂₁H₃₂KNO₈PS₂ [M+K]⁺: 560.0944, found: 560.0939. **¹H NMR** (400 MHz, CDCl₃) δ_H 7.15 (d, *J* = 3.1 Hz, 4H, Aromatic H), 4.55 (br s, 1H, NH), 4.22 (dd, *J* = 8.0, 1.6 Hz, OCH₂CH₂Br), 4.13 (ap. q, *J* = 6.8 Hz, 1H), 3.34 (ap. q, *J* = 6.7 Hz, 2H, CH₂), 3.17 (dd, *J* = 7.8, 4.9 Hz, 4H, OCH₂CH₂Br), 2.77 (t, *J* = 7.0 Hz, 1H, CH₂), 2.35 (s, 6H, CH₃), 1.43 (s, 9H, (CH₃)₃). **¹³C NMR** (101 MHz, CDCl₃) δ_C 194.90, 155.98, 130.24, 120.26, 120.21, 66.73 (d, *J* = 5.9 Hz), 66.28, 41.87, 35.61, 30.69, 29.35, 29.27, 29.20, 28.53. **³¹P NMR** (162 MHz, CDCl₃) δ_P -1.55, -6.31.

N-Fmoc-3-(bis(2-bromoethyl)phosphor)-tyramine



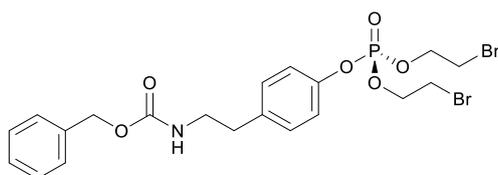
Following general method 1, the reaction was run with **3** on a 30 mg (72 μmol) scale on *N*-Fmoc-tyramine (**17**). The crude product was purified by manual flash column chromatography (0-50% EtOAc/hexane) to afford the title compound as a clear oil (25 mg, 39 μmol, 54%). **HRMS (ESI)** Calculated for C₂₇H₂₈Br₂NNaO₆P [M+Na]⁺: 673.9913, found: 673.9932. **¹H NMR** (400 MHz, CDCl₃) δ_H 7.77 (d, *J* = 7.3 Hz, 2H, Aromatic H), 7.57 (d, *J* = 7.4 Hz, 2H, Aromatic H), 7.40 (t, *J* = 7.5 Hz, 2H, Aromatic H), 7.31 (t, *J* = 7.4 Hz, 2H, Aromatic H), 7.23 – 7.09 (m, 4H, Aromatic H), 4.47 – 4.41 (m, 6H, OCH₂CH₂Br, CH₂ Fmoc), 4.21 (t, *J* = 6.9 Hz, 1H, CH Fmoc), 3.56 – 3.51 (m, 4H, OCH₂CH₂Br), 3.43 (t, *J* = 7.8 Hz, 2H, CH₂CH₂NH), 2.79 (t, *J* = 6.9 Hz, 2H, CH₂CH₂NH). **¹³C NMR** (101 MHz, CDCl₃) δ_C 156.42, 149.02, 144.03, 141.45, 136.28, 130.32, 127.83, 127.17, 125.13, 120.29 (d, *J* = 4.6 Hz), 120.11, 67.70 (OCH₂CH₂Br), 67.65, 66.63 (CH₂ Fmoc), 47.39 (CH Fmoc), 42.31 (CH₂CH₂NH), 35.56 (CH₂CH₂NH), 29.30 (CH₂CH₂Br), 29.22. **IR** (V_{max}, film) 3319, 3038, 2943, 1707, 1505, 1449, 1267, 1214, 1068, 1019, 957, 781, 759, 741, 668 cm⁻¹

***N*-Fmoc-3-(bis(SATE)phosphor)-tyramine**



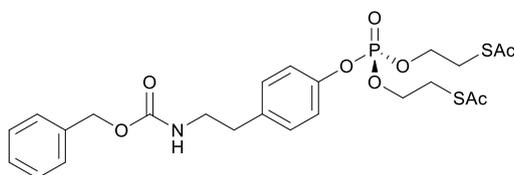
Following general procedure 2, the reaction was run with *N*-Fmoc-3-(bis(2-bromoethyl)phosphor)-tyramine on a 24 mg (39 μ mol) scale. The crude product was purified by manual flash column chromatography (0-50% EtOAc/hexane) to afford the title compound as a yellow oil (20 mg, 32 μ mol, 82%). **HRMS (ESI)** Calculated for $C_{31}H_{34}NNaO_8PS_2$ $[M+Na]^+$: 666.1356, found: 666.1370. **1H NMR** (600 MHz, $CDCl_3$) δ_H 7.77 (d, J = 7.6 Hz, 2H, Aromatic H), 7.57 (d, J = 7.5 Hz, 2H, Aromatic H), 7.40 (t, J = 7.5 Hz, 2H, Aromatic H), 7.31 (t, J = 7.3 Hz, 2H, Aromatic H), 7.14 (t, J = 6.4 Hz, 4H, Aromatic H), 4.42 (d, J = 6.9 Hz, 2H, CH Fmoc), 4.22 (dtd, J = 8.0, 6.6, 3.1 Hz, 4H, OCH_2CH_2SAC), 3.42 (q, J = 6.9 Hz, 2H, CH_2CH_2NH), 3.17 (td, J = 6.8, 3.5 Hz, 4H, OCH_2CH_2SAC), 2.79 (t, J = 6.9 Hz, 2H, CH_2CH_2NH), 2.34 (s, 6H, CH_3). **^{13}C NMR** (151 MHz, $CDCl_3$) δ_c 194.72, 143.95, 141.35, 130.15, 127.70, 127.17, 125.02, 120.18 (d, J = 5.1 Hz), 119.99, 66.62 (dd, J = 5.7 Hz, OCH_2CH_2SAC), 66.53 (CH₂ Fmoc), 47.32 (CH Fmoc), 42.24 (CH₂NH), 35.46 (CH₂CH₂NH), 30.54 (CH₃ SAC), 29.14 (d, J = 7.3 Hz, CH₂SAC), 29.09. **IR** (V_{max} , film) 3322, 3069, 2927, 2848, 1693, 1506, 1450, 1355, 1272, 1244, 1215, 1133, 1061, 1012, 952, 880, 759, 731, 741, 621, 529 cm^{-1}

***N*-CBz-3-(bis(2-bromoethyl)phosphor)-tyramine**



Following general procedure 1, the reaction was run with **3** on a 30 mg (72 μ mol) scale on *N*-CBz-tyramine (**18**). The crude product was purified by manual flash column chromatography (0-50% EtOAc/hexane) to afford the title compound as a clear oil (12 mg, 22 μ mol, 31%). **HRMS (ESI)** Calculated for $C_{22}H_{23}Br_2NNaO_5P$ $[M+Na]^+$: 585.9624, found: 585.9612. **1H NMR** (400 MHz, $CDCl_3$) δ_H 7.34 (d, J = 5.7 Hz, 5H, Aromatic H), 7.15 (s, 4H, Aromatic H), 5.09 (s, 2H, CH₂ CBz), 4.78 (s, 1H, NH), 4.48 – 4.31 (m, 4H, CH_2CH_2Br), 3.58 – 3.46 (m, 4H, CH_2CH_2Br), 3.42 (app. q, J = 6.7 Hz, 2H, CH_2CH_2NH), 2.79 (t, J = 6.9 Hz, 2H, CH_2CH_2NH). **^{13}C NMR** (101 MHz, $CDCl_3$) δ_c 156.41 (C=O), 130.31, 128.69, 128.32, 120.32 (d, J = 4.8 Hz), 67.71 (OCH_2CH_2), 67.65, 65.83 ($COCH_2$), 43.16 (CH₂NH), 35.76 (CH₂CH₂NH), 29.28 (CH₂Br), 29.21. **IR** (V_{max} , film) 3319, 2932, 1707, 1505, 1449, 1268, 1213, 1070, 1018, 959, 778, 746, 698 cm^{-1}

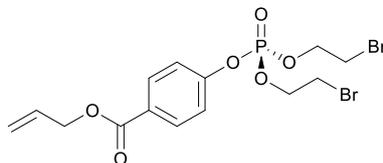
***N*-CBz-3-(bis(SATE)phosphor)-tyramine**



Following general procedure 2, the reaction was run with *N*-CBz-3-(bis(2-bromoethyl)phosphor)-tyramine on a 10 mg (18 μ mol) scale. The crude product was purified by manual flash column chromatography (0-50% EtOAc/hexane) to afford the title compound as a yellow oil (10 mg, 18 μ mol, quantitative). **HRMS (ESI)** Calculated for $C_{24}H_{30}NNaO_8PS_2$ $[M+Na]^+$: 578.1043, found: 578.1038. **1H NMR** (400 MHz, $CDCl_3$) δ_H 7.33 (d, J = 5.5 Hz, 5H, Aromatic H), 7.13 (s, 4H, Aromatic H), 5.08 (s, 2H, CH₂ CBz), 4.80 (s, 1H, NH), 4.25 – 4.14 (m, 4H, OCH_2CH_2SAC), 3.42 (q, J = 6.9 Hz, 2H, CH_2CH_2NH), 3.23 – 3.08 (m, 4H, OCH_2CH_2SAC), 2.78 (t, J = 6.9 Hz, 2H, CH_2CH_2NH), 2.33 (s, 6H, CH_3). **^{13}C NMR** (101 MHz, $CDCl_3$) δ_c 194.90 (C=O), 130.25, 128.68, 128.28 (d, J = 2.4 Hz), 120.33 (d, J = 4.8 Hz),

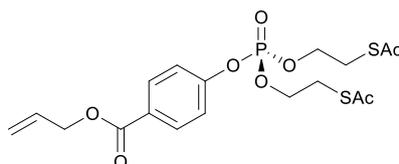
77.36, 66.77 (COCH₂), 66.71, 42.33 (CH₂NH), 35.52 (CH₂CH₂NH), 30.67 (CH₂SAc), 29.83, 29.27 (CH₃), 29.20. ³¹P NMR (162 MHz, CDCl₃) δ_P -6.34. IR (V_{max}, film) 3321, 2932, 1692, 1506, 1455, 1355, 1246, 1214, 1132, 1059, 1013, 953, 835, 776, 738, 698, 622, 527 cm⁻¹

Allyl 4-(bis(2-bromoethyl)phosphor)-benzoate



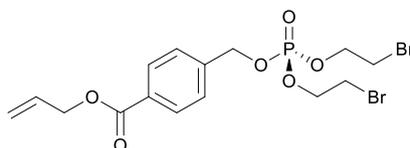
Following general procedure 1, the reaction was run with **3** on a 25 mg (60 μmol) scale on allyl 4-hydroxybenzoate (**19**). The crude product was purified by manual flash column chromatography (0-70% EtOAc/hexane) to afford the title compound as a clear oil (21 mg, 44 μmol, 74 %). HRMS (ESI) Calculated for C₁₄H₁₇Br₂NaO₆P [M+Na]⁺: 492.9027, found: 492.9022. ¹H NMR (400 MHz, CDCl₃) δ_H 8.10 – 8.06 (m, 2H, Aromatic H), 7.31 (dd, *J* = 7.4, 1.8 Hz, 2H, Aromatic H), 6.08 – 5.97 (m, 1H, OCH₂CH=CH₂), 5.43 – 5.37 (m, 1H, OCH₂CH=CH₂), 5.30 (dq, *J* = 10.5, 1.4 Hz, 1H, OCH₂CH=CH₂), 4.82 (dt, *J* = 5.6, 1.4 Hz, 2H, OCH₂CH=CH₂), 4.49 – 4.42 (m, 4H, OCH₂CH₂Br), 3.55 (td, *J* = 5.8, 1.7 Hz, 4H, OCH₂CH₂Br). ¹³C NMR (101 MHz, CDCl₃) δ_C 165.36 (C=O), 153.87 (Aromatic C), 132.14 (Aromatic C), 131.86 (CH=CH₂), 127.54 (Aromatic C), 120.03 (d, *J* = 5.0 Hz, Aromatic C), 118.56 (CH=CH₂), 67.86 (d, *J* = 5.6 Hz, CH₂CH₂Br), 65.84, 29.10 (d, *J* = 7.7 Hz, CH₂CH₂Br).

Allyl 4-(bis(SAc)phosphor)-benzoate



Following general procedure 2, the reaction was run with Allyl 4-(bis(2-bromoethyl)phosphor)-benzoate on a 21 mg (44 μmol) scale. The crude product was purified by manual column chromatography (0-80% EtOAc/hexane) to afford the title compound as a pale-yellow oil (15 mg, 31 μmol, 70%). HRMS (ESI) Calculated for C₁₈H₂₃NaO₈PS₂ [M+Na]⁺: 485.0470, found: 485.0464. ¹H NMR (400 MHz, CDCl₃) δ_H 8.06 (d, *J* = 8.7 Hz, 2H, Aromatic H), 7.28 (d, *J* = 8.7, 1.3 Hz, 2H, Aromatic H), 6.02 (ddt, *J* = 17.4, 10.5, 5.5 Hz, 1H, OCH₂CH=CH₂), 5.39 (dq, *J* = 17.4, 1.5 Hz, 1H, OCH₂CH=CH₂), 5.28 (dq, *J* = 10.5, 1.5 Hz, 1H, OCH₂CH=CH₂), 4.80 (dt, *J* = 5.5, 1.5 Hz, 2H, OCH₂CH=CH₂), 4.26 – 4.20 (m, 4H, OCH₂CH₂SAc), 3.17 (t, *J* = 6.5 Hz, 4H, OCH₂CH₂SAc), 2.33 (s, 6H, CH₃). ¹³C NMR (101 MHz, CDCl₃) δ_C 194.77 (C=O), 165.42 (Aromatic C), 154.14 (d, *J* = 6.4 Hz, Aromatic C), 132.17 (Aromatic C), 131.31 (CH=CH₂), 127.32 (Aromatic C), 120.01 (d, *J* = 5.0, Aromatic C), 118.52 (CH=CH₂), 66.84 (d, *J* = 5.9 Hz, OCH₂CH₂SAc), 65.80, 30.64 (CH₃), 29.17 (OCH₂CH₂SAc).

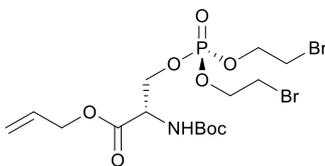
Allyl 4-(bis(2-bromoethyl)phosphor)-methylbenzoate



Following general procedure 1, the reaction was run with **3** on a 54 mg (0.13 mmol) scale on allyl 4-hydroxymethylbenzoate (**20**). The crude product was purified by manual flash column chromatography (0-70% EtOAc/hexane) to afford the title compound in a 2:1 mixture with unreacted **3** as a clear oil (35 mg, 71 μmol, 55 %). HRMS (ESI) Calculated for C₁₉H₂₅Br₂NaO₈P [M+Na]⁺: 506.9184, found: 506.9178. ¹H NMR (400 MHz, CDCl₃) δ_H 8.08 (d, *J* = 8.3 Hz, 2H, Aromatic H), 7.47 (d, *J* = 8.3 Hz, 2H, Aromatic H), 6.03 (ddd, *J* = 17.6, 10.5, 5.5 Hz, 1H, OCH₂CH=CH₂), 5.41 (dd, *J* = 17.6, 1.5 Hz, 1H, OCH₂CH=CH₂), 5.30 (dd, *J* = 10.5, 1.5 Hz, 1H, OCH₂CH=CH₂), 5.19 (d, *J* = 8.3 Hz, 2H, CH₂), 4.83 (dt, *J* = 5.5, 1.5 Hz, 2H, OCH₂CH=CH₂), 4.33 (dtd, *J* = 7.9, 6.0, 1.9 Hz, 4H, OCH₂CH₂Br),

3.52 (t, $J = 6.0$ Hz, 4H, $\text{OCH}_2\text{CH}_2\text{Br}$). ^{13}C NMR (101 MHz, CDCl_3) δ_c 165.85, 140.51 (d, $J = 6.8$ Hz), 132.22, 130.58, 130.18, 127.6, 118.57, 69.13 (d, $J = 5.5$ Hz), 67.36 (d, $J = 5.7$ Hz), 67.22 (d, $J = 5.7$ Hz), 65.86, 29.50 (d, $J = 7.7$ Hz).

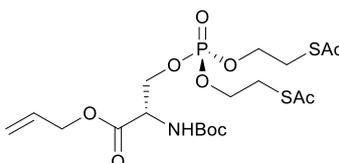
***N*-Boc-Ser(bis(2-bromoethyl)phosphor)-allyl ester**



Following general procedure 1, the reaction was run with **3** on a 25 mg (60 μmol) scale on with *N*-Boc-Ser-allyl ester (**21**) in the presence of Et_3N (2.0 equiv). The crude product was purified by manual flash column chromatography (0-50% EtOAc in hexane) to afford the title compound as a clear oil (9.5 mg, 18 μmol , 30%).

HRMS (ESI) Calculated for $\text{C}_{15}\text{H}_{26}\text{Br}_2\text{NNaO}_8\text{P}$ [$\text{M}+\text{Na}$] $^+$: 559.9660, found: 559.9655. ^1H NMR (400 MHz, CDCl_3) δ_{H} 5.91 (ddt, $J = 17.2, 10.4, 5.8$ Hz, 1H, $\text{OCH}_2\text{CH}=\text{CH}_2$), 5.50 (br. d, $J = 8.3$ Hz, 1H, NH), 5.34 (dq, $J = 17.2, 1.4$ Hz, 1H, $\text{OCH}_2\text{CH}=\text{CH}_2$), 5.27 (dq, $J = 17.2, 1.4$ Hz, 1H, $\text{OCH}_2\text{CH}=\text{CH}_2$), 4.68 (dt, $J = 5.6, 1.6$ Hz, 2H, $\text{OCH}_2\text{CH}=\text{CH}_2$), 4.57 – 4.53 (m, 1H, CHNH_2), 4.50 (ddt, $J = 10.6, 7.4, 3.4$ Hz, 1H, POCH_2), 4.40 – 4.29 (m, 6H, $\text{OCH}_2\text{CH}_2\text{Br}$, POCH_2), 3.54 – 3.49 (m, 4H, $\text{OCH}_2\text{CH}_2\text{Br}$), 1.45 (s, 9H, $(\text{CH}_3)_3$). ^{13}C NMR (101 MHz, CDCl_3) δ_c 168.96 (C=O), 131.36 (CHCH_2), 119.28 (CHCH_2), 80.60, 68.13, 67.28 (d, $J = 5.77$), 66.69, 54.13, 29.51, 29.35, 28.38 (CH_3).

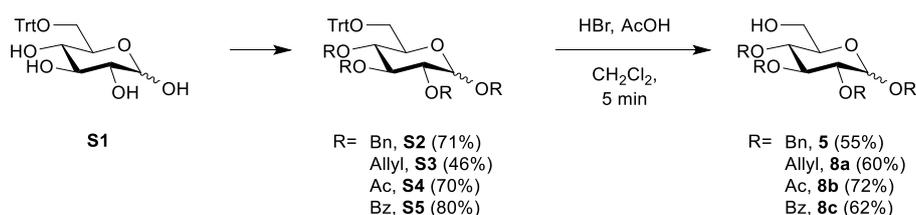
***N*-Boc-Ser(bis(SATE)phosphor)-SATE)-allyl ester**



Following general procedure 2, the reaction was run with *N*-Boc-Ser(bis(2-bromoethyl)phosphor)-allyl ester on a 9.5 mg (18 μmol) scale. The crude product was purified by a silica plug (100% EtOAc) to afford the title compound as a yellow oil (7.4 mg, 14 μmol , 78%). **HRMS (ESI)** Calculated for $\text{C}_{19}\text{H}_{32}\text{NKO}_{10}\text{PS}_2$ [$\text{M}+\text{K}$] $^+$: 568.0842, found: 568.0837. ^1H NMR (400 MHz, CDCl_3) δ_{H} 5.95 – 5.85 (m, 1H, $\text{OCH}_2\text{CH}=\text{CH}_2$), 5.59 (d, $J = 8.3$ Hz, 1H, NH), 5.37 – 5.30 (m, 1H, $\text{OCH}_2\text{CH}=\text{CH}_2$), 5.26 (dt, $J = 10.4, 1.4$ Hz, 1H, $\text{OCH}_2\text{CH}=\text{CH}_2$), 4.68 – 4.65 (m, 2H, $\text{OCH}_2\text{CH}=\text{CH}_2$), 4.54 (ddt, $J = 8.3, 5.5, 3.0$ Hz, 1H, CHNH_2), 4.46 (ddd, $J = 10.4, 7.2, 3.3$ Hz, 1H, POCH_2), 4.31 (ddd, $J = 10.4, 6.0, 2.8$ Hz, 1H, POCH_2), 4.15 – 4.06 (m, 4H, $\text{OCH}_2\text{CH}_2\text{SAC}$), 3.18 – 3.12 (m, 4H, $\text{OCH}_2\text{CH}_2\text{SAC}$), 2.35 (s, 6H, SAC), 1.44 (s, 9H, $(\text{CH}_3)_3$). ^{13}C NMR (101 MHz, CDCl_3) δ_c 194.88, 194.82, 169.00, 131.43, 119.16, 80.48, 66.61, 66.36, 66.12 (d, $J = 4.8$ Hz), 54.07, 30.67, 29.23, 29.15, 29.09, 28.39. ^{31}P NMR (162 MHz, CDCl_3) δ_{P} -1.31.

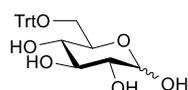
Synthesis of substrates for phosphorylation reactions

Compounds **9a**², **9b**³, **9c**⁴, **9d**⁵, **10**⁶, **13**¹, **14**⁷, **16**⁸, **17**⁸, **18**⁸, **19**⁸, **20**⁸, and **21**⁹ were synthesised as described previously and characterisation data were found to be in accordance with the literature. Compound **15** was synthesised through an adapted literature procedure¹ with the azido transfer reagent made in-situ.¹⁰ Characterisation data matched those described previously.¹



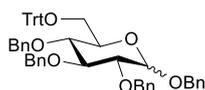
Scheme S1. Synthesis of C6-unprotected glucose derivatives **5** and **8a-c**.

6-O-trityl- α,β -D-glucopyranose (**S1**)



A solution of D-glucose (2.6 g, 14 mmol, 1.0 equiv.) in pyridine (50 mL) was cooled to 0°C before dropwise addition of a solution of trityl chloride (4.3 g, 15 mmol, 1.1 equiv.) in pyridine (13 mL). The resulting solution was allowed to warm to RT and left stirring for 72 hrs. before the reaction was quenched by the addition of MeOH (5 mL). The solvents were removed *in vacuo* and the resulting residue was co-evaporated with toluene (3 × 10 mL). The residue was then dissolved in CH₂Cl₂ (250 mL) and washed consecutively with 1M HCl (100 mL), saturated aqueous NaHCO₃ solution (100 mL), and brine (100 mL). The organic layer was dried over MgSO₄, filtered, and dried *in vacuo* to afford the crude product. The crude product was purified by flash column chromatography on an automated system (0-10% MeOH/CH₂Cl₂) to afford the title compound **S1** as a mixture of anomers, as a white foam (3.0 g, 7.3 mmol, 50%). **HRMS (ESI)** Calculated for C₂₅H₂₆NaO₆ [M+Na]⁺: 445.1622, found: 445.1625. **¹H NMR** (400 MHz, CDCl₃) δ_H 7.53 – 7.01 (m, 15H, Aromatic H), 5.68 – 5.15 (m, 2H, H1), 5.15 – 4.38 (m, 4H), 4.02 – 3.60 (m, 2H), 3.60 – 3.11 (m, 6H). **¹³C NMR** (101 MHz, CDCl₃) δ_C 146.86, 143.75, 143.56, 137.91, 129.71, 129.07, 128.71, 128.26, 127.97, 127.95, 127.90, 127.75, 127.30, 127.16, 127.08, 125.33, 96.36 (C1-β), 92.31 (C1-α), 87.15, 86.76, 82.06, 74.47, 73.47, 71.95, 71.15, 70.32, 64.07 (C6-β), 63.46 (C6-α), 21.50 (OC(Ph)₃). **IR** (Vmax, film) 3358, 3058, 3030, 2928, 2883, 1490, 1448, 1035, 1002, 900, 764, 732, 697, 645 cm⁻¹.

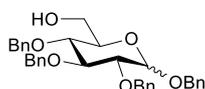
1,2,3,4-tetra-O-benzyl-6-O-trityl- α,β -D-glucopyranoside (**S2**)



To a stirring solution of **S1** (500 mg, 1.18 mmol, 1.00 equiv.) in dry DMF under N₂ at 0 °C was added NaH (60% in mineral oil, 300 mg, 7.40 mmol, 6.27 equiv.). The resulting reaction mixture was left at 0 °C for 30 minutes before the addition of BnBr (0.85 mL, 6.8 mmol, 6.2 equiv.) and TBAI (cat.). Additional DMF (2 mL) was added to solubilise the reaction before allowing the resulting suspension to warm to RT. After 18 hrs. the reaction was quenched by the addition of MeOH (5 mL) and the solvents were removed *in vacuo*. The resulting residue was dissolved in CH₂Cl₂ (50 mL) and washed consecutively with saturated aqueous NH₄Cl (25 mL) solution, H₂O (25 mL) and brine (25 mL). The resulting organic layer was dried over MgSO₄, filtered and solvents removed *in vacuo*. The crude product was purified by automated flash column chromatography (0-15% EtOAc/hexane) to afford the title compound **S2** in a mixture of anomers ($\alpha:\beta$ 2:3), as a clear foam (0.63 g, 0.80 mmol, 71%).

Characterisation data were in accordance with literature values.¹¹

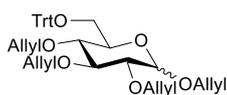
1,2,3,4-tetra-O-benzyl- α,β -D-glucopyranoside (**5**)



A solution of **S2** (450 mg, 0.579 mmol, 1.00 equiv.) in AcOH (5 mL) and CH₂Cl₂ (5 mL) was cooled to 10°C before dropwise addition of HBr (33% in acetic acid, 0.12 mL, 0.88 mmol, 1.2 equiv.). The resulting solution was stirred for 5 min. before the reaction mixture was filtered and rinsed with AcOH into a separating funnel containing CH₂Cl₂ (10 mL) and H₂O (10 mL). The aqueous layer was further extracted with CH₂Cl₂ (3 × 10 mL) and the combined organic layers were washed with saturated aqueous NaHCO₃ solution, dried over MgSO₄, filtered, and concentrated *in vacuo*. The resulting crude product was purified by automated flash column chromatography (0-30% EtOAc/hexane) to afford the title compound **5** in a mixture of anomers (1:1 $\alpha:\beta$) as a clear foam (170 mg, 0.314 mmol, 55%).

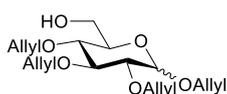
Characterisation data were in accordance with literature values.¹²

1,2,3,4-tetra-O-allyl-6-O-trityl- α,β -D-glucopyranoside (**S3**)



To a stirring solution of **S1** (500 mg, 1.18 mmol, 1.00 equiv.) in dry DMF at 0 °C was added NaH (60% in mineral oil, 300 mg, 7.40 mmol, 6.27 equiv.). The reaction was left at 0 °C for 30 minutes before the addition of allyl bromide (0.70 mL, 6.8 mmol, 6.2 equiv.) and TBAI (cat.). Additional DMF (2 mL) was added to solubilise the reaction before warming to RT. After 18 hrs. the reaction was quenched by the addition of MeOH (5 mL), and the solvents were removed *in vacuo*. The resulting residue was dissolved in CH₂Cl₂ (50 mL) and washed consecutively with sat. aqueous NH₄Cl solution (25 mL), H₂O (25 mL) and brine (25 mL). The organic layer was dried over MgSO₄, filtered, and concentrated *in vacuo*. The crude product **S3** was purified by automated flash column chromatography (0-15% EtOAc/hexane) to afford the separated pure anomers α (0.16 g, 0.27 mmol, 23%) and β (0.32 g, 0.54 mmol, 46%) as clear oils. **α -anomer (major) HRMS (ESI)** Calculated for C₃₇H₄₂NaO₆ [M+Na]⁺: 605.2874, found: 605.2883. **¹H NMR** (400 MHz, CDCl₃) δ _H 7.55 – 7.38 (m, 6H, Aromatic H), 7.36 – 7.15 (m, 9H, Aromatic H), 6.07 – 5.88 (m, 3H, CH=CH₂), 5.56 (ddt, *J* = 17.3, 9.6, 6.0 Hz, 1H, CH=CH₂), 5.09 – 5.43 (m, 6H, CH=CH₂), 4.96 – 5.04 (m, 2H, CH=CH₂), 4.95 (d, *J* = 1.6 Hz, 1H, H1), 4.50 – 4.29 (m, 4H, OCH₂), 4.29 – 4.14 (m, 2H, OCH₂), 4.14 – 4.05 (m, 1H, OCH₂), 3.88 – 3.79 (m, 1H, OCH₂), 3.55 (ddd, *J* = 9.5, 6.1, 2.9 Hz, 1H, H4), 3.43 (dd, *J* = 10.1, 2.0 Hz, 1H, H6'), 3.34 – 3.33 (m, 1H, H3), 3.32 (d, *J* = 2.3 Hz, 1H, H2), 3.26 (ddd, *J* = 9.5, 3.8, 2.0 Hz, 1H, H5), 3.07 (dd, *J* = 10.1, 3.8 Hz, 1H, H6). **¹³C NMR** (101 MHz, CDCl₃) δ _c 144.14, 135.45, 135.13, 134.83, 134.00, 128.92, 127.88, 127.07, 118.38, 117.52, 95.49 (C1), 86.34 (C(Ph)₃), 81.90 (CH-C4), 79.80 (C2, C3), 78.09, 74.69 (OCH₂), 73.97 (OCH₂), 72.48 (OCH₂), 70.44 (C5), 67.97 (OCH₂), 62.53 (C6). **IR** (V_{max}, film) 3057, 2984, 2924, 2875, 1737, 1449, 1265, 1071, 1048, 926, 735, 703, 644 cm⁻¹. **β -anomer (minor) HRMS (ESI)** Calculated for C₃₇H₄₂NaO₆ [M+Na]⁺: 605.2874, found: 605.2883. **¹H NMR** (400 MHz, CDCl₃) δ _H 7.52 (dd, *J* = 7.2, 2.0 Hz, 6H, Aromatic H), 7.38 – 7.19 (m, 12H, Aromatic H), 6.12 – 5.90 (m, 3H, CH=CH₂), 5.59 (ddt, *J* = 16.4, 10.1, 6.0 Hz, 1H, CH=CH₂), 5.14 – 5.40 (m, 6H, CH=CH₂), 5.07 (d, *J* = 3.6 Hz, 1H, H1), 4.96 – 5.05 (m, 2H, CH=CH₂), 4.36 – 4.45 (m, 1H, OCH₂), 4.14-4.26 (m, 5H, OCH₂), 3.78 – 3.85 (m, 1H, H4), 3.75 (t, *J* = 10 Hz, 1H, H5), 3.48 – 3.54 (m, 2H, H2, H3), 3.45 (dd, *J* = 10.0, 1.9 Hz, 1H, H6'), 3.14 (dd, *J* = 10.0, 4.2 Hz, 1H, H6). **¹³C NMR** (101 MHz, CDCl₃) δ _c 144.08, 135.36, 135.31, 134.77, 134.32, 128.92, 127.87, 127.06, 117.31, 117.25, 117.15, 117.01, 102.65 (C1), 86.36 (CPh₃), 84.38 (C4), 81.96 (C2, C3), 77.63, 74.82, 74.60, 73.89, 73.83, 70.09 (C5), 62.45 (C6). **IR** (V_{max}, film) 3057, 2984, 2924, 2875, 1737, 1449, 1265, 1071, 1048, 926, 735, 703, 644 cm⁻¹.

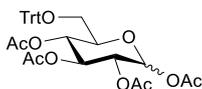
1,2,3,4-tetra-O-allyl- α,β -D-glucopyranoside (**8a**)



A solution of **S3** (163 mg, 0.281 mmol, 1.00 equiv.) in AcOH (0.65 mL) was cooled to 10°C before dropwise addition of HBr (33% in acetic acid, 60 μ L, 0.31 mmol, 1.2 equiv.). The resulting solution was stirred for 30 seconds before the reaction mixture was filtered and rinsed with AcOH into a separating funnel containing CH₂Cl₂ (10 mL) and H₂O (10 mL). The aqueous layer was further extracted with CH₂Cl₂ (3 \times 10 mL) and the combined organic layers were washed with saturated aqueous NaHCO₃ solution, dried over MgSO₄, filtered, and concentrated *in vacuo*. The resulting crude product was purified by automated flash column chromatography (0-100% EtOAc/hexane) to afford the title compound **8** in a mixture of anomers (1:1 α : β) as a clear foam (54 mg, 0.16 mmol, 60%). **HRMS (ESI)** Calculated for C₁₈H₂₈NaO₆ [M+Na]⁺: 363.1778, found: 363.1781. **¹H NMR** (400 MHz, CDCl₃) δ _H 6.03 – 5.82 (m, 8H, CH=CH₂), 5.34 – 5.31 (m, 2H, β H1), 5.30 – 5.07 (m, 16H, CH=CH₂), 4.89 (d, *J* = 3.6 Hz, 1H, α H1), 4.45 – 3.97 (m, 16H, OCH₂), 3.84 (dd, *J* = 11.8, 2.7 Hz, 1H, β H6'), 3.79 (dd, *J* = 12.8, 3.1 Hz, 1H, α H6'), 3.69 (dd, *J* = 12.8, 4.6 Hz, 1H, α H6), 3.69 (dd, *J* = 11.8, 4.6 Hz, 1H, β H6), 3.63 (dt, *J* = 10.0, 3.6 Hz, 1H, α H2), 3.45 – 3.29 (m, 4H, α CH-5, CH-3, β H4, H2), 3.25 (ddd, *J* = 9.4, 4.5, 2.8 Hz, 1H, β H5), 3.19 (t, *J* = 8.3 Hz, 1H, β H3). **¹³C NMR** (101 MHz, CDCl₃) δ _c 135.39, 135.25, 135.09, 134.94, 134.88, 134.74, 133.99, 133.80, 118.25, 117.40, 117.35, 117.29, 117.06, 116.87, 116.59, 102.70 (β C1), 95.78 (α C1), 84.06 (C3), 81.69 (β C2), 81.44 (α C3), 79.54 (α C2), 77.33 (α C4), 75.02 (β C4), 74.53 (OCH₂), 74.37, 74.00, 73.92, 73.81, 72.43, 70.90, 70.60 (β C5), 68.22 (α

C5), 62.09 (β C6), 61.90 (α C6). IR (V_{\max} , film) 3408, 3084, 2821, 2867, 1462, 1347, 1268, 1074, 1044, 990, 923, 735 cm^{-1}

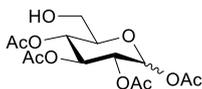
1,2,3,4-tetra-O-acetyl-6-O-trityl- α,β -D-glucopyranoside (**S4**)



To a stirring solution of **S1** (500 mg, 1.18 mmol, 1.00 equiv.) in dry pyridine (10 mL) at 0 °C was added Ac_2O (0.85 mL, 9.1 mmol, 8.3 equiv.) and DMAP (cat.). The resulting solution was allowed to warm to RT and left stirring for 56 hrs. before the reaction was quenched by the addition of MeOH (2.5 mL). The solvents were removed *in vacuo* followed by co-evaporation with toluene (3×5 mL). The resulting residue was dissolved in CH_2Cl_2 (50 mL) and washed consecutively with 1M HCl (25 mL), saturated aqueous NaHCO_3 solution (25 mL), and brine (25 mL). The organic layer was dried over MgSO_4 , filtered, and dried *in vacuo*. The resulting crude product was purified by flash column chromatography on an automated system (0-50% EtOAc/hexane) to afford the title compound **S4** in a mixture of anomers (4:6 $\alpha:\beta$), as a colourless foam (0.47 g, 0.79 mmol, 70%).

Characterisation data were in accordance with literature values.^{13,14}

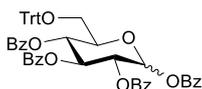
1,2,3,4-tetra-O-acetyl- α,β -D-glucopyranoside (**8b**)



A solution of **S4** (240 mg, 0.407 mmol, 1.00 equiv.) in AcOH (0.95 mL) was cooled to 10°C before addition of HBr (33% in acetic acid, 0.80 mL, 0.47 mmol, 1.2 equiv.). The resulting solution was stirred for 30 seconds before the reaction mixture was filtered and rinsed with AcOH into a separating funnel containing CH_2Cl_2 (10 mL) and H_2O (10 mL). The aqueous layer was further extracted with CH_2Cl_2 (3×10 mL) and the combined organic layers were washed with saturated aqueous NaHCO_3 , dried over MgSO_4 , filtered, and concentrated *in vacuo*. The resulting crude product was purified by automated flash column chromatography (0-100% EtOAc/hexane) to afford the title compound **8b** as a clear foam (0.10 g, 0.29 mmol, 72%), in a mixture of anomers (1:1 $\alpha:\beta$).

Characterisation data were in accordance with literature values.¹⁴

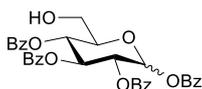
1,2,3,4-tetra-O-benzoyl-6-O-trityl- α,β -D-glucopyranoside (**S5**)



To a stirring solution of **S1** (500 mg, 1.18 mmol, 1.00 equiv.) in dry pyridine (10 mL) at 0 °C was added BzCl (0.80 mL, 6.9 mmol, 6.3 equiv.) and DMAP (cat.). The resulting solution was allowed to warm to RT and left stirring for 56 hrs. before the reaction was quenched by the addition of MeOH (2.5 mL). The solvents were removed *in vacuo* and co-evaporated with toluene (3×5 mL). The resulting residue was dissolved in CH_2Cl_2 (50 mL) and washed consecutively with 1M HCl (25 mL), saturated aqueous NaHCO_3 solution (25 mL), and brine (25 mL). The organic layer was dried over MgSO_4 , filtered, and the solvents removed *in vacuo*. The resulting crude product was purified by flash column chromatography on an automated system (0-30% EtOAc/hexane) to afford the title compound **S5** in a mixture of anomers (2:1 $\alpha:\beta$) as a colourless foam (0.76 g, 0.90 mmol, 80%).

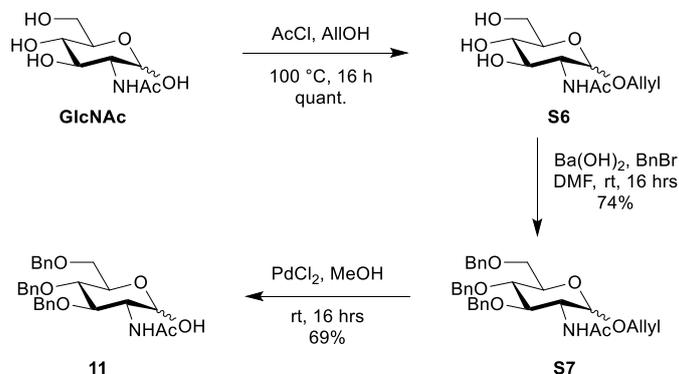
Characterisation data were in accordance with literature values.¹⁵

1,2,3,4-tetra-O-benzoyl- α,β -D-glucopyranoside (**8c**)



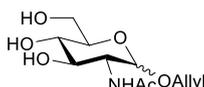
A solution of **S5** (500 mg, 0.583 mmol, 1.00 equiv.) in AcOH (1.4 mL) with 10 drops of CH₂Cl₂ was cooled to 10 °C before dropwise addition of HBr (33% in acetic acid, 0.12 mL, 0.69 mmol, 1.2 equiv.). The resulting solution was stirred for 30 seconds before the reaction mixture was filtered and rinsed with AcOH into a separating funnel containing CH₂Cl₂ (10 mL) and H₂O (10 mL). The aqueous layer was further extracted with CH₂Cl₂ (3 × 10 mL) and the combined organic layers were washed with saturated aqueous NaHCO₃, dried over MgSO₄, filtered, and concentrated *in vacuo*. The resulting crude product was purified by automated flash column chromatography (0-35% EtOAc/hexane) to afford the title compound **8c** in a mixture of anomers, (2:1 α : β) as a clear foam (212 mg, 0.357 mmol, 62%).

Characterisation data were in accordance with literature values.¹⁶



Scheme S2. Synthesis of **11** from *N*-acetyl-D-glucosamine (GlcNAc).

Allyl 2-acetamido-2-deoxy-D-glucopyranoside (**S6**)



To a solution of *N*-acetyl-D-glucosamine (3.0 g, 14 mmol) in allyl alcohol (60 mL) under N₂ atmosphere was added freshly distilled AcCl (1.9 mL, 27 mmol, 2 equiv.) and the reaction mixture was stirred at 100 °C overnight. After cooling to room temperature, the reaction mixture was neutralized with Et₃N (2.1 mL, 15 mmol, 1.1 equiv.) and concentrated *in vacuo*. The residual oil was co-evaporated with toluene to give crude acetamide **S6** (3.6 g) as a brown solid which was used in the next step without further purification.

Characterisation data of crude material were in accordance with literature values.¹⁷

Allyl 2-acetamido-3,4,5-tri-O-benzyl-2-deoxy-D-glucopyranoside (**S7**)

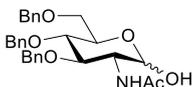


To a solution of **S6** (0.5 g, 2.0 mmol 1.0 equiv.) in dry DMF (19 mL) under N₂ atmosphere were added Ba(OH)₂ (2.0 g, 12 mmol, 6.0 equiv.) and BnBr (1.0 mL, 8.6 mmol, 4.5 equiv.). The mixture was stirred at room temperature for 16 hrs. and then cooled to 0 °C and neutralized with 1M aqueous HCl (10 mL). The reaction was allowed to warm to room temperature, diluted with brine (20 mL) and extracted twice with CH₂Cl₂ (2 × 40 mL). The combined organic layers were dried over MgSO₄, filtered, and concentrated *in vacuo*. The resulting crude

product was purified by automated flash column chromatography (20-60% EtOAc/hexane) to afford allyl 2-acetamido-3,4,5-tri-*O*-benzyl-2-deoxy-D-glucopyranoside **S7** as a white solid (0.75 g, 1.4 mmol, 74%).

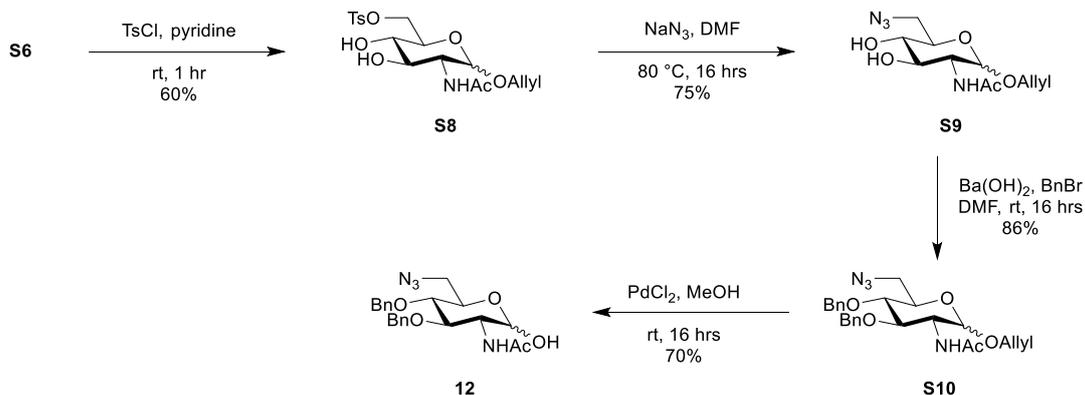
Characterisation data were in accordance with literature values.^{18, 19}

2-acetamido-3,4,5-tri-*O*-benzyl-2-deoxy-D-glucopyranose (**11**)



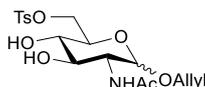
To a solution of **S7** (600 mg, 1.13 mmol, 1.0 equiv.) in MeOH (11 mL) under N₂ atmosphere was added PdCl₂ (40 mg, 0.23 mmol, 0.2 equiv.). The mixture was stirred at room temperature for 16 hrs. and then filtered through a small pad of silica gel and washed with acetone. The filtrate was concentrated *in vacuo*. The resulting crude product was purified by automated flash column chromatography (20-60% EtOAc/hexane) to afford compound **11** as a white solid (0.38 g, 0.78 mmol, 69%).

Characterisation data were in accordance with literature values.²⁰



Scheme S3. Synthesis of **12** from **S6**.

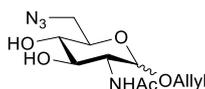
Allyl 2-acetamido-2-deoxy-6-*O*-*p*-toluenesulfonyl-D-glucopyranoside (**S8**)



To a solution of **S6** (2.9 g, 12 mmol 1.0 equiv.) in dry pyridine (60 mL) under N₂ atmosphere was added TsCl (3.5, 19 mmol, 1.6 equiv.). The mixture was stirred at room temperature for 1 hr. and then quenched with H₂O. The mixture was stirred for another 10 min at room temperature and concentrated *in vacuo*. The crude residue was suspended in H₂O (50 mL) and the resulting solution was acidified with 1M HCl (25 mL). The mixture was extracted with CH₂Cl₂ (5 × 100 mL). The combined organic layers were dried with MgSO₄, filtered, and concentrated *in vacuo*. The resulting crude product was purified by automated flash column chromatography (0-10% MeOH/CH₂Cl₂) to afford allyl-2-acetamido-2-deoxy-6-*O*-*p*-toluenesulfonyl-D-glucopyranoside **S8** as a brown foam (2.9 g, 6.9 mmol, 60%).

Characterisation data were in accordance with literature values.²¹

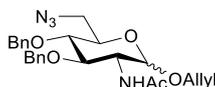
Allyl 2-acetamido-6-azido-2,6-dideoxy-D-glucopyranoside (**S9**)



To a solution of **S8** (0.97 g, 2.3 mmol, 1.0 equiv.) in dry DMF (23 mL) under N₂ atmosphere was slowly added NaN₃ (0.76 g, 12 mmol, 5.0 equiv.). The mixture was stirred at 80 °C overnight, quenched with MeOH, and the solvents were removed *in vacuo*. The resulting crude product was purified by automated flash column chromatography (0-10% MeOH/CH₂Cl₂) to afford allyl 2-acetamido-6-azido-2,6-dideoxy-D-glucopyranoside **S9** as a white solid (0.50 g, 1.8 mmol, 75%).

Characterisation data were in accordance with literature values.²²

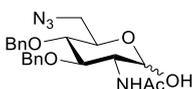
Allyl 2-acetamido-6-azido-3,4-di-O-benzyl-2,6-dideoxy-D-glucopyranoside (**S10**)



To a solution of **S9** (0.50 g, 1.8 mmol, 1.0 equiv.) in dry DMF (18 mL) under N₂ atmosphere were added Ba(OH)₂ (1.2 g, 7.0 mmol, 4.0 equiv.) and BnBr (0.62 mL, 5.2 mmol, 3.0 equiv.). The mixture was stirred at room temperature for 16 hrs. and then cooled to 0 °C and neutralized with 1M aqueous HCl (7 mL). The reaction was allowed to warm to room temperature, diluted with brine (20 mL) and extracted twice with CH₂Cl₂ (2 × 40 mL). The combined organic layers were dried over MgSO₄, filtered, and concentrated *in vacuo*. The resulting crude product was purified by automated flash column chromatography (30-70% EtOAc/hexane) to afford allyl 2-acetamido-6-azido-3,4-di-O-benzyl-2,6-dideoxy-D-glucopyranoside **S10** as a white solid (0.70 g, 1.5 mmol, 86%).

Characterisation data were in accordance with literature values.²¹

2-acetamido-6-azido-3,4-di-O-benzyl-2,6-dideoxy-D-glucopyranose (**12**)

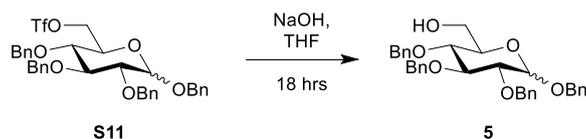


To a solution of **S10** (0.31 g, 0.66 mmol, 1.0 equiv.) in MeOH (7 mL) under N₂ atmosphere was added PdCl₂ (23 mg, 0.13 mmol, 0.2 equiv.). The mixture was stirred at room temperature for 16 hrs. and then filtered through a small pad of silica gel and washed with acetone. The filtrate was concentrated *in vacuo*. The resulting crude product was purified by automated flash column chromatography (40-80% EtOAc/hexane) to afford 2-acetamido-6-azido-3,4-di-O-benzyl-2,6-dideoxy-D-glucopyranose **12** as a white solid (0.20 g, 0.46 mmol, 70%).

Characterisation data were in accordance with literature values.²¹

Recovery of starting material **5** from triflated side-product

During the phosphorylation reaction, we observed the formation of a triflated byproduct (**S11**). We demonstrated that this can be hydrolysed back to starting material using sodium hydroxide, as described below.



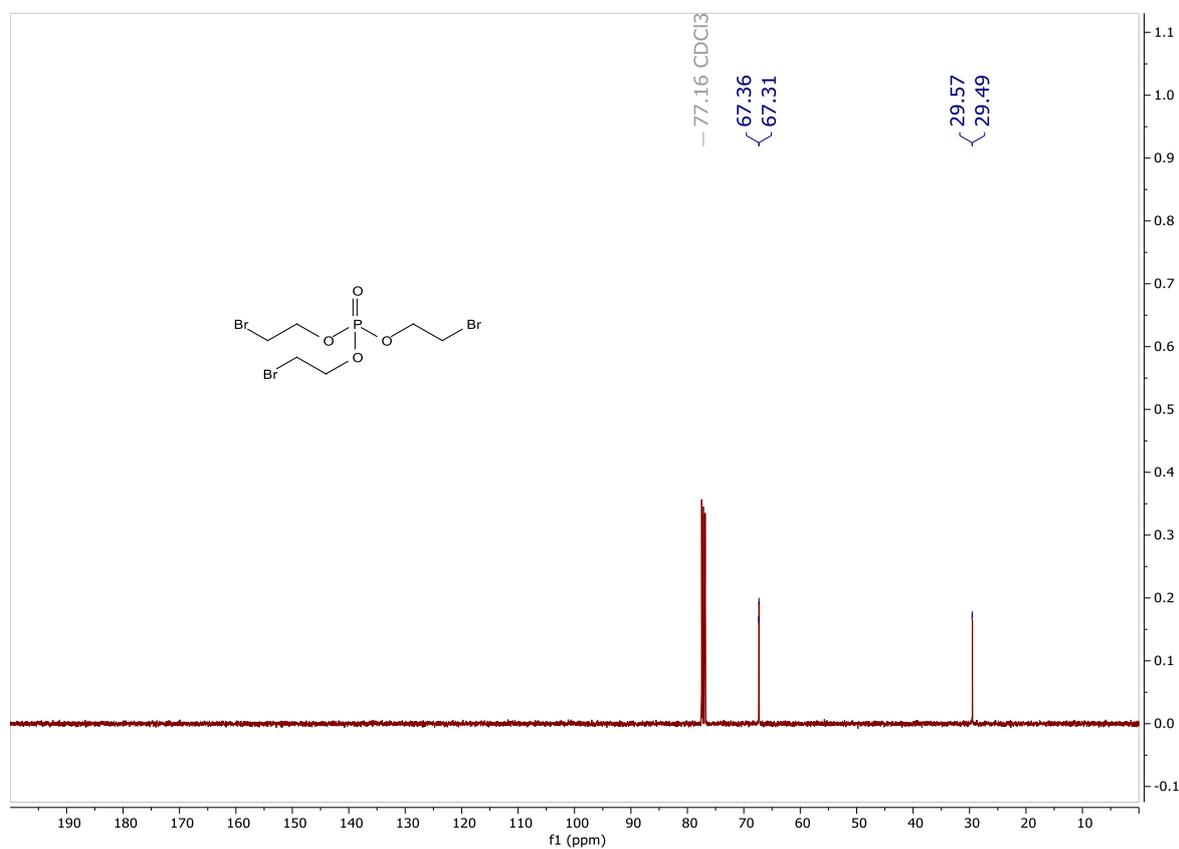
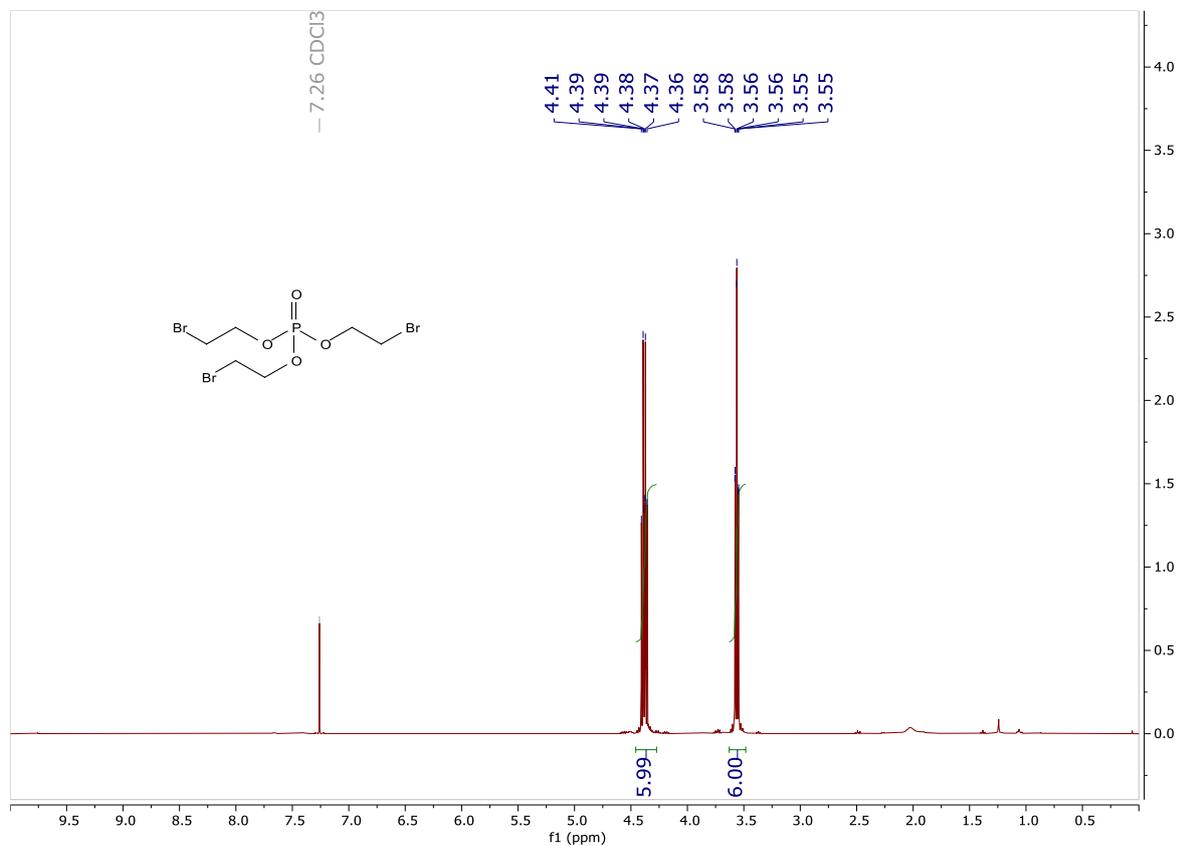
To a stirring solution of the side-product **S11** (30 mg, 44 μmol, 1.0 equiv.) in THF (2 mL) and MeOH (2 mL) was added 1M NaOH (0.15 mL). After 18 hrs. the reaction was quenched by the addition of DOWEX H⁺ resin, washed with MeOH and filtered. The resulting solution was concentrated *in vacuo* and the product was analysed by ¹H, ¹³C NMR and MS to show **5** in a yield of 59%.

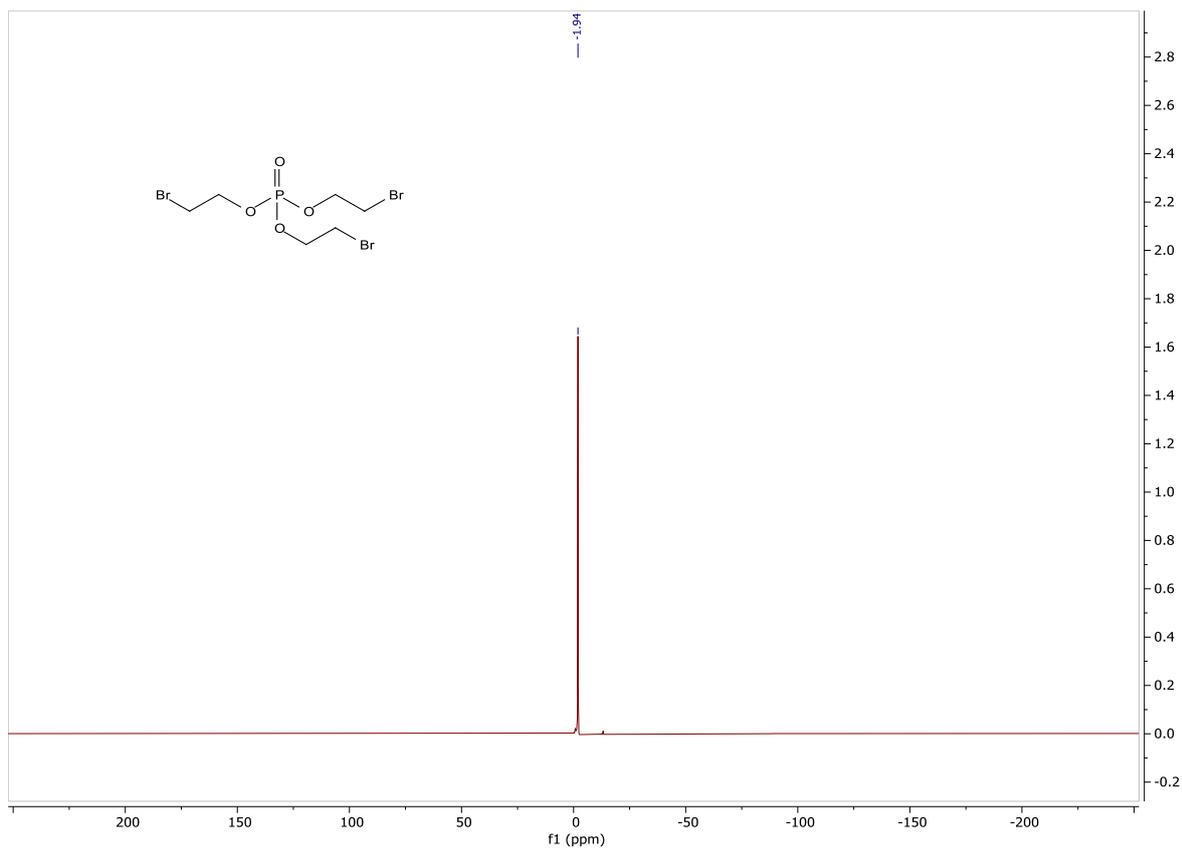
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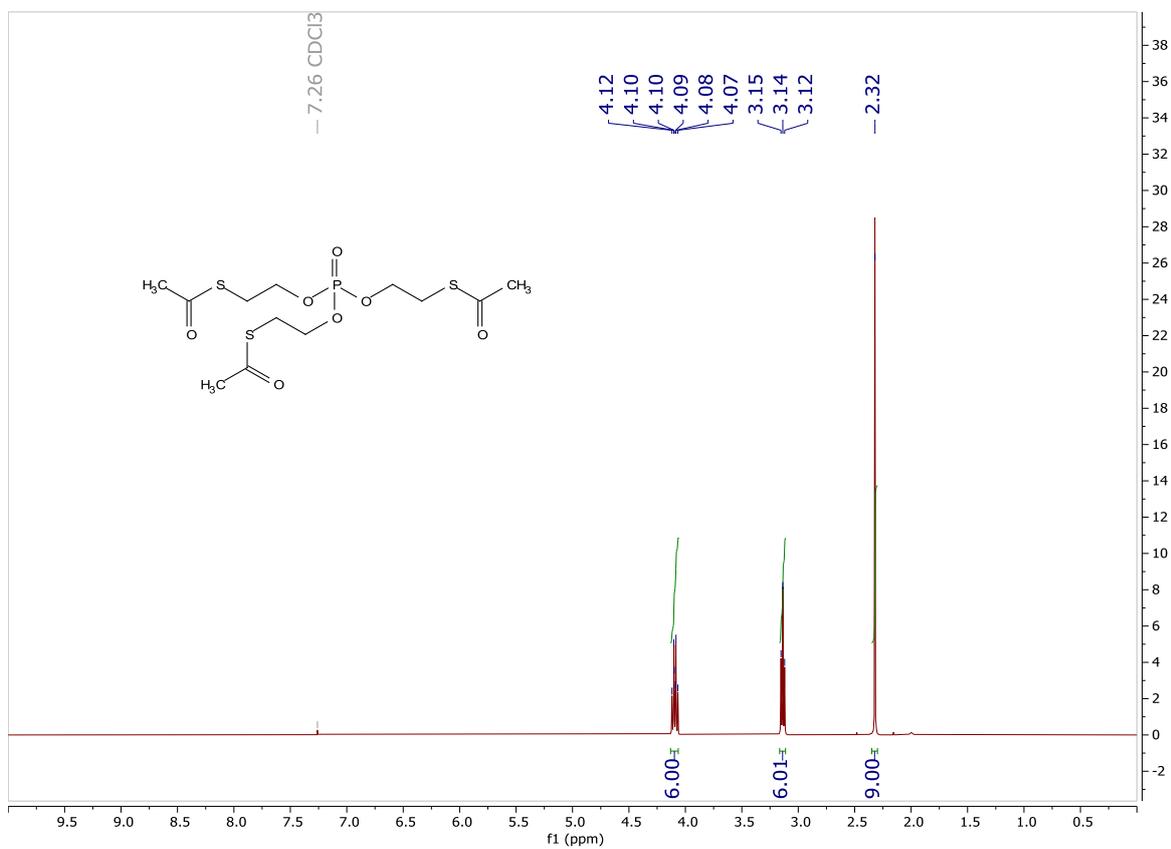
NMR spectra of novel compounds

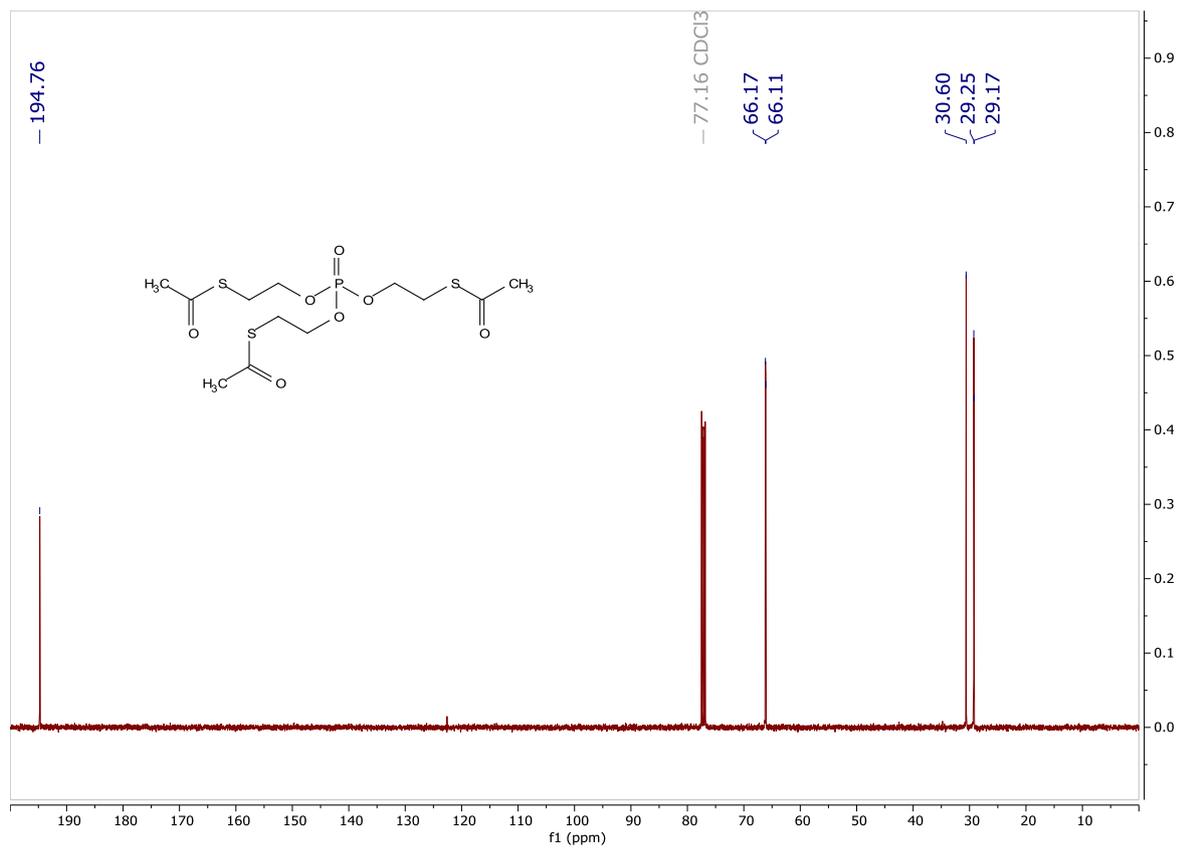
tris(2-bromoethyl)phosphate



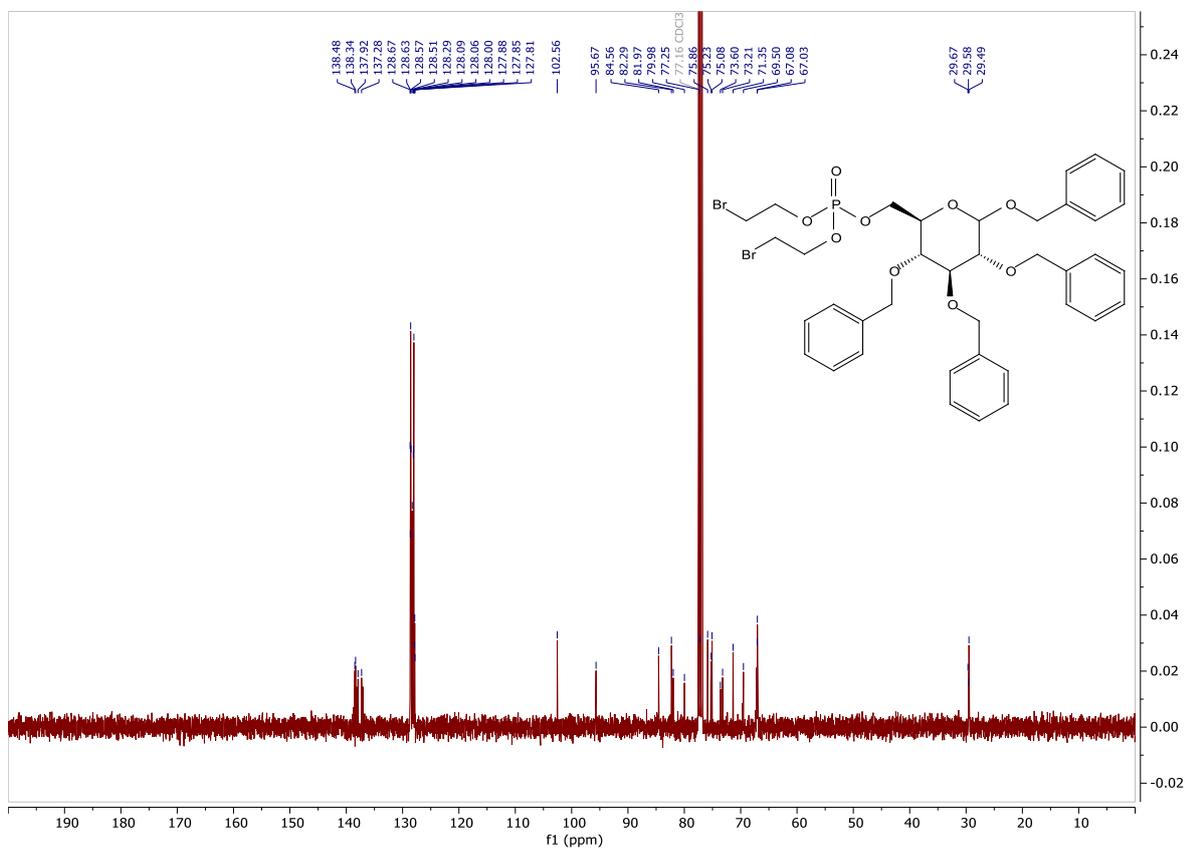
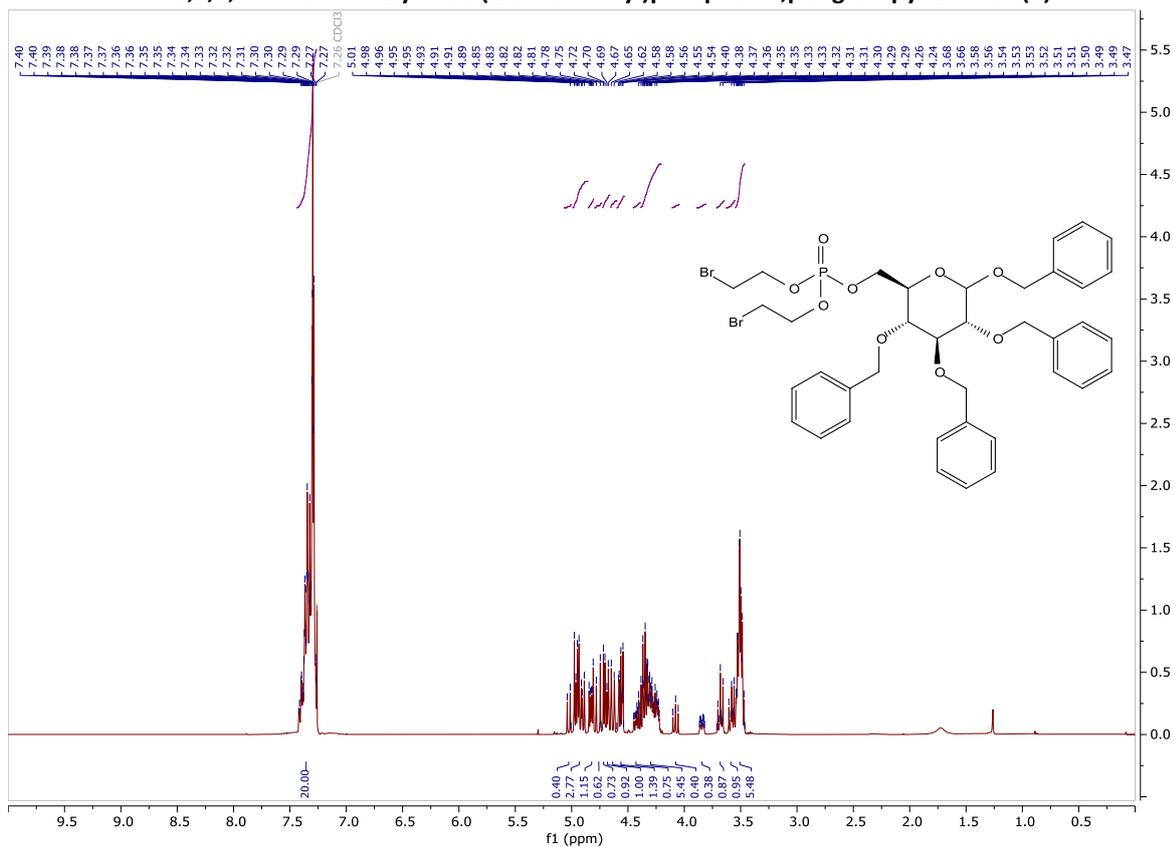


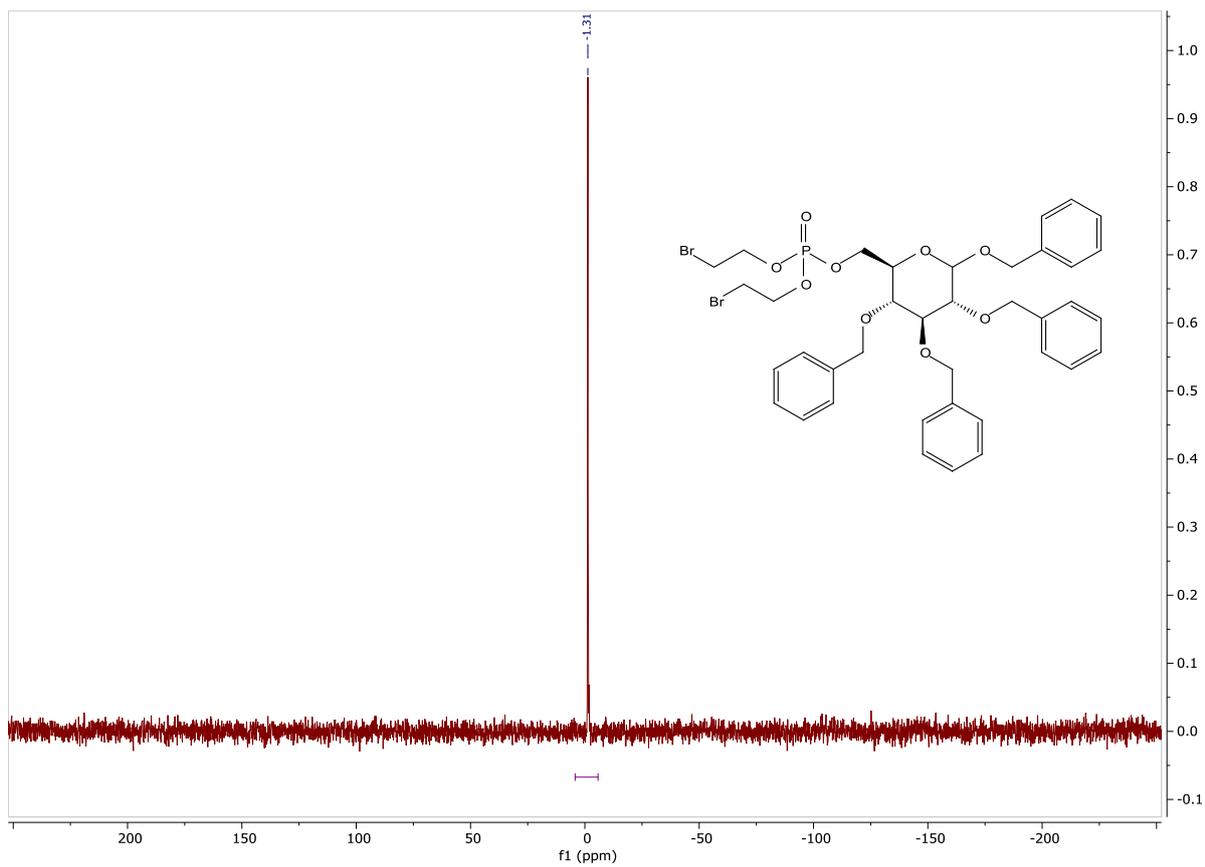
tris(SATE)phosphate (4)



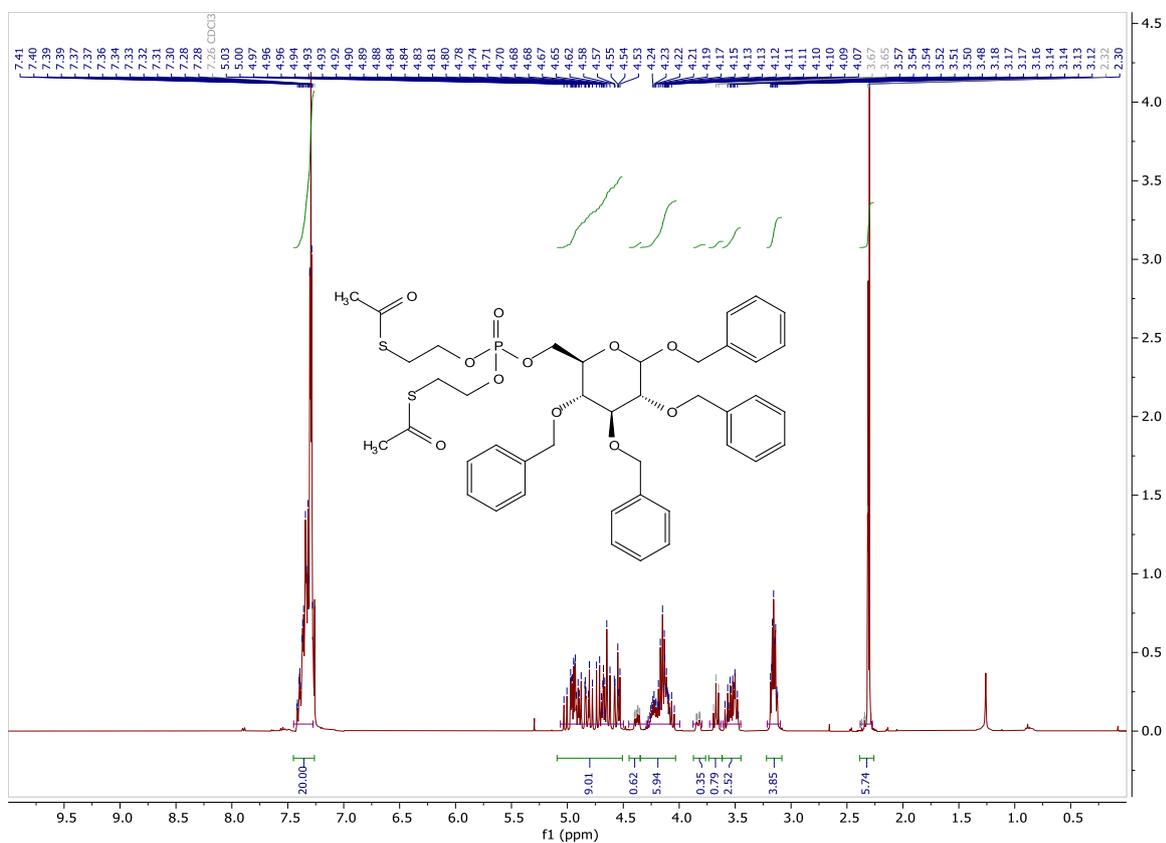


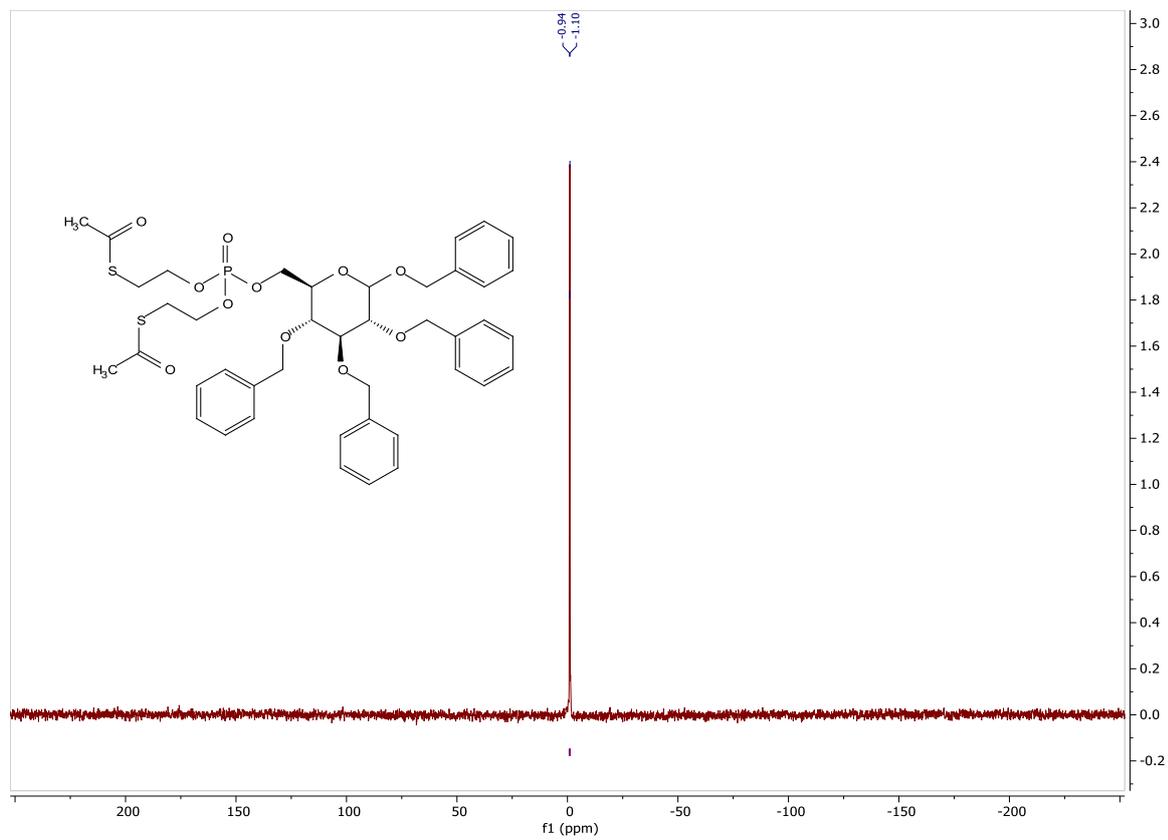
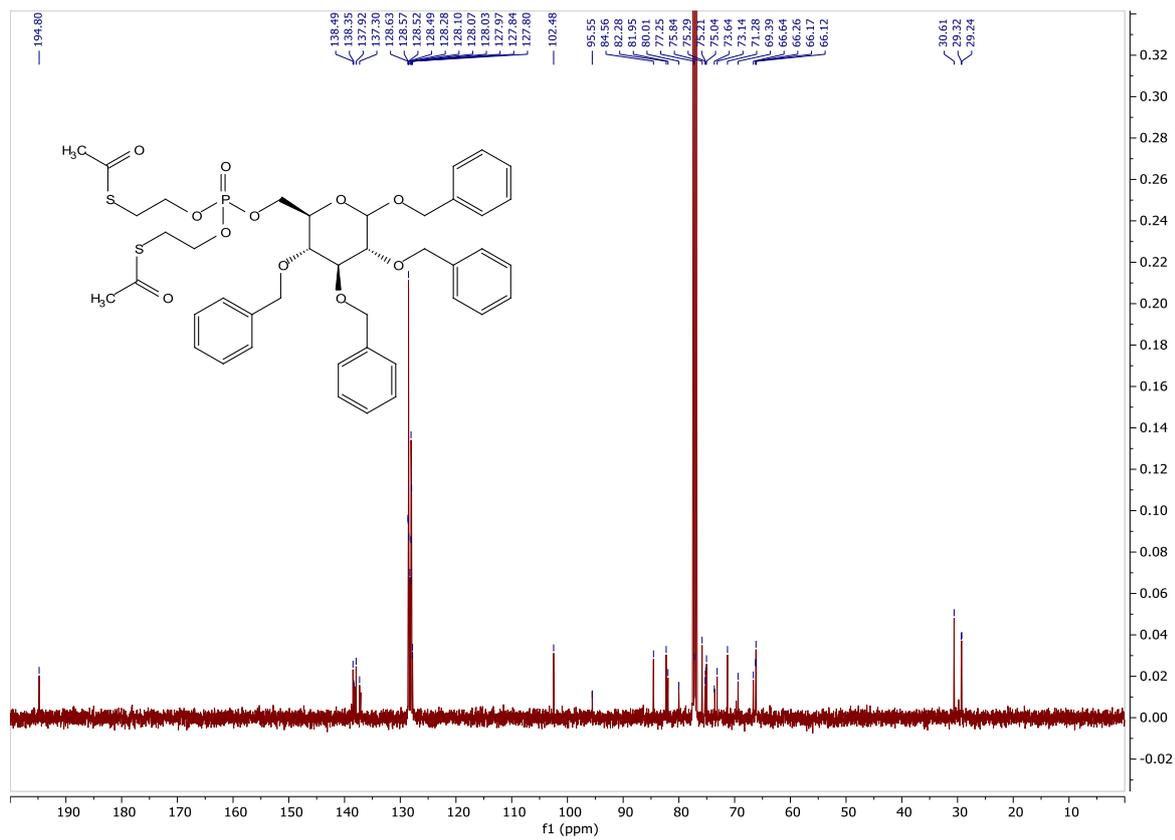
1,2,3,4-tetra-O-benzyl-6-bis(2-bromoethyl)phosphor- α,β -D-glucopyranoside (7)



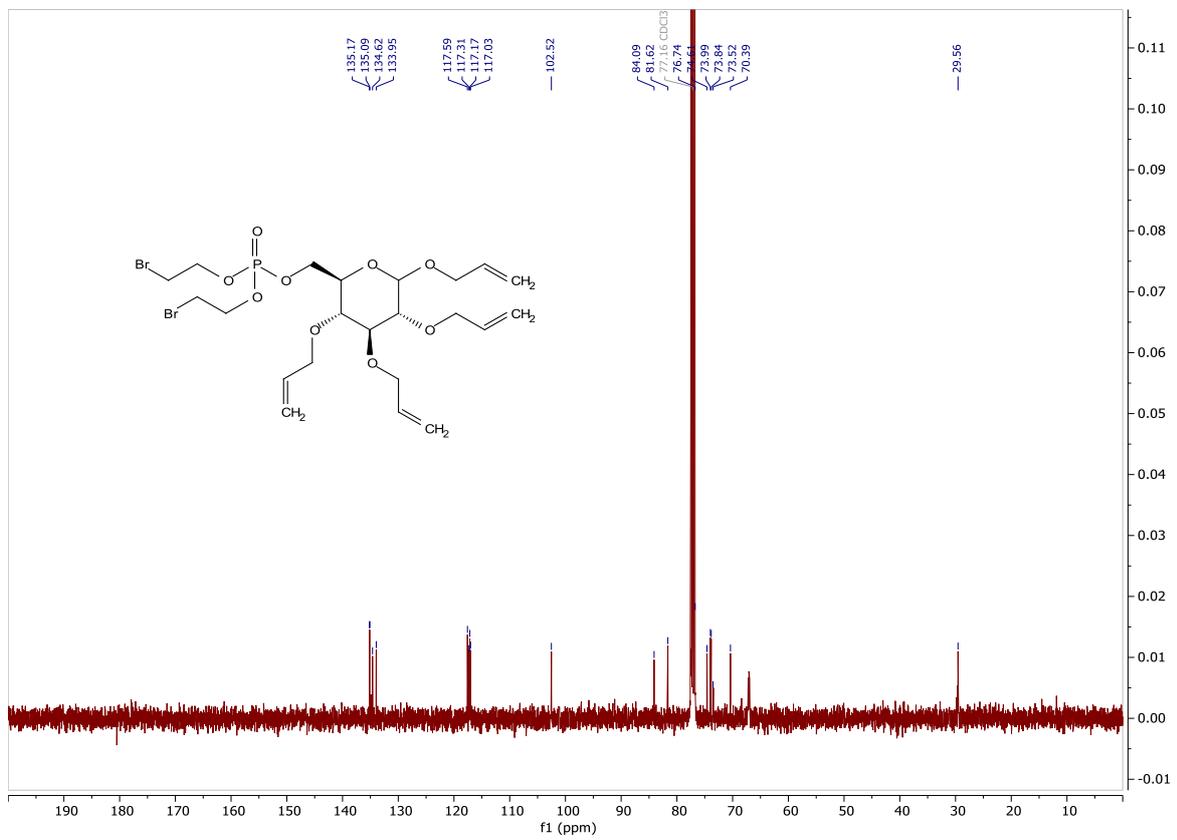
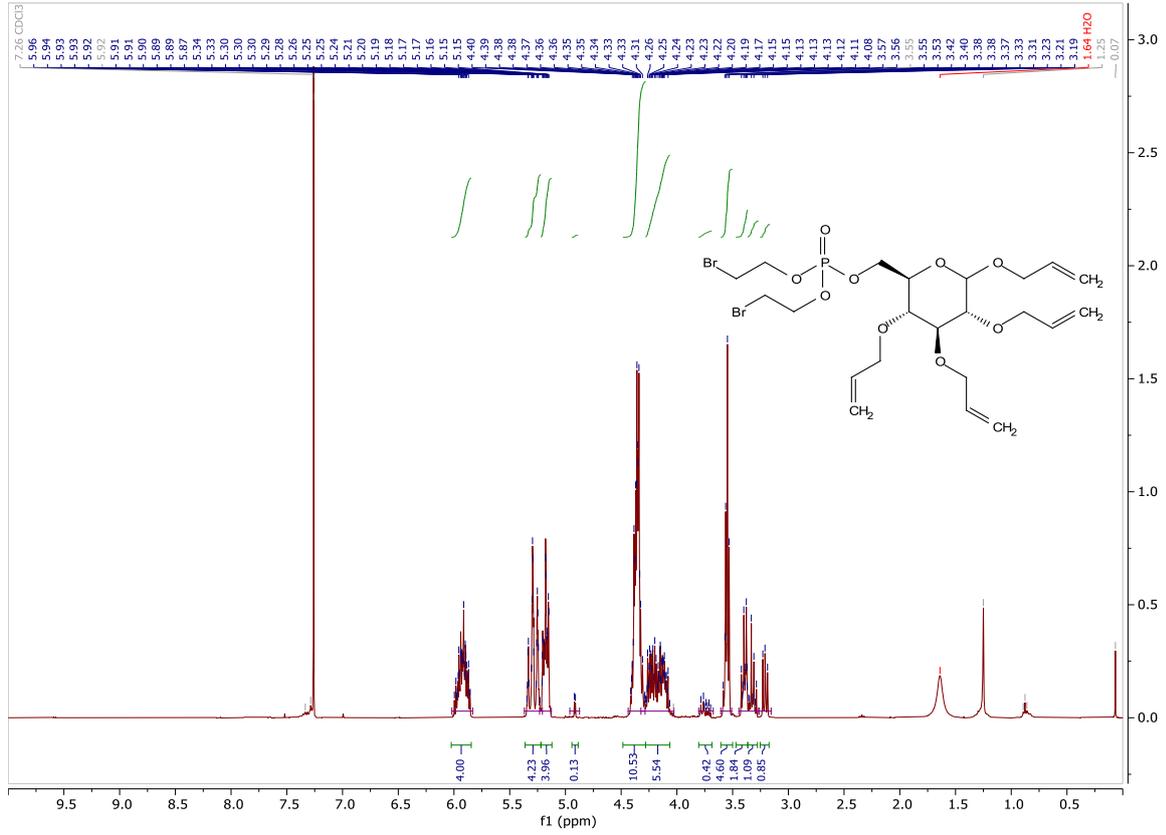


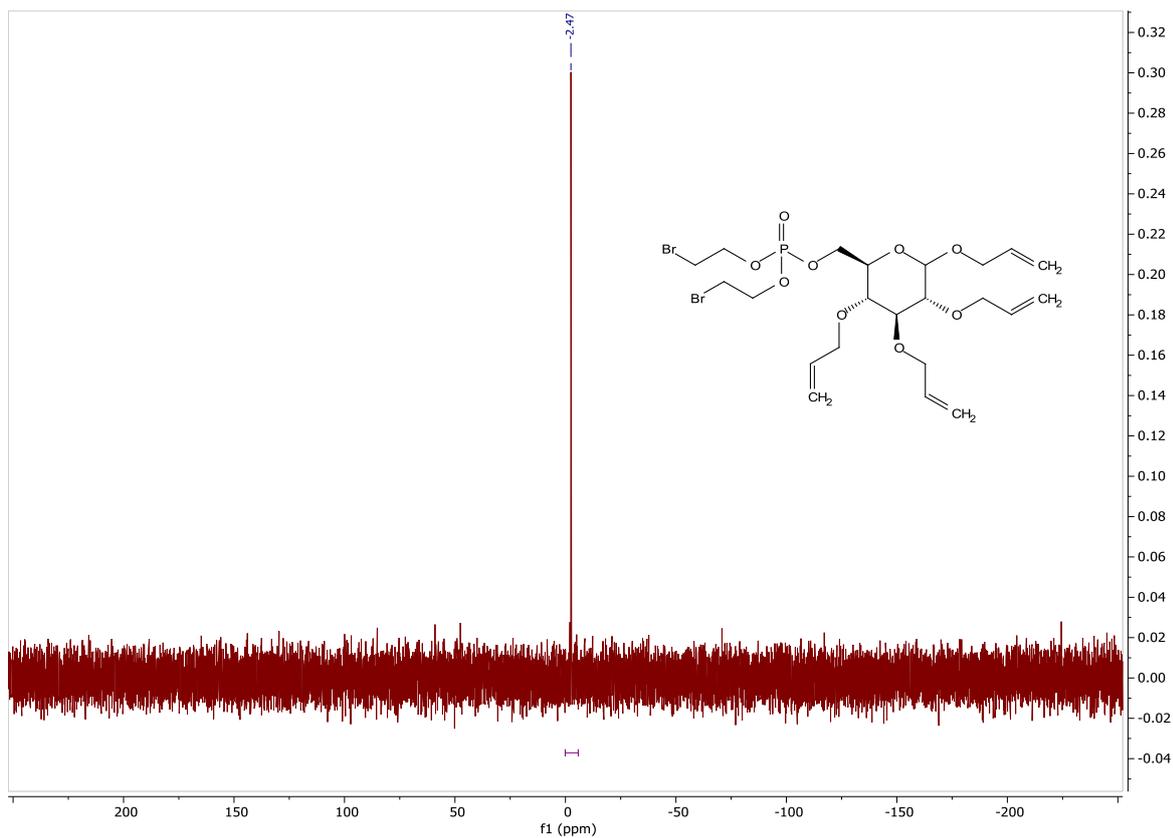
1,2,3,4-tetra-O-benzyl-6-bis(SATE)phosphor- α,β -D-glucopyranoside (6)



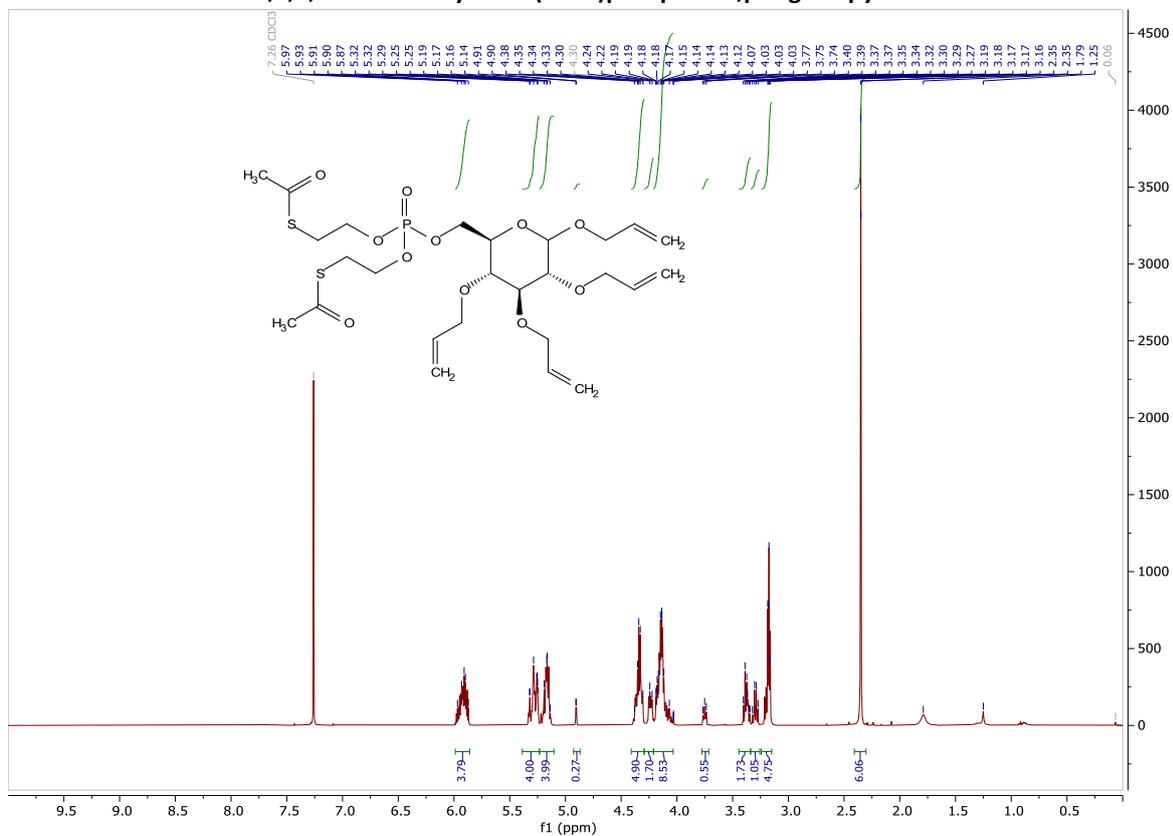


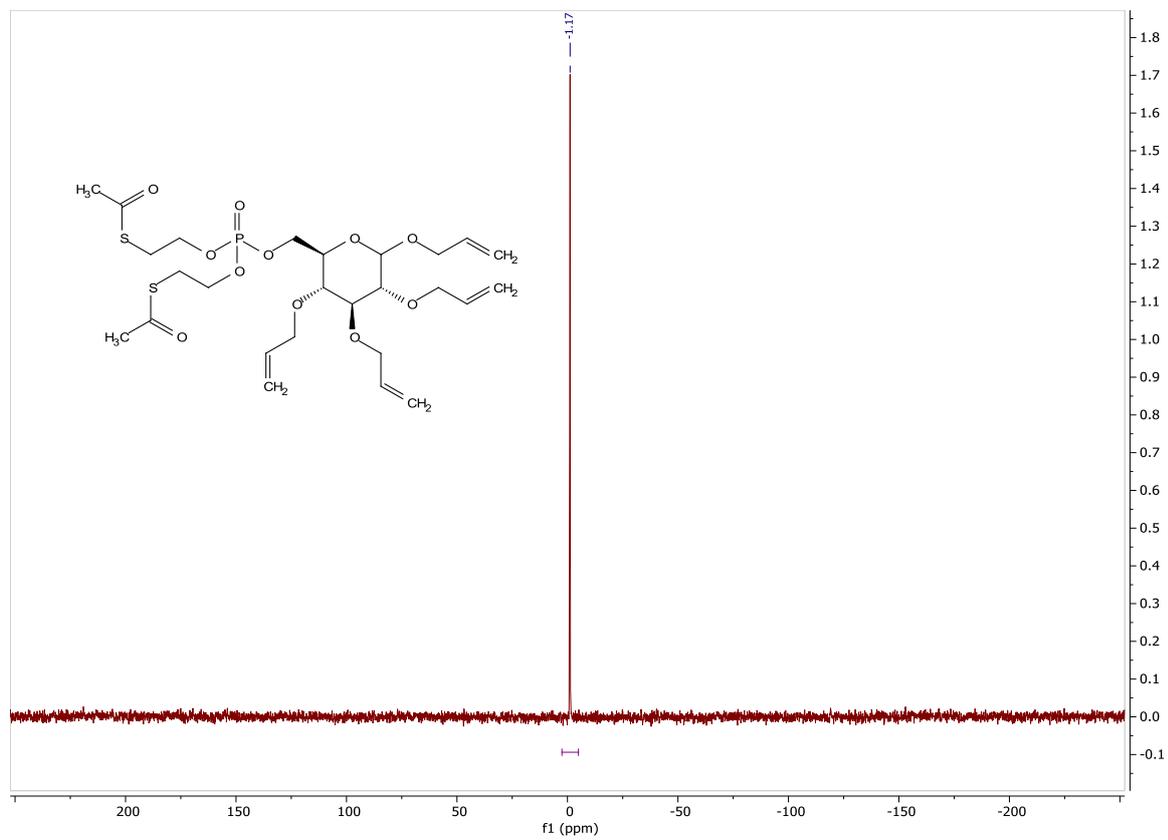
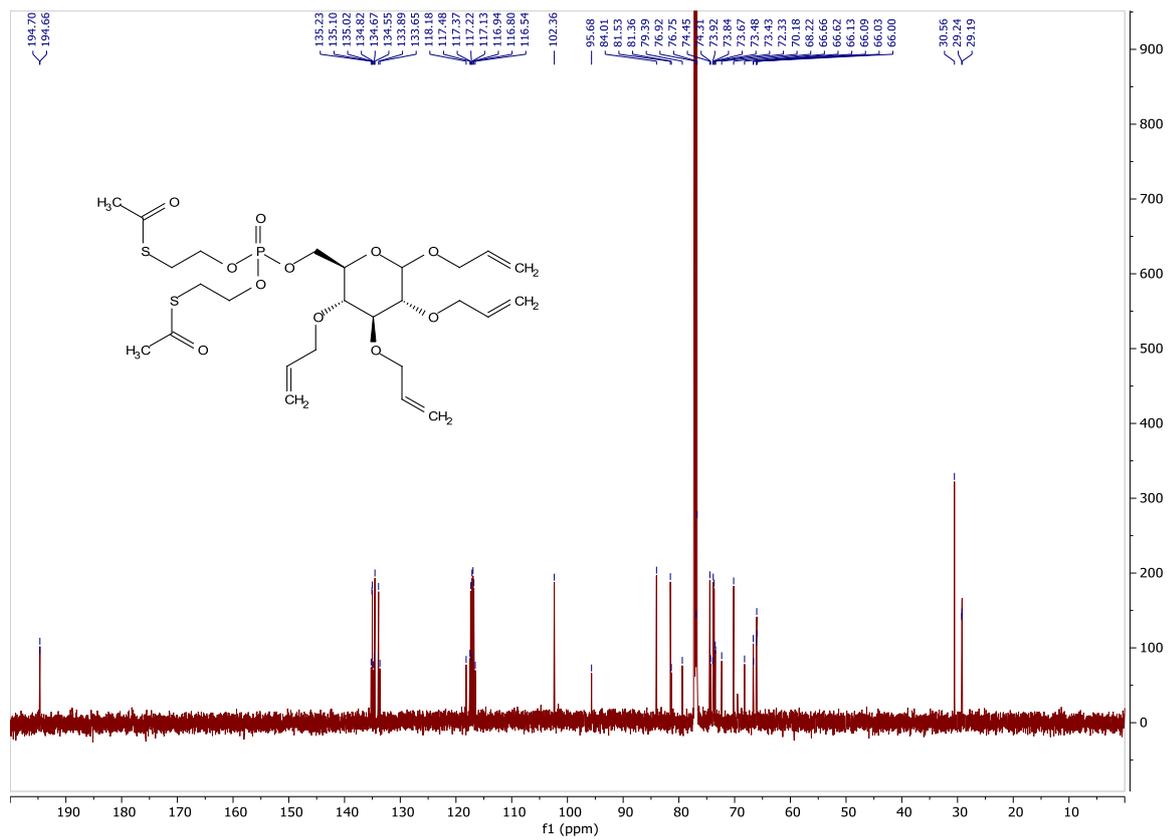
1,2,3,4-tetra-O-allyl-6-bis(2-bromoethyl)phosphor- α,β -D-glucopyranoside



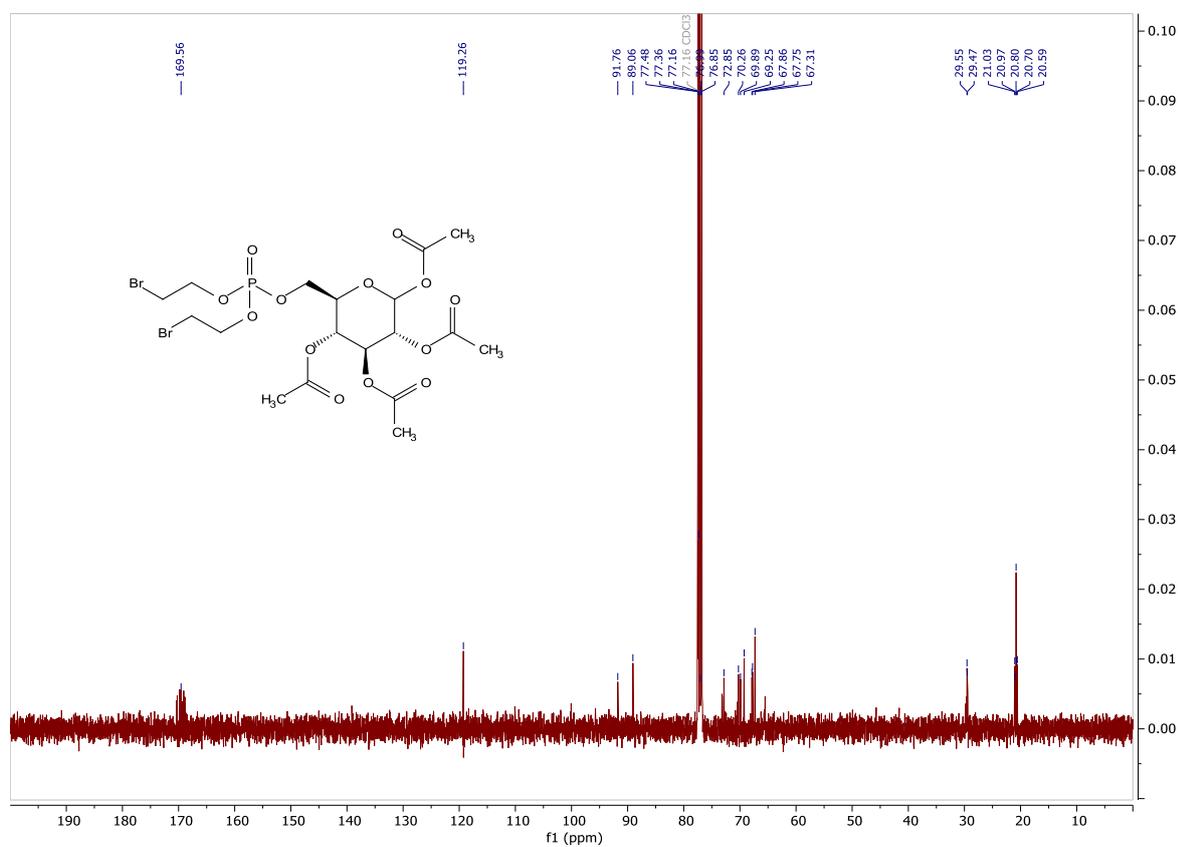
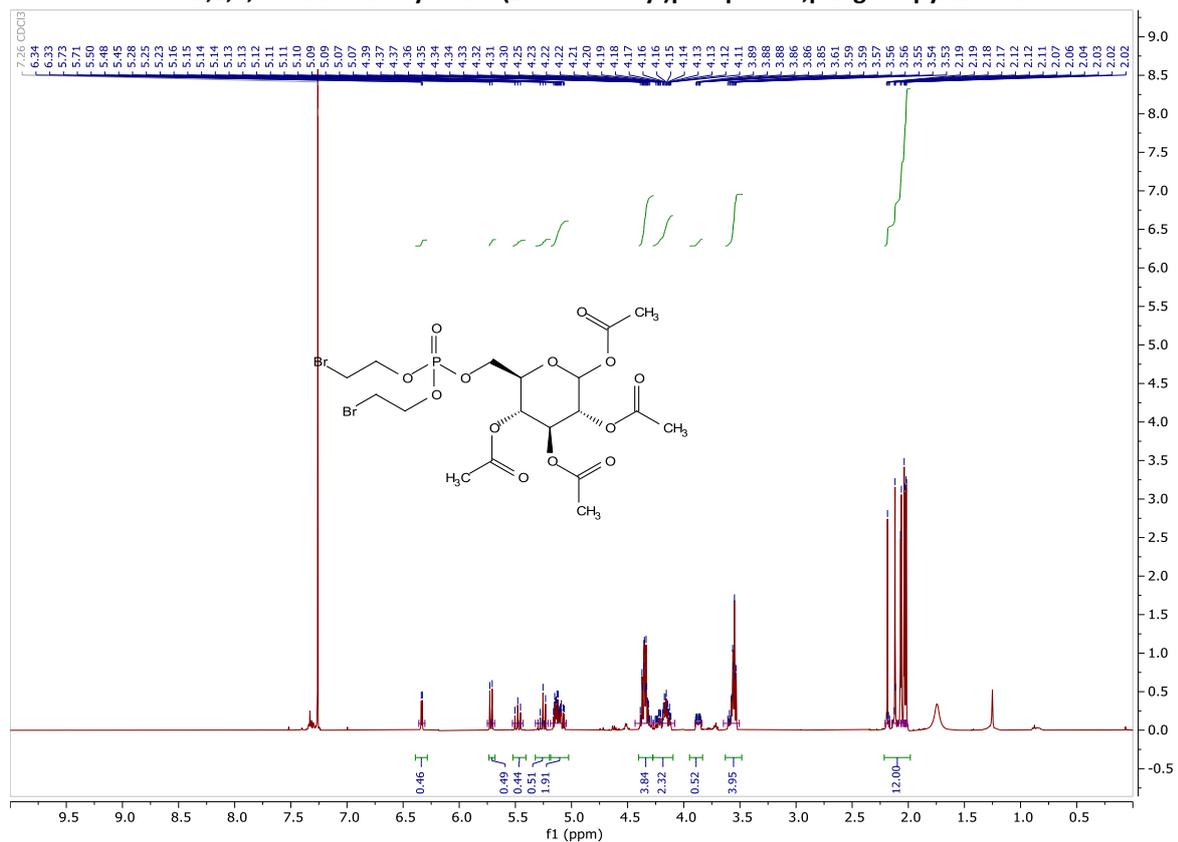


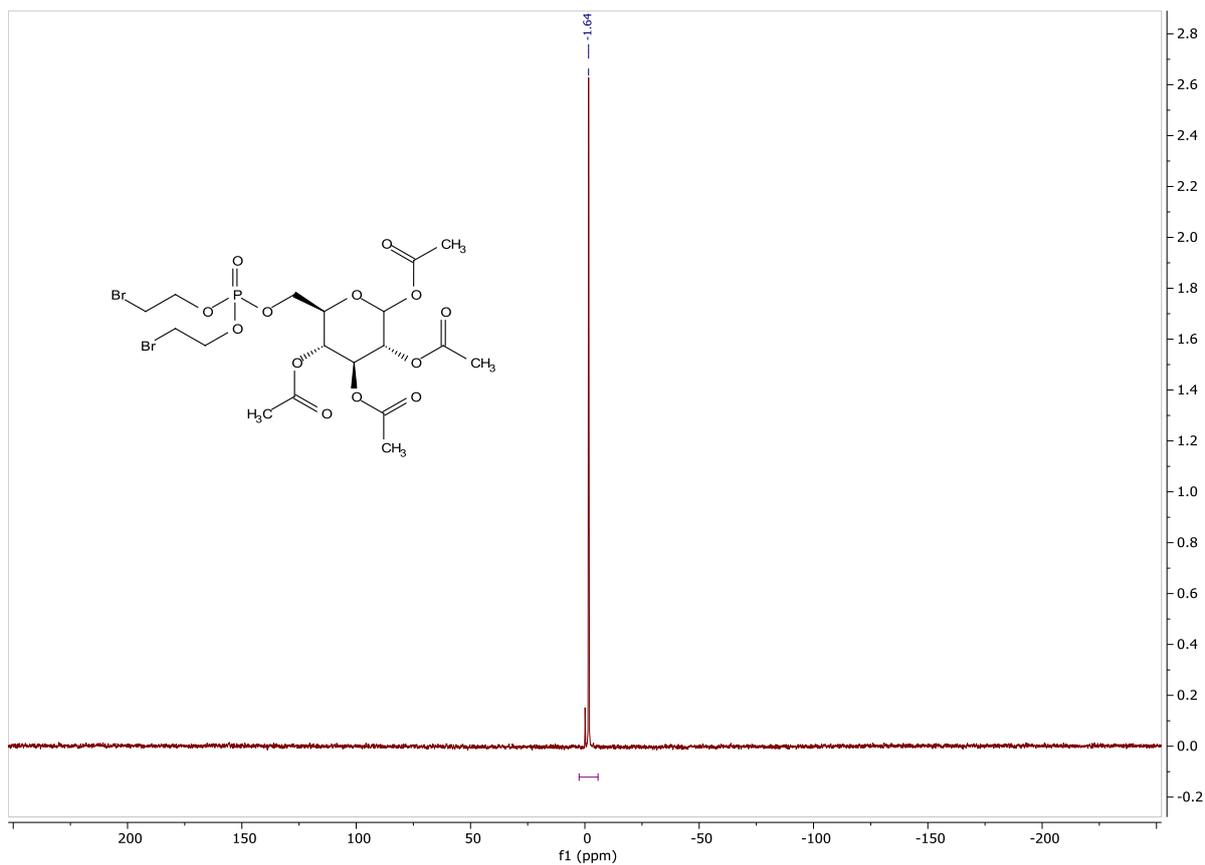
1,2,3,4-tetra-O-allyl-6-bis(SATE)phosphor- α,β -D-glucopyranoside



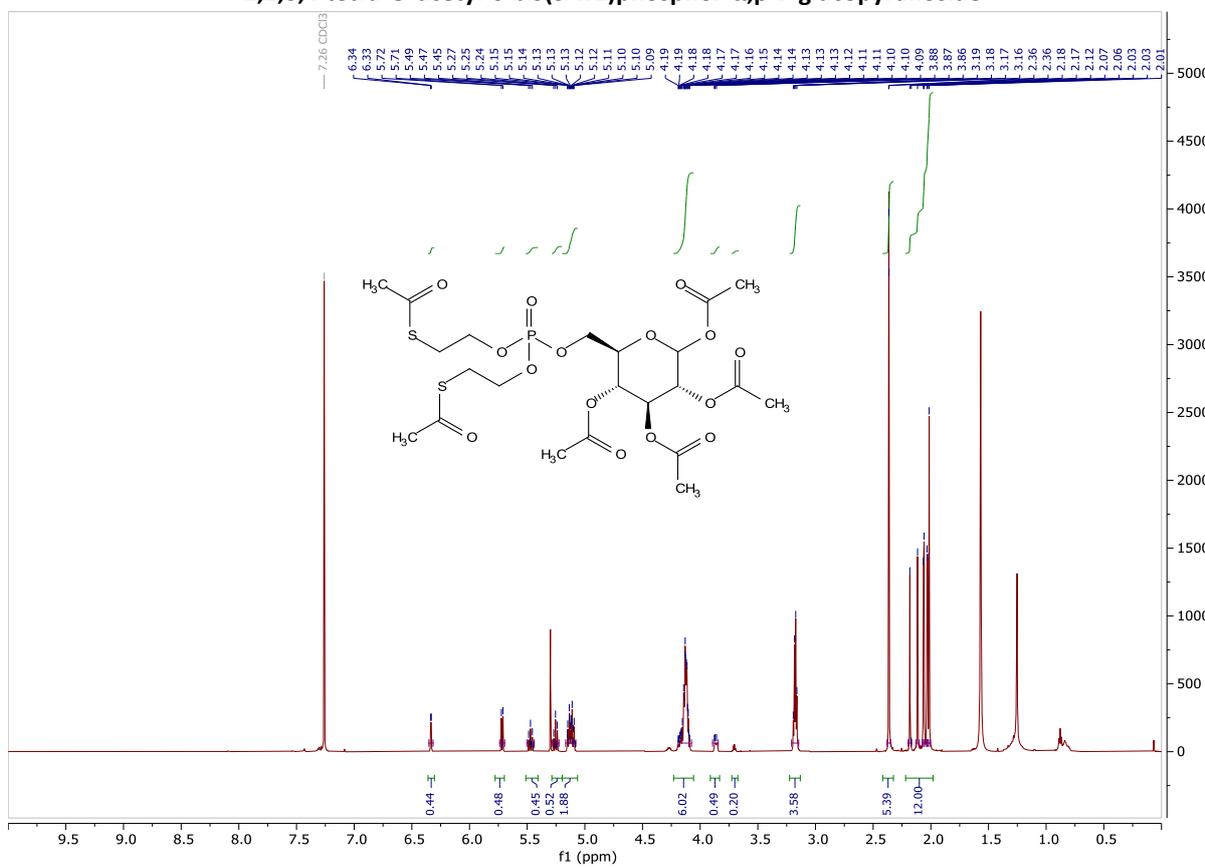


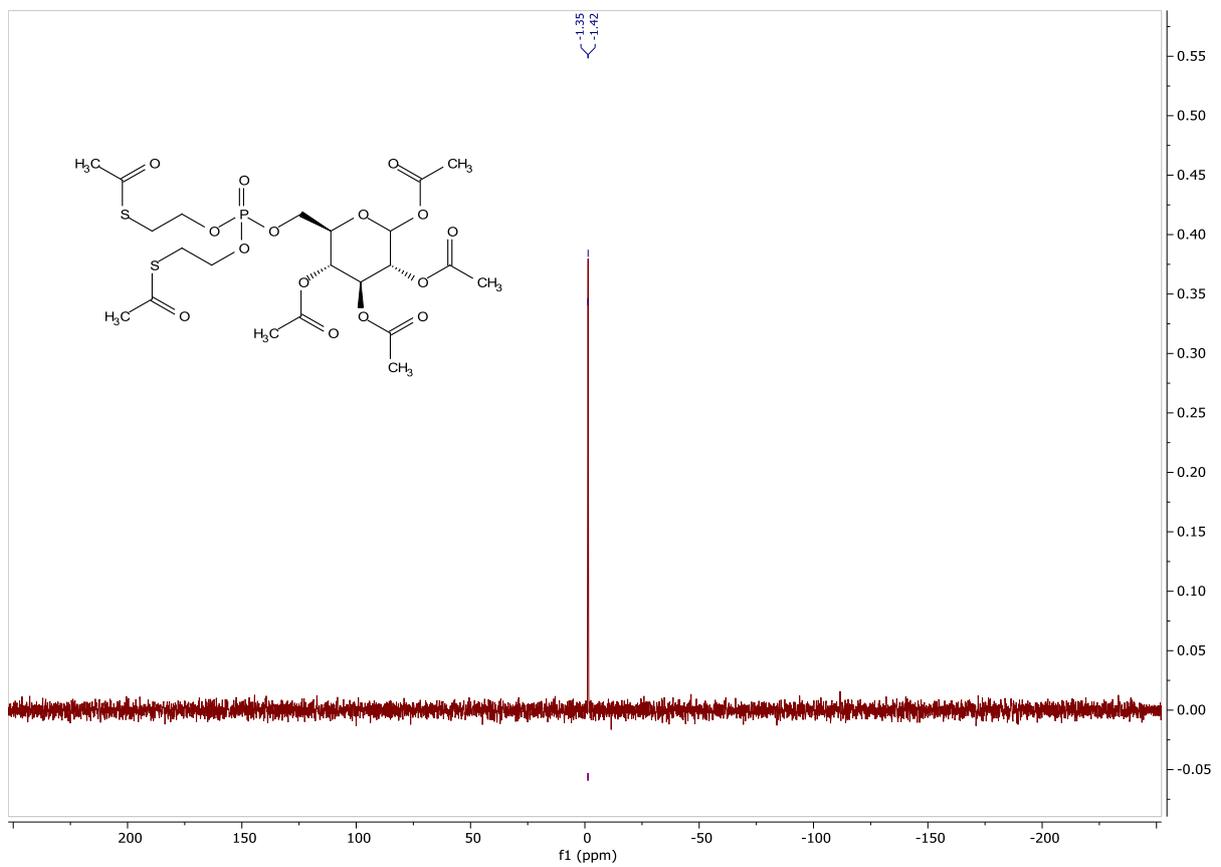
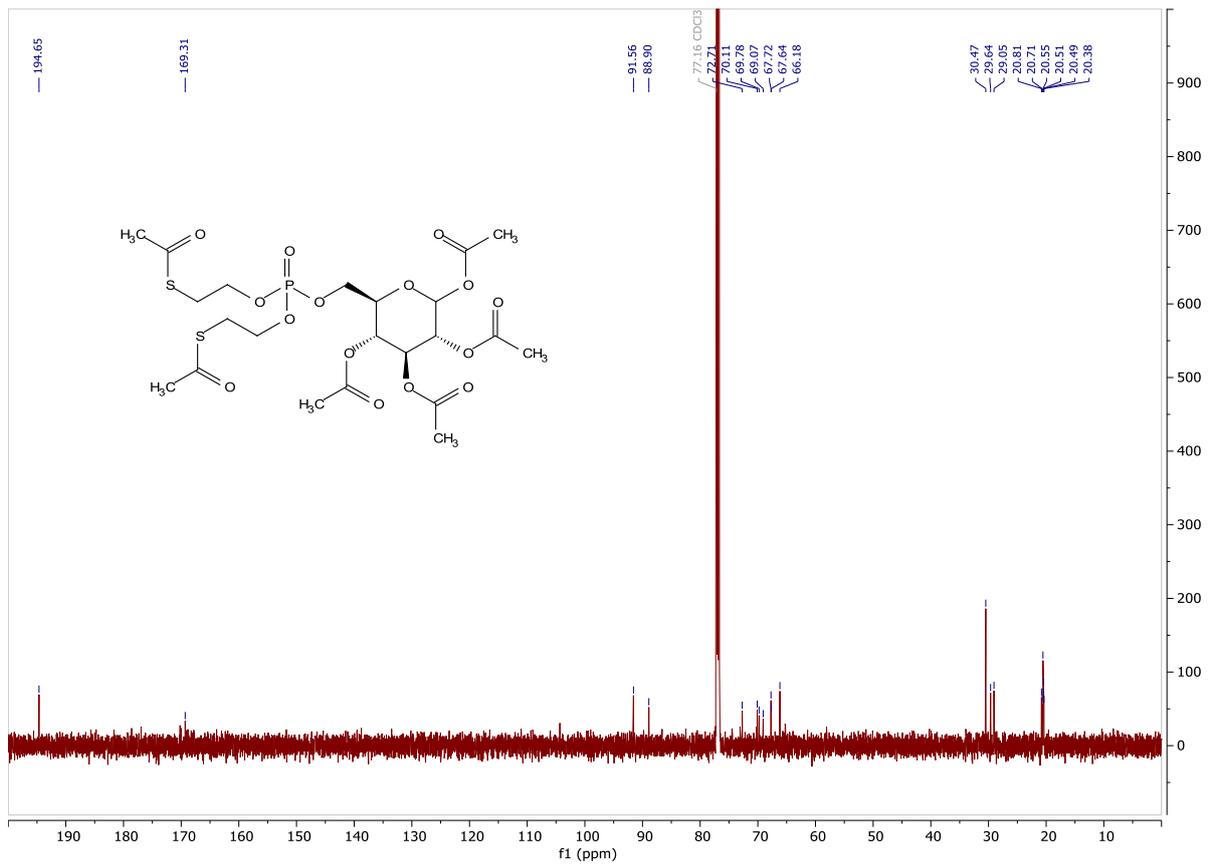
1,2,3,4-tetra-O-acetyl-6-bis-(2-bromoethyl)phosphor- α,β -D-glucopyranoside

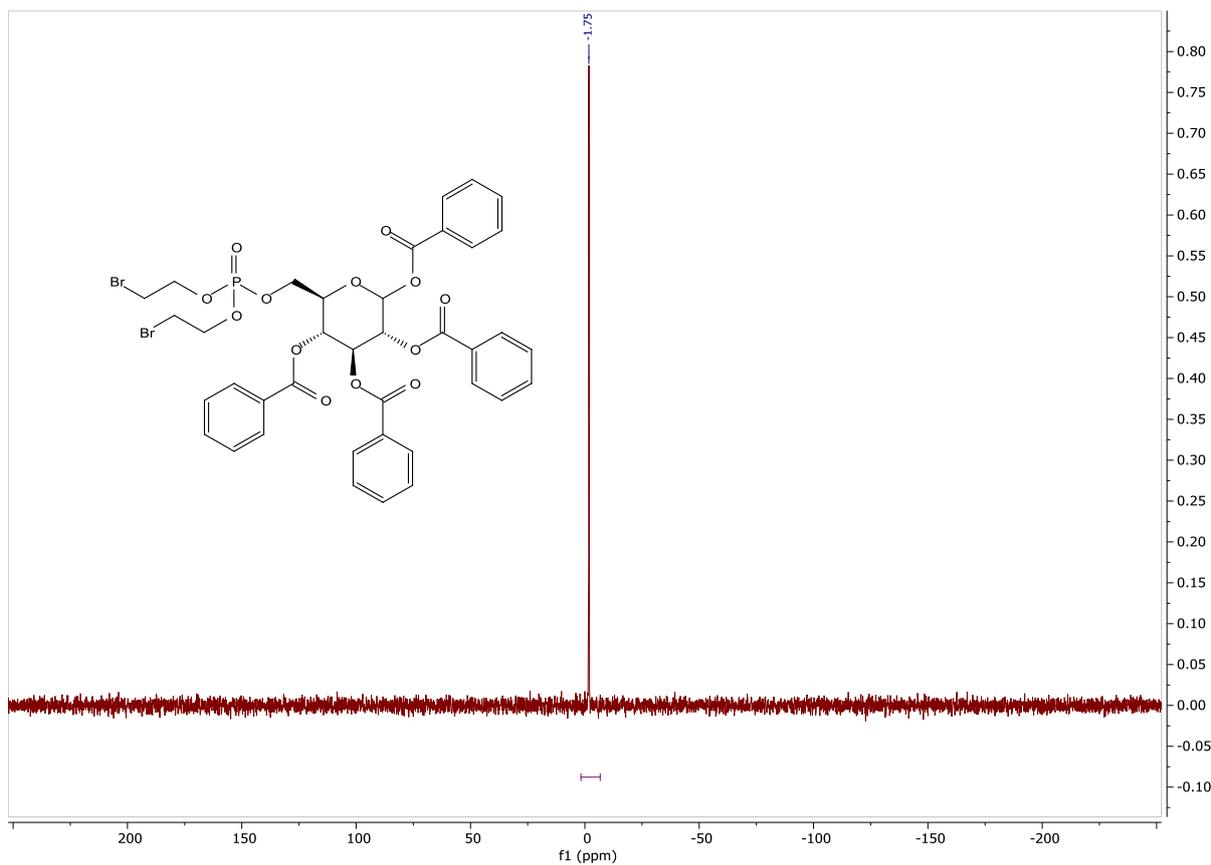




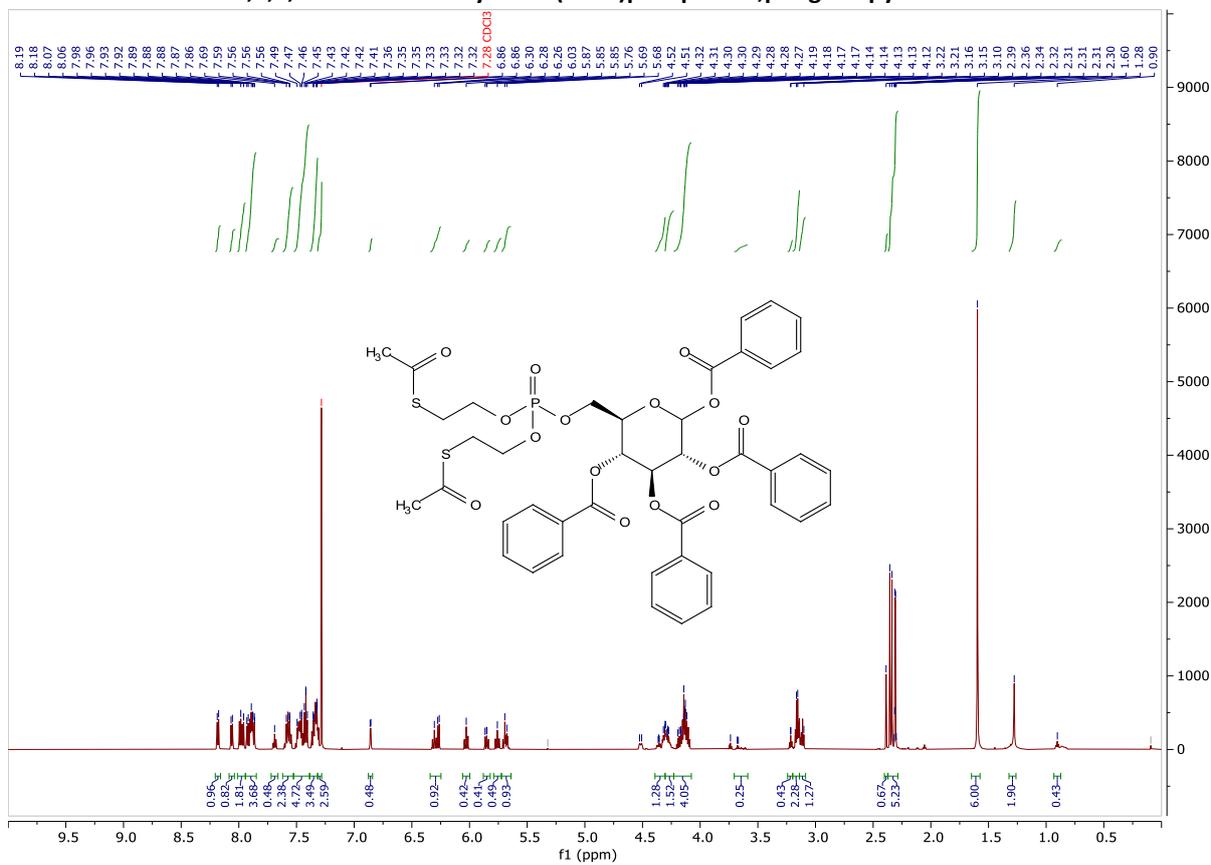
1,2,3,4-*O*-acetyl-6-*bis*(SATE)phosphor- α,β -D-glucopyranoside

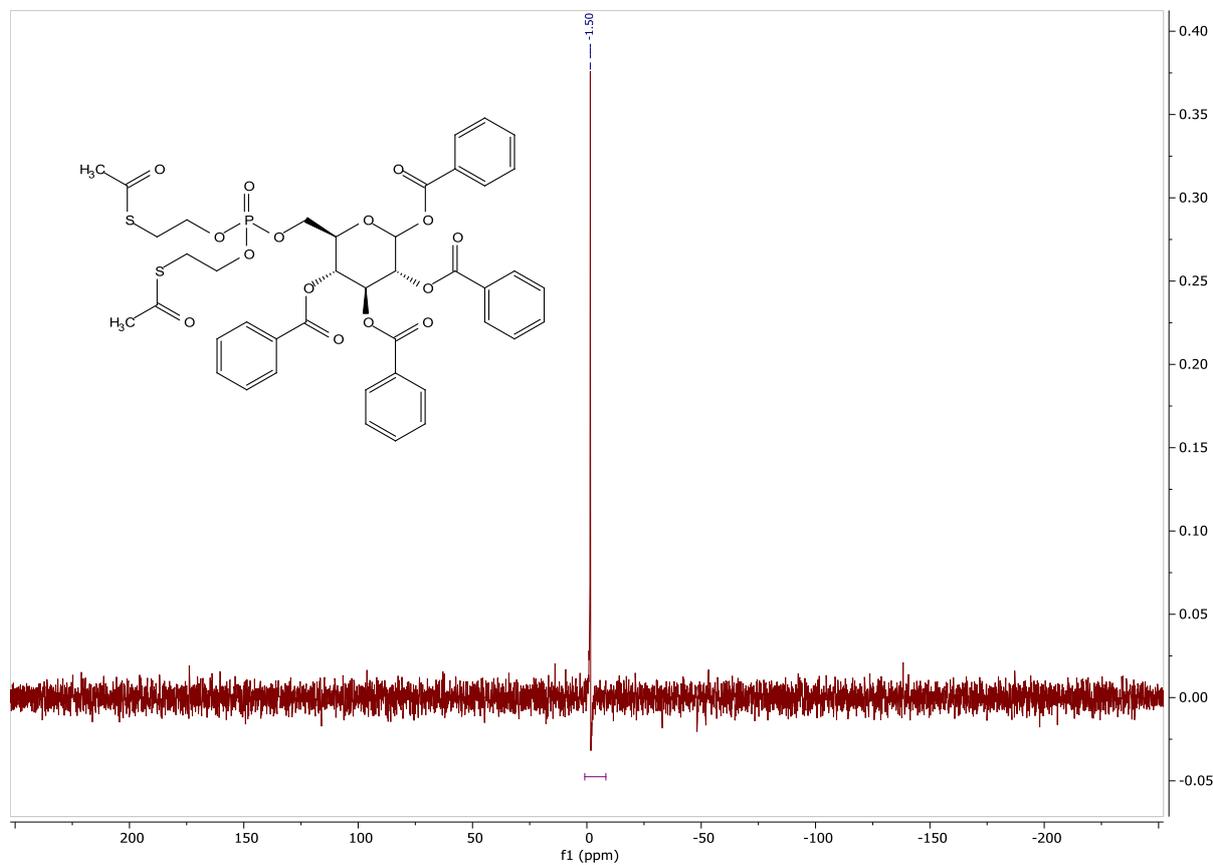
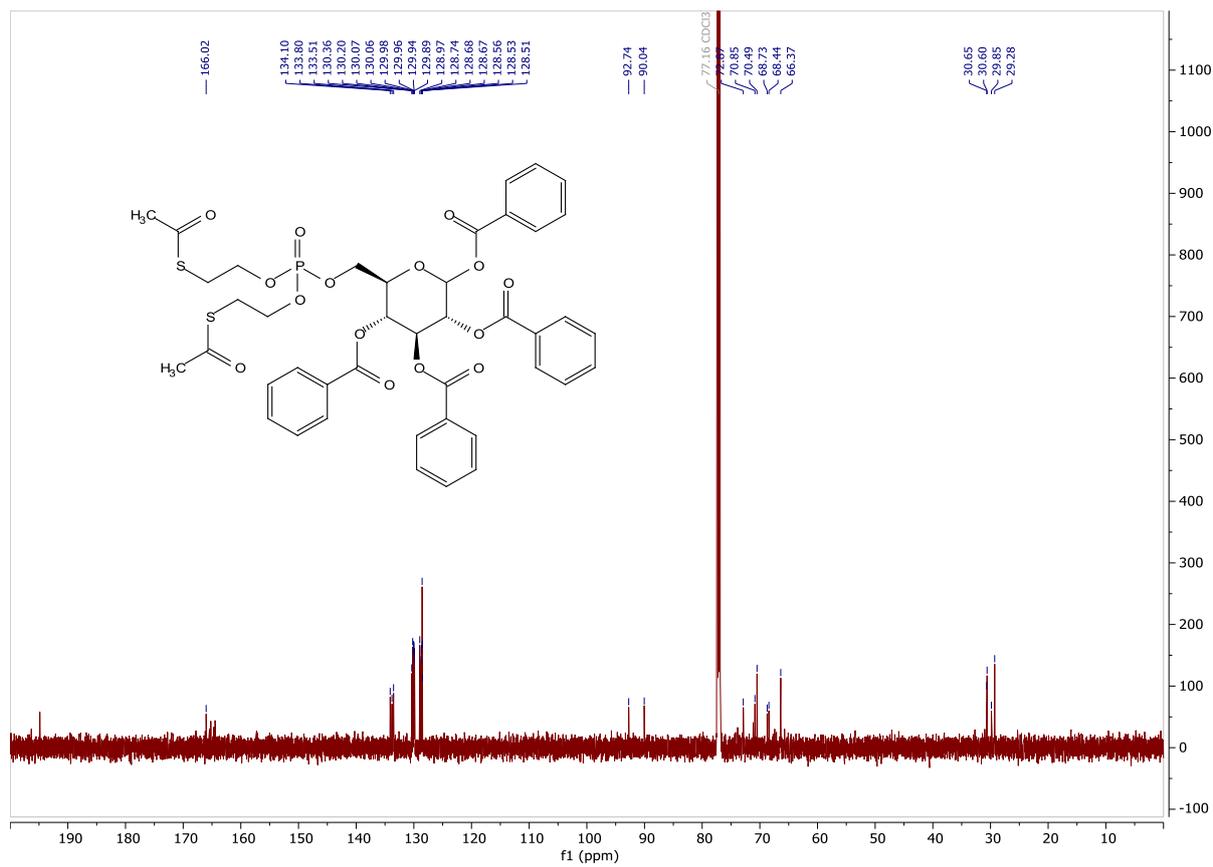




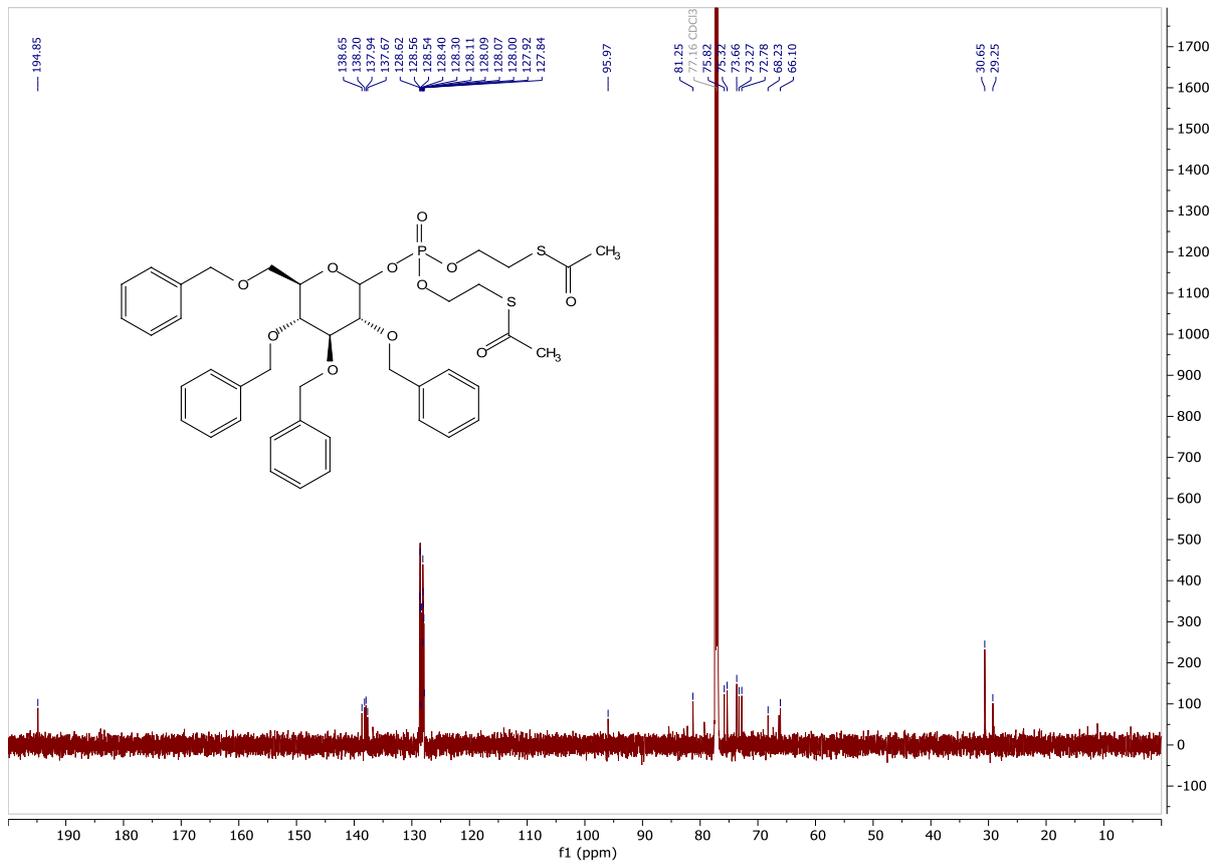
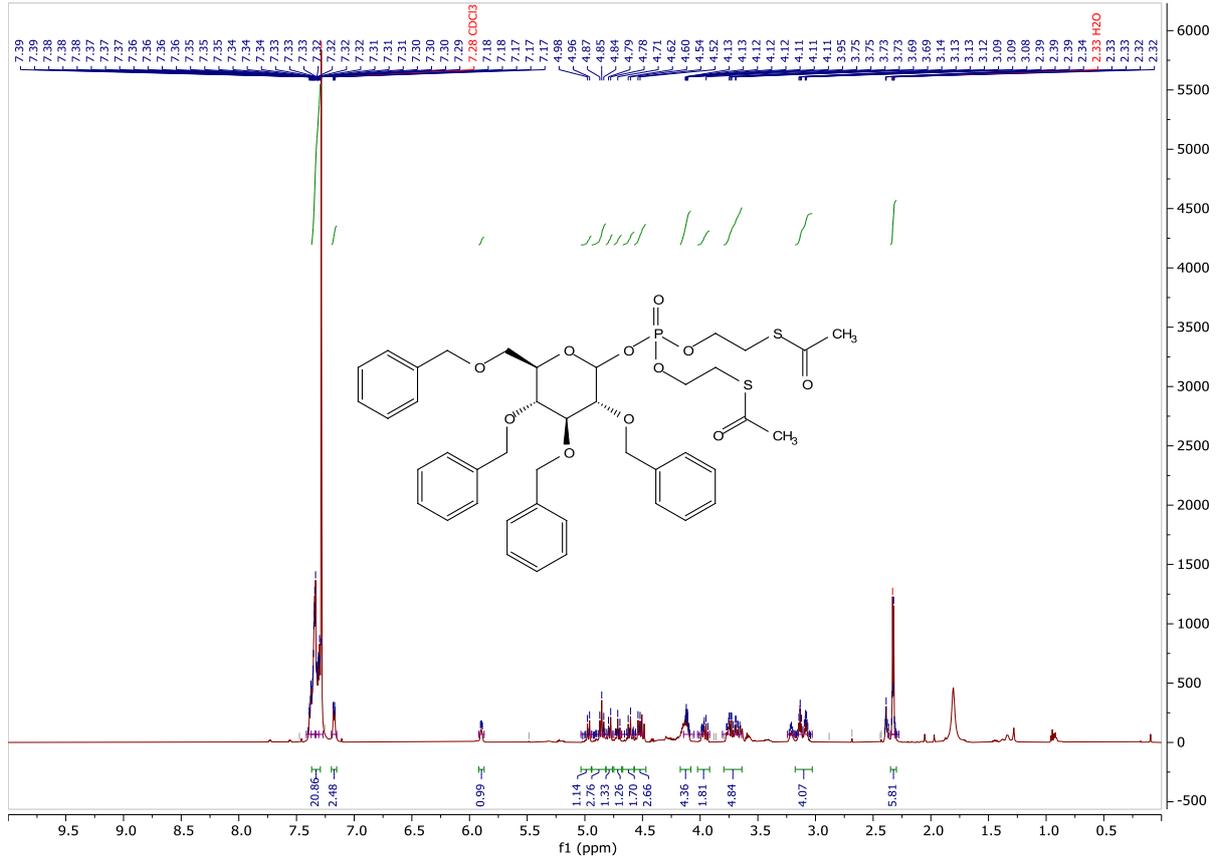


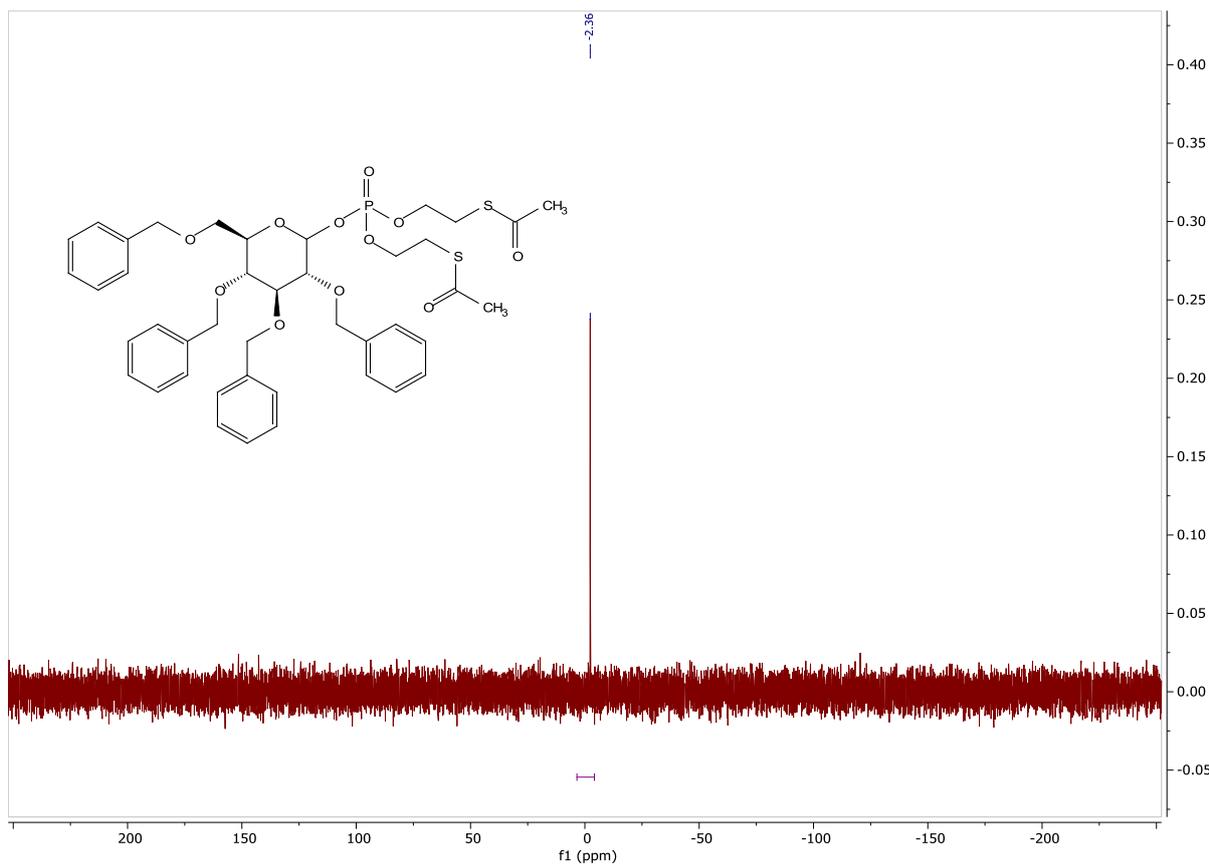
1,2,3,4-tetra-O-benzoyl-6-bis(SATE)phosphor- α,β -D-glucopyranoside



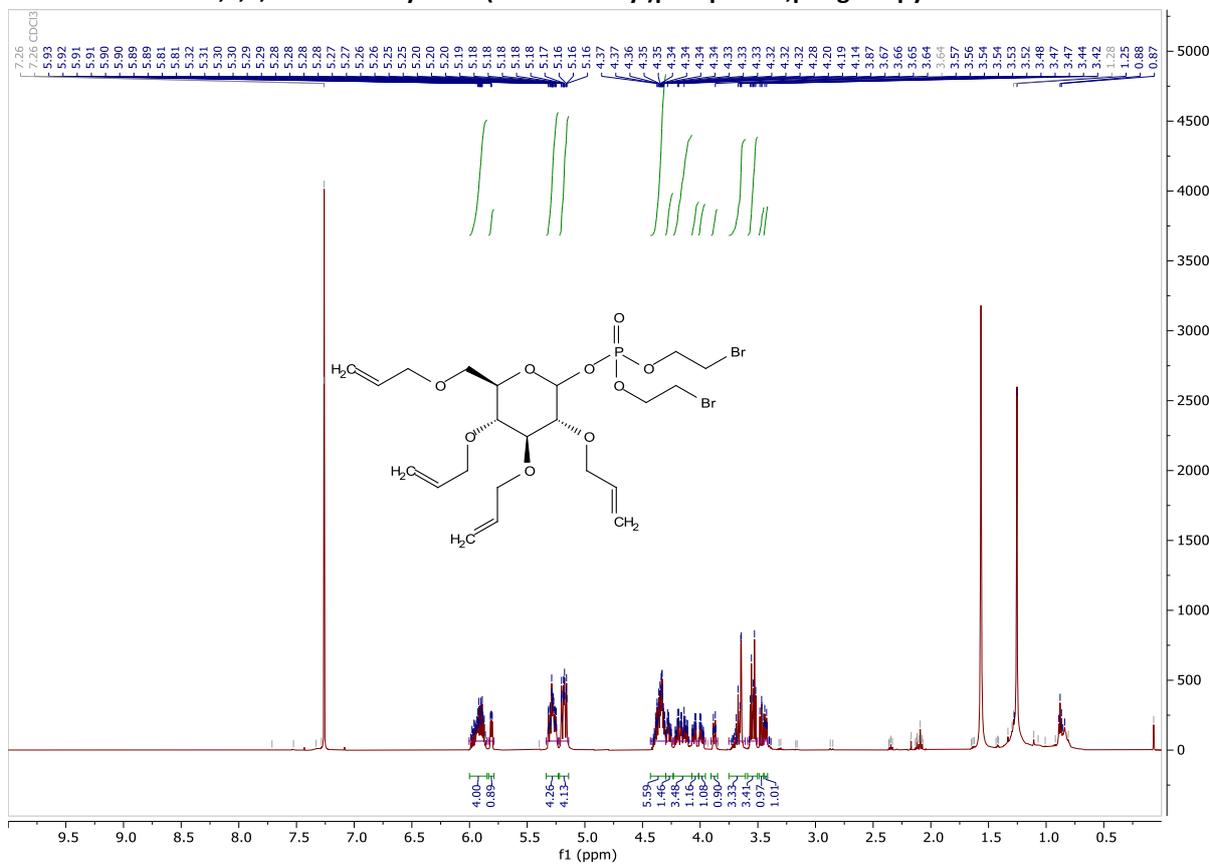


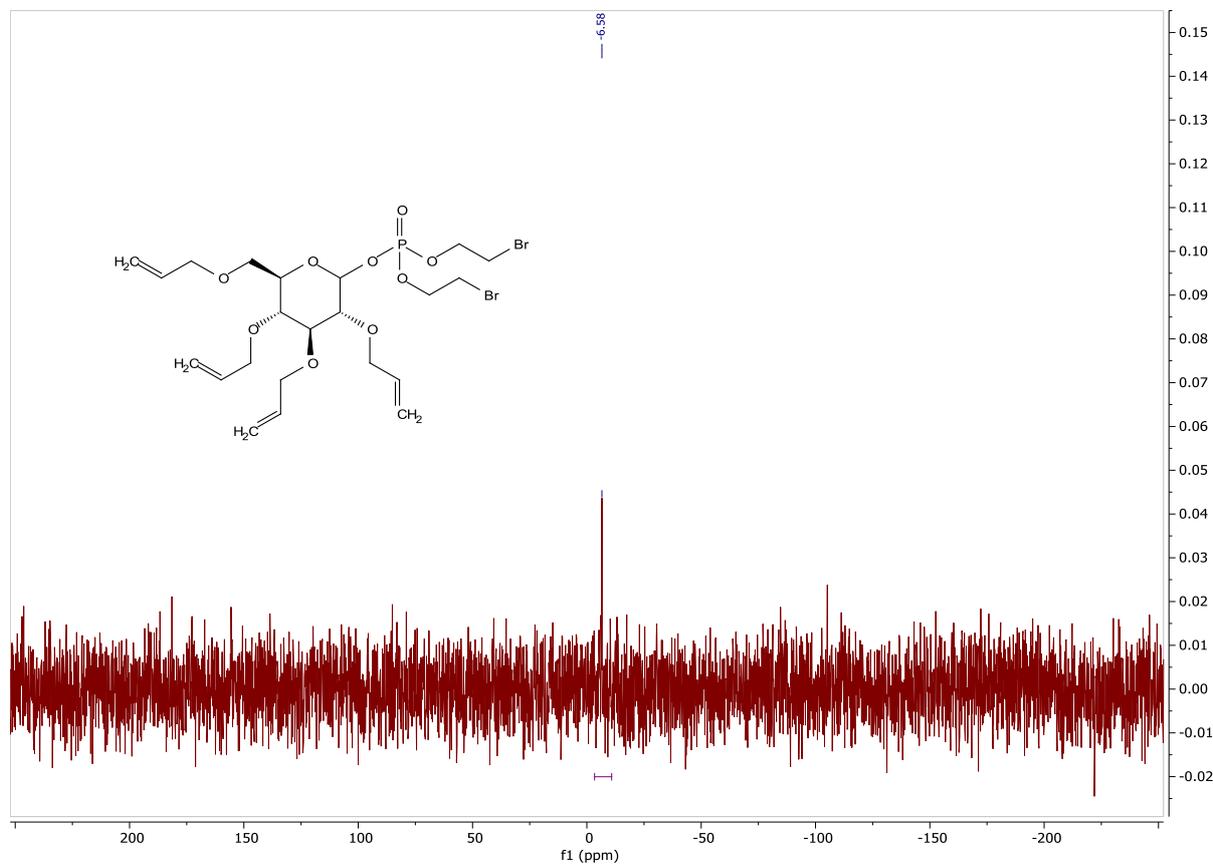
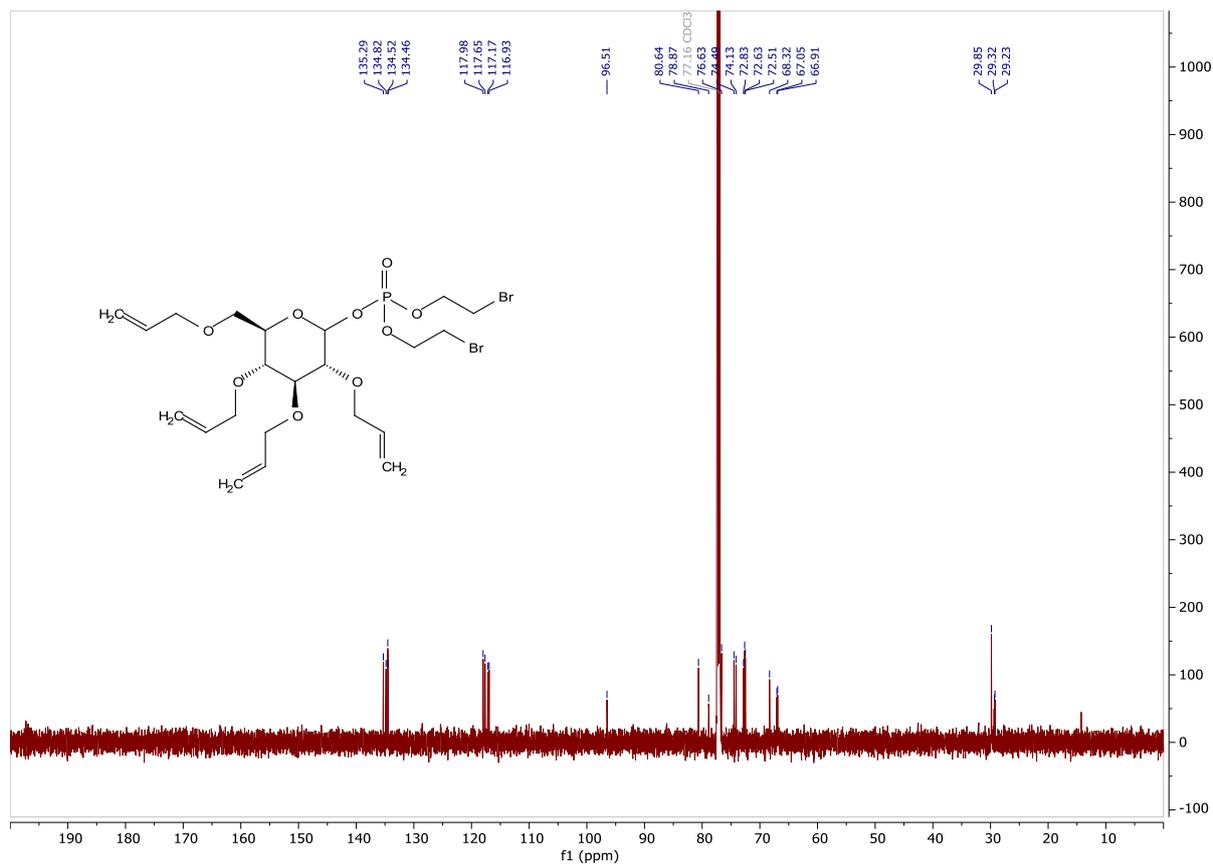
2,3,4,6-tetra-O-benzyl-1-bis(SATE)phosphor- α,β -D-glucopyranoside

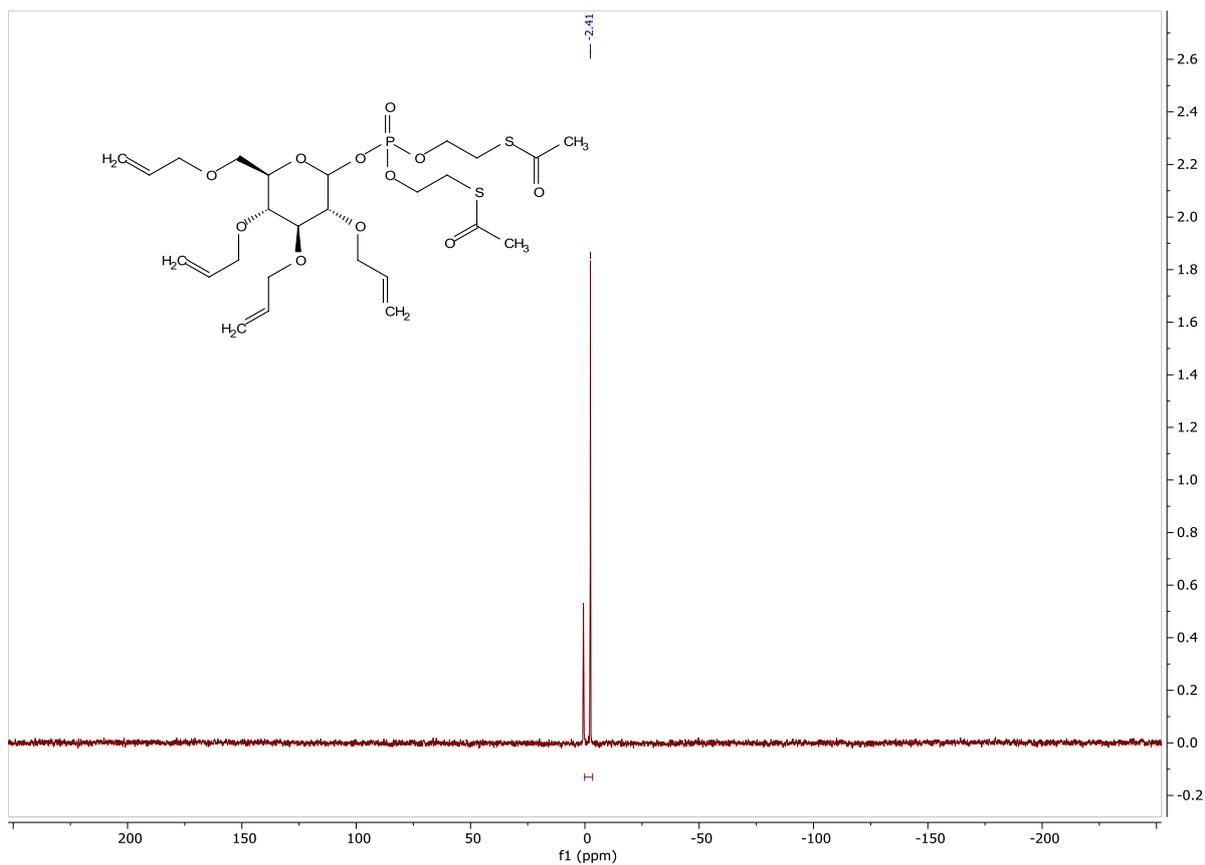




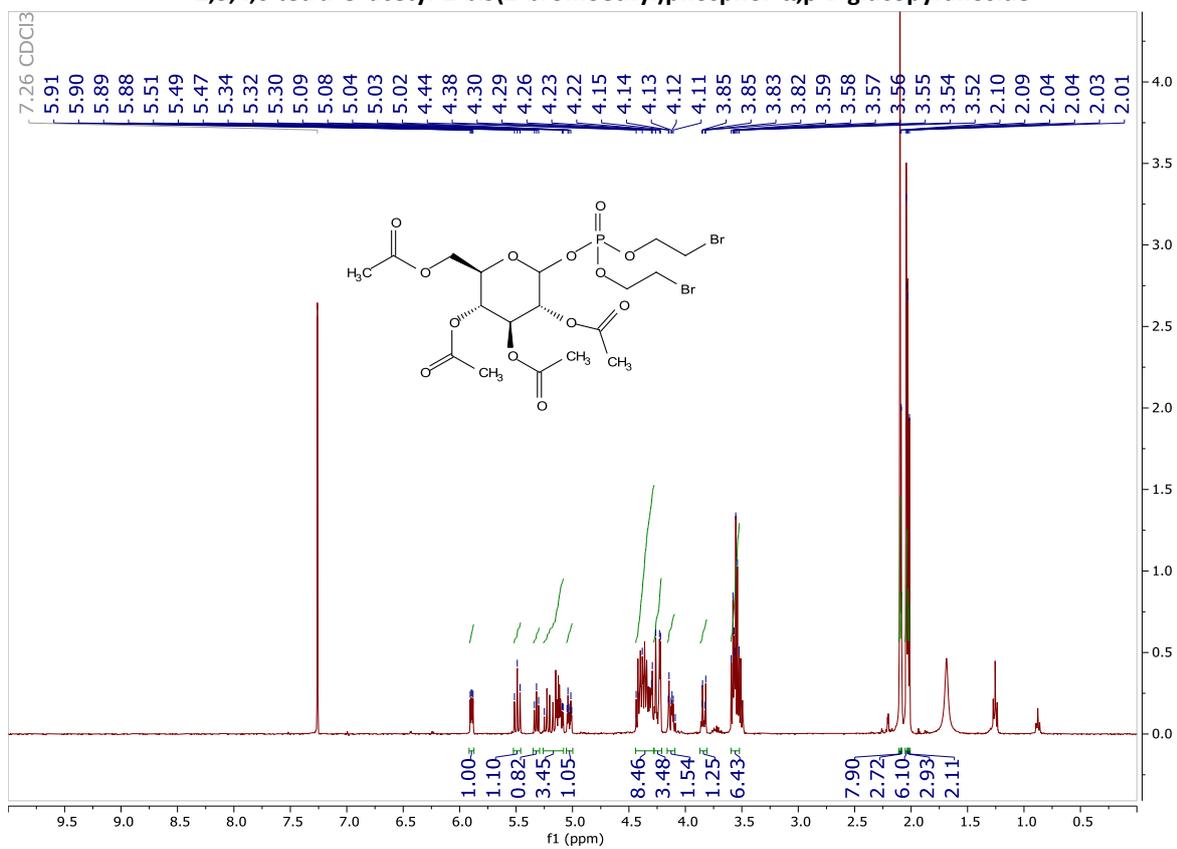
2,3,4,6-tetra-O-allyl-1-bis(2-bromoethyl)phosphor- α,β -D-glucopyranoside

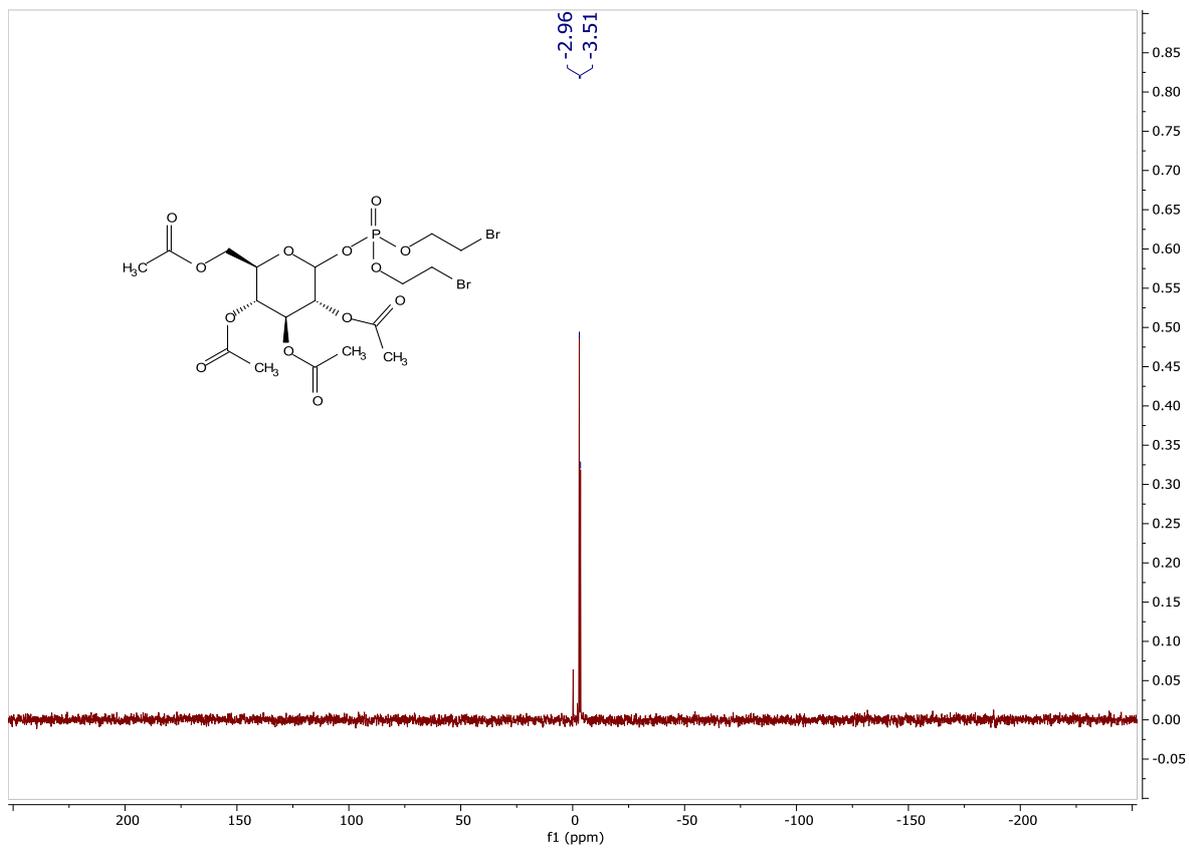
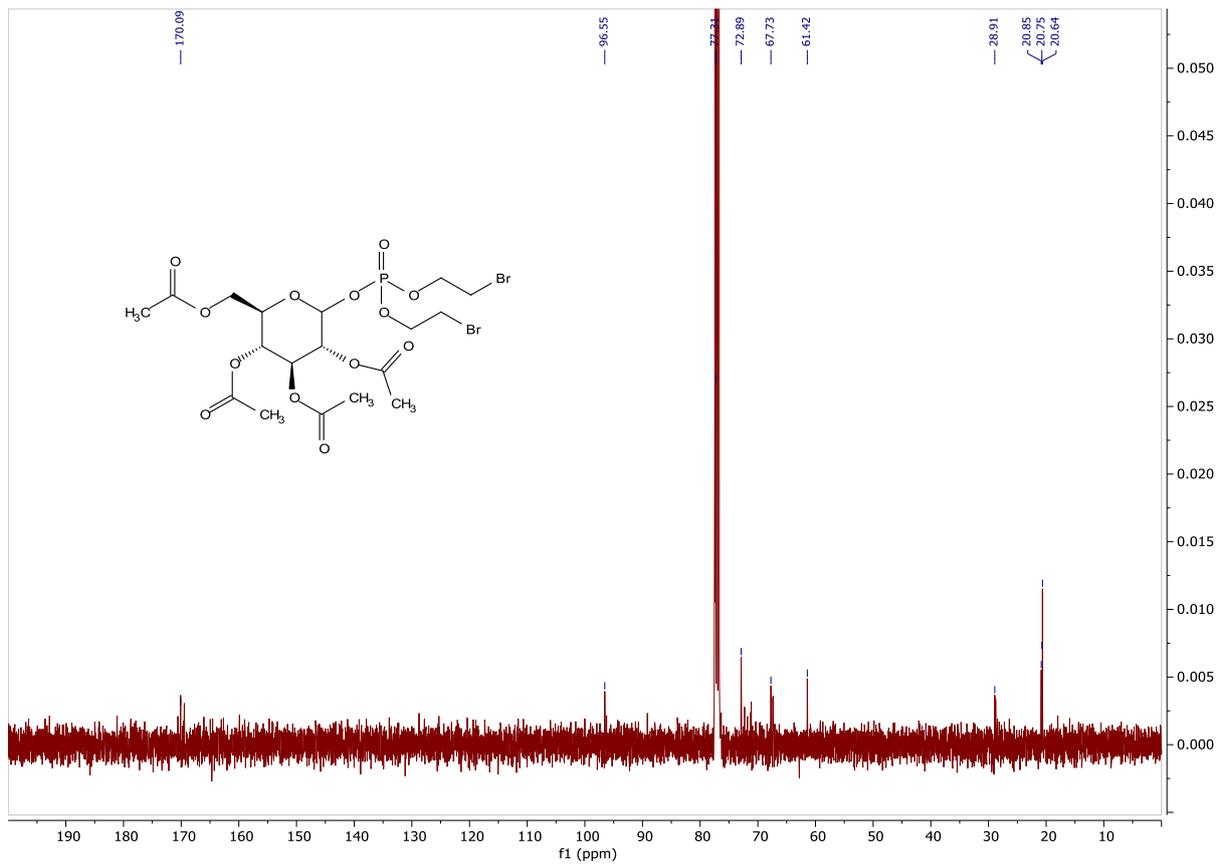




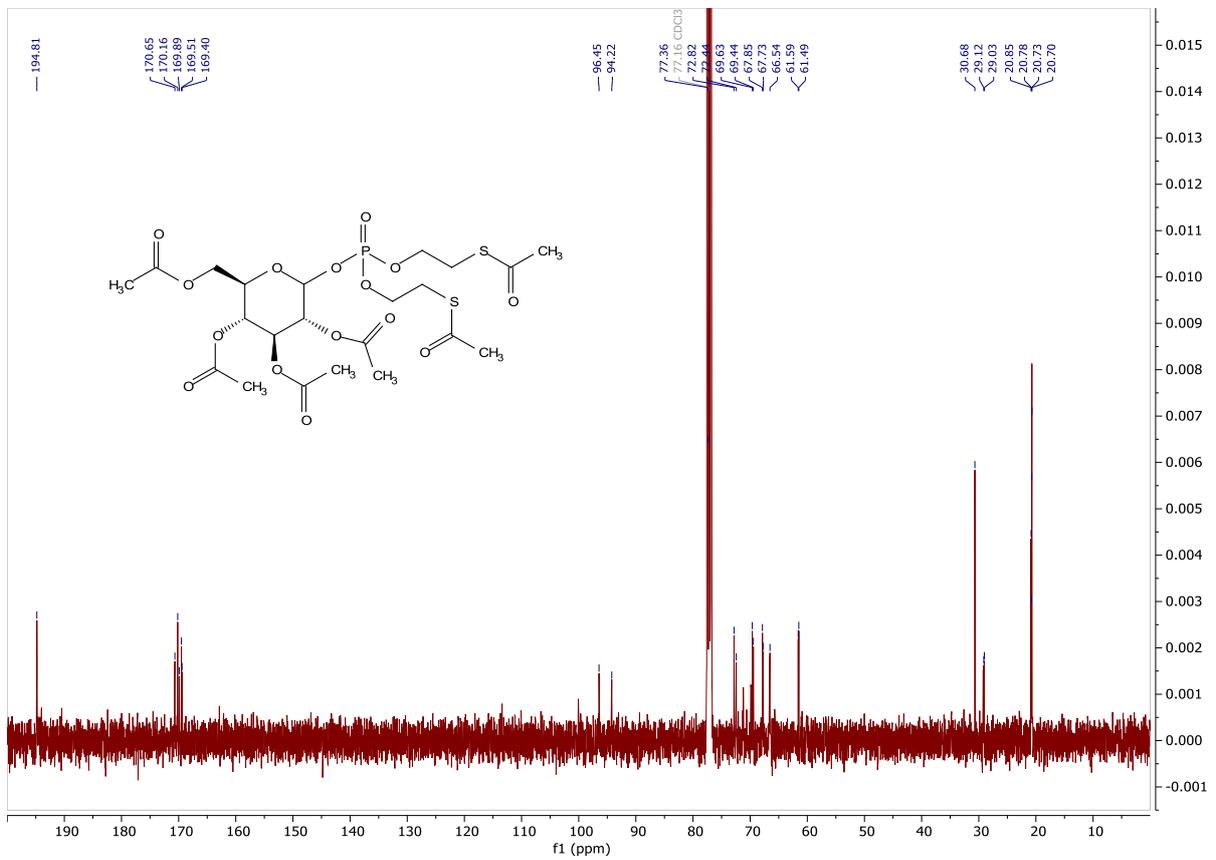
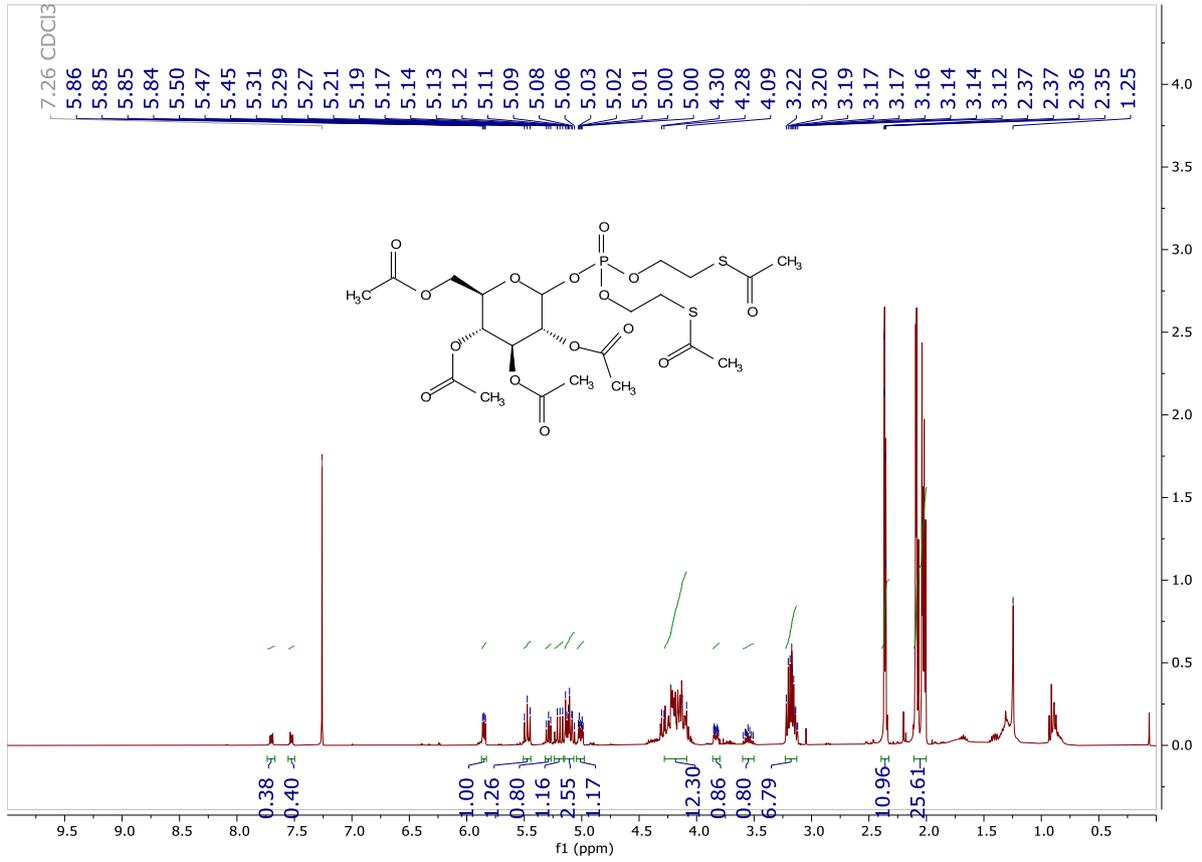


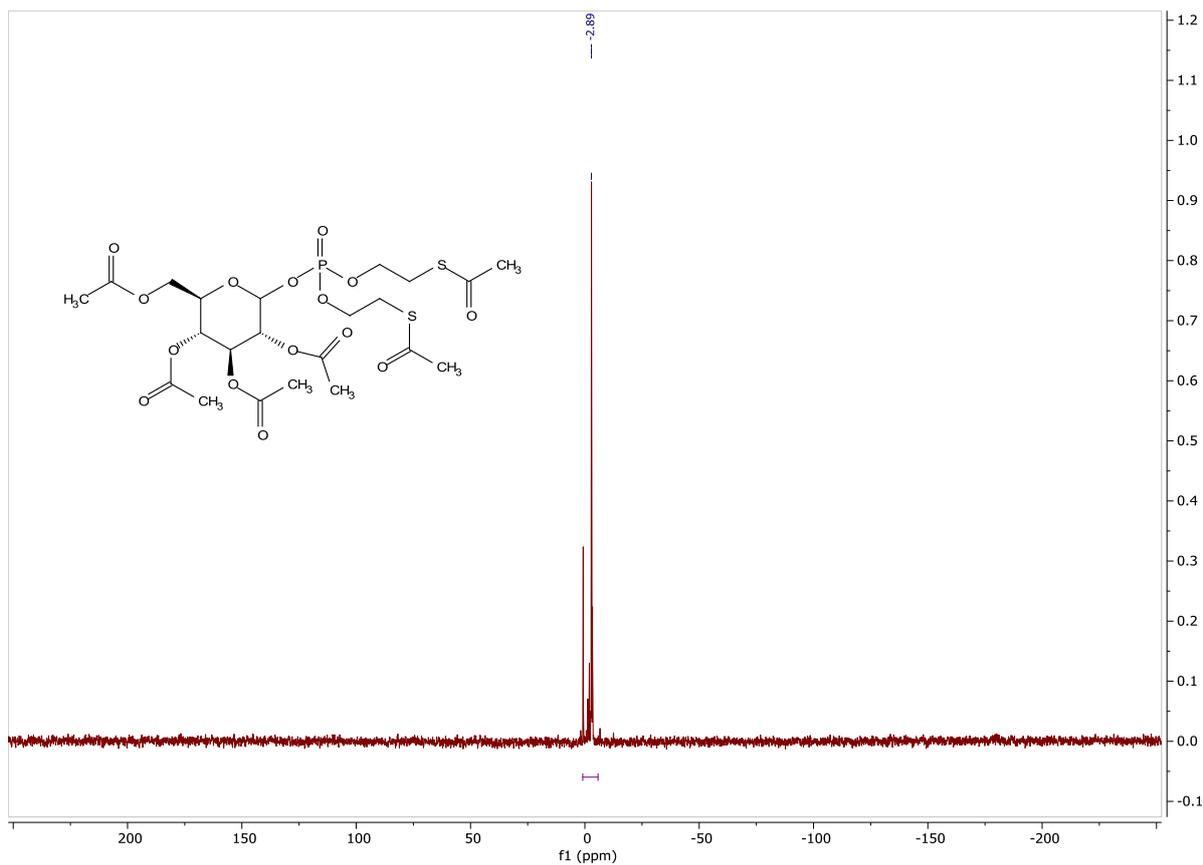
2,3,4,6-tetra-O-acetyl-1-bis(2-bromoethyl)phosphor- α,β -D-glucopyranoside



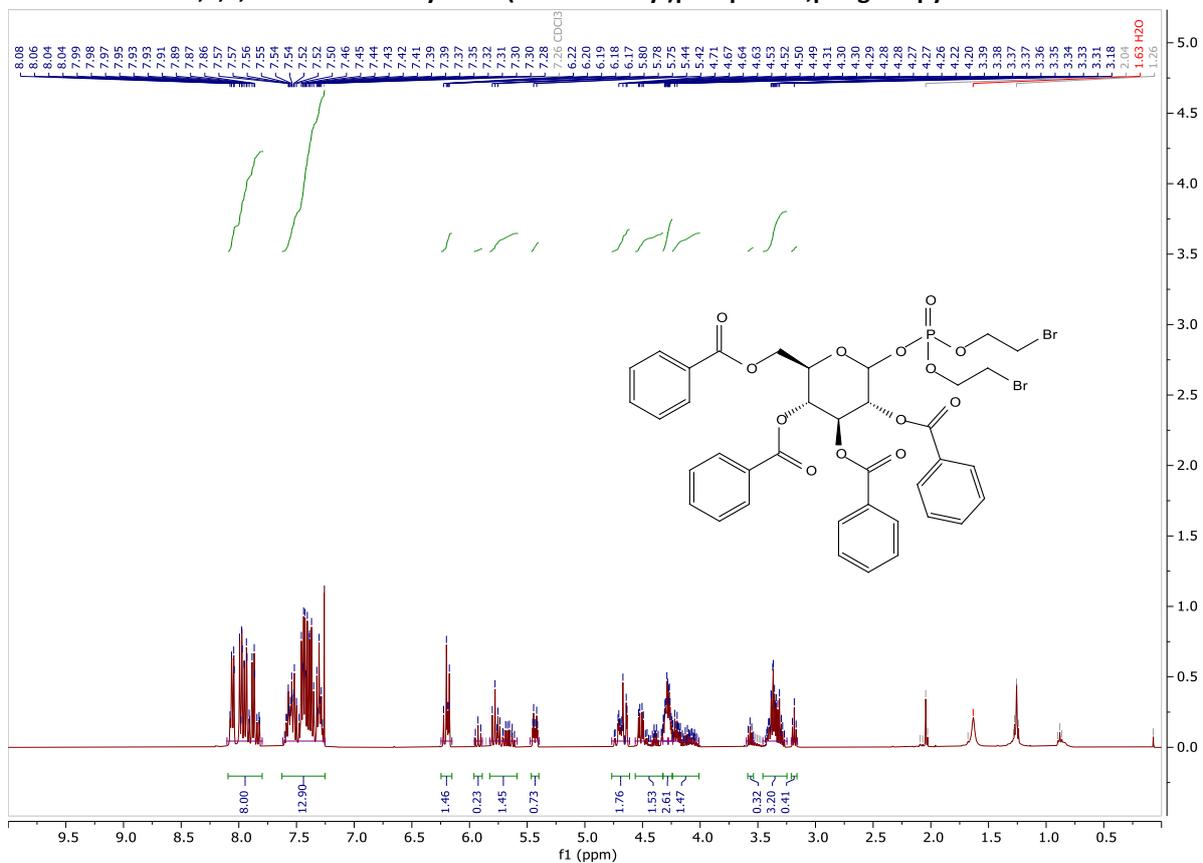


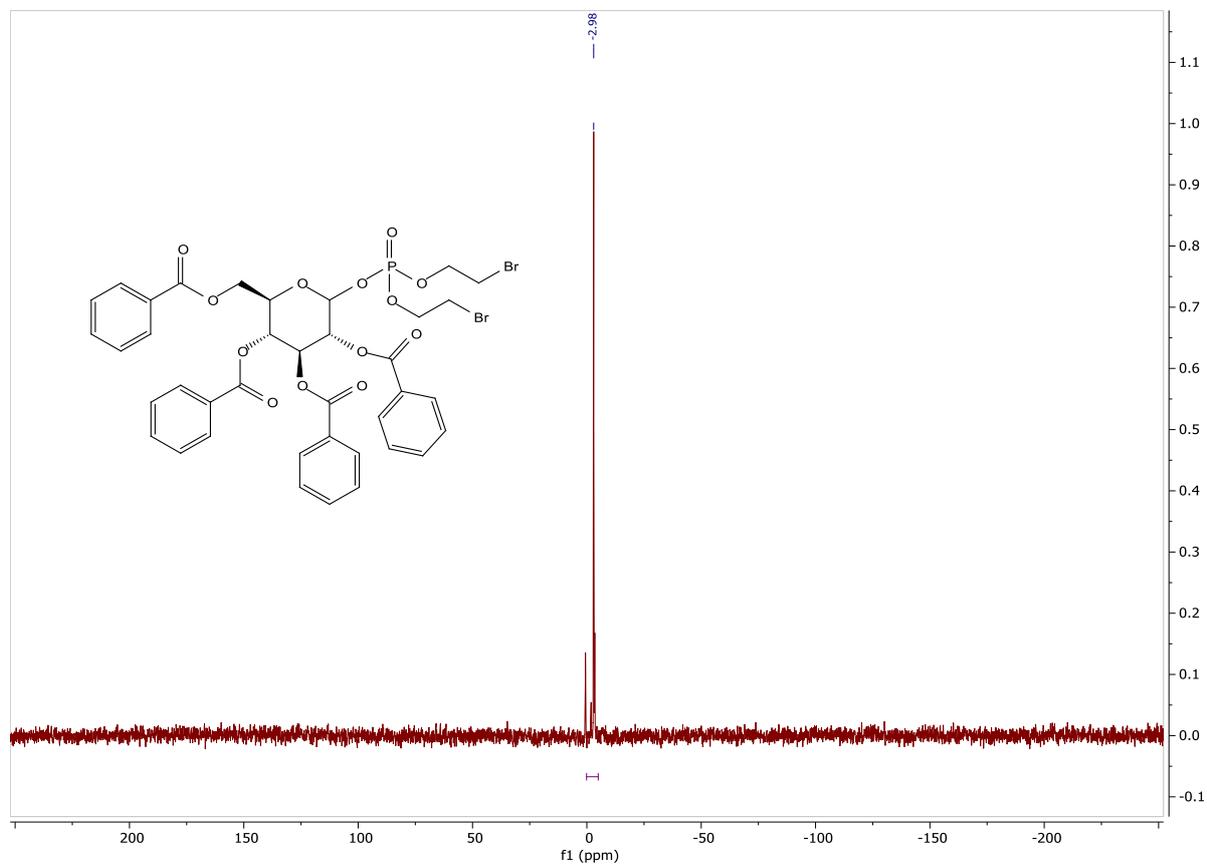
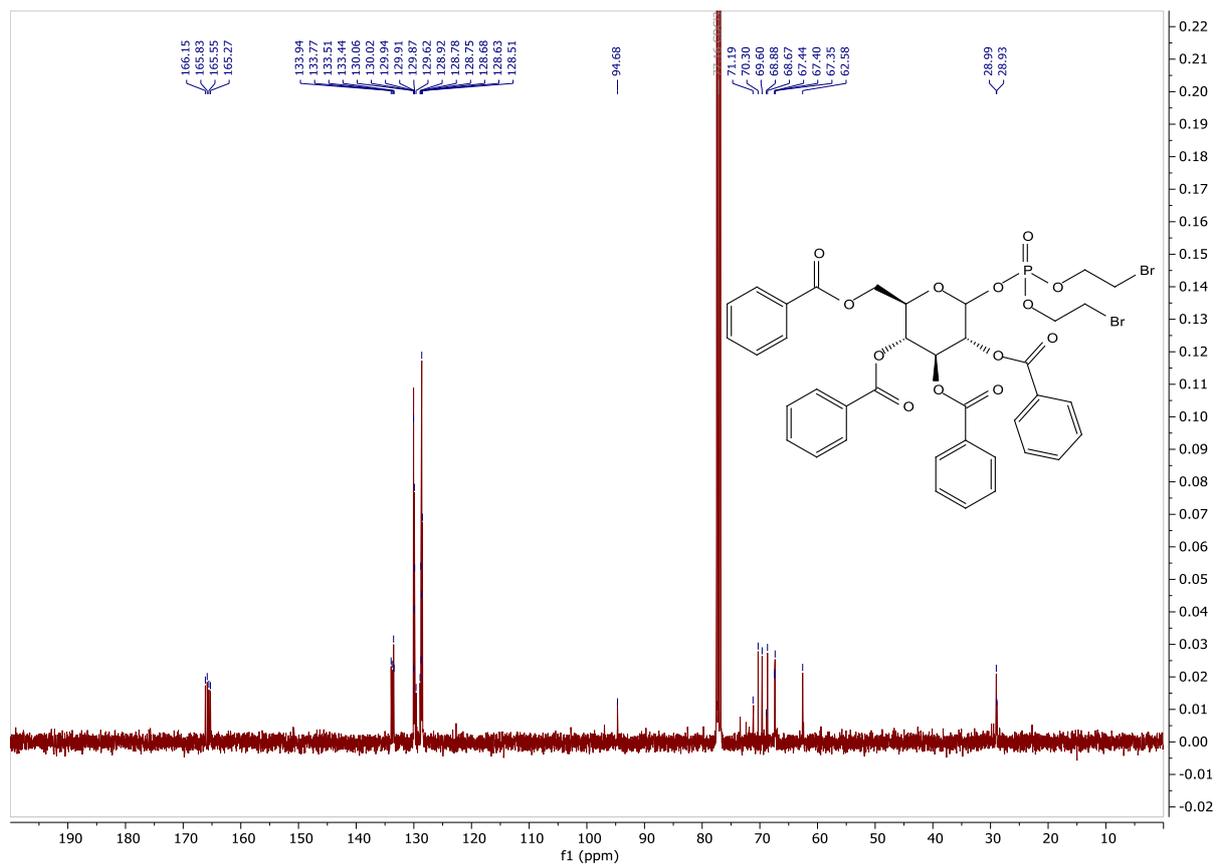
2,3,4,6-tetra-O-acetyl-1-bis(SATE)phosphor- α,β -D-glucopyranoside



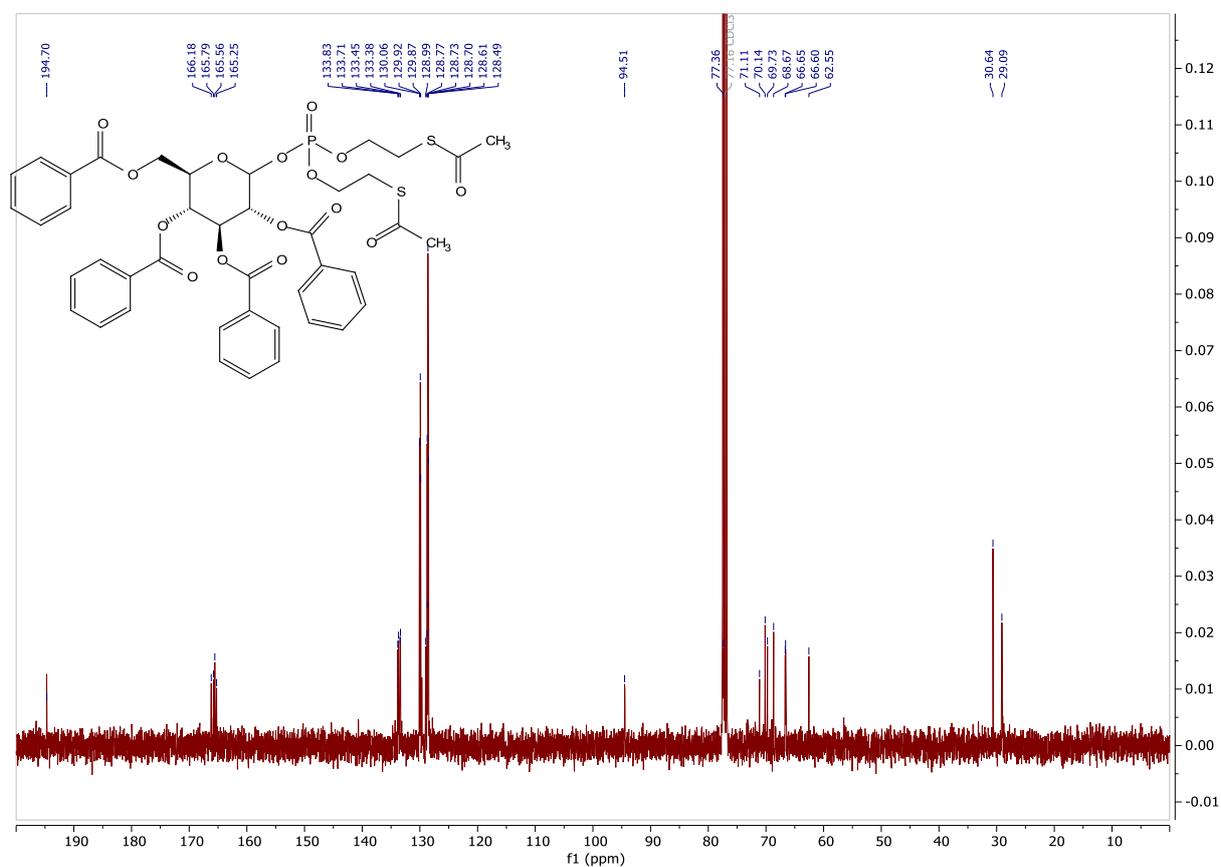
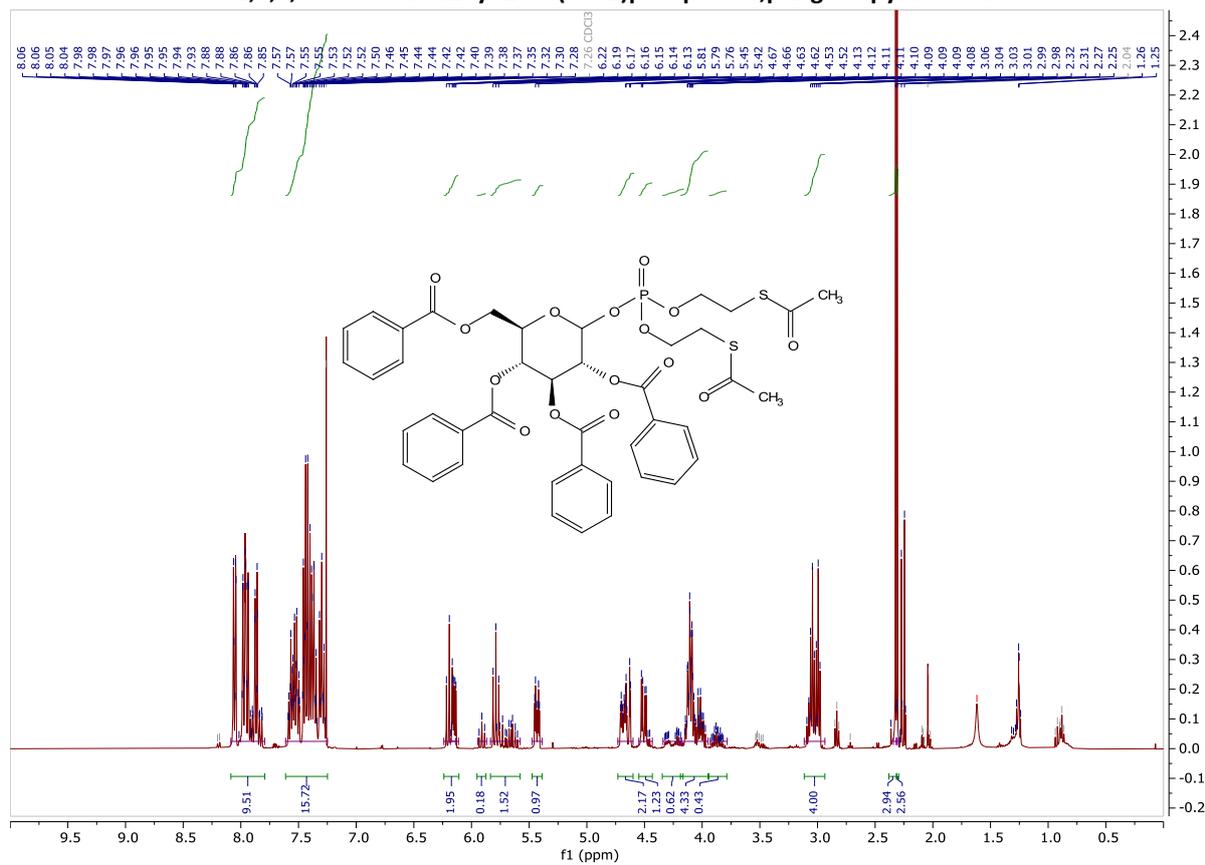


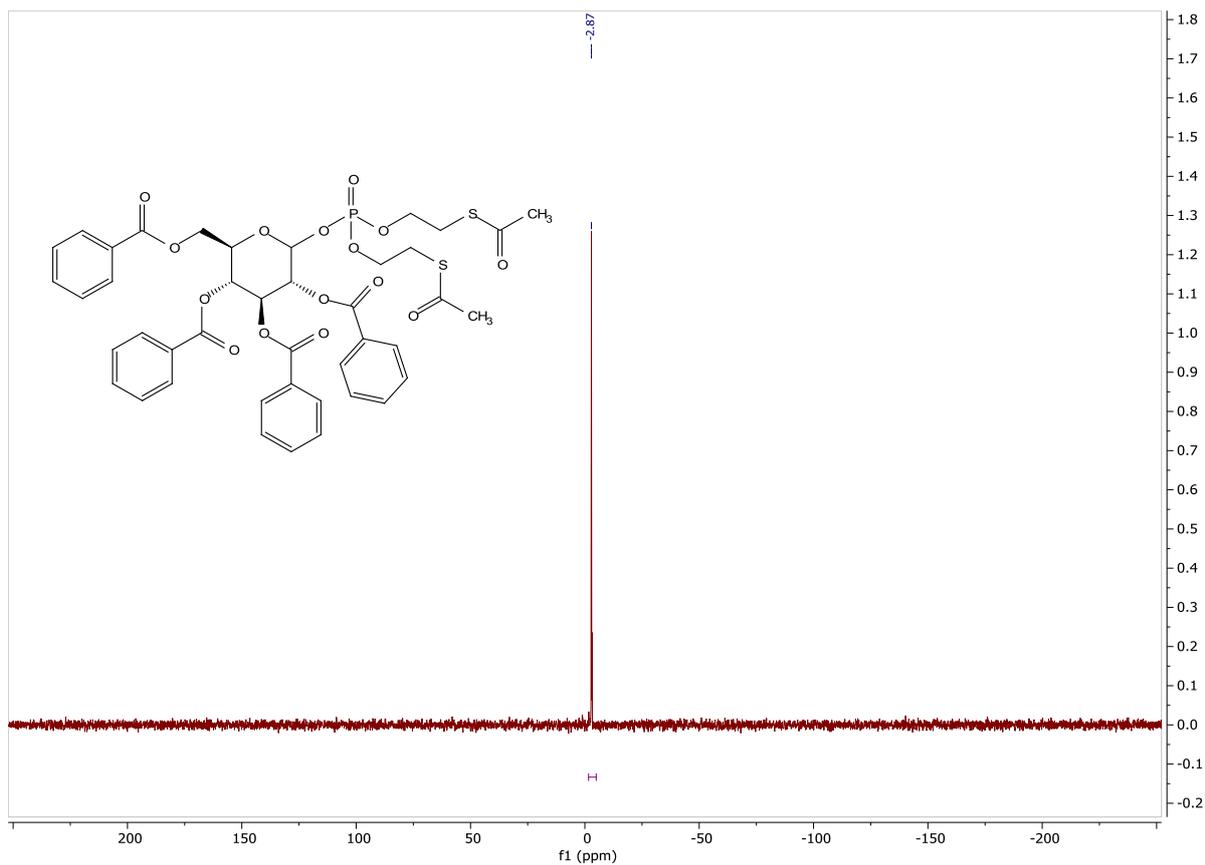
2,3,4,6-tetra-O-benzoyl-1-bis(2-bromoethyl)phosphor- α,β -D-glucopyranoside



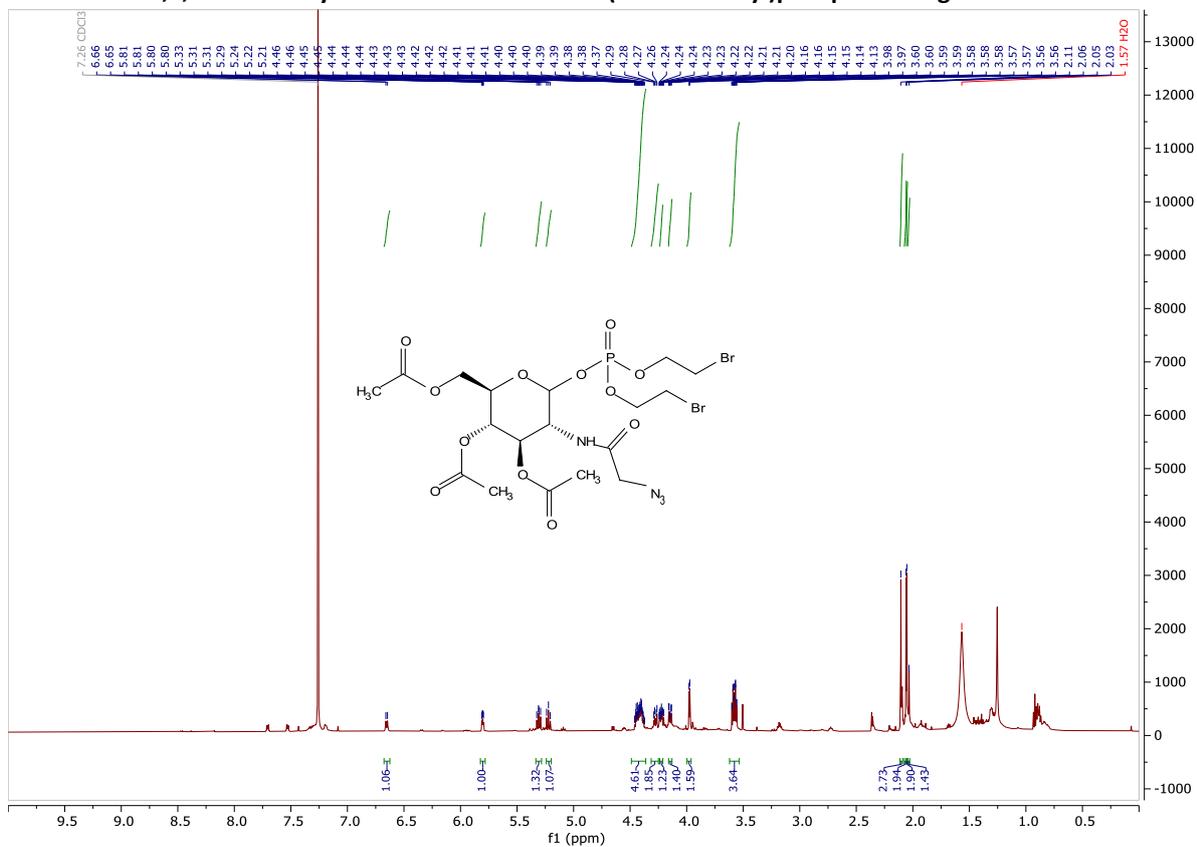


2,3,4,6-tetra-O-benzoyl-1-bis(SATE)phosphor- α,β -D-glucopyranoside

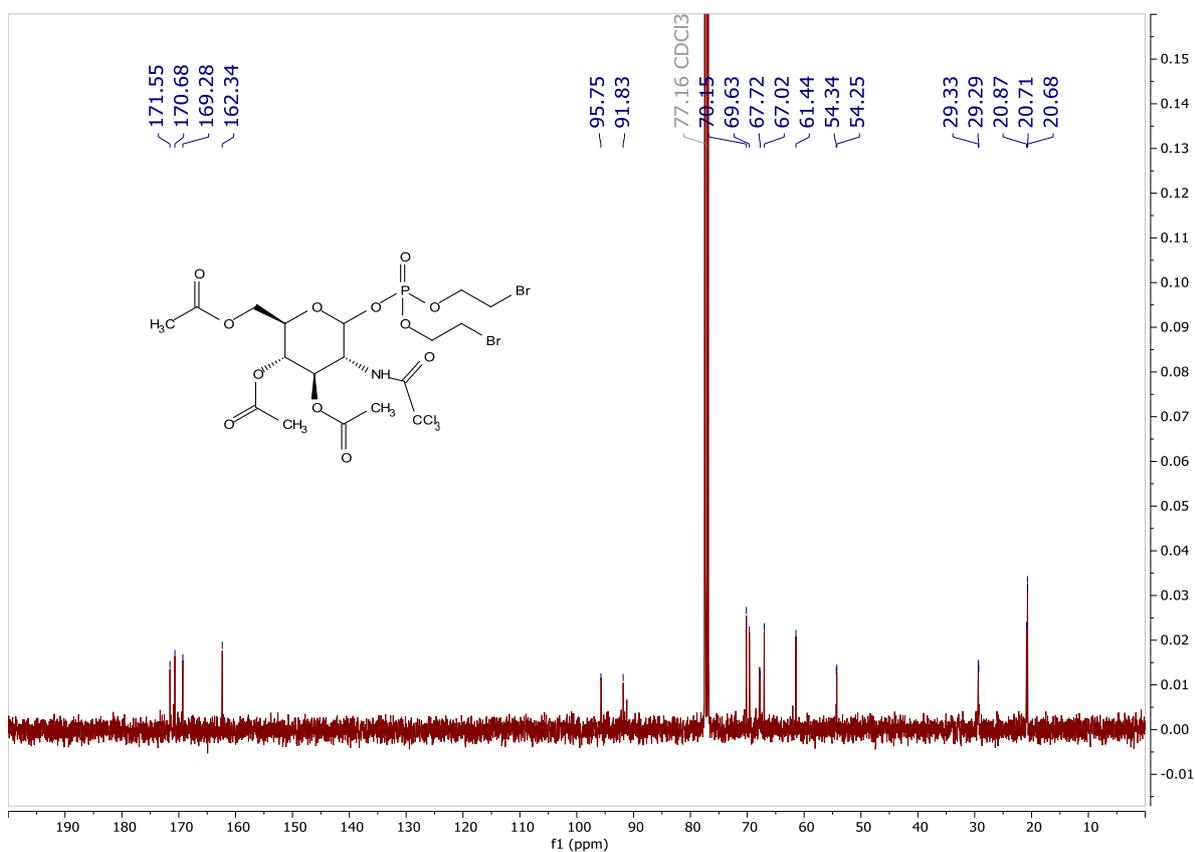
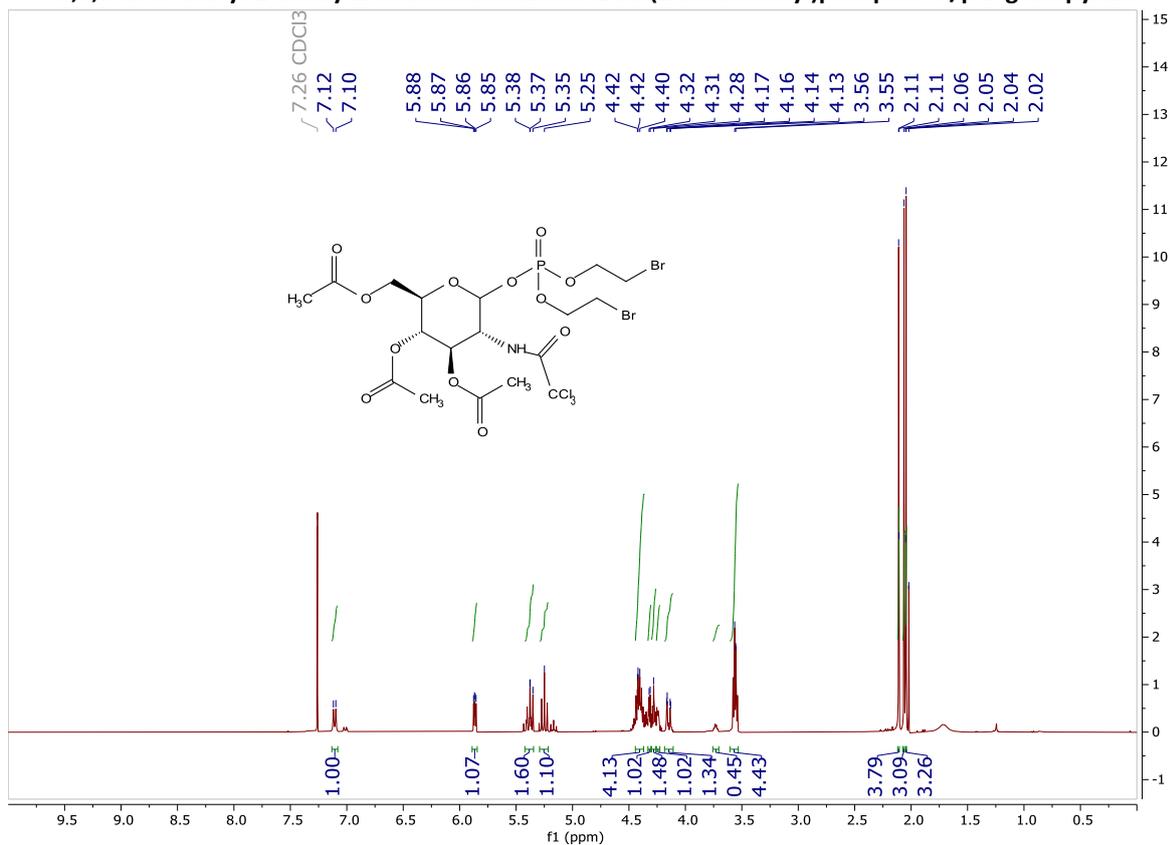




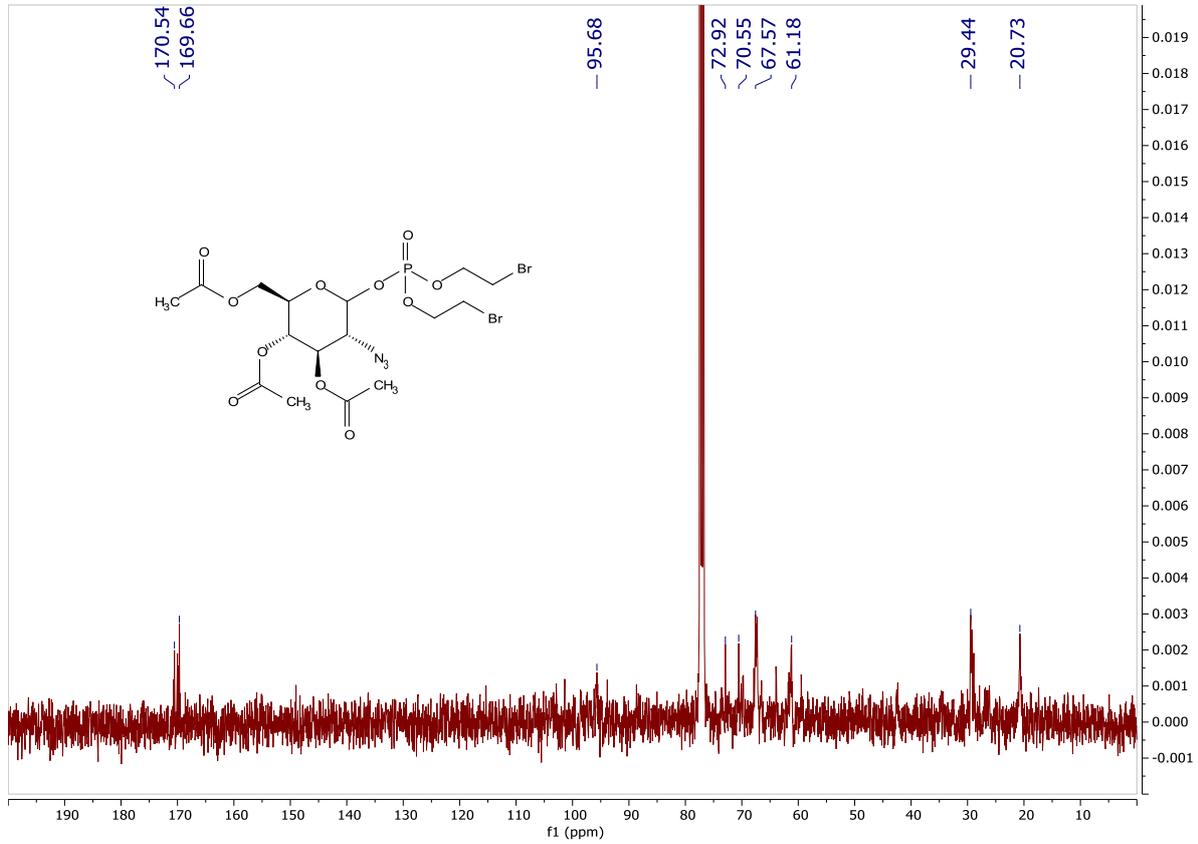
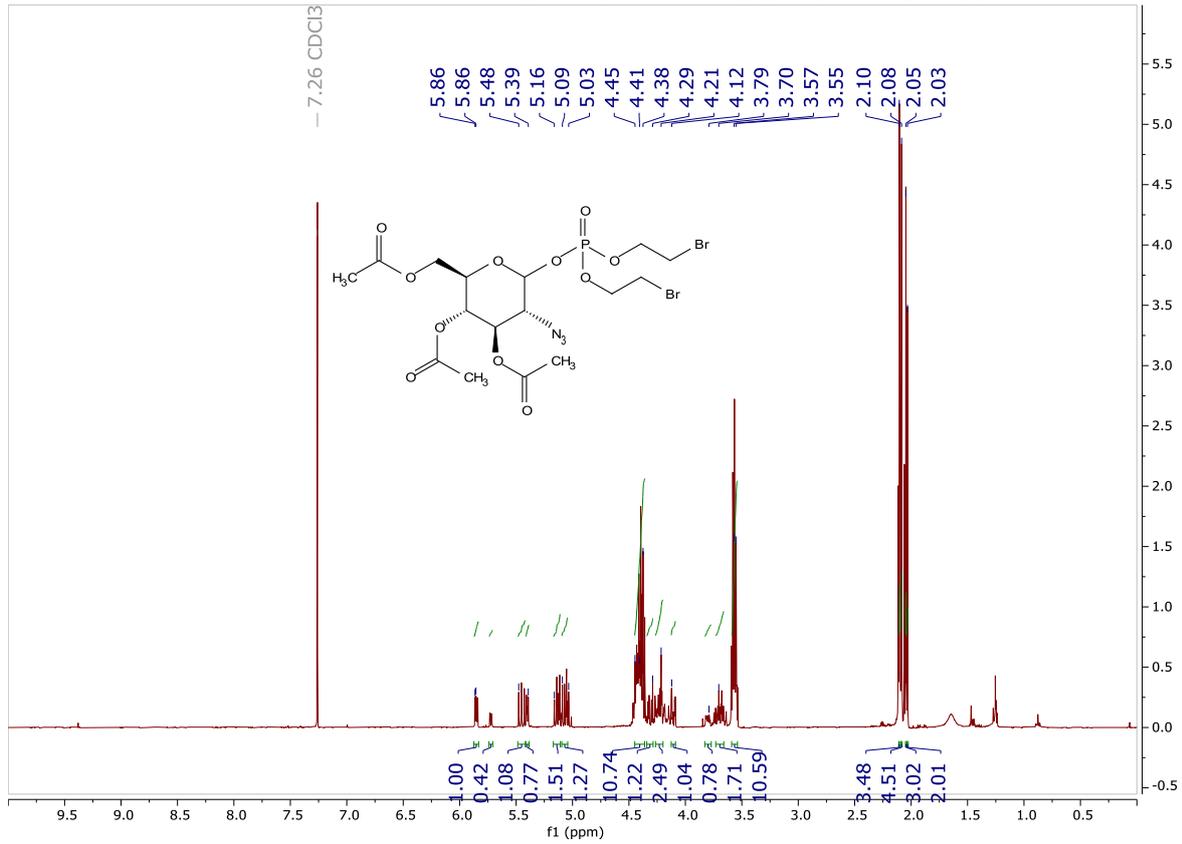
3,4,6-tri-O-acetyl-2-azido-acetimido-1-bis(2-bromoethyl)phosphor- α -D-glucosamine



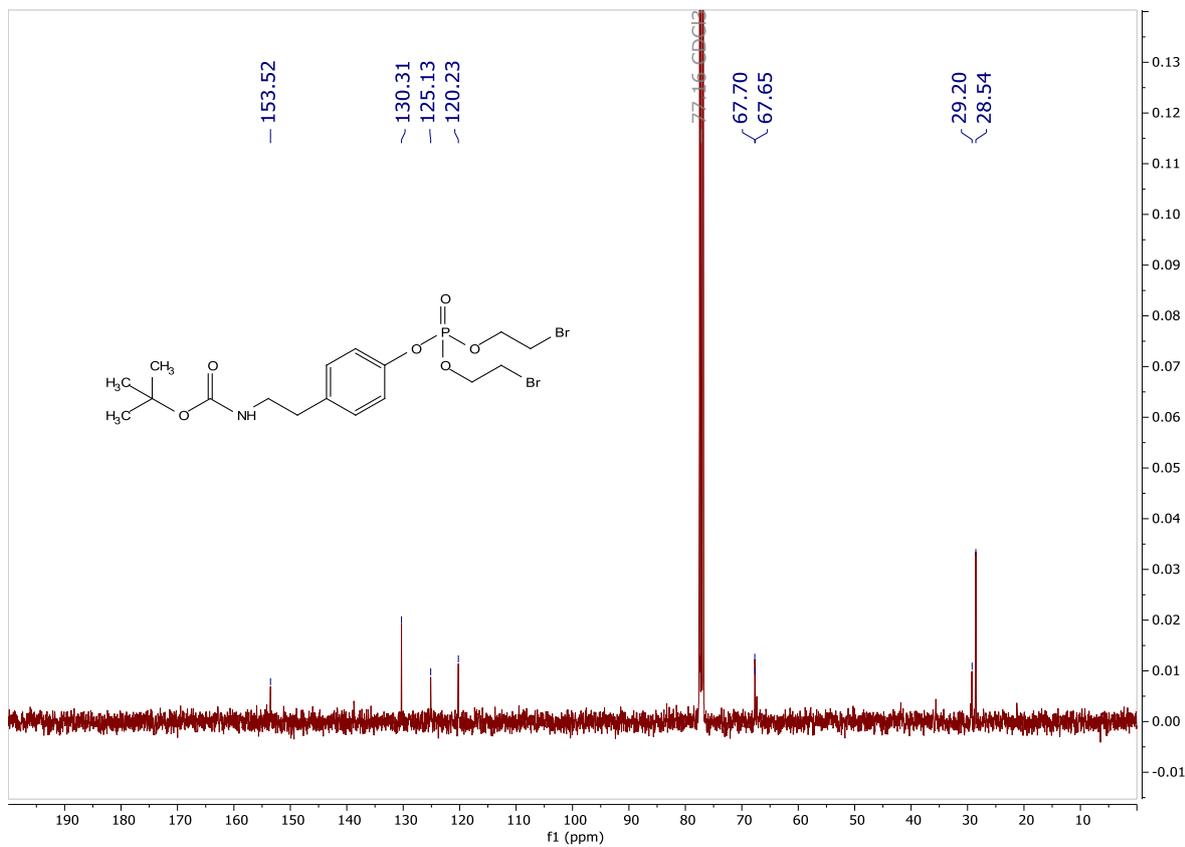
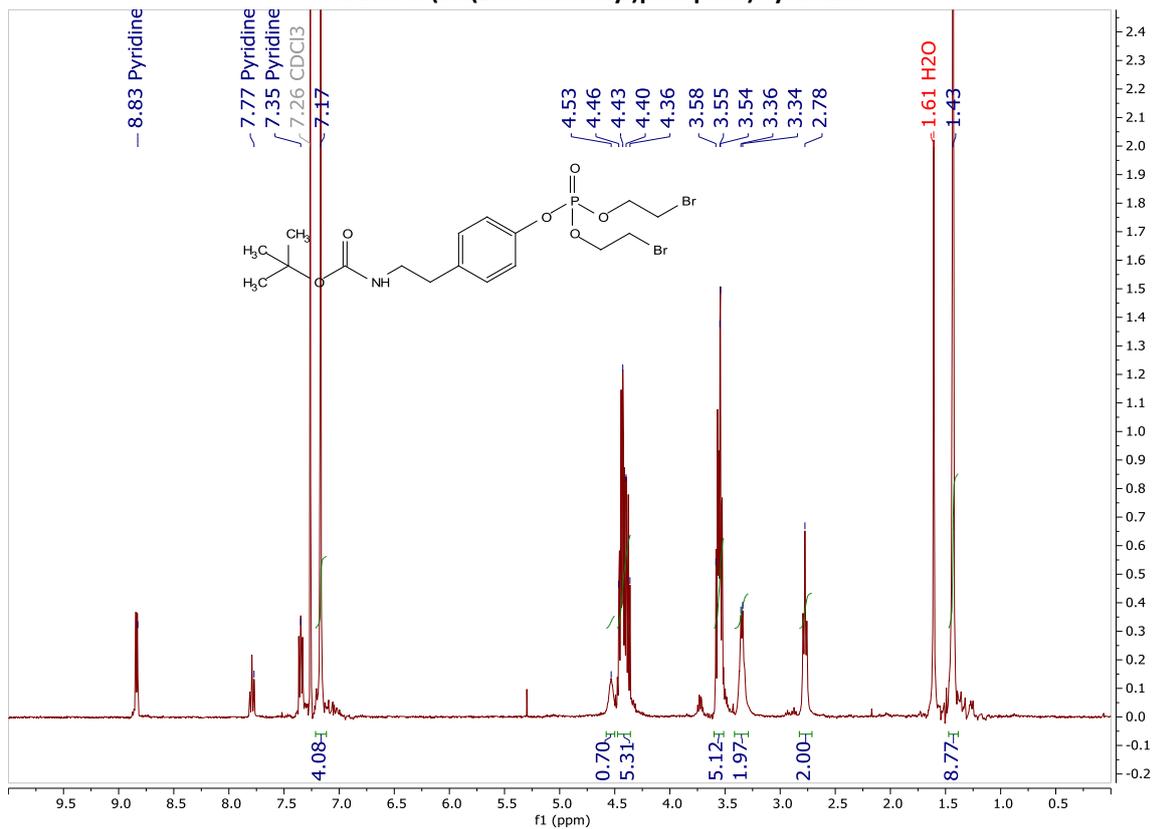
3,4,6-tri-O-acetyl-2-trichloroacetamido-1-bis(2-bromoethyl)phosphor- α/β -D-glucopyranose



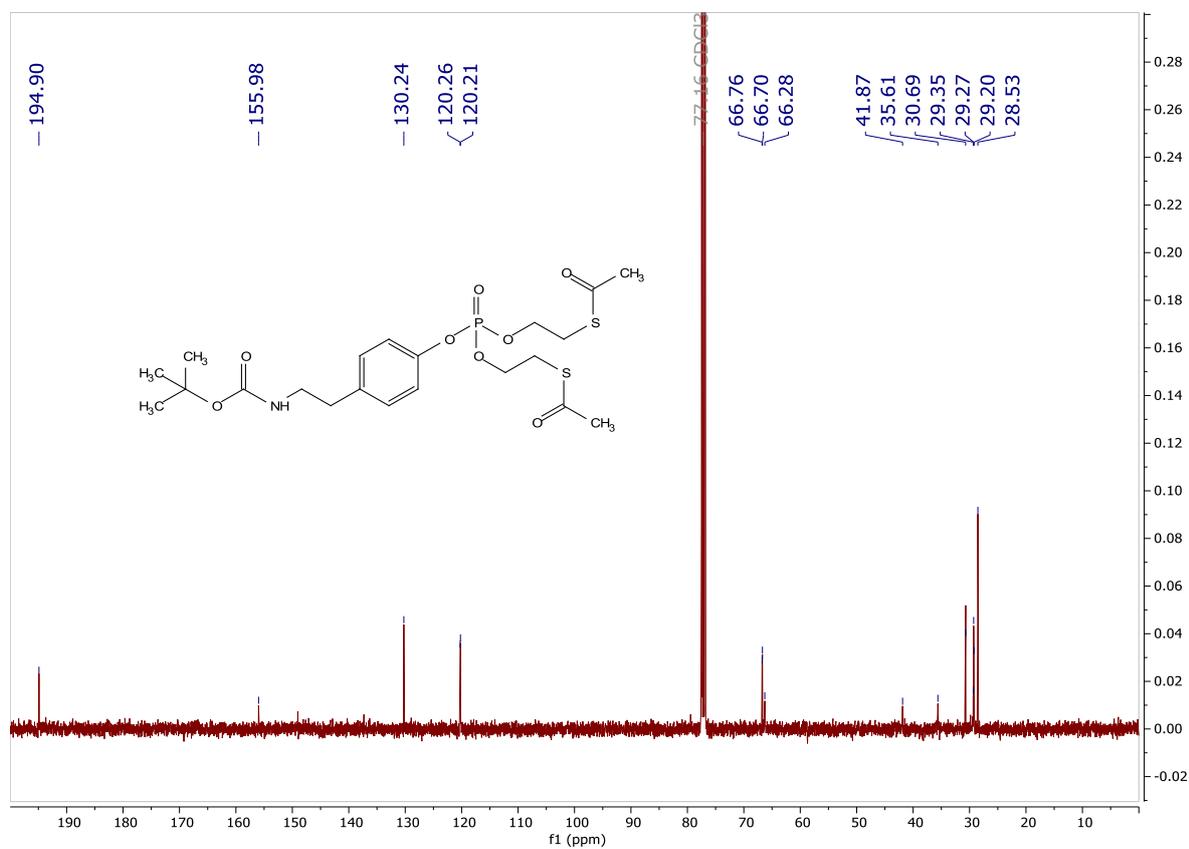
3,4,6-tri-O-acetyl-2-azido-2-deoxy-1-bis(2-bromoethyl)phosphor-D-glucopyranose

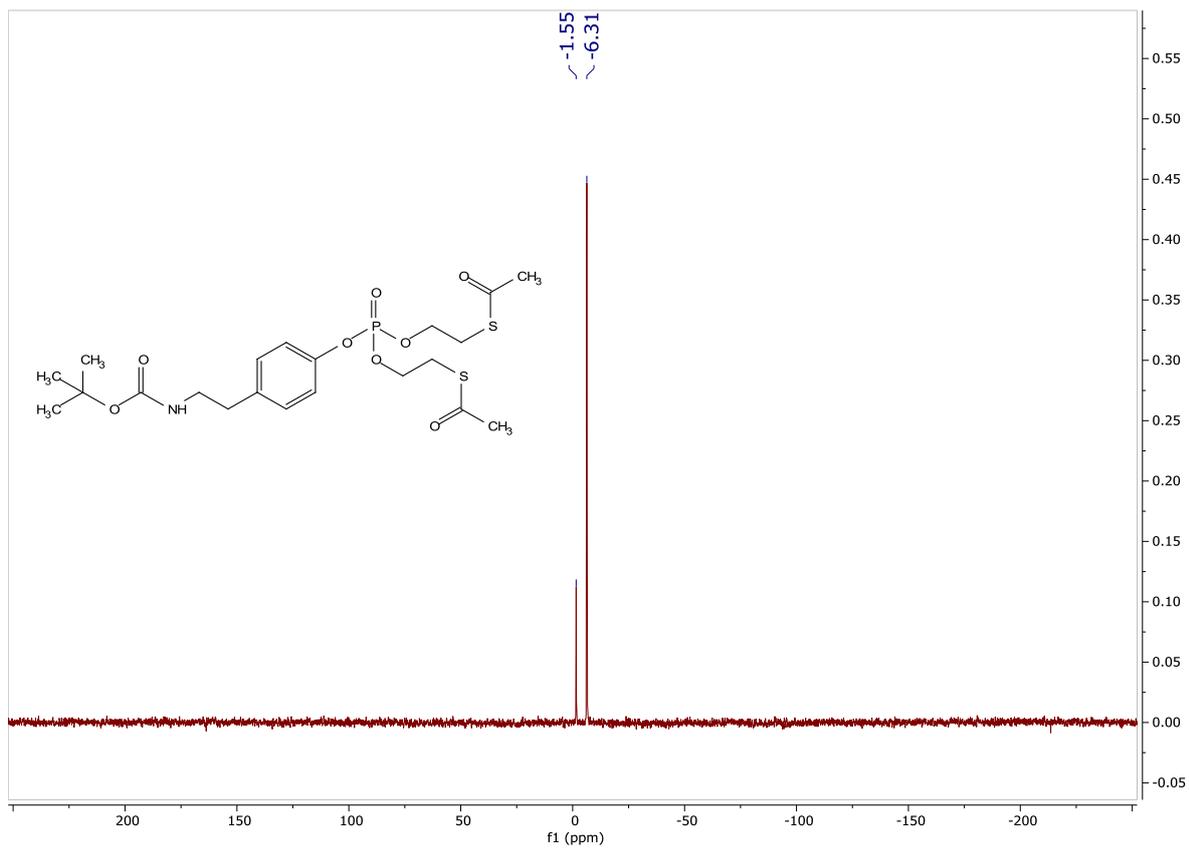


N-Boc-3-(bis(2-bromoethyl)phosphor)-tyramine

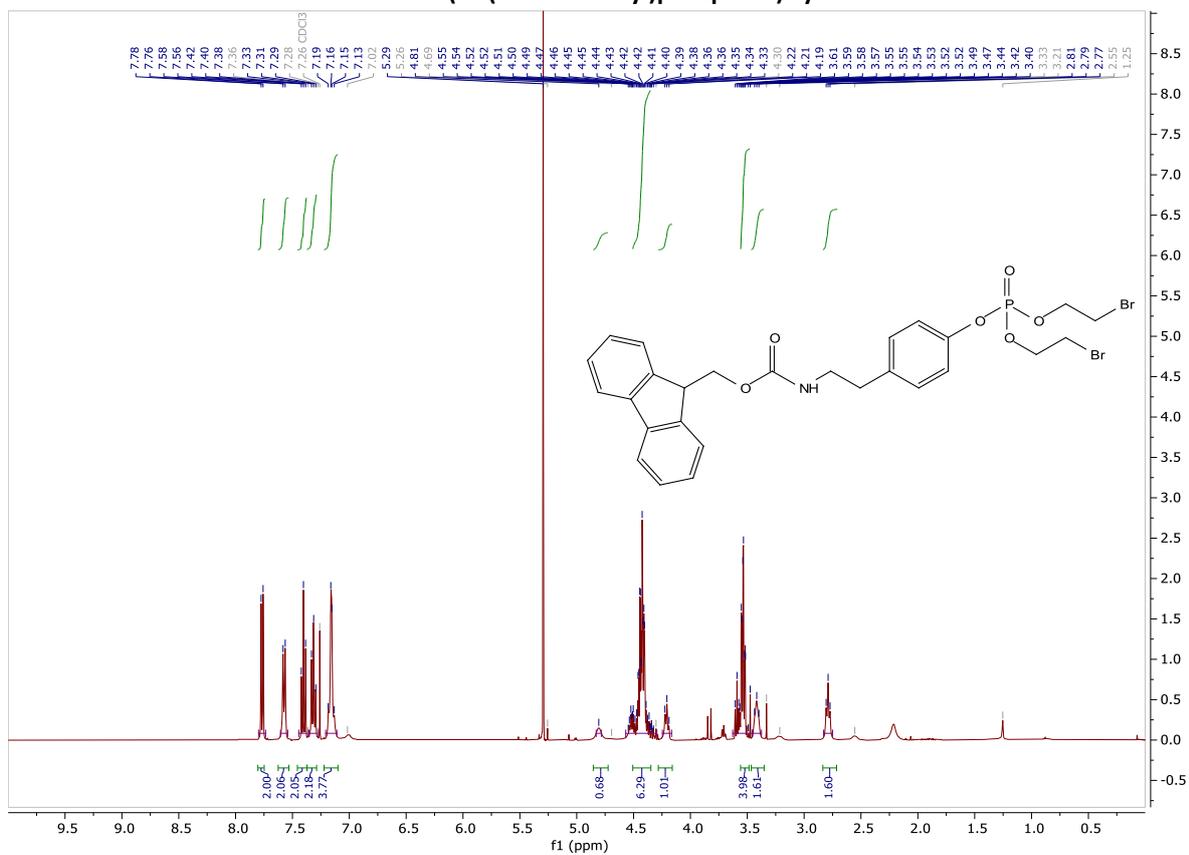


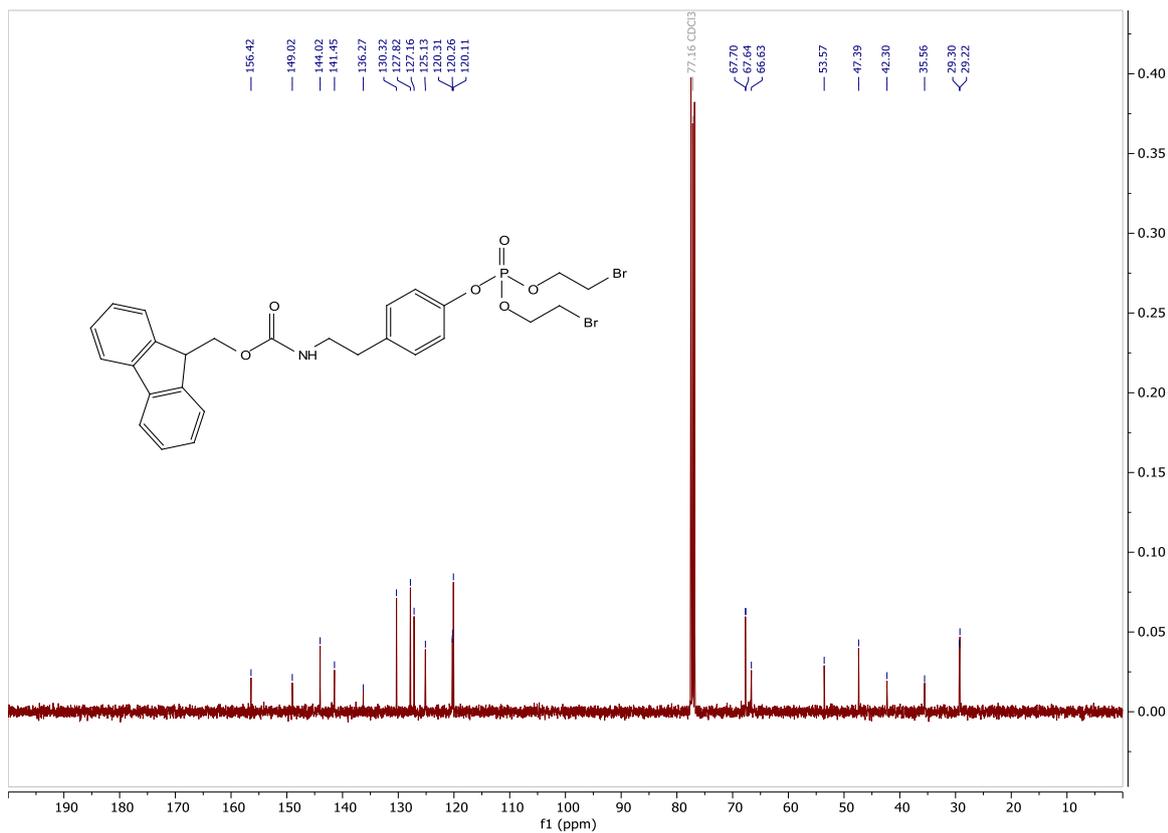
N-Boc-3-(bis(SATE)phosphor)-tyramine



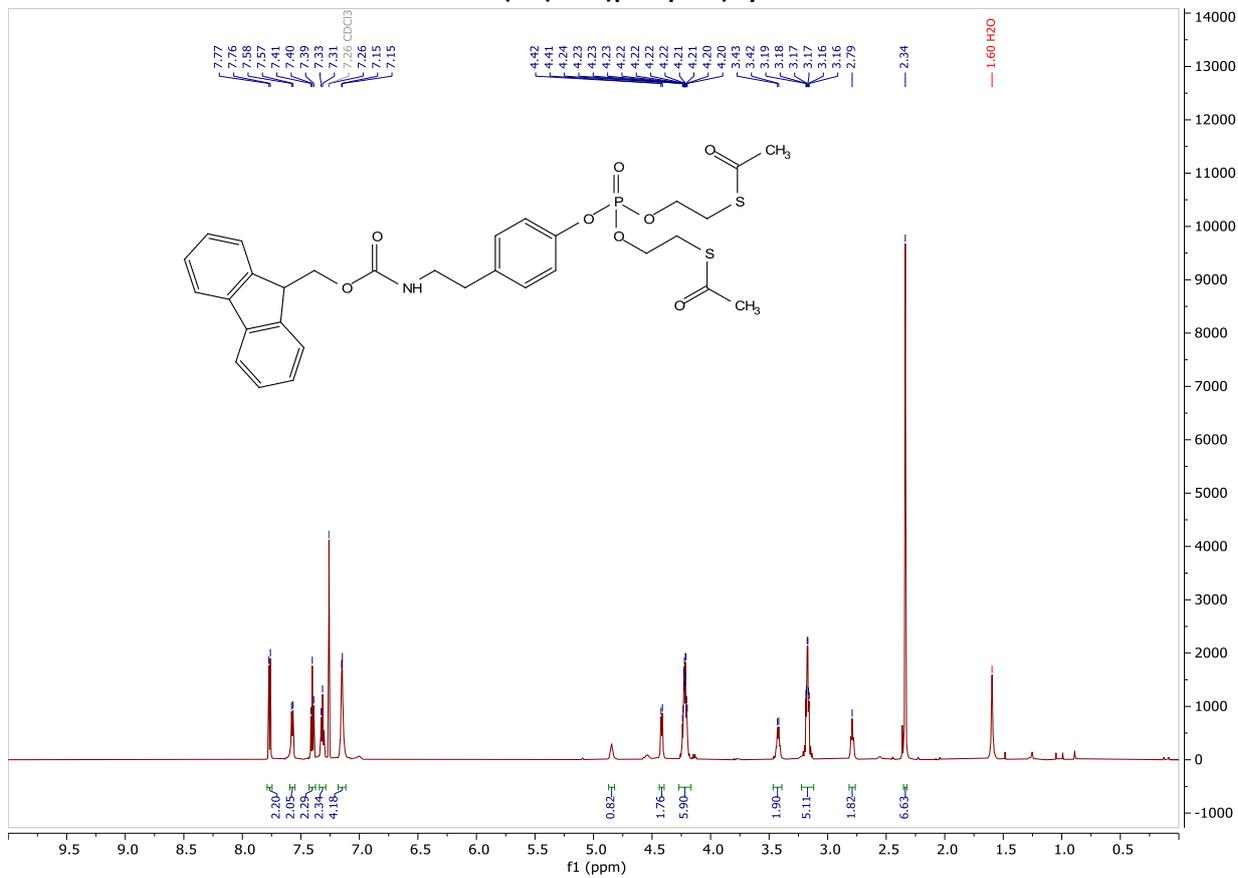


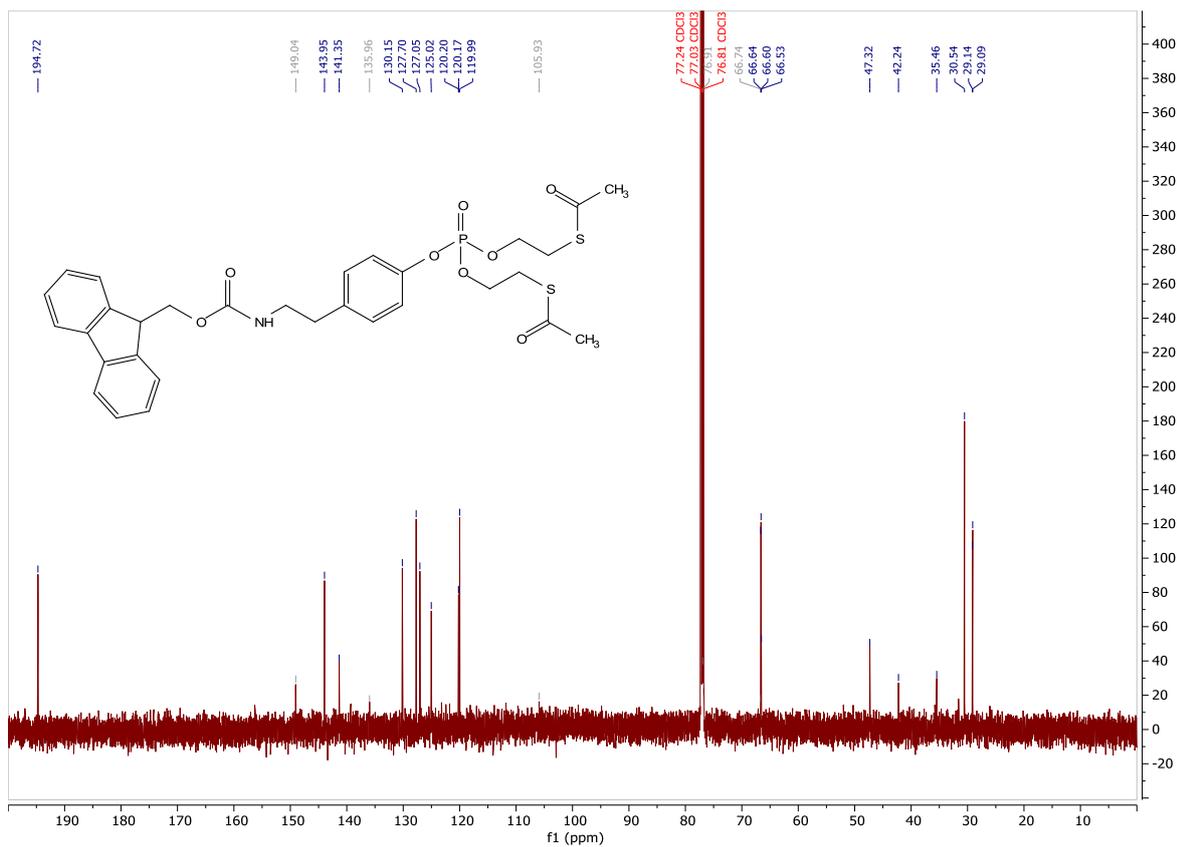
N-Fmoc-3-(bis(2-bromoethyl)phosphate)-tyramine



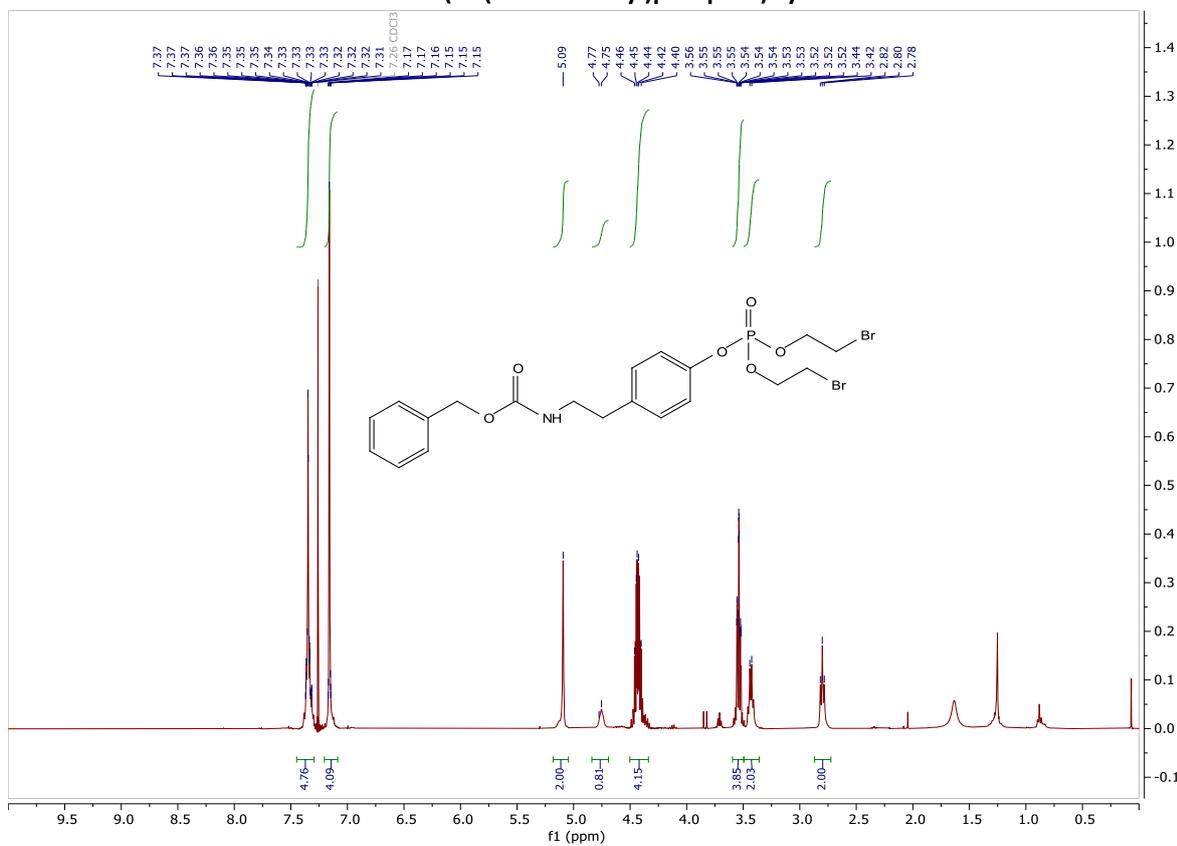


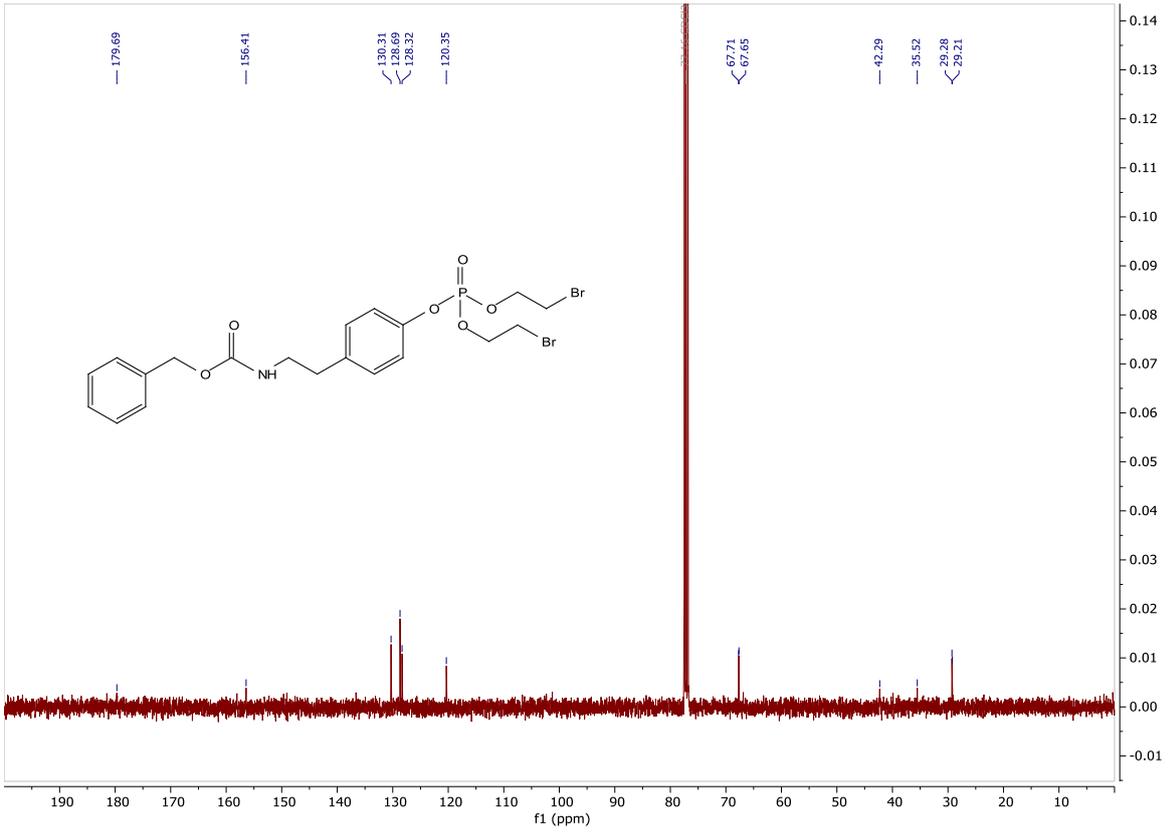
***N*-Fmoc-3-(bis(SATE)phosphor)-tyramine**



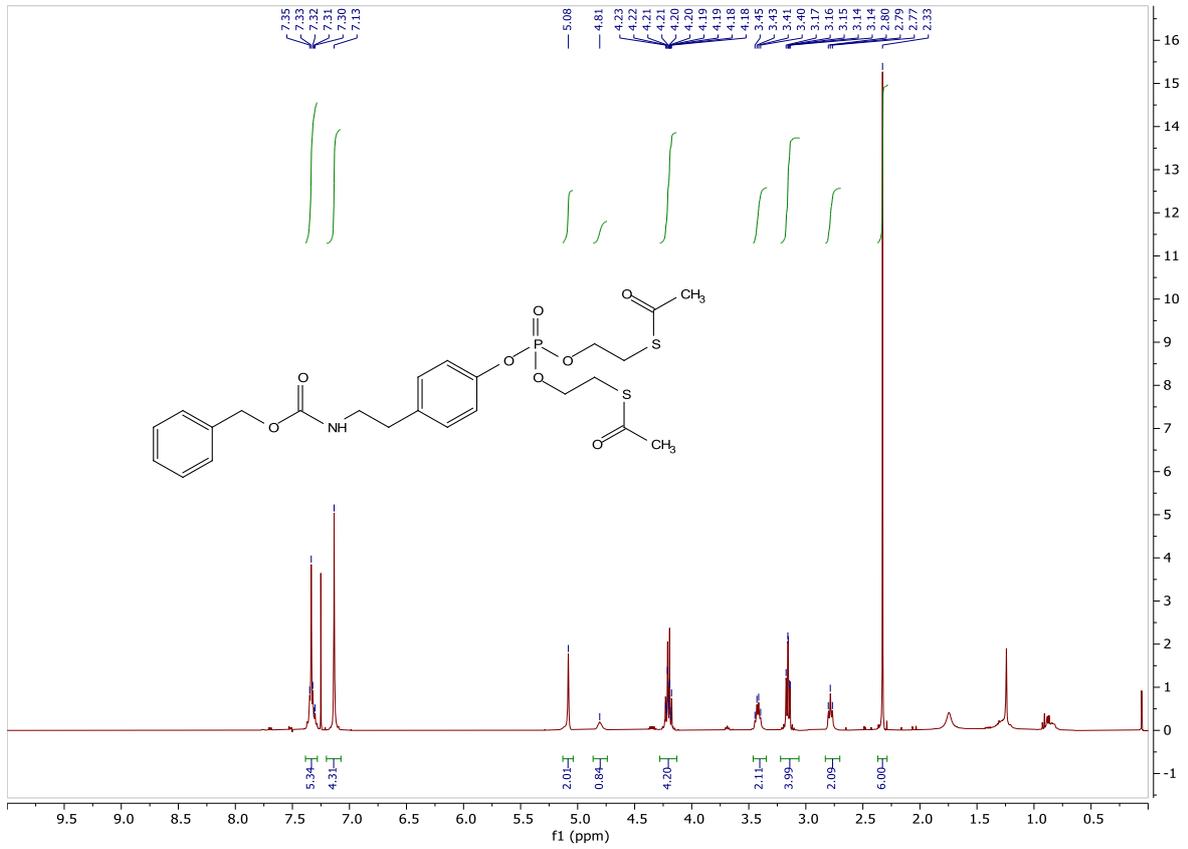


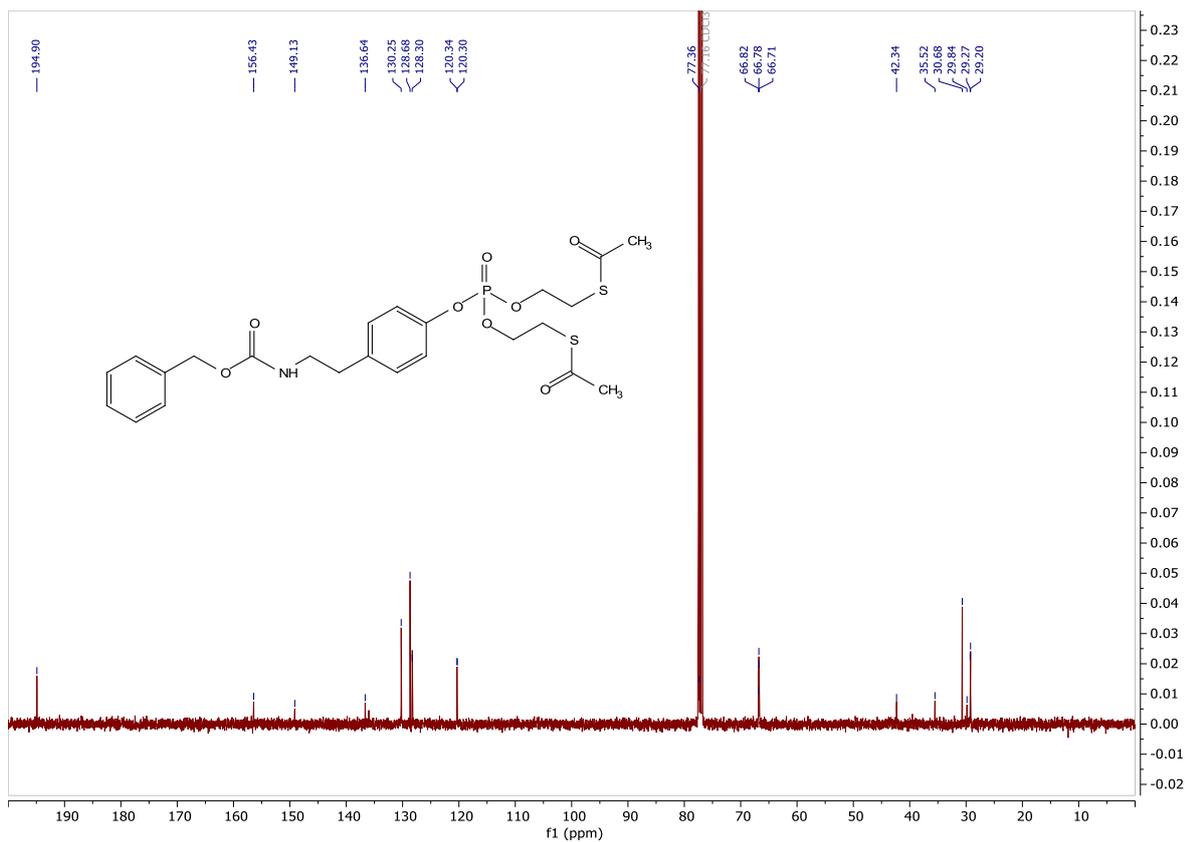
N-Cbz-3-(bis(2-bromoethyl)phosphor)-tyramine



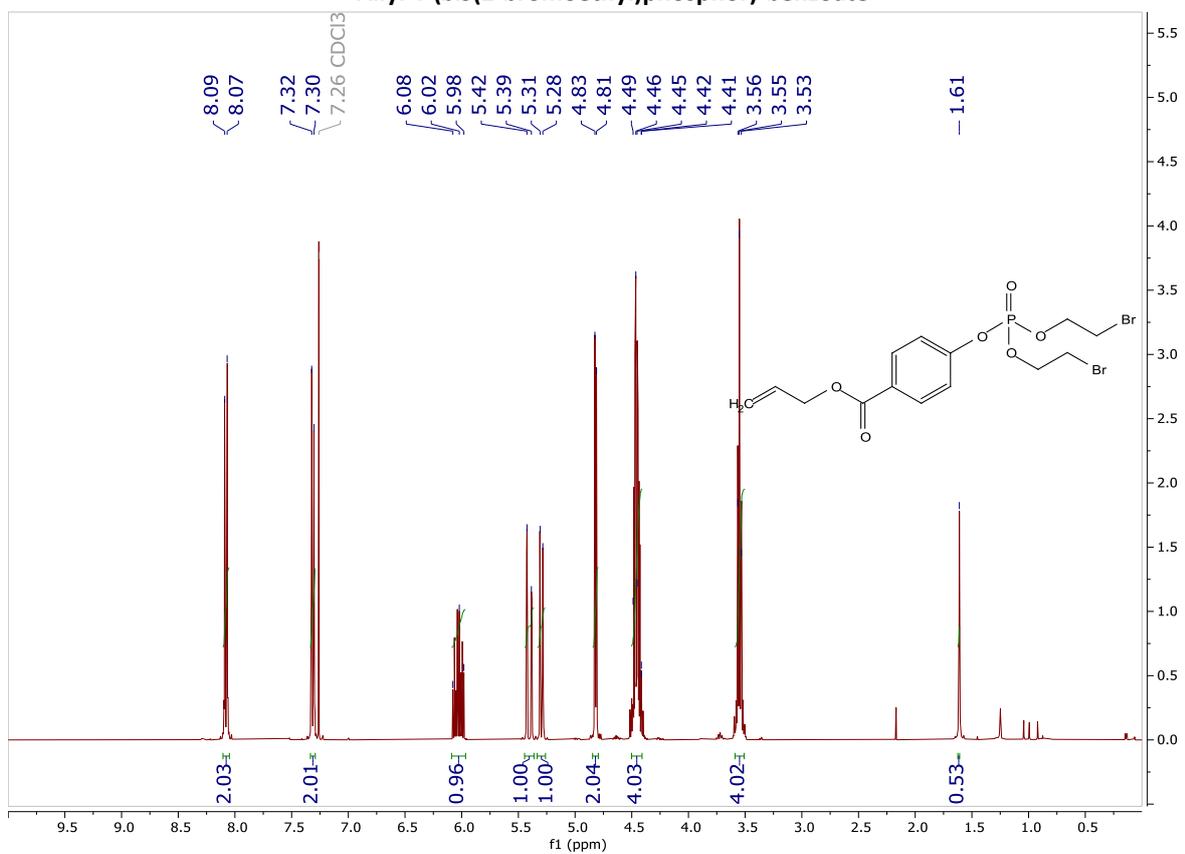


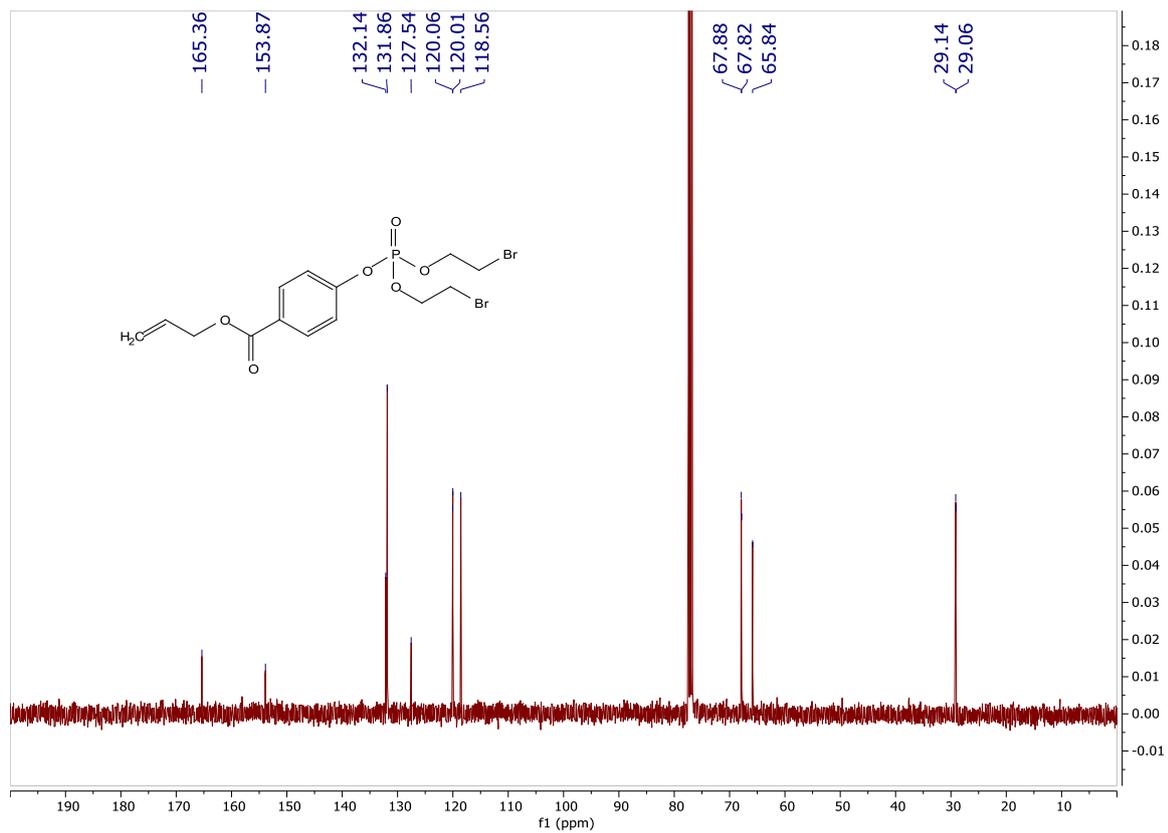
N-CBz-3-(bis(SATE)phosphor)-tyramine



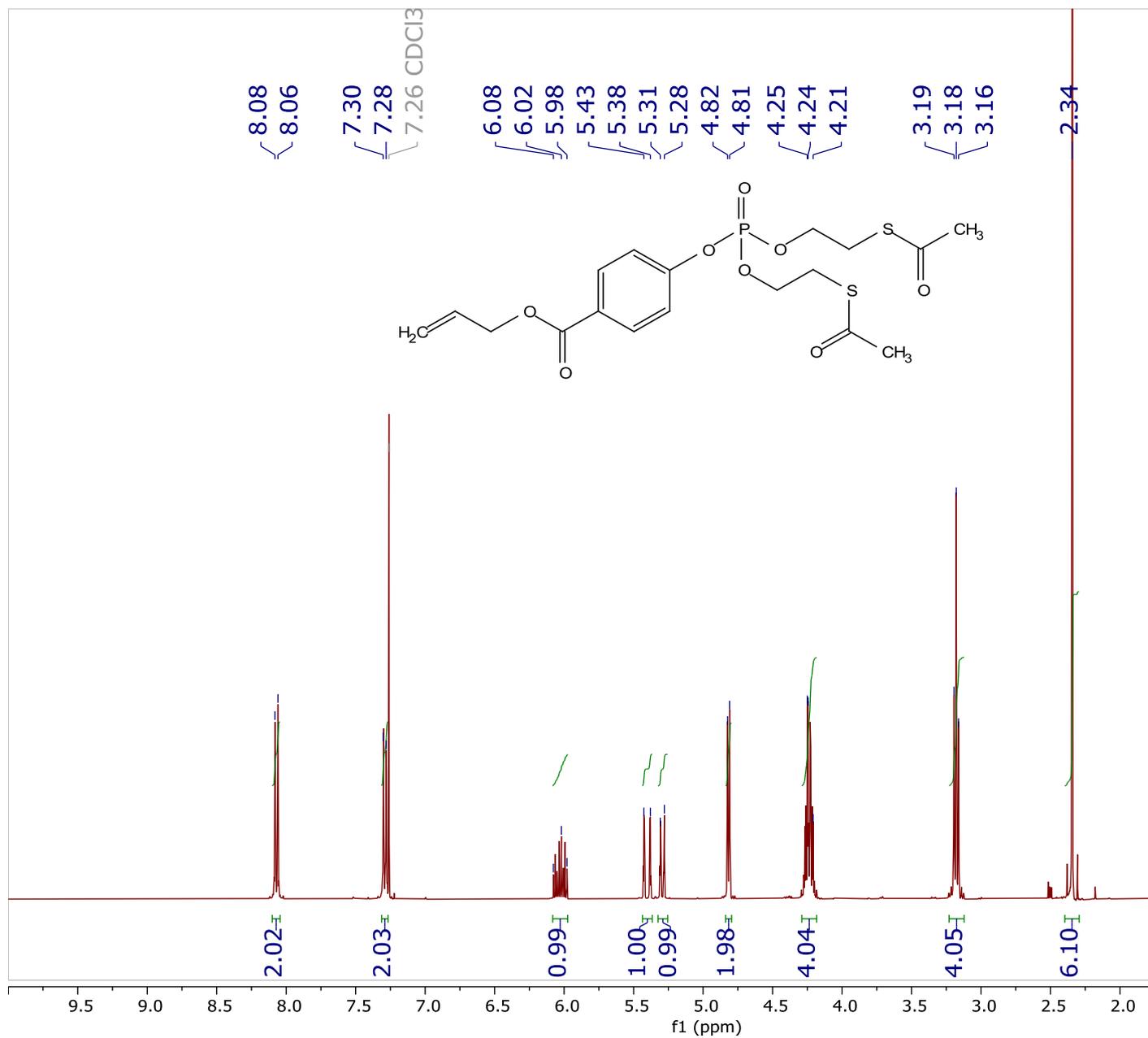


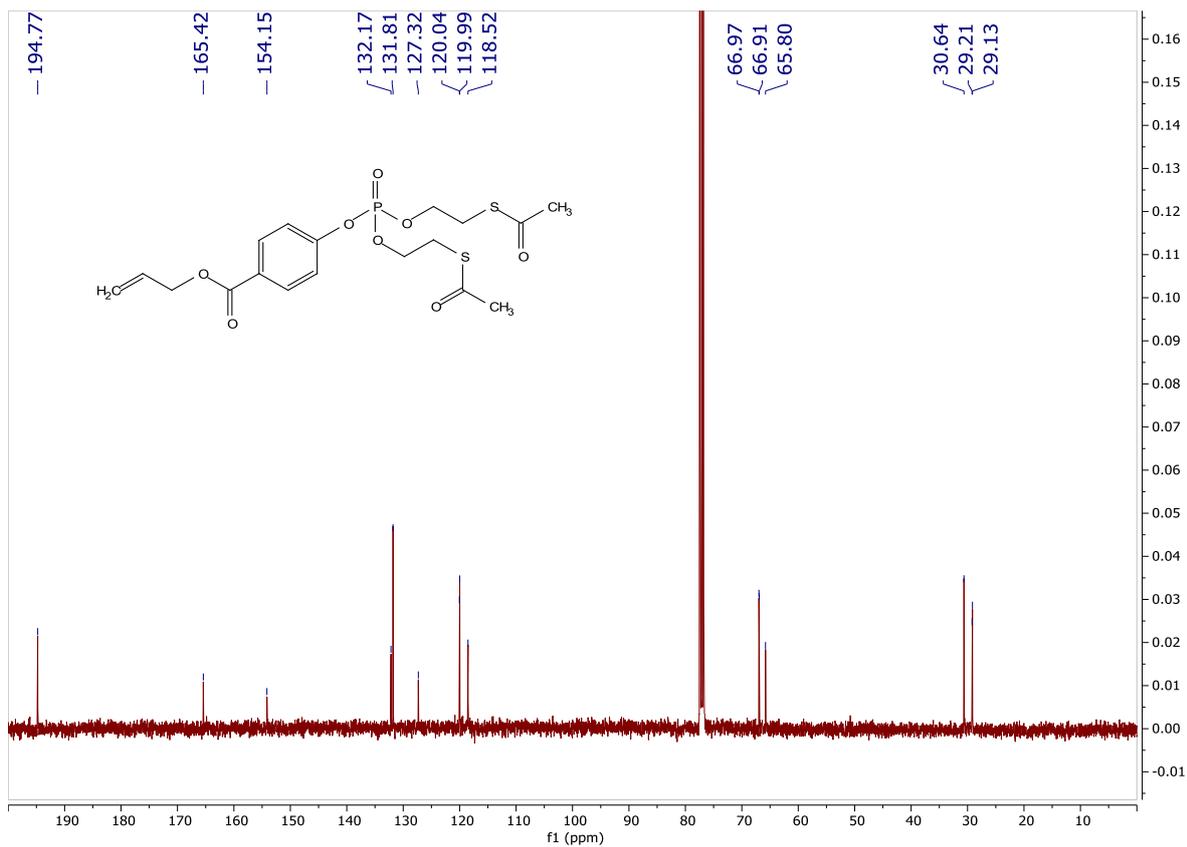
Allyl 4-(bis(2-bromoethyl)phosphor)-benzoate



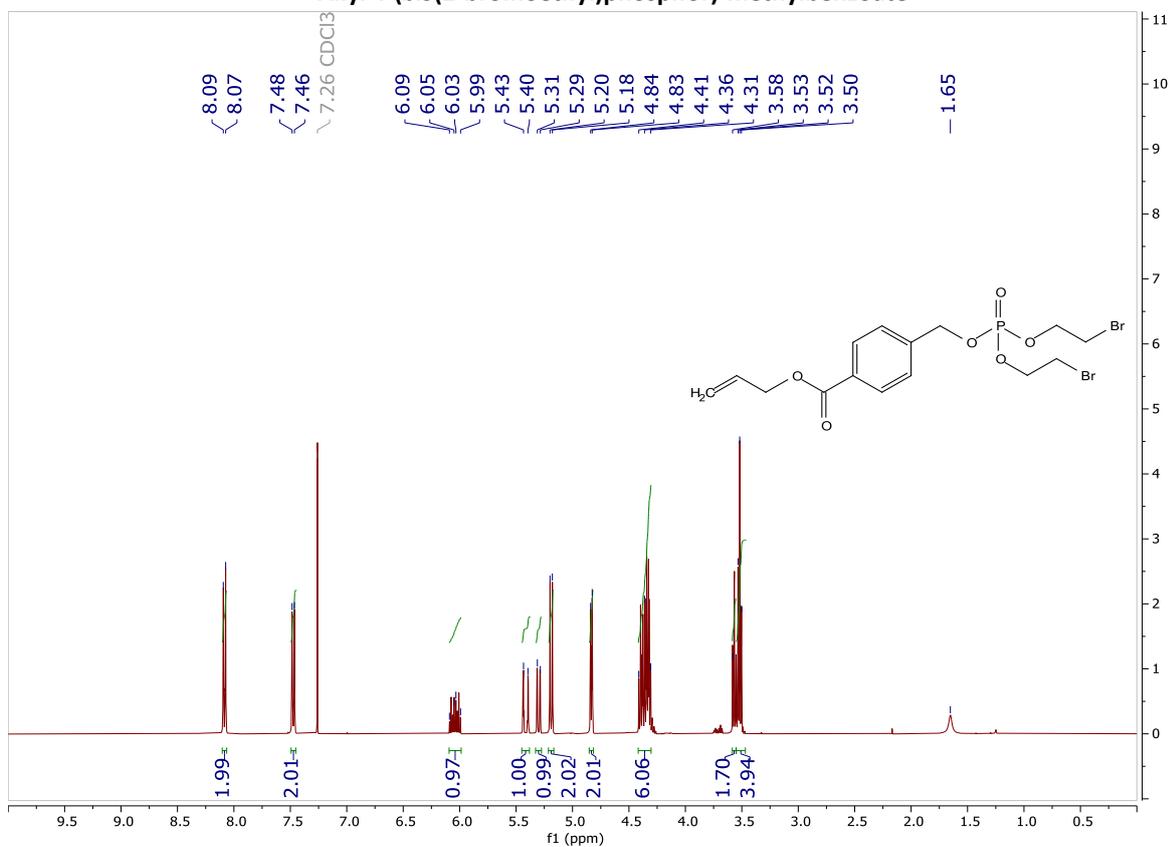


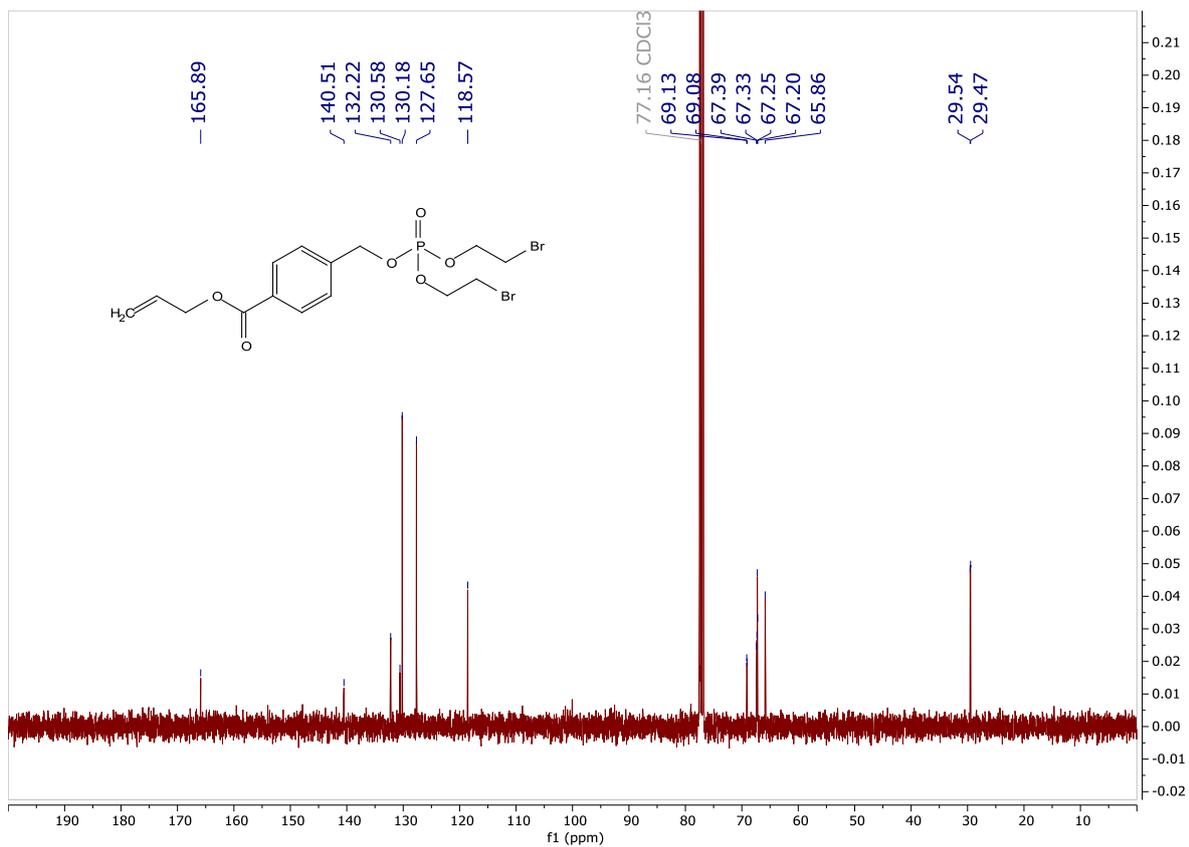
Allyl 4-(bis(SATE)phosphor)-benzoate



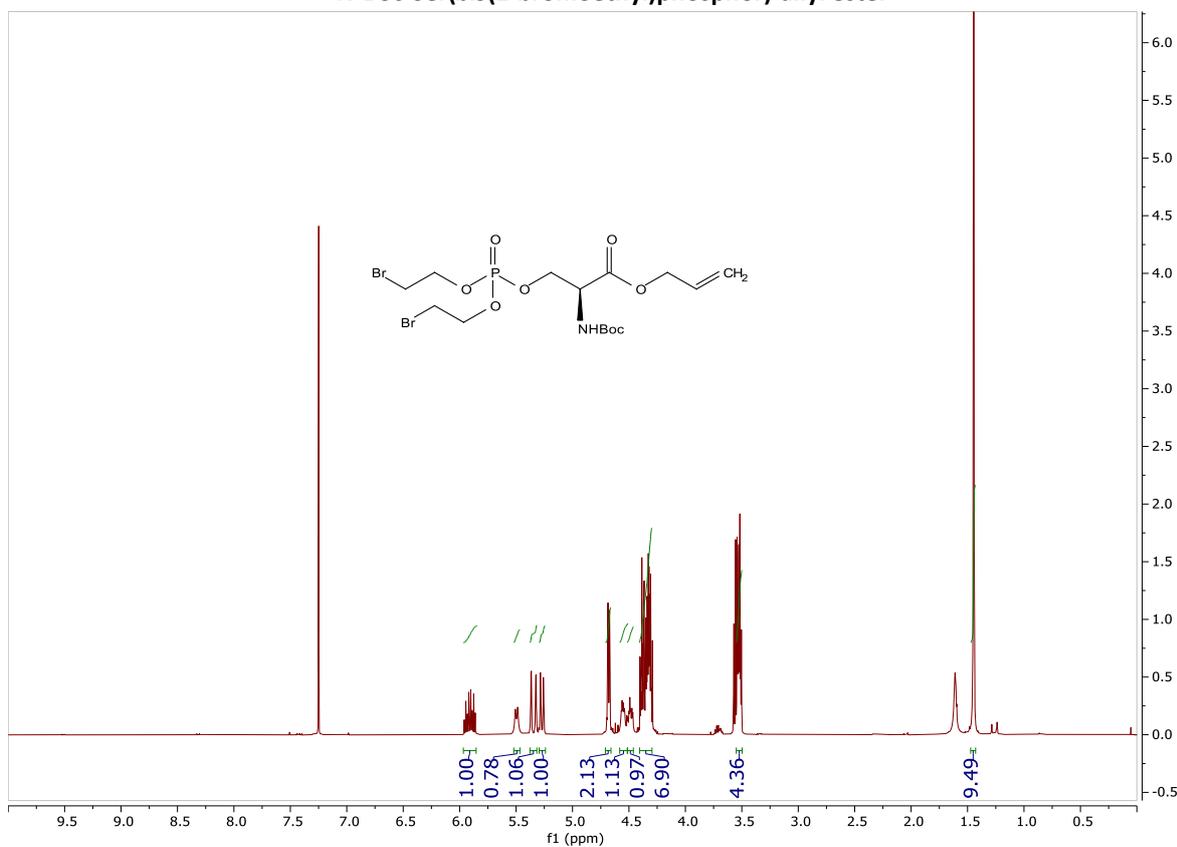


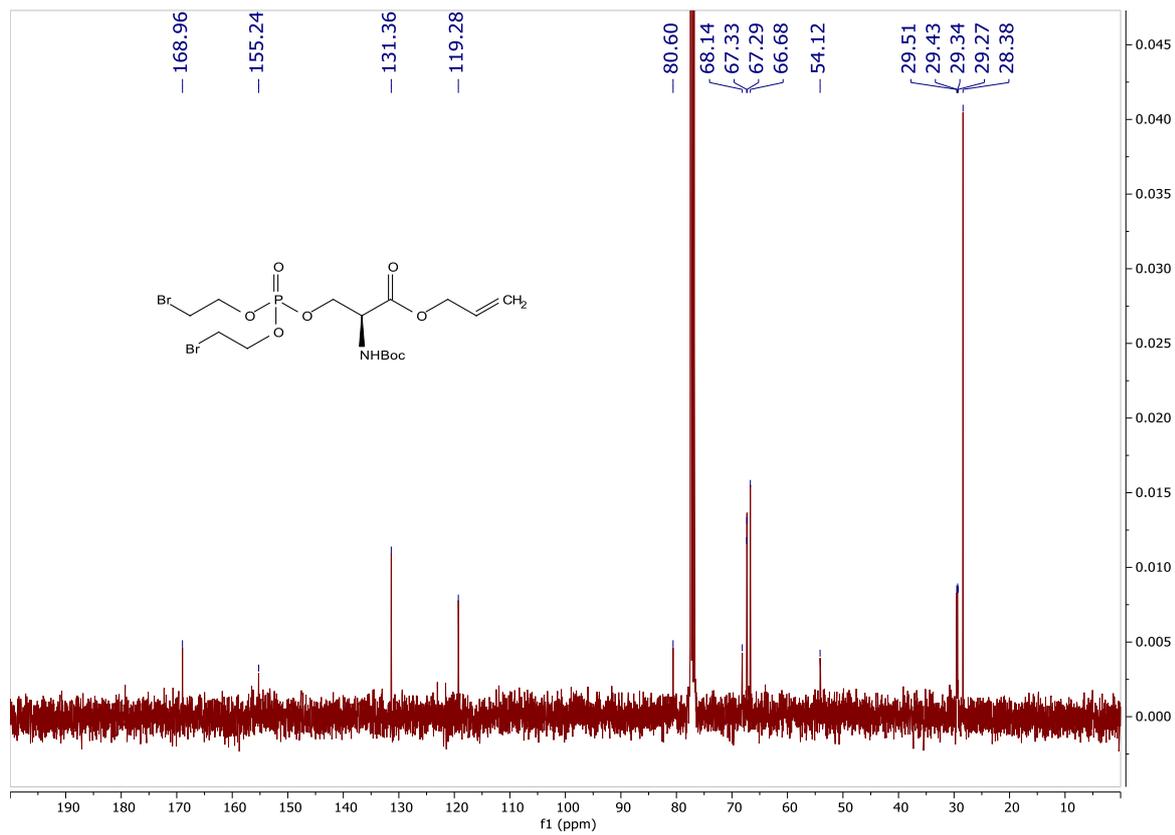
Allyl 4-(bis(2-bromoethyl)phosphor)-methylbenzoate





***N*-Boc-Ser(*bis*(2-bromoethyl)phosphor)-allyl ester**





***N*-Boc-Ser(*bis*(SATE)phosphor)-allyl ester**

