Supporting Information

Regioselective Alkylation of Carbohydrates and Diols: A Cheaper Iron Catalyst, New Applications and Mechanism

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General: All commercially available starting materials and solvents were of reagent grade and used without further purification. Chemical reactions were monitored with thin-layer chromatography using precoated silica gel 60 (0.25 mm thickness) plates. ^{1}H NMR and ^{13}C NMR spectra were recorded using a Bruker Avance 400 instrument or a Bruker DMX 500 instrument at 298K in $CDCl_3$, using the residual signals from $CHCl_3$ (^{1}H: δ = 7.25 ppm; ^{13}C: δ = 77.2 ppm) as the internal standard. ^{1}H NMR peak assignments were made by first-order analysis of the spectra, supported by standard ^{1}H-^{1}H NMR correlation spectroscopy (COSY).

General method for regioselective alkylation of diols and polyols:

1. The substrates (50 mg) were allowed to react with RX (alkylation reagents) (1.1 eq.) in dry acetonitrile (1 mL) or a mixed solvent (MeCN/DMF: 10/1) at 40 °C for 2 - 3 h in the presence of Ag_2O (0.6 eq.), TBAB (0.1 eq.) and $Fe(dipm)_3$ (0.1 eq.). The reaction mixtures were filtered and directly purified by flash column chromatography (hexanes/EtOAc = 3:1 to 1:1) to afford the pure products.
2. Diol and polyol reactants (50 mg) were allowed to react with RX (alkylation reagents) (1.1eq.) in 1 mL of dry acetonitrile at 80 °C for 8 h, in the presence of $Fe(dipm)_3$ (0.1 eq.) and K_2CO_3 (1.5 eq.). After cooling and evaporating the solvent, the reaction mixture was directly purified by flash column chromatography (hexanes–EtOAc 3:1 to 1:1), affording the pure products.

Spectroscopic data of the known products were in accordance with those reported in the literature.

Methyl 3-*O*-(4-methoxybenzyl)-4,6-*O*-benzylidene-*α*-D-mannopyranoside (5). ^{1}H NMR (400 MHz, $CDCl_3$): δ 7.62 – 7.18 (m, 7H, **Ph**CH, MeO-**Ph**CH_2), 6.85 (d, J = 8.6 Hz, 2H, MeO-**Ph**CH_2), 5.60 (s, 1H, PhC**H**), 4.77 (d, J = 11.4 Hz, 1H, MeO-PhC**H**$_2$), 4.72(s, 1H, H-1), 4.62 (d, J = 11.4 Hz, 1H, MeO-PhC**H**$_2$), 4.27 (dd, J_1 = 3.9 Hz, J_2 = 9.6 Hz, 1H, H-4), 4.07 (dd, J_1 = 7.1 Hz, J_2 = 14.3 Hz, 1H, H-6_a), 3.96 (s, 1H, H-2), 3.91–3.75 (m, 6H, H-3, H-5, H-6_b, **Me**O-PhCH_2), 3.36 (s, 3H, OMe), 2.83 (s, 1H, 2-OH) ppm. ^{13}C NMR (100 MHz, $CDCl_3$): δ159.5, 137.7, 130.2, 129.7, 129.0, 128.3, 126.2, 113.9, 101.7, 101.2, 78.9, 75.4, 72.8, 69.9, 69.0, 63.3, 55.4, 55.0 ppm.

Methyl 3-*O*-(4-bromobenzyl)-4,6-*O*-benzylidene-*α*-D-mannopyranoside (6). ^{1}H NMR (400 MHz, $CDCl_3$): δ 7.55–7.32 (m, 7H, **Ph**CH, Br-**Ph**CH_2), 7.21 (d, *J* = 8.3 Hz, 2H, Br-**Ph**CH_2), 5.59 (s, 1H, PhC**H**), 4.82-4.70 (m, 2H, Br-PhC$\mathbf{H_2}$, H-1), 4.66 (d, *J* = 12.2 Hz, 1H, Br-PhC$\mathbf{H_2}$), 4.27 (dd, J_1= 4.1 Hz, J_2= 9.6 Hz, 1H, H-4), 4.08 (dd, J_1 = 7.1 Hz, J_2 = 14.3 Hz, 1H, H-6_a), 4.01 (s, 1H, H-2), 3.94–3.72 (m, 3H, H-3, H-5, H-6_b), 3.37 (s, 3H, OMe), 2.73 (s, 1H, 2-OH) ppm. ^{13}C NMR (100 MHz, $CDCl_3$): δ 137.6, 137.1, 131.7, 129.6, 129.1, 128.4, 126.2, 121.9, 101.8, 101.2, 78.9, 75.7, 72.3, 70.0, 69.0, 63.3, 55.1 ppm.

Methyl 3-*O*-allyl-4,6-*O*-benzylidene-*α*-D-mannopyranoside (7). ^{1}H NMR (400 MHz, $CDCl_3$): δ 7.49 (d, *J* = 7.7 Hz, 2H, **Ph**CH), 7.44-7.30 (m, 3H, **Ph**CH), 5.83-5.61(m, 1H, CH_2C**H**=CH_2), 5.59 (s, 1H, PhC**H**), 5.37-5.25 (m, 2H, CH_2CH=C$\mathbf{H_2}$), 5.19 (d, *J* = 10.4 Hz, 1H, CH_2CH=C$\mathbf{H_2}$), 4.78 (s, 1H, H-1), 4.39-4.23 (m, 2H, C$\mathbf{H_2}$CH=CH_2, H-4), 4.20 (dd, J_1 = 5.9 Hz, J_2 = 12.8 Hz,1H, C$\mathbf{H_2}$CH=CH_2), 4.12-4.00 (m, 2H, H-2, H-6_a), 3.91-3.75 (m, 3H, H-3, H-5, H-6_b), 3.39 (s, 3H, OMe), 2.77 (s, 1H, 2-OH) ppm. ^{13}C NMR (100 MHz, $CDCl_3$): δ 137.7, 134.6, 129.0, 128.3, 126.2, 117.6, 101.7, 101.2, 78.9, 75.3, 72.0, 70.0, 69.0, 63.3, 55.1 ppm.

Methyl 3-*O*-(2-cyanobenzyl)-4,6-*O*-benzylidene-*α*-D-mannopyranoside (8). ^{1}H NMR (400 MHz, $CDCl_3$): δ 7.61 (d, *J* = 7.6 Hz 1H, **Ph**CH), 7.56-7.46 (m, 4H, CN-**Ph**CH_2), 7.41-7.33 (m, 4H, **Ph**CH), 5.61 (s, 1H, PhC**H**), 4.98 (d, *J* = 12.4 Hz, 1H, CN-PhC$\mathbf{H_2}$), 4.92 (d, *J* = 12.4 Hz, 1H, CN-PhC$\mathbf{H_2}$), 4.78 (s, 1H, H-1), 4.29 (dd, J_1 = 4.3 Hz, J_2 = 9.8 Hz, 1H, H-4), 4.23-4.13 (m, 2H, H-2, H-6_a), 3.97-3.77 (m, 3H, H-3, H-5, H-6_b), 3.39 (s, 3H, OMe), 2.90 (s, 1H, 2-OH) ppm. ^{13}C NMR (100 MHz, $CDCl_3$): δ 141.6, 137.6, 133.1, 132.9, 129.1, 128.3, 126.2, 117.8, 111.7, 101.7, 101.3, 78.8, 76.6, 71.0, 69.8, 69.0, 63.4, 55.1.

Methyl 3-*O*-allyl-6-*O*-(*tert*-butyldimethylsilyloxy)-*α*-D-mannopyranoside (10). ^{1}H NMR (400 MHz, $CDCl_3$): δ 6.10-5.88 (m, 1H, $CH_2C\mathbf{H}{=}CH_2$), 5.32 (dd, J_1 = 17.2, J_2 = 1.5 Hz, 1H, $CH_2CH{=}C\mathbf{H}_2$), 5.22 (dd, J_1 = 10.4, J_2 = 1.1 Hz, 1H, $CH_2CH{=}C\mathbf{H}_2$), 4.74 (s, 1H, H-1), 4.23–4.11 (m, 2H, $C\mathbf{H}_2CH{=}CH_2$), 3.97 (s, 1H, H-2), 3.93–3.79 (m, 3H, H-4, H-6_a, H-6_b), 3.67–3.52 (m, 2H, H-3, H-5), 3.37 (s, 3H, OMe), 3.06 (s, 1H, 4-OH), 2.42 (s, 1H, 2-OH), 0.90 (s, 9H, $Si(CH_3)_3$), 0.09 (s, 6H, $Si(CH_3)_2$) ppm. ^{13}C NMR (100 MHz, $CDCl_3$): δ 134.6, 118.0, 100.5, 79.0, 71.0, 70.8, 69.4, 67.9, 65.0, 55.0, 26.0, 18.4, -5.4 ppm.

Table S1 Comparison the isolation yields of alkylalation methods using catalytic amounts of $Fe(dibm)_3$ and $Fe(dipm)_3$.

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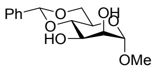
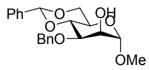
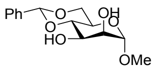
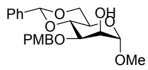
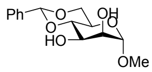
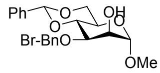
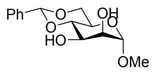
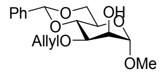
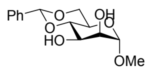
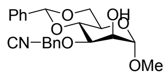
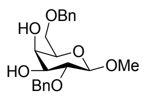
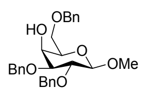
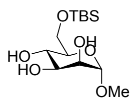
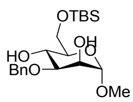
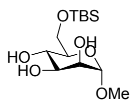
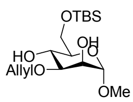
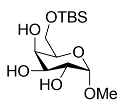
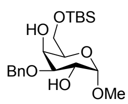
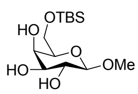
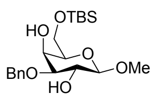
1			96%	93%
2			96%	98%
3			98%	94%
4			98%	94%
5			97%	85%
6			89%	91%
7			91%	91%
8			75%	92%
9			87%	91%
10			89%	94%

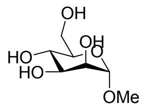
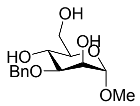
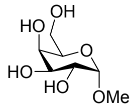
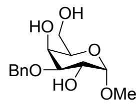
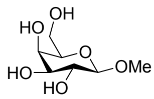
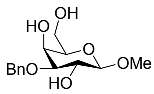
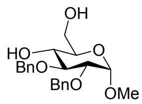
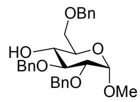
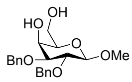
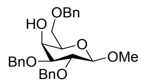
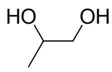
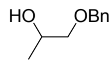
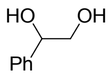
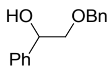
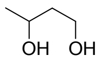
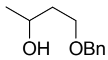
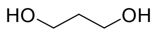
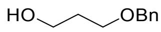
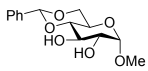
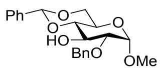
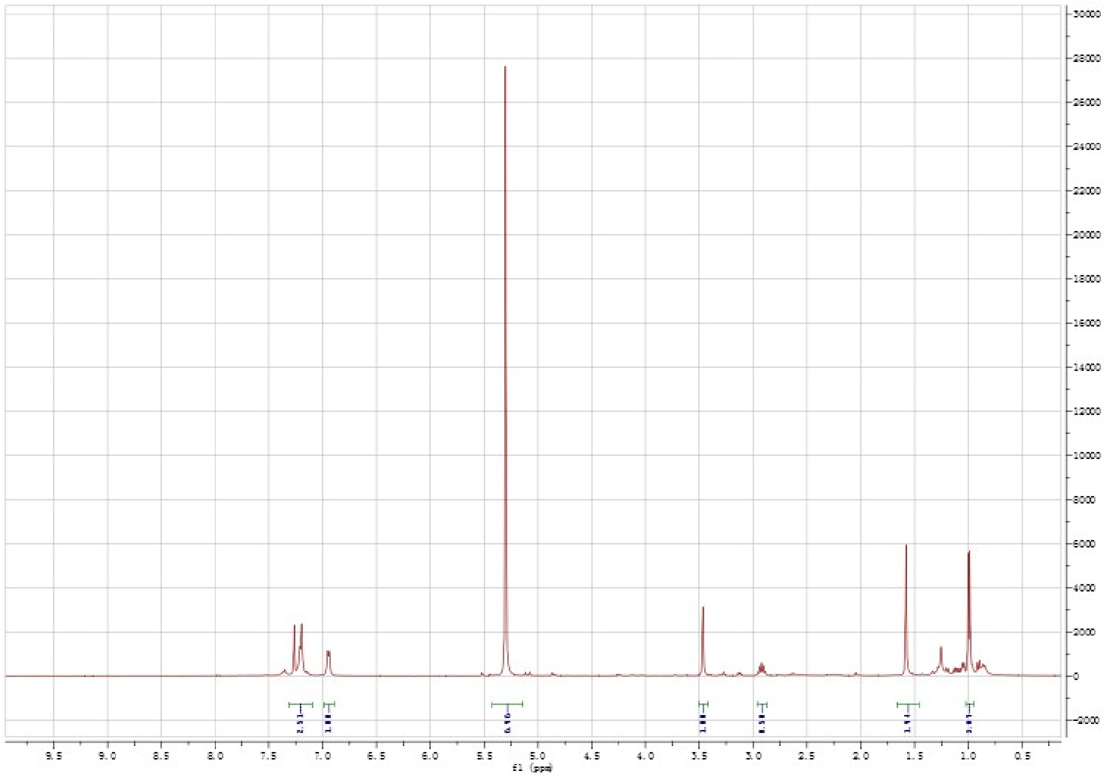
11			86%	80%
12			83%	85%
13			90%	90%
15			98%	78%
16			91%	86%
17			94%	93%
18			75%	75%
19			80%	86%
20			86%	90%
21			58%	64%

Figure S1 Recrystallized $Fe(dipm)_3$.

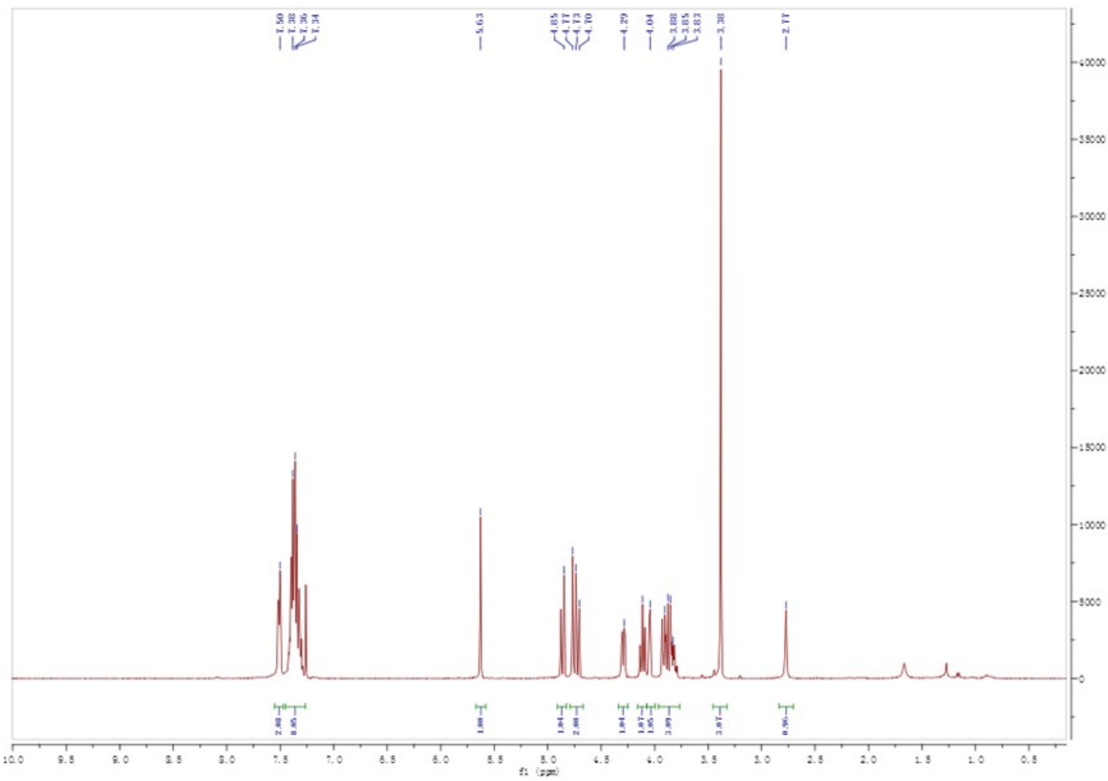
Figure S2

^{1}H-NMR of **2,6-dimethyl-4-benzyl-3,5- heptadione (The product of BnBr and dibm)**



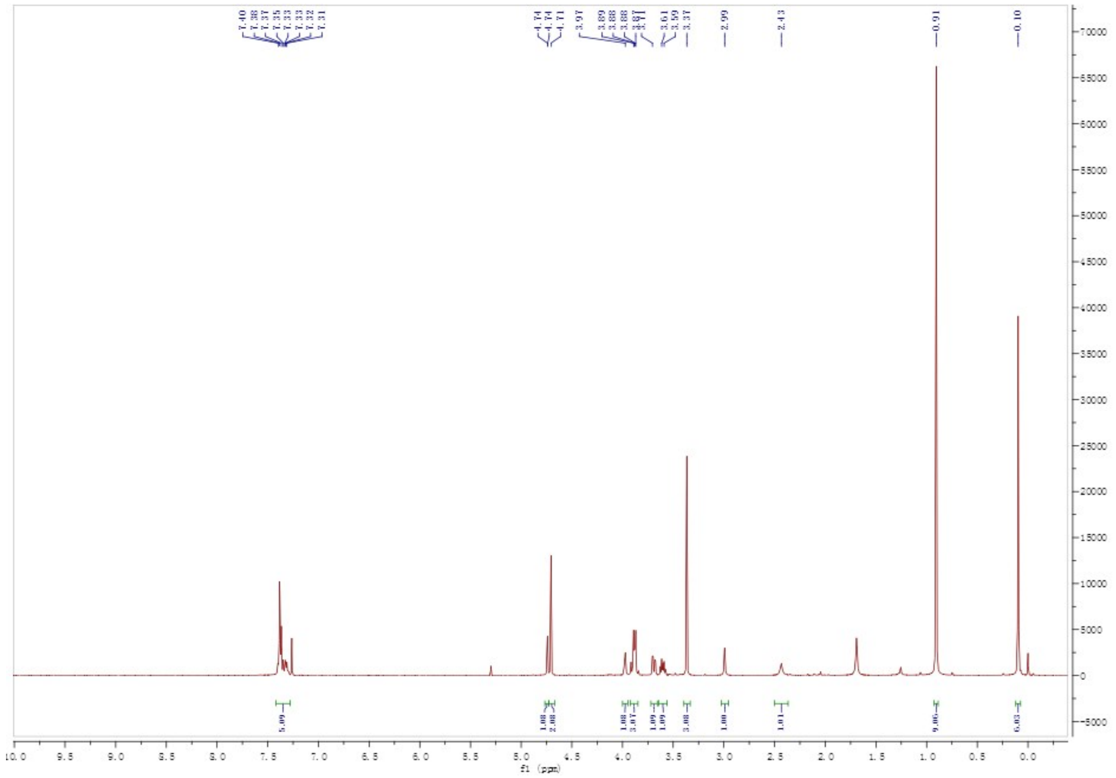
Methyl 3-*O*-benzyl-4, 6-*O*-benzylidene-*α*-D-mannopyranoside (2)[1]:

^{1}H-NMR of compound **2** ($CDCl_3$)



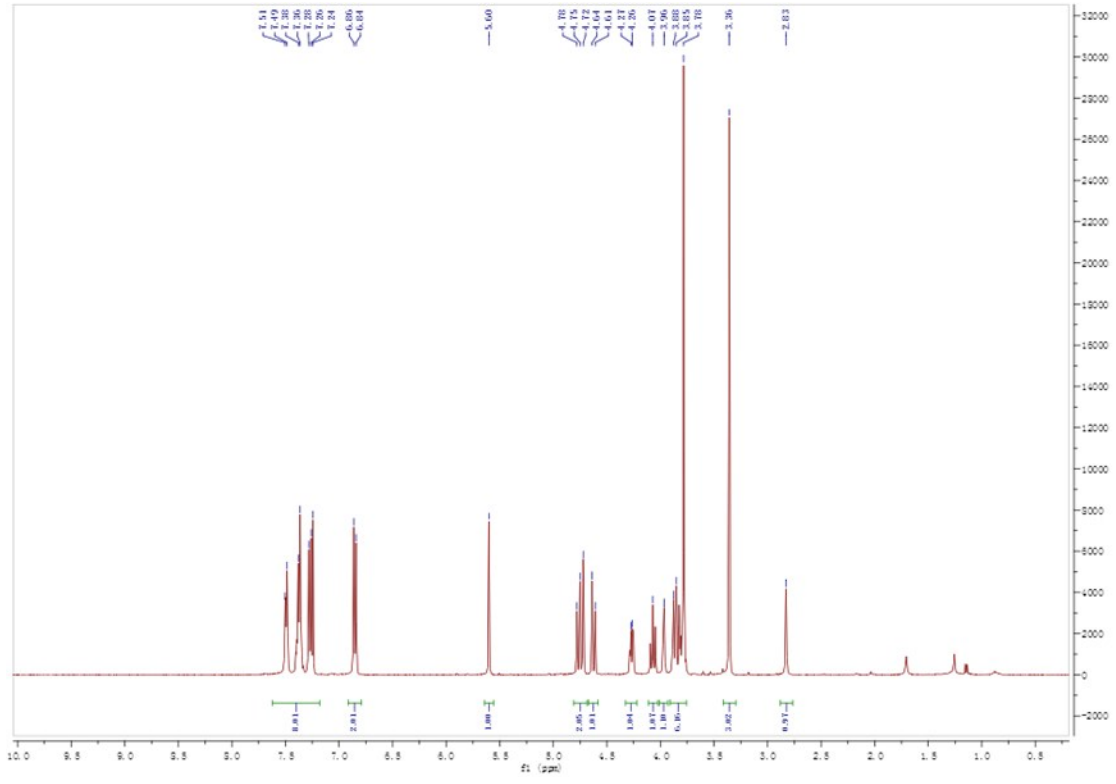
Methyl 3-*O*-benzyl-6-*O*-(*tert*-butyldimethylsilyloxy)-α-D-mannopyranoside (4)[2]:

^{1}H-NMR of compound **4** ($CDCl_3$)

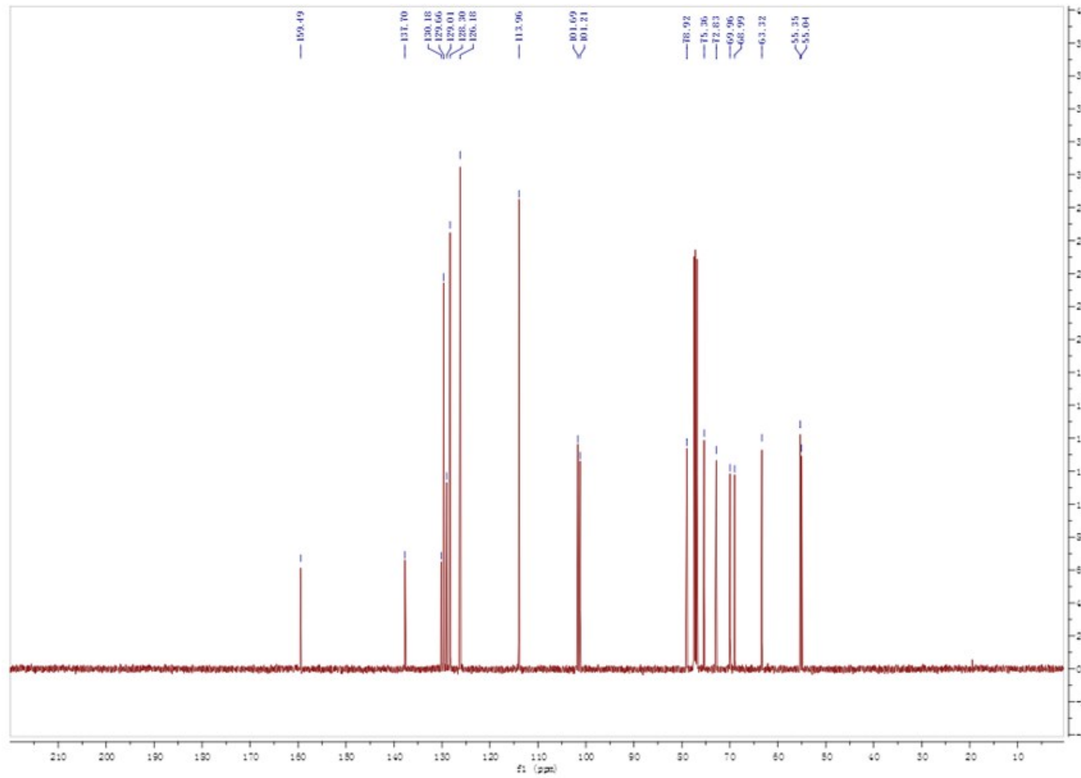


Methyl 3-*O*-(4-methoxybenzyl)-4, 6-*O*-benzylidene-*α*-D-mannopyranoside (5)[3]:

^{1}H-NMR of compound **5** ($CDCl_3$)

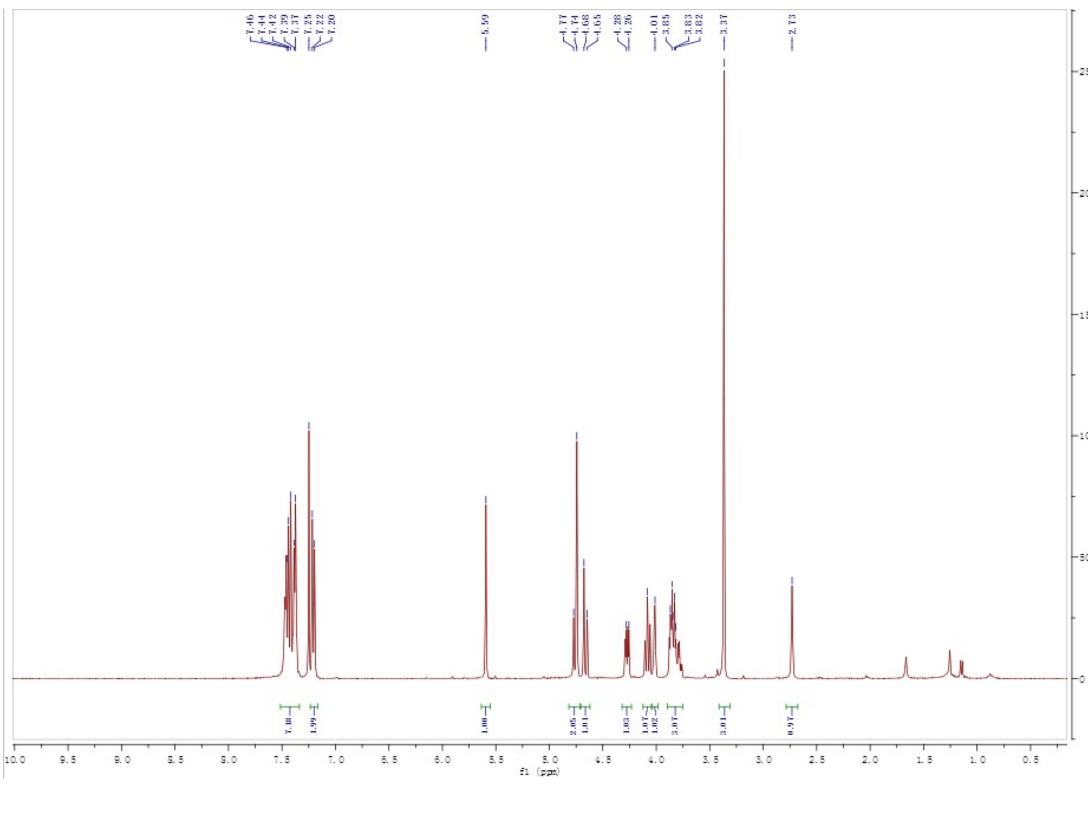


^{13}C-NMR of compound **5** ($CDCl_3$)

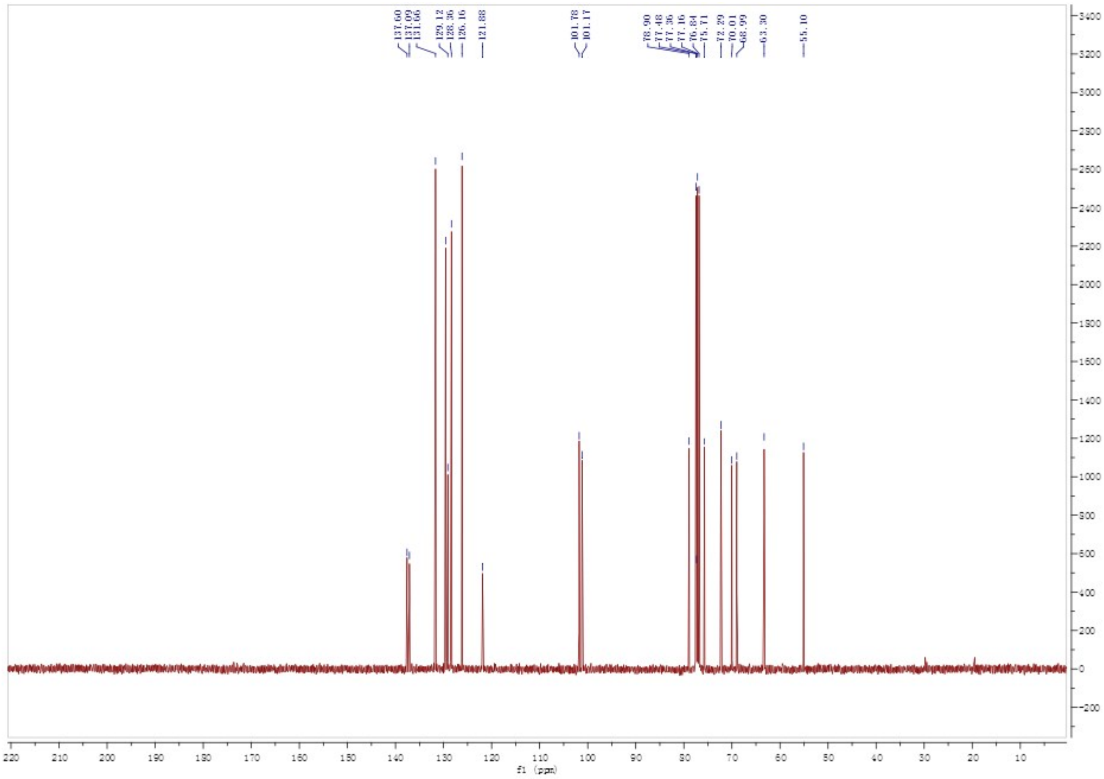


Methyl 3-*O*-(4-bromobenzyl)-4, 6-*O*-benzylidene-*α*-D-mannopyranoside (6)[3]:

^{1}H-NMR of compound **6** ($CDCl_3$)

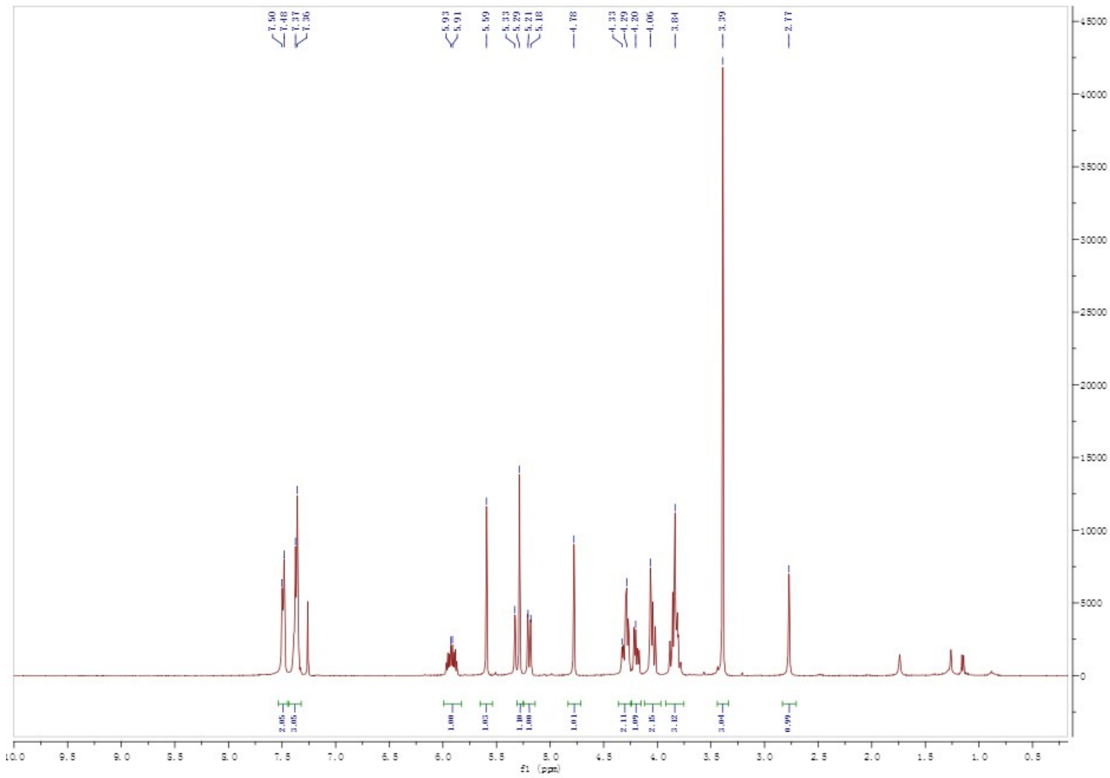


^{13}C-NMR of compound **6** ($CDCl_3$)

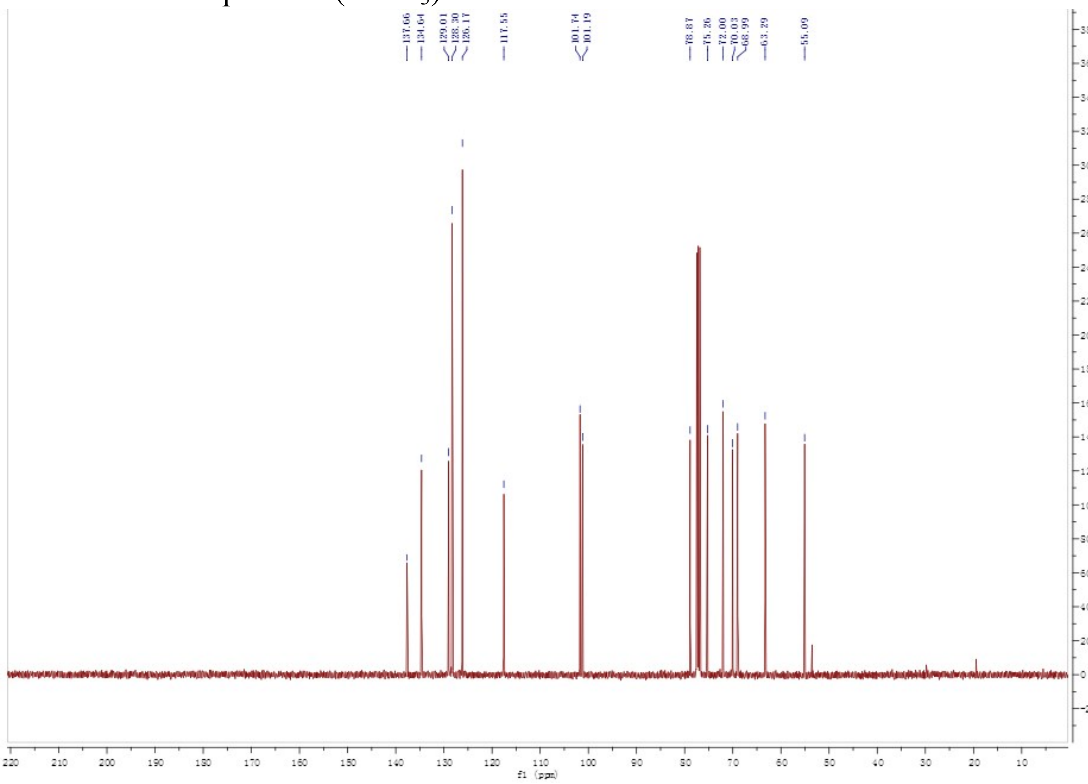


Methyl 3-*O*-allyl-4, 6-*O*-benzylidene-*α*-D-mannopyranoside (7)[3]:

^{1}H-NMR of compound **7** ($CDCl_3$)

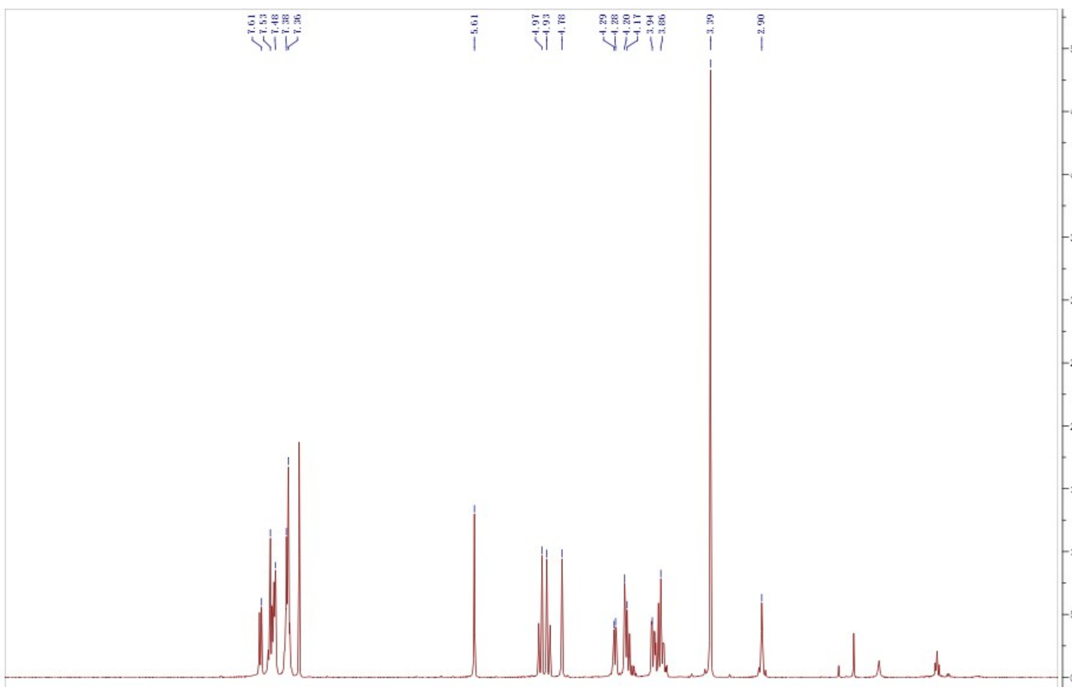


^{13}C-NMR of compound **7** ($CDCl_3$)

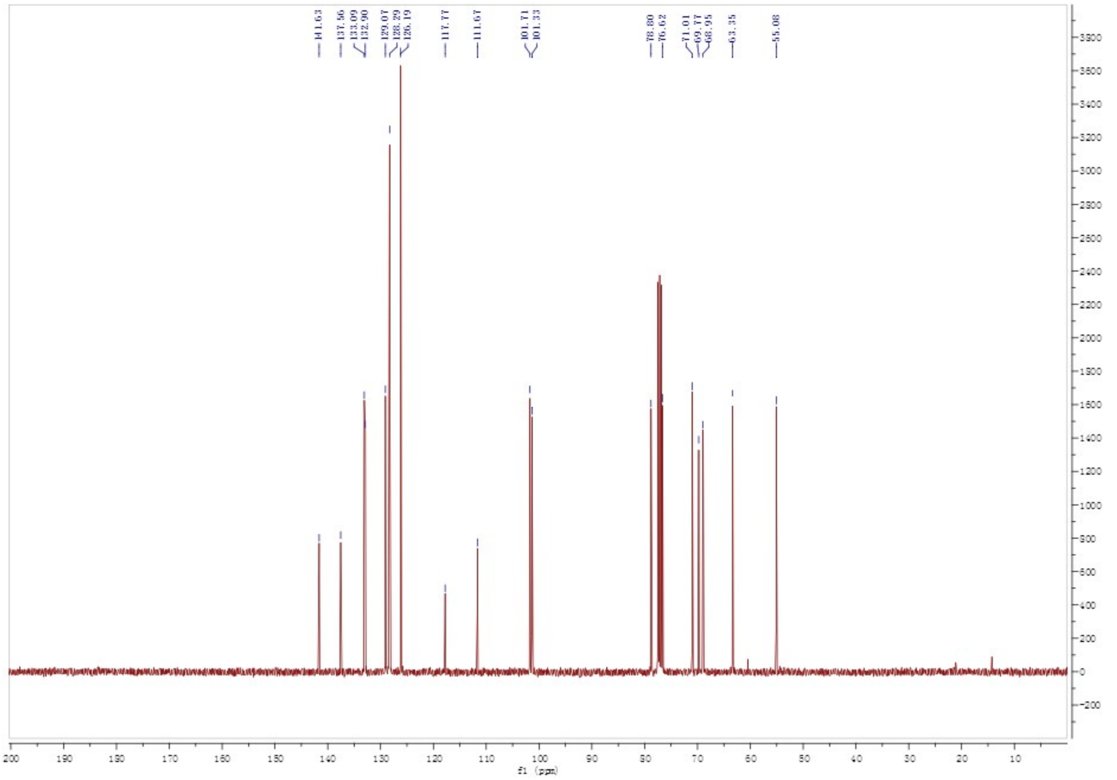


Methyl 3-*O*-(2-cyanobenzyl)-4, 6-*O*-benzylidene-*α*-D-mannopyranoside (8)[3]:

^{1}H-NMR of compound **8** ($CDCl_3$)

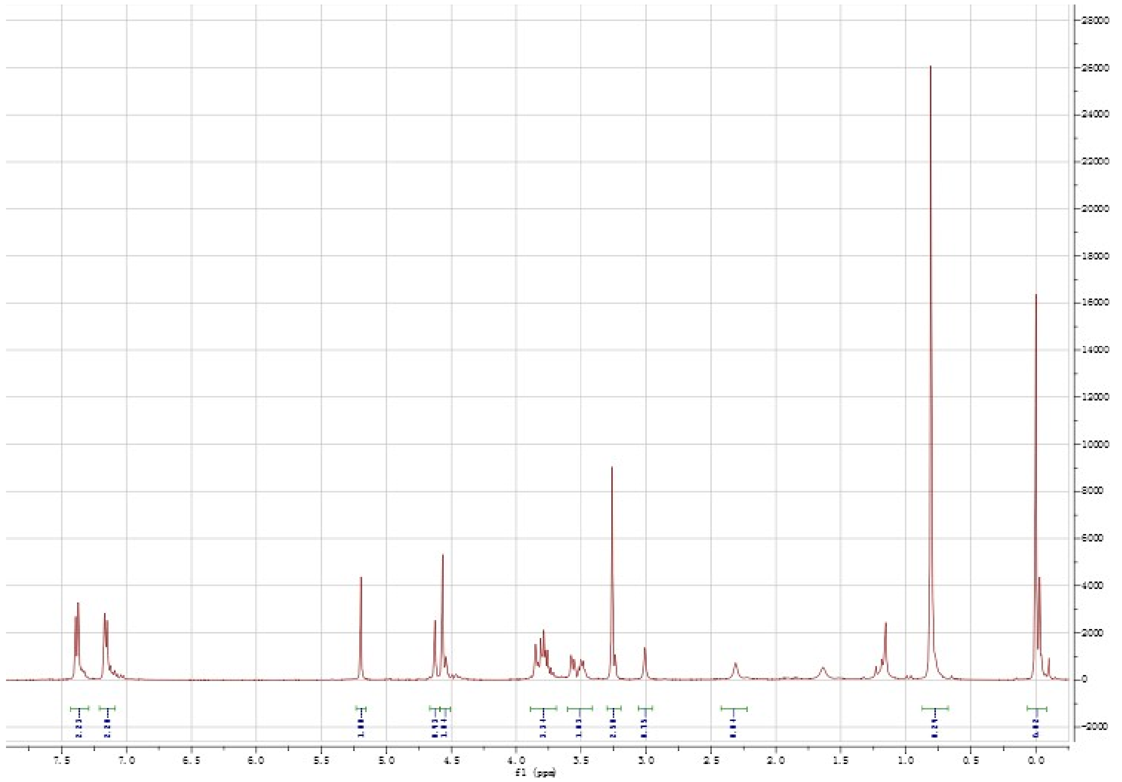


^{13}C-NMR of compound **8** ($CDCl_3$)



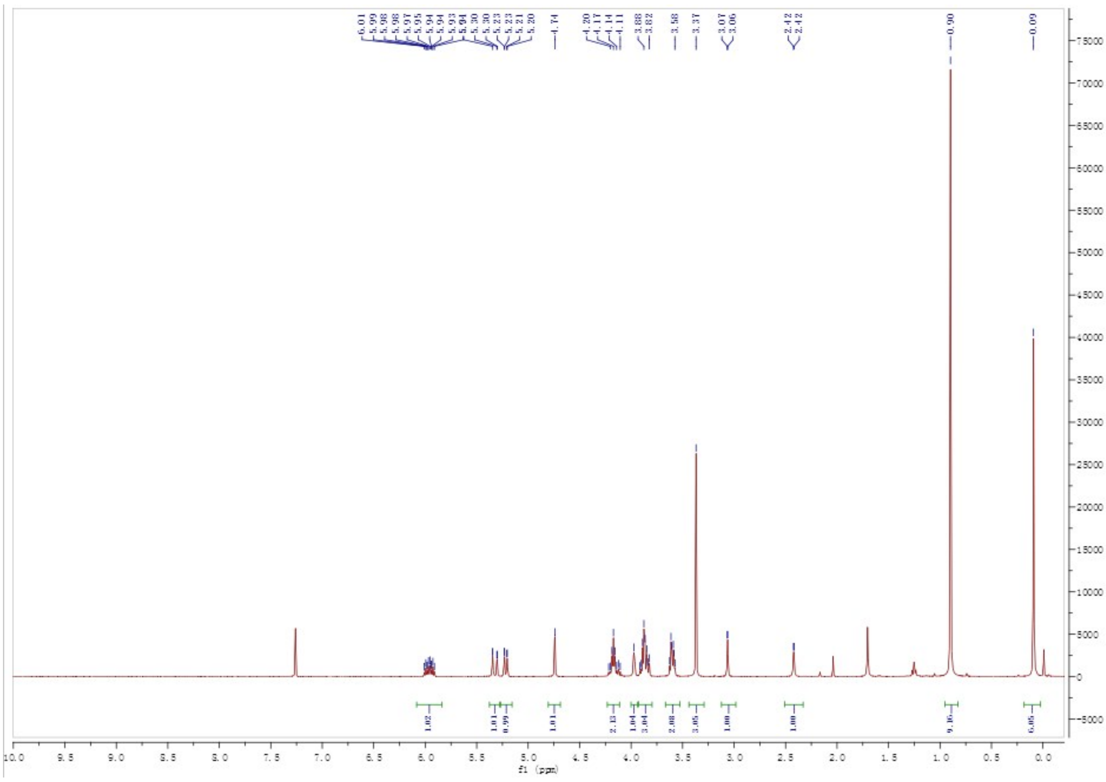
Methyl 3-*O*-(4-bromobenzyl)-6-*O*-(*tert*-butyldimethylsilyloxy)-*α*-D-mannopyranoside (9)[4]:

^{1}H-NMR of compound **9** ($CDCl_3$)

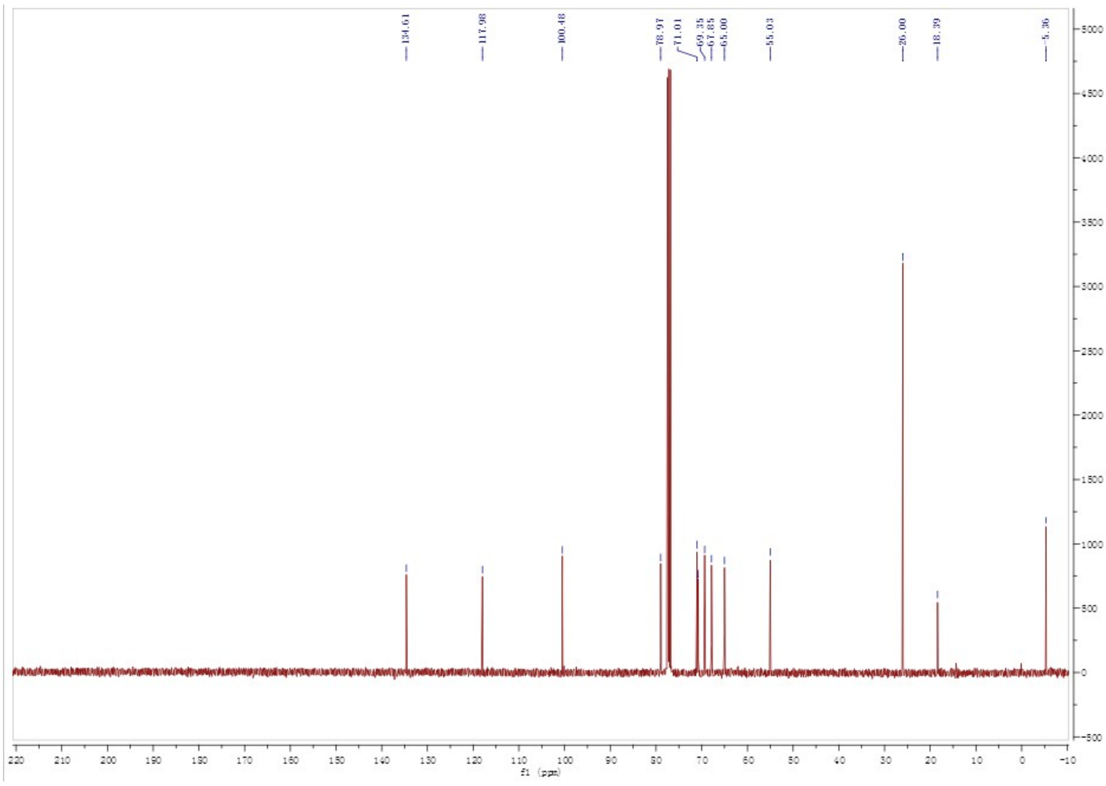


Methyl 3-*O*-allyl-6-*O*-(*tert*-butyldimethylsilyloxy)-*α*-D-mannopyranoside (10)[3]:

^{1}H-NMR of compound **10** ($CDCl_3$)

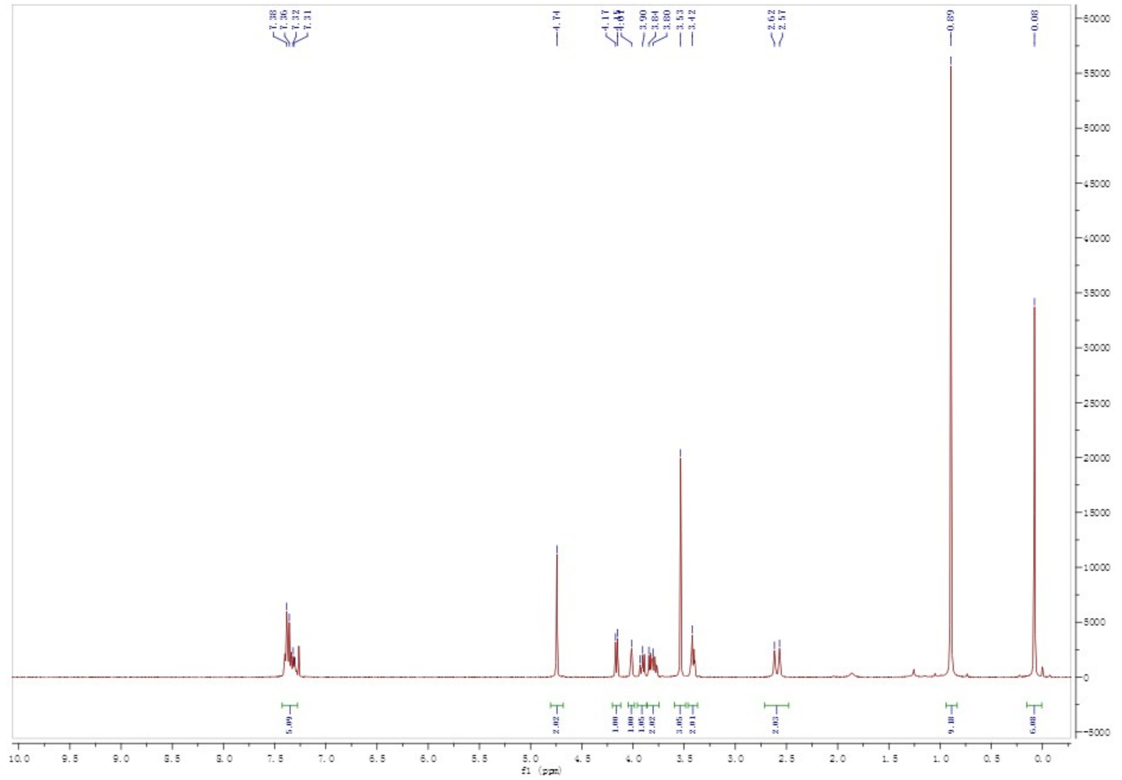


^{13}C-NMR of compound **10** ($CDCl_3$)



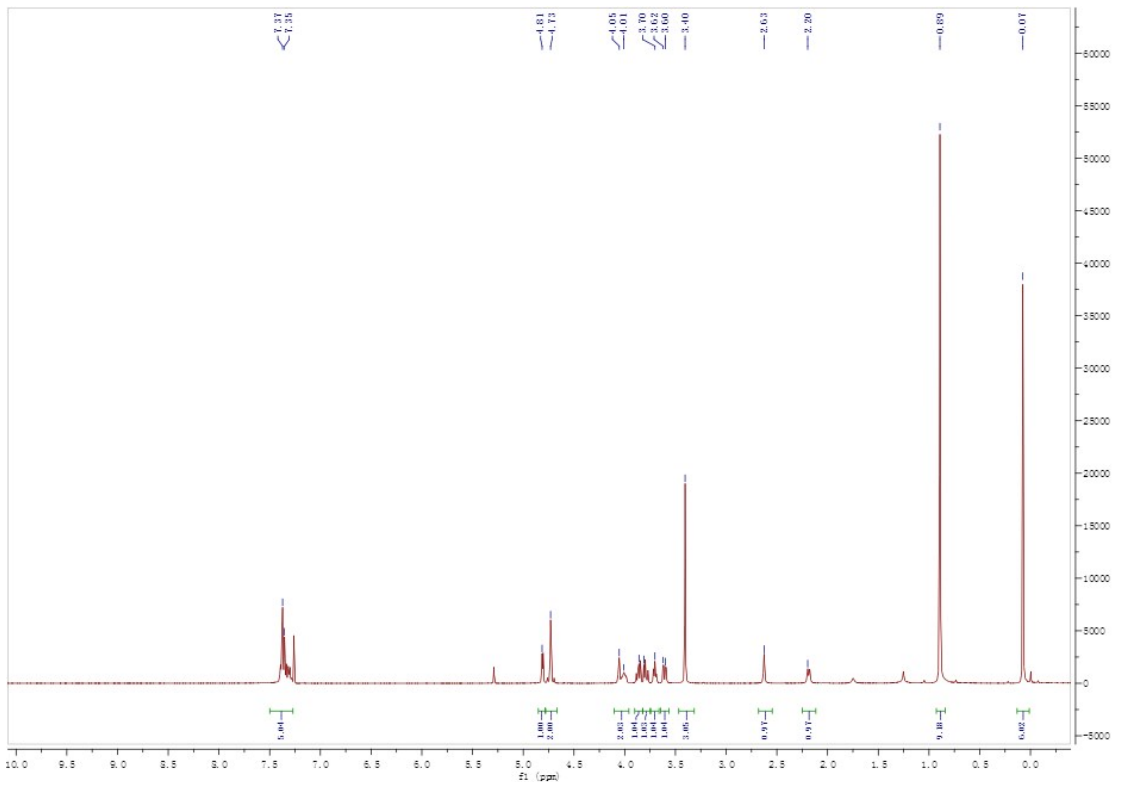
Methyl 3-*O*-benzyl-6-*O*-(*tert*-butyldimethylsilyloxy)-*β*-D-galactopyranoside (12)[4]:

^{1}H-NMR of compound **12** ($CDCl_3$)



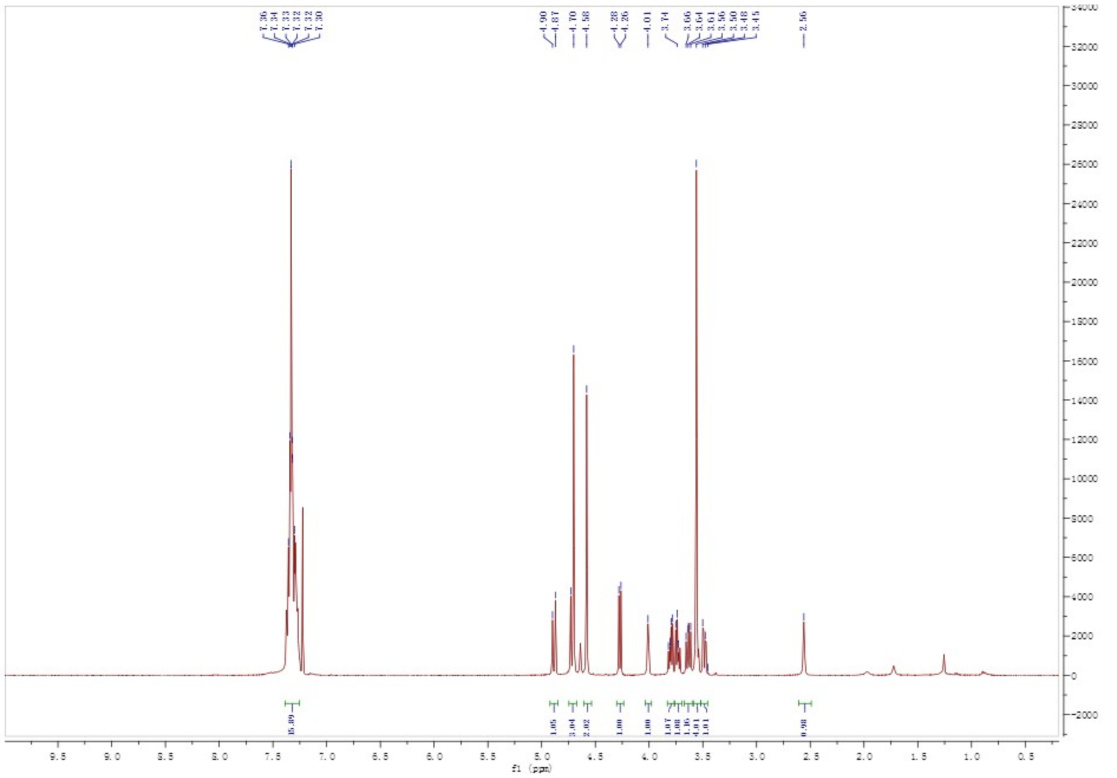
Methyl 3-*O*-benzyl-6-*O*-(*tert*-butyldimethylsilyloxy)-*α*-D-galactopyranoside (14)[4]:

^{1}H-NMR of compound **14** ($CDCl_3$)



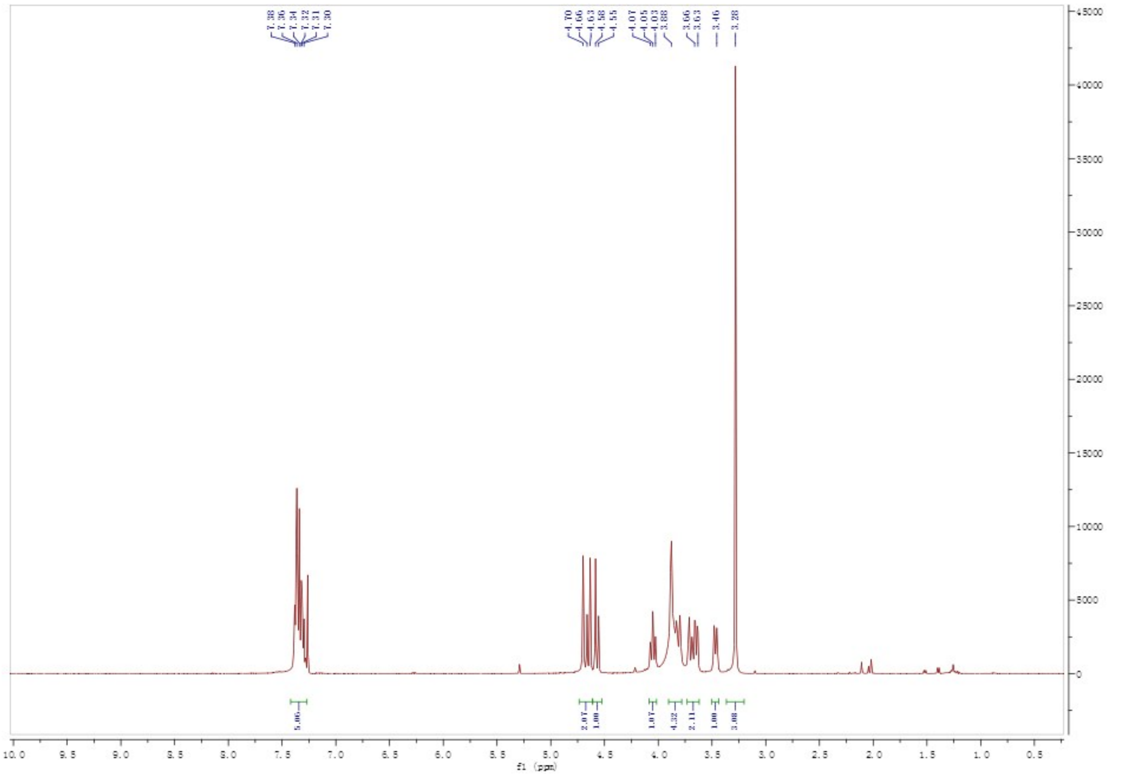
Methyl 2, 3, 6-tri-*O*-benzyl-*β*-D-galactopyranoside (16)[5]:

^{1}H-NMR of compound **16** ($CDCl_3$)



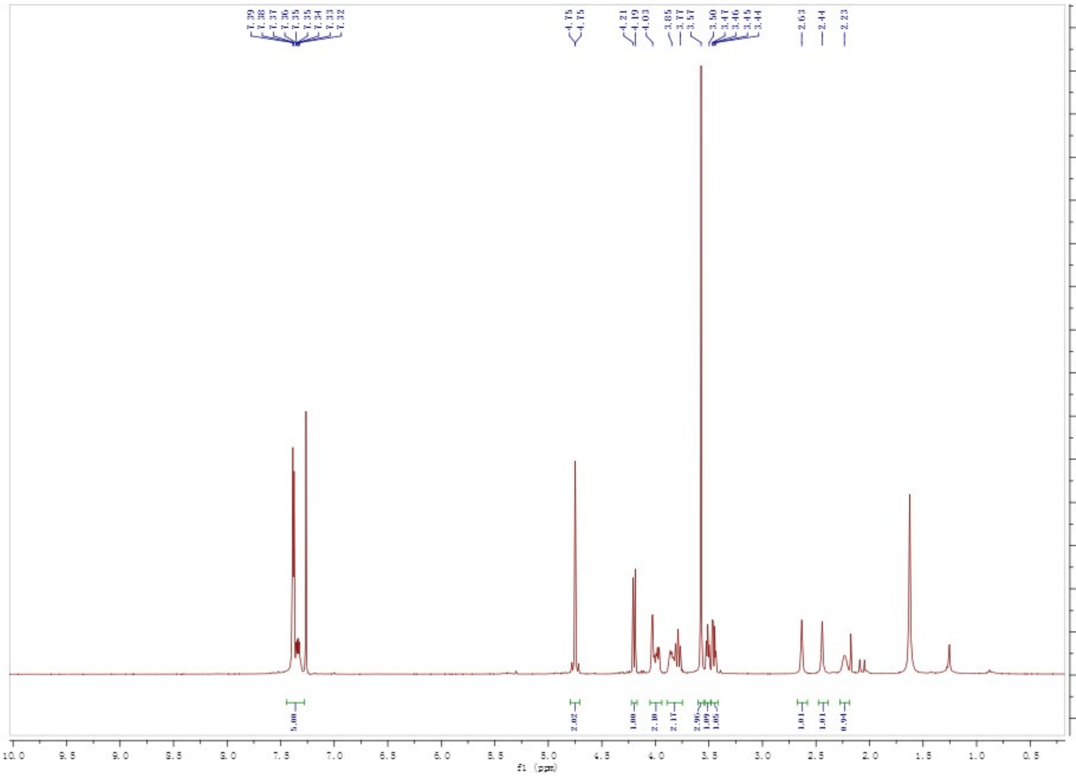
Methyl 3-*O*-benzyl-*α*-D-mannopyranoside (18)[1]:

^{1}H-NMR of compound **18** ($CDCl_3$)



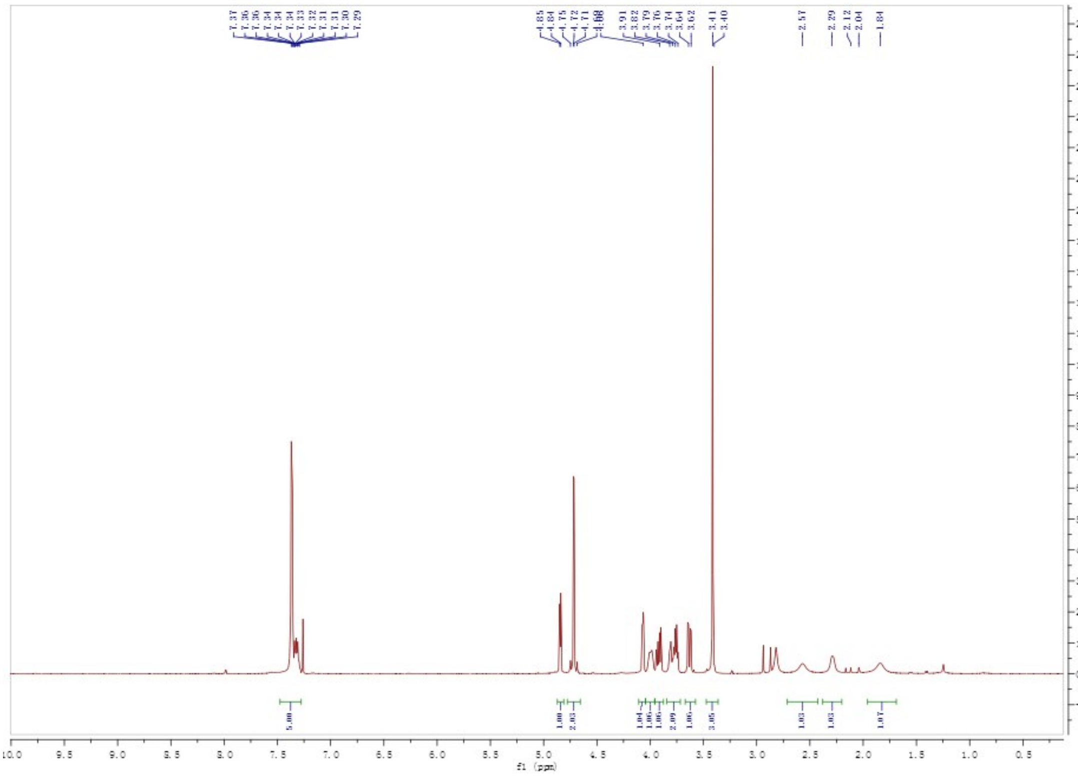
Methyl 3-*O*-benzyl-*β*-D-galactopyranoside (20)[1]:

^{1}H-NMR of compound **20** ($CDCl_3$)



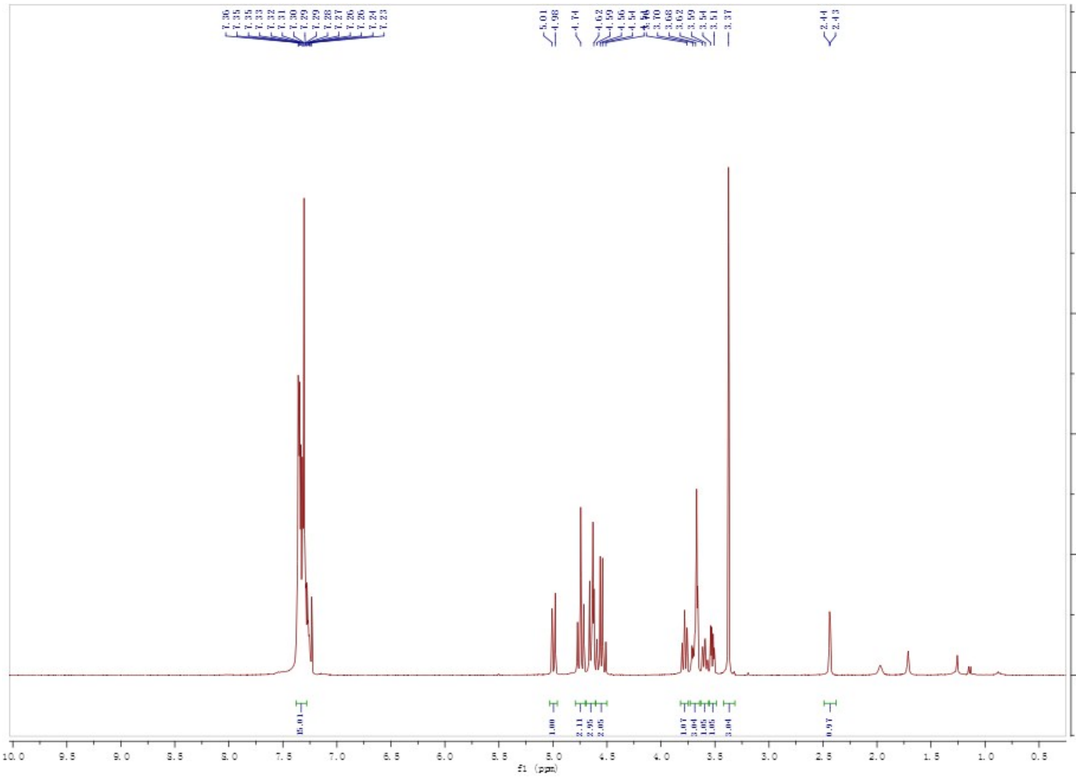
Methyl 3-*O*-benzyl-*α*-D-galactopyranoside (22)[1]:

^{1}H-NMR of compound **22** ($CDCl_3$)



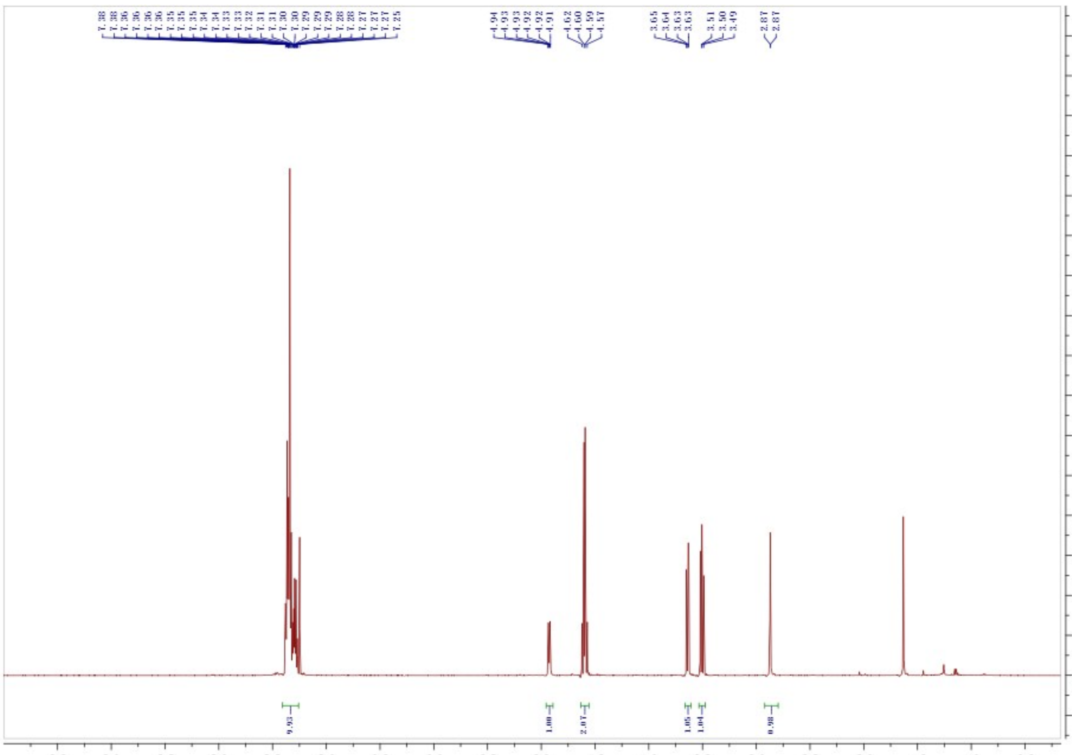
Methyl 2, 3, 6-tri-*O*-benzyl-*α*-D-glucopyranoside (26)[6]:

^{1}H-NMR of compound **26** ($CDCl_3$)



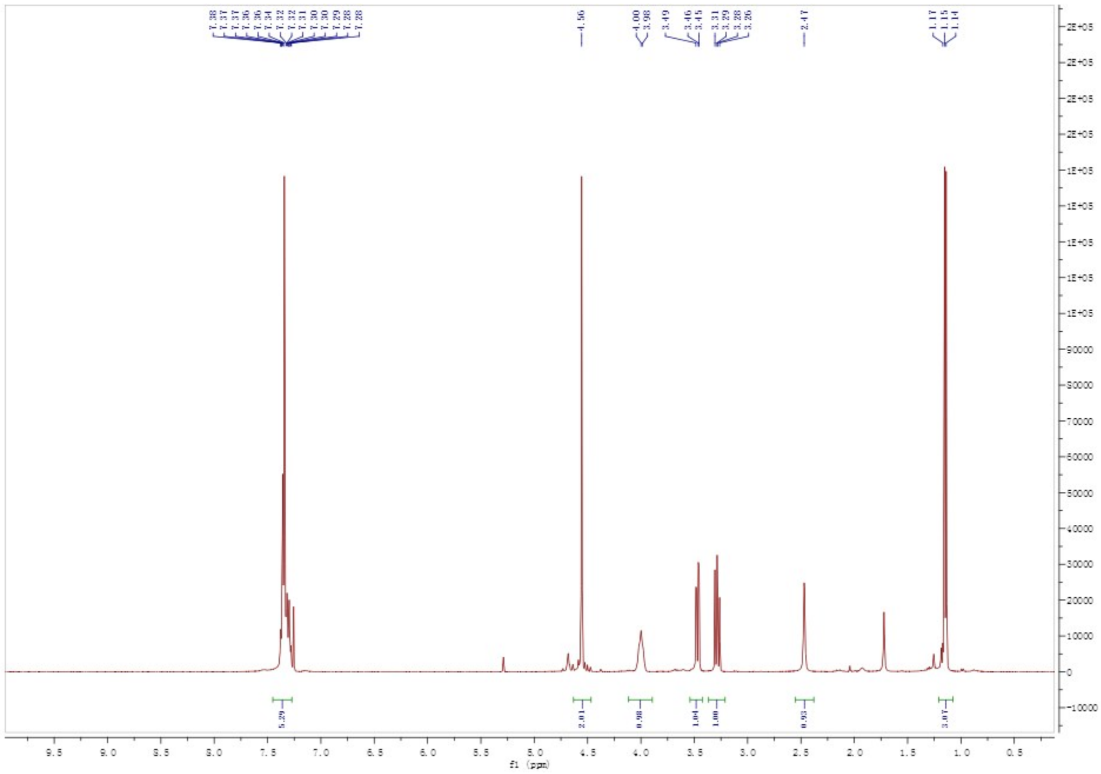
2-*O*-benzyl-1-Phenylethane-1, 2-diol (29)[1]:

^{1}H-NMR of compound **29** ($CDCl_3$)



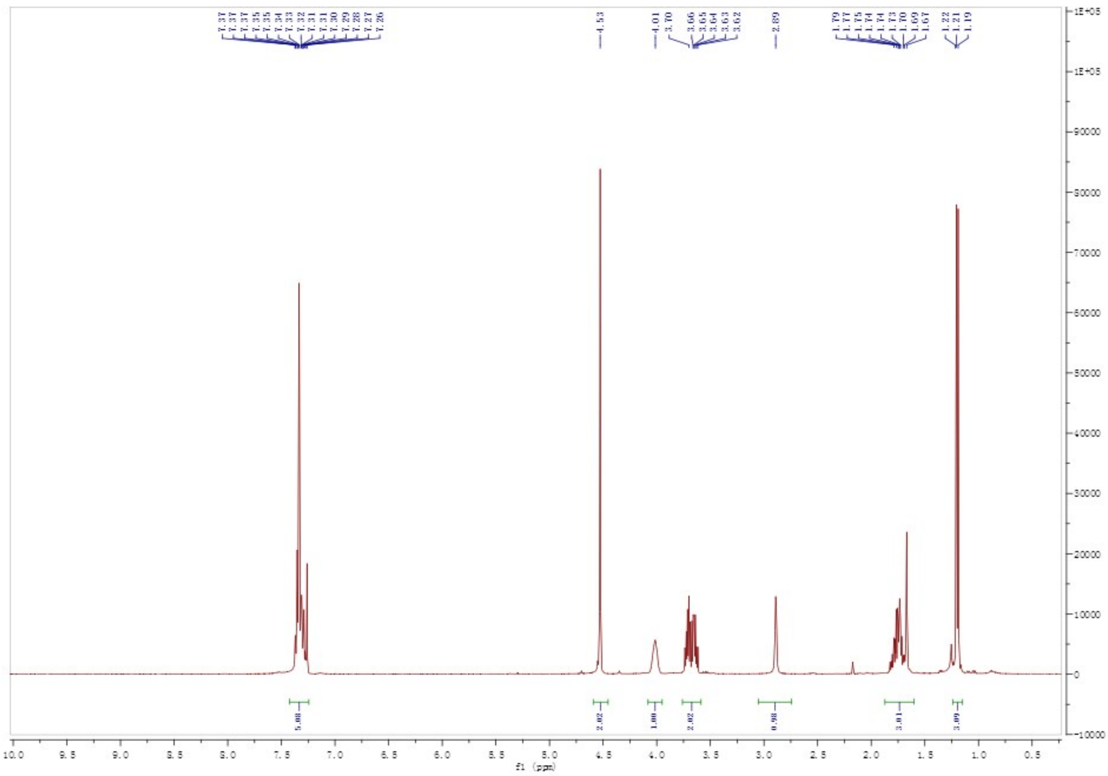
1-*O*-benzyl-1, 2-Propanediol (31)[1]:

^{1}H-NMR of compound **31** ($CDCl_3$)



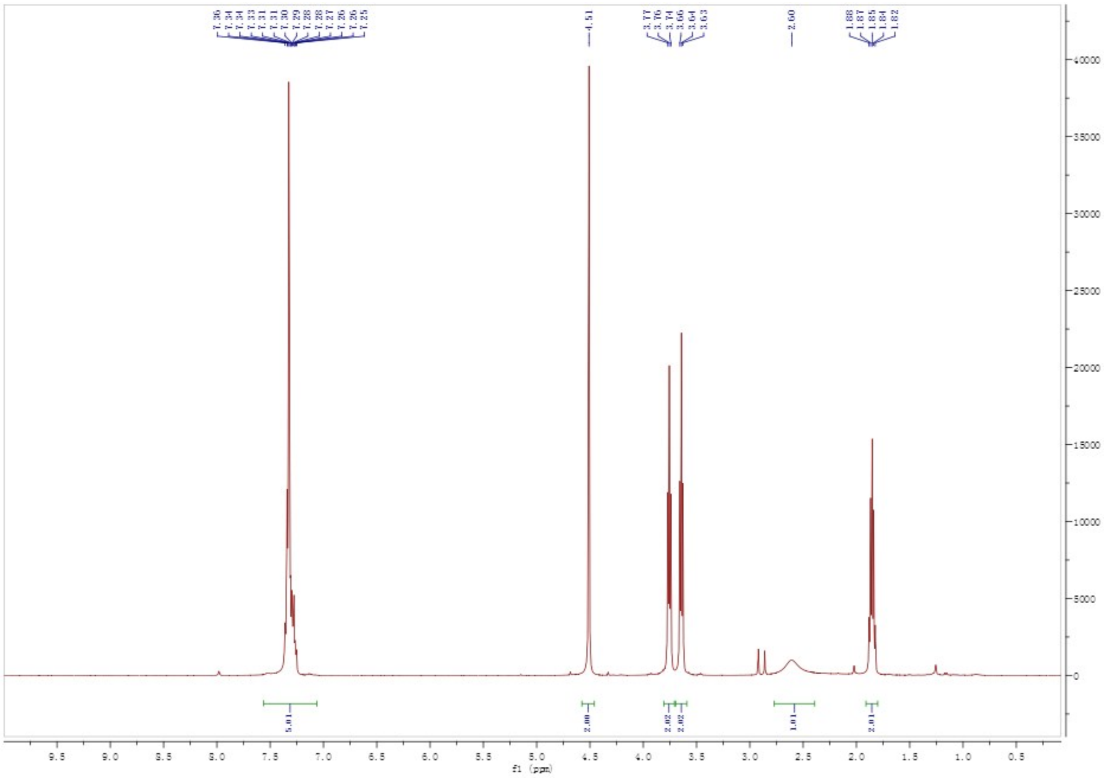
1-*O*-benzyl-1, 3-Butanediol (33)[7]:

^{1}H-NMR of compound **33** ($CDCl_3$)



1-*O*-benzyl-1.3-propanediol (35)[8]:

^{1}H-NMR of compound **35** ($CDCl_3$)



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