<Supporting Information>

Additive Pummerer Reaction of 3,5-*O*-(Di-*tert*-butyl)silylene-4-thiofuranoid Glycal : A High Yield and β-Selective Entry to 4′-Thioribonucleosides

Kazuhiro Haraguchi,* Mitsuhiro Matsui, Shin Takami, and Hiromichi Tanaka

CONTENTS

General Experimental Section

Melting points are uncorrected. ^{1}H and ^{13}C NMR spectra were recorded either at 400 MHz or at 500 MHz. Chemical sifts are reported relative to Me_4Si. Mass spectra (MS) were taken in FAB mode with *m*-nitrobenzyl alcohol as a matrix. Column chromatography was carried out on silica gel. Thin-layer chromatography (TLC) was performed on silica gel. When necessary, analytical samples were purified by high performance liquid chromatography (HPLC). THF was distilled from benzophenone ketyl.

1,4-Anhydro-2-deoxy-3,5-*O*-(di-*t*-butylsilylene)-4-thio-D-*erythro*-pento-1-enitol 1-oxide (6)

To a CH_2Cl_2 (12 mL) solution of **3** (1.04 g, 3.82 mmol) was added CH_2Cl_2 (12 mL) solution of m-CPBA (1.05 g, 6.11 mmol) at 0 °C and the mixture was stirred for 1 h. The reaction mixture was neutralized with Et_3N and partitioned between $CHCl_3$/saturated aq $NaHCO_3$. Silica gel column chromatography (hexane/AcOEt = 2/1) of the organic layer gave a mixture of (***S_R***)-**6** (major isomer) and (***S_S***)-**6** (minor isomer) (926.9 mg, 84%). (***S_R***)-**6** (t_R 14 min) and (***S_S***)-**6** (t_R 18 min) were separated by HPLC (hexane/AcOEt = 1/4).

Physical data for (***S_R***)-**6**: m.p. 163-164 °C. UV(MeOH)λ_{max} 249 nm (ε 830). ^{1}H NMR ($CDCl_3$)δ 1.01 and 1.08 (18H, each as s, t-Bu), 2.77 (1H, ddd, *J* = 7.4, *J* = 10.4, *J* = 5.6

Hz), 4.52 (1H, t, $J = J = 10.4$ Hz), 4.61 (1H, dd, $J = 5.6$ and $J = 10.4$ Hz), 5.92 (1H, dt, $J = J = 1.6$ and $J = 8.0$ Hz), 6.79 (1H, dd, $J = 2.0$ and $J = 6.0$ Hz), 7.06 (1H, dd, $J = 6.0$ and $J = 1.6$ Hz); ^{13}C NMR ($CDCl_3$) δ 19.97, 22.66, 26.93, 27.20, 63.93, 74.93, 78.38, 136.72, 140.11. FAB-MS (*m/z*) 289 ($M^+ + H$). *Anal*. Calcd for $C_{13}H_{24}O_3SSi$: C, 54.13; H, 8.39. Found: C, 54.26; H, 8.59.

Physical data for (***S**S*)-**6**: m.p. 156-159 °C. ^{1}H NMR ($CDCl_3$)δ 1.03 and 1.05 (9H, each as s, Si-*t*-Bu), 3.67 (1H, ddd, $J = 5.2$, $J = 12.4$ and $J = 8.4$ Hz), 4.51 (1H, dd, $J = 12.4$ and $J = 10.4$ Hz), 4.76-4.81 (2H, m, H-3 and 5b), 6.64 (1H, dd, $J = 6.4$ and $J = 2.0$ Hz), 6.71 (1H, dd, $J = 6.4$ and $J = 0.8$ Hz); ^{13}C NMR ($CDCl_3$) δ 20.19, 22.46, 26.94, 27.17, 62.59, 64.17, 80.68, 133.79, 148.35. FAB-MS (*m/z*) 289 ($M^+ + H$). *Anal*. Calcd for $C_{13}H_{24}O_3SSi$: C, 54.13; H, 8.39. Found: C, 54.46; H, 8.58.

Additive Pummerer reaction of 6 with Ac_2O/TMSOTf: Formation of 1,2-di-*O*-acetyl-3,5-*O*-(di-*t*-butylsilylene)-β,α-4-thioribofuranose (7) and 1-*O*-Acetyl-3,5-*O*-(di-*t*-butylsilylene)-2-*O*-(trifluoromethanesulfonyl)-β,α-4-thioribofuranose (8)

To a CH_2Cl_2 (2.5 mL) solution of **6** (43.3 mg, 0.15 mmol) was added Ac_2O (22 μL, 0.23 mmol) and TMSOTf (15 μL, 0.08 mmol) at 0 °C under Ar atmosphere and the mixture was stirred for 7 h. The reaction mixture was partitioned between $CHCl_3$/saturated aq $NaHCO_3$ and column chromatography (hexane/AcOEt = 50/1) of the organic layer gave **7** (11.6 mg, 20%, syrup, β-isomer/α-isomer = 12:1) and **8** (15.9 mg, 22%, syrup, β-isomer/α-isomer = 7:1).

Physical data for **7** (β-anomer): m.p. 105-107 °C. ^{1}H NMR ($CDCl_3$)δ 1.00 and 1.07 (18H, each as s, Si-*t*-Bu), 2.10 and 2.13 (6H, each as s, Ac), 3.66-3.73 (2H, m), 4.02 (1H, t, $J = J = 11.2$ Hz), 4.28-4.35 (2H, m), 5.47 (1H, d, $J = 3.2$ Hz), 5.70 (1H, s); NOE experiment: H-1/H-4 (1.7%) and H-2/H-3 (7.3%); ^{13}C NMR ($CDCl_3$) δ 20.79, 20.86, 22.67, 26.91, 27.18, 44.61, 68.43, 78.55, 79.06, 169.30, 169.48. FAB-MS (*m/z*) 391 (M^+ + H) and 331 (M^+ - OAc). *Anal*. Calcd for $C_{17}H_{30}O_6SSi$: C, 52.28; H, 7.74. Found: C, 52.42; H, 7.89.

Physical data for **7** (α-anomer): ^{1}H NMR ($CDCl_3$)δ 1.01 and 1.04 (18H, each as s, Si-*t*-Bu), 2.07 and 2.19 (6H, each as s, Ac), 3.91-3.99 (2H, m), 4.17 (1H, dd, $J =$ 4.6 and $J = 7.4$ Hz), 4.27 (1H, dd, $J = 3.2$ and $J = 10.8$ Hz), 6.70 (1H, t, $J = J = 4.6$ Hz), 6.21 (1H, d, $J = 4.6$ Hz); NOE experiment: H-1/H-2 (12%) and H-1/H-3 (4.8%); ^{13}C NMR ($CDCl_3$) δ 20.12, 20.67, 22.74, 26.88, 27.16, 45.94, 72.73, 75.28, 78.69, 169.76, 169.88. FAB-MS (*m/z*) 391 (M^+ + H) and 331 (M^+ - OAc). *Anal*. Calcd for $C_{17}H_{30}O_6SSi$: C, 52.28; H, 7.74. Found: C, 52.56; H, 7.87.

Physical data for **8**: ^{1}H NMR ($CDCl_3$) (β-isomer) δ 1.02 and 1.09 (18H, each as s, Si-*t*-Bu), 2.11 (3H, s), 3.62-3.69 (1H, m), 4.04 (1H, t, $J_{4,5a} = J_{5a,5b} = 10.6$ Hz), 4.34 (1H, dd, $J = 4.4$ and $J = 10.6$ Hz), 4.40 (1H, dd, $J = 3.4$ and $J = 10.2$ Hz), 5.31 (1H, d, $J = 3.4$ Hz), 5.89 (1H, s); (α-isomer, selected data) δ 1.01 and 1.05 (18H, each as s, Si-*t*-Bu), 2.16 (3H, s), 3.21-3.27 (1H, m), 4.04 4.27 (1H, dd, $J = 4.8$ and $J = 10.0$ Hz), 4.95 (1H, dd, $J_2 = 10.3$ and $J = 5.3$ Hz), 4.95 (1H, dd, $J = 10.3$ and $J = 5.3$ Hz), 6.02 (1H, $J = 5.3$ Hz);

^{13}C NMR ($CDCl_3$) δ (β-anomer) 20.1, 20.8, 22.8, 26.7, 27.3, 44.0, 68.5, 76.7, 78.1, 78.5, 88.7, 168.8; (α-anomer, selected data) 19.9, 20.9, 22.7, 26.8, 27.2, 40.3, 68.9, 71.8, 77.2, 86.0. FAB-MS (*m/z*) 481 (M^++H), 421 (M^+–OAc). High resolution FAB-MS (*m/z*) calcd for $C_{16}H_{27}F_3O_7S_2Si$: 481.0998. Found: 481.0962.

Additive Pummerer reaction of 6 with $Ac_2O/SnCl_4$: Formation of 9

To a CH_2Cl_2 (2.5 mL) solution of **6** (43.3 mg, 0.15 mmol) was added Ac_2O (44 μL, 0.46 mmol) and $SnCl_4$ (1.0 M CH_2Cl_2 solution) (0.31 mL, 0.31 mmol) at 0 °C under Ar atmosphere and the mixture was stirred overnight. The reaction mixture was partitioned between $CHCl_3$/saturated aq $NaHCO_3$ and column chromatography (hexane/AcOEt = 60/1) of the organic layer gave **9** (36.3 mg, 52%, syrup, β-isomer/α-isomer = 5:1): ^{1}H NMR ($CDCl_3$) (β-isomer)δ 1.09 and 1.10 (18H, each as s, Si-*t*-Bu), 2.07, 2.11 and 2.16 (9H, each as s), 3.69-3.73 (1H, m), 4.12 (1H, dd, *J* = 7.3 and *J* = 11.4 Hz), 4.47 (1H, dd, *J* = 5.4 and *J* = 11.4 Hz), 4.53 (1H, dd, *J* = *J* = 3.4 Hz), 4.90 (1H, dd, *J* = 3.4 and *J* = 6.6 Hz), 5.93 (1H, d, *J* = 3.4 Hz). (α-isomer, selected data)δ 1.11 and 1.14 (18H, each as s, Si-*t*-Bu), 3.83-3.87 (1H, m), 4.07 (1H, dd, *J* = 7.3 and *J* = 11.4 Hz), 4.41 (1H, dd, *J* = 5.1 and *J* = 3.5 Hz), 4.96 (1H, dd, *J* = 3.5 and *J* = 1.5 Hz), 6.19 (1H, d, *J* = 5.1 Hz); ^{13}C NMR ($CDCl_3$) δ (β-anomer) 20.70, 20.80, 21.06, 21,33, 22.56, 27.24, 27.34, 48.97, 64.98, 65.24, 76.43, 82.31, 169.54, 169.92, 170.50; (α-anomer) 20.74, 20.93, 21.66, 22.63, 27.63, 27.20, 27.46, 29.65, 51.60, 61.32, 78.45, 78.61, 170.11, 170.31, 170.43. FAB-MS (*m/z*) 469 and 471 (M^++H). *Anal*. Calcd for $C_{19}H_{33}ClO_7SSi$: C, 48.86; H, 7.17.

Found: C, 49.20; H, 7.22.

Additive Pummerer reaction of 6 with Ac_2O/TMSOAc/BF_3 OEt_2: Formation of 7,10 and 11

To a CH_2Cl_2 (25 mL) solution of **6** (1.15 g, 3.99 mmol) was added Ac_2O (2.6 mL, 27.93 mmol), TMSOAc (4.2 mL, 27.93 mmol) and BF_3 • OEt_2 (3.5 mL, 27.93 mmol) at 0 °C under Ar atmosphere and the mixture was stirred overnight. The reaction mixture was partitioned between $CHCl_3$/saturated aq $NaHCO_3$ and column chromatography (hexane/AcOEt = 40/1-20/1) of the organic layer gave **7** (967.2 mg, 62%, solid, β-isomer/α-isomer = 13:1), **10** (54.3 mg, 3%, syrup, β-isomer/α-isomer = 13:1) and **11** (334.9 mg, 17%, syrup, β-isomer/α-isomer = 4.9:1).

Physical data for **10**: ^{1}H NMR ($CDCl_3$) (β-isomer)δ 1.05 and 1.06 (18H, each as s, Si-*t*-Bu), 2.07, 2.09 and 2.13 (9H, each as s), 3.64-3.69 (1H, m), 4.18 (1H, dd, *J* = 7.2 and *J* = 11.6 Hz), 4.43 (1H, dd, *J* = 5.6 and *J* = 11.4 Hz), 4.59 (1H, dd, *J* = 5.6 and *J* = 8.8 Hz), 5.41 (1H, dd, *J* = 3.2 and *J* = 3.6 Hz), 5.81 (1H, d, *J* = 3.2 Hz); (α-isomer, selected data) δ 3.40-3.45 (1H, m), 4.52 (1H, dd, $J_{4,5b}$ = 4.6 and *J* = 11.4 Hz), 5.21 (1H, dd, *J* = 4.4 and *J* = 9.2 Hz), 5.94 (1H, d, *J* = 4.4 Hz); ^{13}C NMR ($CDCl_3$) δ (β-anomer) 20.14, 20.69, 20.91, 26.73, 26,79, 21,19, 29.70, 49.08, 64.91, 74.48, 77.88, 79.21, 169.66, 169.92, 170.44; δ (α-isomer, selected data) 26.81, 45.75, 65.46, 74.23, 76.11, 78.17,170.42. FAB-MS (*m/z*) 393 (M^+–OAc). *Anal*. Calcd for $C_{19}H_{33}FO_7SSi$• 1/3AcOEt: C, 50.67; H, 7.46. Found: C, 51.02; H, 7.37.

Physical data for **11**: ^{1}H NMR ($CDCl_3$) (β-isomer) δ 1.07 and 1.08 (18H, s, Si-*t*-Bu), 2.10, 2.13 and 2.15 (12H, each as s), 3.68-3.73 (1H, m), 4.12 (1H, dd, *J* = 7.6 and *J* = 11.6 Hz), 4.51 (1H, dd, *J* = 4.4 and *J* = 11.6 Hz), 4.79 (1H, dd, *J* = 3.6 and *J* = 7.2 Hz), 5.50 (1H, dd, *J* = 2.8 and *J* = 3.6 Hz), 5.77 (1H, d, *J* = 2.8 Hz); (α-isomer) δ 1.09 and 1.11 (18H, each as s), 2.06, 2.08, 2.10 and 2.14 (12H, each as s), 3.79 (1H, dt, *J* = 2.0, *J* = 4.8 and *J* = 6.8 Hz), 410 (1H, dd, *J* = 4.8 and *J* = 10.8 Hz), 4.15 (1H, dd, *J* = 6.8 and *J* = 10.8 Hz), 4.90 (1H, dd, *J* = 4.4 and *J* = 2.0 Hz), 5.28 (1H, dd, *J* = 5.6 and *J* = 4.4 Hz), 6.24 (1H, d, *J* = 5.6 Hz); ^{13}C NMR ($CDCl_3$) δ (β-anomer) 20.30, 20.49, 20.54, 20.65, 22.11, 26.81, 26.88, 48.57, 64.85, 72.35, 74.69, 77.29, 78.73, 169.30, 169.44, 169.47, 169.97; δ (α-anomer) 20.56, 20.64, 20.93, 21.31, 22.45, 27.03, 27.11, 27.17, 50.03, 64.87, 74.47, 76.19, 76.32, 169.61, 169.68, 170.09, 170.33. FAB-MS (*m/z*) 433 (M^+–OAc). *Anal*. Calcd for $C_{21}H_{36}O_9SSi$: C, 51.20; H, 7.37. Found: C, 51.41; H, 7.56.

1-[2-*O*-Acetyl-3,5-*O*-(di-*t*-butylsilylene)-4-thio-β,α-D-ribofuranosyl]uracil (12)

To an CH_3CN (3.5 mL) solution of bis-*O*-trimethylsilyluracil, prepared from uracil (90.8 mg, 0.81 mmol) and BSA (0.4 mL, 1.62 mmol,), was added an CH_2Cl_2 (3.5 mL) solution of **7** (104.1 mg, 0.27 mmol) and TMSOTf (0.21 mL, 1.08 mmol) at 0 °C under Ar atmosphere and the mixture was stirred at 60 °C for 24 h. The reaction mixture was partitioned between $CHCl_3$/saturated aq $NaHCO_3$ and column chromatography (hexane/AcOEt = 3/1) of the organic layer gave **12** (111.7 mg, 93%, **12β/12α** = 22:1) as a foam: UV (MeOH)λ_{max} 264 nm (ε 10500),λ_{min} 232 nm (ε 2400); ^{1}H NMR ($CDCl_3$)

(**12β**)δ 1.00 and 1.05 (18H, each as s), 2.15 (3H, s), 3.70-3.76 (1H, m), 4.12 (1H, dd, *J* = 10.4 and *J* = 11.2 Hz), 4.27 (1H, dd, *J* = 4.4 and *J* = 10.0 Hz), 4.41 (1H, dd, *J* = 4.4 and *J* = 11.2 Hz), 5.50 (1H, dd, *J* = 0.8 and *J* = 4.4 Hz), 5.83 (1H, d, *J* = 8.2 Hz), 5.96 (1H, d, *J* = 0.8 Hz), 7.61 (1H, d, *J* = 8.2 Hz), 9.18 (1H, br);(**12α**, selected data)δ 1.01 and 1.07 (18H, each as s), 2.12 (3H, s), 5.21 (1H, dd, *J* = 7.2 and *J* = 9.5 Hz), 5.89 (1H, d, *J* = 8.2 Hz), 6.11 (1H, d, *J* = 7.2 Hz), 7.86 (1H, d, *J* = 8.2 Hz); NOE experiment (β-isomer): H-1'/H-4' (1.2%), H-6/H-2' (2.5%), H-6/H-5'a (6.2%), CO$\underline{CH_3}$/H-4' (0.6%); ^{13}C NMR ($CDCl_3$) δ (**12β**) 20.06, 20.82, 22.84, 26.84, 27.17, 27.32, 46.34, 63.61, 67.80, 79.38, 103.36, 140.30, 149.74, 162.00, 168.86. FAB-MS (*m/z*) 443 (M^++H). *Anal*. Calcd for $C_{19}H_{30}N_2O_6SSi$ 1/4AcOEt: C, 51.70; H, 6.94; N, 6.02. Found: C, 51.98; H, 7.07; N, 5.83.

1-[2-*O*-Acetyl-3,5-*O*-(di-t-butylsilylene)-4-thio-β,α-D-ribofuranosyl]thymine (13)

To an CH_3CN (3.5 mL) solution of bis-*O*-trimethylsilylthymine, prepared from thymine (102.1 mg, 0.81 mmol) and BSA (0.4 mL, 1.62 mmol), was added an CH_2Cl_2 (3.5 mL) solution of **7** (106.6 mg, 0.27 mmol) and TMSOTf (0.21 mL, 1.08 mmol) at 0 °C under Ar atmosphere and the mixture was stirred at 80 °C for 19 h. The reaction mixture was partitioned between $CHCl_3$/sat. $NaHCO_3$ and silica gel column chromatography (hexane/AcOEt = 3/1) of the organic layer gave **13** (114.8 mg, 93%, **13β/13α** = 22:1) as a foam: UV (MeOH)λ_{max} 269 nm (ε 9700),λ_{min} 236 nm (ε 2400); ^{1}H NMR ($CDCl_3$) (**13β**)δ 1.00 and 1.07 (18H, each as s), 1.96 (3H, d, *J* = 1.2 Hz), 2.05 (3H, s), 3.68-3.75

(1H, m), 4.14 (1H, dd, *J* = 10.4 and *J* = 11.2 Hz), 4.34 (1H, dd, *J* = 4.4 and *J* = 10.2 Hz), 4.40 (1H, dd, *J* = 4.8 and *J* = 11.2 Hz), 5.50 (1H, dd, *J* = 0.8 and *J* = 4.4 Hz), 5.96 (1H, d, *J* = 0.8 Hz), 7.30 (1H, d, *J* = 1.2 Hz), 8.84 (1H, br); (**13α**, selected data)δ 0.99 and 1.05 (18H, each as s), 2.00 (3H, d, *J* = 1.3 Hz), 2.13 (3H, s), 3.62-3.67 (1H, m), 4.26 (1H, dd, *J* = 4.8 and *J* = 10.2 Hz), 5.23 (1H, dd, *J* = 7.3 and *J* = 9.5 Hz), 6.12 (1H, d, *J* = 7.3 Hz), 7.39 (1H, d, *J* = 1.3 Hz); NOE experiment (**13β**): H-1'/H-4' (2.0%), H-6/H-2' (4.0%), H-6/H-3' (7.0%); ^{13}C NMR ($CDCl_3$) δ (**13β**) 12.76, 20.07, 20.84, 22.85, 26.85, 26.89, 27.17, 46.51, 63.61, 67.69, 79.48, 112.09, 136.02, 149.78, 162.69, 168.99. FAB-MS (*m/z*) 457 (M^++H). *Anal*. Calcd for $C_{20}H_{32}N_2O_6SSi$ 1/4AcOEt: C, 52.70; H, 7.16; N, 5.85. Found: C, 52.64; H, 7.31; N, 5.66.

1-[2-*O*-Acetyl-3,5-*O*-(di-*t*-butylsilylene)-4-thio-β,α-D-ribofuranosyl]-*N*-acetylcytosine (14)

To an CH_3CN (3.5 mL) solution of bis-*N*,*O*-trimethylsilyl-*N*-acetylcytosine, prepared from *N*-acetylcytosine (128.6 mg, 0.84 mmol) and BSA (0.42 mL, 1.68 mmol,), was added an CH_2Cl_2 (3.5 mL) solution of **7** (108 mg, 0.28 mmol) and TMSOTf (0.22 mL, 1.12 mmol) at 0 °C under Ar atmosphere and the reaction mixture was stirred at 60 °C for 15 h. The reaction mixture was partitioned between $CHCl_3$/sat. $NaHCO_3$ and silica gel column chromatography (hexane/AcOEt = 1/1) of the organic layer gave **14** (123.4 mg, 91%, **14β/14α** = 23:1) as a foam: UV (MeOH) $\lambda_{shoulder}$ 305 nm (ε 4400) and 279 nm (ε 6500), λ_{max} 249 nm (ε 11900),λ_{min} 228 nm (ε 6400); ^{1}H NMR ($CDCl_3$) (**14β**)

δ 0.99 and 1.04 (18H, each as s), 2.15 and 2.27 (6H, each as s), 3.73-3.79 (1H, m), 4.14 (1H, dd, *J* = 10.4 and *J* = 11.2 Hz), 4.24 (1H, dd, *J* = 4.0 and *J* = 11.2 Hz), 4.42 (1H, dd, *J* = 4.4 and *J* = 10.2 Hz), 5.58 (1H, d, *J* = 4.4 Hz), 6.02 (1H, s), 7.49 (1H, d, *J* = 7.2 Hz), 8.13 (1H, d, *J* = 7.2 Hz), 9.81 (1H, br); (**14α**)δ 1.02 and 1.07 (18H, each as s), 2.09 and 2.26 (6H, each as s), 3.80-3.86 (1H, m), 4.00 (1H, t, *J* = *J* = 10.3 Hz), 4.27 (1H, dd, *J* = 4.6 and *J* = 10.3 Hz), 5.31 (1H, d, *J* = 6.4 and *J* = 6.3 Hz), 6.19 (1H, d, *J* = 6.4), 7.53 (1H, d, *J* = 7.7 Hz), 8.24 (1H, d, *J* = 7.7 Hz), 9.61 (1H, br); NOE experiment (**14β**): H-1'/H-4' (0.8%), H-6/H-2' (2.5%) and H-6/H-3' (5.2%); ^{13}C NMR ($CDCl_3$) δ (**14β**) 19.86, 20.83, 22.69, 24.79, 26.80, 27.10, 45.91, 64.98, 67.99, 76.94, 78.73, 97.47, 145.29, 155.02, 162.86, 168.58, 171.44. FAB-MS (*m/z*) 484 (M^++H). *Anal*. Calcd for $C_{21}H_{33}N_3O_6SSi$: C, 52.15; H, 6.88; N, 8.69. Found: C, 52.18; H, 6.98; N, 8.45.

9-[2-*O*-Acetyl-3,5-*O*-(di-*t*-butylsilylene)-4-thio-β,α-D-ribofuranosyl]-6-chloropurine (15) and 7-[2-*O*-Acetyl-3,5-*O*-(di-*t*-butylsilylene)-4-thio-β,α-D-ribofuranosyl]-6-chloropurine (16)

To an CH_3CN (3.5 mL) solution of *N*-trimethylsilyl-6-chloropurine, prepared from 6-chloropurine (129.8 mg, 0.84 mmol) and BSA (0.21 mL, 0.84 mmol,), was added an CH_2Cl_2 (3.5 mL) solution of **7** (108.2 mg, 0.28 mmol) and TMSOTf (0.22 mL, 1.12 mmol) at 0 °C under Ar atmosphere and the mixture was stirred at 80 °C for 8 h. The reaction mixture was partitioned between $CHCl_3$/sat. $NaHCO_3$ and preparative TLC purification (hexane/AcOEt = 2/1) of the organic layer gave **15** (78.8 mg, 58%,

15β/15α= 24:1, syrup) and **16** (28.4 mg, 21%, **16β/16α** = 23:1, solid).

Physical data for **15**: UV (MeOH)λ_{max} 265 nm (ε 8800),λ_{min} 229 nm (ε 3000); ^{1}H NMR ($CDCl_3$) (**15β**)δ 1.03 and 1.08 (18H, each as s), 2.22 (3H, s), 3.85-3.91 (1H, m), 4.25 (1H, dd, *J* = 10.4 and *J* = 10.8 Hz), 4.45 (1H, dd, *J* = 4.8 and *J* = 10.8 Hz), 4.93 (1H, dd, *J* = 4.0 and *J* = 10.0 Hz), 5.64 (1H, d, *J* = 4.0 Hz), 5.98 (1H, s), 8.35 and 8.77 (2H, each as s); (**15α**, selected data)δ 2.27 (3H, s), 5.93 (1H, d, *J* = 4.0 Hz), 8.33 and 8.74 (2H, each as s); NOE experiment (β-isomer): H-1'/H-4' (1.4%), H-8/H-3' (3.7%); ^{13}C NMR ($CDCl_3$) δ (**15β**) 20.08, 20.85, 22.86, 26.88, 27.17, 29.69, 46.10, 61.37, 67.94, 77.67, 78.86, 132.46, 143.98, 151.15, 152.20, 169.27. HMBC spectra; H-1'/C-4; FAB-MS (*m/z*) 487 and 485 (M^++H). *Anal*. Calcd for $C_{20}H_{29}ClN_4O_4SSi$ 1/10H_2O: C, 49.34; H, 6.05; N, 11.51. Found: C, 49.65; H, 5.97; N, 11.14.

Physical data for **16**: m.p. 212-215 °C. UV (MeOH)λ_{max} 273 nm (ε 6500), $\lambda_{shoulder}$ 256 nm (ε 5700),λ_{min} 232 nm (ε 3600); ^{1}H NMR ($CDCl_3$)) (**16β**)δ 1.01 and 1.03 (18H, each as s), 2.17 (3H, s), 3.83-3.90 (1H, m), 4.21 (1H, dd, *J* = *J* = 11.2 Hz), 4.37 (1H, dd, *J* = 3.6 and *J* = 11.2 Hz), 4.50 (1H, dd, *J* = 4.4 and *J* = 10.2 Hz), 5.73 (1H, d, *J* = 4.4 Hz), 6.41 (1H, s), 8.51 and 8.93 (2H, each as s); (**16α**, selected data)δ 5.86 (1H, dd, *J* = 4.4 and *J* = 3.2 Hz), 6.93 (1H, d, *J* = 4.4 Hz), 8.89 and 8.90 (2H, each as s); NOE experiment: H-1'/H-4' (2.0%), H-8/H-2' (2.0%), H-8/H-3' (5.0%); ^{13}C NMR ($CDCl_3$) δ (**16β**) 20.02, 20.71, 22.83, 26.85, 27.11, 29.69, 45.81, 63.29, 67.99, 77.47, 78.85, 122.40, 143.04, 147.25, 153.10, 168.45.; HMBC spectra; H-1'/C-5; FAB-MS

(*m/z*) 487 and 485 (M^++H). *Anal*. Calcd for $C_{20}H_{29}ClN_4O_4SSi$ 2/3AcOEt: C, 50.06; H, 6.36; N, 10.30. Found: C, 50.37; H, 6.20; N, 10.63.

9-[2-*O*-Acetyl-3,5-*O*-(di-*t*-butylsilylene)-4-thio-β,α-D-ribofuranosyl]-2-amino-6-chloropurine (17) and 7-[2-*O*-Acetyl-3,5-*O*-(di-*t*-butylsilylene)-4-thio-β,α-D-ribofuranosyl]-2-amino-6-chloropurine (18)

To an CH_3CN (3 mL) solution of bis-*N,O*-trimethylsilyl-2-amino-6-chloropurine, prepared from 2-amino-6-chloropurine (132.3 mg, 0.78 mmol) and BSA (0.39 mL, 1.56 mmol), was added an $ClCH_2CH_2Cl$(3 mL) solution of **7** (101.5 mg, 0.26 mmol) and TMSOTf (0.2 mL, 1.04 mmol) at 0 °C under Ar atmosphere and the reaction mixture was stirred at 100 °C for 28 h. The reaction mixture was partitioned between $CHCl_3$/sat. $NaHCO_3$ and preparative TLC purification (hexane/AcOEt = 1/1) of the organic layer gave **17** (63.3 mg, 49%, **17β/17α**= 23:1, syrup) and **18** (29 mg, 22%, **18β/18α** = 13:1, syrup).

Physical data for **17**: UV (MeOH)λ_{max} 310 nm (ε 7800), 250 nm (ε 6500) and 224 nm (ε 19000),λ_{min} 272 nm (ε 1400) and 241 nm (ε 5900); ^{1}H NMR ($CDCl_3$) (**17β**)δ 1.02 and 1.07 (18H, each as s), 2.20 (3H, s), 3.80-3.86 (1H, m), 4.20 (1H, dd, *J* = *J* = 11.2 Hz), 4.43 (1H, dd, *J* = 4.8 and *J* = 11.2 Hz), 4.85 (1H, dd, *J* = 4.0 and *J* = 10.2 Hz), 5.13 (2H, br), 5.66 (1H, d, *J* = 4.0 Hz), 5.75 (1H, s), 7.96 (1H, s); (**17α**, selected data)δ 2.09 (3H, s), 5.18 (2H, br), 6.73 (1H, d, *J* = 4.8 Hz), 8.62 (1H, s); NOE experiment: H-1'/H-4' (1.9%), H-8/H-2' (3.8%); ^{13}C NMR ($CDCl_3$) (**17β**) δ 20.04, 20.87, 22.85, 26.86,

27.18, 45.91, 60.90, 68.01, 77.45, 78.96, 125.91, 140.80, 151.85, 153.06, 158.94, 169.13. HMBC spectra; H-1'/C-4; FAB-MS (*m/z*) 500 and 502 (M^++H). *Anal*. Calcd for $C_{20}H_{30}ClN_5O_4SSi$: C, 48.03; H, 6.05; N, 14.00. Found: C, 48.40; H, 5.98; N, 14.21.

Physical data for **18**: UV (MeOH)λ_{max} 326 nm (ε 4700) and 220 nm (ε 23500), λ_{min} 279 nm (ε 700); ^{1}H NMR ($CDCl_3$)δ 1.00 and 1.02 (18H, each as s), 2.02 (3H, s), 3.78-3.85 (1H, m), 4.18 (1H, dd, *J* = 10.4 and *J* = 11.4 Hz), 4.32 (1H, dd, *J* = 4.0 and *J* = 10.2 Hz), 4.47 (1H, dd, *J* = 4.5 and *J* = 11.4 Hz), 5.14 (2H, br), 5.70 (1H, d, *J* = 4.0 Hz), 6.23 (1H, s), 8.57 (1H, s); (**18α**, selected data)δ 6.73 (1H, d, *J* = 4.8 Hz); NOE experiment: H-8/H-2' (1.1%) and H-1'/H-4' (0.8%); ^{13}C NMR ($CDCl_3$) (for **18β**) δ 20.01, 20.74, 22.81, 26.86, 27.12, 29.69, 45.55, 63.07, 68.04, 78.88, 116.34, 143.58, 146.79, 159.55, 000.00, 168.43.; HMBC spectra; H-1'/C-5; FAB-MS (*m/z*) 500 and 502 (M^++H); (+KI) 538 and 540 (M^++H). *Anal*. Calcd for $C_{20}H_{30}ClN_5O_4SSi$ · 1/10 AcOEt: C, 48.15; H, 6.10; N, 13.76. Found: C, 47.85; H, 6.05; N, 13.41.

2-[2-*O*-Acetyl-3,5-*O*-(di-*t*-butylsilylene)-4-thio-β,α-D-ribofuranosyl]thiophene (20)

To an CH_2Cl_2 (5.0 mL) solution of **7** (102.1 mg, 0.26 mmol) was added 2-tributylstannylthiphene (0.25 mL, 0.78 mmol) and TMSOTf (0.15 mL, 0.78 mmol) at –70 °C under Ar atmosphere and the reaction mixture was stirred at 0 °C 12.5 h. The reaction mixture was partitioned between $CHCl_3$/saturated aq $NaHCO_3$ and preparative TLC (hexane/AcOEt = 10/1) of the organic layer gave **20** (84.9 mg, 79%, **20β/20α** =

23:1, syrup).

Physical data of **20**: UV (MeOH)λ_{max} 238 nm (ε 7300),λ_{min} 211 nm (ε 1800); ^{1}H NMR ($CDCl_3$) (**20β**)δ 1.02 and 1.03 (18H, each as s), 2.16 (3H, s), 3.76-3.83 (1H, m), 4.12 (1H, dd, *J* = 11.0 and *J* = 10.0 Hz), 4.37 (1H, dd, *J* = 4.4 and *J* = 10.0 Hz), 4.42 (1H, dd, *J* = 3.6 and *J* = 10.0 Hz), 4.63 (1H, s), 5.36 (1H, d, *J* = 3.6 Hz), 6.96 (1H, dd, *J* = 3.5 and *J* = 5.1 Hz), 7.08 (1H, dt, *J* = 1.2 and *J* = 3.5 Hz), 7.23 (1H, dd, *J* = 1.2 and *J* = 5.1 Hz); (**20α**, selected data) δ 2.07 (3H, s), 3.70 (1H, ddd, *J* = 4.6, *J* = 10.0 and *J* = 11.0 Hz), 3.98 (1H, dd, *J* = 10.3 and *J* = 11.0 Hz), 4.60 (1H, d, *J* = 8.8 Hz), 5.41 (1H, dd, *J* = 8.8 and *J* = 9.0 Hz), 6.90 (1H, dd, *J* = 3.4 and *J* = 5.1 Hz), 7.01 (1H, ddd, *J* = 0.8, *J* = 1.2 and *J* = 5.0 Hz), 7.16 (1H, dd, *J* = 2.2 and *J* = 4.5 Hz); NOE experiment (**20β**): H-1'/H-4' (2%), H-3/H-2' (2.0%); ^{13}C NMR ($CDCl_3$) δ 20.09, 21.10, 22.74, 26.95, 27.20, 45.26, 47.65, 68.48, 79.01, 81.12, 125.49, 125.83, 127.28, 144.97, 170.06. FAB-MS (*m/z*) 415 (M^++H). *Anal*. Calcd for $C_{19}H_{30}O_4S_2Si$: C, 55.03; H, 7.29. Found: C, 54.98; H, 7.35.

2-[2-*O*-Acetyl-3,5-*O*-(di-*t*-butylsilylene)-4-thio-β,α-D-ribofuranosyl]furan (21)

To an CH_2Cl_2 (5.0 mL) solution of **7** (102.3 mg, 0.26 mmol) was added 2-tributylstannylfuran (0.25 mL, 0.78 mmol) and TMSOTf (0.15 mL, 0.78 mmol) at –70 °C under Ar atmosphere and the reaction mixture was stirred at – 10 °C for 5.5 h. The reaction mixture was partitioned between $CHCl_3$/saturated aq $NaHCO_3$ and preparative TLC (hexane/AcOEt = 10/1) of the organic layer gave a mixture of **20** (63

mg, 61%, **21β/21α** = 24:1, syrup): UV (MeOH)λ_{max} 225 nm (ε 11000),λ_{min} 206 nm (ε 7200); ^{1}H NMR ($CDCl_3$) (**21β**)δ 1.00 and 1.05 (18H, each as s), 2.15 (3H, s), 3.73-3.79 (1H, m), 4.08 (1H, t, *J* = *J* = 10.4 Hz), 4.37 (1H, dd, *J* = 4.4 and *J* = 10.4 Hz), 4.42 (1H, dd, *J* = 4.0 and *J* = 10.4 Hz), 4.63 (1H, s), 5.36 (1H, d, *J* = 4.0 Hz), 6.11 (1H, dt, *J* = 0.8 and *J* = 3.2 Hz), 6.16 (1H, dd, *J* = 2.0, *J* = 3.2 Hz), 7.25 (1H, dd, *J* = 0.8 and *J* = 2.0 Hz); (**21α**, selected data) δ 3.78 (1H, dd, *J* = 10.0 and *J* = 11.2 Hz), 6.20 (1H, dd, *J* = 2.0 and *J* = 3.2 Hz), 7.27 (1H, dd, *J* = 0.8 and *J* = 2.0 Hz); NOE experiment (for **21β**): H-1'/H-4' (2%), H-3/H-2' (1.0%); ^{13}C NMR ($CDCl_3$) (for **21β**) δ 20.08, 21.08, 22.74, 26.97, 27.24, 29.69, 44.97, 45.10, 68.41, 77.63, 79.99, 107.72, 142.80, 152.35, 169.72. FAB-MS (*m/z*) 399 (M^++H). *Anal*. Calcd for $C_{19}H_{30}O_5SSi$: C, 57.25; H, 7.59. Found: C, 57.28; H, 7.71.

Reaction of 7 with cyanotrimethylsilane: (2*R*)-(2-Cyano-2-methyl)-1,2-dideoxy-[3,5-*O*-(di-*t*-butylsilylene)-4-thio-α-D-ribofuranoso][3,4-*d*][1,3]dioxolane (22a) and (2*S*)-(2-Cyano-2-methyl)-1,2-dideoxy-[3,5-*O*-(di-*t*-butylsilylene)-4-thio-α-D-ribofuranoso][3,4-*d*][1,3]dioxolane (22b)

To a CH_2Cl_2 (3.0 mL) solution of **7** (78.1 mg, 0.2 mmol) was added cyanotrimethylsilane (0.13 mL, 1.0 mmol) and TMSOTf (0.19 mL, 1.0 mmol) at – 70 °C under Ar atmosphere and the reaction mixture was stirred at 0 °C for 21 h. The reaction mixture was partitioned between $CHCl_3$/saturated aq $NaHCO_3$ and column chromatography (hexane/AcOEt = 100/1) of the organic layer gave **22a** (19.4 mg, 27%,

solid) and **22b** (7.3 mg, 10%, solid).

Physical data for **22a** : m.p. 116-118 °C. IR (neat) 2231 cm^{-1} (CN). ^1H NMR ($CDCl_3$)δ 1.03 and 1.06 (18H, each as s), 1.86 (3H, s), 3.54-3.60 (1H, m), 3.97 (1H, dd, *J* = 11.4 and *J* = 10.4 Hz), 4.09 (1H, dd, *J* = 4.4 and *J* = 10.4 Hz), 4.32 (1H, dd, *J* = 4.4 and *J* = 10.2 Hz), 5.01 (1H, dd, *J* = 6.0 and *J* = 4.4 Hz), 5.80 (1H, d, *J* = 6.0 Hz); NOE experiment: CH_3/H-4 (3.0%); ^{13}C NMR ($CDCl_3$) δ 20.26, 22.71, 24.26, 26.84, 27.16, 44.60, 66.39, 81.12, 81.84, 84.92, 100.34, 116.60. FAB-MS (*m/z*) 358 (M^+ + H) and 331 (M^+ – CN). High resolution FAB-MS (*m/z*) calcd for $C_{16}H_{27}F_3O_7S_2Si$: 481.0998. Found: 481.0962.

Physical data for **22b**: m.p. 148-151 °C. IR (neat) 2231 cm^{-1} (CN). ^1H NMR ($CDCl_3$)δ 1.06 and 1.07 (18H, each as s), 1.86 (3H, s), 3.90 (1H, t, *J* = *J* = 10.4 Hz), 4.04-4.12 (2H, m), 4.37 (1H, dd, *J* = 4.4 and *J* = 9.6 Hz), 4.81 (1H, dd, *J* = 4.8 and *J* = 4.4 Hz), 6.03 (1H, d, *J* = 4.8 Hz); ^{13}C NMR ($CDCl_3$) δ 20.26, 22.76, 26.97, 27.09, 27.17, 46.70, 67.67, 81.59, 83.83.76, 86.51, 101.34, 117.79. FAB-MS (*m/z*) 358 (M^+ + H) and 331 (M^+ – CN). High resolution FAB-MS (*m/z*) calcd for $C_{16}H_{28}O_4$ NSSi: 358.1508. Found: 358.1489.

2-*O*-Acetyl-1-phenylthio-3,5-*O*-(di-*t*-butylsilylene)-β,α-D-4-thioribofuranose (23)

To a CH_2Cl_2 (5.0 mL) solution of **7** (242.6 mg, 0.62 mmol) was added TMSSPh (0.59 mL, 3.1 mmol) and $SnCl_4$ (1 M solution in CH_2Cl_2) (1.9 mL, 1.86 mmol) at −70 °C under Ar atmosphere and the reaction mixture was stirred at −10 °C for 10 h. The

reaction mixture was partitioned between $CHCl_3$/saturated aq $NaHCO_3$ and column chromatography (hexane/AcOEt = 100/1) of the organic layer gave **23** (237.5 mg, 87%, syrup, β−isomer/α-isomer = 24/1): UV (MeOH)λ_{max} 253 nm (ε 5100),λ_{min} 242 nm (ε 4700); ^{1}H NMR ($CDCl_3$) (β-isomer)δ 0.98 and 1.02 (18H, each as s, Si-*t*-Bu), 2.08 (3H, s, Ac), 3.68 (1H, ddd, *J* = 4.4, *J* = 10.7 and *J* = 10.7 Hz), 4.00 (1H, t, *J* = *J* = 10.7 Hz), 4.27-4.30 (2H, m), 4.47 (1H, s), 5.52 (1H, d, $J_{2,3}$ = 3.4 Hz); (α-isomer, selected data) δ 2.05 (3H, s, Ac), 3.31 (1H, ddd, *J* = 4.4, *J* = *J* = 10.4 Hz), 4.56 (1H, *J* = 7.6 Hz), 3.31 (1H, dd, *J* = 7.6 and *J* = 9.0 Hz); NOE experiment (β-isomer): H-1/H-4 (0.7%); ^{13}C NMR ($CDCl_3$) δ 20.05, 20.95, 22.67, 26.92, 27.24, 45.21, 53.72, 68.39, 78.60, 79.46, 128.34, 129.16, 132.49, 133.85, 169.55. FAB-MS (*m/z*) 441 (M^+ + H). *Anal*. Calcd for $C_{21}H_{32}O_4S_2Si$: C, 57.23; H, 7.32. Found: C, 57.44; H, 7.37.

2-*O*-(t-Butyldimethylsilyl)-3,5-*O*-(di-*t*-butylsilylene)-1-phenylthio-β,α-D-4-thioribofuranose (24)

Compound **23** (224.5 mg, 0.51 mmol) was treated with methanolic ammonia (20 mL) at rt overnight. The reaction mixture was evaporated to dryness and the residue was dried in vacuo overnight. To a DMF (5 mL) solution of the residue was added imidazole (520.8 mg, 7.65 mmol) and TBDMSCl (922.3 mg, 6.12 mmol) at 0 °C under Ar atmosphere and the mixture was stirred at rt overnight. The reaction mixture was partitioned between AcOEt/H_2O and column chromatography (hexane/AcOEt = 200/1) of the organic layer gave **24** (232.9 mg, 89%, β−isomer/α-isomer = 24/1) as a solid: mp

72-74 °C; UV (MeOH)λ_{max} 263 nm (ε 2900),λ_{min} 254 nm (ε 2800); ^{1}H NMR ($CDCl_3$)δ –0.24 and 0.05 (6H, each as s, Si-*t*-Bu), 0.80 (9H, s), 0.99 and 1.06 (18H, each as s), 3.68-3.73 (1H, m), 4.01 (1H, t, *J* = *J* = 11.2 Hz), 4.25 (1H, s), 4.26-4.30 (3H, m), 7.33-7.35 and 7.51-7.54 (5H, each as m);); (α-isomer, selected data) δ 3.32-3.38 (1H, m), 4.49 (1H, *J* = 7.2 Hz); NOE experiment (β-isomer): H-1/H-4 (1.0%); ^{13}C NMR ($CDCl_3$) δ –5.57, –4.33, 18.01, 20.09, 22.73, 25.75, 26.97, 27.53, 44.26, 58.06, 69.03, 79.57, 79.76, 128.70, 129.27, 134.08, 134.24. FAB-MS (*m/z*) 455 (M^+ – *t*-Bu) and 551 (M^+ + K). *Anal*. Calcd for $C_{25}H_{44}O_3S_2Si_2$: C, 58.54; H, 8.65. Found: C, 58.71; H, 8.91.

1-*O*-Acetoxy-2-*O*-(*t*-butyldimethylsilyl)-3,5-*O*-(di-*t*-butylsilylene)-β-D-4-thioribofuranose (25)

To an AcOH (3.8 mL, 67.08 mmol) solution of **24** (221.1 mg, 0.43 mmol) was added $Hg(OAc)_2$ (602.9 mg, 1.89 mmol) at rt under Ar atmosphere and the mixture was stirred at rt for 14 h. The reaction mixture was diluted with $CHCl_3$. The solution washed with H_2O, saturated $NaHCO_3$ and 5% KCN. Silica gel column chromatography (hexane/AcOEt = 150/1) of the organic layer gave **25** (190.6 mg, 96%, β–isomer/α-isomer = 24/1) as a solid: mp 104-105 °C. ^{1}H NMR ($CDCl_3$)δ 0.13 and 0.15 (6H, each as s), 0.92 (9H, s), 1.02 and 1.07 (18H, each as s), 2.08 (3H, s), 3.70 (1H, ddd, *J* = 4.6, *J* = 11.4 and *J* = 3.2 Hz), 4.01 (1H, dd, *J* = 11.4 and *J* = 10.0 Hz), 4.16 (1H, dd, *J* = 3.2 and *J* = 10.0 Hz), 4.28-4.32 (2H, m), 5.60 (1H, d, *J* = 0.7 Hz); (α-isomer, selected data) δ 2.09 (1H, s), 3.91 (1H, d, *J* = 11.2 and *J* = 10.0 Hz), 5.66 (1H, *J* = 5.2 Hz); NOE

experiment : H-1/H-4 (0.7%); ^{13}C NMR ($CDCl_3$) δ –5.20, –4.38, 18.16, 20.15, 21.10, 22.76, 25.81, 27.00, 27.47, 43.53, 69.06, 77.44, 80.05, 82.32, 169.59. FAB-MS (*m/z*) 463 (M^+ + H) and 403 (M^+ – OAc). *Anal*. Calcd for $C_{21}H_{42}O_5SSi_2$: C, 54.50; H, 9,15. Found: C, 54.39; H, 9.33.

1-*C*-Cyano-2-(*t*-butyldimethylsilyl)-3,5-*O*-(di-*t*-butylsilylene)-β-D-4-thioribofuranose (27)

To a CH_2Cl_2 (5 mL) solution of **25** (159.9 mg, 0.35 mmol) was added TMSBr (0.28 mL, 2.1 mmol) at 0 °C under Ar atmosphere and the mixture was stirred at rt for 27 h. To the reaction mixture was added $Hg(CN)_2$ (884.2 mg, 3.5 mmmol) and CH_3CN (5 mL) and the mixture was stirred at rt for 22 h. The reaction mixture was partitioned between $CHCl_3$ and saturated aq $NaHCO_3$ and column chromatography (hexane/AcOEt = 100/1) of the organic layer gave **27** (95.1 mg, 63%) as a solid: mp 137-139 °C. IR (neat) 2241 cm^{-1} (CN). ^{1}H NMR ($CDCl_3$)δ 0.15 and 0.18 (12H, each as s), 0.93 (9H, s), 1.01 and 1.06 (18H, each as s), 3.58 (1H, s), 3.77 (1H, ddd, *J* = 3.1, *J* = 11.2 and *J* = 4.6 Hz), 4.08 (1H, dd, *J* = 11.2 and *J* = 10.1 Hz), 4.21 (1H, dd, *J* = 3.2 and *J* = 10.1 Hz), 4.33 (1H, dd, *J* = 4.6 and *J* = 10.1 Hz), 4.60 (1H, d, *J* = 3.1 Hz); NOE experiment: H-1/H-4 (0.9%); ^{13}C NMR ($CDCl_3$) δ –5.30, –4.40, 18.11, 20.09, 22.75, 25.76, 26.91 27.37, 35.51, 44.23, 68.31, 77.57, 81.86, 118.34. FAB-MS (*m/z*) 430 (M^+ + H). *Anal*. Calcd for $C_{20}H_{39}NO_3SSi_2$: C, 55.89; H, 9.15; N. 3.26. Found: C, 55.96; H, 9.32; N. 3.18.

Ethyl 2-[2-*O*-(*t*-butyldimethylsilyl)-3,5-*O*-(di-*t*-butylsilylene)-β-D-4-

thioribofuranosyl]-thiazole-4-carboxylate (29)

To a $ClCH_2CH_2Cl$ (6.0 mL) solution of **27** (95.6 mg, 0.063 mmol) was added ethyl cystein hydrochloride (246.4 mg, 1.32 mmol) and *i*-Pr_2NEt (0.23 mL, 1.32 mmol) at 0 °C under Ar atmosphere and the mixture was stirred at rt for 5 days. The reaction mixture was partitioned between $CHCl_3$ and saturated aq NH_4Cl and column chromatography (hexane/AcOEt = 20/1) of the organic layer gave **27** (99 mg, solid, 80%). To a CH_2Cl_2 (6.0 mL) solution of **28** was added DBN (49 μL, 0.40 mmol) and $BrCCl_3$ (27 μL, 0.27 mmol) at 0 °C under Ar atmosphere and the mixture was stirred at rt for 6 h. The reaction mixture was partitioned between $CHCl_3$ and saturated aq NH_4Cl and column chromatography (hexane/AcOEt = 40/1) of the organic layer gave **29** (89.2 mg, 88%) as a syrup: UV (MeOH)λ_{max} 237 nm (ε 7700), λ_{min} 222 nm (ε 5900); ^{1}H NMR ($CDCl_3$)δ 0.16 and 0.24 (6H, each as s), 0.97 (9H, s), 1.02 and 1.02 (18H, each as s), 1.40 (3H, t, J = 7.1 Hz), 3.86 (1H, ddd, *J* = 4.6, *J* = 10.8 and *J* = 10.9 Hz), 4.10 (1H, dd, *J* = 11.2 and *J* = 10.8 Hz), 4.27 (1H, dd, *J* = 3.1 and *J* = 10.9 Hz), 4.37-4.40 (3H, m), 4.53 (1H, s), 4.59 (1H, d, *J* = 3.1 Hz), 8.09 (1H, s).; NOE experiment: H-1'/H-4' (1.6%); ^{13}C NMR ($CDCl_3$) δ –4.98, –4.20, 14.26, 18.14, 20.09, 22.77, 25.87, 26.96, 27.40, 44.40, 53.00, 61.37, 68.98, 79.98, 80.37, 128.12, 147.97, 161.37, 173.86. FAB-MS (*m/z*) 560 (M^+ + H). *Anal*. Calcd for $C_{25}H_{45}NO_5S_2Si_2$: C, 53.63; H, 8.10; N, 2.50. Found: C, 53.37; H, 8.37; N, 2.49.

2-[2-*O*-(*t*-butyldimethylsilyl)-3,5-*O*-(di-*t*-butylsilylene)-β-D-4-thioribofuranosyl]-

thiazole-4-carboxamide (30)

Compound **29** (86 mg, 0.15 mmol) was treated with methanolic ammonia (20 mL) at rt for 9 h. The reaction mixture was evaporated to dryness and the residue was chromatographed (hexane/AcOEt = 5/1) on a silica gel to give **30** (78.8 mg, 99%) as a solid: mp 168-169 °C; UV (MeOH)λ_{max} 234 nm (ε 8240), λ_{min} 228 nm (ε 8170); ^{1}H NMR ($CDCl_3$)δ 0.18 and 0.24 (6H, each as s), 0.99 (9H, s), 1.02 and 1.03 (18H, each as s), 3.87 (1H, ddd, *J* = 10.0, *J* = 11.2 and *J* = 4.6 Hz), 4.10 (1H, dd, *J* = 11.2 and *J* = 10.0 Hz), 4.22 (1H, dd, , *J* = 3.2 and *J* = 10.0 Hz), 4.40 (1H, dd, *J* = 4.6 and *J* = 10.0 Hz), 4.47 (1H, s), 4.56 (1H, d, *J* = 3.2 Hz), 5.86 and 7.03 (2H, each as br), 8.08 (1H, s).; NOE experiment: H-1'/H-4' (1.6%); ^{13}C NMR ($CDCl_3$) δ –4.99, –4.23, 18.24, 20.10, 22.79, 25.89, 26.95, 27.37, 44.34, 52.77, 68.91, 76.74, 80.21, 125.05, 150.14, 162.82, 173.57. FAB-MS (*m/z*) 531 (M^+ + H) and 473 (M^+ – *t*-Bu). *Anal*. Calcd for $C_{23}H_{42}N_2O_4S_2Si_2$: C, 52.03; H, 7.97; N, 5.28. Found: C, 52.10; H, 8.12; N, 5.23.

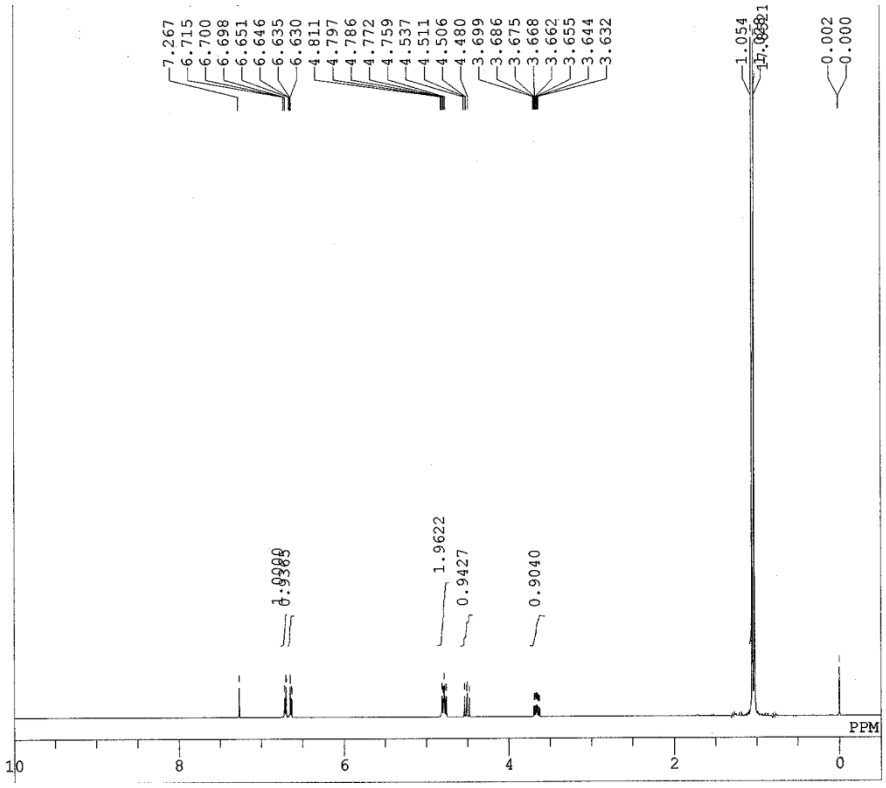
4′-Thiotiazofurin (31)

To a stirred THF (5 mL) solution of **30** (88.8 mg, 0.17 mmol) was added $Bu_4NF{\cdot}3H_2O$ (172.6 mg, 0.66 mmol) and the mixture was stirred at rt for 3 h. The reaction mixture was evaporated to dryness and the residue was chromatographed (8% MeOH in CH_2Cl_2) on a silica gel to give **31** (44.1 mg, 94%) as a solid: mp 171-172 °C; UV (MeOH)λ_{max} 234 nm (ε 8100), λ_{min} 226 nm (ε 8000); ^{1}H NMR (CD_3OD)δ 3.45 (1H, dt, *J* = 4.0 and *J* = 6.3 Hz), 3.67 (1H, dd, *J* = 6.3 and *J* = 11.5 Hz), 3.79 (1H, dd, *J*

= 6.3 and *J* = 11.5 Hz), 4.20 (1H, t, *J* = 4.0 Hz), 4.37 (1H, dd, *J* = 4.0 and *J* = 6.3 Hz), 4.68 (1H, d, *J* = 6.3 Hz), 8.14 (1H, s); ^{13}C NMR ($CDCl_3$) δ 51.3, 54.1, 65.5, 76.8, 81.9, 126.2, 150.9, 165.6, 174.1; FAB-MS (*m/z*) 277 (M^+ + H). *Anal*. Calcd for $C_9H_{12}N_2O_4S_2$: C, 39.12; H, 4.38; N, 10.14. Found: C, 39.04; H, 4.24; N, 9.74.

Fig. 1: ^{1}H NMR and ^{13}C NMR spectrum of compound **(*S*$_R$)-6** in $CDCl_3$

Fig. 2: ^{1}H NMR and ^{13}C NMR spectrum of compound (*Ss*)-**6** in $CDCl_3$


7.267
6.715
6.700
6.698
6.651
6.646
6.635
6.630
4.811
4.797
4.786
4.772
4.759
4.537
4.511
4.506
4.480
3.699
3.686
3.675
3.668
3.662
3.655
3.644
3.632
1.054
0.002
0.000
1.9622
0.9427
0.9040
PPM
10
8
6
4
2
0

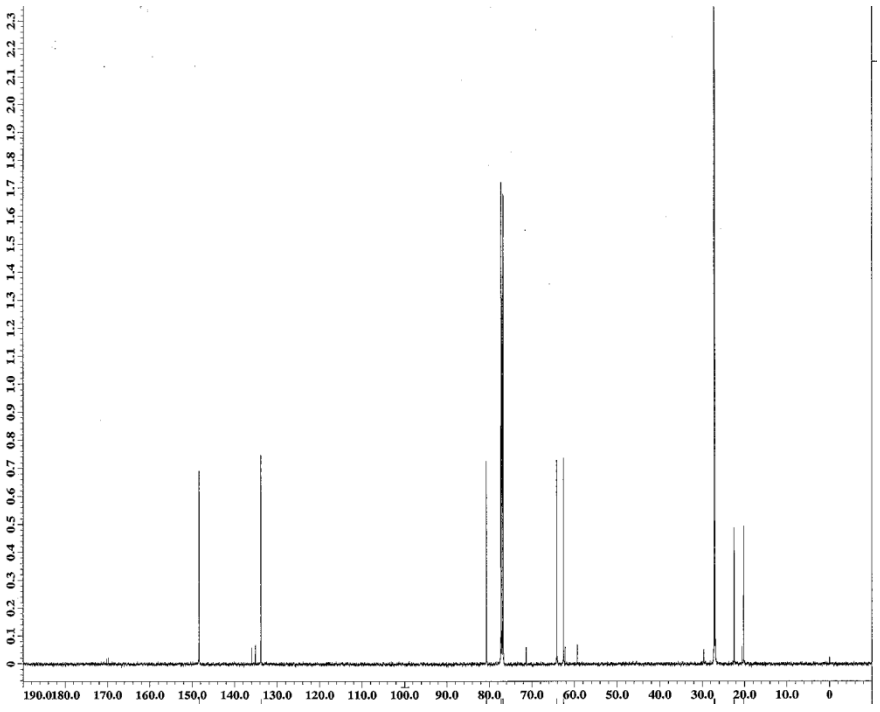
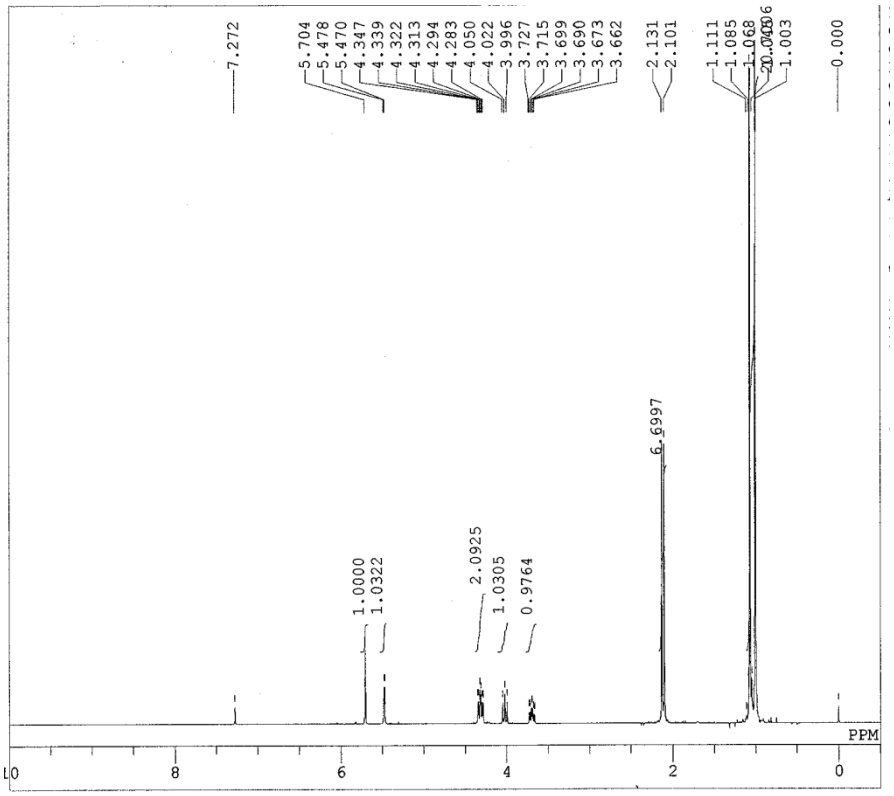


Fig. 3: ^{1}H NMR and ^{13}C NMR spectrum of compound **7β** in $CDCl_3$



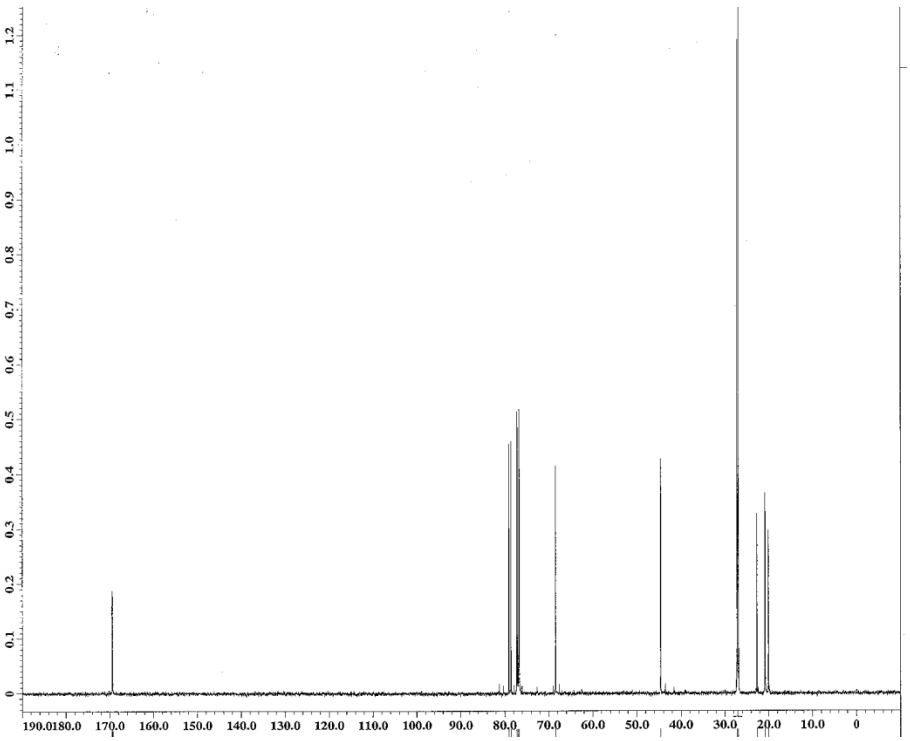
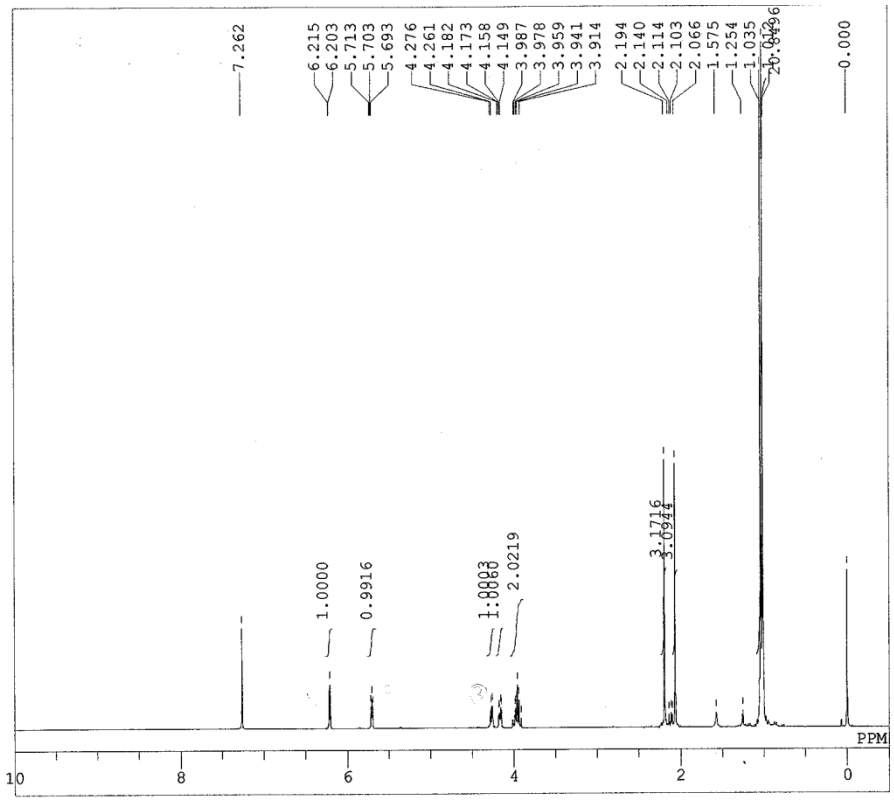


Fig. 4: ^{1}H NMR and ^{13}C NMR spectrum of compound **7α** in $CDCl_3$



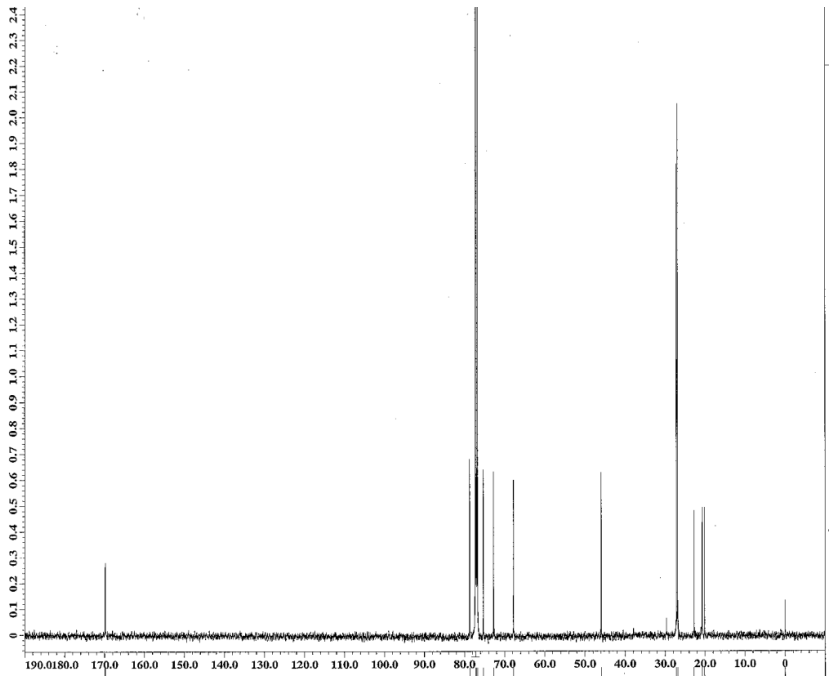
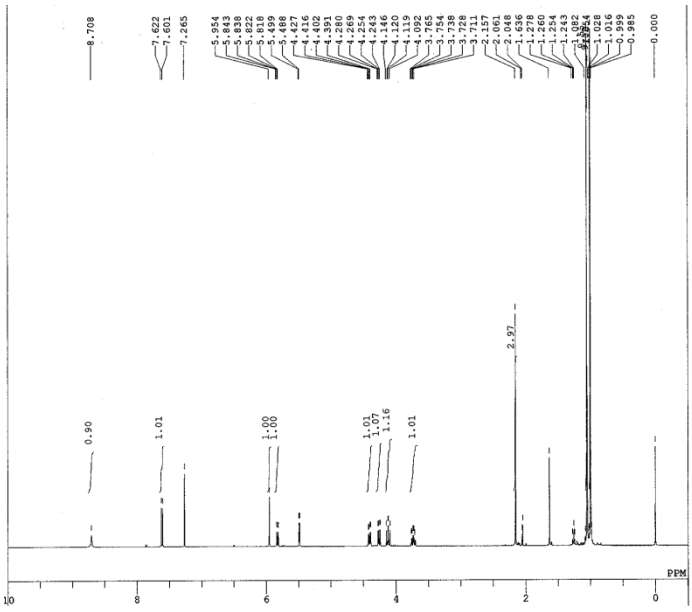


Fig. 5: ^{1}H NMR and ^{13}C NMR spectrum of compound **12β** in $CDCl_3$



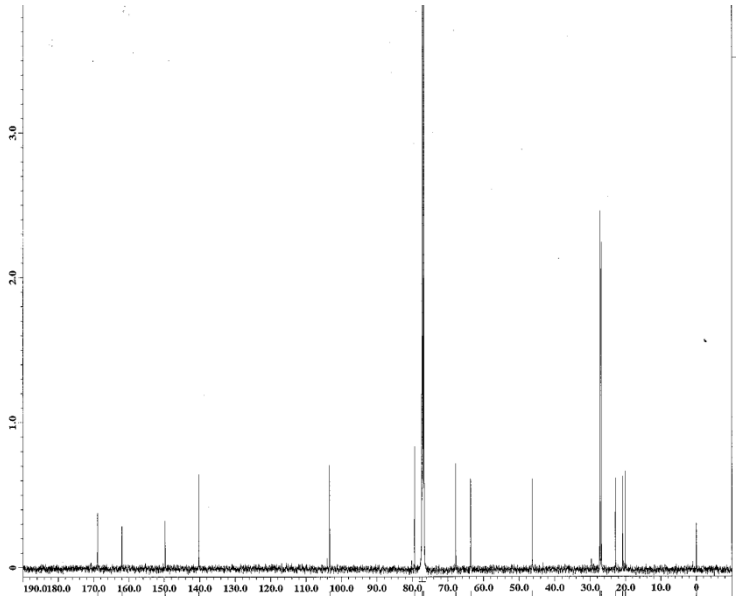
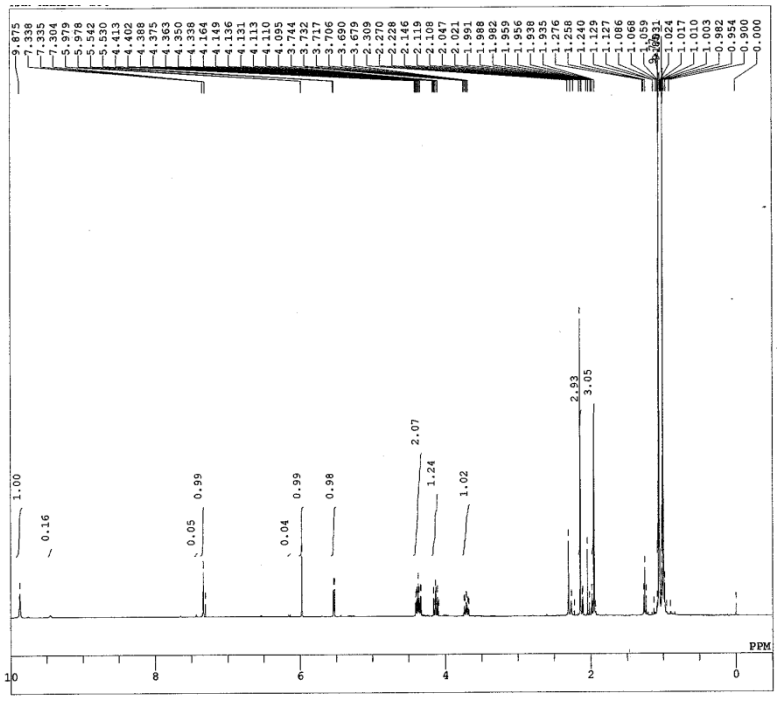


Fig. 6: ^{1}H NMR and ^{13}C NMR spectrum of compound **13β** in $CDCl_3$



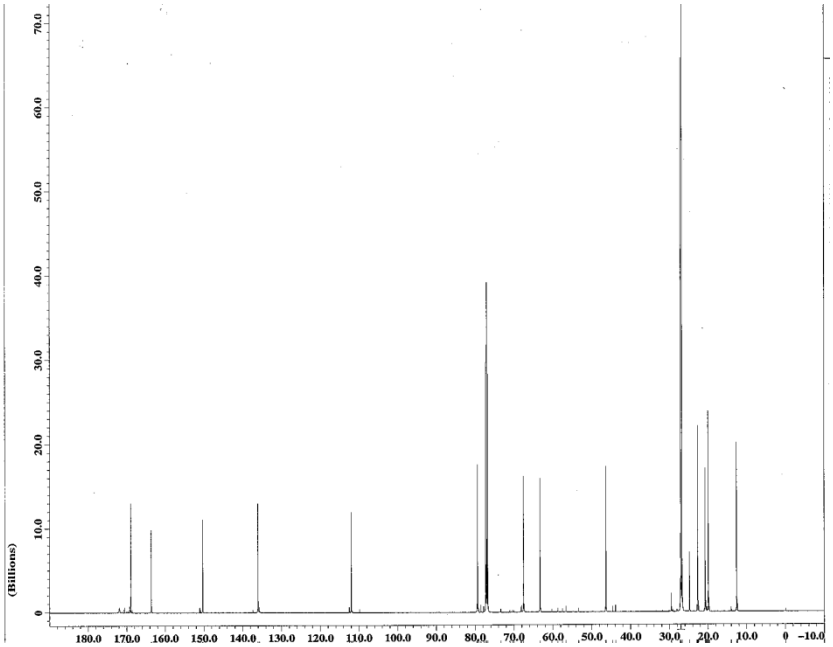
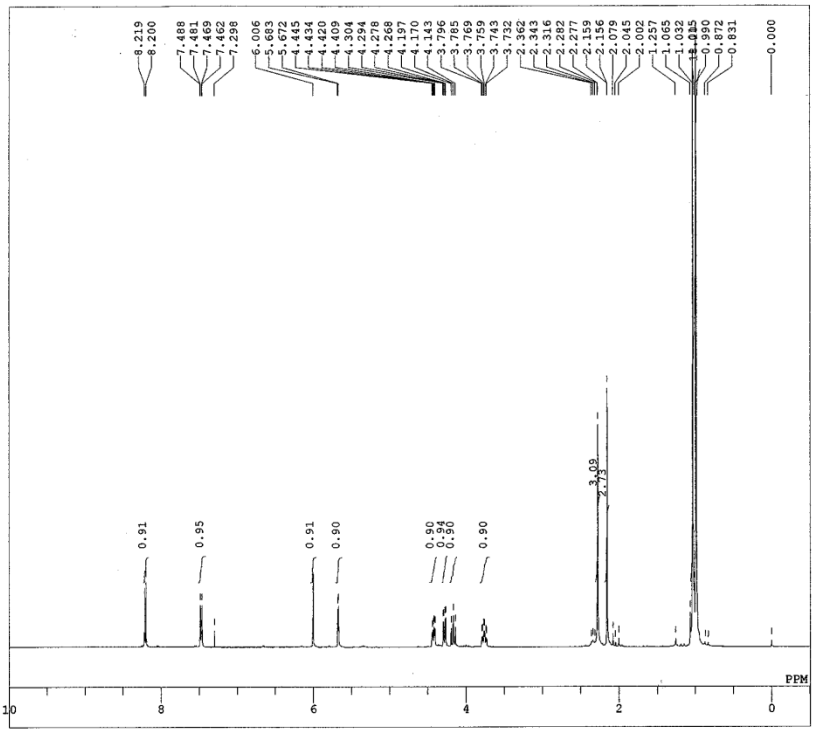


Fig. 7: ^{1}H NMR and ^{13}C NMR spectrum of compound **14β** in $CDCl_3$



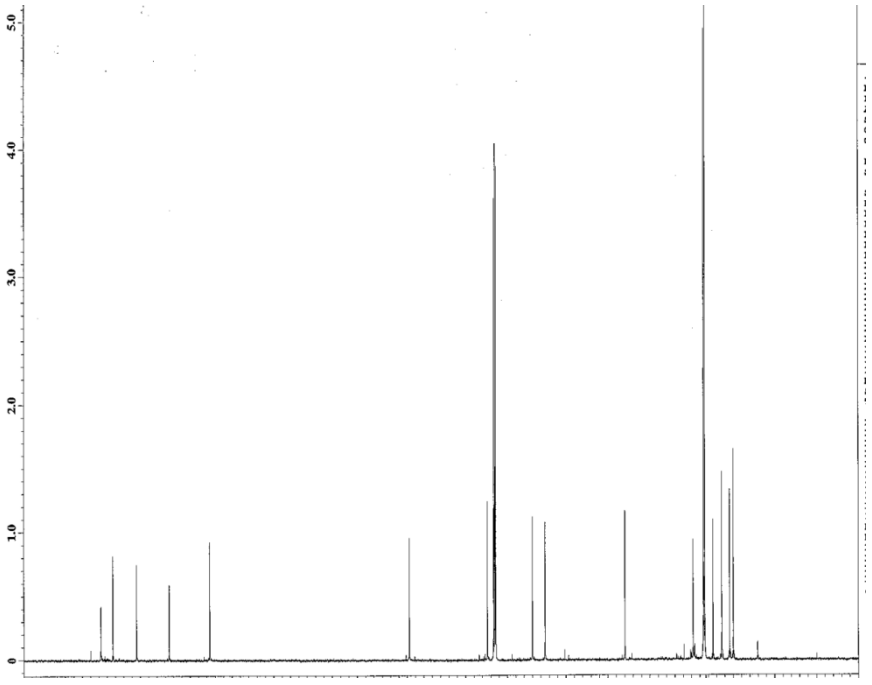
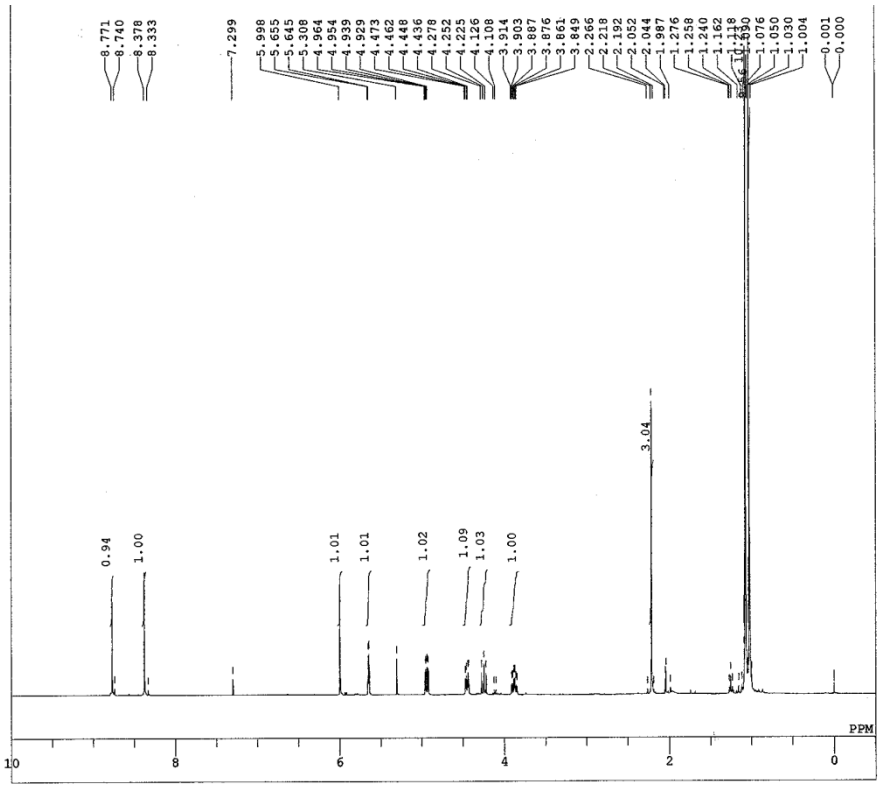


Fig. 8: ^{1}H NMR and ^{13}C NMR spectrum of compound **15β** in $CDCl_3$



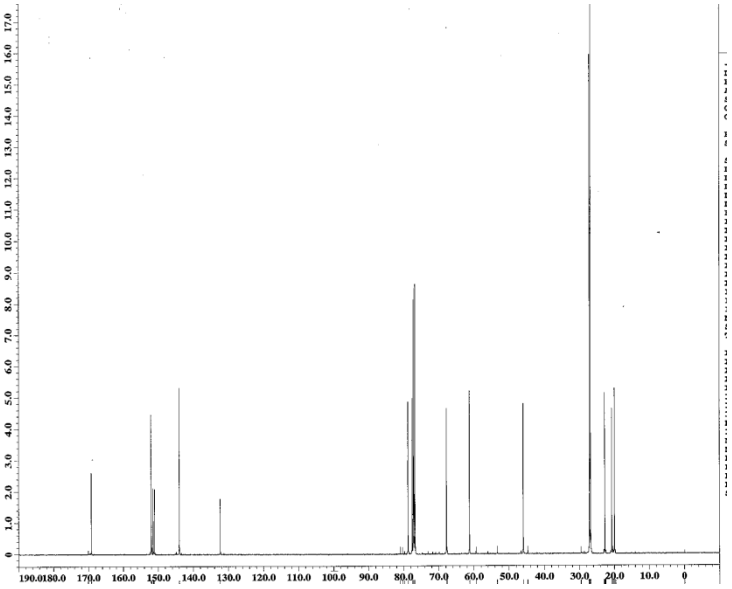
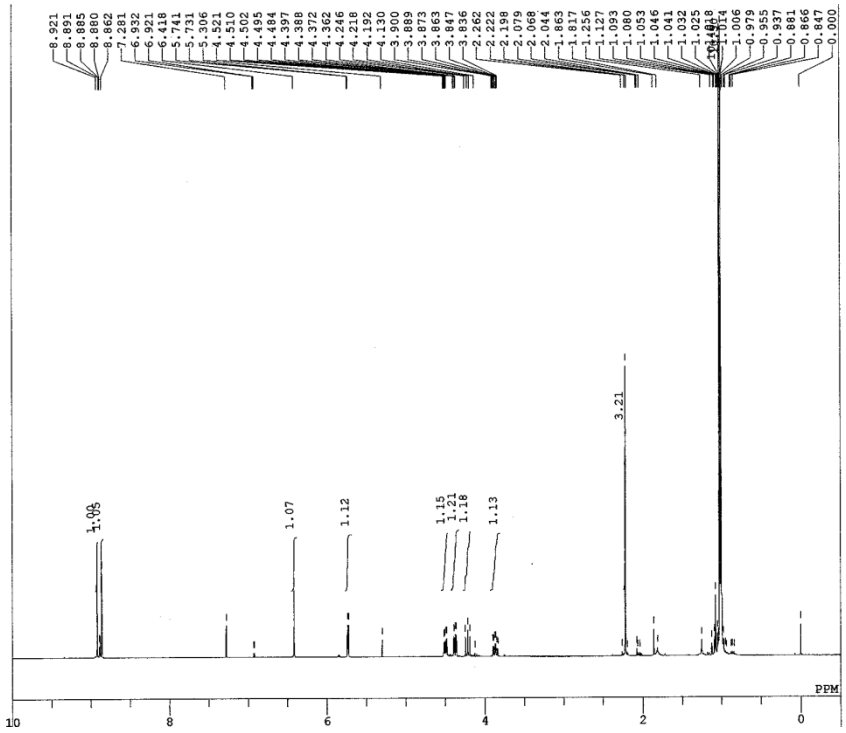


Fig. 9: ^{1}H NMR and ^{13}C NMR spectrum of compound **16β** in $CDCl_3$



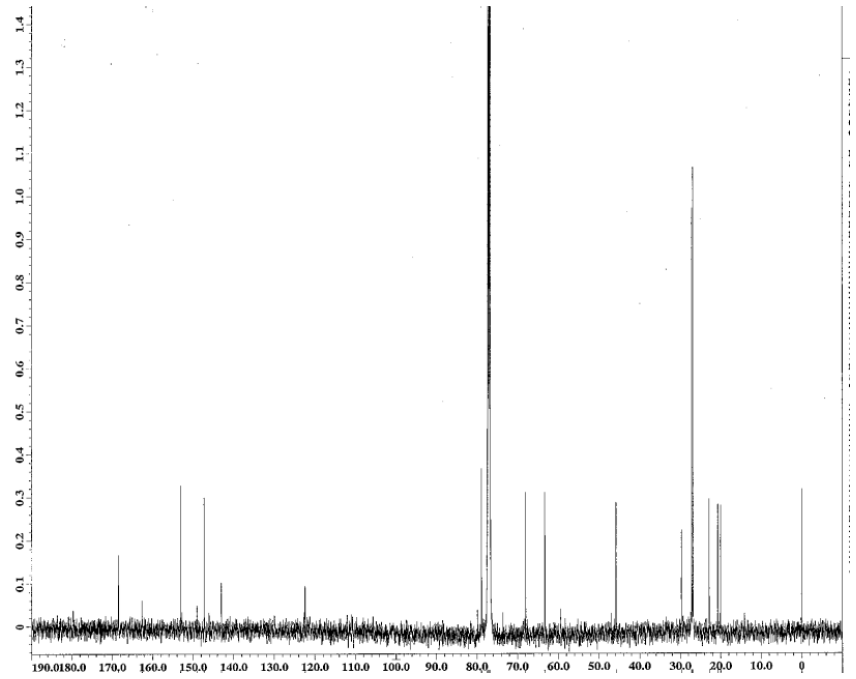
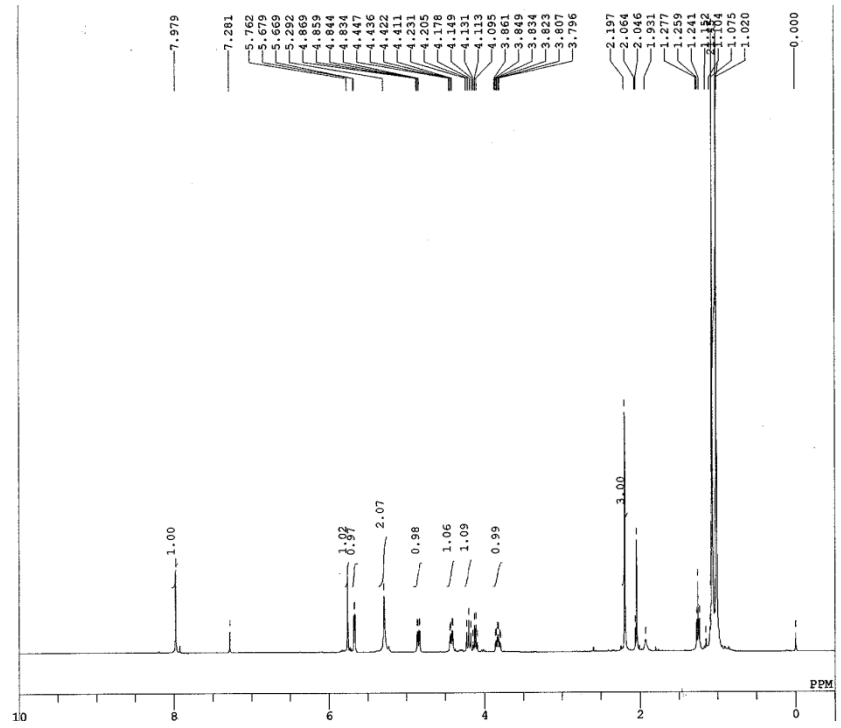


Fig. 10: ^{1}H NMR and ^{13}C NMR spectrum of compound **17β** in $CDCl_3$



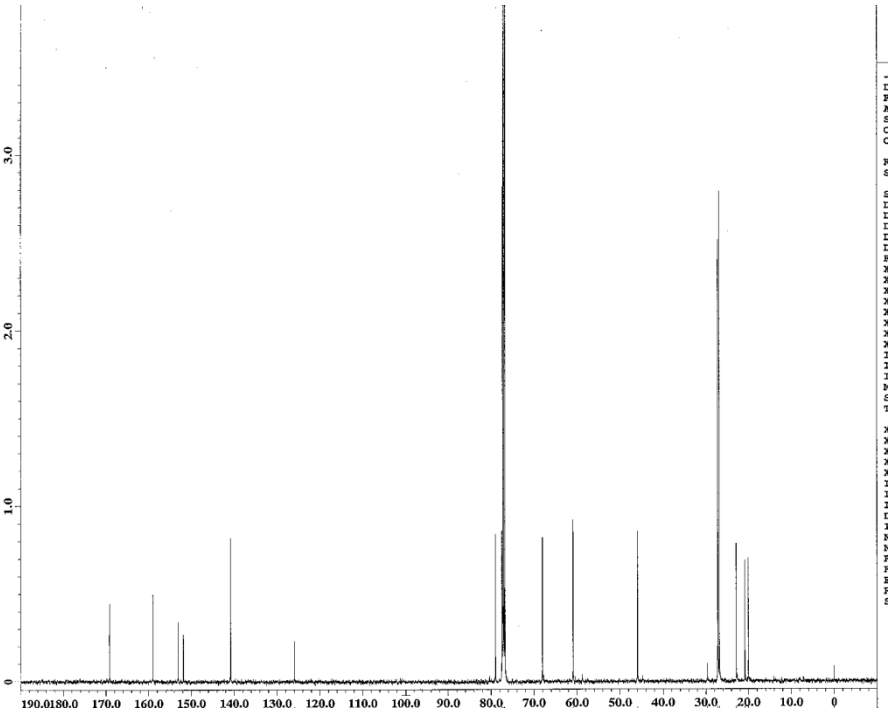
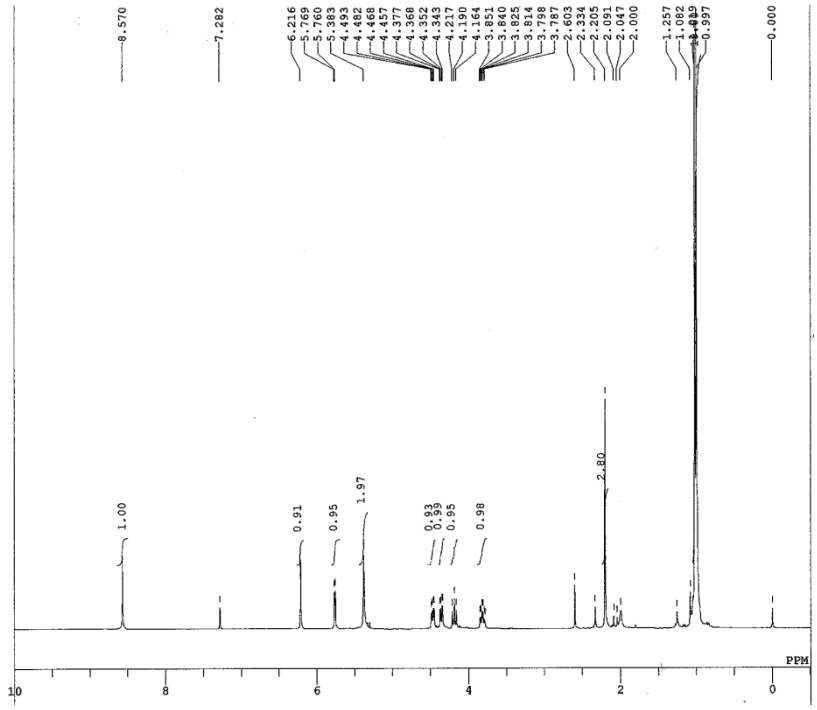


Fig. 11: ^{1}H NMR and ^{13}C NMR spectrum of compound **18β** in $CDCl_3$



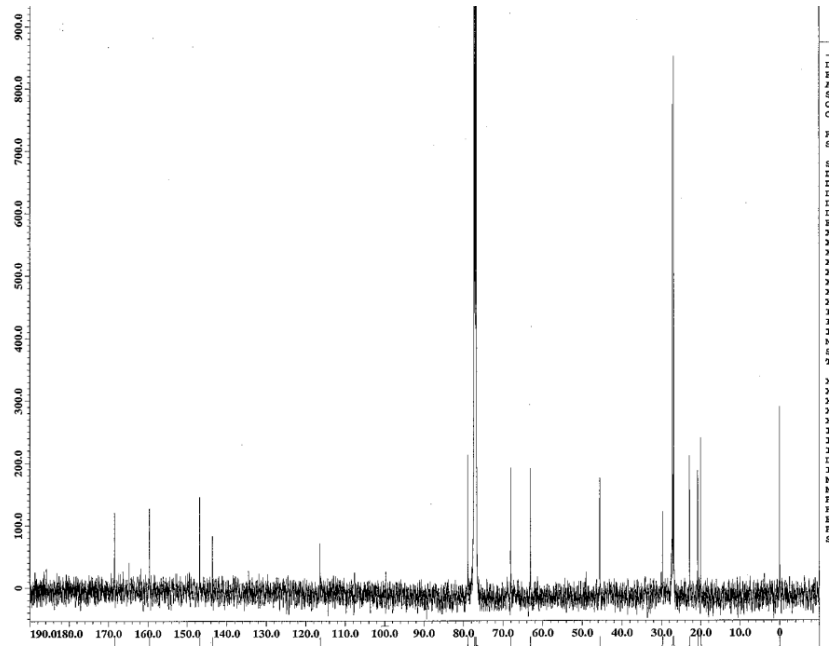
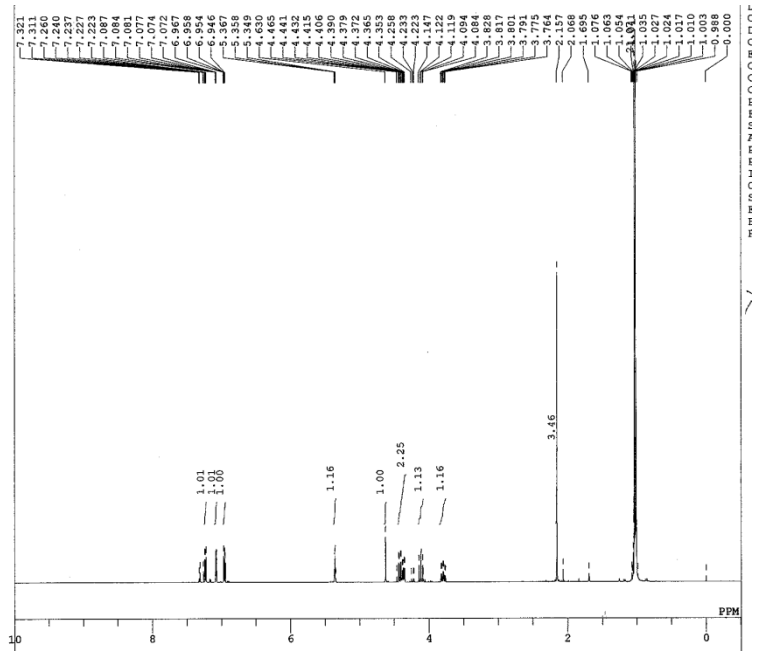


Fig. 12: ^{1}H NMR and ^{13}C NMR spectrum of compound **20β** in $CDCl_3$



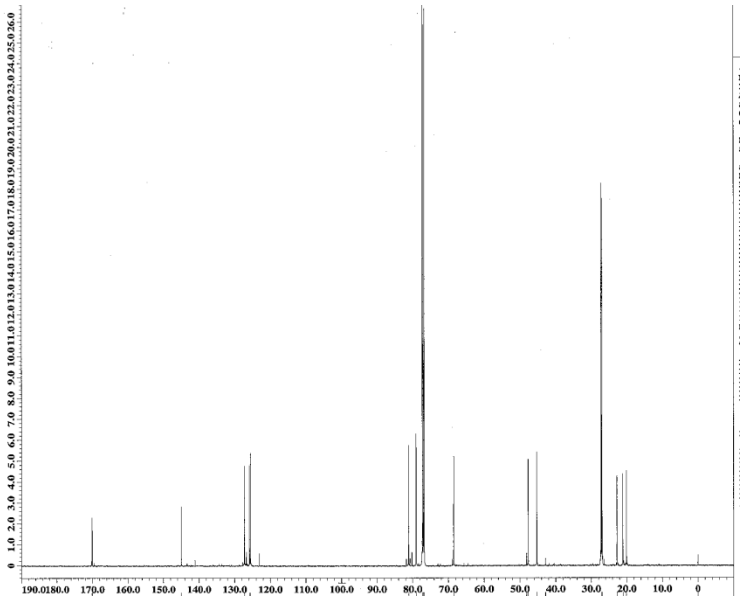
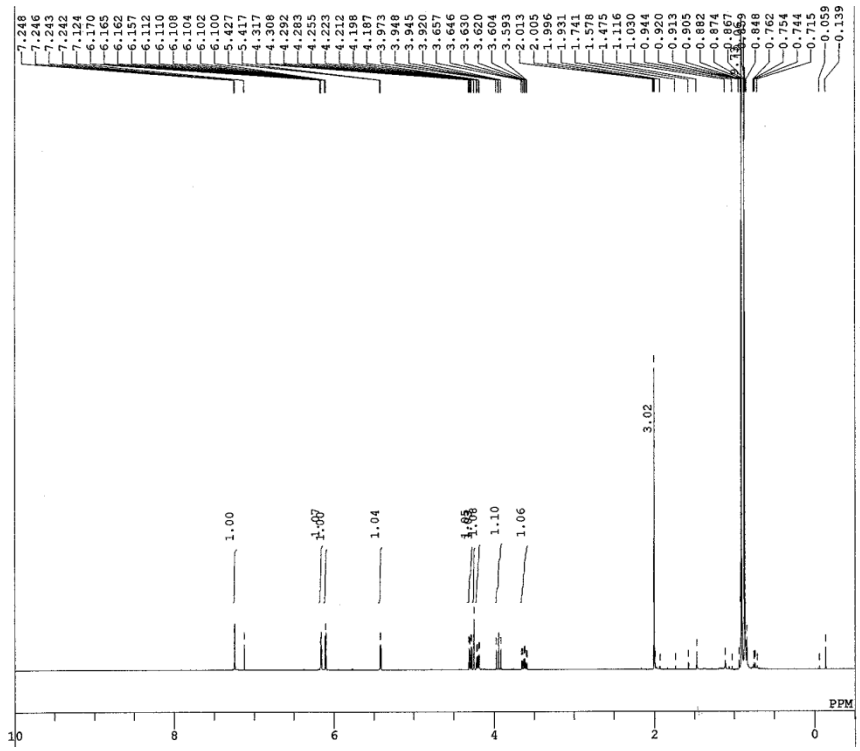


Fig. 13: ^{1}H NMR and ^{13}C NMR spectrum of compound **21β** in $CDCl_3$



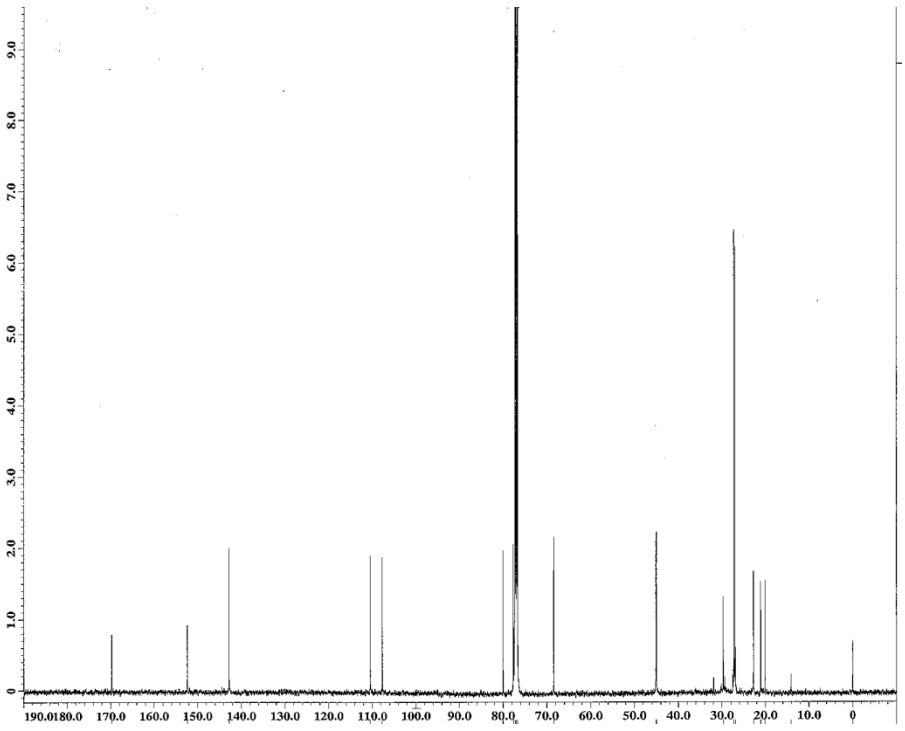
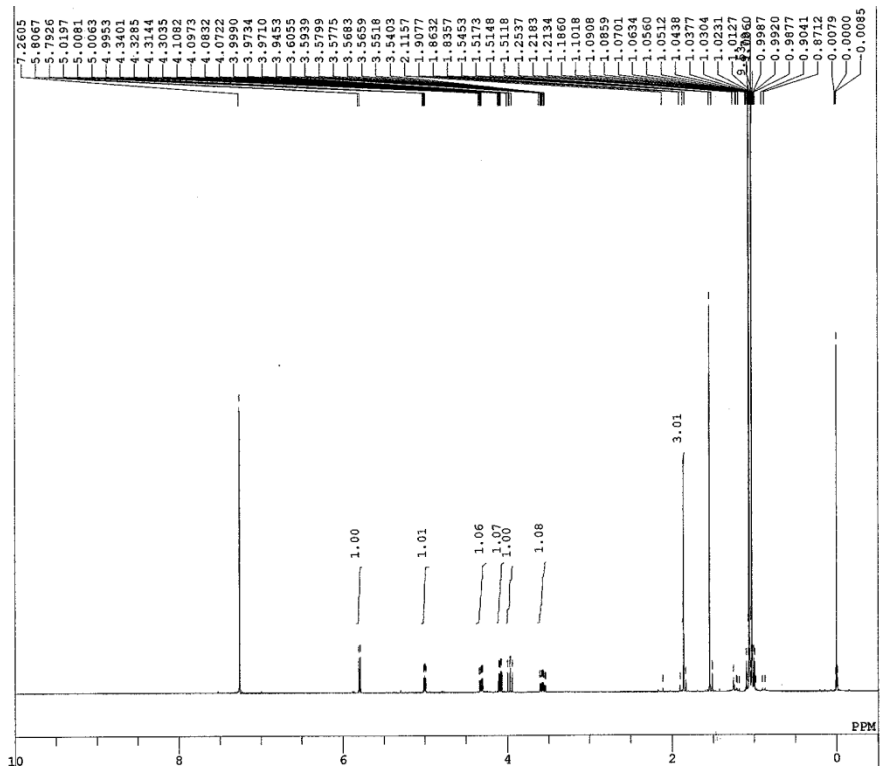


Fig. 14: ^{1}H NMR and ^{13}C NMR spectrum of compound **22a** in $CDCl_3$



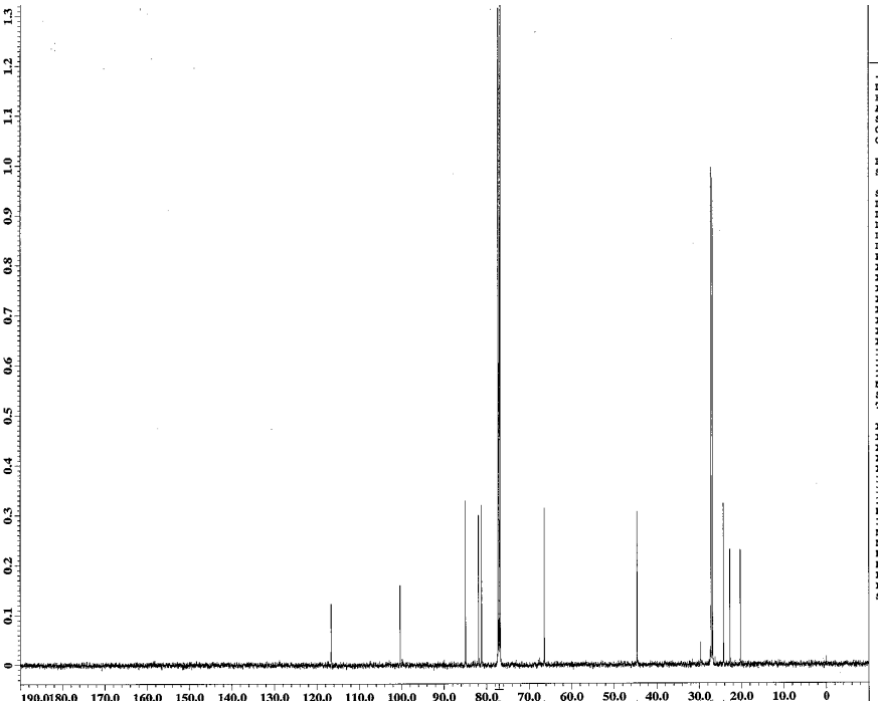
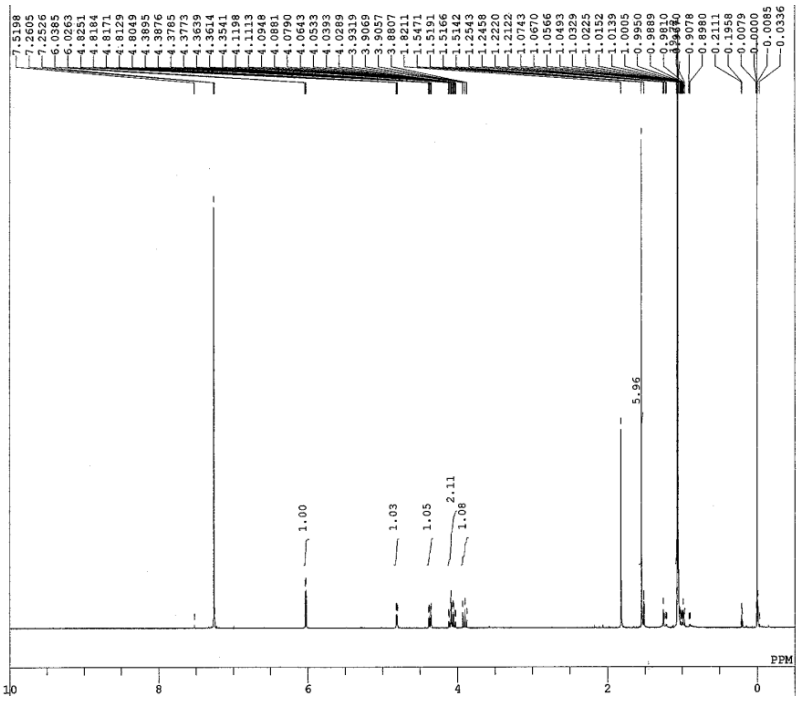


Fig. 15: ^{1}H NMR and ^{13}C NMR spectrum of compound **22b** in $CDCl_3$



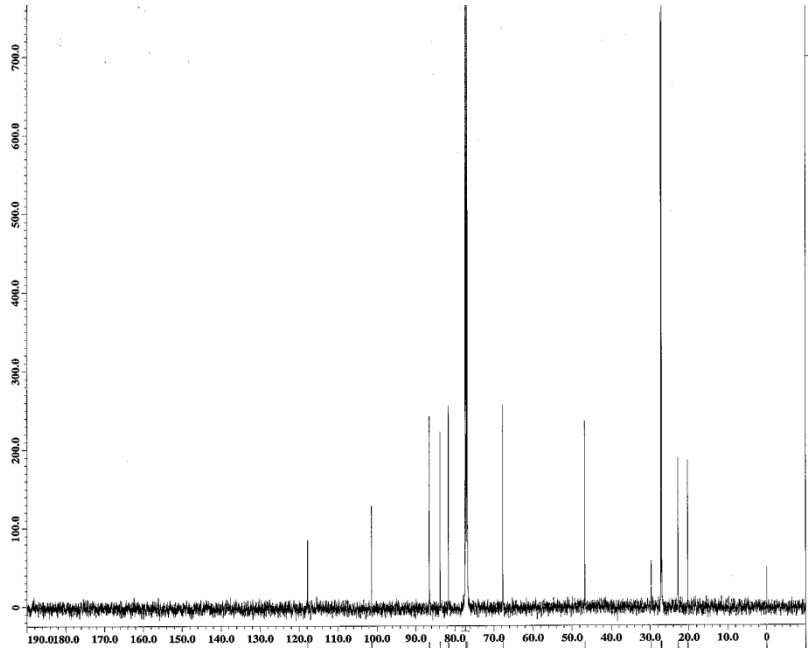
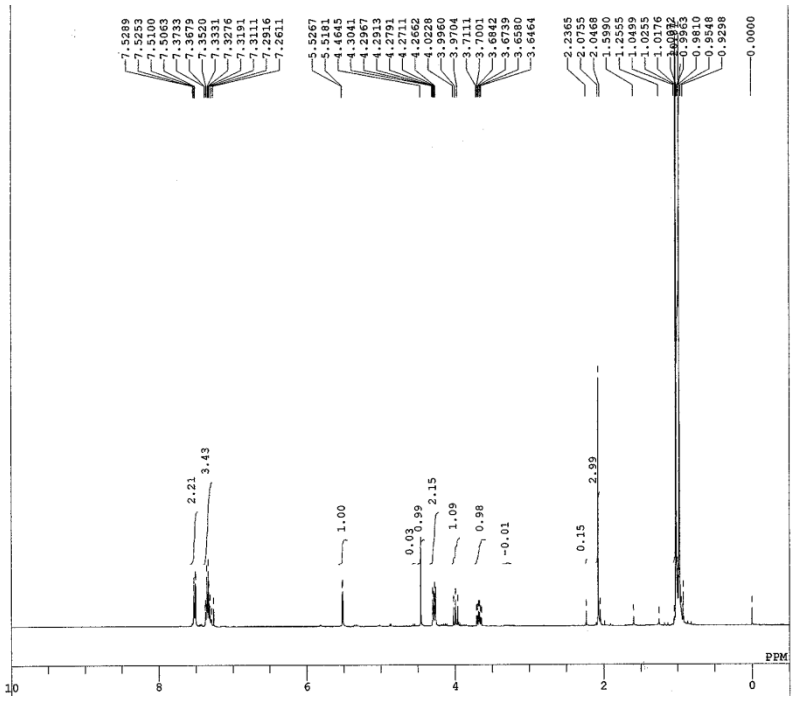


Fig. 16: ^{1}H NMR and ^{13}C NMR spectrum of compound **23** in $CDCl_3$



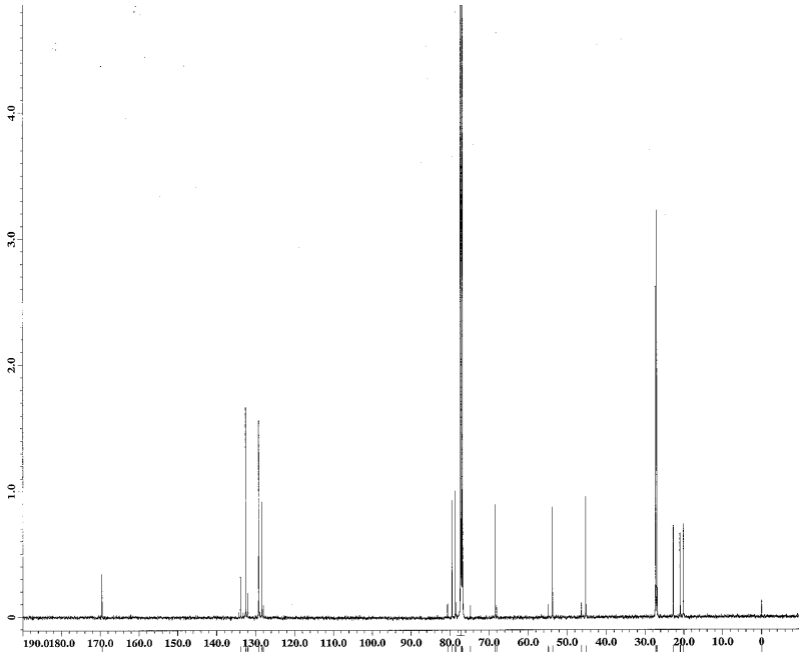
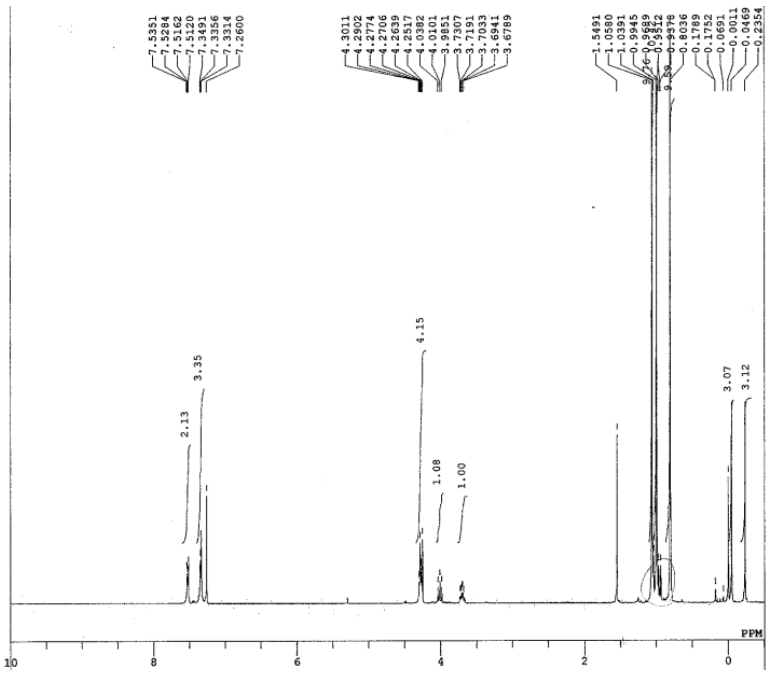


Fig. 17: ^{1}H NMR and ^{13}C NMR spectrum of compound **24** in $CDCl_3$



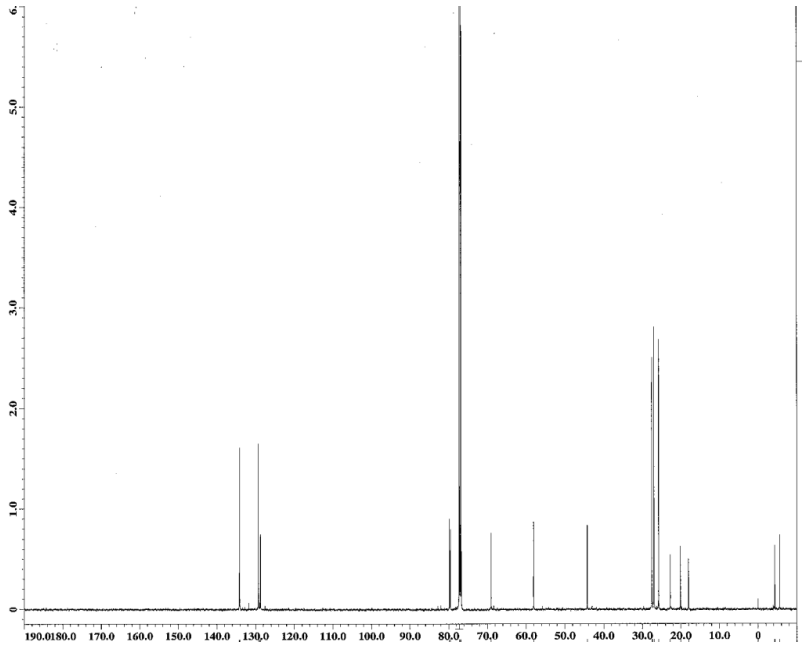
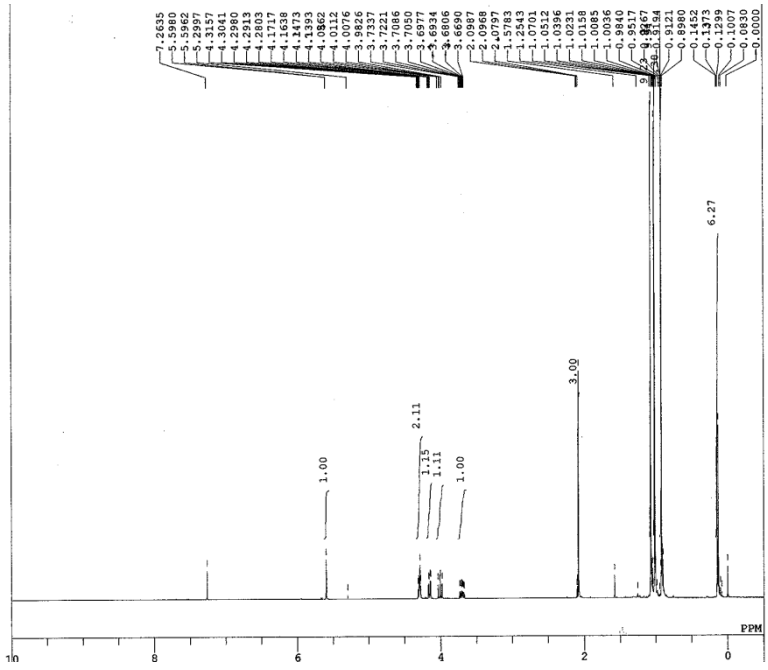


Fig. 18: ^{1}H NMR and ^{13}C NMR spectrum of compound **25** in $CDCl_3$



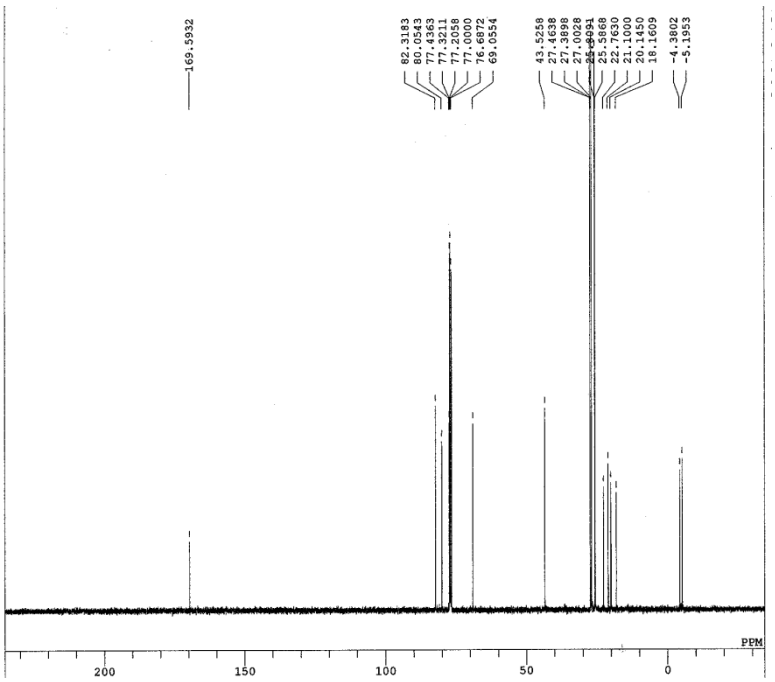
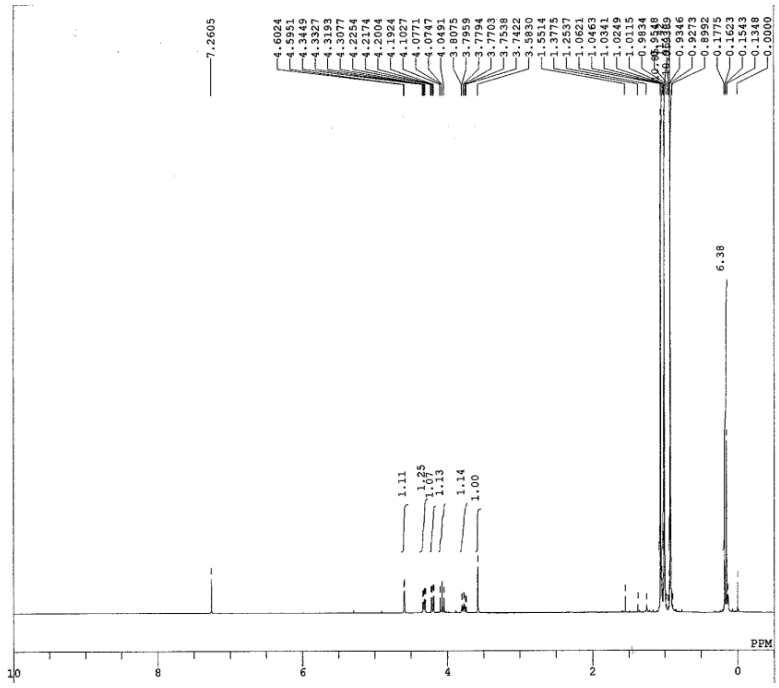


Fig. 19: ^{1}H NMR and ^{13}C NMR spectrum of compound **27** in $CDCl_3$



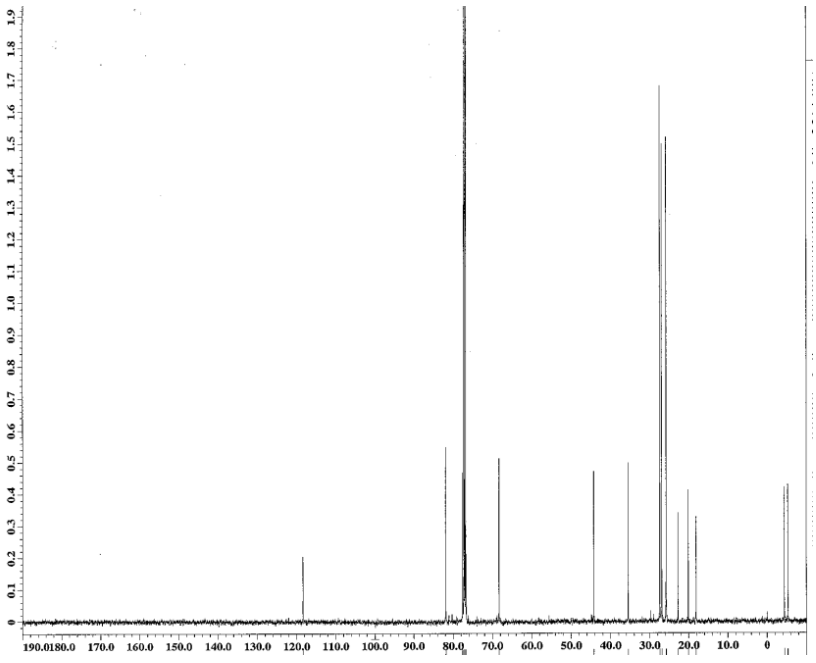
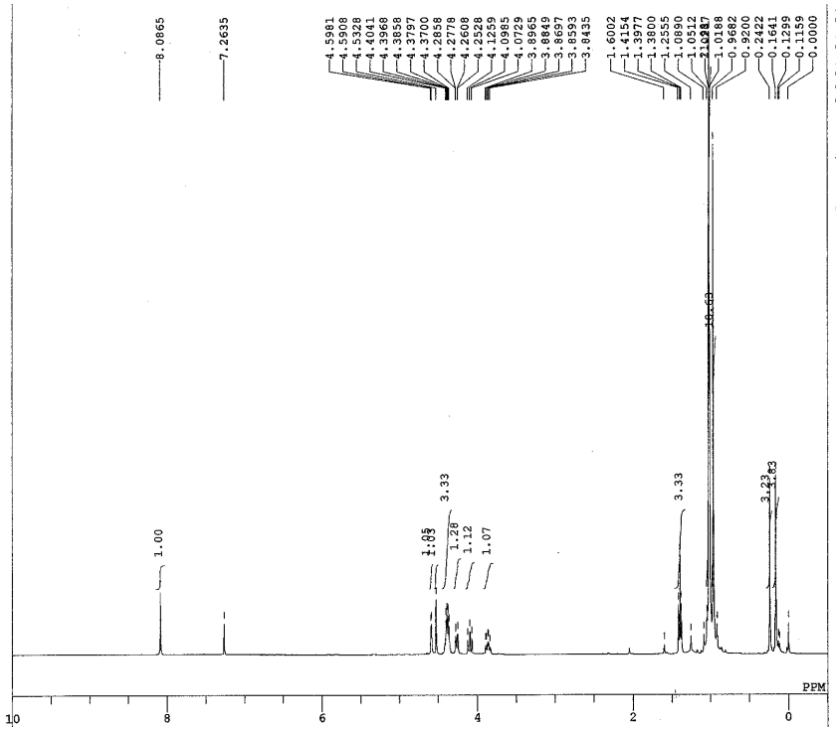


Fig. 20: ^{1}H NMR and ^{13}C NMR spectrum of compound **29** in $CDCl_3$



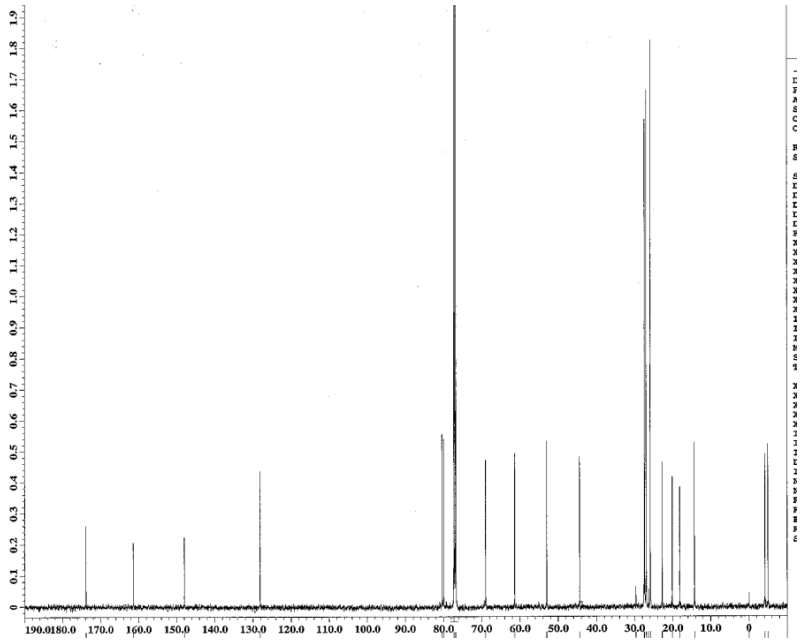
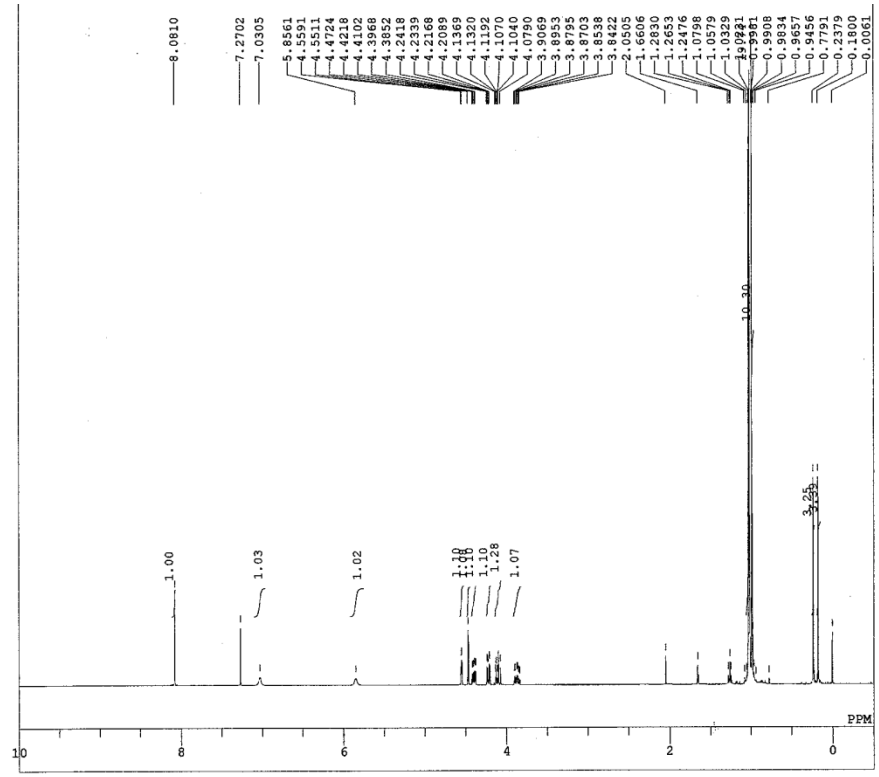


Fig. 21: ^{1}H NMR and ^{13}C NMR spectrum of compound **30** in $CDCl_3$



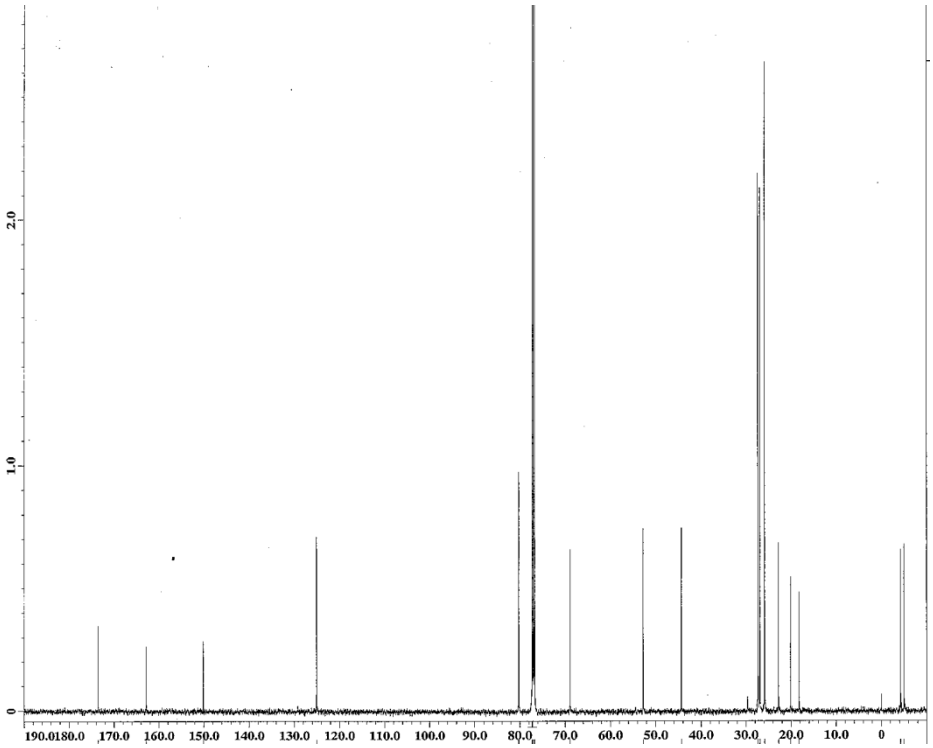


Fig. 22: ^{1}H NMR and ^{13}C NMR spectrum of compound **31** in CD_3OD