A NEW IMPROVED STRATEGY FOR THE SYNTHESIS OF THE DINUCLEOTIDE pdCpA: AN EFFICIENT METHOD FOR THE DEPROTECTION OF CYANOETHYL, TBDPS, AND BENZOYL GROUPS IN ONE-STEP AT HIGH PRESSURE

Masanori Kataoka,[1]* Chiharu Fukui,[1] Akiko Mimoto,[1] Hideaki Kuge,[2] Koichi Honke,[2] and Hiyoshizo Kotsuki[3]*

[1]*Oceanography Section, Science Research Center, Kochi University, Akebono-cho, Kochi 780-8520, Japan*
m.kataoka@kochi-u.ac.jp

[2]*Department of Biochemistry, Kochi University Medical School, Nankoku, Kochi 783-8505, Japan*

[3]*Laboratory of Natural Products Chemistry, Faculty of Science, Kochi University, Akebono-cho, Kochi 780-8520, Japan*
kotsuki@kochi-u.ac.jp

Table of Contents

General.

UV spectra were taken in MeOH on a Nanodrop ND-1000 spectrometer. FTIR spectra were measured in KBr on a JASCO FT/IR-6200 spectrometer. NMR spectra were obtained in CD_3OD or D_2O on a JEOL ECA-500 instrument. ^1H NMR chemical shifts are described as δ values in ppm relative to TMS. ^{31}P NMR chemical shifts are reported as δ values in ppm downfield from 85% H_3PO_4. High-performance liquid chromatography (HPLC) using a Waters BEH C18 column (ODS-1.7 μm, ø2.1 mm x 50 mm, 260 nm) was carried out on a Waters ACQUITY UPLC with a PDA eλ photodiode array absorption detector. Matrix-Assisted-Laser-Desorption/ionization-Time-of-flight (MALDI-TOF) mass analysis was achieved on an AB-SCIEX MALDI-TOF/TOF5800 (3-hydroxypicolinic acid/ammonium citrate or 2,5-dihydroxy benzoic acid were used as a matrix). Automated chromatograph system using High-Flush column (30 μm silica gel) or Prif-Pack column (30 μm ODS) carried out on Yamazen YFLC AI-580 or Shoko Scientific Purif-compact. Unless otherwise noted, all reactions were carried out at 25 °C. Powdery molecular sieves 4A (MS 4A) were used after drying the commercially supplied one (Nacalai Tesque) at 200 °C for 12 h in vacuo. Organic solvents and reagents were used as the commercially supplied ones.

Reagents.

Imidazole (Nacalai Tesque), *N*4-(benzoyl)-5'-*O*-(*p*,*p*'-dimethoxytrityl)-2'-deoxycytidine 3'-(2-cyanoethyl-*N*,*N*-diisopropylphosphoramidite) (**3**) (Glen Research, 96% purity), *N*7-benzoyladenosine (Carbosynth, 99% purity), trichloroacetic acid (Katayama Chemical, 99% purity), 2-butanone peroxide (Sigma-Aldrich, ~31 wt% in 2,2,4-trimethyl-1,3-pentanediol diisobutyrate), bis(trimethylsilyl) peroxide (Gelest, Inc.), bis(cyanoethyl)-phosphoramidite (Toront Research Chemicals Inc., 98.0% purity). Anhydrous DMF (Sigma-Aldrich, 99.8%), CH_2Cl_2 (Kanto Kagaku, 99.5%), AcOEt (Junsei Chemical Co., 99.0%), MeOH (Nacalai Tesque, 99.0% purity), *n*-hexane (Nacalai Tesque, 99.0% purity), MeCN (Nacalai Tesque, 99.0% purity), 1,4-dioxane (Nacalai Tesque, 98.0%), and *n*-Bu_4NOH (Merck, 20% solution in H_2O) were purchased and used as received.

Analytical TLC was preformed on Silica Gel 60 F_{254} and Silica Gel 60 RP-18 F_{254}s (Merck).

2',3'-*O*-Di(*t*-butyldimethylsilyl)-*N*6-benzoyladenosine (**2**),[1] and benzimidazolium triflate[2] were prepared according to the literature procedures.

Preparation of 2-cyanoethyl [*N*4-(benzoyl-2'-deoxycytidylyl)(3'-5')[2',3'-*O*-di(*t*-butyl-dimethylsilyl)-*N*6-benzoyladenosine] (4).

Method A: A mixture of 2',3'-*O*-di(*t*-butyldimethylsilyl)-*N*6-benzoyladenosine (**2**, 1.8 g, 3.0 mmol), 2'-deoxycitidine phosphoramidite (**3**, 3.0 g, 3.6 mmol), and MS 4A (260 mg) in dry CH_2Cl_2 (9 mL) was stirred at 25 °C for 1 h. Then benzimidazolium triflate (1.2 g, 4.5 mmol) was added, and the mixture was stirred for an additional 2 h. After that, 2-butanone peroxide solution (31 wt% in 2,2,4-trimethyl-1,3-pentanediol diisobutyrate, 1.0 mL, 1.6 mmol) was added, and stirring was continued for 30 min. An insoluble substance formed was removed by filtration through Celite, and the mother liquor was diluted with CH_2Cl_2 (15 mL), which was treated with 3% CCl_3CO_2H in CH_2Cl_2 (100 mL), and stirring was continued for 10 min at ambient temperature. The resulting mixture was poured into satd $NaHCO_3$ (600 mL) with vigorous stirring, followed by separation, dried (Na_2SO_4), and concd to give the crude dinucleotide **4** as a glassy oil. The crude product was subjected to filter on 40 μm silica gel (120 g, eluted with AcOEt / MeOH = 100 : 0 → 70 : 30), then the eluent was concd and purified by reverse-phase chromatography on preparative LC system (30 μm ODS, 120 g, Shoko Scientific Co. Ltd., eluted with distilled H_2O / MeOH = 15 : 85 → 0 : 100) to give the protected dCpA **4** (2.4 g, 75% yield) as an amorphous solid.

Method B: A mixture of 2',3'-*O*-di(*t*-butyldimethylsilyl)-*N*6-benzoyladenosine (**2**, 1.8 g, 3.0 mmol), 2'-deoxycitidine phosphoramidite (**3**, 3.0 g, 3.6 mmol), and MS 4A (260 mg) in dry CH_2Cl_2 (9 mL) was stirred at 25 °C for 1 h. Then benzimidazolium triflate (1.2 g, 4.5 mmol) was added, and the mixture was stirred for an additional 2 h. After that bis(trimetylsilyl) peroxide (2.7g, 15 mmol) was added, and stirring was continued for 1 h. An insoluble substance formed was removed by filtration through Celite and the mother liquor was concd. The residue was then treated with 3% CCl_3CO_2H in CH_2Cl_2 (100 mL), and stirring was continued for 10 min at ambient temperature. The resulting mixture was poured into satd $NaHCO_3$ (600 mL) with vigorous stirring, followed by separation, dried (Na_2SO_4), and concd to give the crude dinucleotide **4** as a glassy oil. The crude product was subjected to filter on 40 μm silica gel (120 g, eluted with AcOEt / MeOH = 100 : 0 → 70 : 30), then the eluent was concd and purified by reverse-phase chromatography on preparative LC system (30 μm ODS, 120 g, Shoko Scientific Co. Ltd.) (eluted with double-distilled H_2O / MeOH = 15 : 85 → 0 : 100) to give the protected dCpA **4** (1.4 g, 44% yield) as an amorphous solid.

Compound 4: FTIR (KBr) ν 3410, 1697, 1660, 1614, 1581, 1486, 1402 cm^{-1}; UV (MeOH) λ_{max} 260 nm (ε 54,600); ^1H NMR (500 MHz, $CDCl_3$) δ 9.23–9.12 (1H, br s), 8.79 (1H, s), 8.83–8.71 (1H, br s), 8.36, 8.29 (1H, two singlets), 8.27–8.21 (1H, two doublets, *J* = 6.3 and 6.9 Hz), 8.06 (2H, two doublets, *J* = 6.9 and 7.5 Hz), 7.88 (2H, d, *J* = 6.9 Hz), 7.60 (2H, dd, *J* = 6.9 and 8.0 Hz), 7.53–7.49 (5H, m), 6.21, 6.20 (1H, two triplets, *J* = 6.7 and 6.7 Hz), 6.02,

6.01 (1H, two doublets, J = 2.3 and 4.0 Hz), 5.19–5.13, 5.02–4.97 (1H, two multiplets), 4.89, 4.81 (1H, two triplets, J = 2.3 and 4.0 Hz), 4.59–4.37 (2H, m), 4.36–4.18 (5H, m), 3.89–3.82 (2H, m), 3.81–3.78, 3.63–3.56 (1H, two broad singlets), 2.83–2.66 (1H, m), 2.78 (2H, t, J = 6.0 Hz), 2.49, 2.32 (1H, two ddd, J = 6.7, 6.7, 6.7, 6.7, 6.7, and 6.7 Hz), 0.94, 0.93 (9H, two singlets), 0.89, 0.84 (9H, two singlets), 0.14, 0.12 (3H, two singlets), 0.12, 0.10 (3H, two singlets), 0.08, 0.03 (3H, two singlets), and 0.02, –0.11 (3H, two singlets); ^{31}P NMR (202.5 MHz, $CDCl_3$): δ –1.75, –1.10; MALDI-TOF/MS calcd for $C_{48}H_{64}N_9O_{12}PSi_2$ $[M + H]^+$ m/z 1046.40, found m/z 1046.66.

Preparation of 2-cyanoethyl [5'-di(2-cyanoethyl)phosphoryl-*N*4-(benzoyl-2'-deoxy-cytidylyl)(3'-5')[2',3'-*O*-di(*t*-butyldimethylsilyl)-*N*6-benzoyladenosine] (5).

Method A: A mixture of the protected dCpA **4** (1.8g, 1.7 mmol), bis(2-cyanoethyl)-*N*,*N*-diisopropylphosphoramidite **2** (680 mg, 2.5 mmol), and MS 4A (260 mg) in dry CH_2Cl_2 (3.4 mL) was stirred at 25 °C for 1 h. To this mixture was added benzimidazolium triflate (900 mg, 3.4 mmol), and the mixture was stirred for an additional 1 h. Then 2-butanone peroxide solution (31 wt% in 2,2,4-trimethyl-1,3-pentanediol diisobutyrate, 600 μL, 890 μmol) was added, and the mixture was stirred for 30 min. An insoluble substance formed was removed by filtration through Celite, and the solution was concd. The crude product was purified on silica gel (120 g), and subjected to column chromatography on 30 μm ODS (120 g, eluted with double-distilled H_2O / MeOH = 15 : 85 → 0 : 100) to give the protected pdCpA **4** (1.9 g, 90% yield) as an amorphous solid.

Method B: A mixture of the protected dCpA **4** (1.2 g, 1.2 mmol), bis(2-cyanoethyl)-*N*,*N*-diisopropylphosphoramidite **2** (500 mg, 1.8 mmol), and MS 4A (260 mg) in dry CH_2Cl_2 (3.6 mL) was stirred at 25 °C for 1 h. To this mixture was added benzimidazolium triflate (640 mg, 2.4 mmol), and the mixture was stirred for an additional 1 h. Then bis(trimetylsilyl) peroxide (1.1 g, 5.9 mmol) was added, and the mixture was stirred for 1 h. An insoluble substance formed was removed by filtration through Celite, and the solution was concd. The crude product was purified on silica gel (120 g), and subjected to column chromatography on 30 μm ODS (120 g, eluted with double-distilled H_2O / MeOH = 15 : 85 → 0 : 100) to give the protected pdCpA **4** (1.1 g, 74% yield) as an amorphous solid.

Compound 5: FTIR (KBr) ν 1698, 1668, 1615, 1577, 1487, 1405 cm^{-1}; UV (MeOH) λ_{max} 260 nm (ε 40,200); ^{1}H NMR (500 MHz, $CDCl_3$) δ 9.38–9.32, 9.36–9.30 (1H, two broad singlets), 8.83–8.66 (1H, br s), 8.80, 8.79 (1H, two singlets), 8.32, 8.29 (1H, two singlets), 8.05 (2H, d, J = 7.5), 8.06, 7.96 (1H, two doublets, J = 6.9 and 7.5 Hz), 7.88 (2H, d, J = 7.5 Hz), 7.62–7.46 (7H, m), 6.22, 6.18 (1H, two triplets, J = 7.0 and 7.3 Hz), 6.02, 6.01 (1H, two doublets, J = 2.9 and 3.4 Hz), 5.14–5.09, 5.08–5.03 (1H, two multiplets), 4.89, 4.84 (1H, two triplets, J = 2.9 and 3.4 Hz), 4.52-4.08 (13H, m), 2.88-2.68 (7H, m), 2.26, 2.20 (1H, two ddd,

J = 7.0, 7.0, 7.0, 7.3, 7.3, and 7.3 Hz), 0.94 (9H, s), 0.86, 0.84 (9H, two singlets), 0.14 (3H, s), 0.12 (3H, s), 0.04, 0.03 (3H, two singlets), –0.08, –0.12 (3H, two singlets); ^{31}P NMR (202.5 MHz, $CDCl_3$) δ –1.59, –1.14, –1.70 –1.75; MALDI-TOF/MS calcd for $C_{54}H_{72}N_{11}O_{15}P_2Si_2$ [M + H]$^+$ m/z 1232.42, found m/z 1232.76.

Preparation of (5'-phosphoryldeoxycytidylyl)(3'-5')(adenosine) (1).

Method A: To a solution of the protected pdCpA **5** (57 mg, 46 μmol) in MeOH (750 μL) and 1,4-dioxane (110 μL) was added 28% aq NH_4OH (900 μL), and the mixture was transferred to a Teflon reaction vessel and kept at 0.8 GPa and 25 °C for 14 h. After concentration, the crude product was subjected to reverse-phase short-column chromatography on 30 μm ODS (30 g) eluted with a mixture of double-distilled H_2O and MeCN (0 : 100 → 95 : 5) to provide the ammonium salt of pdCpA **1** as an amorphous solid (19 mg, 60% yield).

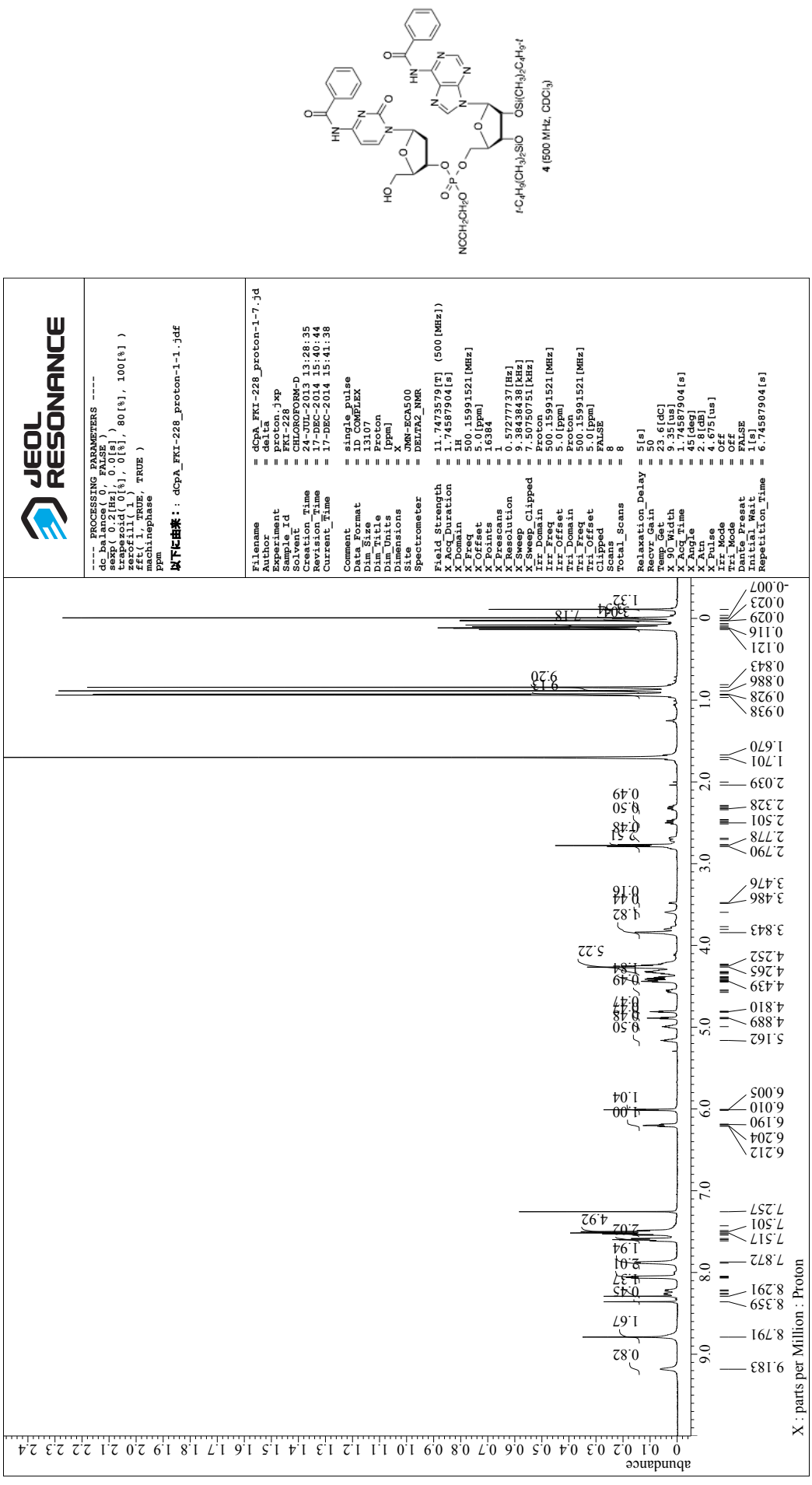
Method B: To a solution of the protected pdCpA **5** (370 mg, 300 μmol) in MeOH (3.7 mL), 1,4-dioxane (540 μL), and double-distilled H_2O (1.8 mL) was added 20% aq n-Bu_4NOH (2.5 mL, 1.8 mmol), and the mixture was transferred to a Teflon reaction vessel and kept at 0.8 GPa and 25 °C for 14 h. After dilution by addition of double-distilled H_2O, the mixture was subjected to gel filtration on Sephadex G-10 (480 mL, eluted with double-distilled H_2O / MeOH = 80 : 20) to give the tetra-n-butylammonium salt of pdCpA **1** (480 mg, 97% yield estimated by OD_{260}) as an amorphous solid.

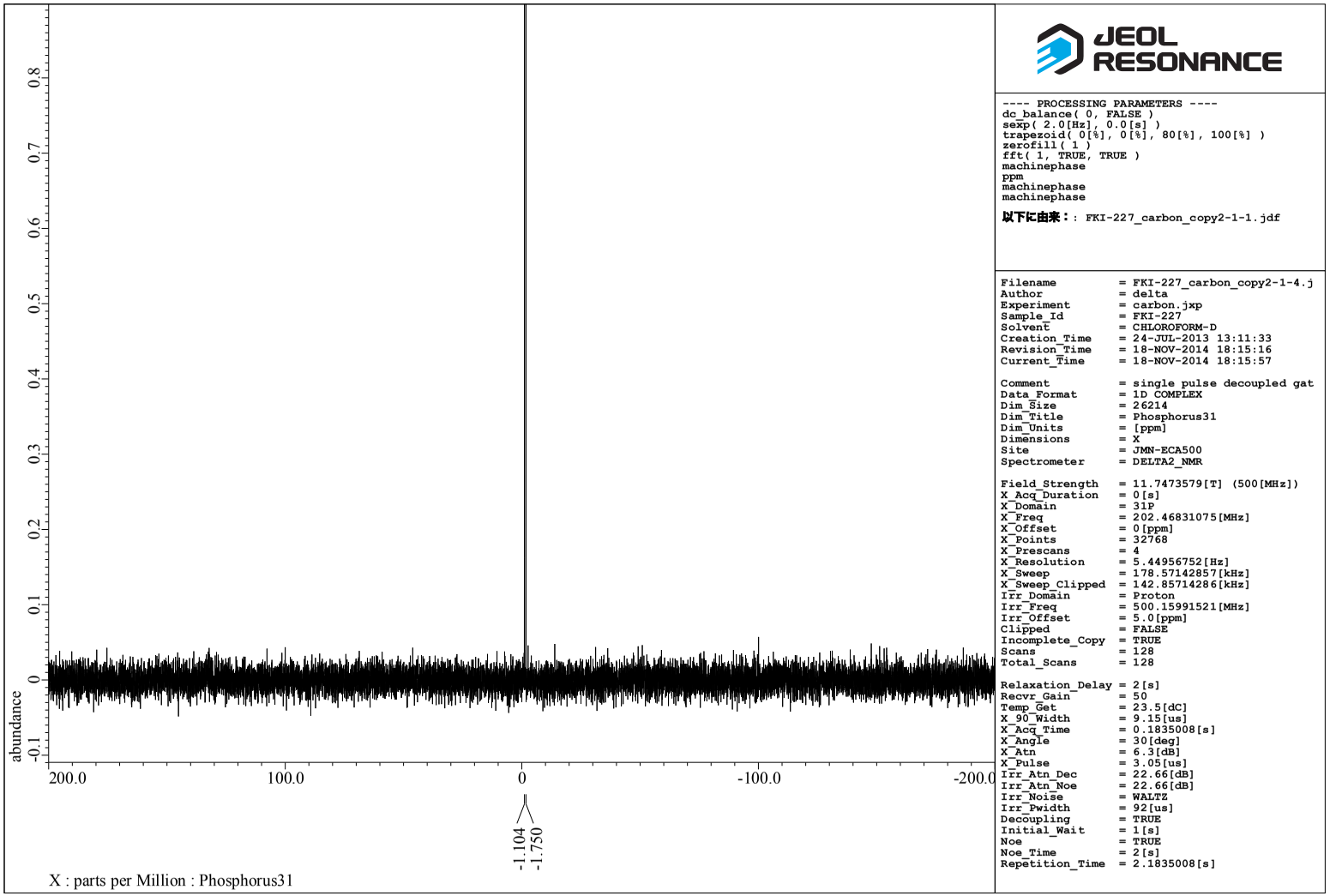
Compound 1 (as its tetra-n-butylammonium salt): FTIR (KBr) ν 1653, 1604, 1576, 1488, 1378 cm^{-1}; UV (MeOH) λ_{max} 260 nm (ε 23,800); ^{1}H NMR (500 MHz, CD_3OD) δ 8.62 (1H, s), 8.17 (1H, s), 8.10 (1H, d, J = 7.5 Hz), 6.41 (1H, dd, J = 5.4, 8.3 Hz), 6.11 (1H, d, J = 6.3 Hz), 5.94 (1H, d, J = 7.5 Hz), 4.98–4.92 (1H, m), 4.72 (1H, dd, J = 6.0 and 6.9 Hz), 4.59–4.54 (1H, m), 4.32–4.28 (1H, m), 4.26–4.22 (1H, m), 4.13–3.97 (4H, m), 3.62 (1H, t, J = 6.9 Hz), 3.26–3.14 (24H, m), 2.65–2.56 (1H, m), 2.40 (1H, t, J = 7.2 Hz), 2.28–2.19 (1H, m), 1.69–1.59 (24H, m, TBA), 1.40 (24H, sexted, J = 7.5 Hz), 1.01 (36H, t, J = 7.5 Hz); ^{31}P NMR (202.5 MHz, CD_3OD) δ 4.28, –0.46; MALDI-TOF/MS calcd for $C_{19}H_{27}N_8O_{13}P_2$ [M + H]$^+$ m/z 637.12, found m/z 637.52.

References

[1] Zhu, X.-F.; Williams, H. J.; Scott, A. I. *J. Chem. Soc., Perkin Trans. 1* **2000**, 2305.

[2] Hayakawa, Y.; Kataoka, M.; Noyori, R. *J. Org. Chem.* **1996**, *61*, 7996.


JEOL RESONANCE
---- PROCESSING PARAMETERS ----
dc_balance(0, FALSE)
sexp(0.2[Hz], 0.0[s])
trapezoid(0[%], 0[%], 80[%], 100[%])
zerofill(1)
fft(1, TRUE, TRUE)
machinephase
ppm
以下化合物：: dCpA_FKI-228_proton-1-1.jdf
Filename = dCpA_FKI-228_proton-1-7.jd
Author = delta
Experiment = proton.jxp
Sample_Id = FKI-228
Solvent = CHLOROFORM-D
Creation_Time = 24-JUL-2013 13:28:35
Revision_Time = 17-DEC-2014 15:40:44
Current_Time = 17-DEC-2014 15:41:38
Comment = single_pulse
Data_Format = 1D COMPLEX
Dim_Size = 13107
Dim_Title = Proton
Dim_Units = [ppm]
Dimensions = X
Site = JMN-ECA500
Spectrometer = DELTA2_NMR
Field_Strength = 11.7473579[T] (500[MHz])
X_Acq_Duration = 1.74587904[s]
X_Domain = H
X_Freq = 500.15991521[MHz]
X_Offset = 5.0[ppm]
X_Points = 16384
X_Prescans = 1
X_Resolution = 0.57277737[Hz]
X_Sweep = 9.38438438[kHz]
X_Sweep_Clipped = 7.50750751[kHz]
Irr_Domain = Proton
Irr_Freq = 500.15991521[MHz]
Irr_Offset = 5.0[ppm]
Tri_Domain = Proton
Tri_Freq = 500.15991521[MHz]
Tri_Offset = 5.0[ppm]
Clipped = FALSE
Scans = 8
Total_Scans = 8
Relaxation_Delay = 5[s]
Recvr_Gain = 50
Temp_Get = 23.6[dC]
X_90_Width = 9.35[us]
X_Acq_Time = 1.74587904[s]
X_Angle = 45[deg]
X_Atn = 2.8[dB]
X_Pulse = 4.675[us]
Irr_Mode = Off
Tri_Mode = Off
Decpl_Presat = FALSE
Initial_Wait = 1[s]
Repetition_Time = 6.74587904[s]
4 (500 MHz, CDCl3)
abundance
X : parts per Million : Proton

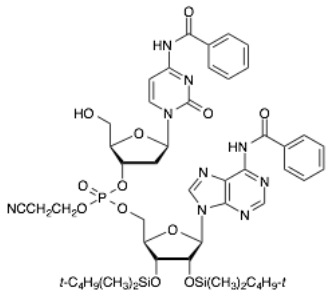


JEOL RESONANCE

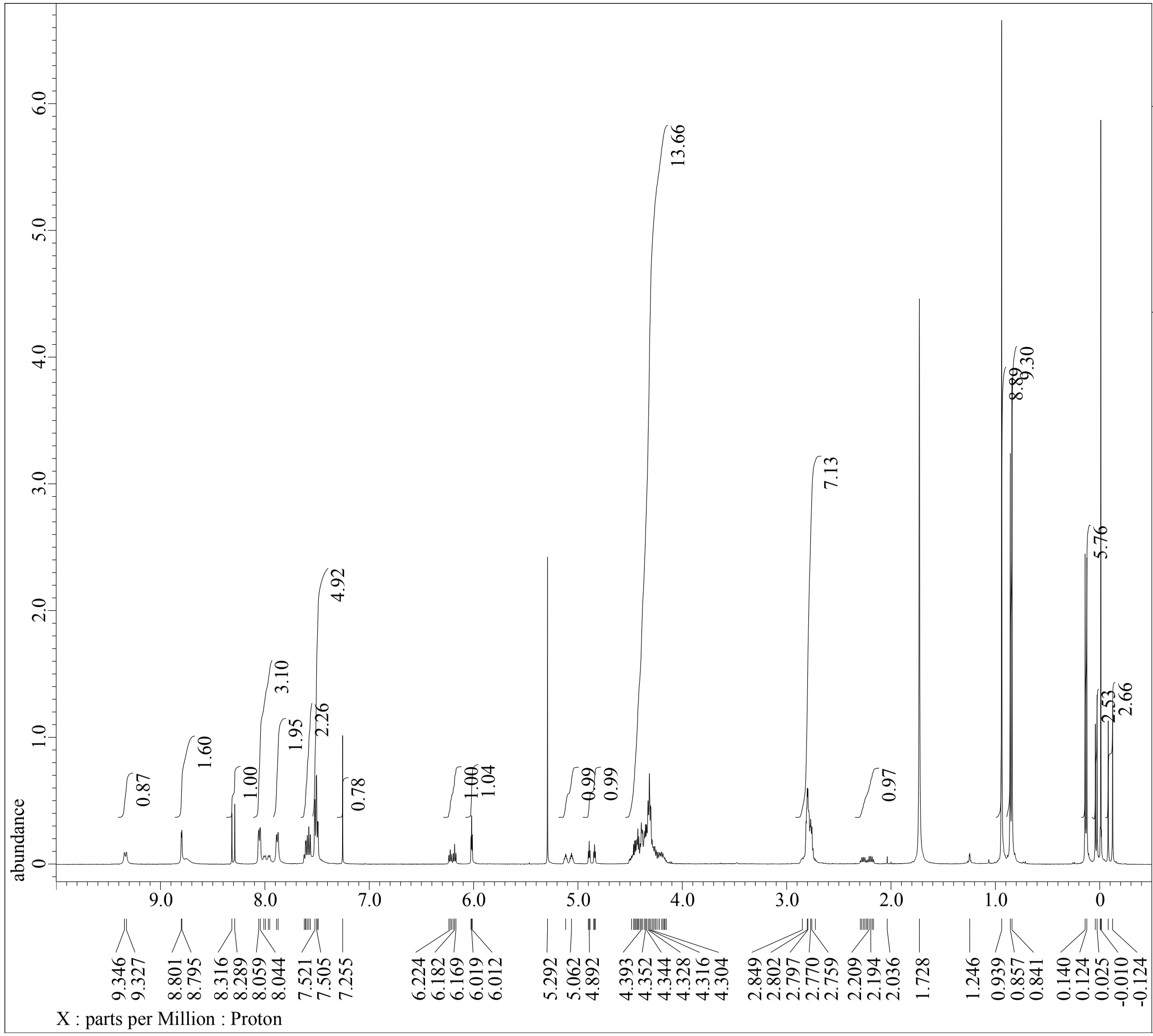
```
---- PROCESSING PARAMETERS ----
dc_balance( 0, FALSE )
sexp( 2.0[Hz], 0.0[s] )
trapezoid( 0[%], 0[%], 80[%], 100[%] )
zerofill( 1 )
fft( 1, TRUE, TRUE )
machinephase
ppm
machinephase
machinephase
```

以下に由来：: FKI-227_carbon_copy2-1-1.jdf

```
Filename          = FKI-227_carbon_copy2-1-4.j
Author            = delta
Experiment        = carbon.jxp
Sample_Id         = FKI-227
Solvent           = CHLOROFORM-D
Creation_Time     = 24-JUL-2013 13:11:33
Revision_Time     = 18-NOV-2014 18:15:16
Current_Time      = 18-NOV-2014 18:15:57

Comment           = single pulse decoupled gat
Data_Format       = 1D COMPLEX
Dim_Size          = 26214
Dim_Title         = Phosphorus31
Dim_Units         = [ppm]
Dimensions        = X
Site              = JMN-ECA500
Spectrometer      = DELTA2_NMR

Field_Strength    = 11.7473579[T] (500[MHz])
X_Acq_Duration    = 0[s]
X_Domain          = 31P
X_Freq            = 202.46831075[MHz]
X_Offset          = 0[ppm]
X_Points          = 32768
X_Prescans        = 4
X_Resolution      = 5.44956752[Hz]
X_Sweep           = 178.57142857[kHz]
X_Sweep_Clipped   = 142.85714286[kHz]
Irr_Domain        = Proton
Irr_Freq          = 500.15991521[MHz]
Irr_Offset        = 5.0[ppm]
Clipped           = FALSE
Incomplete_Copy   = TRUE
Scans             = 128
Total_Scans       = 128

Relaxation_Delay  = 2[s]
Recvr_Gain        = 50
Temp_Get          = 23.5[dC]
X_90_Width        = 9.15[us]
X_Acq_Time        = 0.1835008[s]
X_Angle           = 30[deg]
X_Atn             = 6.3[dB]
X_Pulse           = 3.05[us]
Irr_Atn_Dec       = 22.66[dB]
Irr_Atn_Noe       = 22.66[dB]
Irr_Noise         = WALTZ
Irr_Pwidth        = 92[us]
Decoupling        = TRUE
Initial_Wait      = 1[s]
Noe               = TRUE
Noe_Time          = 2[s]
Repetition_Time   = 2.1835008[s]
```



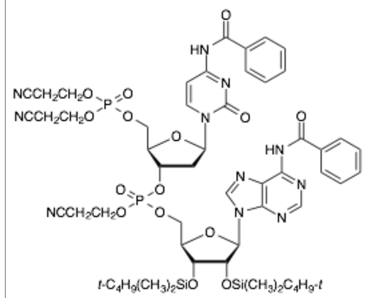
4 (202 MHz, $CDCl_3$)



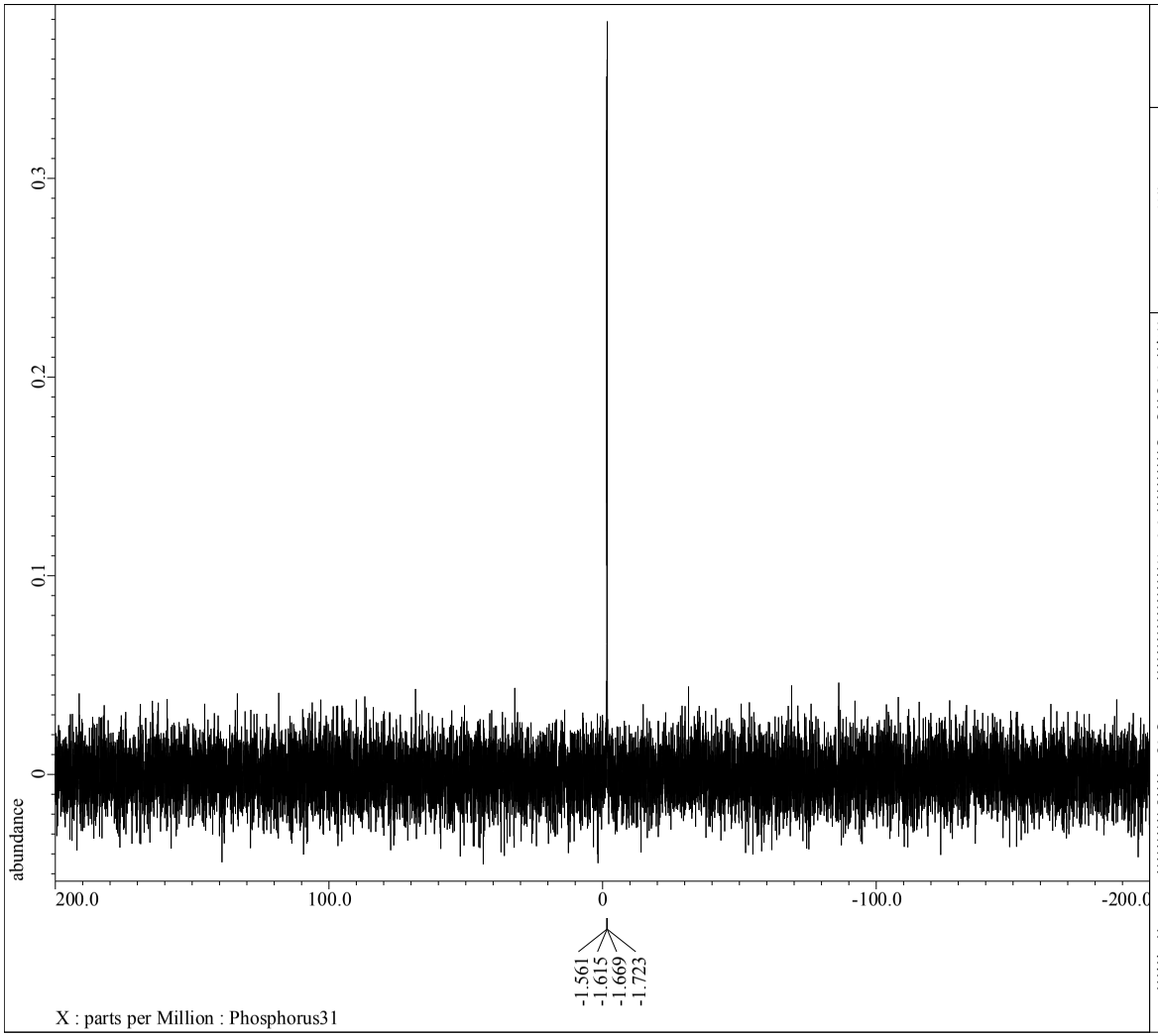
JEOL RESONANCE

```
---- PROCESSING PARAMETERS ----
dc_balance( 0, FALSE )
sexp( 0.2[Hz], 0.0[s] )
trapezoid( 0[%], 0[%], 80[%], 100[%] )
zerofill( 1 )
fft( 1, TRUE, TRUE )
machinephase
ppm
以下に由来：: Full-pdCpA_FKI-96-2_proton-1-1.jdf
```

```
Filename           = Full-pdCpA_FKI-96-2_proton
Author             = delta
Experiment         = proton.jxp
Sample_Id          = FKI-96-2
Solvent            = CHLOROFORM-D
Creation_Time      = 18-JUN-2012 16:25:46
Revision_Time      = 17-DEC-2014 15:53:59
Current_Time       = 17-DEC-2014 15:54:54

Comment            = single_pulse
Data_Format        = 1D COMPLEX
Dim_Size           = 13107
Dim_Title          = Proton
Dim_Units          = [ppm]
Dimensions         = X
Site               = JMN-ECA500
Spectrometer       = DELTA2_NMR

Field_Strength     = 11.7473579[T] (500[MHz])
X_Acq_Duration     = 1.74587904[s]
X_Domain           = 1H
X_Freq             = 500.15991521[MHz]
X_Offset           = 5.0[ppm]
X_Points           = 16384
X_Prescans         = 1
X_Resolution       = 0.57277737[Hz]
X_Sweep            = 9.38438438[kHz]
X_Sweep_Clipped    = 7.50750751[kHz]
Irr_Domain         = Proton
Irr_Freq           = 500.15991521[MHz]
Irr_Offset         = 5.0[ppm]
Tri_Domain         = Proton
Tri_Freq           = 500.15991521[MHz]
Tri_Offset         = 5.0[ppm]
Clipped            = FALSE
Scans              = 8
Total_Scans        = 8

Relaxation_Delay   = 5[s]
Recvr_Gain         = 50
Temp_Get           = 21.4[dC]
X_90_Width         = 9.35[us]
X_Acq_Time         = 1.74587904[s]
X_Angle            = 45[deg]
X_Atn              = 2.8[dB]
X_Pulse            = 4.675[us]
Irr_Mode           = Off
Tri_Mode           = Off
Dante_Presat       = FALSE
Initial_Wait       = 1[s]
Repetition_Time    = 6.74587904[s]
```



5 (500 MHz, $CDCl_3$)

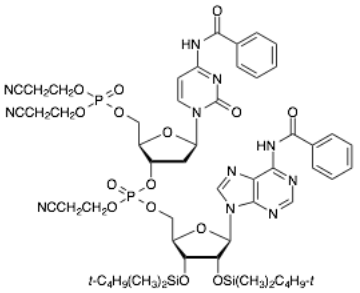


JEOL RESONANCE

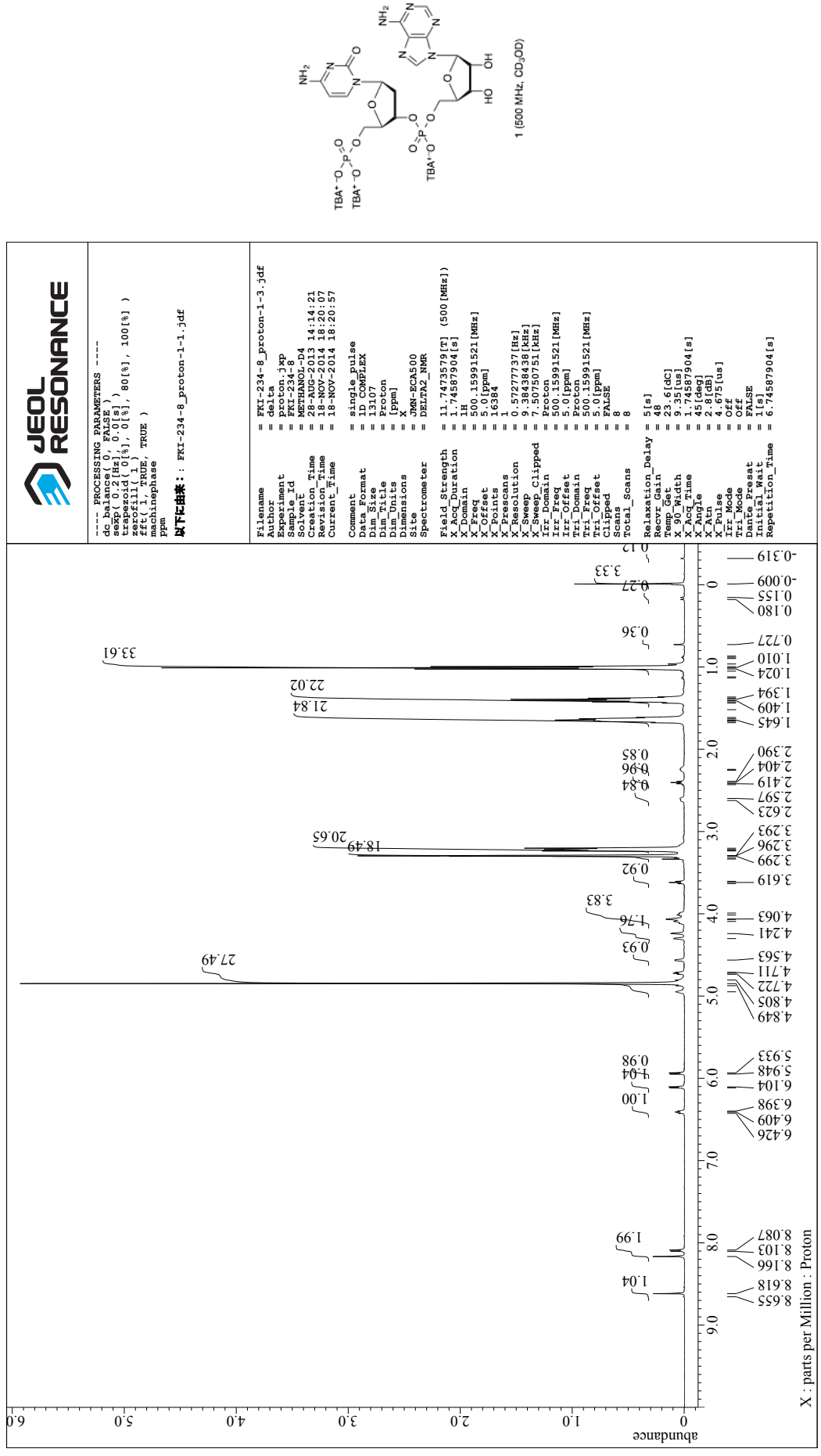
```
---- PROCESSING PARAMETERS ----
dc_balance( 0, FALSE )
sexp( 2.0[Hz], 0.0[s] )
trapezoid( 0[%], 0[%], 80[%], 100[%] )
zerofill( 1 )
fft( 1, TRUE, TRUE )
machinephase
ppm
```

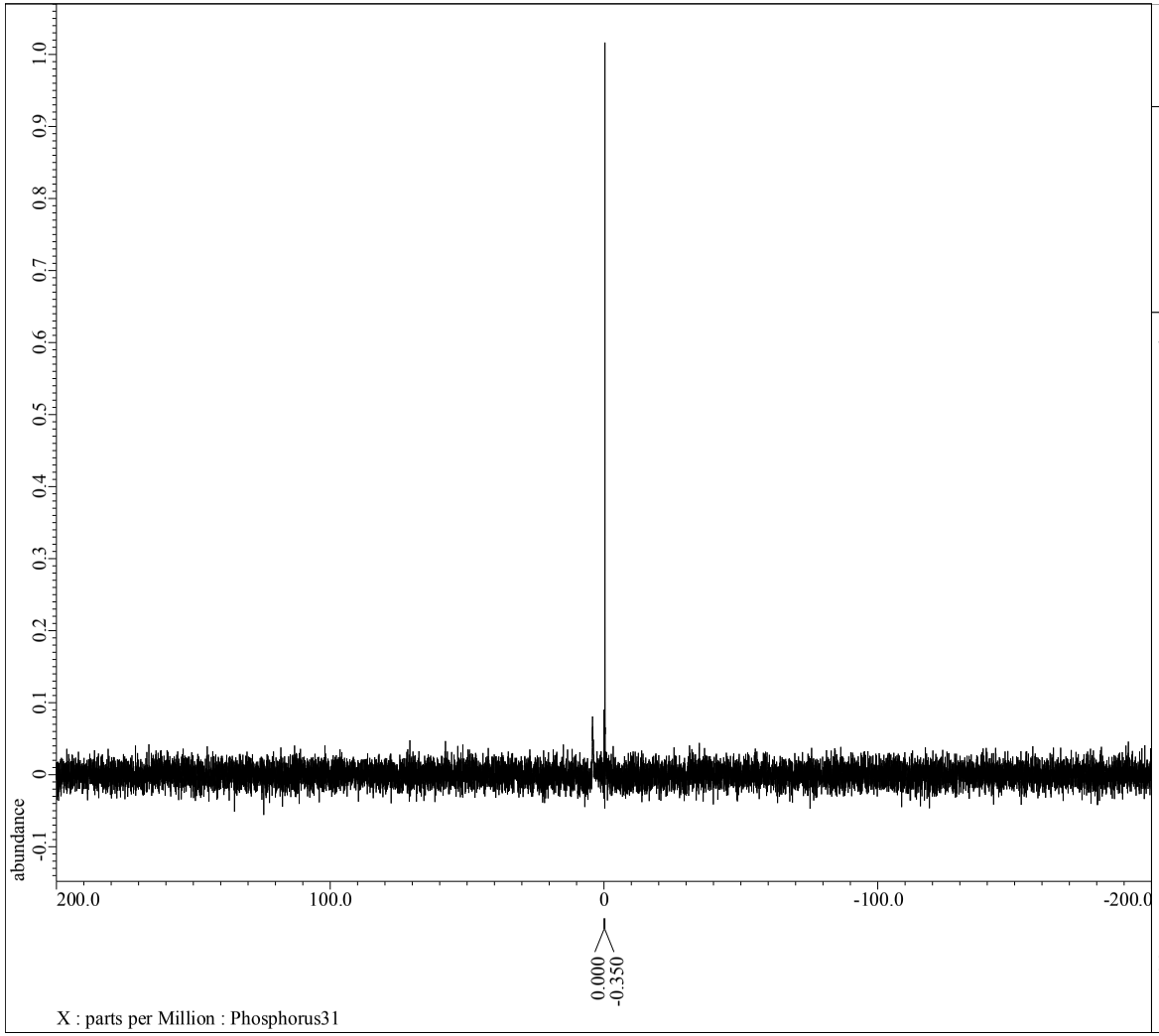
以下に由来：: FKI-344-345_carbon-1-1.jdf

```
Filename          = FKI-344-345_carbon-1-2.jdf
Author            = delta
Experiment        = carbon.jxp
Sample_Id         = FKI-344-355
Solvent           = CHLOROFORM-D
Creation_Time     =  9-OCT-2014 16:19:49
Revision_Time     = 18-NOV-2014 17:48:37
Current_Time      = 18-NOV-2014 17:49:24

Comment           = single pulse decoupled gat
Data_Format       = 1D COMPLEX
Dim_Size          = 26214
Dim_Title         = Phosphorus31
Dim_Units         = [ppm]
Dimensions        = X
Site              = JMN-ECA500
Spectrometer      = DELTA2_NMR

Field_Strength    = 11.7473579[T] (500[MHz])
X_Acq_Duration    = 0.1835008[s]
X_Domain          = 31P
X_Freq            = 202.46831075[MHz]
X_Offset          = 0[ppm]
X_Points          = 32768
X_Prescans        = 4
X_Resolution      = 5.44956752[Hz]
X_Sweep           = 178.57142857[kHz]
X_Sweep_Clipped   = 142.85714286[kHz]
Irr_Domain        = Proton
Irr_Freq          = 500.15991521[MHz]
Irr_Offset        = 5.0[ppm]
Clipped           = FALSE
Scans             = 128
Total_Scans       = 128

Relaxation_Delay  = 2[s]
Recvr_Gain        = 50
Temp_Get          = 23.1[dC]
X_90_Width        = 9.15[us]
X_Acq_Time        = 0.1835008[s]
X_Angle           = 30[deg]
X_Atn             = 6.3[dB]
X_Pulse           = 3.05[us]
Irr_Atn_Dec       = 22.66[dB]
Irr_Atn_Noe       = 22.66[dB]
Irr_Noise         = WALTZ
Irr_Pwidth        = 92[us]
Decoupling        = TRUE
Initial_Wait      = 1[s]
Noe               = TRUE
Noe_Time          = 2[s]
Repetition_Time   = 2.1835008[s]
```



5 (202 MHz, $CDCl_3$)


JEOL RESONANCE
---- PROCESSING PARAMETERS ----
do_baseline(0, FALSE)
segment(1, 0[s])
trapezoid(0[%], 0[%], 80[%], 100[%])
zerofill(1)
fft(1, TRUE, TRUE)
machinephase
ppm
以下化合物：: FKI-234-8_proton-1-1.jdf
Filename = FKI-234-8_proton-1-3.jdf
Author = delta
Experiment = pro-234-8
Sample_Id = FKI-234-8
Solvent = METHANOL-D4
Creation_Time = 28-AUG-2013 14:14:21
Revision_Time = 18-NOV-2014 18:20:07
Current_Time = 18-NOV-2014 18:20:57
Comment = single_pulse
Data_Format = 1D COMPLEX
Dim_Size = 13107
Dim_Title = Proton
Dim_Units = [ppm]
Dimensions = X
Site = JNM-ECA500
Spectrometer = DELTA2_NMR
Field_Strength = 11.74735579[T] (500[MHz])
X_Acq_Duration = 1.74587904[s]
X_Domain = 1H
X_Freq = 500.15991521[MHz]
X_Offset = 5.0[ppm]
X_Points = 16384
X_Prescans = 1
X_Resolution = 0.57277737[Hz]
X_Sweep = 9.38438438[kHz]
X_Sweep_Clipped = 7.50750751[kHz]
Irr_Domain = Proton
Irr_Freq = 500.15991521[MHz]
Irr_Offset = 5.0[ppm]
Tri_Domain = Proton
Tri_Freq = 500.15991521[MHz]
Tri_Offset = 5.0[ppm]
Clipped = FALSE
Scans = 8
Total_Scans = 8
Relaxation_Delay = 5[s]
Recvr_Gain = 48
Temp_Get = 23.6[dC]
X_90_Width = 9.35[us]
X_Acq_Time = 1.74587904[s]
X_Angle = 45[deg]
X_Atn = 2.8[dB]
X_Pulse = 4.675[us]
Tri_Mode = Off
Dante_Presat = FALSE
Initial_Wait = 1[s]
Repetition_Time = 6.74587904[s]
1 (500 MHz, CD3OD)
abundance
X : parts per Million : Proton

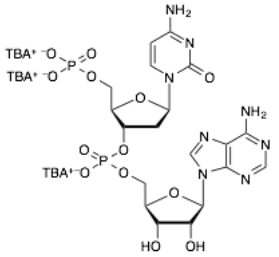


JEOL RESONANCE

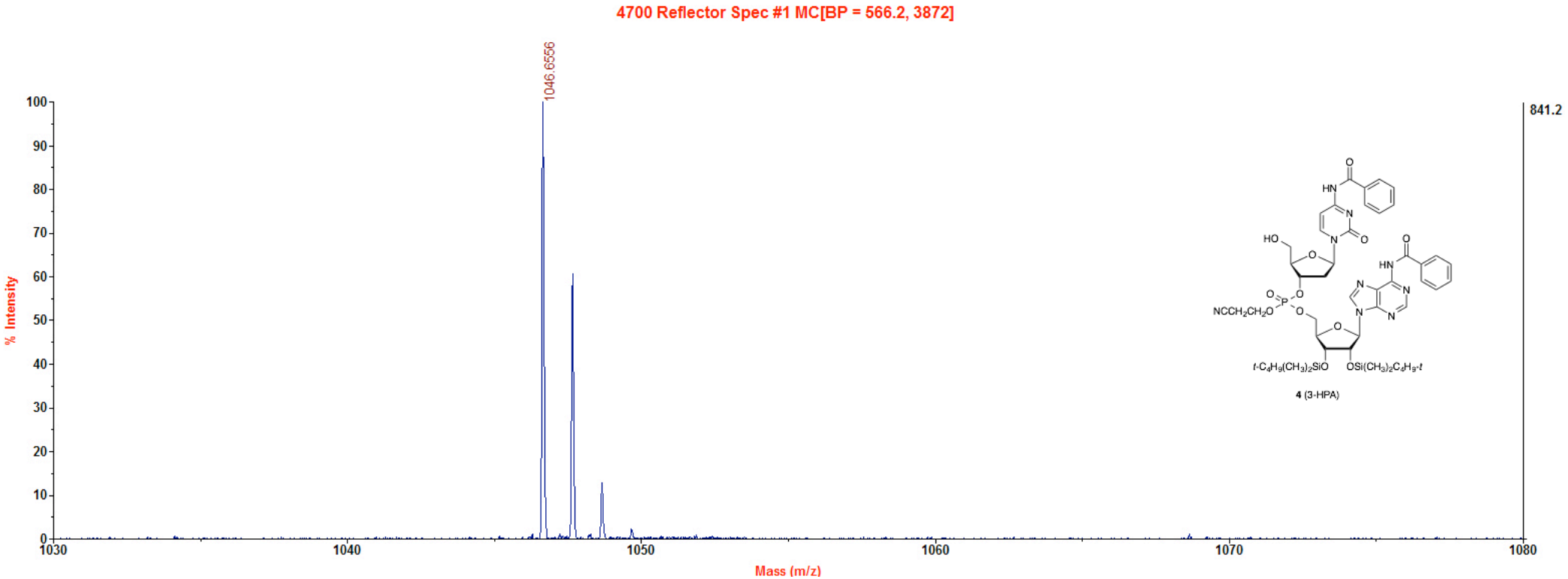
```
---- PROCESSING PARAMETERS ----
dc_balance( 0, FALSE )
sexp( 2.0[Hz], 0.0[s] )
trapezoid( 0[%], 0[%], 80[%], 100[%] )
zerofill( 1 )
fft( 1, TRUE, TRUE )
machinephase
ppm
machinephase
machinephase
machinephase
```

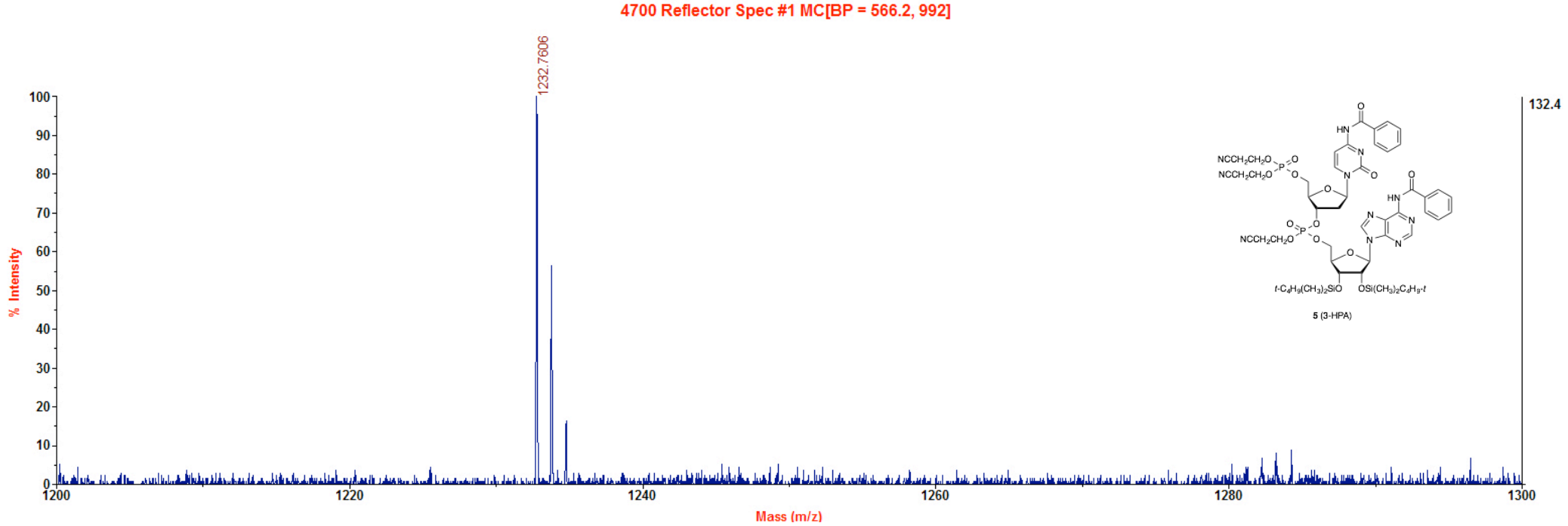
以下に由来：: FKI-234-8_carbon-1-1.jdf

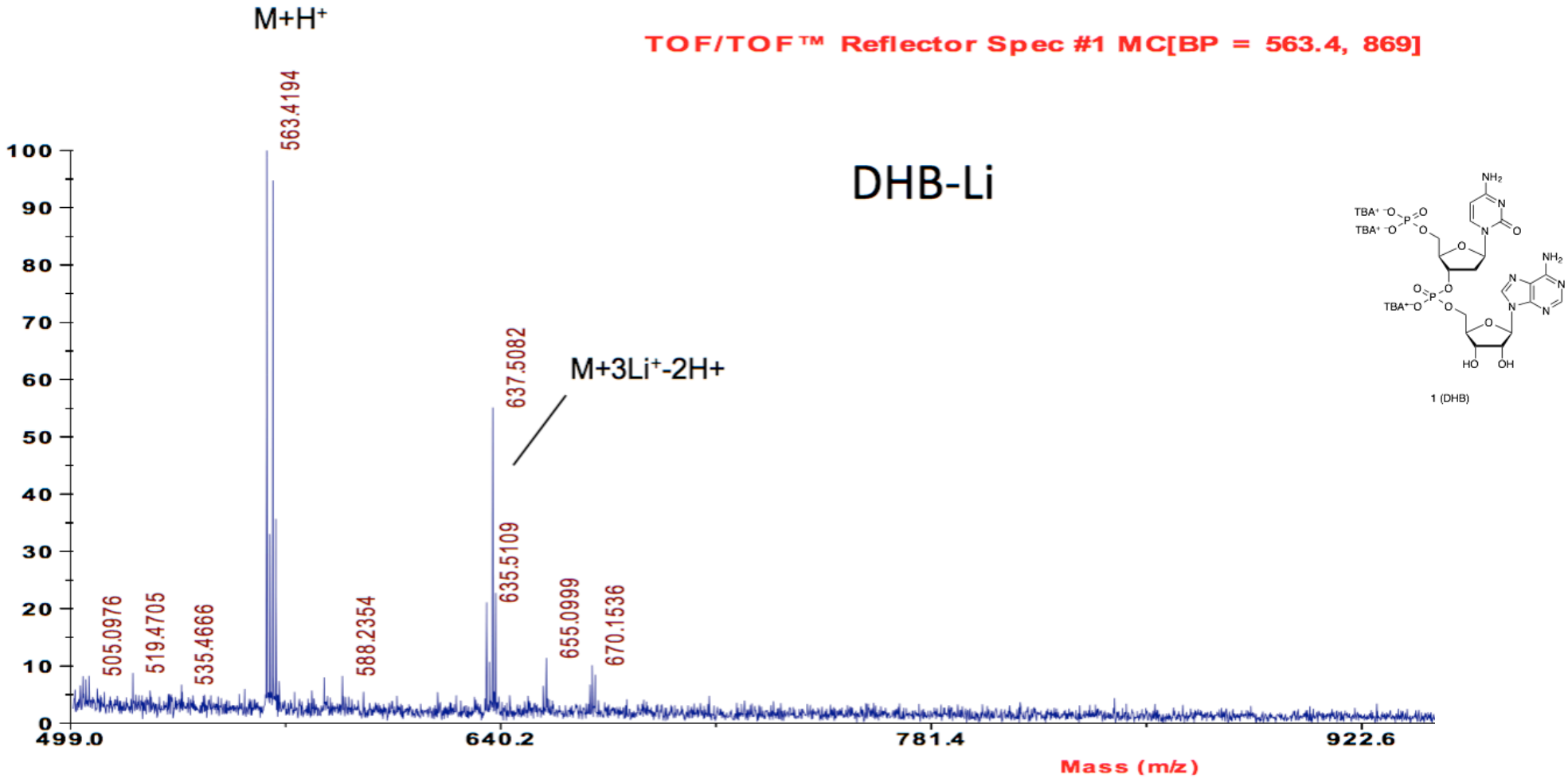
```
Filename          = FKI-234-8_carbon-1-6.jdf
Author            = delta
Experiment        = carbon.jxp
Sample_Id         = FKI-234-8
Solvent           = METHANOL-D4
Creation_Time     = 28-AUG-2013 14:19:19
Revision_Time     = 18-NOV-2014 18:21:36
Current_Time      = 18-NOV-2014 18:22:13

Comment           = single pulse decoupled gat
Data_Format       = 1D COMPLEX
Dim_Size          = 26214
Dim_Title         = Phosphorus31
Dim_Units         = [ppm]
Dimensions        = X
Site              = JMN-ECA500
Spectrometer      = DELTA2_NMR

Field_Strength    = 11.7473579[T] (500[MHz])
X_Acq_Duration    = 0.1835008[s]
X_Domain          = 31P
X_Freq            = 202.46831075[MHz]
X_Offset          = 0[ppm]
X_Points          = 32768
X_Prescans        = 4
X_Resolution      = 5.44956752[Hz]
X_Sweep           = 178.57142857[kHz]
X_Sweep_Clipped   = 142.85714286[kHz]
Irr_Domain        = Proton
Irr_Freq          = 500.15991521[MHz]
Irr_Offset        = 5.0[ppm]
Clipped           = FALSE
Scans             = 128
Total_Scans       = 128

Relaxation_Delay  = 2[s]
Recvr_Gain        = 50
Temp_Get          = 24.1[dC]
X_90_Width        = 9.15[us]
X_Acq_Time        = 0.1835008[s]
X_Angle           = 30[deg]
X_Atn             = 6.3[dB]
X_Pulse           = 3.05[us]
Irr_Atn_Dec       = 22.66[dB]
Irr_Atn_Noe       = 22.66[dB]
Irr_Noise         = WALTZ
Irr_Pwidth        = 92[us]
Decoupling        = TRUE
Initial_Wait      = 1[s]
Noe               = TRUE
Noe_Time          = 2[s]
Repetition_Time   = 2.1835008[s]
```



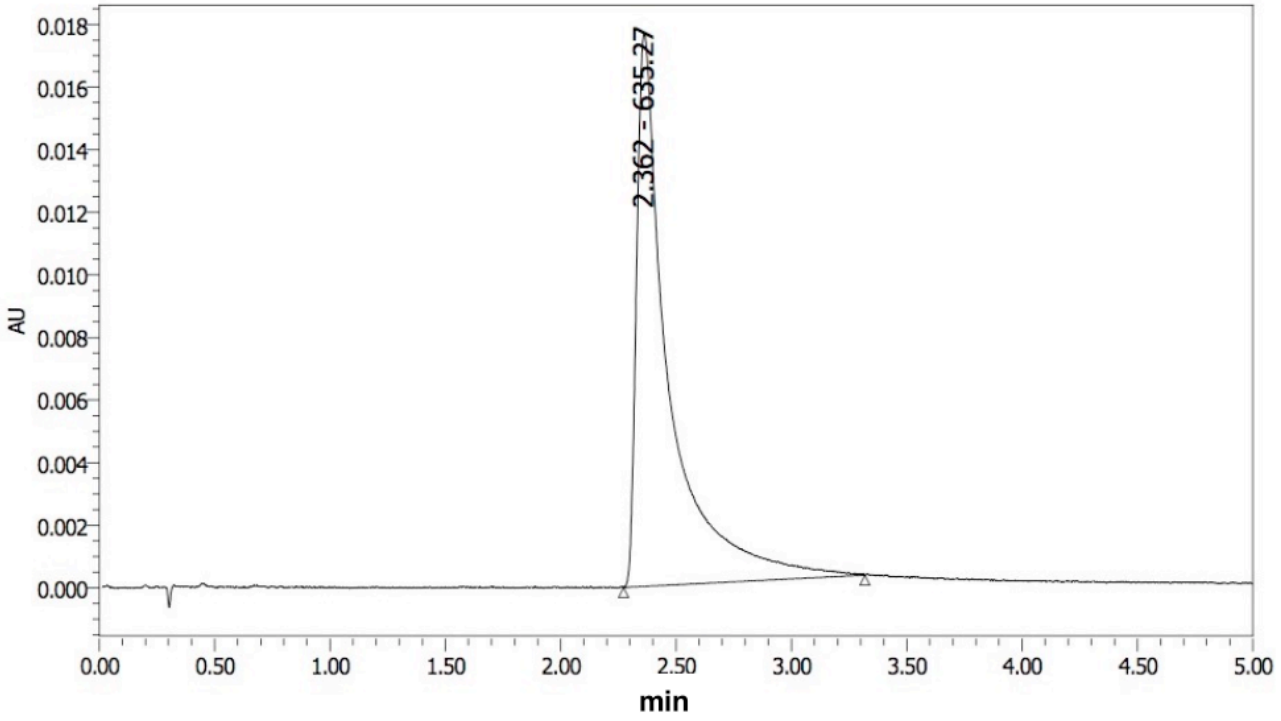
1 (202 MHz, CD_3OD)

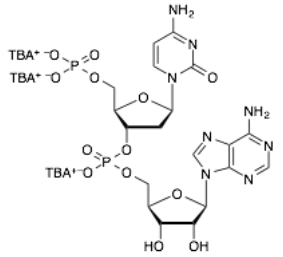

4700 Reflector Spec #1 MC[BP = 566.2, 3872]
1046.6556
841.2
% Intensity
Mass (m/z)
100
90
80
70
60
50
40
30
20
10
0
1030
1040
1050
1060
1070
1080
HO
HN
O
N
O
O
P
NCCH2CH2O
t-C4H9(CH3)2SiO
OSi(CH3)2C4H9-t
4 (3-HPA)


4700 Reflector Spec #1 MC[BP = 566.2, 992]
1232.7606
132.4
% Intensity
Mass (m/z)
100
90
80
70
60
50
40
30
20
10
0
1200
1220
1240
1260
1280
1300
5 (3-HPA)


M+H+
TOF/TOF™ Reflector Spec #1 MC[BP = 563.4, 869]
563.4194
DHB-Li
637.5082
M+3Li+-2H+
635.5109
655.0999
670.1536
505.0976
519.4705
535.4666
588.2354
100
90
80
70
60
50
40
30
20
10
0
499.0
640.2
781.4
922.6
Mass (m/z)
TBA+ -O
TBA+ -O
TBA+ -O
NH2
HO
OH
1 (DHB)

UV 260 nm





1 (1% HCOOH in acetonitrile—water)

PDA