Electronic Supporting Information

There is no universal mechanism for the cleavage of RNA model compounds in the presence of metal ion catalysts

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Calculation of rate constants for the uncatalysed cleavage of uridine 3'-alkyl esters

Rate constants for the uncatalysed cleavage were calculated using parameters reported by Kosonen *& al*.[1] (Kosonen;Yousefi-Salakdeh;Strömberg;& Lönnberg, 1998). Partial rate constants reported for the cleavage of uridine 3'-esters 4c, 4e, 4g and 4h allowed calculation of β_{LG} values for these processes. Using β_{LG} values obtained and known pK_a values[2] for the leaving group alcohols, partial rate constants for the cleavage of other corresponding alkyl esters were calculated. The rate constant for the uncatalysed cleavage at a given pH could then be calculated using equation 1. from *Ref.* 1.

Eq.1. $$k_{obs}=(k_a[H^+]^2/K+k_b[H^+]/K+k_c+k_dK_w/[H^+])/([H^+]/K+1)$$

Rate constants k_a, k_b k_c and k_d refer to acid catalyzed reaction of neutral phosphodiester, acid catalyzed reaction of monoanionic phosphodiester, spontaneous cleavage of monoanionic phosphodiester and base-catalysed cleavage of monoanionic phosphodiester, respectively. K is the equilibrium constant for deprotonation of the neutral phosphate to a monoanionic species. A value of 12.4 was used for the water autoprotolysis constant pK_w at 90 °C.[3] The proportions of partial reactions were calculated by dividing the corresponding term with k_{obs}. Calculated rate constants as a function of pH are shown in Fig. S1.

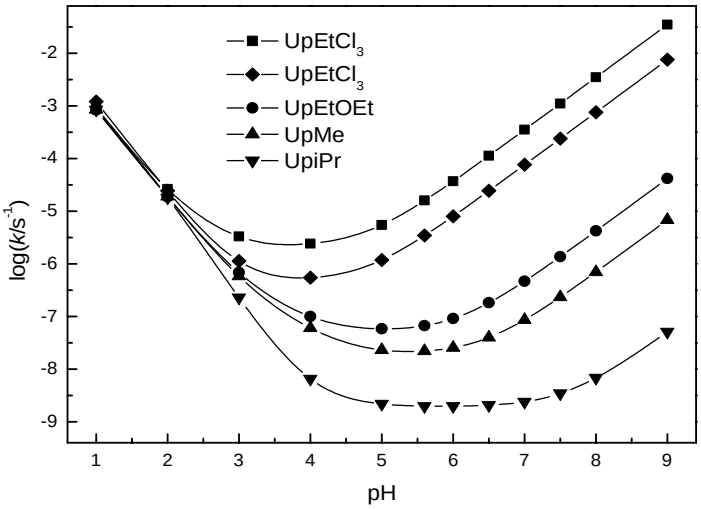


Fig. S1. Calculated rate constants for the cleavage of uridine 3'-alkyl phosphates as a function of pH. Calculation is based on parameters reported by Kosonen *et al.* 1. $UpEtCl_3$ (uridine 3'-trichloroethylphosphate (4h), $UpEtCl_2$ (uridine 3'-dichloroethylphosphate (4g), UpEtOEt (uridine 3'-ethoxyethylphosphate (4e), UpMe (uridine 3'-methylphosphate (4d), UpiPr (uridine 3'-isopropylphosphate (4b).

Rate constants for the uncatalysed cleavage of $UpEtCl_3$ and aryl esters at different temperatures

Rate constants of the cleavage of $UpEtCl_3$ were determined at three temperatures, 90 °C, 75 °C and 60 °C, at pH 6.5. pH was adjusted with MOPSO buffer. pK_a of MOPSO at different temperatures was calculated on the basis of data found in literature[4] and hydroxide ion concentration under experimental conditions was calculated using pK_w values from *ref.* 3. Logarithmic second-order rate constants for hydroxide ion catalyzed reaction were plotted against 1/T according to Arrhenius equation. Parameters obtained from a linear fit were used to calculate k_2 values at lower temperatures. Rate constants for the background reaction of uridine 3'-aryl esters 3a-e at 50 °C we calculated by interpolation using experimentally determined values obtained at pH 6.5 at 25 °C and 90 °C.

Table S1. Calculation of rate constants of the background reaction for the cleavage of $UpEtCl_3$ at different temperatures.

	T=363 K	T=348 K	T=333 K	T=323 K	T=298 K
k_{obs} /10^{-6} s^{-1}	26.3±0.4	5.80±0.05	1.62±0.07	0.46[a]	0.021[a]
pK_w[b]	12.4	12.7	13.0	13.3	14.0
$[HO^-]$/M, pH 6.5	$1.26x10^{-6}$	$6.31x10^{-7}$	$3.2x10^{-7}$	$1.58x10^{-7}$	$3.17x10^{-8}$
k_2 /$M^{-1}s^{-1}$	20.9	9.21	5.06	2.93[a]	0.65[a]

[a] Calculated on the basis of values obtained at higher temperatures as explained in the text. [b] From *Ref.* 3

Table S2. Rate constants of cleavage of uridine 3'-alkyl phosphates in the presence of monometallic Zn^{2+} and Cu^{2+} complexes at 90 °C.

	$UpEtCl_3$ 4h	$UpEtCl_2$ 4g	$UpEtF_2$ 4f	UpEtOEt 4e	UpMe 4d	UpEt 4c	UpiPr 4b	UpnPe 4a
pK_a[a]	12.2	12.9	13.0	14.8	15.5	15.8	17.1	17.3
k_0 /10^{-6} s^{-1} pH 6.6[b]	72.6	12.3	9.54	0.13	0.029	0.018	0.0021	0.0016
k_{obs}/10^{-6} s^{-1} pH 6.6 10 mM Zn^{2+}-8	2100±40	1800±40		251±3		54±1	1.7±0.1	
k_{obs}/10^{-6} s^{-1} pH 6.6 2 mM Zn^{2+}-8	400±30	320±10	370±20	55±3	62±2		0.11±0.01	0.14±0.01
k_{obs}/10^{-6} s^{-1} pH 6.6 2 mM Zn^{2+}-9	110±3	40.0±0. 2		5.6±0.2		0.67±0.05	0.17±0.04	
k_{obs}/10^{-6} s^{-1} pH 6.6 2 mM Zn^{2+}-9	73±4	30±1	27±1	3.6±0.2	5.3±0.2		0.25±0.01	0.11±0.01
k_{obs}/10^{-6} s^{-1} pH 6.6 2 mM Zn^{2+}-10	210±3	70±1		5.4±0.3		0.50±0.02	0.05±0.02	
k_{obs}/10^{-6} s^{-1} pH 6.6 2 mM Zn^{2+}-11	100±1	20±1		0.17±0.01		0.045±0.004	0.009±0.002	
k_{obs}/10^{-6} s^{-1} pH 6.6 2 mM Zn^{2+}-12	70±1	20.0±0.1		0.17±0.04		0.06±0.02	0.017±0.001	
k_{obs}/10^{-6} s^{-1} pH 6.6 2 mM Zn^{2+}-13	80.0±0.4	20.0±0.2		0.16±0.01		0.033±0.005	0.015±0.004	
k_{obs}/10^{-6} s^{-1} pH 6.6 10 mM Cu^{2+}-14	820±6	180±2	150±1	39±3	44±4		3.0±0.2	1.9±0.1
k_{obs}/10^{-6} s^{-1} pH 6.6 10 mM Cu^{2+}-15	4400±60	2100±300	760±30	290±2	60±1		9.1±0.3	13±1
k_0 /10^{-7} s^{-1} pH 5.6[b]	90.3	18.9	15	0.59	0.21	0.13	0.02	0.02
k_{obs}/10^{-6} s^{-1} pH 5.6 10 mM Zn^{2+}-8	280±1	150±1		58.3±0.5		11.3±0.3	0.94±0.05	
k_{obs}/10^{-5} s^{-1} pH 5.6 10 mM Zn_{aq}[c]	19.0±0.4	7.6±0.1		3.5±0.3		1.6±0.2	0.32±0.01	
k_{obs}/10^{-6} s^{-1} pH 5.6 2 mM Zn_{aq}	24±2	13.5±0.3	12.6±0.4	2.6±0.1				

[a] From *ref.* 2 except for that for 4a that was determined kinetically in 1 M NaOH at 25 °C using known β_{LG} value of -1.34 from ref. 5. [b] Rate constant of the uncatalysed reaction calculated as described above. [c] Data taken from *ref.*6.

Table S3. Rate constants of the cleavage of uridine 3'-aryl phosphates in the presence of monometallic Zn^{2+} and Cu^{2+} complexes.

	UpPh 3a	Up-*p*ClPh 3b	Up-*o*ClPh 3c	$UpPhCl_2$ 3d	$UpPhNO_2$ 3e
pK_a [a]	9.95	9. 38	8.48	7.51	7.14
k_{uncat} / 10^{-6} s^{-1}, pH 6.5, 25 °C	0.39±0.1	1.33±0.02	1.84±0.04	13.2±0.3	43.1±0.6
k_{obs}/ 10^{-6} s^{-1} pH 6.5, 25 °C, 2 mM Zn^{2+}-8	2.56±0.07	7.5±0.4	13.9±0.5	164±4	770±20
k_{obs}/ 10^{-6} s^{-1} pH 6.5, 25 °C, 10 mM Cu^{2+}-14	10.1±0.2	48±3	104±3	1420±40	5020±90
k_{obs}/ 10^{-6} s^{-1} pH 6.5, 25 °C, 10 mM Cu^{2+}-15	44.6±0.8	222±9	377±8	3300±200	7700±200
k_{uncat} / 10^{-4} s^{-1}, pH 6.5, 90 °C	3.65±0.05	9.1±0.2	11.7±0.4	51±3	106±5
k/ 10^{-4} s^{-1}, pH 6.5, 90 °C, 2 mM Zn^{2+}-9	6.3±0.2	16.9±0.3	20.8±5	133±7	580±40
k/ 10^{-4} s^{-1}, pH 6.5, 90 °C, 2 mM Zn^{2+}-8	46±2	91±3	126±3		
k/ 10^{-4} s^{-1}, pH 6.5, 90 °C, 10 mM Cu^{2+}-14	10.4±0.5	40.0±0.2	52±2		
k/ 10^{-4} s^{-1}, pH 6.5, 90 °C, 10 mM Cu^{2+}-15	82.0±0.4	280±2	540±20		
k_{uncat} / 10^{-6} s^{-1}, pH 5.9, 25 °C [b]	0.25±0.02	0.68±0.02	0.95±0.01	5.06±0.04	18.9±0.1
k/ 10^{-6} s^{-1} pH 5.9, 25 °C, 10 mM Zn^{2+}_{aq} [b]	0.71±0.02	2.4±0.2	4.35±0.03	58.6±0.8	620±20
k/ 10^{-6} s^{-1} pH 5.9, 25 °C , 10 mM Zn^{2+}-8	2.56±0.03	11.5±0.3	23.3±0.4	260±8	1100±10
k_{uncat} / 10^{-5} s^{-1}, pH 7.5, 25 °C [a]	0.618	1.40	1.92	10.4	
k/ 10^{-3} s^{-1}, pH 7.5, 25 °C [a] 10 mM Zn^{2+}-8	0.095±0.003	0.45±0.01	1.39±0.04	10.3±0.1	

[a] From. *ref.* 7. [b] From. *ref.* 6.

Synthesis and characterization of phosphodiester substrates and ligands.

General procedures. The NMR spectra were recorded on a Bruker AV 500 or 400 spectrometer. The mass spectra were acquired using either a Bruker micrOTOF-Q ESI-MS spectrometer or Perkin-Elmer Sciex API 365 triple quadrupole spectrometer. Ethanol, dichloromethane and acetonitrile were dried by storage over molecular sieves. A semipreparative column ODS Hypersil RP-18, 250×10 mm, 5 µm was used for HPLC purification of the synthesis products. Commercially available bipyridine (Acros), terpyridine (ABCR), 1,4,7-triazacyclononane (TCI), 1,4,7-triazacyclononane trihydrobromide (Aldrich) 1,5,9-triazacyclododecane (TCI) and 1,5,9-triazacyclododecane trihydrobromide (Aldrich) were used as received. The synthesis of alkyl esters 4b-4h and phenyl ester 3a has been reported before.[8] Uridine 3'-phosphoesters 3b-3e and 4a, methyl phosphonate 7b as well as ligands 17 a, 17b, 19b, 21b and 22 were synthesized in the present work using known methods as described below. ^{1}HNMR spectra for the purified products are attached at the end of the document.

Synthesis of uridine 3´-neopentyl phosphate (4a). 4a was synthesized by the common phosphoramidite method from commercially available 5'-*O*-dimethoxytrityl-2'-*O*-triisopropylsilyloxymethyluridine- 3'-[(2-cyanoethyl)-(*N*,*N*-diisopropyl)]-phosphoramidite and neopentanol using a previously described method.[8] ^{1}H NMR δ_H (500 MHz, CD_3OD): 8,07 (1H, d, *J*=8,0 Hz, H6), 5,97 (1H, d, *J*=5,0 Hz, H1´), 5,75 (1H, d, *J*=8,0 Hz, H5), 4,59 (1H, m, H3´) 4,33 (1H, t, *J*=5,0 Hz, H2´), 4,26 (1H, m, H4´), 3,85 (2H, s, CH_2), 3,61 (2H, m, H5´,H5´´), 0,965 (9H, s, 3×CH_3). ^{31}P NMR (202 MHz, D_2O): 4,20. ESI- -MS: m/z 393,1158 $[M-H]^-$

Synthesis of uridine 3´-methylphosphonate (*7b*). 7b was synthesized as described previously by Mäki *et al*.[9] After coupling of 2´,5´-di-*O*-(*tert*-butyldimethylsilyl)uridine[10-12] (0,50 g, 1 mmol) and methylphosphorylbis(1,2,4-triazole),[13] obtaining 2´,5´-di-*O*-(*tert*-butyldimethylsilyl)uridine-3´-methylphosphonate, the *tert*-butyldimethylsilyl protecting groups were removed with 0,5 M tetrabutylammoniumfluoride in tetrahydrofuran. The crude product was purified by RP HPLC on a semipreparative column, eluting with a mixture of water and acetonitrile. Finally, the product was treated

with cation exchange resin (AG 50W-X2). Yield 0,078 g (24 %). ^{1}H NMR δ_H (500 MHz, D_2O): 7,80 (1H, d, *J*=8,3 Hz, H6), 5,88 (1H, d, *J*= 5,1 Hz, H1´), 5,83 (1H, d, *J*=8,0 Hz, H5), 4,55 (1H, m, H3´) 4,37 (1H, t, *J*=5,1 Hz, H2´), 4,20 (1H, d, *J*=2,9 Hz, H4´), 3,83 (1H, dd, *J*= 2,9 Hz, *J*=12,8 Hz, H5´), 3,75 (1H, dd, *J*=4,2 Hz, *J*=12,8 Hz, H5´´), 1,31 (3H, d, *J*=16,9 Hz, P-CH_3). ^{31}P NMR (202 MHz, D_2O): 28,37 ESI^- -MS: *m/z* 321,30 $[M-H]^-$

Synthesis of uridine 3´-aryl phosphates 3b-3e. The 5´-*O*-(4-monomethoxytrityl-2´-*O*-(tetrahydropyran-2-yl)-uridine 3´-arylphosphates were synthesized from 5´-*O*-(4-monomethoxytrityl-2´-*O*-(tetrahydropyran-2-yl)-uridine and commercially available substituted phenyl phosphorodichloridate as described previously.[5-7] The acid labile monomethoxytrityl and tetrahydropyranyl protecting groups were removed with a mixture of acetonitrile and 0.2 M aqueous hydrogen chloride (1:1) at room temperature (25).[6] After 30-45 min the pH of the solution was adjusted to 4.7 with aqueous sodium acetate. After extraction with dichloromethane, the aqueous phase was evaporated to dryness. The product was purified by RP HPLC on a semipreparative column. A mixture of acetonitrile and water was used as an eluent; 10 min isocratic elution with 3 % acetonitrile, then 30 min linear gradient to 50 % acetonitrile. The purified products were lyophilized and characterized by ^{1}H, ^{31}P and MS spectroscopy.

Uridine 3´-(4-chlorophenyl) phosphate (3b): ^{1}H NMR δ_H (500 MHz, CD_3OD): 8,05 (1H, d, *J*=8,1 Hz, H6), 7,29 (2H, d, *J*=9,3 Hz, PhCl), 7,26 (2H, d, *J*=9,1 Hz, PhCl), 5,97 (1H, d, *J*=5,3 Hz, H1´), 5,72 (1H, d, *J*=8,1 Hz, H5), 4,71 (1H, m, H3´), 4,33 (1H, t, *J*=5,3 Hz, H2´), 4,24 (1H, d, *J*=3,6 Hz, H4´), 3,81 (1H, dd, *J*=2,4 Hz, *J*=12,4 Hz, H5´), 3,75 (1H, dd, J=2,6 Hz, J=12,2 Hz, H5´´). ^{31}P NMR (202 MHz, CD_3OD): -5,09. ESI^- -MS: *m/z* 433,04 $[M-H]^-$

Uridine 3´-(2-chlorophenyl) phosphate (3c): ^{1}H NMR δ_H (500 MHz, CD_3OD): 8,09 (1H, d, *J*=8,3 Hz, H6), 7,62 (1H, d, *J*=8,2 Hz, PhCl), 7,39 (1H, d, *J*=7,9 Hz, PhCl), 7,26 (1H, m, PhCl) 7,06 (1H, t, *J*=7,6 Hz, PhCl), 5,97 (1H, d, *J*= 5,1 Hz, H1´), 5,72 (1H, d, *J*=8,3 Hz, H5), 4,79 (1H, m, H3´), 4,36 (1H, t, *J*=4,7 Hz, H2´), 4,29 (1H, m, H4´), 3,82 (2H, m, H5´ ja H5´´). ^{31}P NMR (202 MHz, CD_3OD): -5,27. ESI^- -MS: *m/z* 433,05 $[M-H]^-$

Uridine 3´-(2,5-dichlorophenyl) phosphate (3d): ^{1}H NMR δ_H (500 MHz, CD_3OD): 8,08 (1H, d, *J*=8,0 Hz, H6), 7,74 (1H, d, *J*=1,9 Hz, $PhCl_2$), 7,38 (1H, d, *J*=8,5 Hz, $PhCl_2$), 7,08 (1H, dd, *J*=2,2 Hz, *J*=8,45, $PhCl_2$), 5,98 (1H, d, *J*=5,4 Hz, H1´), 5,72 (1H, d, *J*=8,3 Hz), 4,78 (1H, m, H3´), 4,36 (1H, t, *J*=4,9 Hz, H2´), 4,31 (1H, m, H4´), 3,83 (2H, m, H5´ ja H5´´). ^{31}P NMR (202 MHz, CD_3OD): -5,59. ESI^- -MS: *m/z* 467,02 $[M-H]^-$

Uridine 3´-(4-nitrophenyl) phosphate (3e): ^{1}H NMR δ_H (500 MHz, CD_3OD): 8,25 (2H, d, *J*=9,4 Hz, NO_2Ph), 8,04 (1H, d, *J*=7,9 Hz, H6), 7,49 (2H, d, *J*=9,1 Hz, NO_2Ph), 5,99 (1H, d, *J*=6,1 Hz, H1´), 5,73 (1H, d, *J*=8,3 Hz, H5) 4,79 (1H, m, H3´) 4,38 (1H, t, *J*=4,9 Hz, H2´), 4,27 (1H, d, *J*=3,0 Hz, H4´), 3,82 (1H, dd, *J*=2,5 Hz, *J*=12,4 Hz, H5´), 3,76 (1H, dd, *J*=2,6 Hz, *J*=12,4 Hz, H5´´). ^{31}P NMR (202 MHz, CD_3OD): -6,14. ESI^- -MS: *m/z* 444,04 $[M-H]^-$

Synthesis of N,N,N´,N´-tetrakis(2-pyridylmethyl)-2-hydroxy-1,3-propanediamine (19b): A mixture of picolyl chloride hydrochloride (0,607 g, 3,64 mmol), 1,3-diamino-2-propanol (82 mg, 0,91 mmol) and potassium carbonate (1,75 g, 13 mmol) in 30 ml of acetonitrile was refluxed smoothly 48 hours with magnetic stirring. The reaction mixture was evaporated to dryness. The residue was dissolved with water and extracted with dichloromethane. The organic phase was dried with Na_2SO_4 and evaporated to dryness. The crude product was purified by silica gel chromatography using a stepwise gradient of methanol (5-20 %) in dichloromethane. The pure product was obtained as brown oil. Yield 0,1159 g (28 %) ^{1}H NMR δ_H (500 MHz, CD_3OD): 8,43 (d, 4H, *J*=4,5 Hz), 7,77 (t, 4H, *J*=7,5 Hz), 7,52 (d, 4H, *J*=7,5 Hz), 7,28 (d, 4H, *J*=4,5 Hz), 3,98 (m, 1H), 3,83 (d, 8H), 2,64 (dd, 2H, *J*=13,5 Hz, *J*=4,0 Hz), 2,53 (dd, 2H, *J*=13,5 Hz, *J*=7,5). ESI^+ -MS: *m/z* 455,2389 $[M+H]^+$.

Synthesis of N,N,N´,N´-tetrakis(4-imidazoylmethyl)-2-hydroxy-1,3-propanediamine (22):[14] 4-hydroxymethylimidazole hydrochloride was first converted to 4-chloromethylimidazole hydrochloride.[15] 1,3-diamino-2-propanol (0,135 g, 1,5 mmol) was dissolved in dry ethanol. Triethylamine (5 mL) was added and the reaction mixture was heated at reflux. 4-chloromethylimidazole hydrochloride was dissolved in dry ethanol and added dropwise to the reaction mixture. After 3.5 h reflux, reaction mixture was evaporated to dryness. The residue was dissolved with 30 mL of dry dichloromethane and stirred for 1.5 h. Organic phase was filtered at atmospheric pressure and evaporated to dryness. The remaining triethylammonium salt was removed by treating the crude product with anion exchange resin (DOWEX 1-X8). Yield 0,311 g (50 %). ^{1}H NMR δ_H (500 MHz, D_2O): 7,64 (s, 2H), 7,61 (s, 2H), 7,01 (s, 2H), 6,95 (s, 2H), 3,76 (m, 1H), 3,61 (s, 4H), 3,57 (s, 4H), 2,53 (d, 2H, *J*=6 Hz), 2,32 (d, 2H, *J*=6 Hz). ^{13}C NMR (500 MHz, D_2O): 135,9; 132,96; 118,48; 65,69; 56,44; 49,76. ESI^+ -MS: *m/z* 411,2577 $[M+H]^+$

Synthesis of 1,3-Bis(1,4,7-triazacyclonon-1-yl)-2-hydroxypropane (17a): The ligand was synthesized as described previously by Iranzo *et al*.[16] ^{1}H NMR δ_H (500 MHz, $CDCl_3$): 4,17 (tt, 1H, *J*=9,5 Hz, *J* = 2,5 Hz), 3,59-3,52 (m, 8H), 3,25 (t, 8H, *J*=5,8 Hz), 3,09-3,04 (m, 4H), 2,99-2,94 (m, 4H), 2,70 (dd, 2H, *J*=14 Hz, *J*=2,5 Hz), 2,59 (dd, 2H, *J*=9,8 Hz, *J*=14,3 Hz). ESI^+-MS: *m/z* 315,34 $[M+H]^+$

Synthesis of 1,3-Bis(1,4,7-triazacyclonon-1-yl)-propane (17b): The ligand was synthesized as described previously by Saito *et al*.[17] In order to remove the HBr salt, the ligand (42 mg) was mixed with 4 M NaOH solution (15 ml) and the mixture was stirred 2 h at room temperature. The water solution was extracted with chloroform (4×20 ml). The organic phase was dried with Na_2SO_4 and evaporated to dryness. ^{1}H NMR δ_H (500 MHz, D_2O): 3,49 (s, 8H), 3,24 (t, 8H, *J*=6 Hz), 2,97 (t, 8H, *J*=6 Hz), 2,67 (t, 4H, *J*=8 Hz), 1,77 (m, 2H). ^{13}C NMR (500 MHz, D_2O): 68,15; 52,09; 47,15; 43,31; 41,89. ESI^+-MS: *m/z* 299,2923 $[M+H]^+$.

Synthesis of 1,3-Bis(1,5,9-triazacyclododec-1-yl)-2-hydroxypropane (21b): The ligand was synthesized as described previously by Mohamed *et al*.[18] ^{1}H NMR δ_H (500 MHz, CD_3OD): 4,11 (m, 1H), 2,91-2,76 (m, 21H), 2,56 (dd, 2H, *J*=13 Hz *J*=9,5 Hz), 2,47 (dt, 4H, *J*=13 Hz *J*=4,5 Hz), 2,14 (dd, 2H, *J*=13 Hz *J*=2,8 Hz), 1,88 (m, 2H), 1,72 (m, 9H). ESI^+-MS: *m/z* 399,3817 $[M+H]^+$

References

1 M. Kosonen, E.Yousefi-Salakdeh, R.Strömberg and H. Lönnberg, *J. Chem. Soc., Trans. 2,* 1998, 1589-1595.

2 E.P. Serjeant and P. Dempsey, *Ionization constants of organic acids in aqueous solutions. IUPAC Chemical data series 23.* Pergamon Press, Oxford, 1979

3 H.S. Harned and B.B. Owen, *The physical chemistry of electrolytic solutions.* Chapman and Hall Ltd., London, 1958

4 Y.C. Wu, P.A. Berezensky, P.A. Feng and W.F. Koch, *Anal. Chem.,* 1993, 65, 1084-1087.

5 M. Kosonen, E. Yousefi-Salakdeh, R. Strömberg and H. Lönnberg, *J. Chem. Soc., Perkin Trans. 2*, 1997, 2661-2666

6 S. Mikkola, E. Stenman, K. Nurmi, E. Yousefi-Salakdeh, R. Strömberg and H. Lönnberg,. *J. Chem. Soc., Perkin Trans.,* 1999, 1619-1625

7 A. M. Davis, A.D. Hall and A. Williams, *J. Am. Chem. Soc.,* 1998, 110, 5105-5108.

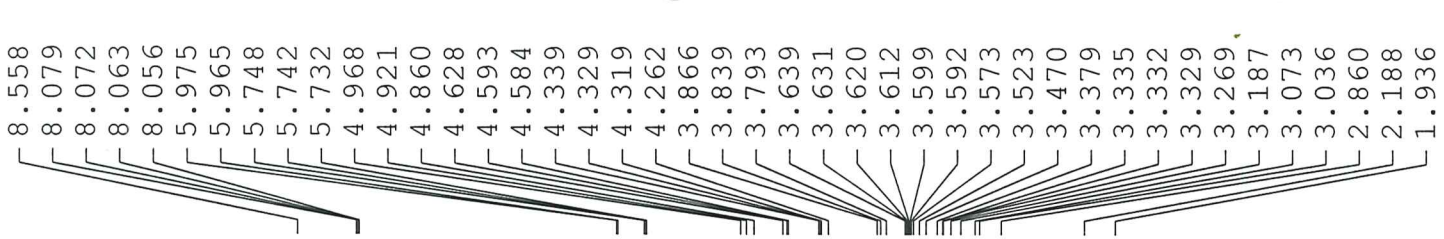
8 H. Korhonen, S. Mikkola and N.H. Williams, *Eur. J. Chem.,* 2012, 18, 659-670.

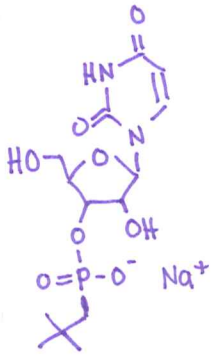
9 E. Mäki, M. Oivanen, P. Poijärvi and H. Lönnberg, *J. Chem. Soc., Perkin Trans. 2,* 1999, 2493-2499.

10 G.H. Hakimelahi, Z.A. Proba and K.K. Ogilvie, *Can. J. Chem.,*1982, 60*,* 1106-1113.
11 K.K. Ogilvie, S.L. Beaucage, A.L. Schifman, N.Y. Theriault and K.L. Sadana, *Can. J. Chem.* 1978, 56, 2768-2780.
12 K.K. Ogilvie, A.L. Schifman and C.L. Penney, *Can. J. Chem.,* 1979, 57*,* 2230-2238.
13 A. Kraszewski and J. Stawinski, *Tetrahedron Lett.,* 1980, 21*,* 2935-2936.
14 B. Wilson, L. Gude, M. Fernández, A. Lorente and K.B. Grant, *Inorg. Chem.,*2005, 44*,* 6159-6173.
15 R. Turner, *J. Am. Chem. Soc.,* 1949, 71*,* 3476-3478.
16 O. Iranzo, T. Elmer, J.P. Richard and J.R. Morrow, *Inorg. Chem.,* 2003, 42*,* 7737-7746.
17 K. Saito, S. Pant and M.T.V. Hearn, *J. Appl. Polym. Sci.,* 2011, 122*,* 2174-2180.
18 M.F. Mohamed, A.A. *Neverov* and R.S. Brown, *Inorg. Chem.,* 2009, 48, 11425-11433.

Attachements:

Uridine 3'-neopentyl phosphate (4a)





Uridine-3'-neopentylphosphate

Current Data Parameters

NAME	Neo
EXPNO	1
PROCNO	1

F2 - Acquisition Parameters

Date_	20111212
Time	9.15
INSTRUM	AV500
PROBHD	5 mm PABBI 1H-
PULPROG	zg30
TD	65536
SOLVENT	MeOD
NS	16
DS	2
SWH	10330.578 Hz
FIDRES	0.157632 Hz
AQ	3.1720407 sec
RG	456.1
DW	48.400 usec
DE	6.00 usec
TE	298.1 K
D1	1.00000000 sec
MCREST	0.00000000 sec
MCWRK	0.01500000 sec

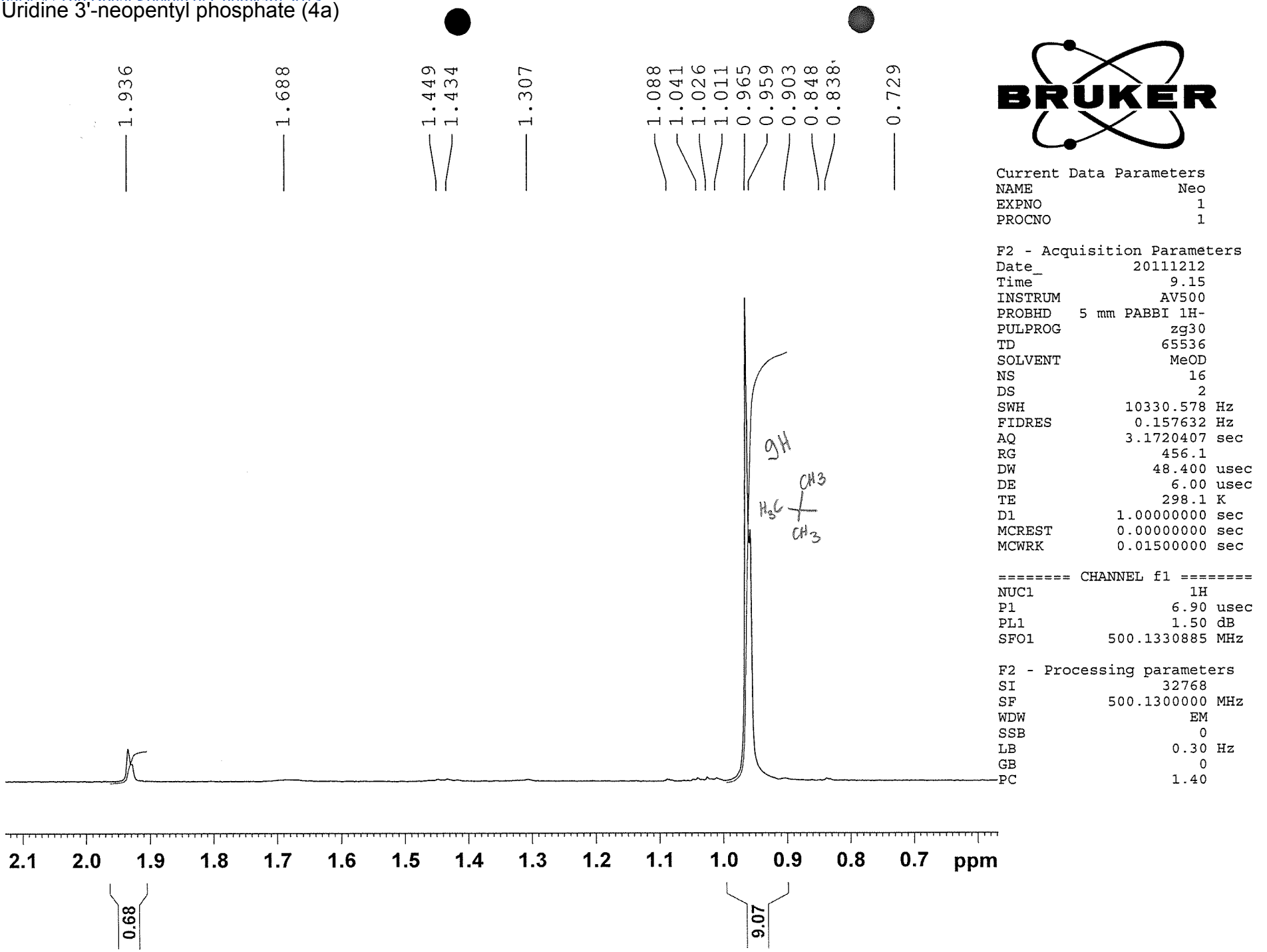
======== CHANNEL f1 ========

NUC1	1H
P1	6.90 usec
PL1	1.50 dB
SFO1	500.1330885 MHz

F2 - Processing parameters

SI	32768
SF	500.1300000 MHz
WDW	EM
SSB	0
LB	0.30 Hz
GB	0
PC	1.40

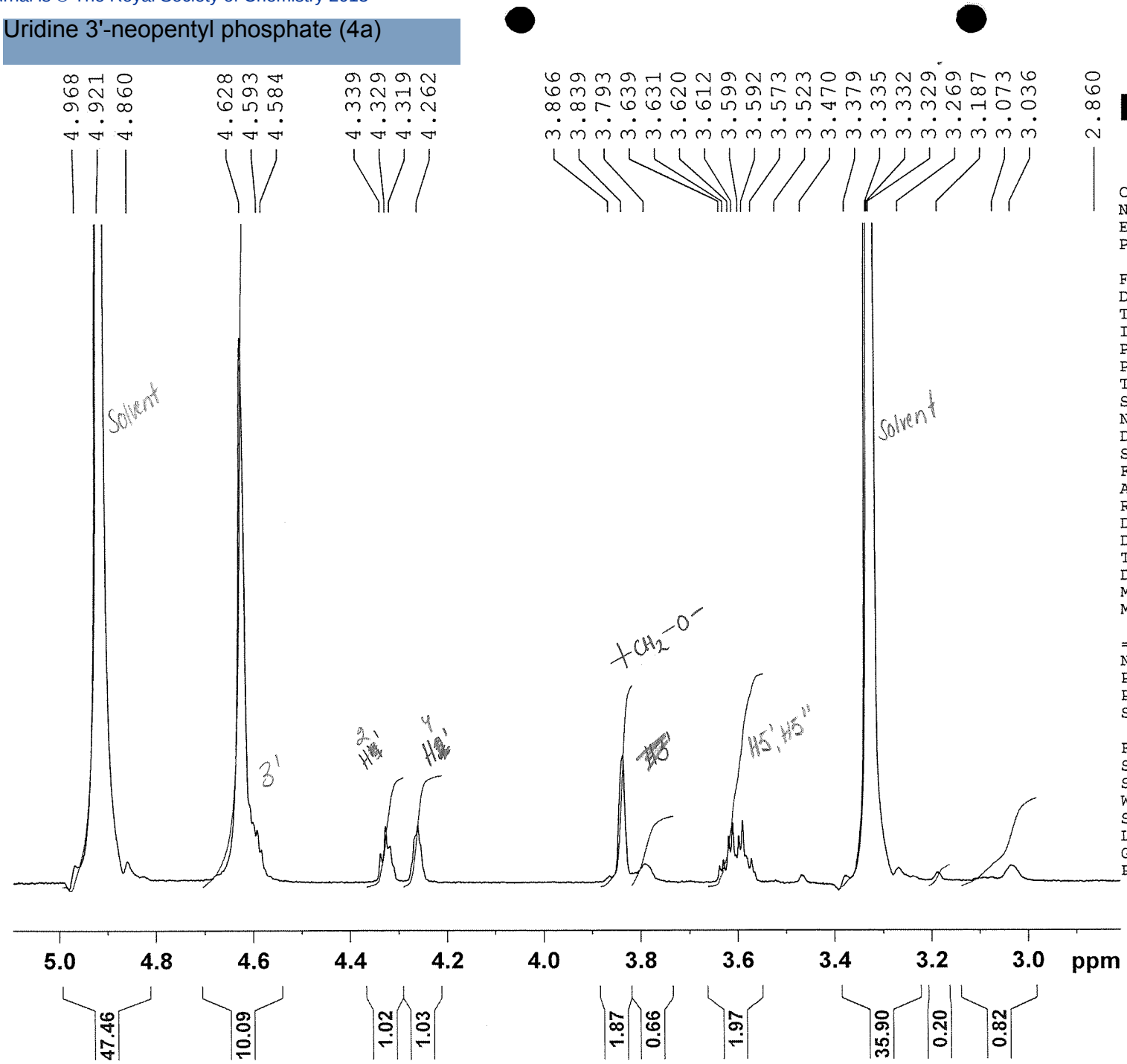
Uridine 3'-neopentyl phosphate (4a)



BRUKER

```
Current Data Parameters
NAME                  Neo
EXPNO                   1
PROCNO                  1

F2 - Acquisition Parameters
Date_           20111212
Time                9.15
INSTRUM            AV500
PROBHD   5 mm PABBI 1H-
PULPROG             zg30
TD                 65536
SOLVENT             MeOD
NS                    16
DS                     2
SWH           10330.578 Hz
FIDRES         0.157632 Hz
AQ             3.1720407 sec
RG                456.1
DW                48.400 usec
DE                 6.00 usec
TE                298.1 K
D1           1.00000000 sec
MCREST       0.00000000 sec
MCWRK        0.01500000 sec

======== CHANNEL f1 ========
NUC1                  1H
P1                 6.90 usec
PL1                1.50 dB
SFO1        500.1330885 MHz

F2 - Processing parameters
SI                 32768
SF          500.1300000 MHz
WDW                  EM
SSB                   0
LB                 0.30 Hz
GB                    0
PC                 1.40
```

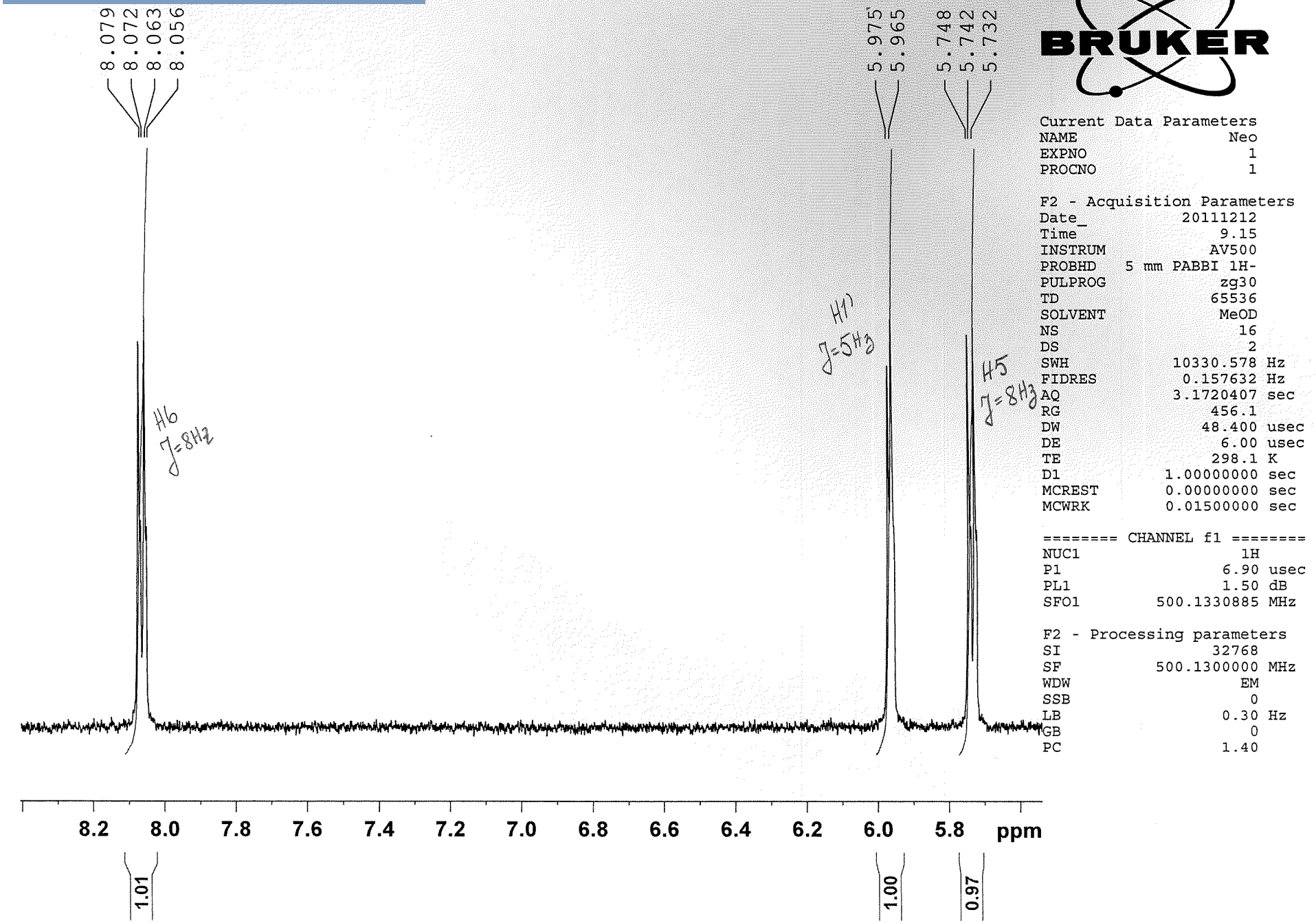
Uridine 3'-neopentyl phosphate (4a)



BRUKER

```
Current Data Parameters
NAME                      Neo
EXPNO                       1
PROCNO                      1

F2 - Acquisition Parameters
Date_              20111212
Time                   9.15
INSTRUM               AV500
PROBHD    5 mm PABBI 1H-
PULPROG                zg30
TD                    65536
SOLVENT                MeOD
NS                       16
DS                        2
SWH              10330.578 Hz
FIDRES            0.157632 Hz
AQ                3.1720407 sec
RG                    456.1
DW                  48.400 usec
DE                   6.00 usec
TE                   298.1 K
D1              1.00000000 sec
MCREST          0.00000000 sec
MCWRK           0.01500000 sec

======== CHANNEL f1 ========
NUC1                      1H
P1                    6.90 usec
PL1                   1.50 dB
SFO1           500.1330885 MHz

F2 - Processing parameters
SI                     32768
SF             500.1300000 MHz
WDW                       EM
SSB                        0
LB                    0.30 Hz
GB                         0
PC                    1.40
```

Uridine 3'-neopentyl phosphate (4a)

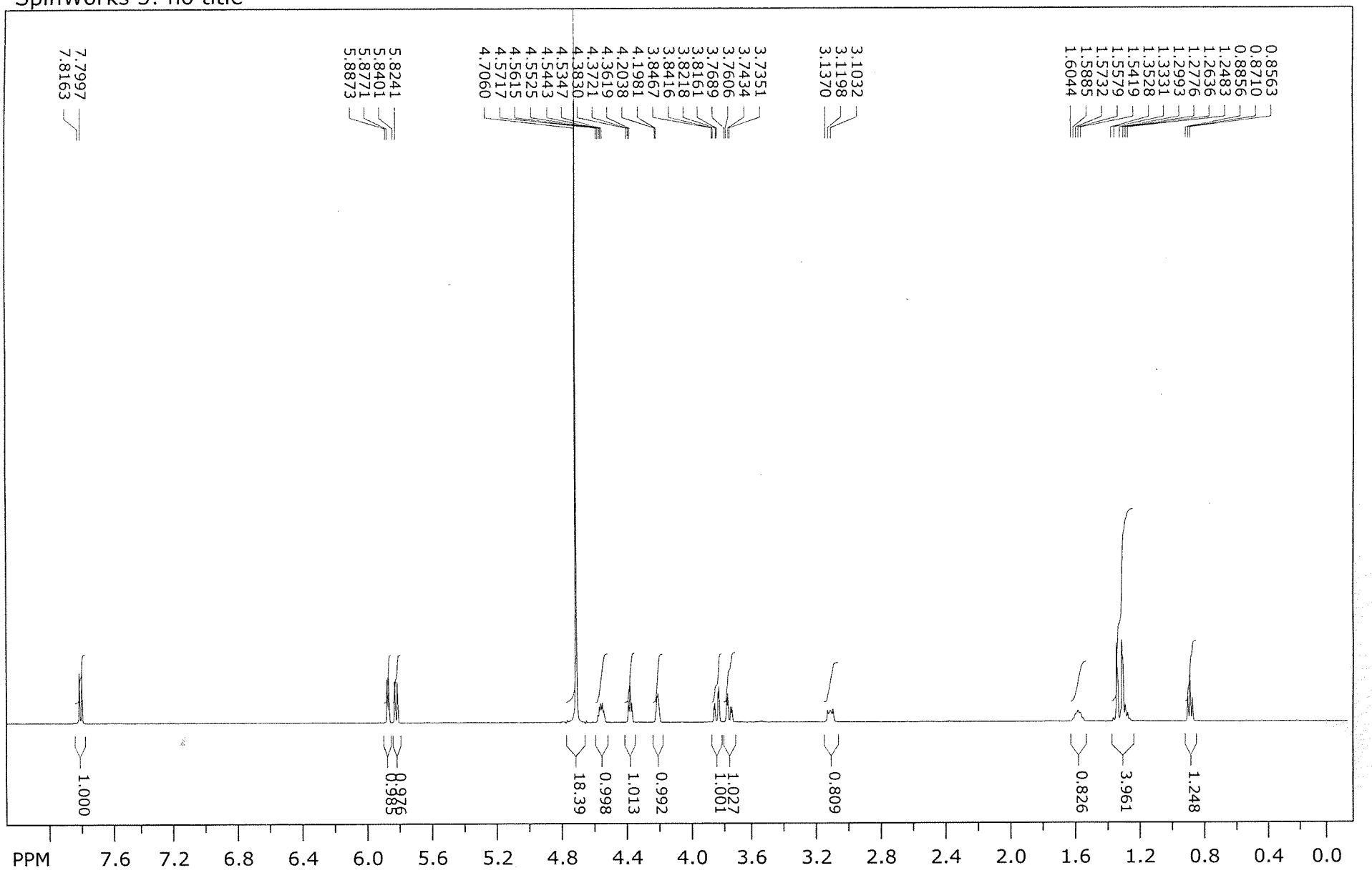


BRUKER

```
Current Data Parameters
NAME                  Neo
EXPNO                   1
PROCNO                  1

F2 - Acquisition Parameters
Date_            20111212
Time                9.15
INSTRUM            AV500
PROBHD   5 mm PABBI 1H-
PULPROG             zg30
TD                 65536
SOLVENT             MeOD
NS                    16
DS                     2
SWH           10330.578 Hz
FIDRES         0.157632 Hz
AQ             3.1720407 sec
RG                 456.1
DW                48.400 usec
DE                 6.00 usec
TE                298.1 K
D1             1.00000000 sec
MCREST         0.00000000 sec
MCWRK          0.01500000 sec

======== CHANNEL f1 ========
NUC1                   1H
P1                  6.90 usec
PL1                 1.50 dB
SFO1         500.1330885 MHz

F2 - Processing parameters
SI                 32768
SF           500.1300000 MHz
WDW                   EM
SSB                    0
LB                0.30 Hz
GB                     0
PC                 1.40
```

Uridine 3-methylphosphonate **(7b)**

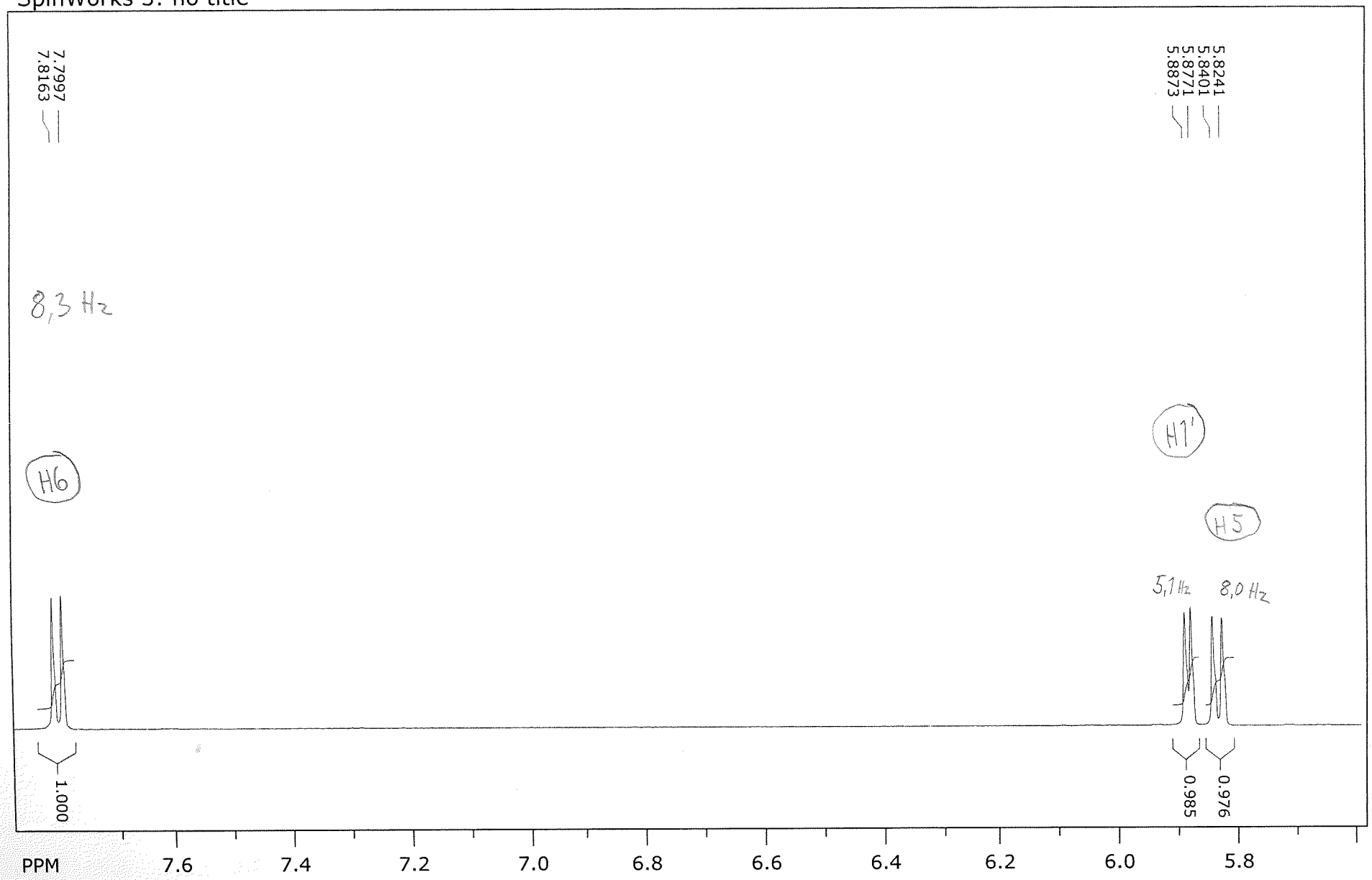
SpinWorks 3: no title



file: F:\urd-3'-Mephos\1\fid expt: <zg30>
transmitter freq.: 500.133089 MHz
time domain size: 65536 points
width: 10330.58 Hz = 20.6557 ppm = 0.157632 Hz/pt
number of scans: 16

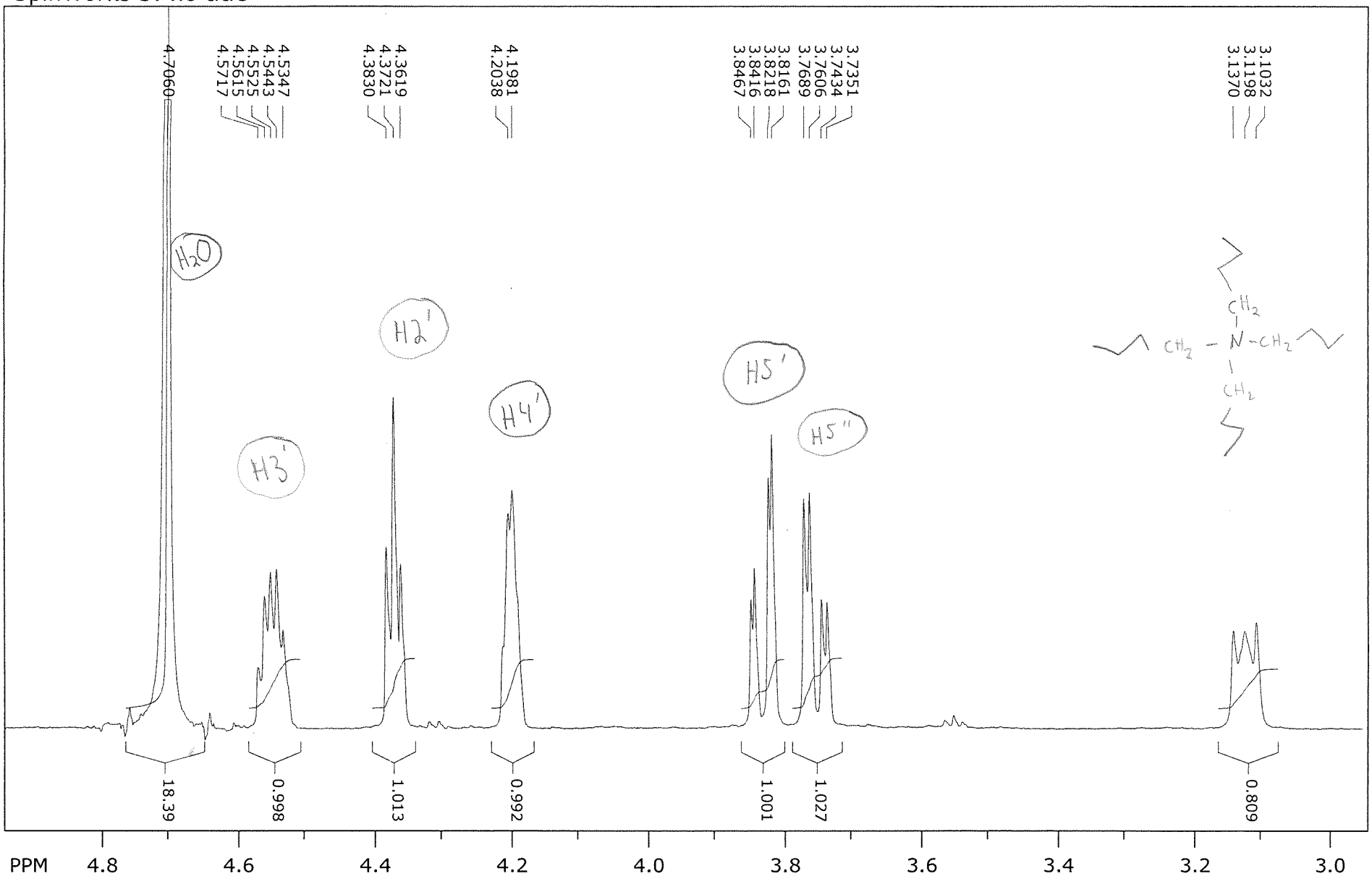
freq. of 0 ppm: 500.130000 MHz
processed size: 32768 complex points
LB: 0.300 GF: 0.0000
Hz/cm: 168.193 ppm/cm: 0.33630

SpinWorks 3: no title



file: F:\urd-3'-Mephos\1\fid expt: <zg30>
transmitter freq.: 500.133089 MHz
time domain size: 65536 points
width: 10330.58 Hz = 20.6557 ppm = 0.157632 Hz/pt
number of scans: 16

freq. of 0 ppm: 500.130000 MHz
processed size: 32768 complex points
LB: 0.300 GF: 0.0000
Hz/cm: 46.047 ppm/cm: 0.09207

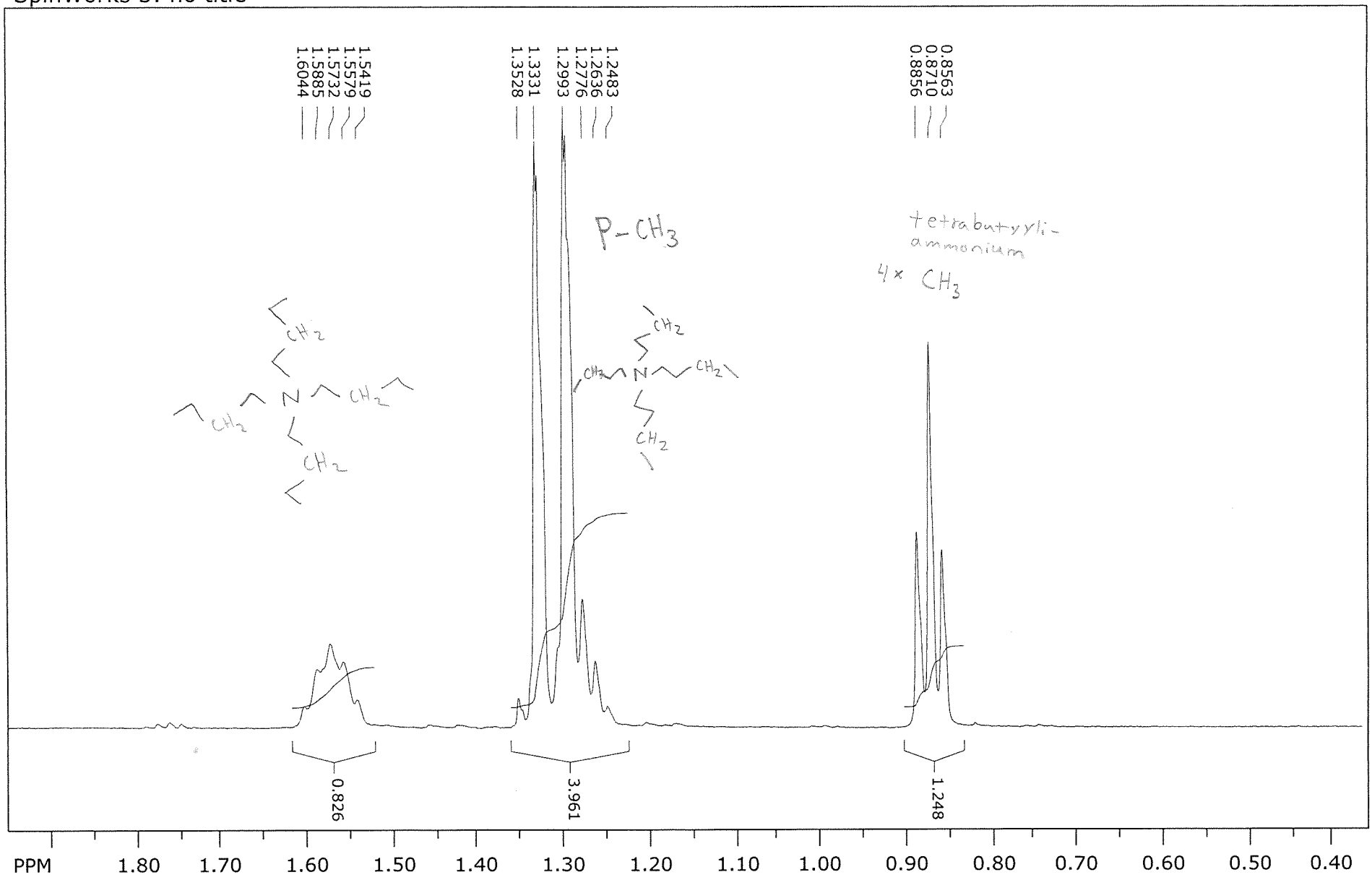


file: F:\urd-3'-Mephos\1\fid expt: <zg30>
transmitter freq.: 500.133089 MHz
time domain size: 65536 points
width: 10330.58 Hz = 20.6557 ppm = 0.157632 Hz/pt
number of scans: 16

freq. of 0 ppm: 500.130000 MHz
processed size: 32768 complex points
LB: 0.300 GF: 0.0000
Hz/cm: 40.036 ppm/cm: 0.08005

Uridine 3-methylphosphonate **(7b)**

SpinWorks 3: no title

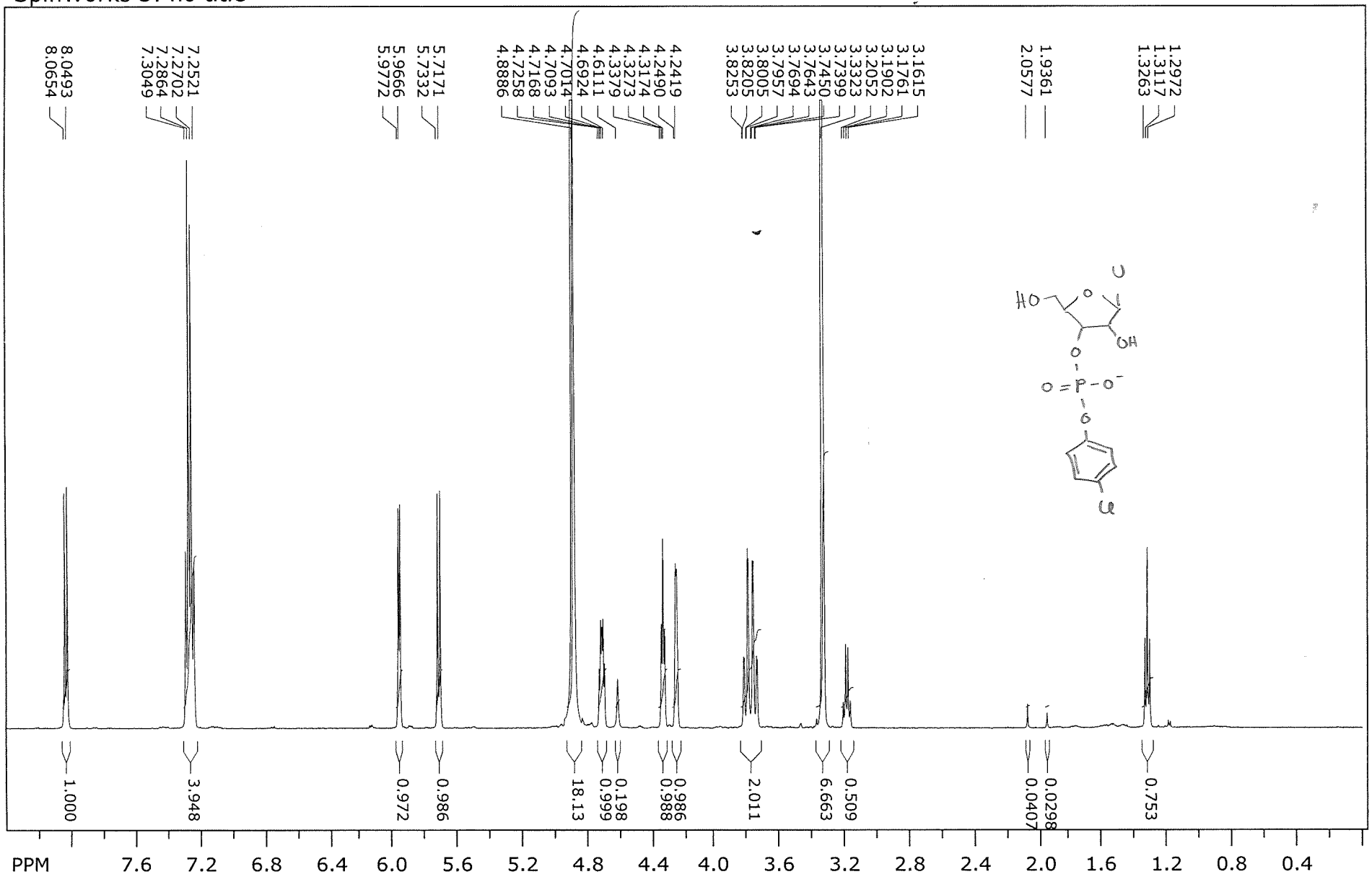


file: F:\urd-3'-Mephos\1\fid expt: <zg30>
transmitter freq.: 500.133089 MHz
time domain size: 65536 points
width: 10330.58 Hz = 20.6557 ppm = 0.157632 Hz/pt
number of scans: 16

freq. of 0 ppm: 500.130000 MHz
processed size: 32768 complex points
LB: 0.300 GF: 0.0000
Hz/cm: 31.868 ppm/cm: 0.06372

Uridine 3'-(4-chlorophenyl) phosphate

SpinWorks 3: no title

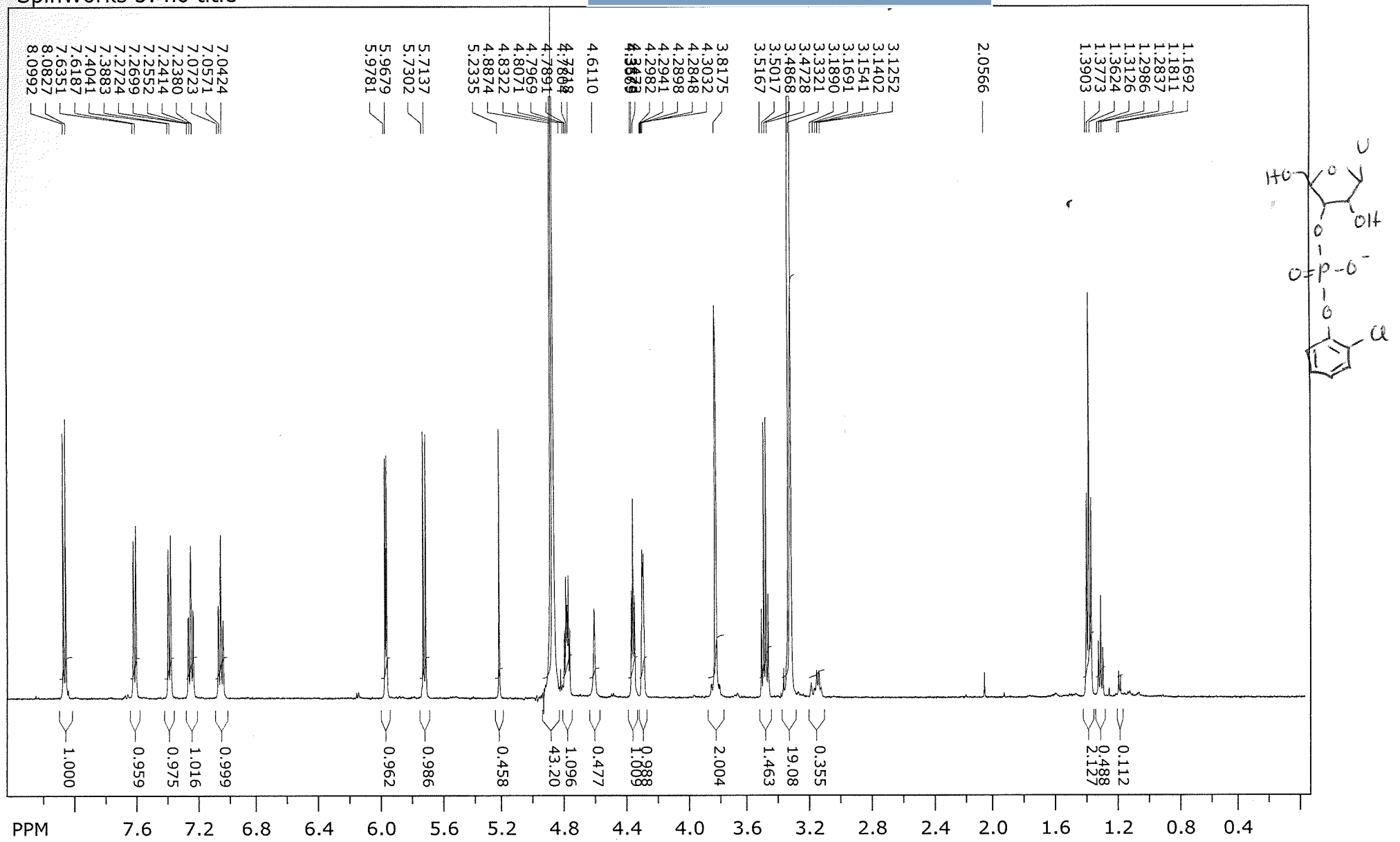


file: F:\nmr\4-kloori\1\fid expt: <zg30>
transmitter freq.: 500.133089 MHz
time domain size: 65536 points
width: 10330.58 Hz = 20.6557 ppm = 0.157632 Hz/pt
number of scans: 16

freq. of 0 ppm: 500.130000 MHz
processed size: 32768 complex points
LB: 0.300 GF: 0.0000
Hz/cm: 169.255 ppm/cm: 0.33842

Uridine 3'-(2-chlorophenyl) phosphate

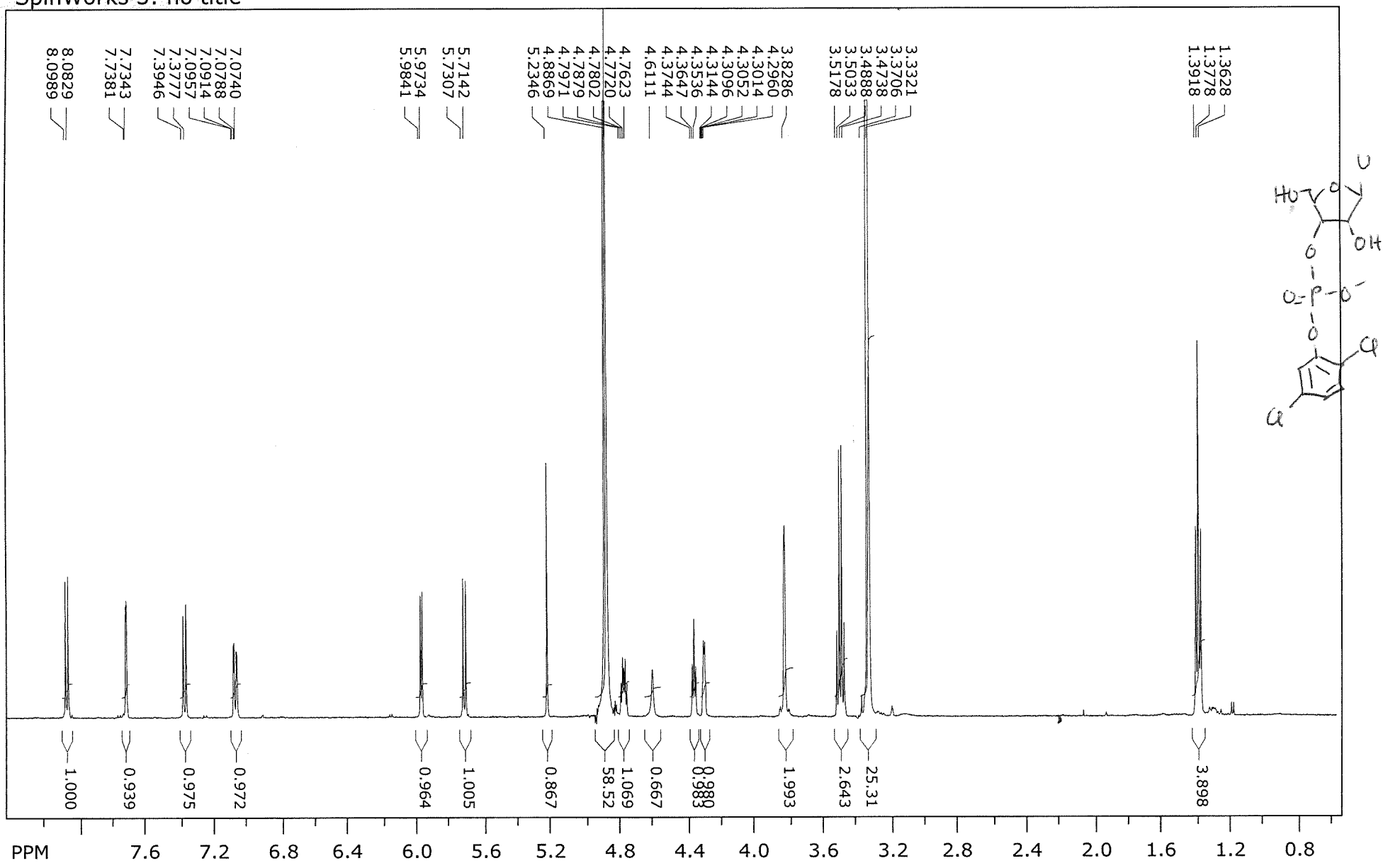
SpinWorks 3: no title



file: F:\2-cl\3\fid expt: <zg30>
transmitter freq.: 500.133089 MHz
time domain size: 65536 points
width: 10330.58 Hz = 20.6557 ppm = 0.157632 Hz/pt
number of scans: 16

freq. of 0 ppm: 500.130000 MHz
processed size: 32768 complex points
LB: 0.300 GF: 0.0000
Hz/cm: 170.317 ppm/cm: 0.34054

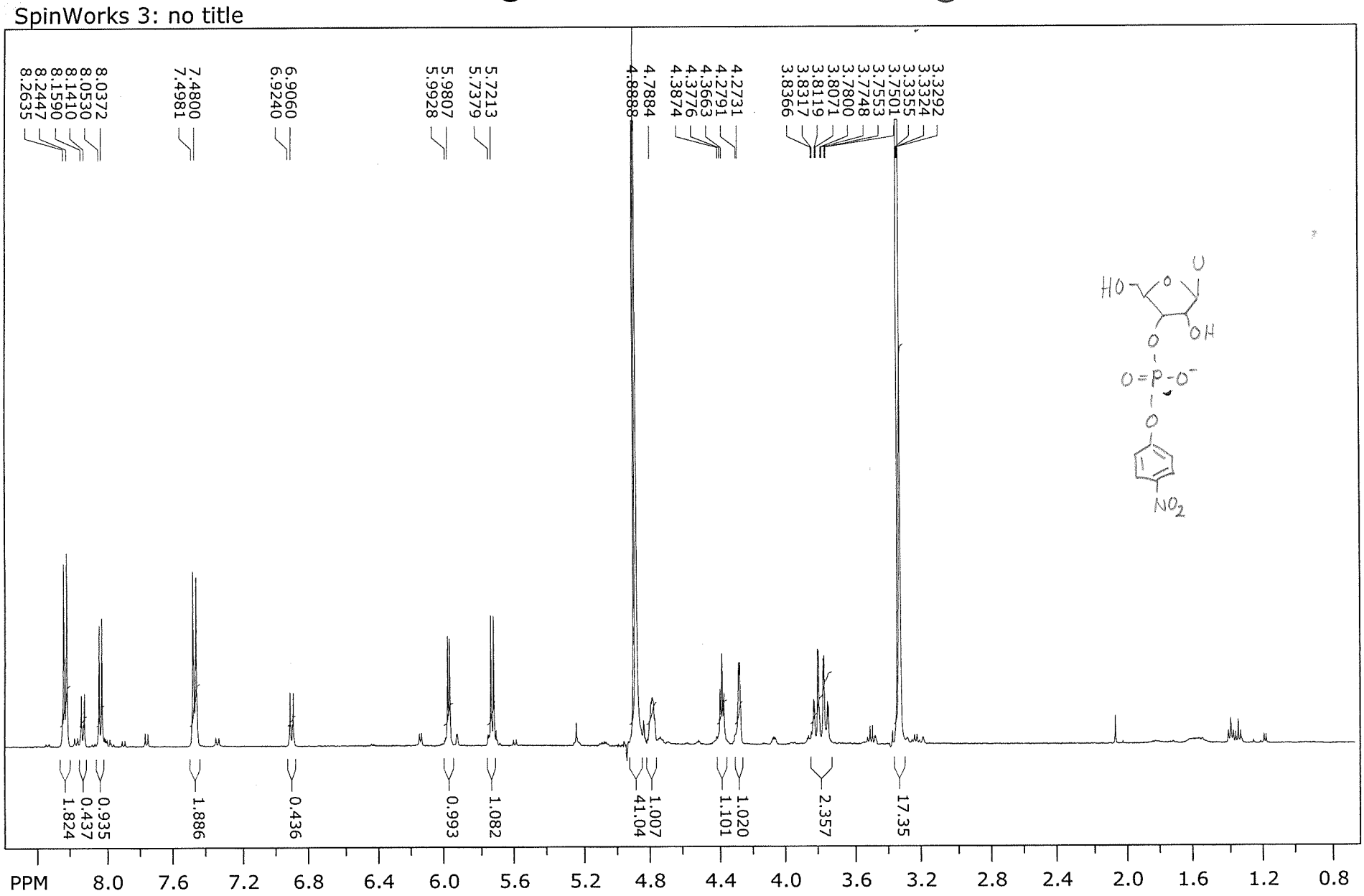
Uridine 3'-(2,5-di-chlorophenyl) phosphate



file: F:\2,5-cl\1\fid expt: <zg30>
transmitter freq.: 500.133089 MHz
time domain size: 65536 points
width: 10330.58 Hz = 20.6557 ppm = 0.157632 Hz/pt
number of scans: 16

freq. of 0 ppm: 500.130000 MHz
processed size: 32768 complex points
LB: 0.300 GF: 0.0000
Hz/cm: 157.924 ppm/cm: 0.31576

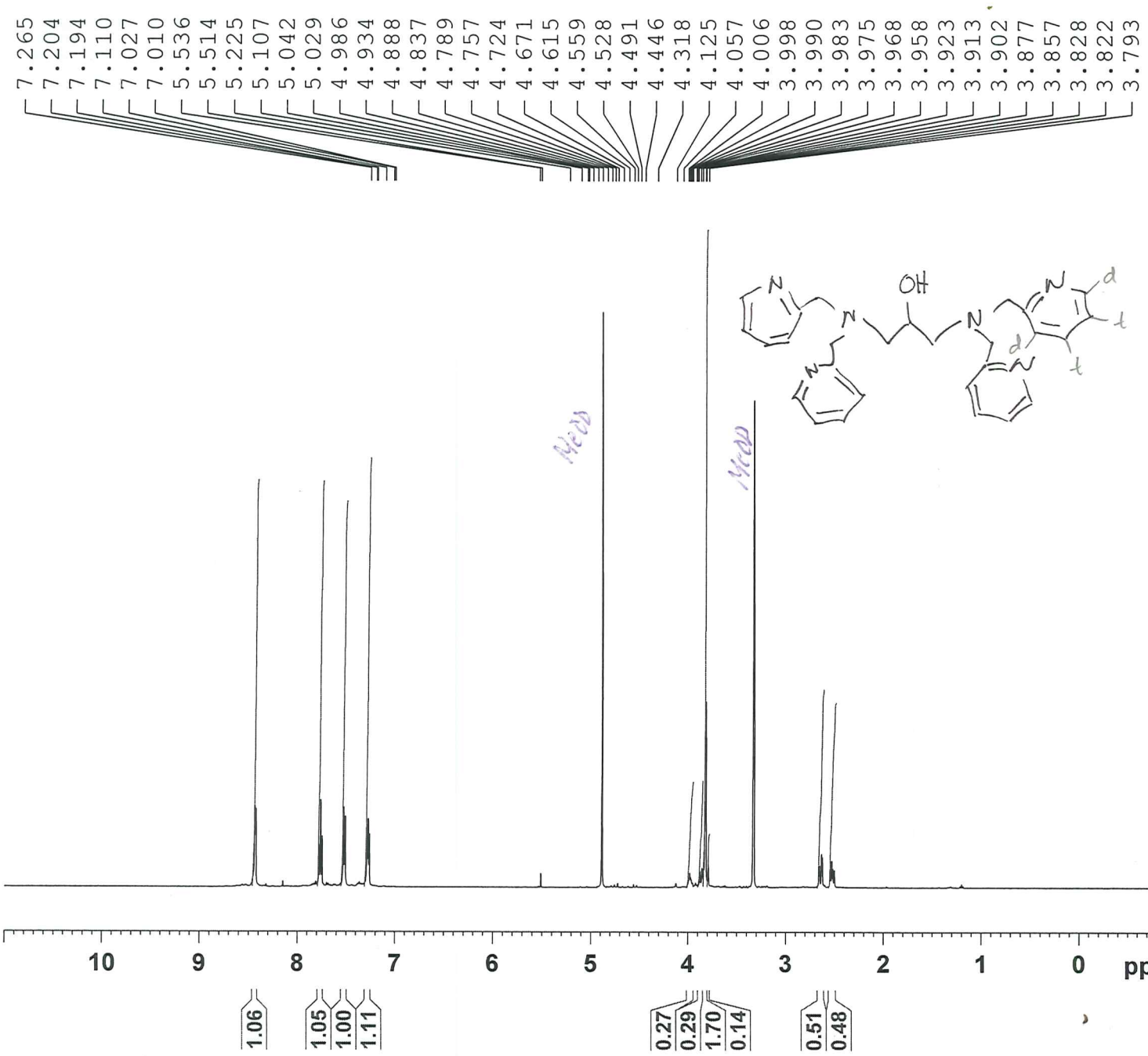
Uridine 3'-(4-nitrophenyl) phosphate



file: F:\nmr\NO2\1\fid expt: <zg30>
transmitter freq.: 500.133089 MHz
time domain size: 65536 points
width: 10330.58 Hz = 20.6557 ppm = 0.157632 Hz/pt
number of scans: 16

freq. of 0 ppm: 500.130000 MHz
processed size: 32768 complex points
LB: 0.300 GF: 0.0000
Hz/cm: 159.341 ppm/cm: 0.31860

N,N,N´,N´-tetrakis(2-pyridylmethyl)-2-hydroxy-1,3-propanediamine (19b):



BRUKER

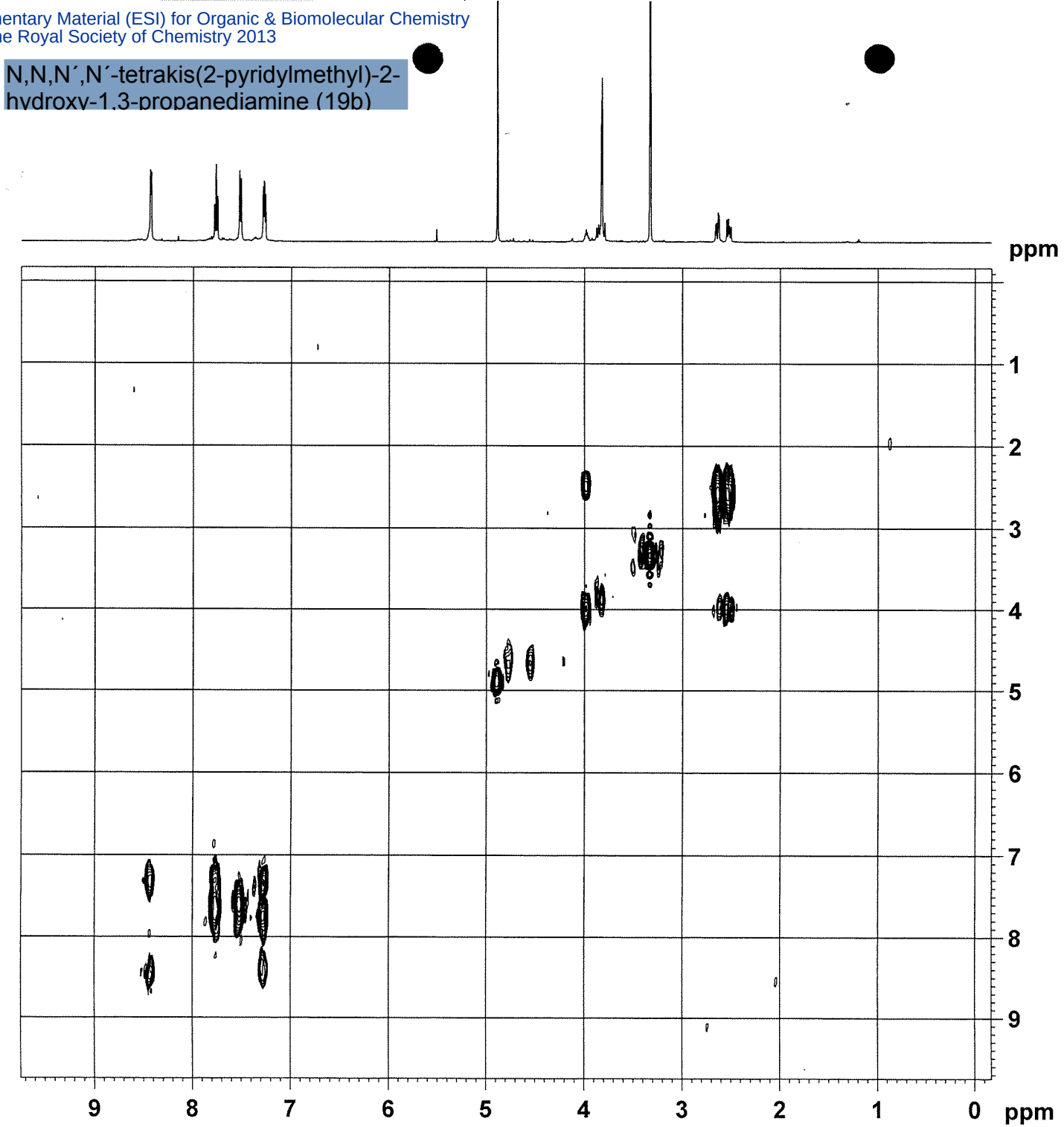
Current Data Parameters
NAME Lig05032012
EXPNO 1
PROCNO 1

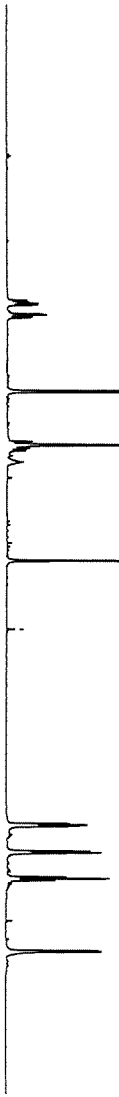
F2 - Acquisition Parameters
Date_ 20120305
Time 9.09
INSTRUM AV500
PROBHD 5 mm PABBI 1H-
PULPROG zg30
TD 65536
SOLVENT MeOD
NS 16
DS 2
SWH 10330.578 Hz
FIDRES 0.157632 Hz
AQ 3.1720407 sec
RG 456.1
DW 48.400 usec
DE 6.00 usec
TE 298.1 K
D1 1.00000000 sec
MCREST 0.00000000 sec
MCWRK 0.01500000 sec

======== CHANNEL f1 ========
NUC1 1H
P1 6.90 usec
PL1 1.50 dB
SFO1 500.1330885 MHz

F2 - Processing parameters
SI 32768
SF 500.1300000 MHz
WDW EM
SSB 0
LB 0.30 Hz
GB 0
PC 1.00

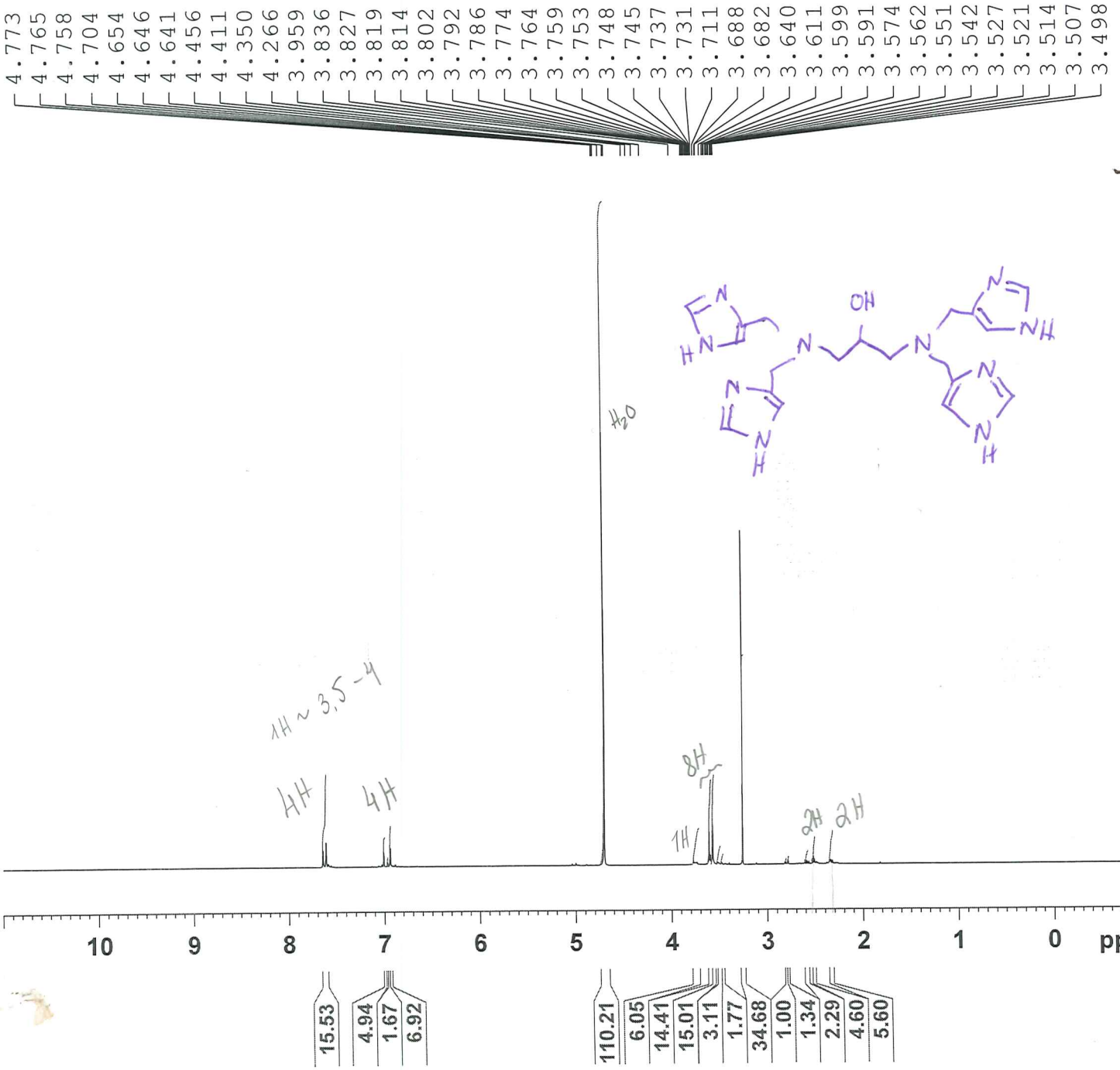
N,N,N´,N´-tetrakis(2-pyridylmethyl)-2-hydroxy-1,3-propanediamine (19b)





```
Current Data Parameters
NAME          Lig05032012
EXPNO                   2
PROCNO                  1

F2 - Acquisition Parameters
Date_            20120305
Time                9.13
INSTRUM             AV500
PROBHD   5 mm PABBI 1H-
PULPROG       cosygpmfqf
TD                  1024
SOLVENT              DMSO
NS                      2
DS                      2
SWH            6666.667 Hz
FIDRES         6.510417 Hz
AQ             0.0769250 sec
RG               20642.5
DW                75.000 usec
DE                 6.00 usec
TE                298.1 K
D0             0.00000300 sec
D1             2.00000000 sec
d13            0.00000400 sec
D16            0.00020000 sec
IN0            0.00015000 sec
MCREST         0.00000000 sec
MCWRK          2.00000000 sec

======== CHANNEL f1 ========
NUC1                   1H
P1                 6.90 usec
PL1                1.50 dB
SFO1         500.1330069 MHz

======= GRADIENT CHANNEL =====
GPNAM1          SINE.100
GPNAM2          SINE.100
GPNAM3          SINE.100
GPX1                0.00 %
GPX2                0.00 %
GPX3                0.00 %
GPY1                0.00 %
GPY2                0.00 %
GPY3                0.00 %
GPZ1               16.00 %
GPZ2               12.00 %
GPZ3               40.00 %
P16              1000.00 usec

F1 - Acquisition parameters
ND0                     1
TD                     65
SFO1           500.133 MHz
FIDRES       102.564102 Hz
SW            13.330 ppm
FnMODE                 QF

F2 - Processing parameters
SI                   1024
SF           500.1300000 MHz
WDW                  SINE
SSB                     0
LB                 0.00 Hz
GB                      0
PC                   1.00

F1 - Processing parameters
SI                   1024
MC2                    QF
SF           500.1300000 MHz
WDW                  SINE
SSB                     0
LB                 0.00 Hz
GB                      0
```

N,N,N´,N´-tetrakis(4-imidazoylmethyl)-2-hydroxy-1,3-propanediamine (22)



BRUKER

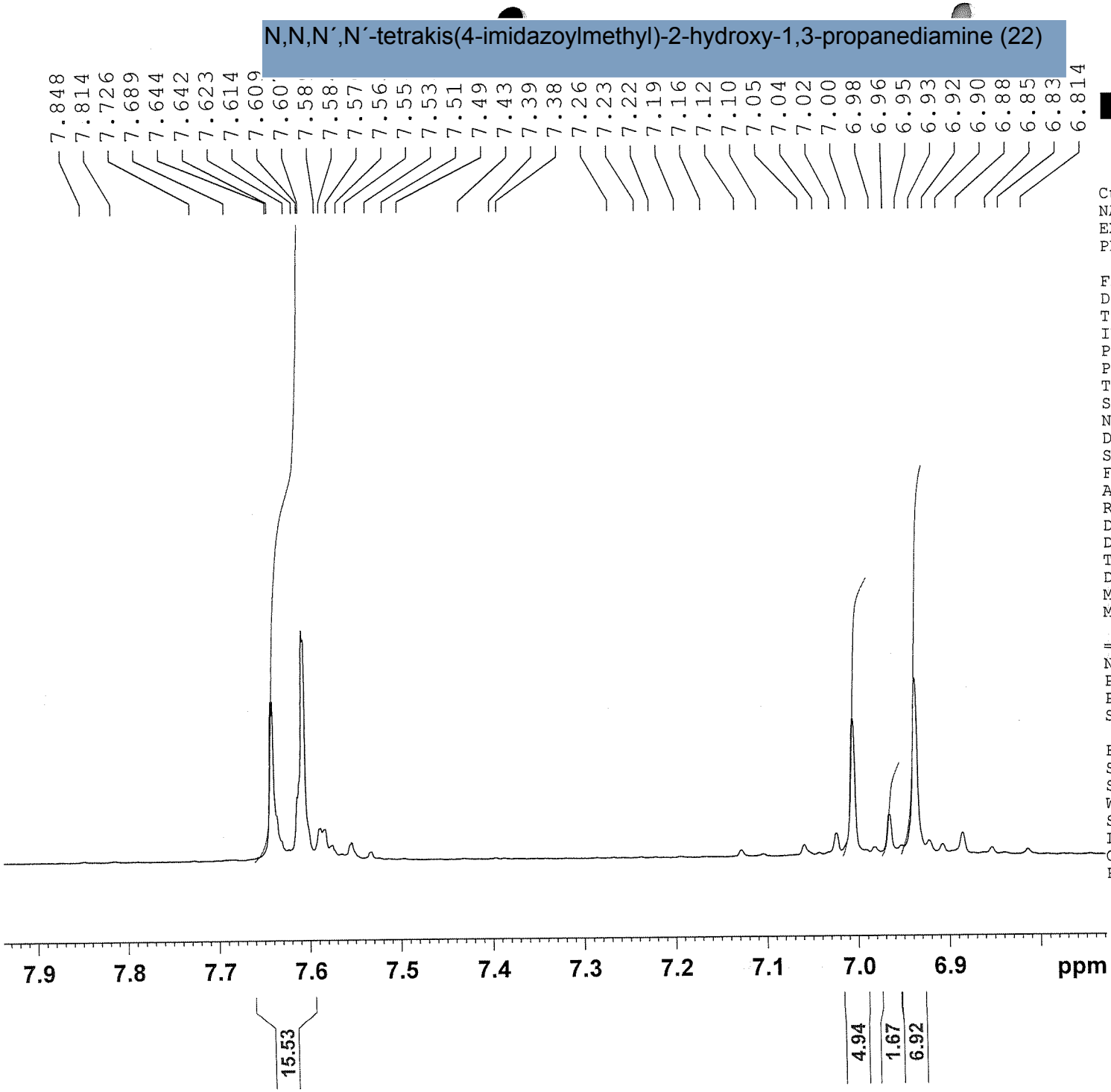
Current Data Parameters
NAME im-kationv
EXPNO 1
PROCNO 1

F2 - Acquisition Parameters
Date_ 20070625
Time 11.12
INSTRUM AV500
PROBHD 5 mm PABBI 1H-
PULPROG zg30
TD 65536
SOLVENT D2O
NS 16
DS 2
SWH 10330.578 Hz
FIDRES 0.157632 Hz
AQ 3.1720407 sec
RG 362
DW 48.400 usec
DE 6.00 usec
TE 298.1 K
D1 1.00000000 sec
MCREST 0.00000000 sec
MCWRK 0.01500000 sec

======== CHANNEL f1 ========
NUC1 1H
P1 6.90 usec
PL1 1.50 dB
SFO1 500.1330885 MHz

F2 - Processing parameters
SI 32768
SF 500.1300000 MHz
WDW EM
SSB 0
LB 0.30 Hz
GB 0
PC 1.00

N,N,N´,N´-tetrakis(4-imidazoylmethyl)-2-hydroxy-1,3-propanediamine (22)



BRUKER

Current Data Parameters

NAME	im-kationv
EXPNO	1
PROCNO	1

F2 - Acquisition Parameters

Date_	20070625
Time	11.12
INSTRUM	AV500
PROBHD	5 mm PABBI 1H-
PULPROG	zg30
TD	65536
SOLVENT	D2O
NS	16
DS	2
SWH	10330.578 Hz
FIDRES	0.157632 Hz
AQ	3.1720407 sec
RG	362
DW	48.400 usec
DE	6.00 usec
TE	298.1 K
D1	1.00000000 sec
MCREST	0.00000000 sec
MCWRK	0.01500000 sec

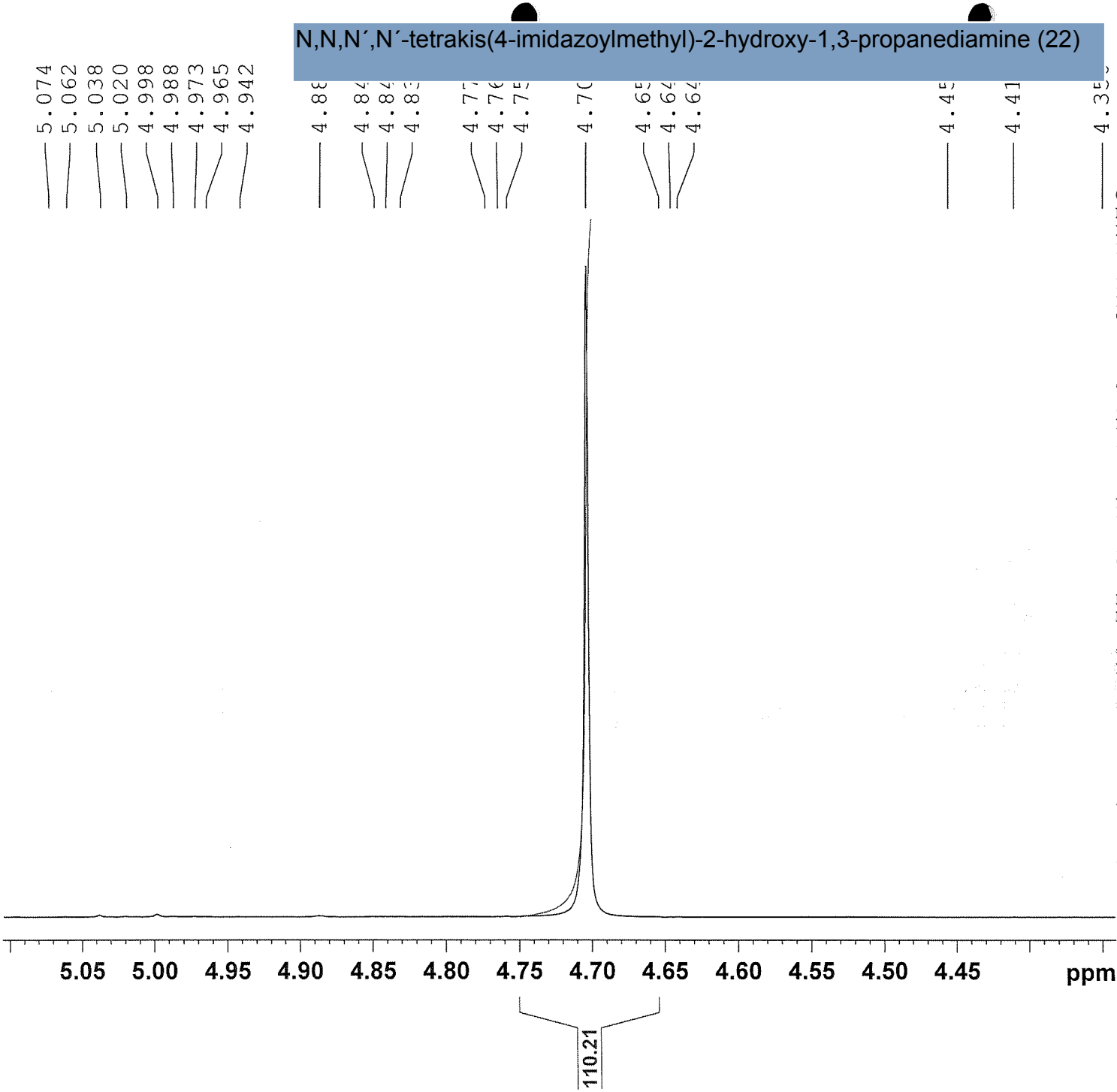
======== CHANNEL f1 ========

NUC1	1H
P1	6.90 usec
PL1	1.50 dB
SFO1	500.1330885 MHz

F2 - Processing parameters

SI	32768
SF	500.1300000 MHz
WDW	EM
SSB	0
LB	0.30 Hz
GB	0
PC	1.00

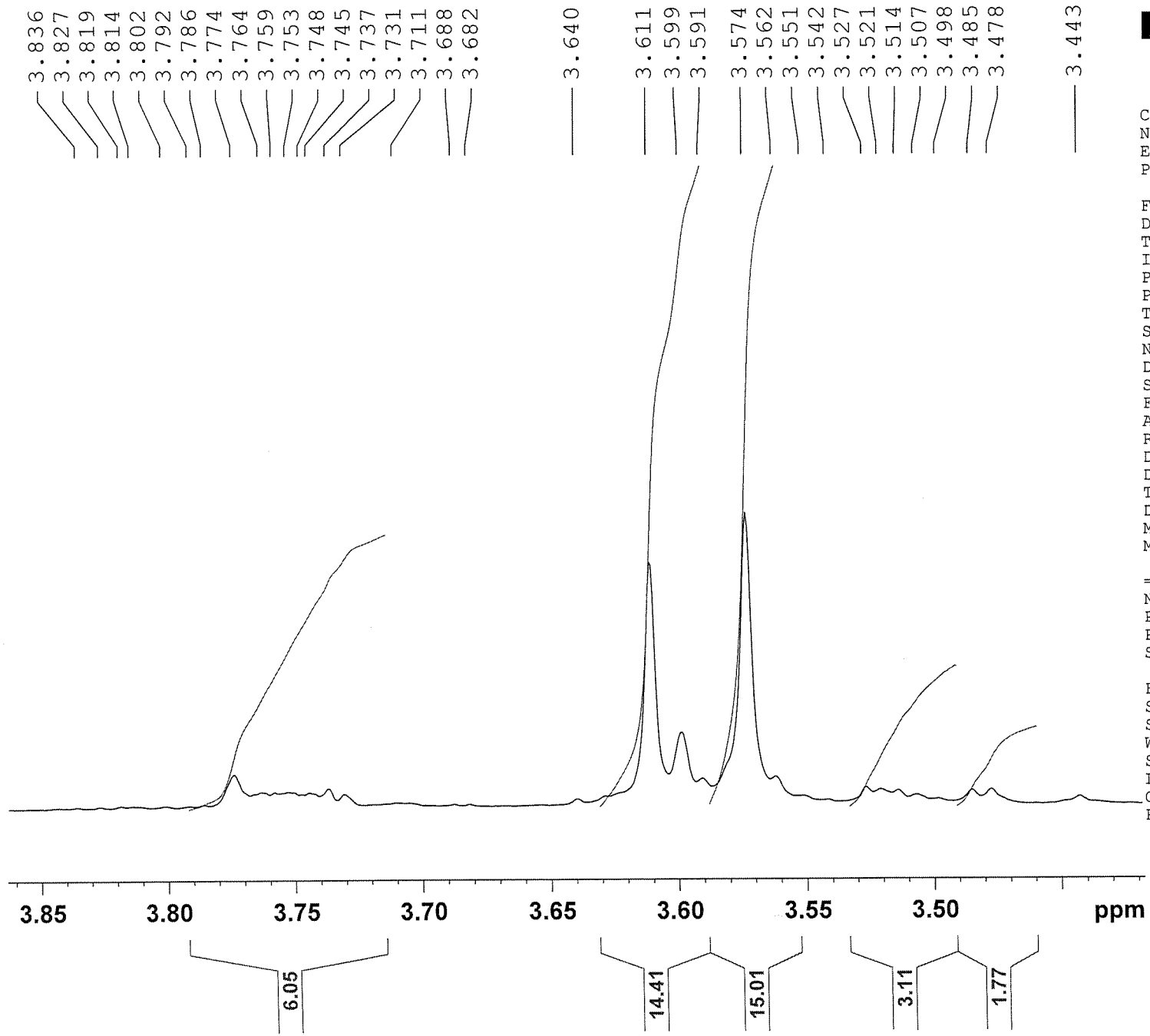
N,N,N´,N´-tetrakis(4-imidazoylmethyl)-2-hydroxy-1,3-propanediamine (22)



BRUKER

```
Current Data Parameters
NAME          im-kationv
EXPNO                  1
PROCNO                 1

F2 - Acquisition Parameters
Date_           20070625
Time              11.12
INSTRUM           AV500
PROBHD   5 mm PABBI 1H-
PULPROG            zg30
TD                65536
SOLVENT             D2O
NS                   16
DS                    2
SWH           10330.578 Hz
FIDRES         0.157632 Hz
AQ             3.1720407 sec
RG                  362
DW                48.400 usec
DE                 6.00 usec
TE                298.1 K
D1            1.00000000 sec
MCREST        0.00000000 sec
MCWRK         0.01500000 sec

======== CHANNEL f1 ========
NUC1                1H
P1                6.90 usec
PL1               1.50 dB
SFO1        500.1330885 MHz

F2 - Processing parameters
SI                 32768
SF          500.1300000 MHz
WDW                  EM
SSB                   0
LB                0.30 Hz
GB                    0
PC                1.00
```

N,N,N´,N´-tetrakis(4-imidazoylmethyl)-2-hydroxy-1,3-propanediamine (22)



Current Data Parameters

NAME	im-kationv
EXPNO	1
PROCNO	1

F2 - Acquisition Parameters

Date_	20070625
Time	11.12
INSTRUM	AV500
PROBHD	5 mm PABBI 1H-
PULPROG	zg30
TD	65536
SOLVENT	D2O
NS	16
DS	2
SWH	10330.578 Hz
FIDRES	0.157632 Hz
AQ	3.1720407 sec
RG	362
DW	48.400 usec
DE	6.00 usec
TE	298.1 K
D1	1.00000000 sec
MCREST	0.00000000 sec
MCWRK	0.01500000 sec

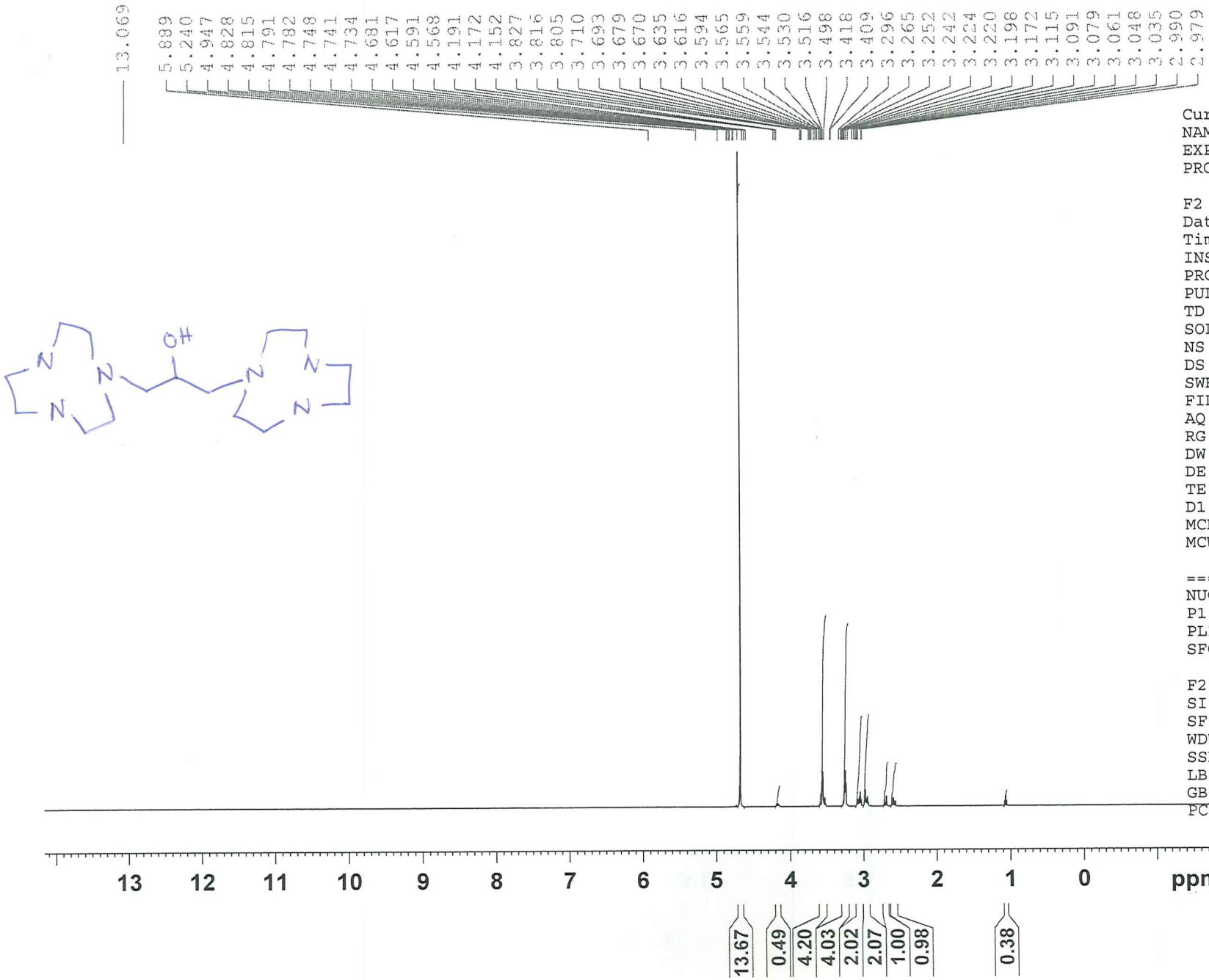
======== CHANNEL f1 ========

NUC1	1H
P1	6.90 usec
PL1	1.50 dB
SFO1	500.1330885 MHz

F2 - Processing parameters

SI	32768
SF	500.1300000 MHz
WDW	EM
SSB	0
LB	0.30 Hz
GB	0
PC	1.00

1,3-Bis(1,4,7-triazacyclonon-1-yl)-2-hydroxypropane (17a)



Current Data Parameters

NAME	L2(OH)
EXPNO	1
PROCNO	1

F2 - Acquisition Parameters

Date_	20120912
Time	8.10
INSTRUM	AV500
PROBHD	5 mm PABBI 1H-
PULPROG	zg30
TD	65536
SOLVENT	CDCl3
NS	8
DS	0
SWH	8012.820 Hz
FIDRES	0.122266 Hz
AQ	4.0895586 sec
RG	645.1
DW	62.400 usec
DE	6.00 usec
TE	298.1 K
D1	1.00000000 sec
MCREST	0.00000000 sec
MCWRK	0.01500000 sec

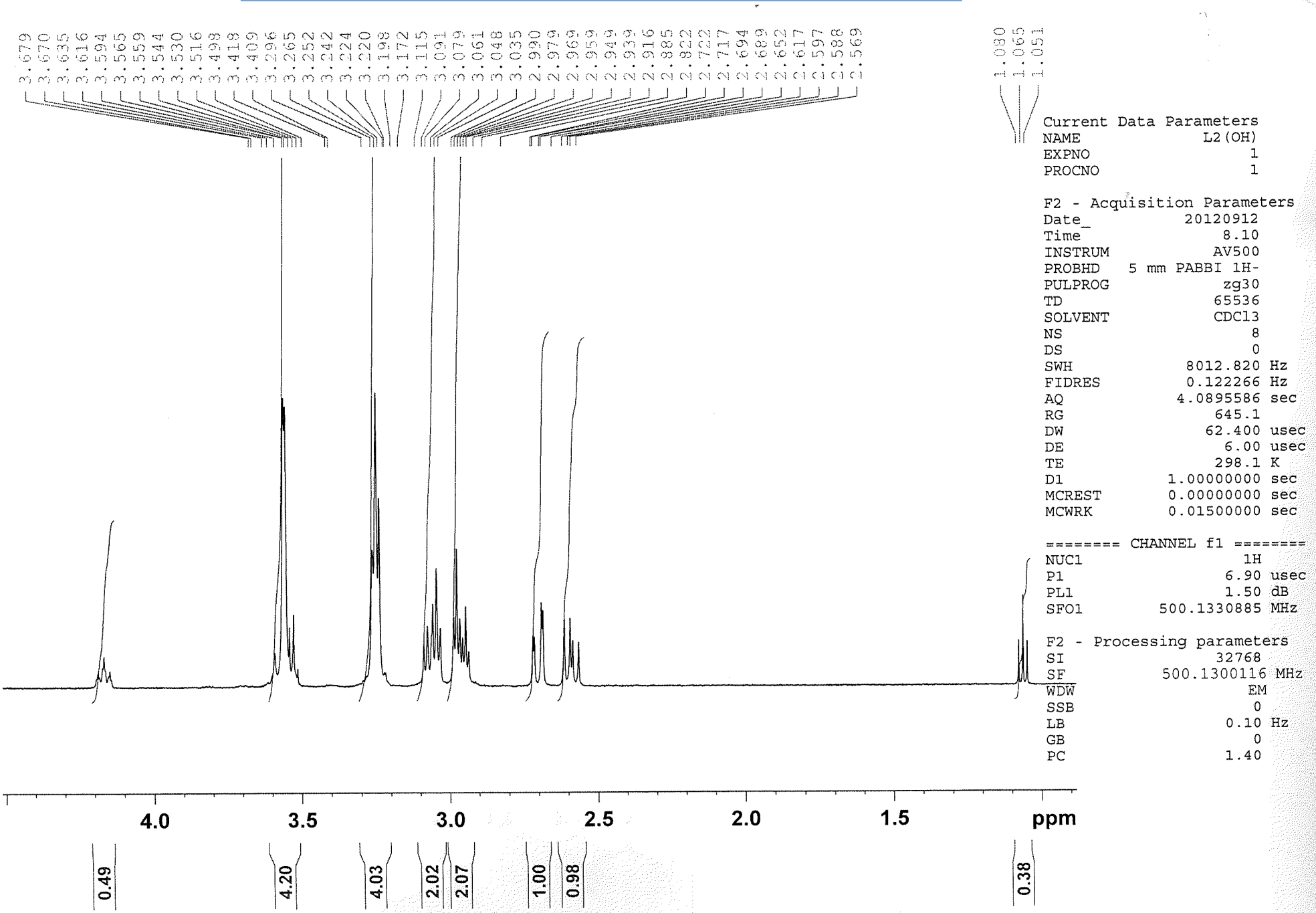
======== CHANNEL f1 ========

NUC1	1H
P1	6.90 usec
PL1	1.50 dB
SFO1	500.1330885 MHz

F2 - Processing parameters

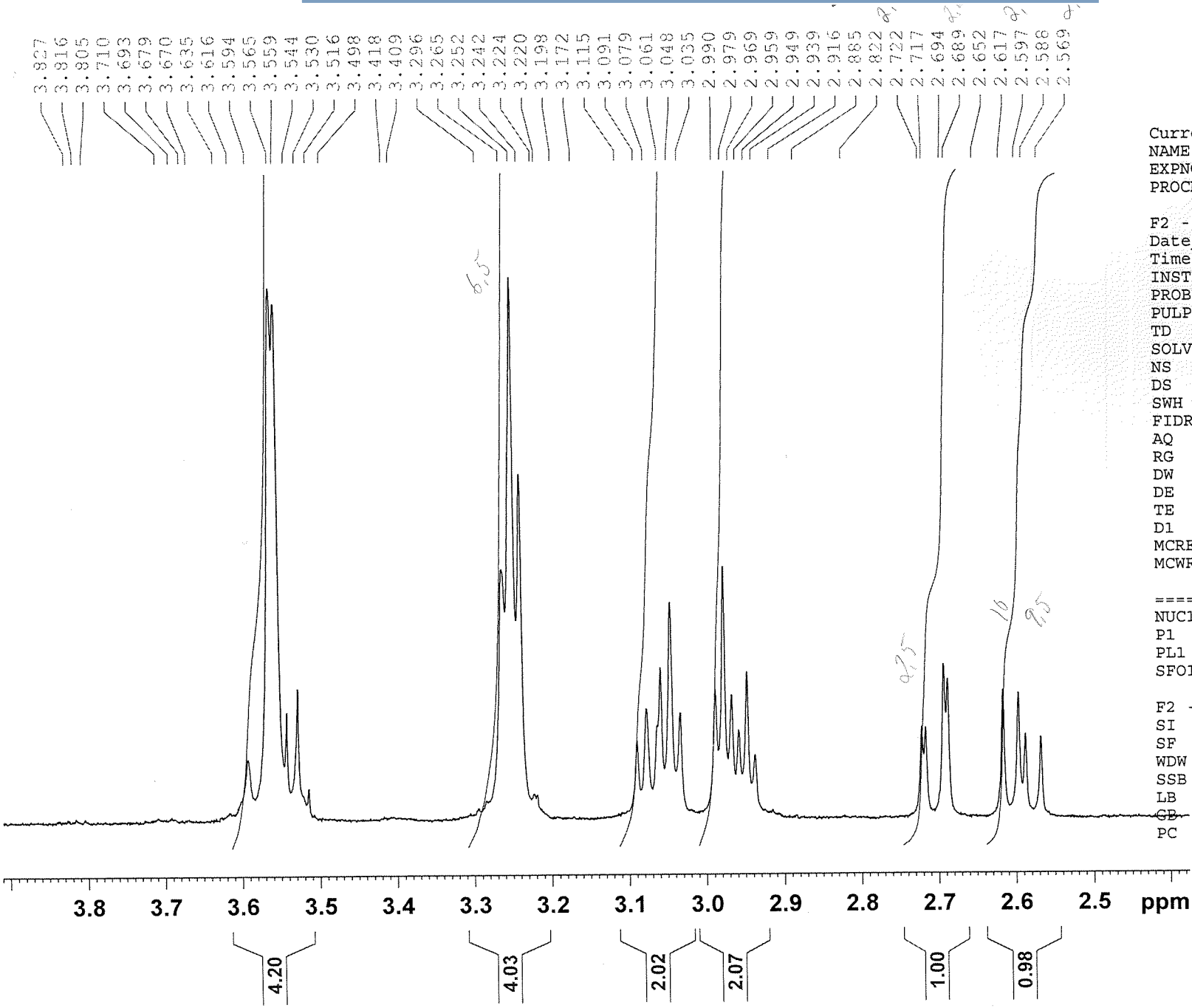
SI	32768
SF	500.1300116 MHz
WDW	EM
SSB	0
LB	0.10 Hz
GB	0
PC	1.40

1,3-Bis(1,4,7-triazacyclonon-1-yl)-2-hydroxypropane (17a)



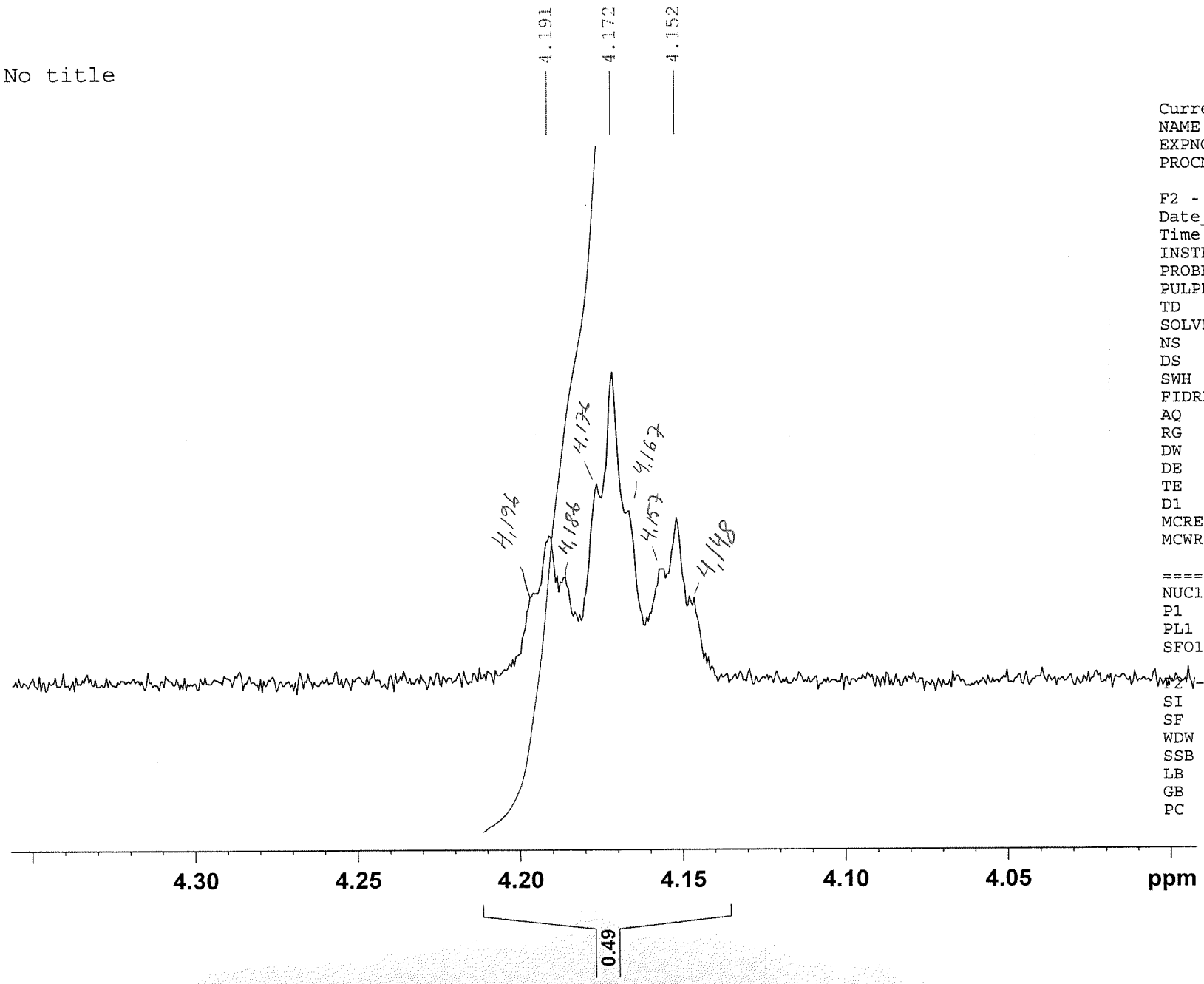

```
Current Data Parameters
NAME                  L2(OH)
EXPNO                      1
PROCNO                     1

F2 - Acquisition Parameters
Date_              20120912
Time                   8.10
INSTRUM               AV500
PROBHD    5 mm PABBI 1H-
PULPROG                zg30
TD                    65536
SOLVENT               CDCl3
NS                         8
DS                         0
SWH               8012.820 Hz
FIDRES            0.122266 Hz
AQ               4.0895586 sec
RG                     645.1
DW                  62.400 usec
DE                   6.00 usec
TE                   298.1 K
D1             1.00000000 sec
MCREST         0.00000000 sec
MCWRK          0.01500000 sec

======== CHANNEL f1 ========
NUC1                      1H
P1                   6.90 usec
PL1                  1.50 dB
SFO1          500.1330885 MHz

F2 - Processing parameters
SI                     32768
SF            500.1300116 MHz
WDW                       EM
SSB                        0
LB                   0.10 Hz
GB                         0
PC                    1.40
```

1,3-Bis(1,4,7-triazacyclonon-1-yl)-2-hydroxypropane (17a)




```
Current Data Parameters
NAME                  L2(OH)
EXPNO                      1
PROCNO                     1

F2 - Acquisition Parameters
Date_                20120912
Time                     8.10
INSTRUM                AV500
PROBHD    5 mm PABBI 1H-
PULPROG                 zg30
TD                     65536
SOLVENT                CDCl3
NS                         8
DS                         0
SWH                8012.820 Hz
FIDRES            0.122266 Hz
AQ                4.0895586 sec
RG                     645.1
DW                  62.400 usec
DE                   6.00 usec
TE                   298.1 K
D1              1.00000000 sec
MCREST          0.00000000 sec
MCWRK           0.01500000 sec

======== CHANNEL f1 ========
NUC1                      1H
P1                   6.90 usec
PL1                  1.50 dB
SFO1          500.1330885 MHz

F2 - Processing parameters
SI                     32768
SF            500.1300116 MHz
WDW                       EM
SSB                        0
LB                   0.10 Hz
GB                         0
PC                    1.40
```

1,3-Bis(1,4,7-triazacyclonon-1-yl)-2-hydroxypropane (17a)



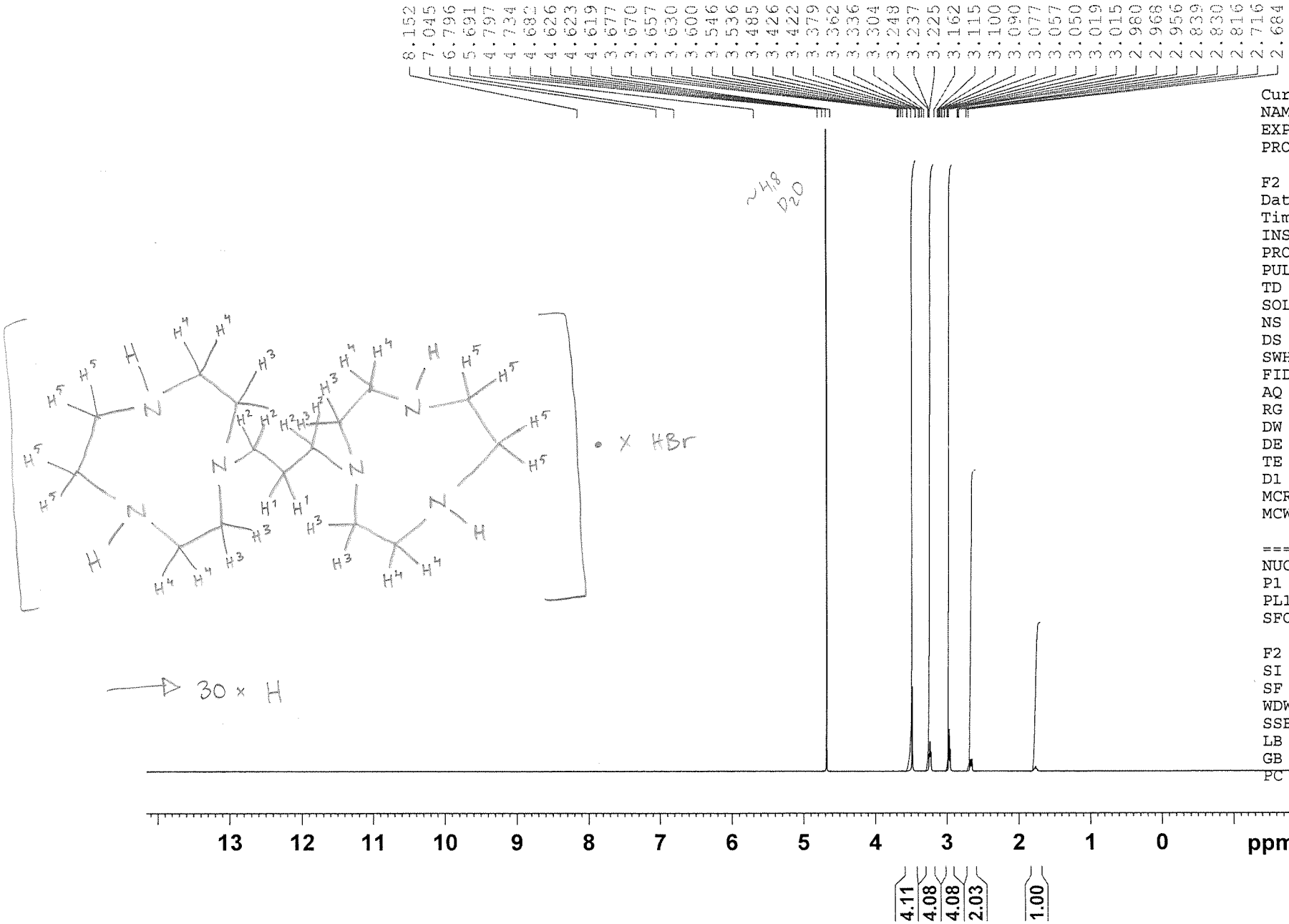

```
Current Data Parameters
NAME                  L2(OH)
EXPNO                      1
PROCNO                     1

F2 - Acquisition Parameters
Date_              20120912
Time                   8.10
INSTRUM               AV500
PROBHD    5 mm PABBI 1H-
PULPROG                zg30
TD                    65536
SOLVENT               CDCl3
NS                        8
DS                        0
SWH               8012.820 Hz
FIDRES            0.122266 Hz
AQ                4.0895586 sec
RG                    645.1
DW                 62.400 usec
DE                  6.00 usec
TE                  298.1 K
D1              1.00000000 sec
MCREST          0.00000000 sec
MCWRK           0.01500000 sec

======== CHANNEL f1 ========
NUC1                    1H
P1                  6.90 usec
PL1                 1.50 dB
SFO1          500.1330885 MHz

F2 - Processing parameters
SI                     32768
SF            500.1300116 MHz
WDW                       EM
SSB                        0
LB                  0.10 Hz
GB                         0
PC                      1.00
```

1,3-Bis(1,4,7-triazacyclonon-1-yl)-propane (17b)

L1 • x HBr

½

Bruker 500 MHz



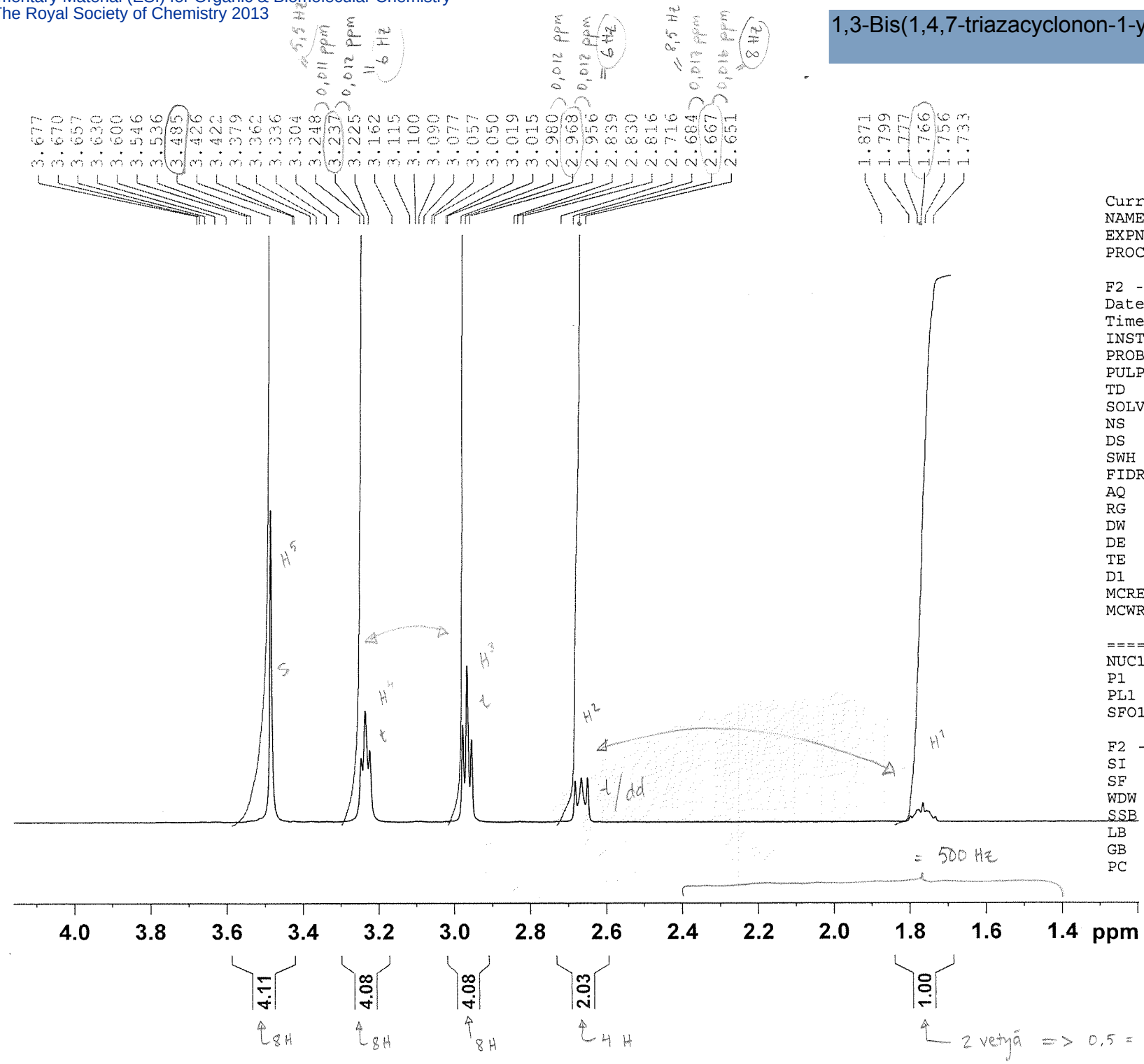
Current Data Parameters
NAME L1 (1) .121207
EXPNO 1
PROCNO 1

F2 - Acquisition Parameters
Date_ 20121207
Time 13.44
INSTRUM AV500
PROBHD 5 mm PABBI 1H-
PULPROG zg30
TD 65536
SOLVENT ~~CDCl3~~ D_2O
NS 8
DS 0
SWH 8012.820 Hz
FIDRES 0.122266 Hz
AQ 4.0895586 sec
RG 574.7
DW 62.400 usec
DE 6.00 usec
TE 298.2 K
D1 1.00000000 sec
MCREST 0.00000000 sec
MCWRK 0.01500000 sec

======== CHANNEL f1 ========
NUC1 1H
P1 ~~6.90~~ usec
PL1 1.50 dB
SFO1 500.1330885 MHz

F2 - Processing parameters
SI 32768
SF 500.1300116 MHz
WDW no
SSB 0
LB 0.00 Hz
GB 0
PC 1.40

1,3-Bis(1,4,7-triazacyclonon-1-yl)-propane (17b)



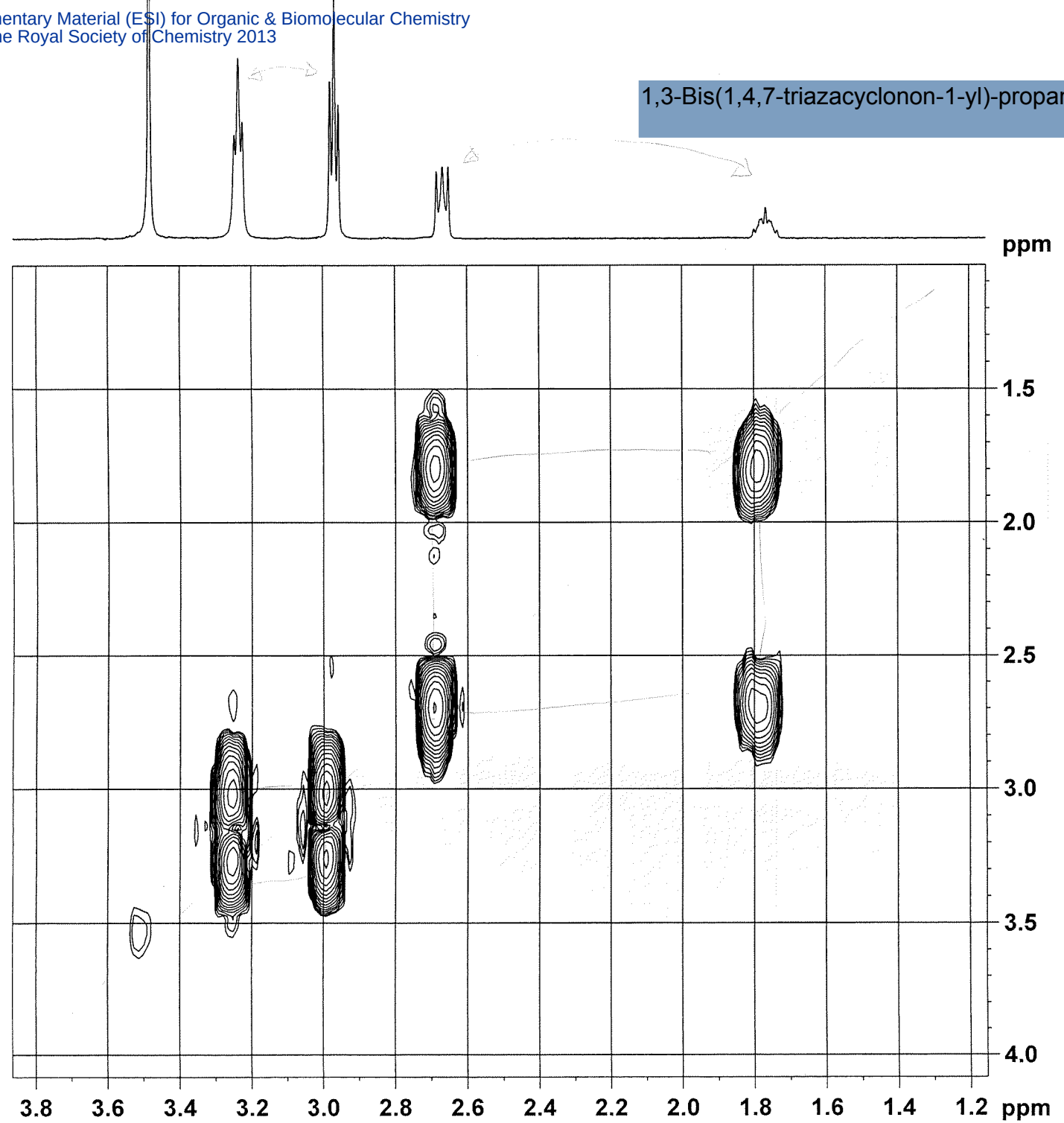
Current Data Parameters
NAME L1.1.121207
EXPNO 1
PROCNO 1

F2 - Acquisition Parameters
Date_ 20121207
Time 13.44
INSTRUM AV500
PROBHD 5 mm PABBI 1H-
PULPROG zg30
TD 65536
SOLVENT ~~CDCl3~~ D_2O
NS 8
DS 0
SWH 8012.820 Hz
FIDRES 0.122266 Hz
AQ 4.0895586 sec
RG 574.7
DW 62.400 usec
DE 6.00 usec
TE 298.2 K
D1 1.00000000 sec
MCREST 0.00000000 sec
MCWRK 0.01500000 sec

======== CHANNEL f1 ========
NUC1 1H
P1 6.90 usec
PL1 1.50 dB
SFO1 500.1330885 MHz

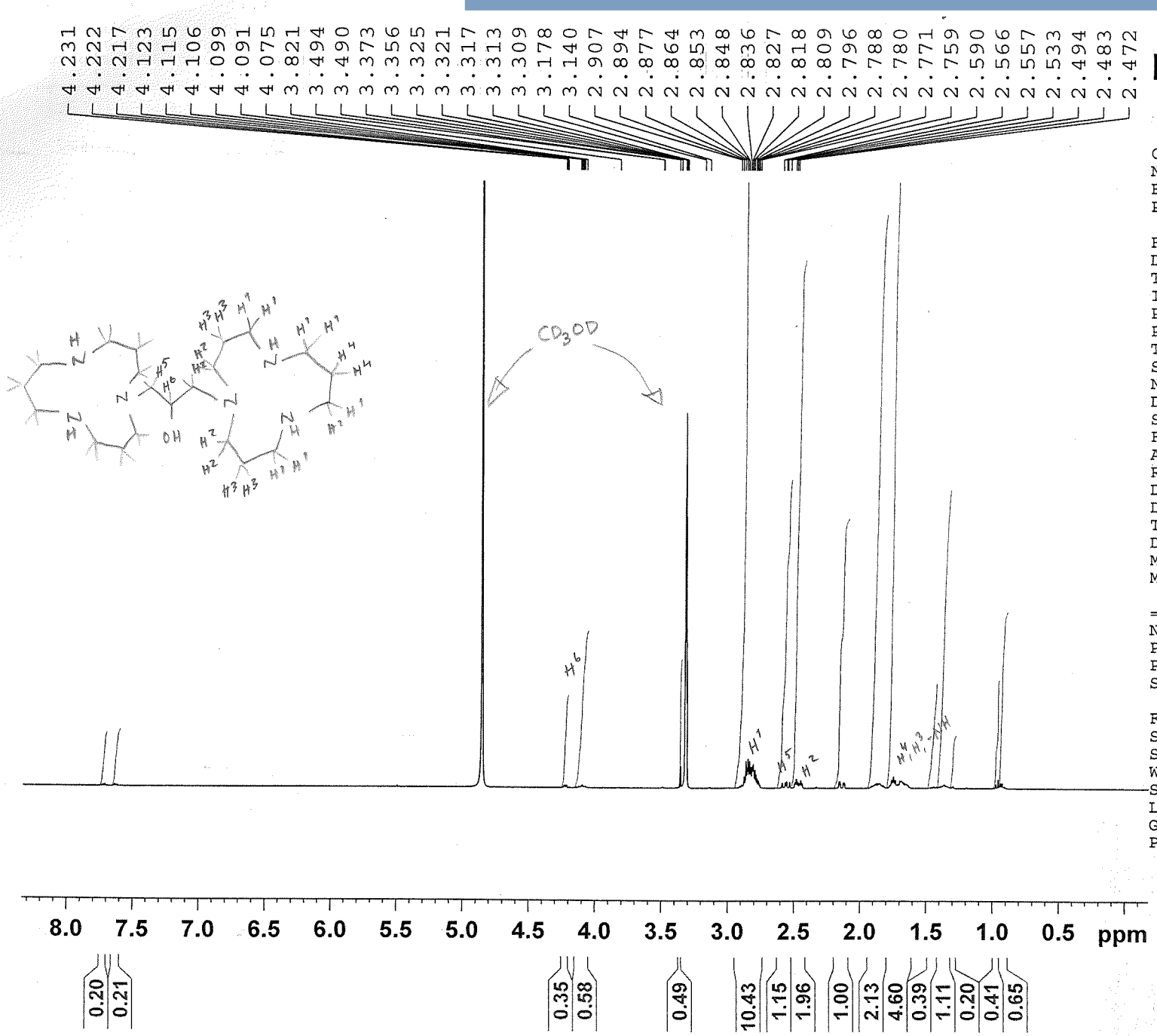
F2 - Processing parameters
SI 32768
SF 500.1300116 MHz
WDW no
SSB 0
LB 0.00 Hz
GB 0
PC 1.40

1,3-Bis(1,4,7-triazacyclonon-1-yl)-propane (17b)




```
Current Data Parameters
NAME          L1.1.121207
EXPNO                   2
PROCNO                  1

F2 - Acquisition Parameters
Date_            20121207
Time                13.51
INSTRUM             AV500
PROBHD   5 mm PABBI 1H-
PULPROG       cosygpmfgf
TD                   1024
SOLVENT             ~DMSO~ D2O
NS                      2
DS                      2
SWH            6666.667 Hz
FIDRES         6.510417 Hz
AQ             0.0769250 sec
RG                     64
DW              75.000 usec
DE               6.00 usec
TE               298.1 K
D0             0.00000300 sec
D1             2.00000000 sec
d13            0.00000400 sec
D16            0.00020000 sec
IN0            0.00015000 sec
MCREST         0.00000000 sec
MCWRK          2.00000000 sec

======== CHANNEL f1 ========
NUC1                   1H
P1                 6.90 usec
PL1                1.50 dB
SFO1         500.1330069 MHz

====== GRADIENT CHANNEL =====
GPNAM1           SINE.100
GPNAM2           SINE.100
GPNAM3           SINE.100
GPX1                0.00 %
GPX2                0.00 %
GPX3                0.00 %
GPY1                0.00 %
GPY2                0.00 %
GPY3                0.00 %
GPZ1               16.00 %
GPZ2               12.00 %
GPZ3               40.00 %
P16              1000.00 usec

F1 - Acquisition parameters
ND0                     1
TD                    120
SFO1          500.133 MHz
FIDRES         55.555557 Hz
SW                13.330 ppm
FnMODE                 QF

F2 - Processing parameters
SI                   1024
SF           500.1300000 MHz
WDW                  SINE
SSB                     0
LB                 0.00 Hz
GB                      0
PC                 1.00

F1 - Processing parameters
SI                   1024
MC2                    QF
SF           500.1300000 MHz
WDW                  SINE
SSB                     0
LB                 0.00 Hz
GB                      0
```

1,3-Bis(1,5,9-triazacyclododec-1-yl)-2-hydroxypropane (21b):



BRUKER

Current Data Parameters
NAME L2OH
EXPNO 1
PROCNO 1

F2 - Acquisition Parameters
Date_ 20130225
Time 13.01
INSTRUM av400
PROBHD 5 mm BBO BB-1H
PULPROG zg30
TD 65536
SOLVENT ~~CDCl3~~ CD_3OD
NS 16
DS 2
SWH 8250.825 Hz
FIDRES 0.125898 Hz
AQ 3.9715922 sec
RG 512
DW 60.600 usec
DE 6.00 usec
TE 298.1 K
D1 1.00000000 sec
MCREST 0.00000000 sec
MCWRK 0.01500000 sec

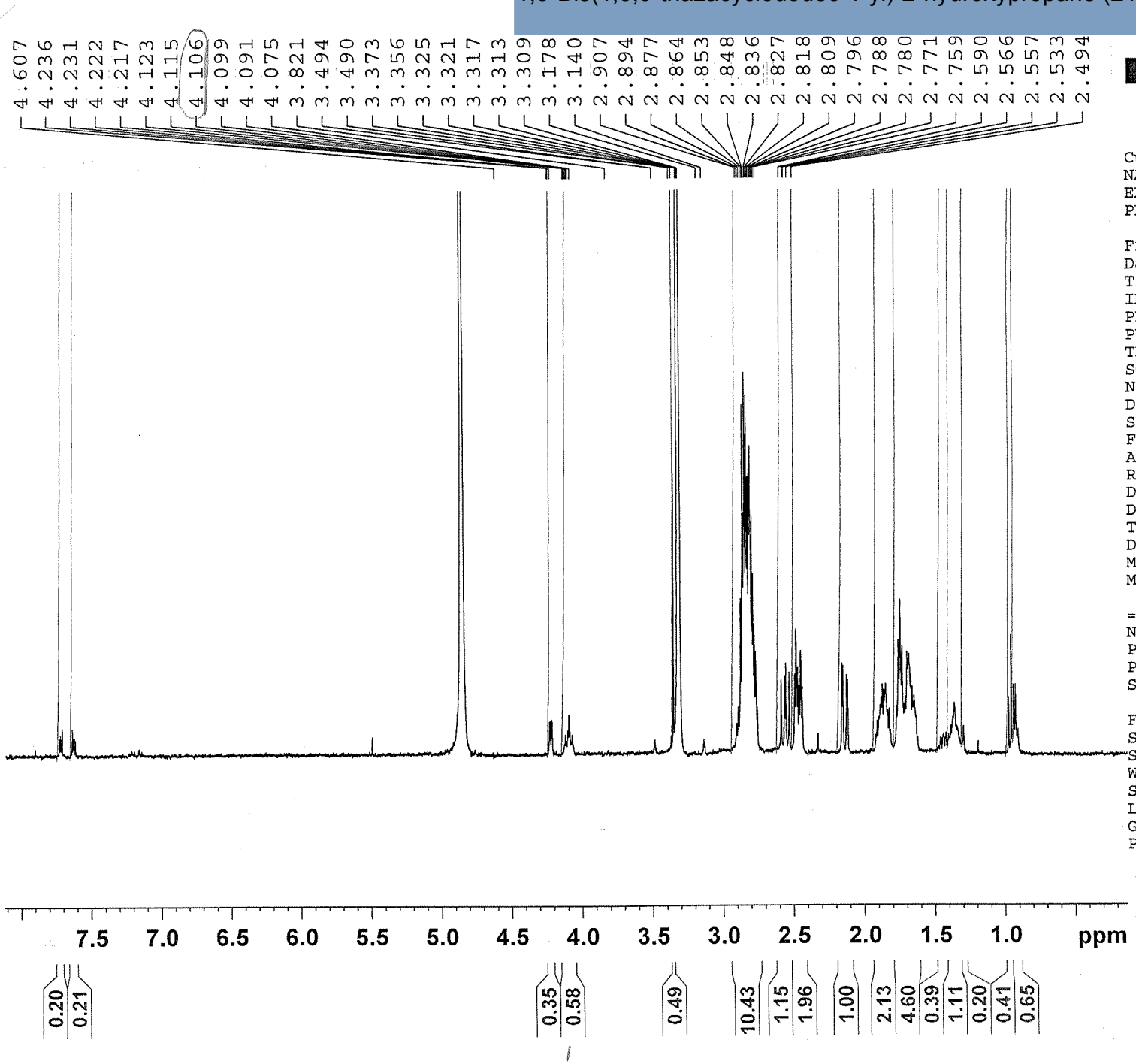
======== CHANNEL f1 ========
NUC1 1H
P1 8.10 usec
PL1 -1.00 dB
SFO1 399.7524686 MHz

F2 - Processing parameters
SI 32768
SF 399.7500000 MHz
WDW EM
SSB 0
LB 0.30 Hz
GB 0
PC 1.00

1H ~ 0,58

ARVIOITU PUHTAUS:
80-90% ol. → 0,9 x

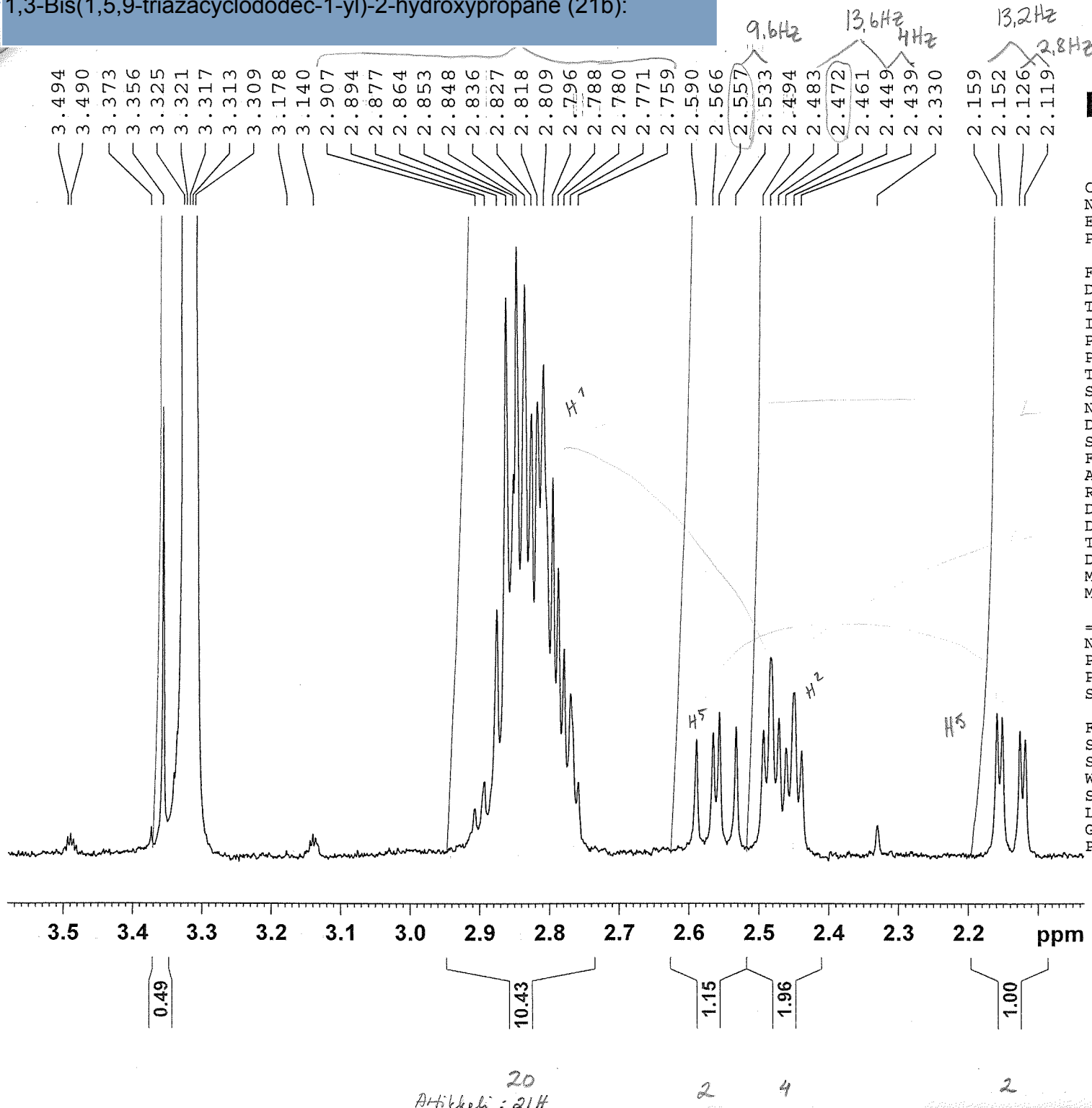
1,3-Bis(1,5,9-triazacyclododec-1-yl)-2-hydroxypropane (21b):



BRUKER

```
Current Data Parameters
NAME                  L2OH
EXPNO                    1
PROCNO                   1

F2 - Acquisition Parameters
Date_              20130225
Time                 13.01
INSTRUM              av400
PROBHD    5 mm BBO BB-1H
PULPROG              zg30
TD                  65536
SOLVENT             CDCl3   CH3OD
NS                      16
DS                       2
SWH               8250.825 Hz
FIDRES            0.125898 Hz
AQ                3.9715922 sec
RG                     512
DW                  60.600 usec
DE                   6.00 usec
TE                   298.1 K
D1              1.00000000 sec
MCREST          0.00000000 sec
MCWRK           0.01500000 sec

======== CHANNEL f1 ========
NUC1                   1H
P1                   8.10 usec
PL1                 -1.00 dB
SFO1          399.7524686 MHz

F2 - Processing parameters
SI                     32768
SF            399.7500000 MHz
WDW                       EM
SSB                        0
LB                    0.30 Hz
GB                         0
PC                      1.00
```

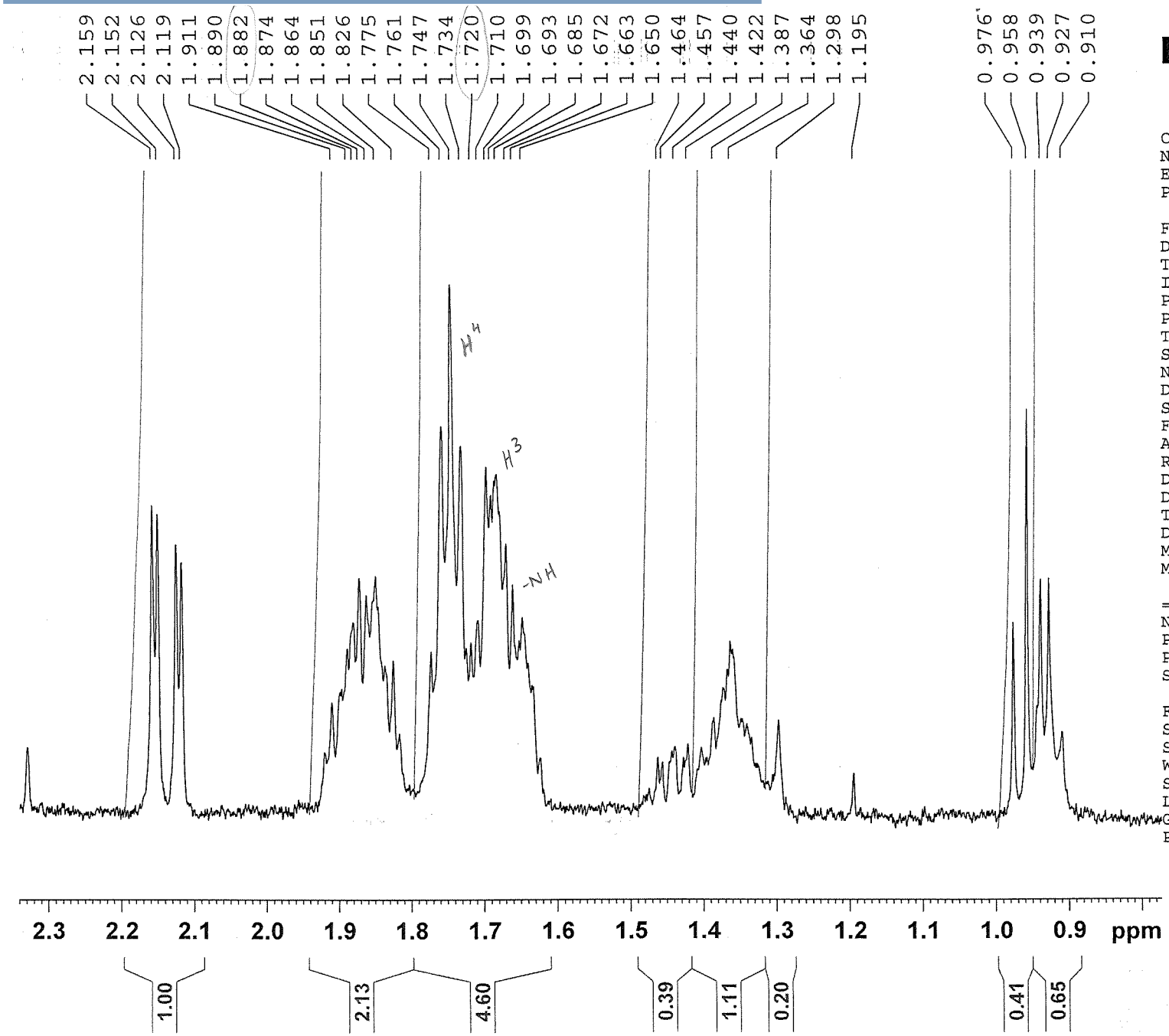
1,3-Bis(1,5,9-triazacyclododec-1-yl)-2-hydroxypropane (21b):



BRUKER

```
Current Data Parameters
NAME                  L2OH
EXPNO                    1
PROCNO                   1

F2 - Acquisition Parameters
Date_              20130225
Time                 13.01
INSTRUM              av400
PROBHD    5 mm BBO BB-1H
PULPROG              zg30
TD                  65536
SOLVENT             ~~CDCl3~~ CD3OD
NS                      16
DS                       2
SWH               8250.825 Hz
FIDRES            0.125898 Hz
AQ                3.9715922 sec
RG                     512
DW                  60.600 usec
DE                   6.00 usec
TE                  298.1 K
D1              1.00000000 sec
MCREST          0.00000000 sec
MCWRK           0.01500000 sec

======== CHANNEL f1 ========
NUC1                    1H
P1                   8.10 usec
PL1                 -1.00 dB
SFO1          399.7524686 MHz

F2 - Processing parameters
SI                   32768
SF            399.7500000 MHz
WDW                     EM
SSB                      0
LB                    0.30 Hz
GB                       0
PC                    1.00
```

1,3-Bis(1,5,9-triazacyclododec-1-yl)-2-hydroxypropane (21b):



BRUKER

Current Data Parameters

NAME	L2OH
EXPNO	1
PROCNO	1

F2 - Acquisition Parameters

Date_	20130225
Time	13.01
INSTRUM	av400
PROBHD	5 mm BBO BB-1H
PULPROG	zg30
TD	65536
SOLVENT	~~CDCl3~~ CD_3OD
NS	16
DS	2
SWH	8250.825 Hz
FIDRES	0.125898 Hz
AQ	3.9715922 sec
RG	512
DW	60.600 usec
DE	6.00 usec
TE	298.1 K
D1	1.00000000 sec
MCREST	0.00000000 sec
MCWRK	0.01500000 sec

======== CHANNEL f1 ========

NUC1	1H
P1	8.10 usec
PL1	-1.00 dB
SFO1	399.7524686 MHz

F2 - Processing parameters

SI	32768
SF	399.7500000 MHz
WDW	EM
SSB	0
LB	0.30 Hz
GB	0
PC	1.00