Stereoselective Monoalkyl Diazene Synthesis for Mild Reductive Transformations. Direct Synthesis of Densely Substituted Pyridines and Pyrimidines.

by

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Professor Mohammad Movassaghi..... .....
Thesis Supervisor

Professor Stephen L. Buchwald..... .....

To my family

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Preface

Portions of this work have been adapted from the following articles that were co-written by the author and are reproduced in part with permission from:

Movassaghi, M.; Ahmad, O. K. "*N*-Isopropylidene-*N'*-2-Nitrobenzenesulfonyl Hydrazine. A Reagent for Reduction of Alcohols via the Corresponding Monoalkyl Diazenes." *J. Org. Chem.* **2007**, *72*, 1838.

Movassaghi, M.; Hill, M. D.; Ahmad, O. K. "Direct Synthesis of Pyridine Derivatives." *J. Am. Chem. Soc.* **2007**, *129*, 10096.

Movassaghi, M.; Ahmad, O. K. "Stereospecific Palladium-Catalyzed Route to Monoalkyl Diazenes for Mild Allylic Reduction." *Angew. Chem. Int. Ed.* **2008**, *47*, 8909.

Movassaghi M., Ahmad, O. K. "Benzenesulfonic Acid, 2-Nitro-(1-Methylethylidene)hydrazide." *e-Encyclopedia of Reagents for Organic Synthesis* **2008**.

Ahmad, O. K.; Hill, M. D.; Movassaghi, M. "Synthesis of Densely Substituted Pyrimidine Derivatives." *J. Org. Chem.* **2009**, *74*, 8460.

Stereoselective Monoalkyl Diazene Synthesis for Mild Reductive Transformations. Direct Synthesis of Densely Substituted Pyridines and Pyrimidines.

by

Omar K. Ahmad

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ABSTRACT

I. *N*-Isopropylidene-*N*'-2-Nitrobenzenesulfonyl Hydrazine. A Reagent for Reduction of Alcohols via the Corresponding Monoalkyl Diazenes

The development of a new reagent *N*-isopropylidene-*N'*-2-nitrobenzenesulfonyl hydrazine (IPNBSH) is described. IPNBSH is used in the reduction of alcohols via the loss of dinitrogen from transiently formed monoalkyl diazene intermediates that can be accessed by sequential Mitsunobu displacement, hydrolysis, and fragmentation under mild reaction conditions.

II. Stereospecific Palladium-Catalyzed Route to Monoalkyl Diazenes for Mild Allylic Reduction

The first single-step stereospecific transition metal-catalyzed conversion of allylic electrophiles into monoalkyl diazenes is described. This synthesis of allylic monoalkyl diazenes offers a new strategy for asymmetric synthesis by the reduction of optically active substrates or the use of chiral catalyst systems for the reduction of racemic and prochiral substrates. Sensitive substrates are reduced in a highly selective manner.

III. Direct Synthesis of Pyridine Derivatives

A single-step conversion of various *N*-vinyl and *N*-aryl amides to the corresponding pyridine and quinoline derivatives, respectively, is described. The process involves amide activation with trifluoromethanesulfonic anhydride in the presence of 2-chloropyridine followed by π-nucleophile addition to the activated intermediate and annulation.

IV. Synthesis of Densely Substituted Pyrimidine Derivatives

The direct condensation of cyanic acid derivatives with *N*-vinyl and *N*-aryl amides to afford the corresponding C4-heteroatom substituted pyrimidines is described. The use of cyanic bromide and thiocyanatomethane in this chemistry provides versatile azaheterocycles poised for further derivatization. The synthesis of a variety of previously inaccessible C2- and C4-pyrimidine derivatives using this methodology is noteworthy.

Thesis Supervisor: Professor Mohammad Movassaghi
Title: Associate Professor of Chemistry

Table of Contents

Abbreviations

Å	angstrom
[α]	specific rotation
Ac	acetyl
AIBN	2,2'-azobisisobutyronitrile
anis	anisaldehyde
aq	aqueous
atm	atmosphere
br	broad
Bu	butyl
°C	degree Celcius
calc'd	calculated
CAM	ceric ammonium molybdate
2-Clpyr	2-chloropyridine
cm	centimeter
cm^{-1}	wavenumber
COSY	correlation spectroscopy
d	doublet
d	deuterium
δ	parts per million
dba	dibenzylydene acetone
DEAD	diethyl azodicarboxylate
diam	diameter
DMAP	4-dimethylaminopyridine
DMF	*N*,*N*-dimethylformamide
DMSO	dimethylsulfoxide
dr	diastereomeric ratio
ee	enantiomeric excess
EI	electron ionization
equiv	equivalent
ESI	electronspray ionization
Et	ethyl
FT	Fourier transform
g	gram
g	gradient
GC	gas chromatography
h	hour
ht	height
hν	photochemical irradiation
HMBC	heteronuclear multiple bond correlation
HPLC	high performance liquid chromatography
HRMS	high resolution mass spectroscopy
HSQC	heteronuclear single quantum correlation
Hz	Hertz
i	iso

IR	infrared
J	coupling constant
kcal	kilocalorie
KHMDS	potassium hexamethyldislylamide
L	liter
LAH	lithium aluminum hydride
LDA	lithium diisopropylamide
LHMDS	lithium hexadislylamide
lit.	literature value
m	medium
m	multiplet
M	molar
μ	micro
Me	methyl
mg	milligram
MHz	megahertz
min	minute
mL	mililiter
mm	millimeter
mmol	millimole
μmol	micromole
mol	mole
MS	mass spectrometry
m/z	mass to charge ratio
n	normal
NBS	*N*-bromosucinnimide
NCS	*N*-chlorosucinnimide
nm	nanometer
NMM	*N*-methylmorpholine
NMR	nuclear magnetic resonance
nOe	nuclear Overhauser effect
NOESY	nuclear Overhauser effect spectroscopy
o.d.	outer diameter
p	para
Ph	phenyl
PMA	phosphomolybdic acid
PMB	*para*-methoxybenzyl
ppm	parts per million
Pr	propyl
Pyr	pyridine
q	quartet
R_f	retention factor
ROESY	rotating frame Overhauser effect spectroscopy
s	singlet
s	strong
str	stretch

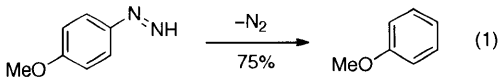
t	triplet
TBAF	tetra-*n*-butylammonium fluoride
TBS	*tert*-butyldimethylsilyl
TBDPS	*tert*-butyldiphenylsilyl
TFA	trifluoroacetic acid
Tf_2O	trifluoromethanesulfonic anhydride
THF	tetrahydrofuran
TLC	thin layer chromatography
TMS	trimethyl silyl
Ts	toluene sulfonyl
UV	ultraviolet
w	weak
Xphos	dicyclohexyl(2',4',6'-triisopropylbiphenyl-2-yl)phosphine

Chapter I

N-Isopropylidene-*N'*-2-Nitrobenzenesulfonyl Hydrazine: A Reagent for Reduction of Alcohols via the Corresponding Monoalkyl Diazenes

Introduction and Background

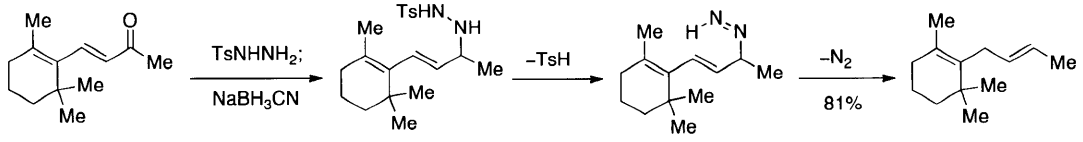
The loss of dinitrogen from monoalkyl diazene intermediates is common in a wide range of transformations in organic chemistry.[1] Some of the pioneering work in this area was done by Kosower[2] who demonstrated, through a series of mechanistic studies, that aryl and saturated alkyl diazenes lose dinitrogen via a bimolecular radical pathway to generate the corresponding reduction products (eq 1).



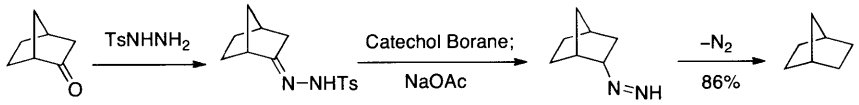
(1)

Several powerful methodologies for carbonyl reduction involve initial condensation with an arenesulfonyl hydrazide followed by reduction of the corresponding hydrazone leading to first the loss of sulfinic acid to generate the diazene intermediate, followed by loss of dinitrogen (Scheme 1) to afford the reduced product. Hutchins[1d] and Kabalka[1e] reported the reduction of a variety of ketones and aldehydes using monoalkyl diazene intermediates.

Hutchins:



Kabalka:

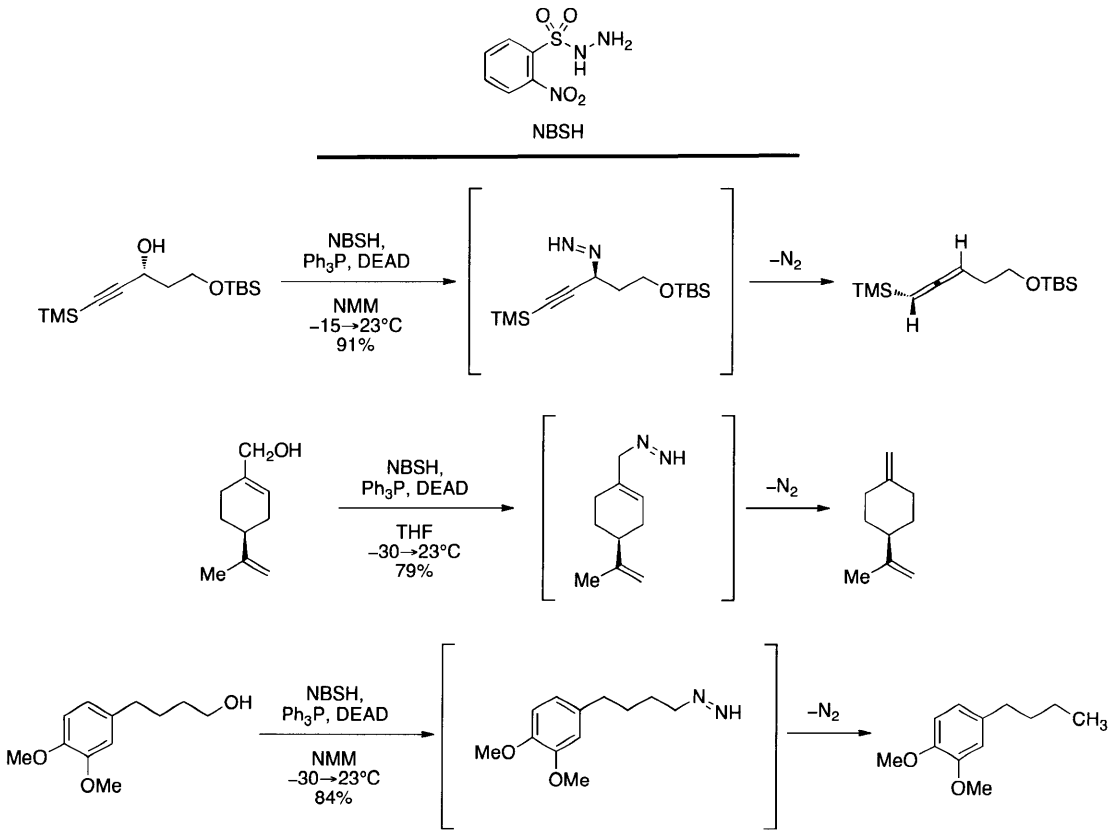


Scheme 1. Reduction of ketones using monoalkyl diazenes.

In 1996, Myers reported a highly efficient, mild, and stereospecific conversion of a variety of propargylic alcohols to the corresponding allenes[3a] via a Mitsunobu[4] reaction using the reagent 2-nitrobenzenesulfonyl hydrazine[5] (NBSH). It is noteworthy that this report was the first example of direct the use of alcohols to generate monoalkyl diazenes. Subsequent reports discussed the use of NBSH in the reduction of allylic, benzylic, and saturated alcohols (Scheme 2).[3b-c] This direct reduction of alcohols via the corresponding

monoalkyl diazene intermediates under mild reaction conditions presents a highly versatile methodology for organic synthesis.[6]

Myers:



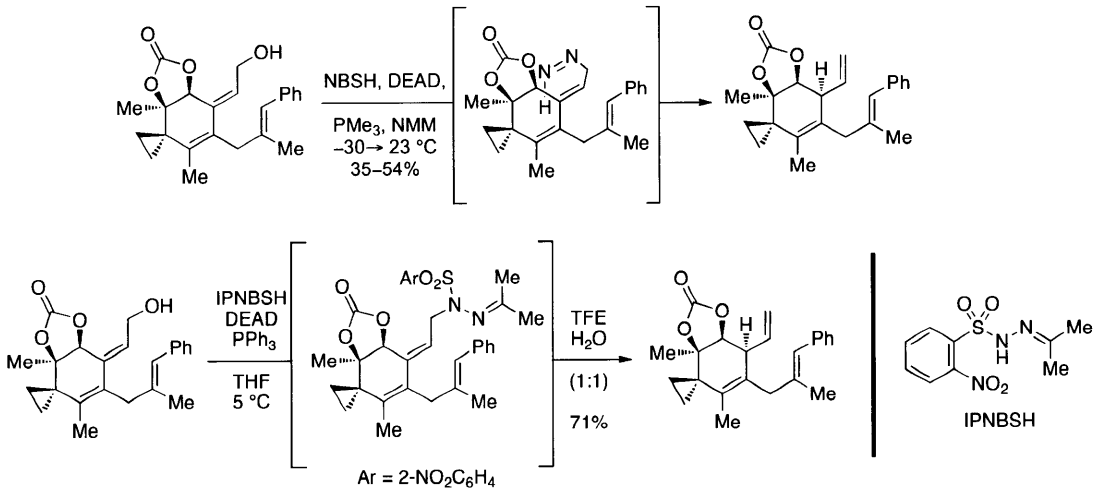
Scheme 2. Reduction of alcohols using NBSH.

The stereospecific displacement of an alcohol by the reagent NBSH under the Mitsunobu reaction conditions affords the corresponding 1,1-disubstituted sulfonyl hydrazide.[3] Warming of the reaction mixture to ambient temperature provides the corresponding monoalkyl diazene by elimination of 2-nitrobenzenesulfinic acid. Sigmatropic[3a-b] loss of dinitrogen from the unsaturated monoalkyl diazene, or expulsion of dinitrogen via a free-radical[3c] pathway from the saturated monoalkyl diazene, affords the corresponding reduction product. The thermal sensitivity of NBSH in solution and the corresponding Mitsunobu adduct necessitate the execution of the initial step in these transformations at sub-ambient temperatures (–30 to –15 °C). At lower temperatures a competitive and undesired Mitsunobu reaction of the alcohol substrate with 2-

nitrobenzenesulfinic acid, the thermal decomposition[7] product of NBSH is obviated.[3] For less reactive alcohols, the use of higher substrate concentrations and excess reagents in *N*-methyl morpholine has been described.[3b-c]

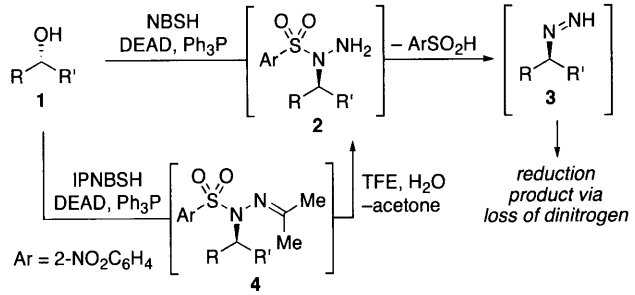
Results and Discussion

In the context of the total synthesis of (–)-irofulven, previous work[8] in our laboratory showed the use of the reagent *N*-isopropylidene-*N'*-2-nitrobenzenesulfonyl hydrazine (IPNBSH) to be advantageous over NBSH in a surprisingly difficult[9] reductive allylic transposition reaction (Scheme 3).



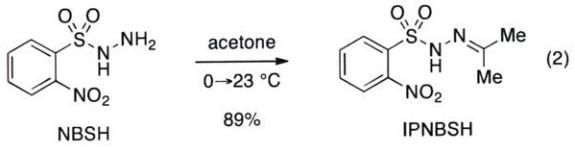
Scheme 3. Reductive transposition reaction for the total synthesis of (–)-irofulvene.

As shown in Scheme 4, the Mitsunobu displacement of an alcohol with IPNBSH results in the stable and isolable arenesulfonyl hydrazone **4**. We developed mild reaction conditions for in situ hydrolysis of hydrazone **4** to the same hydrazide **2** accessed using NBSH.



Scheme 4. Monoalkyl diazene synthesis using IPNBSH.

IPNBSH can be prepared by dissolution of the readily available NBSH[5] in acetone (eq 2). For optimal results, a solution of IPNBSH in acetone is triturated from hexanes to give the desired reagent as a white solid. Comparison of the X-ray structure of IPNBSH (crystallized from ethyl acetate) with that of the closely related acetone *p*-toluenesulfonyl hydrazone[10] reveals slightly longer C–S (1.774 vs. 1.753 Å) and shorter N(2)–S (1.636 vs. 1.637 Å) bonds consistent with greater interaction between the nitrogen(2) and sulfur in IPNBSH (Figure 1). The smaller N–N–S bond angle found in IPNBSH (112.4° vs. 114.1°) was expected to reduce the steric interaction of the *syn*-coplanar N–H and C-Me groups.



(2)

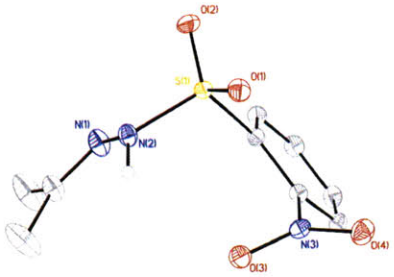
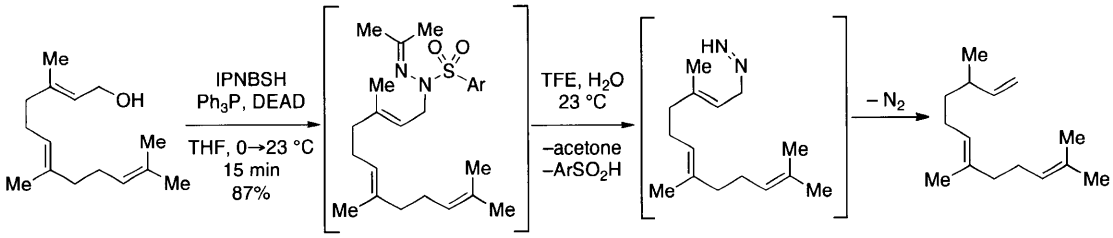


Figure 1. Crystal structure of IPNBSH

Significantly, the greater thermal stability of IPNBSH compared to NBSH was expected to provide flexibility for the Mitsunobu reaction while offering equally rapid thermal fragmentation after hydrolysis of the adduct **4** (Scheme 4). The hydrazone moiety in IPBNSH prevents elimination of sulfinic acid and makes the reagent more thermally stable. For comparison, heating a solution of IPNBSH in DMSO-d_6 [0.02M] at 50 °C for 30 minutes did not result in decomposition while a significant quantity of NBSH (~60%) was found to fragment under the same conditions. Solutions of IPNBSH as described above did not decompose at 75 or 100 °C after 30 min whereas considerable decomposition was observed at 150 °C within minutes. The greater thermal stability of IPNBSH allows it to be stored at room temperature for several months.

The utility of IPNBSH in the challenging reductive allylic transposition mentioned above prompted our evaluation of this reagent's broader utility for organic synthesis.

Addition of diethylazadicarboxylate (DEAD, 1.2 equiv) to a solution of *trans,trans*-farnesol (**1a**, 1 equiv, Scheme 5), IPNBSH (1.2 equiv), and triphenylphosphine (Ph_3P, 1.2 equiv) in THF (9.0 mL) rapidly (15 min) provided the desired Mitsunobu adduct **4a** in 86% isolated yield. The isolation of **4a** is not necessary and its direct hydrolysis under optimal conditions was achieved by introduction of trifluoroethanol–water (TFE–H_2O, 1:1) upon completion of the Mitsunobu reaction. These conditions for the hydrolysis step were found to be superior to others explored including the use of substoichiometric quantities of acetic acid, $Sc(OTf)_3$, or use of other co-solvents (MeOH and EtOH). The hydrolysis step results in elimination of 2-nitrobenzenesulfinic acid followed by sigmatropic loss of dinitrogen to give the triene **5a** in 87% isolated yield. The ease of hydrolysis of these hydrazones under mild conditions is likely due to the rapid fragmentation of the corresponding sulfonyl hydrazide derivatives at room temperature.[11]



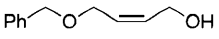
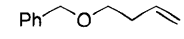
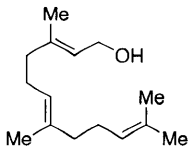
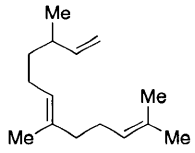
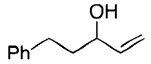
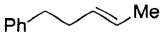
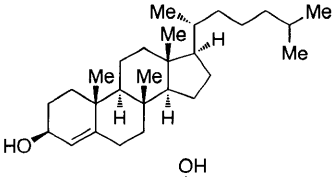
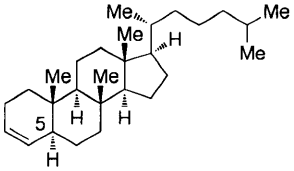
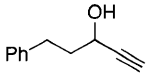
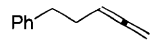
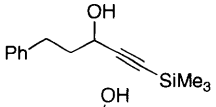
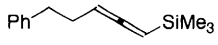
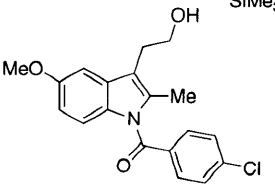
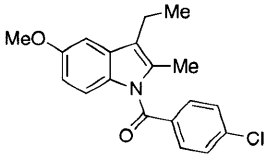
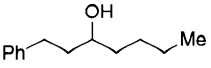
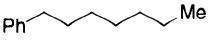
Scheme 5. Reduction of *trans,trans*-farnesol using IPNBSH.

A uniform set of reaction conditions proved effective for a single-step reduction of a range of alcohols (Table 1). Allylic alcohols (Table 1, entries 1-4) and propargylic alcohols (Table 1, entries 5-6) provided the desired reduction products via the expected sigmatropic loss of dinitrogen from the intermediate monoalkyl diazenes generated by in situ hydrolysis. For unhindered primary alcohols the reaction could be conducted at even lower concentration (0.05M) and sub-ambient temperatures with equal efficiency. The use of IPNBSH allowed the use of other solvents (e.g., toluene, fluorobenzene, and chlorobenzene) in place of THF with similar results.

Interestingly, while the Mitsunobu reaction with the primary alcohol in entry 7 of Table 1 proceeded smoothly under standard conditions (adduct isolated in 93% yield), the

hydrolysis of the corresponding hydrazone adduct **4** under the conditions used for propargylic and allylic substrates proved ineffective, affording less than 20% yield of the

Table 1. Reduction of Alcohols using IPNBSH [a]

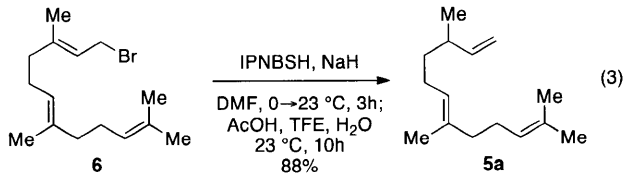
Entry	Substrate	Product	Yield(%)[b]
1			84[c]
2			82[c,d]
3			69[e]
4			60[f]
5			70
6			87
7			87[g]
8			35[g]

[a] Conditions: Ph_3P (1.2 equiv), DEAD (1.2 equiv), IPNBSH (1.2 equiv), THF [0.1M], 0→23°C, 2h; TFE–H_2O (1:1), 2h. [b] Average of two experiments. [c] Hydrolysis step required 3 h. [d] The Mitsunobu reaction was complete in 15 min. [e] *E*:*Z* = 93:7. [f] 2.0 equiv of reagents was used; contains <8% of C5-diastereomer. [g] 1.6 equiv of reagents was used; $PhNHNH_2$ (5.0 equiv) was used in place of TFE–H_2O.

desired reduction product.[12] We reasoned that while slow hydrolysis and generation of unsaturated (propargylic and allylic) monoalkyl diazenes led to an efficient sigmatropic loss of dinitrogen, the loss of dinitrogen from saturated monoalkyl diazenes would be optimal at higher concentrations of the diazene intermediate.[2,13] The replacement of the hydrolysis step with a hydrazone exchange reaction (phenylhydrazine), reduced the time

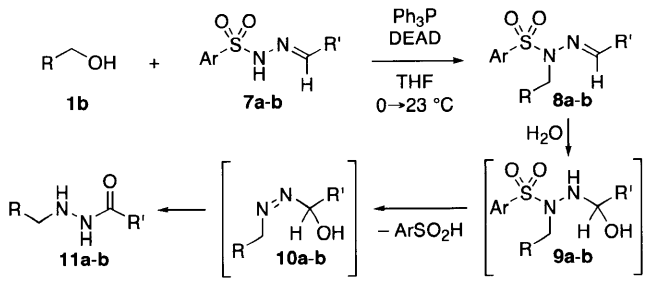
for the complete consumption of the Mitsunobu adduct from 4h to 30 min (TLC analysis).[14] The limitation of IPNBSH is its greater sensitivity toward sterically hindered substrates as compared to NBSH. For example, the Mitsunobu reaction with the saturated secondary alcohol in entry 8 of Table 1 proved difficult as compared to the reaction of unsaturated secondary alcohols (Table 1, entries 3-6). More forcing reaction conditions did not increase the isolated yield of the desired product and returned the starting alcohol.[15]

The thermal stability of IPNBSH allows for unique transformations such as the one shown in equation 3. *N*-Alkylation of the corresponding sodium sulfonamide of IPNBSH with allylic bromide **6** followed by in situ hydrolysis afforded the desired terminal alkene **5a** via sigmatropic loss of dinitrogen. This single-step *N*-alkylation–reduction strategy offers a valuable alternative to the Mitsunobu reaction.



(3)

In addition to IPNBSH, we examined a series of other hydrazone derivatives as potential reagents for the conversion of alcohols to the corresponding monoalkyl diazenes. These included the 2-nitrobenzenesulfonyl hydrazones of trifluoroacetone, dichloroacetone, cyclobutanone, benzaldehyde, acetaldehyde, and trimethylacetaldehyde, in addition to methanesulfonyl hydrazones of acetone and benzaldehyde. IPNBSH was identified as the best reagent based on optimal reactivity in the Mitsunobu reaction and ease of hydrolysis of the corresponding adduct. Interestingly, while the Mitsunobu reaction of the aldehyde hydrazone derivatives proceeded with equal efficiency as IPNBSH their hydrolysis gave the corresponding carbonyl hydrazide and not the expected monoalkyl diazene derivative or the reduction product (Scheme 6). This is likely due to isomerization[16] of transient α-hydroxyalkyldiazene intermediates **10a-b**.



Ar = 2-$NO_2C_6H_4$; R = (4-chloro-phenyl)-[5-methoxy-2-methyl-3-(2-ethyl)-indol-1-yl]-methanone; **7a-11a**, R' = Me; **7b-11b**, R' = ^{t}Bu

Scheme 6. Isomerization of α-hydroxyalkyldiazenes

Conclusion

The reagent IPNBSH serves as a complementary reagent to NBSH for conversion of alcohols to the corresponding reduction products via monoalkyl diazene intermediates. Attractive features of this reagent include ease of preparation, storage, and use due to excellent thermal stability. IPNBSH offers flexibility with respect to solvent choice, reaction temperature, order of addition, and concentration of substrate and reagents in the Mitsunobu reaction.

---

[1] For representative examples, see: (a) Szmant, H. H.; Harnsberger, H. F.; Butler, T. J.; Barie, W. P. *J. Org. Chem.* **1952**, *74*, 2724. (b) Nickon, A.; Hill, A. S. *J. Am. Chem. Soc.* **1964**, *86*, 1152. (c) Corey, E. J.; Cane, D. E.; Libit, L. *J. Am. Chem. Soc.* **1971**, *93*, 7016. (d) Hutchins, R. O.; Kacher, M.; Rua, L. *J. Org. Chem.* **1975**, *40*, 923. (e) Kabalka, G. W.; Chandler, J. H. *Synth. Commun.* **1979**, *9*, 275. (f) Corey, E. J.; Wess, G.; Xiang, Y. B.; Singh, A. K. *J. Am. Chem. Soc.* **1987**, *109*, 4717. (g) Myers, A. G.; Kukkola, P. J. *J. Am. Chem. Soc.* **1990**, *112*, 8208. (h) Myers, A. G.; Finney, N. S. *J. Am. Chem. Soc.* **1990**, *112*, 9641. (i) Guziec, F. S., Jr.; Wei, D. *J. Org. Chem.* **1992**, *57*, 3772. (j) Wood, J. L.; Porco, J. A., Jr.; Taunton, J.; Lee, A. Y.; Clardy, J.; Schreiber, S. L. *J. Am. Chem. Soc.* **1992**, *114*, 5898. (k) Bregant, T. M.; Groppe, J.; Little, R. D. *J. Am. Chem. Soc.* **1994**, *116*, 3635. (l) Ott, G. R.; Heathcock, C. H. *Org. Lett.* **1999**, *1*, 1475. (m) Chai, Y.; Vicic, D. A.; McIntosh, M. C. *Org. Lett.* **2003**, *5*, 1039. (n) Sammis, G. M.; Flamme, E. M.; Xie, H.; Ho, D. M.; Sorensen, E. J. *J. Am. Chem. Soc.* **2005**, *127*, 8612.

[2] (a) Kosower, E. M. *Acc. Chem. Res.* **1971**, *4*, 193. (b) Tsuji, T.; Kosower, E. M. *J. Am. Chem. Soc.* **1971**, *93*, 1992.

[3] (a) Myers, A. G.; Zheng, B. *J. Am. Chem. Soc.* **1996**, *118*, 4492. (b) Myers, A. G.; Zheng, B. *Tetrahedron Lett.* **1996**, *37*, 4841. (c) Myers, A. G.; Movassaghi, M.; Zheng, B. *J. Am. Chem. Soc.* **1997**, *119*, 8572.

[4] (a) Mitsunobu, O. *Synthesis* **1981**, 1. (b) Hughes, D. L. *Org. React.* **1982**, *42*, 335.

[5] NBSH can be prepared by addition of hydrazine hydrate to 2-nitrobenzenesulfonyl chloride, see: (a) Dann, A. T.; Davies, W. *J. Chem. Soc.* **1929**, 1050. (b) Myers, A. G.; Zheng, B.; Movassaghi, M. *J. Org.*

Chem. **1997**, *62*, 7507. (c) Myers, A. G.; Zheng, B. *Org. Synth.* **1999**, 76, 178. (d) Myers, A. G.; Movassaghi M. *e-Encyclopedia of Reagents for Organic Synthesis* **2003**.

[6] For examples in the utility of NBSH in synthesis, see: (a) Shepard, M. S.; Carreira, E. M. *J. Am. Chem. Soc.* **1997**, *119*, 2597. (b) Corey, E. J.; Huang, A. X. *J. Am. Chem. Soc.* **1999**, *121*, 710. (c) Arredondo, V. M.; Tian, S.; McDonald, F. E.; Marks, T. J. *J. Am. Chem. Soc.* **1999**, *121*, 3633. (d) Kozmin, S. A.; Rawal, V. H. *J. Am. Chem. Soc.* **1999**, *121*, 9562. (e) Charette, A. B.; Jolicoeur, E.; Bydlinski, G. A. S. *Org. Lett.* **2001**, *3*, 3293. (f) Haukaas, M. H.; O'Doherty, G. A. *Org. Lett.* **2002**, *4*, 1771. (g) Regás, D.; Afonso, M. M.; Rodríguez, M. L.; Palenzuela, J. A. *J. Org. Chem.* **2003**, *68*, 7845. (h) McGrath, M. J.; Fletcher, M. T.; König, W. A.; Moore, C. J.; Cribb, B. W.; Allsopp, P. G.; Kitching, W. *J. Org. Chem.* **2003**, *68*, 3739. (i) Ng, S.-S., Jamison, T. F. *Tetrahedron* **2005**, *61*, 11405. (j) Michael, F. E.; Duncan, A. P.; Sweeney, Z. K.; Bergman, R. G. *J. Am. Chem. Soc.* **2005**, *127*, 1752. (k) Charest, M. G.; Lerner, C. D.; Brubaker, J. D.; Siegel, D. R.; Myers, A. G. *Science* **2005**, *308*, 395.

[7] Hünig, S.; Müller, H. R.; Thier, W. *Angew. Chem., Int. Ed. Engl.* **1965**, *4*, 271.

[8] (a) Movassaghi, M.; Piizzi, G.; Siegel, D. S.; Piersanti, G. *Angew. Chem. Int. Ed.* **2006**, *45*, 5859. (b) Siegel, D. S.; Piizzi, G.; Piersanti, G.; Movassaghi, M. *J. Org. Chem.* **2009**, *74*, 9292.

[9] For other examples, see: (a) Ott, G. R.; Heathcock, C. H. *Org. Lett.* **1999**, *1*, 1475. (b) The use of high reaction temperatures described in Vostrikov, N. S.; Vasikov, V. Z.; Miftakhov, M. S. *Russ. J. Org. Chem.* **2005**, *41*, 967 likely cause decomposition of NBSH.

[10] Ojala, C. R.; Ojala, W. H.; Pennamon, S. Y.; Gleason, W. B. *Acta Cryst.* **1998**, *C54*, 57.

[11] Consistent with this hypothesis, hydrolysis of the Mitsunobu adducts of secondary alcohols is faster than those derived from primary alcohols.

[12] Addition of acetic acid, 2,6-lutidine, or 1,4-cyclohexadiene, and the use of ethanedithiol instead of water did not improve the yield of the reduction product.

[13] Due to the bimolecular nature of the reaction, a faster release of the sulfonyl hydrazine derivative and formation of the diazene intermediate could provide a more efficient free-radical loss of dinitrogen. Myers, A. G.; Movassaghi, M.; Zheng, B. *Tetrahedron Lett.* **1997**, *38*, 6569.

[14] The addition of phenylhydrazine was only necessary in the deoxygenation of saturated alcohols.

[15] Unfortunately, procedural variants described in a more recent related report Keith, J. M.; Gomez, L. *J. Org. Chem.* **2006**, *71*, 7113 did not provide an advantage over the initial conditions.

[16] Tezuka, T.; Otsuka, T.; Wang, P.-C.; Murata, M. *Tetrahedron Lett.* **1986**, *27*, 3627.

Experimental Section

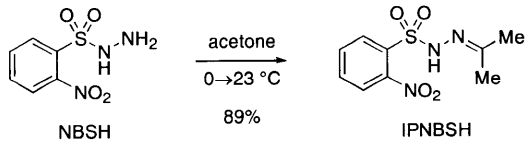
General Procedures. All reactions were performed in oven-dried or flame-dried round bottomed flasks or modified Schlenk (Kjeldahl shape) flasks. The flasks were fitted with rubber septa and reactions were conducted under a positive pressure of argon. Stainless steel syringes or cannulae were used to transfer air- and moisture-sensitive liquids. Flash column chromatography was performed as described by Still et al. using silica gel (60-Å pore size, 32–63 μm, standard grade, Sorbent Technologies) or non-activated alumina gel (80–325 mesh, chromatographic grade, EM Science).[1] Analytical thin–layer chromatography was performed using glass plates pre-coated with 0.25 mm 230–400 mesh silica gel or neutral alumina gel impregnated with a fluorescent indicator (254 nm). Thin layer chromatography plates were visualized by exposure to ultraviolet light and/or by exposure to an ethanolic phosphomolybdic acid (PMA), an acidic solution of *p*-anisaldehyde (anis), an aqueous solution of ceric ammonium molybdate (CAM), an aqueous solution of potassium permanganate ($KMnO_4$) or an ethanolic solution of ninhydrin followed by heating (<1 min) on a hot plate (~250 °C). Organic solutions were concentrated on Büchi R-200 rotary evaporators at ~20 Torr (house vacuum) at 25–35 °C, then at ~1 Torr (vacuum pump) unless otherwise indicated.

Materials. Commercial reagents and solvents were used as received with the following exceptions: Dichloromethane, diethyl ether, tetrahydrofuran, acetonitrile, toluene, and triethylamine were purchased from J.T. Baker (Cycletainer™) and were purified by the method of Grubbs et al. under positive argon pressure.[2] The molarity of *n*-butyllithium solutions was determined by titration using diphenylacetic acid as an indicator (average of three determinations).[3] Chlorobenzene was distilled over $CaCl_2$ under an argon atmosphere, 2,6-lutidene over CaH_2 under an argon atmosphere, and 2,2,2-trifluoroethanol over calcium sulfate and sodium bicarbonate under an argon atmosphere. Neopentyl alcohol was purified by sublimation in vacuo.

Instrumentation. Proton nuclear magnetic resonance (^{1}H NMR) spectra were recorded with Bruker 400 AVANCE, Bruker inverse probe 600 AVANCE and Varian inverse probe 500 INOVA spectrometers. Chemical shifts are recorded in parts per million from internal tetramethylsilane on the δ scale and are referenced from the residual protium in the NMR solvent ($CHCl_3$: δ 7.27, CD_3CN: ▫ 1.96). Data are reported as follows: chemical shift [multiplicity (s = singlet, d = doublet, t = triplet, q = quartet, m = multiplet), coupling constant(s) in Hertz, integration, assignment]. Carbon-13 nuclear magnetic resonance (^{13}C NMR) spectra were recorded with Bruker 400 AVANCE, Bruker inverse probe 600 AVANCE and Varian 500 INOVA spectrometers and are recorded in parts per million from internal tetramethylsilane on the δ scale and are referenced from the carbon resonances of the solvent ($CDCl_3$: δ 77.2). Data are reported as follows: chemical shift [multiplicity (s = singlet, d = doublet, t = triplet, q = quartet, m = multiplet), coupling constant(s) in Hertz, assignment]. Infrared data were obtained with a Perkin-Elmer 2000 FTIR and are reported as follows: [frequency of absorption (cm^{-1}), intensity of absorption (s = strong, m = medium, w = weak, br = broad), assignment]. Gas chromatography was performed on an Agilent Technologies 6890N Network GC System with a HP-5 5% Phenyl Methyl Siloxane column. We are grateful for the assistance of Dr. Peter Mueller (X-ray Crystallographic Laboratory, Department of Chemistry, Massachusetts Institute of Technology) and Mr. Michael A. Schmidt with the X-ray crystal structure of IPNBSH. We are grateful to Dr. Li Li for

1. Still, W. C.; Kahn, M.; Mitra, A. *J. Org. Chem.* **1978**, *43*, 2923.
2. Pangborn, A. B.; Giardello, M. A.; Grubbs, R. H.; Rosen, R. K.; Timmers, F. J. *Organometallics* **1996**, *15*, 1518.
3. Kofron, W. G.; Baclawski, L. M. *J. Org. Chem.* **1976**, *41*, 1879.

obtaining mass spectrometric data at the Department of Chemistry's Instrumentation Facility, Massachusetts Institute of Technology.

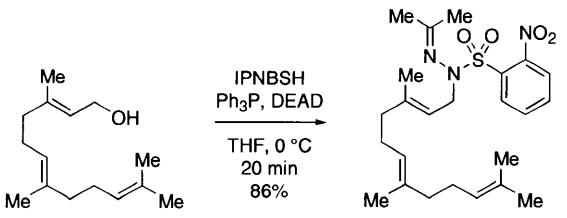


_N_-Isopropylidene-_N'_-2-nitrobenzenesulfonyl hydrazine (IPNBSH, eq 2):[4]

A sample of NBSH[5] (1.14 g, 5.24 mmol, 1 equiv) was dissolved in acetone (8.0 mL) at 0 °C. After 30 min, the solvent was removed in vacuo and the residue was dissolved in acetone (4 mL). Slow addition of the acetone solution to a volume of hexanes (150 mL), collection of the fine powder by filtration, followed by sequential hexanes rinses (2 × 5 mL), and removal of volatiles by high vacuum provided triturated IPNBSH[4] as a white solid (1.20 g, 89%).

^{1}H NMR (500 MHz, $CDCl_3$, 20 °C) δ:	8.30–8.28 (m, 1H, Ar**H**), 7.87–7.85 (m, 2H, SO_2N**H**, Ar**H**), 7.79–7.77 (m, 2H, Ar**H**), 1.96 (s, 3H, CH_3), 1.92 (s, 3H, CH_3).
^{13}C NMR (125 MHz, $CDCl_3$, 20 °C) δ:	159.0, 148.4, 134.3, 133.4, 132.9, 131.9, 125.4, 25.5, 17.1.
FTIR (neat) cm^{-1}:	3264 (m), 1551 (s), 1375 (s), 1347 (m), 1177 (s).
HRMS (ESI):	calc'd for $C_9H_{12}N_3O_4S$ $[M+H]^+$: 258.0543, found: 258.0548.
Melting Point:	139–140 °C (dec.).

4. Movassaghi, M.; Piizzi, G.; Siegel, D. S.; Piersanti, G. *Angew. Chem. Int. Ed.* **2006**, 45, 5859.
5. (a) Dann, A. T.; Davies, W. *J. Chem. Soc.* **1929**, 1050 (b) Myers, A. G.; Zheng, B.; Movassaghi, M. *J. Org. Chem.* **1997**, *62*, 7507. (c) Myers, A. G.; Movassaghi M. *e-Encyclopedia of Reagents for Organic Synthesis* **2003**.



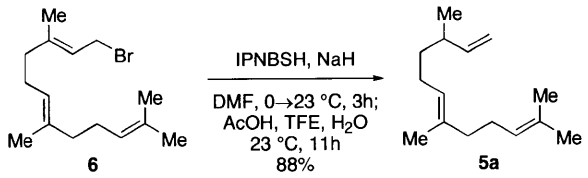
1a **4a**

<u>*N*-Isopropylidene-*N'*-((2E,6E)-3,7,11-trimethyl-dodeca-2,6,10-trienyl)-*N'*-2-nitrobenzene-sulfonyl hydrazide (4a, Scheme 5):</u>

DEAD (0.30 mL, 1.9 mmol, 1.2 equiv) was added drop-wise to a solution of IPNBSH (487 mg, 1.89 mmol, 1.20 equiv), *trans,trans*-farnesol (**1a**, 400 μL, 1.57 mmol, 1 equiv), and triphenylphosphine (496 mg, 1.89 mmol, 1.20 equiv) in anhydrous THF (30 mL) at 0 °C under an argon atmosphere. After 20 min, the volatiles were removed and the residue was purified by flash column chromatography on silica gel (30% ethyl acetate in hexanes) to afford the sulfonyl hydrazide **4a** (624 mg, 86%).

^{1}H NMR (500 MHz, $CDCl_3$, 20 °C) δ:	7.98–7.96 (m, 1H, Ar**H**), 7.73–7.68 (m, 2H, Ar**H**), 7.55–7.54 (m, 1H, Ar**H**), 5.08–5.04 (m, 3H, C=C**H**), 3.84 (d, 2H, J = 7.0, NC**H**$_2$), 2.12 (s, 3H, ((N=C)C**H**$_3$), 2.11 (s, 3H, ((N=C)C**H**$_3$), 2.07–2.01 (m, 4H, (C**H**$_2$)$_2$), 1.98–1.94 (m, 4H, (C**H**$_2$)$_2$), 1.68 (s, 3H, C**H**$_3$), 1.62 (s, 3H, C**H**$_3$), 1.60 (s, 3H, C**H**$_3$), 1.58 (s, 3H, C**H**$_3$).
^{13}C NMR (125 MHz, $CDCl_3$, 20 °C) δ:	182.8, 149.7, 142.5, 135.6, 134.1, 131.9, 131.5, 130.9, 128.3, 124.3, 123.7, 123.6, 117.0, 49.5, 39.9, 39.7, 26.6, 26.5, 25.9, 25.2, 21.2, 17.8, 16.5, 16.1.
FTIR (neat) cm^{-1}:	2918 (br s), 1644 (m), 1589 (m), 1547 (s), 1439 (s), 1372 (s).
HRMS (ESI):	calc'd for $C_{24}H_{36}N_3O_4S$ $[M+H]^+$: 462.2421, found: 462.2412.

TLC (40% EtOAc in hexanes), R_f: 0.40 (UV, $KMnO_4$).

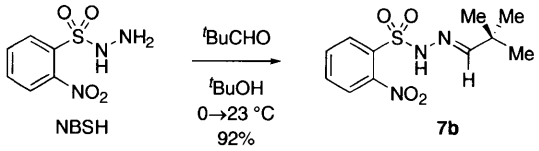


***(E)*-3,7,11-Trimethyldodeca-1,6,10-triene (5a, eq 3):**[6]

A solution of IPNBSH (96 mg, 0.37 mmol, 1.3 equiv) in anhydrous DMF (1.5 mL) was added slowly to a suspension of sodium hydride (8.6 mg, 0.36 mmol, 1.2 equiv) in anhydrous DMF (1.5 mL) at 0 °C under an argon atmosphere to give an orange solution. After 1.5 h, *trans,trans*-farnesyl bromide (**6**, 81 μL, 0.30 mmol, 1 equiv) was added to the sodium amide solution and the resulting mixture was allowed to warm to 23 °C. After 3 h, excess base was quenched with glacial acetic acid (86 μL, 1.5 mmol, 5.0 equiv), and the reaction mixture was diluted by the addition of a mixture of trifluoroethanol and water (1:1, 1.5 mL). After 11 h, the reaction mixture was diluted with water (25 mL) and extracted with diethyl ether (3 × 25 mL). The combined organic layers were dried over anhydrous sodium sulfate, were filtered, and were concentrated. The residue was purified by flash column chromatography on silica gel (100% ^{n}pentane) to afford the triene **5a** (54 mg, 88%). All spectroscopic data were in agreement with the literature.[6]

^{1}H NMR (400 MHz, $CDCl_3$, 20 °C) δ:	5.75–5.68 (m, 1H, C=C**H**), 5.13–5.10 (m, 2H, C=C**H**), 4.98–4.91 (m, 2H, C=C**H**), 2.14–1.98 (m, 7H, C**H**$_2$, C**H**), 1.69 (s, 3H, C**H**$_3$), 1.61 (s, 3H, C**H**$_3$), 1.60 (s, 3H, C**H**$_3$), 1.36–1.33 (m, 2H, C**H**$_2$), 0.99 (d, 3H, J = 8 Hz, (CH)C**H**$_3$).
^{13}C NMR (125 MHz, $CDCl_3$, 20 °C) δ:	145.0, 135.1, 131.5, 124.7, 124.6, 112.7, 39.9, 37.5, 36.9, 26.9, 25.9, 25.8, 20.4, 17.9, 16.2.
FTIR (neat) cm^{-1}:	3077 (m), 2966 (s), 2915 (s), 2856 (s), 1640 (m), 1453 (s), 1376 (s).
MS (*m/z*):	calc'd for $C_{15}H_{26}$ $[M]^+$: 206, found: 206.
TLC (40% EtOAc in hexanes), *Rf*:	0.80 (CAM, $KMnO_4$).

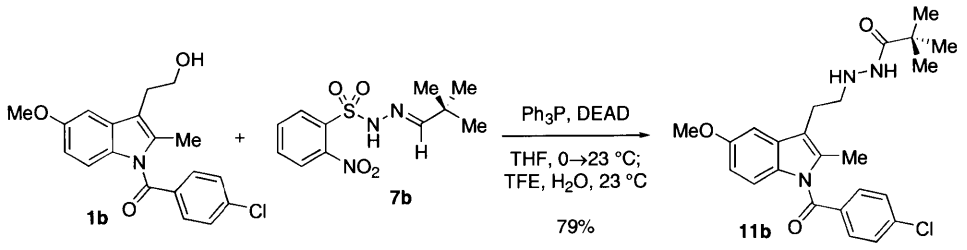
6. For prior syntheses of **5a**, see Saplay, K. M.; Sahni, R.; Damodaran, N. P.; Dev, S. *Tetrahedron* **1980**, *36*, 1455 and Myers, A. G.; Zheng, B. *Tetrahedron Lett.* **1996**, *37*, 4841.



(*E*)-*N*'-(2,2-dimethyl-propylidene)-2-nitrobenzenesulfono-hydrazide (Scheme 6):

NBSH (1.00 g, 4.62 mmol, 1 equiv) was dissolved in a solution of excess 2,2-dimethyl-propionaldehyde in *t*butanol (80% v/v, 8.0 mL) at 0 °C. After 30 min, the volatiles were removed under reduced pressure, and the residue was dissolved in dichloromethane (2 mL). Slow addition of this solution to a volume of hexanes (125 mL), collection of the resulting fine brown powder by filtration, followed by successive hexane rinses (2 × 5 mL) provided the hydrazone **7b** as a brown solid (1.16g, 92%).

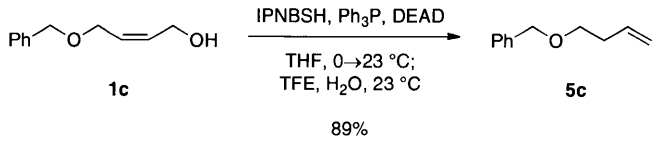
^{1}H NMR (400 MHz, $CDCl_3$, 20 °C) δ:	8.24–8.21 (m, 1H, Ar**H**), 7.91 (s, 1H, N**H**), 7.86–7.76 (m, 3H, Ar**H**), 7.26 (s, 1H, N=C**H**), 0.99 (s, 9H, (C**H**$_3$)$_3$).
^{13}C NMR (125 MHz, $CDCl_3$, 20 °C) δ:	163.1, 134.4, 133.3, 132.6, 131.6, 125.1, 35.4, 27.2.
FTIR (neat) cm^{-1}:	3238 (s), 1548 (s), 1366 (s), 1321 (m), 1173 (s).
HRMS (ESI):	calc'd for $C_{11}H_{15}N_3O_4S$ $[M+H]^+$: 286.0856, found: 286.0848.
TLC (50% EtOAc in hexanes), R_f:	0.8 (UV, CAM).



2,2-Dimethyl-propionic acid *N'*-{2-[1-(4-chloro-benzoyl)-5-methoxy-2-methyl-1*H*-indol-3-yl]-ethyl} hydrazide (11b, Scheme 6):

DEAD (78 μL, 0.50 mmol, 1.6 equiv) was added drop-wise to a solution of (*E*)-*N'*-(2,2-dimethyl-propylidene)-2-nitrobenzenesulfono-hydrazide (**7b**, 137 mg, 0.502 mmol, 1.63 equiv), *N*-(4-chlorobenzoyl)-3-(2-hydroxyethyl)-5-methoxy-2-methylindole (**1b**, 106 mg, 0.308 mmol, 1 equiv), and triphenylphosphine (133 mg, 0.505 mmol, 1.64 equiv) in anhydrous THF (3 mL) at 0 °C under an argon atmosphere. After 5 min, the reaction mixture was allowed to warm to 23 °C. After 30 min, a mixture of trifluoroethanol and water (1:1, 1.5 mL) was added to the reaction. After 11 h, the reaction mixture was partitioned between diethyl ether (25 mL) and water (10 mL). The organic layer was washed with water (3 × 10 mL), was dried over anhydrous sodium sulfate, was concentrated under reduced pressure, and the residue was purified by flash column chromatography on silica gel (75% ethyl acetate in hexanes) to give the hydrazide **11b** (107 mg, 79%).

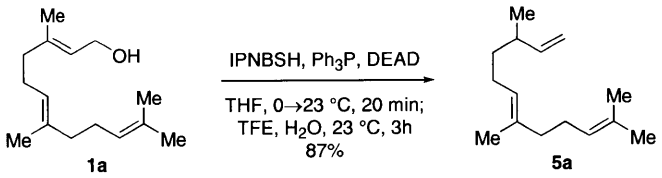
^{1}H NMR (500 MHz, $CDCl_3$, 20 °C) δ:	7.67–7.63 (m, 2H, Ar**H**), 7.48–7.46 (m, 2H, Ar**H**), 7.11 (s, 1H, (CO)N**H**), 6.96–6.95 (d, 1H, *J* = 4.0 Hz, Ar**H**), 6.91–6.89 (d, 1H, *J* = 8.0 Hz, Ar**H**), 6.68–6.66 (dd, 1H, *J* = 8.0, 4.0 Hz, Ar**H**), 4.77 (br s, 1H, N**H**), 3.85 (s, 3H, O**CH**$_3$), 3.10–3.06 (t, 2H, *J* = 8.0 Hz, **CH**$_2$), 2.87–2.83 (t, 2H, *J* = 8.0 Hz, **CH**$_2$), 2.35 (s, 3H, **CH**$_3$), 1.15 (s, 9H, (**CH**$_3$)$_3$).
^{13}C NMR (125 MHz, $CDCl_3$, 20 °C) δ:	177.9, 168.4, 156.1, 139.2, 134.7, 134.2, 131.3, 130.7, 129.2, 117.3, 115.2, 111.4, 101.3, 99.9, 55.9, 51.7, 38.0, 27.3, 23.4, 13.5.
FTIR (neat) cm^{-1}:	3305 (br m), 2960 (m), 1679 (s), 1478 (s), 1365 (s), 1325 (s).
HRMS (ESI):	calc'd for $C_{24}H_{29}ClN_3O_3$ $[M+H]^+$: 442.1897, found: 442.1900.
TLC (75% EtOAc in hexanes), *Rf*:	0.3 (UV, CAM, anis.



But-3-enyloxymethyl-benzene (5c, Table 1, Entry 1):[7]

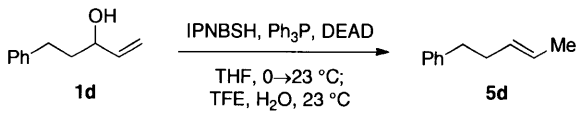
DEAD (66 ◘L, 0.42 mmol, 1.2 equiv) was added dropwise to a solution of IPNBSH (107 mg, 0.416 mmol, 1.20 equiv), *(Z)*-4-(benzyloxy)but-2-en-1-ol (**1c**, 62 mg, 0.347 mmol, 1 equiv), and triphenylphosphine (109 mg, 0.417 mmol, 1.20 equiv) in anhydrous THF (3.5 mL) at 0 °C under an argon atmosphere. After 5 min, the reaction mixture was allowed to warm to 23 °C. After 2 h, a mixture of trifluoroethanol and water (1:1, 1.8 mL) was added to the reaction mixture. After 3 h, the reaction mixture was diluted with water (30 mL) and extracted with diethyl ether (3 × 30 mL). The combined organic layers were dried over anhydrous sodium sulfate, were filtered, and were concentrated. The residue was purified by flash column chromatography on silica gel (4% diethyl ether in "pentane) to give **5c** (50 mg, 89%). TLC (4% diethyl ether in pentane), *Rf*: 0.3 (anis). All spectroscopic data were in agreement with the literature.[7]

7. For a prior synthesis of **S5c**, see Cleary, P. A.; Woerpel, K. A, *Org. Lett.*, **2005**, *7*, 5531.



***(E)*-3,7,11-Trimethyldodeca-1,6,10-triene (5a, Table 1, entry 2):**

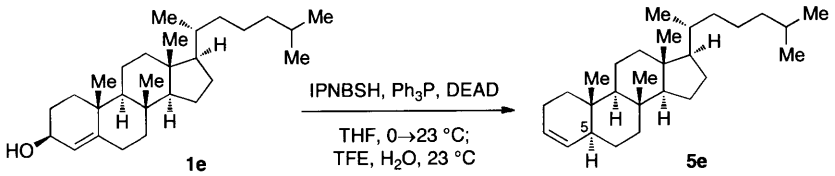
DEAD (74 μL, 0.47 mmol, 1.2 equiv) was added drop-wise to a solution of IPNBSH (122 mg, 0.474 mmol, 1.21 equiv), *trans,trans*-farnesol (**1a**, 0.100 mL, 0.393 mmol, 1 equiv), and triphenylphosphine (124 mg, 0.473 mmol, 1.21 equiv) in anhydrous THF (9.0 mL) at 0 °C under an argon atmosphere. After 5 min, the reaction mixture was allowed to warm to 23 °C. After 20 min, a mixture of trifluoroethanol and water (1:1, 4.5 mL) was added to the reaction mixture to enable formation of the allylic diazene intermediate. After 3 h, the reaction mixture was partitioned between diethyl ether (25 mL) and water (25 mL), and the aqueous layer was extracted with diethyl ether (2 × 25 mL). The combined organic layers were dried over anhydrous sodium sulfate, were filtered, and were concentrated. The residue was purified by flash column chromatography on silica gel (100% *n*pentane) to give triene **5a** (71 mg, 87%).



***(E)*-5-Phenylpent-2-ene (5d, Table 1, Entry 3):**[8]

DEAD (55 μL, 0.35 mmol, 1.1 equiv) was added drop-wise to a solution of IPNBSH (89 mg, 0.35 mmol, 1.1 equiv), 5-phenylpent-1-en-3-ol (**1d**, 50 mg, 0.31 mmol, 1 equiv), and triphenylphosphine (91 mg, 0.35 mmol, 1.1 equiv) in anhydrous THF (2.9 mL) at 0 °C under an argon atmosphere. After 5 min, the reaction mixture was allowed to warm to 23 °C. After 2 h, a mixture of trifluoroethanol and water (1:1, 2.9 mL) was added to the reaction mixture to enable the formation of the intermediate allyl diazene. After 2 h, the reaction mixture was partitioned between diethyl ether (25 mL) and water (25 mL) and the aqueous layer was extracted with diethyl ether (2 × 25mL). The combined organic layers were dried over anhydrous sodium sulfate, were filtered, and were concentrated. The residue was purified by flash column chromatography on silica gel (100% *n*pentane) to give the alkene **5d** (34 mg, 74%). TLC (pentane), *Rf*: 0.5 ($KMnO_4$). ^1H NMR (400 MHz) analysis revealed an *E*:*Z* ratio of 93:7. All spectroscopic data were in agreement with the literature.[8]

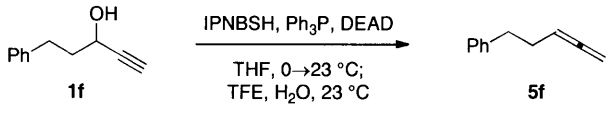
8. For a prior synthesis of **S5d**, see Buss, A. D.; Warren, S. *J. Chem. Soc., Perkin Trans I*, **1985**, 2307 and Myers, A. G.; Zheng, B. *Tetrahedron Lett.* **1996**, *37*, 4841.



5α-Cholest-3-ene (5e, Table 1, Entry 4):[9]

DEAD (45 μL, 0.28 mmol, 2.0 equiv) was added drop-wise to a solution of IPNBSH (72 mg, 0.28 mmol, 2.0 equiv), cholest-4-en-3-ol (**1e**, 54 mg, 0.14 mmol, 1 equiv), and triphenylphosphine (74 mg, 0.28 mmol, 2.0 equiv) in anhydrous THF (1.4 mL) at 0 °C under an argon atmosphere. After 5 min, the reaction mixture was allowed to warm to 23 °C. After 2 h, a mixture of trifluoroethanol and water (1:1, 0.7 mL) was added to the reaction mixture. After 2 h, the reaction mixture was diluted with water (25 mL) and extracted with diethyl ether (3 × 25mL). The combined organic layers were dried over anhydrous sodium sulfate, were filtered, and were concentrated. The residue was purified by flash column chromatography on silica gel (100% hexanes) to give the alkene **5e** (31 mg, 60%). TLC (Pentane), *Rf*: 0.8 (CAM). ^{1}H NMR (500 MHz) analysis revealed the presence of <8% of the C_5-diastereomers. All spectroscopic data were in agreement with the literature.[9]

9. For prior syntheses of **S5e**, see patent-JP,05-051329,A and Myers, A. G.; Zheng, B. *Tetrahedron Lett.* **1996**, *37*, 4841.



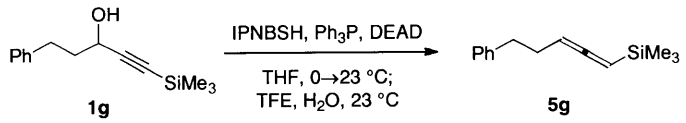
1f 5f

70%

5-Phenylpenta-1,2-diene (5f, Table 1, Entry 5):[10]

DEAD (67.5 μL, 0.429 mmol, 1.20 equiv) was added drop-wise to a solution of IPNBSH (110 mg, 0.429 mmol, 1.20 equiv), 5-phenylpent-1-yn-3-ol (**1f**, 57 mg, 0.36 mmol, 1 equiv), and triphenylphosphine (112 mg, 0.428 mmol, 1.20 equiv) in anhydrous THF (3.5 mL) at 0 °C under an argon atmosphere. After 5 min, the reaction mixture was allowed to warm to 23 °C. After 2 h, a mixture of trifluroethanol and water (1:1, 1.7 mL) was added to the reaction mixture to enable the formation of the propargylic diazene intermediate. After 2 h, the reaction mixture was partitioned between *n*pentane (25 mL) and water (25 mL). The organic layer was washed with water (2 × 25mL), was dried over anhydrous sodium sulfate, was filtered, and was concentrated. The residue was purified by flash column chromatography on silica gel (100% *n*pentane) to give the allene **5f** (36 mg, 70%). TLC (100% *n*pentane), *Rf*: 0.6 (anis). All spectroscopic data were in agreement with the literature.[10]

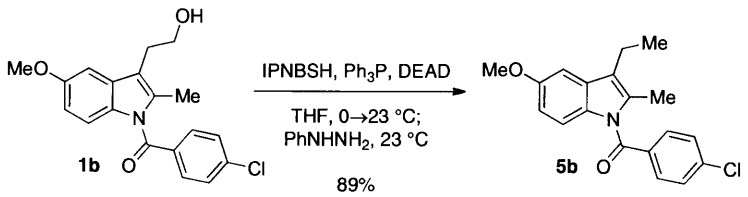
10. For a prior synthesis of **S5f**, see Ohno, H.; Miyamura, K.; Tanaka, T. *J. Org. Chem.* **2002**, *67*, 1359.



Trimethyl-(5-phenylpenta-1,2-dienyl)-silane (5g, Table 1, Entry 6):[11]

DEAD (43 μL, 0.27 mmol, 1.2 equiv) was added drop-wise to a solution of IPNBSH (69 mg, 0.27 mmol, 1.2 equiv), 5-phenyl-1-(trimethylsilyl)pent-1-yn-3-ol (**1g**, 52 mg, 0.22, 1 equiv), and triphenylphosphine (71 mg, 0.27, 1.2 equiv) in anhydrous THF (2.2 mL) at 0 °C under an argon atmosphere. After 5 min, the reaction mixture was allowed to warm to 23 °C. After 2 h, a mixture of trifluoroethanol and water (1:1, 1.1 mL) was added to the reaction mixture to enable the formation of the propargylic diazene intermediate. After 2.5 h, the reaction mixture was diluted with water (25 mL) and extracted with diethyl ether (3 × 25mL). The combined organic layers were dried over anhydrous sodium sulfate, were filtered, and were concentrated. The residue was purified by flash column chromatography on silica gel (100% *n*pentane) to afford the allene **5g** (41 mg, 86%). TLC (*n*pentane), R*f*: 0.4 (UV, anis). All spectroscopic data were in agreement with the literature.[11]

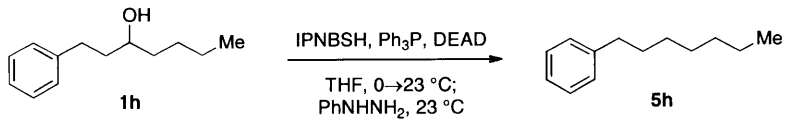
11. For a prior synthesis of **S5g**, see Danheiser, R. L.; Carini, D. J., Fink, D. M., Basak, A. *Tetrahedron*, **1983**, *39*, 935.



1-(4-Chlorobenzoyl)-3-ethyl-5-methoxy-2-methyl-indole (5b, Table 1, Entry 7):[12]

DEAD (44 μL, 0.28 mmol, 1.6 equiv) was added drop-wise to a solution of IPNBSH (71 mg, 0.28 mmol, 1.6 equiv), *N*-(4-chlorobenzoyl)-3-(2-hydroxyethyl)-5-methoxy-2-methylindole (**1b**, 59 mg, 0. 17 mmol, 1 equiv), and triphenylphosphine (73 mg, 0.28 mmol, 1.6 equiv) in anhydrous THF (1.7 mL) at 0 °C under an argon atmosphere. After 5 min, the reaction mixture was allowed to warm to 23 °C. After 30 min, phenylhydrazine (85 μL, 0.86 mmol, 5.0 equiv) was added via syringe and the mixture was kept at ambient temperature. After 4 h, the reaction mixture was diluted with diethyl ether (25 mL) and washed with water (25 mL). The aqueous layer was extracted with diethyl ether (2 × 25 mL), and the combined organic layers were dried over anhydrous sodium sulfate, were filtered, and were concentrated. The residue was purified by flash column chromatography on silica gel (5% ethyl acetate in hexanes) to afford **5b** (50 mg, 89%). TLC (5% ethyl acetate in hexanes), *Rf*: 0.3 (UV, CAM anis). All spectroscopic data were in agreement with the literature.[12]

12. For prior syntheses of **S5b** and **S5h**, see Myers, A. G.; Movassaghi, M.; Zheng, B. *J. Am. Chem. Soc.* **1997**, *119*, 8572.



1-Phenylheptane (5h, Table 1, Entry 8):[12]

DEAD (290 μL, 1.84 mmol, 2.50 equiv) was added drop-wise to a solution of IPNBSH (474 mg, 1.84 mmol, 2.50 equiv), 1-phenylheptan-3-ol (**1h**, 142 mg, 0.737 mmol, 1 equiv), and triphenylphosphine (485 mg, 1.85 mmol, 2.51 equiv) in anhydrous THF (5.2 mL) at 0 °C under an argon atmosphere. After 5 min, the reaction mixture was allowed to warm to 23 °C. After 20 h, phenyl hydrazine (360 μL, 3.67 mmol, 4.98 equiv) was added via syringe and the resulting mixture was kept at ambient temperature. After 13 h, the reaction mixture was partitioned between *n*pentane (25 mL) and water (25 mL). The organic layer was washed with water (4 × 25 mL), was dried over anhydrous sodium sulfate, was filtered, and was concentrated. The residue was purified by flash column chromatography (100% *n*pentane) to afford 1-heptylbenzene (**5h**, 46 mg, 35%). TLC (30% EtOAc in hexanes), *Rf*: 0.9 (CAM). All spectroscopic data were in agreement with the literature.[12]

Crystal Structure of IPNBSH.

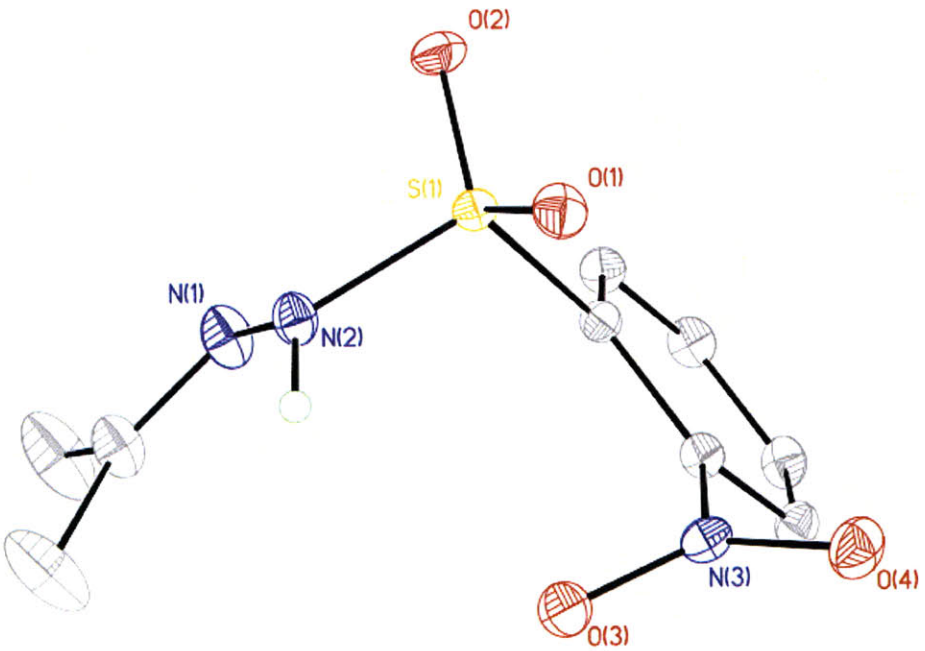


Table S1. Crystal data and structure refinement for IPNBSH.

Identification code	06182	
Empirical formula	C9 H11 N3 O4 S	
Formula weight	257.27	
Temperature	100(2) K	
Wavelength	0.71073 Å	
Crystal system	Monoclinic	
Space group	P2(1)/n	
Unit cell dimensions	a = 8.1746(3) Å	α= 90°.
	b = 15.1930(5) Å	β= 107.4690(10)°.
	c = 9.8516(3) Å	γ = 90°.
Volume	1167.11(7) Å^3	
Z	4	
Density (calculated)	1.464 Mg/m^3	
Absorption coefficient	0.285 mm^{-1}	
F(000)	536	
Crystal size	0.50 x 0.50 x 0.40 mm^3	
Theta range for data collection	2.55 to 29.57°.	
Index ranges	-10<=h<=11, -21<=k<=21, -13<=l<=13	
Reflections collected	22799	
Independent reflections	3274 [R(int) = 0.0201]	
Completeness to theta = 29.57°	100.0 %	
Absorption correction	Semi-empirical from equivalents	
Max. and min. transmission	0.8946 and 0.8707	
Refinement method	Full-matrix least-squares on F^2	
Data / restraints / parameters	3274 / 1 / 159	
Goodness-of-fit on F^2	1.060	
Final R indices [I>2sigma(I)]	R1 = 0.0299, wR2 = 0.0848	
R indices (all data)	R1 = 0.0310, wR2 = 0.0858	
Largest diff. peak and hole	0.485 and -0.387 e.Å^{-3}	

Table S2. Atomic coordinates (x 10^4) and equivalent isotropic displacement parameters ($Å^2$x 10^3) for IPNBSH. U(eq) is defined as one third of the trace of the orthogonalized U^{ij} tensor.

	x	y	z	U(eq)
O(4)	14328(1)	638(1)	10896(1)	19(1)
O(1)	10353(1)	1177(1)	10334(1)	16(1)
O(2)	8502(1)	2204(1)	8564(1)	19(1)
S(1)	9667(1)	1478(1)	8889(1)	13(1)
N(2)	8713(1)	623(1)	7983(1)	14(1)
N(1)	8126(1)	787(1)	6509(1)	20(1)
C(2)	7743(2)	110(1)	5704(1)	21(1)
C(1)	7901(2)	-824(1)	6199(1)	37(1)
C(3)	7091(2)	277(1)	4136(1)	42(1)
O(3)	12382(1)	-78(1)	9276(1)	17(1)
N(3)	13246(1)	580(1)	9726(1)	13(1)
C(4)	11421(1)	1759(1)	8265(1)	13(1)
C(5)	13012(1)	1342(1)	8763(1)	13(1)
C(6)	14415(1)	1592(1)	8345(1)	16(1)
C(8)	12641(1)	2704(1)	6852(1)	19(1)
C(9)	11247(1)	2452(1)	7304(1)	16(1)
C(7)	14214(1)	2279(1)	7368(1)	18(1)

Table S3. Bond lengths [Å] and angles [°] for IPNBSH.

O(4)-N(3)	1.2281(11)	O(1)-S(1)-C(4)	107.68(4)
O(1)-S(1)	1.4388(7)	N(2)-S(1)-C(4)	107.74(4)
O(2)-S(1)	1.4292(7)	N(1)-N(2)-S(1)	112.40(7)
S(1)-N(2)	1.6356(9)	C(2)-N(1)-N(2)	116.15(9)
S(1)-C(4)	1.7735(10)	N(1)-C(2)-C(1)	125.50(10)
N(2)-N(1)	1.4077(11)	N(1)-C(2)-C(3)	116.64(10)
N(1)-C(2)	1.2791(14)	C(1)-C(2)-C(3)	117.86(10)
C(2)-C(1)	1.4929(16)	O(3)-N(3)-O(4)	124.90(8)
C(2)-C(3)	1.4971(15)	O(3)-N(3)-C(5)	117.30(8)
O(3)-N(3)	1.2277(11)	O(4)-N(3)-C(5)	117.75(8)
N(3)-C(5)	1.4725(12)	C(9)-C(4)-C(5)	118.36(9)
C(4)-C(9)	1.3937(13)	C(9)-C(4)-S(1)	119.30(7)
C(4)-C(5)	1.3972(13)	C(5)-C(4)-S(1)	122.25(7)
C(5)-C(6)	1.3836(13)	C(6)-C(5)-C(4)	122.59(9)
C(6)-C(7)	1.3954(14)	C(6)-C(5)-N(3)	116.71(8)
C(8)-C(7)	1.3916(15)	C(4)-C(5)-N(3)	120.65(8)
C(8)-C(9)	1.3958(14)	C(5)-C(6)-C(7)	118.33(9)
		C(7)-C(8)-C(9)	120.64(9)
O(2)-S(1)-O(1)	120.16(5)	C(4)-C(9)-C(8)	119.85(9)
O(2)-S(1)-N(2)	108.32(5)	C(8)-C(7)-C(6)	120.21(9)
O(1)-S(1)-N(2)	105.58(4)		
O(2)-S(1)-C(4)	106.84(5)		

Symmetry transformations used to generate equivalent atoms:

Table S4. Anisotropic displacement parameters ($Å^2 x\ 10^3$)for IPNBSH. The anisotropic displacement factor exponent takes the form: $-2\pi^2[\ h^2a^{*2}U^{11} + ... + 2\ h\ k\ a^*\ b^*\ U^{12}\ ]$

	U^{11}	U^{22}	U^{33}	U^{23}	U^{13}	U^{12}
O(4)	17(1)	23(1)	14(1)	2(1)	1(1)	2(1)
O(1)	17(1)	19(1)	12(1)	-1(1)	6(1)	-1(1)
O(2)	16(1)	17(1)	24(1)	-1(1)	7(1)	5(1)
S(1)	12(1)	13(1)	13(1)	-1(1)	5(1)	0(1)
N(2)	15(1)	14(1)	12(1)	1(1)	2(1)	-2(1)
N(1)	26(1)	19(1)	13(1)	2(1)	1(1)	-3(1)
C(2)	27(1)	19(1)	15(1)	1(1)	3(1)	-3(1)
C(1)	67(1)	18(1)	20(1)	-1(1)	3(1)	-3(1)
C(3)	72(1)	29(1)	14(1)	2(1)	-2(1)	-10(1)
O(3)	16(1)	14(1)	22(1)	1(1)	7(1)	-2(1)
N(3)	12(1)	15(1)	14(1)	2(1)	5(1)	2(1)
C(4)	13(1)	13(1)	13(1)	-1(1)	5(1)	-1(1)
C(5)	14(1)	12(1)	12(1)	1(1)	4(1)	-1(1)
C(6)	13(1)	17(1)	17(1)	0(1)	5(1)	-2(1)
C(8)	23(1)	16(1)	18(1)	3(1)	7(1)	-2(1)
C(9)	17(1)	14(1)	16(1)	2(1)	4(1)	1(1)
C(7)	18(1)	19(1)	18(1)	1(1)	7(1)	-5(1)

Table S5. Hydrogen coordinates (x 10^4) and isotropic displacement parameters ($Å^2 x\ 10^3$) for IPNBSH.

	x	y	z	U(eq)
H(2)	9188(18)	134(8)	8292(15)	17
H(1A)	9116	-978	6588	56
H(1B)	7356	-1211	5395	56
H(1C)	7333	-895	6938	56
H(3A)	7065	913	3958	63
H(3B)	5930	36	3757	63
H(3C)	7850	-8	3665	63
H(6)	15489	1304	8713	19
H(8)	12514	3171	6186	22
H(9)	10183	2751	6958	19
H(7)	15154	2457	7053	22

Table S6. Hydrogen bonds for IPNBSH [Å and °].

D-H...A	d(D-H)	d(H...A)	d(D...A)	<(DHA)
N(2)-H(2)...O(3)	0.851(12)	2.518(13)	3.0751(11)	123.9(12)
N(2)-H(2)...O(1)#1	0.851(12)	2.374(13)	3.1702(11)	156.0(13)

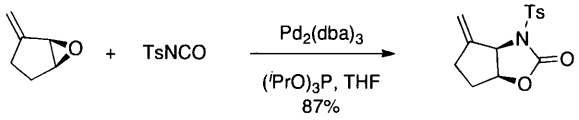
Symmetry transformations used to generate equivalent atoms:
#1 -x+2,-y,-z+2

Chapter II

Stereospecific Palladium-Catalyzed Route to Monoalkyl Diazenes for Mild Allylic Reduction

Introduction and Background

Transition metal-catalyzed allylic alkylation reactions have been utilized extensively in synthetic organic chemistry.[1,2] These reactions include many powerful transformations that focus on carbon–heteroatom bond formation including reports concerning the use of nitrogen nucleophiles. Significantly, Trost's first reported asymmetric transition metal–catalyzed allylic alkylation reaction with a nitrogen nucleophile in the synthesis of oxazolidinones[3] (eq 1) has been followed by a series of exciting disclosures regarding the use of other nitrogen nucleophiles.[4]



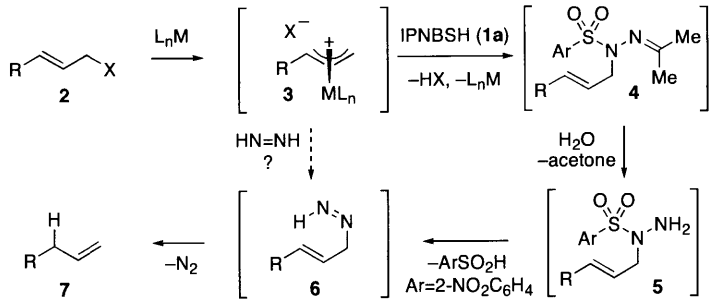
(1)

Trost described the catalytic asymmetric synthesis of oxazolidinones starting with racemic epoxides[5] and the Dynamic Kinetic Asymmetric Transformation (DYKAT) of vinyl epoxides using imides as nucleophiles.[6,7] Hayashi reported the allylic alkylation of primary amine and carbamate nucleophiles with good regioselectivity using a palladium catalyst and ferrocene ligands.[8] It has also been demonstrated that sodium salts of sulfonamides, carbonyl hydrazides, and carbamates, as well as primary amines can act as nucleophiles.[9] Hartwig and Takeuchi reported the use of iridium-catalysts for such allylic alkylation reactions.[10,11] Carreira described the use of sulfamic acid as an ammonia equivalent for a direct iridium-catalyzed allylic alkylations of allylic alcohols.[12] Enders has reported that iron-catalyzed allylic alkylations of primary and secondary amines proceed in good regioselectivity.[13] Furthermore, phosphoramide,[14] hydrazine and hydroxylamine derivatives,[15] azide,[16] and heterocyclic nucleophiles[17] have been utilized in transition metal-catalyzed allylic alkylation reactions (Table 1).

Table 1. Nitrogen nucleophiles for transition metal-catalyzed allylic alkylation.

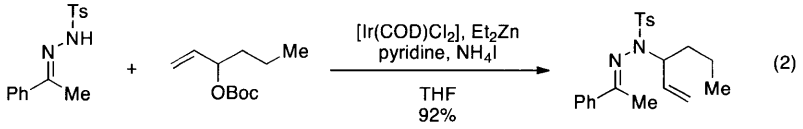
Nucleophile	Reference	Nucleophile	Reference
RNH_2	4,8	$RR'NNH_2$	15
RR'NH	10,13	$RONH_2$	15
RSO_2NHR'	3,8	$RCONHNH_2$	8
Phthalimide	5,6	H_2NSO_3H	12
$(Boc)_2NH$	4,8	Purine	17
$(EtO)_2PONHBoc$	14	$TMSN_3$	16

As discussed in chapter I, we reported the use of *N*-isopropylidene-*N'*-2-nitrobenzenesulfonyl hydrazide (IPNBSH, **1a**) for the conversion of alcohols to the corresponding monoalkyl diazenes via the Mitsunobu reaction.[18,19] Our observations on the chemistry of **1a** prompted our investigation of its use as a diimide surrogate in a transition metal-catalyzed synthesis of monoalkyl diazenes (Scheme 1). Diimide itself is not suitable as a nucleophiles because of its thermal instability and propensity to disproportionate to generate hydrazine and dinitrogen.[20] We envisioned the interception of the π–allyl complex **3** with sulfonyl hydrazone **1a** to give hydrazone **4**. In situ hydrolysis and fragmentation of **4**[18,21] would unravel the allylic diazene **6**, and upon sigmatropic loss of dinitrogen afford the desired product **7**. Consequently, the use of IPNBSH in place of diimide would enable the conversion of **3** to diazene **6** without isolation of intermediates.



Scheme 1. Metal-catalyzed Synthesis of Allylic Diazenes.

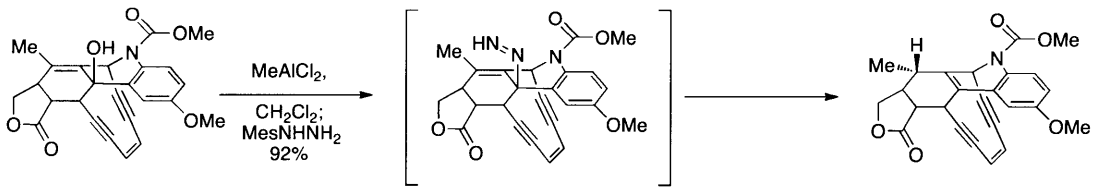
Although nitrogen nucleophiles had been used extensively for transition metal-catalyzed allylic alkylation reactions, only one example of *N*-sulfonyl hydrazones as nucleophiles, using iridium as a catalyst, had been reported (eq 2).[22] One of the initial goals of this study was to investigate the viability of sulfonyl hydrazones as nucleophiles in the presence of different catalyst systems particularly those with potential for asymmetric synthesis.



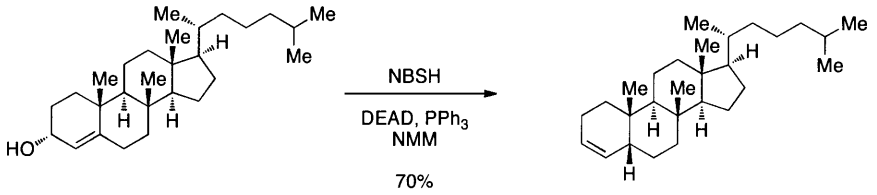
(2)

We were interested in exploring the possibility of extension of this chemistry to asymmetric reduction using IPNBSH. Although there were several reports of the formation of enantioenriched monoalkyl diazenes (Schreiber's report of the studies toward the synthesis of Dynemicin A[23] and Myers' example of the use of cholestenol as a substrate for NBSH chemistry[24] (Scheme 2) are noteworthy), there were no examples of an asymmetric synthesis of diazene intermediates . We envisioned the use of chiral catalyst systems in transition metal catalysis for the synthesis of monoalkyl diazenes would, for the first time, provide access to enantioenriched diazenes using racemic or prochiral substrates as starting materials.

Schreiber:



Myers:

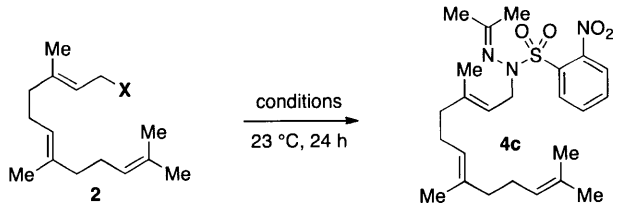


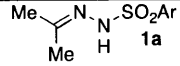
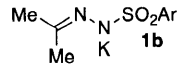
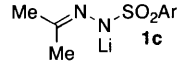
Scheme 2. Enantioenriched monoalkyl diazenes.

Results and Discussion

We initially focused on the development of efficient conditions for the Pd-catalyzed allylation of sulfonyl hydrazones (Table 2). Allylic carbonates were found to be superior substrates as compared to allylic bromide or allylic acetate substrates. The use of sulfonamide salts enhanced the rate of the desired Pd-catalyzed allylic alkylation. Under optimal conditions, we found treatment of carbonate **2a** with $[\eta^3\text{-allylPdCl}]_2$ (2.5 mol%), triphenylphosphine (10 mol%), and potassium sulfonylhydrazide **1b** (1.0 equiv)[25] at 23 °C for 24 h afforded the desired adduct **4c** in 88% yield.

Table 2. Initial screen.



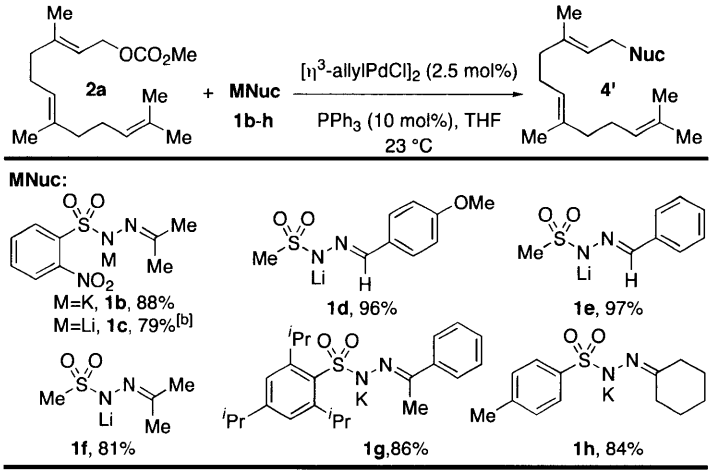
Entry	X	Nucleophile	Conditions[a]	Conversion (%)
1	OCO_2Me, **2a**	 **1a**	**A**, CH_2Cl_2, Na_2CO_3 (40 mol%)	72
2	OAc	**1a**	**A**, CH_2Cl_2, Na_2CO_3 (40 mol%)	12
3	OAc	**1a**	**A**, CH_2Cl_2, Na_2CO_3 (1.1 equiv)	0
4	OAc	**1a**	**B**, THF, Cs_2CO_3 (10 mol%)	0
5	Br	**1a**	**A**, CH_2Cl_2, Na_2CO_3 (40 mol%)	0
6	OCO_2Me, **2a**	 **1b**	**A**, THF	>99
7	OCO_2Me, **2a**	**1b**	**A**, DMF	65
8	OCO_2Me, **2a**	 **1c**	**A**, THF	44
9	OCO_2Me, **2a**	**1c**	**A**, THF 12-crown-4 (10 mol%)	>99

[a] Conditions: A = $[\eta^3\text{-allylPdCl}]_2$ (2.5 mol%), PPh_3 (10 mol%); B = $Pd_2(dba)_3$ (2.5 mol%), PPh_3 (7.5 mol%). Ar = 2-$NO_2C_6H_4$.

These reaction conditions can be used with both aldehyde and ketone derived sulfonyl hydrazone salts as nucleophiles (Table 3). Methanesulfonyl and arenesulfonyl hydrazones derived from both saturated and unsaturated carbonyl precursors were

successfully converted to the desired hydrazone adducts.[26] While the potassium derivative **1b** proved more effective as a reagent as compared to the lithium derivative **1c**, where possible the greater solubility of the lithium sulfonylhydrazides was advantageous in providing faster and complete conversion.

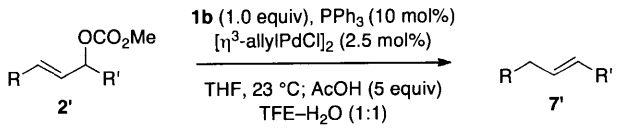
Table 3. Sulfonyl hydrazone nucleophiles.[a]

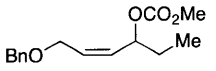
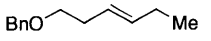
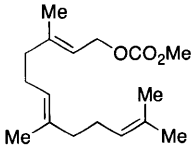
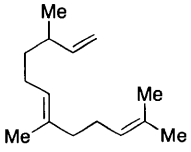
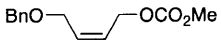
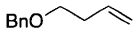
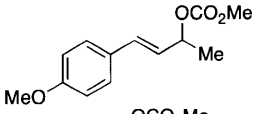
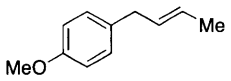
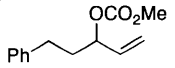
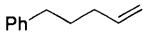
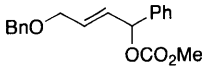
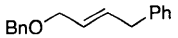
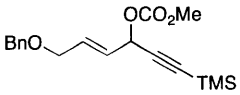
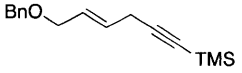
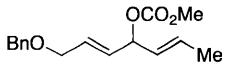
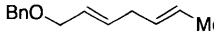
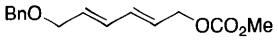
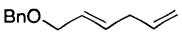


[a] Isolated yields of the corresponding adducts **4'**; average of two experiments. [b] Inclusion of 12-crown-4 (10 mol%) was found to be optimal.

We next explored the generality of these conditions for the Pd-catalyzed displacement of allylic carbonates with the reagent **1b** (Table 4). Gratifyingly, not only both primary and secondary allylic carbonates served as substrates, but also the planned mild in situ hydrolysis proved effective for a wide range of substrates. Even highly sensitive substrates such as the doubly activated carbonates (Table 4, entries 6-8) were successfully converted to the corresponding adducts (i.e., **4**, Scheme 1) and hydrolyzed to give the desired reduction products. Importantly, the use of related doubly activated alcohol substrates under the Mitsunobu or metal hydride reaction conditions results in significant decomposition and elimination.[27] Furthermore, the regioselective reduction of substrates shown in entries 4-9 demonstrates the versatility of this method where alternative free-radical based reduction methodologies[28] lead to complex mixtures of products. Additionally, treatment of carbonate **2b** with allylpalladiumchloride dimer, tri-^{n}buytlphosphine and ammonium formate in 1,4-dioxane lead to significant decomposition

Table 4. Reduction of Allylic Carbonates.

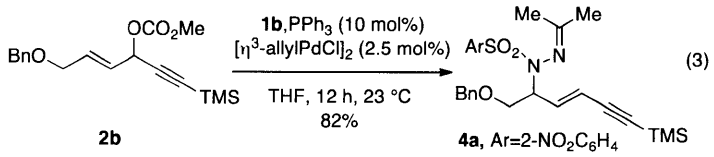


Entry	Substrate	Product	Yield (%)[a]
1			76[b]
2			86
3			91
4			59[b,c]
5			75
6			82[d]
7			54[d]
8			73[e]
9			68

[a] Isolated yield of the reduction product; average of two experiments. [b] *E*:*Z*, 95:5. [c] Modified conditions: **1a** (1 equiv) and Na_2CO_3 (10 mol%) used in place of **1b** in CH_2Cl_2. [d] *E*:*Z*, 96:4. [e] C2 *E*:*Z*, 96:4; C5 *E*:*Z*, 95:5.

of the starting material and afforded <15% of the desired non-conjugated product (compare to Table 4, entry 7).[27] While the high level of stereoselection for *E*-alkene products is due to the sigmatropic loss of dinitrogen from an allylic diazene intermediate,[19b,29] the regiochemical preference in the reduction is reflective of the initial adduct formation favoring conjugated products. This is illustrated by the exclusive

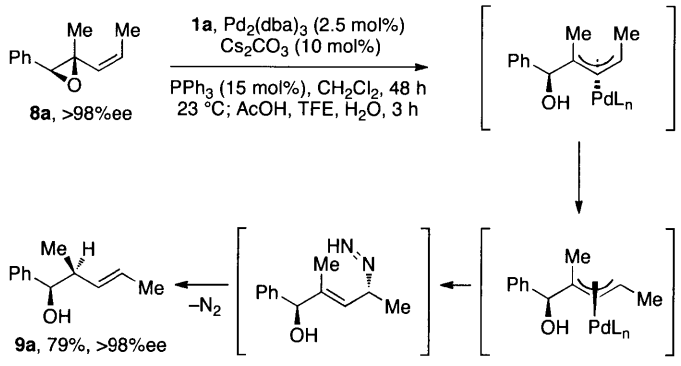
isolation of adduct **4a** (eq 3) from carbonate **2b** if no water is added to the reaction mixture (Table 2, entry 7).



(3)

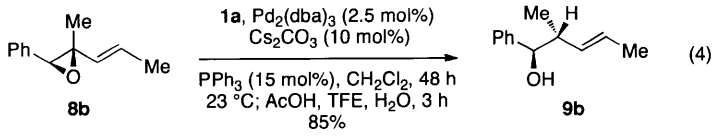
Entries 6-8 of Table 4 are consistent with net S_N2' displacement of carbonates with reagent **1b** to give conjugated sulfonylhydrazones that are ultimately subject to sigmatropic loss of dinitrogen, affording the unconjugated products. For comparison, treatment of methyl 5-phenylpent-1-en-3-yl carbonate with **1b** under the optimal conditions gives 5-phenylpent-1-ene (Table 4, entry 5), while treatment of the corresponding alcohol, 5-phenylpent-1-en-3-ol, with **1a** under Mitsunobu conditions affords the isomeric (*E*)-5-phenylpent-2-ene as a result of direct S_N2 displacement with **1a** followed by sigmatropic loss of dinitrogen (Chapter I, Table 1, entry 3).[18]

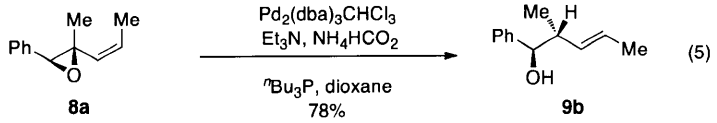
Vinyl epoxides also serve as substrates[30] for this Pd-catalyzed synthesis of allylic diazenes. The use of $Pd_2(dba)_3$ in conjunction with **1a** and cesium carbonate as the base additive more efficiently provided the desired reduction product (Scheme 3). Importantly, this chemistry provides a mild and highly stereoselective conversion of allylic epoxides to the corresponding homoallylic alcohol products. As shown in Scheme 2, exposure of optically active *Z*-allylic epoxide **8a** (>98% ee) gave the desired *syn*-homoallylic alcohol **9a** (>98% ee) in 79% yield. The product is isolated as the *E*-alkene (>98:2, *E*:*Z*) as expected for fragmentation of allylic diazene intermediates.[19b,29]



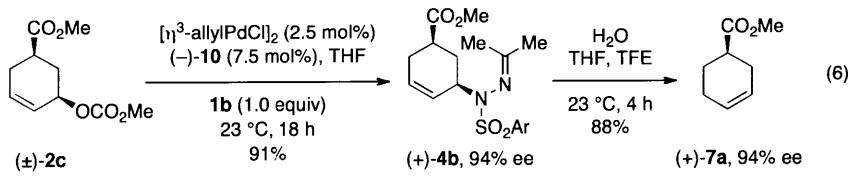
Scheme 3. Palladium-catalyzed conversion of allylic epoxides to allylic diazenes.

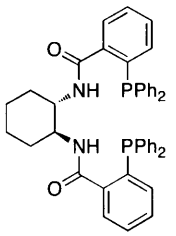
Additionally, treatment of the isomeric *E*-allylic epoxide **8b** resulted in the stereoselective synthesis of the *anti*-homoallylic alcohol derivative **9b** (eq 4). It should be noted that the use of formic acid in the Pd-catalyzed reduction of **8a** as the reducing agent results in the *anti*-diastereomer **9b** (eq 5),[31] highlighting the distinction between the reduction chemistry described here and other related processes.

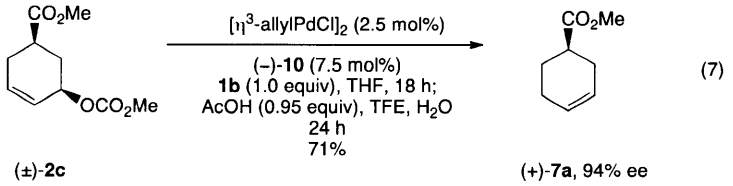




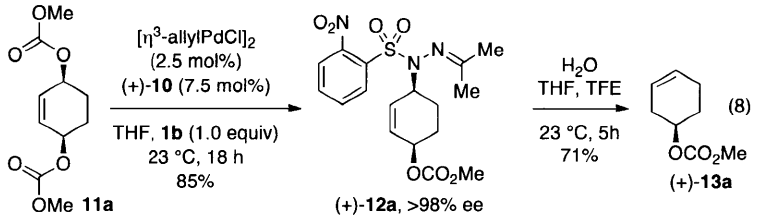
The transformations mentioned above highlight the potential development of catalytic asymmetric variants of this reduction chemistry.[2] We were delighted to find the treatment of carbonate (±)-**2c** and reagent **1b** with a catalyst system comprised of Trost's[32] (*1S,2S*)-(–)-1,2-diaminocyclohexane-*N,N'*-bis(2'-diphenylphosphinobenzoyl) (–)-(**10**) ligand (7.5 mol%) and [η^3-allylPdCl]$_2$ (2.5mol%) gave the sulfonylhydrazone adduct (+)-**4b** in 91% yield and 94% ee (eq 6). Mild hydrolysis of hydrazone (+)-**4b** resulted in the optically active ester (+)-**7a** in 88% yield and 94% ee. The enantiomeric excess was determined by hydrolysis and iodolactonization of the product, followed by chiral HPLC analysis of the iodolactone. The absolute stereochemistry of adduct (+)-**4b** was established by comparison of the optical rotation of the product (+)-**7a** to literature values. Importantly, the conversion of (±)-**2c** to (+)-**7a** can be effected without isolation of (+)-**4b** by direct hydrolysis after complete consumption of (±)-**2c**, affording (+)-**7a** in 71% yield (eq 7).

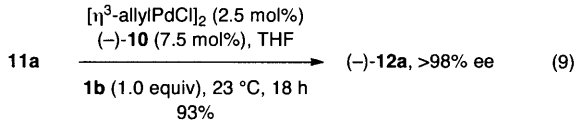


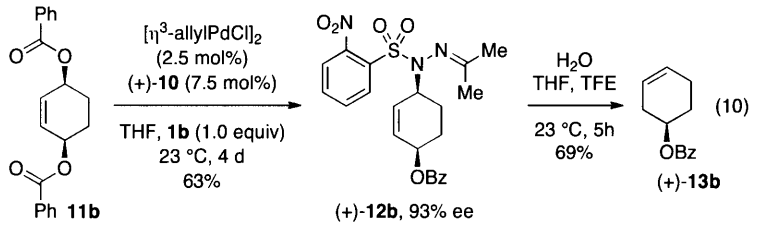




Additionally, treatment of the *meso*-dicarbonate **11a** with reagent **1b** under the optimized reaction conditions employing ligand (+)-**10** afforded the adduct (+)-**12a** in >98% ee and 85% yield (eq 8).[33] The ready availability of both enantiomers of the ligand **10** gives easy access to either enantiomer of the desired adduct and the corresponding reduction product (eq 9). Notably, this chemistry is also amenable to the use of allylic benzoate electrophiles. The catalytic asymmetric synthesis of the adduct (+)-**12b** proceeded with a good level of enantioselection (93% ee), albeit with a more slow reaction rate as compared to allylic carbonates or epoxides examined (eq 10). The mild hydrolysis of the hydrazone adducts **12a** and **12b** provided the corresponding reductively transposed products (+)-**13a** and (+)-**13b** (eqs 8 and 10). Substrates (±)-**2c** and **11a** provide examples for the successful use of both symmetrical and asymmetrical electrophilic π-allyl ligands, respectively, on the intermediate Pd-complex in these processes.







Conclusion

We describe a mild and stereospecific reduction of allylic carbonates and vinyl epoxide substrates. Pd-catalyzed activation of allylic electrophiles efficiently provides a range of *N*-alkylated sulfonyl hydrazones. When *N*-allylated derivatives of IPNBSH (**1a**) are prepared using this methodology, in situ hydrolysis provides access to the corresponding reduction products. This chemistry offers a unique solution to stereospecific synthesis of monoalkyl diazene intermediates from allylic electrophiles under mild reaction conditions. Sensitive substrates that are incompatible with other methods are reduced in a highly stereoselective and regioselective manner. The catalytic asymmetric activation of electrophiles coupled with this new entry to allylic monoalkyl diazenes offers new opportunities for asymmetric synthesis.

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[1] Tsuji, J.; Takahashi, H.; Morikawa, M. *Tetrahedron Lett.* **1965**, 4387.

[2] Trost, B. M.; Crawley, M. L. *Chem. Rev.* **2003**, *102*, 2921.

[3] Trost, B. M.; Sudhakar, A. *J. Am. Chem. Soc.* **1987**, *109*, 3792.

[4] For a review, please see. Johannsen, M.; Jorgensen, K. A. *Chem. Rev.* **1998**, *98*, 1689.

[5] Trost, B. M.; Van Vranken, D. L.; Bingel, C. *J. Am. Chem. Soc.* **1992**, *114*, 9327.

[6] Trost, B. M.; Bunt, R. C.; Lemoine, R. C.; Calkins, T. L. *J. Am. Chem. Soc.* **2000**, *122*, 5968.

[7] Trost, B. M.; Aponick, A. *J. Am. Chem. Soc.* **2006**, *128*, 3931.

[8] Hayashi, T.; Kishi, K.; Yamamoto, A.; Ito, Y. *Tetrahedron Lett.* **1990**, *31*, 1743.

[9] von Matt, P.; Loiseleur, O.; Koch, G.; Pfaltz, A. Lefeber, C.; Feucht, T.; Helmchen, G. *Tetrahedron: Asymmetry* **1994**, *5*, 573.

[10] Hartwig, J. F.; Ohmura, T. *J. Am. Chem. Soc.* **2002**, *124*, 15164.

[11] Takeuchi, R.; Shiga, N. *Org. Lett.* **1999**, *1*, 265.

[12] Defieber, C.; Ariger, M. A.; Moriel, P.; Carreira, E. M. *Angew. Chem. Int. Ed.* **2007**, *46*, 3139-3144.

[13] Enders, D.; Finkman, M. *Synlett.* **1993**, *6*, 401.

[14] Hutchins, R. O.; Wei, J.; Rao, S. J. *J. Org. Chem.* **1994**, *59*, 4007.

[15] Johns, A. M.; Liu, Z.; Hartwig, J. F. *Angew. Chem. Int. Ed.* **2007**, *46*, 7259.

[16] Trost, B. M.; Pulley, S. R. *J. Am. Chem. Soc.* **1995**, *117*, 10143.

[17] Trost, B. M.; Shi, Z. *J. Am. Chem. Soc.* **1996**, *118*, 3037.

[18] Movassaghi, M.; Ahmad, O. K. *J. Org. Chem.* **2007**, *72*, 1838.

[19] (a) Myers, A. G.; Zheng, B. *J. Am. Chem. Soc.* **1996**, *118*, 4492. (b) Myers, A. G.; Zheng, B. *Tetrahedron Lett.* **1996**, *37*, 4841.

[20] Thiele, J. *Liebigs Ann. Chem.* **1892**, *271*, 127.

[21] (a) Hünig, S.; Müller, H. R.; Their, W. *Angew. Chem. Int. Ed. Engl.* **1965**, *4*, 271. (b) Kosower, E. M. *Acc. Chem. Res.* **1971**, *4*, 193 (c) Corey, E. J.; Cane, D. E.; Libit, L. *J. Am. Chem. Soc.* **1971**, *93*, 7016.

[22] Matunas, R.; Lai, A. J.; Lee, C. *Tetrahedron* **2005**, *61*, 6298.

[23] Wood, J. L.; Porco, J. A.; Taunton, J.; Lee, A. Y.; Clardy, J.; Schreiber, S. L. *J. Am. Chem. Soc.* **1992**, *114*, 5898.

[24] Myers, A. G.; Zheng, B. *Tetrahedron Lett.* **1996**, *37*, 4841.

[25] Treatment of **1a** with KH affords the stable and storable **1b.**

[26] While being versatile synthetic intermediates, hydrazones are also utilized as dyes and as pharmacologically active compounds.

[27] For a review, see: Tsuji, J.; Mandai, T. *Synthesis* **1996**, 1.

[28] Maity, S.; Ghosh, S. *Tetrahedron Lett.* **2007**, *48*, 3355.

[29] Myers, A. G.; Kukkola, P. J. *J. Am. Chem. Soc.* **1990**, *112*, 8208.

[30] Trost, B. M.; Bunt, R. C.; Lemoine, R. C.; Calkins, T. L. *J. Am. Chem. Soc.* **2000**, *122*, 5968.

[31] Oshima, M.; Yamazaki, H.; Shimizu, I.; Nisar, M.; Tsuji, J. *J. Am. Chem. Soc.* **1989**, *111*, 6280.

[32] Trost, B. M.; Bunt, R. C. *J. Am. Chem. Soc.* **1994**, *116*, 4089.

[33] The absolute stereochemistries in equations 4-6 are depicted based on analogy to other nucleophiles used in these systems, see a) Trost, B. M.; Cook, G. G. *Tetrahedron Lett.* **1996**, *37*, 7485; b) Trost, B. M.; Chupak, L. S.; Lübbers, T. *J. Am. Chem. Soc.* **1998**, *120*, 1732.

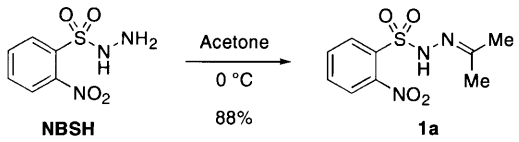
Experimental Section

General Procedures. All reactions were performed in oven-dried or flame-dried round bottomed flasks, modified Schlenk (Kjeldahl shape) flasks, or glass pressure vessels. The flasks were fitted with rubber septa and reactions were conducted under a positive pressure of argon. Stainless steel syringes or cannulae were used to transfer air- and moisture-sensitive liquids. Flash column chromatography was performed as described by Still et al. using silica gel (60-Å pore size, 32–63 μm, standard grade, Sorbent Technologies) or non-activated alumina gel (80–325 mesh, chromatographic grade, EM Science).[1] Analytical thin–layer chromatography was performed using glass plates pre-coated with 0.25 mm 230–400 mesh silica gel or neutral alumina gel impregnated with a fluorescent indicator (254 nm). Thin layer chromatography plates were visualized by exposure to ultraviolet light and/or by exposure to an ethanolic phosphomolybdic acid (PMA), an acidic solution of *p*-anisaldehyde (anis), an aqueous solution of ceric ammonium molybdate (CAM), an aqueous solution of potassium permanganate ($KMnO_4$) or an ethanolic solution of ninhydrin followed by heating (<1 min) on a hot plate (~250 °C). Organic solutions were concentrated on Büchi R-200 rotary evaporators at ~10 Torr (house vacuum) at 25–35 °C, then at ~0.5 Torr (vacuum pump) unless otherwise indicated.

Materials. Commercial reagents and solvents were used as received with the following exceptions: Dichloromethane, diethyl ether, tetrahydrofuran, acetonitrile, and toluene were purchased from J.T. Baker (Cycletainer™) and were purified by the method of Grubbs et al. under positive argon pressure.[2] TFE was distilled from calcium sulfate and stored sealed under an argon atmosphere. Potassium hydride was purchased as a 35% dispersion in mineral oil, washed four times with hexanes and stored in a glove box.

Instrumentation. Proton nuclear magnetic resonance (^{1}H NMR) spectra were recorded with a Varian inverse probe 500 INOVA spectrometer or a Bruker 400 AVANCE spectrometer. Chemical shifts are recorded in parts per million from internal tetramethylsilane on the δ scale and are referenced from the residual protium in the NMR solvent ($CHCl_3$: δ 7.27). Data is reported as follows: chemical shift [multiplicity (s = singlet, d = doublet, q = quartet, m = multiplet), integration, coupling constant(s) in Hertz, assignment]. Carbon-13 nuclear magnetic resonance spectra were recorded with a Varian 500 INOVA spectrometer or a Bruker 400 AVANCE spectrometer and are recorded in parts per million from internal tetramethylsilane on the δ scale and are referenced from the carbon resonances of the solvent ($CDCl_3$: δ 77.2). Data is reported as follows: chemical shift [multiplicity (s = singlet, d = doublet, q = quartet, m = multiplet), coupling constant(s) in Hertz, assignment]. Infrared data were obtained with a Perkin-Elmer 2000 FTIR and are reported as follows: [frequency of absorption (cm^{-1}), intensity of absorption (s = strong, m = medium, w = weak, br = broad), assignment]. We thank Dr. Li Li at the Massachusetts Institute of Technology Department of Chemistry Instrumentation Facility for obtaining mass spectroscopic data.

[1] W. C. Still, M. Kahn, A. Mitra *J. Org. Chem.* **1978**, *43*, 2923.
[2] A. B. Pangborn, M. A. Giardello, R. H. Grubbs, R. K. Rosen, F. J. Timmers *Organometallics* **1996**, *15*, 1518.

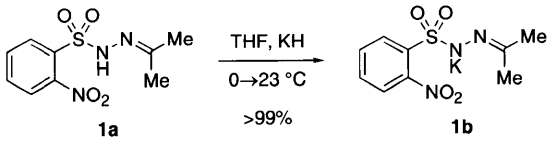


***N*-Isopropylidene-*N'*-2-nitrobenzenesulfonyl hydrazine (IPNBSH):**

2-Nitrobenzenesulfonylhydrazide[3] (NBSH, 2.52 g, 11.6 mmol, 1 equiv) was dissolved in acetone (10 mL) at 0 °C, leading to precipitation of IPNBSH. After 1 h, the solvent was removed under reduced pressure and the residue was dissolved in acetone (20 mL). Slow addition of this acetone solution to a well stirred volume of hexanes (300 mL) at 23 °C lead to trituration of IPNBSH, collection of the fine powder by filtration, followed by sequential hexanes rinses (2 × 10 mL), and removal of volatiles under reduced pressure provided IPNBSH **1a**[4] as a white solid (2.62 g, 88%).

^{1}H NMR (500 MHz, $CDCl_3$, 20 °C) δ:	8.30–8.28 (m, 1H, Ar**H**), 7.87–7.85 (m, 2H, SO_2N**H**, Ar**H**), 7.79–7.77 (m, 2H, Ar**H**), 1.96 (s, 3H, C**H**$_3$), 1.92 (s, 3H, C**H**$_3$).
^{13}C NMR (125 MHz, $CDCl_3$, 20 °C) δ:	159.0, 148.4, 134.3, 133.4, 132.9, 131.9, 125.4, 25.5, 17.1.
FTIR (neat) cm^{-1}:	3264 (m), 1551 (s), 1375 (s), 1347 (m), 1177 (s).
HRMS (ESI):	calc'd for $C_9H_{12}N_3O_4S$ $[M+H]^+$: 258.0543, found: 258.0548.
Melting Point:	139–140 °C (dec.).

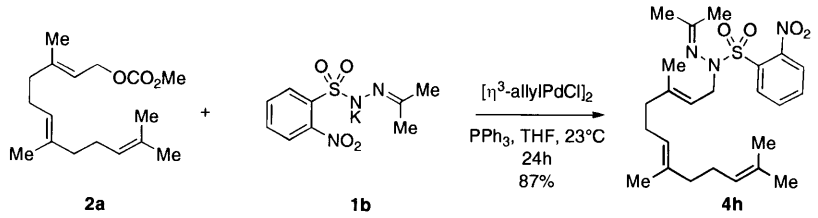
[3] A. G. Myers, B. Zheng, M. Movassaghi *J Org. Chem.* **1997**, *62*, 7507.
[4] M. Movassaghi, O. K. Ahmad *J. Org. Chem.* **2007**, *72*, 1838.



Potassium 1-(2-nitrophenylsulfonyl)-2-(propan-2-ylidene)hydrazin-1-ide (1b):

A solution of IPNBSH **1a** (507 mg, 1.97 mmol, 1 equiv) in THF (15 mL) was added to a suspension of potassium hydride (79 mg, 1.97 mmol, 1.00 equiv) in THF (5 mL) at 0 °C via cannula. The product began to precipitate out as a yellow solid within five min at which point the reaction mixture was allowed to warm to 23 °C. After 30 min, the volatiles were removed under reduced pressure, and the yellow solid obtained was dried under reduced pressure for 24 hours to afford the potassium sulfonylhydrazide **1b** (580 mg, >99%). The reagent **1b** is hygroscopic and is best stored and handled in a glove-box.

^{1}H NMR (500 MHz, DMSO-d_6, 20 °C) δ:	7.83–7.82 (m, 1H, Ar**H**), 7.66–7.58 (m, 3H, Ar**H**), 1.74 (s, 3H, C**H**$_3$), 1.72 (s, 3H, C**H**$_3$).
^{13}C NMR (125 MHz, CD_3CN, 20 °C) δ:	151.4, 149.4, 138.2, 132.5, 132.2, 132.0, 124.3, 25.0, 17.4.
FTIR (nujol) cm^{-1}:	2972 (s), 2726 (m), 1536 (s), 1464 (s), 1377 (s).
HRMS (ESI):	calc'd for $C_9H_{12}N_3O_4SK$ $[M+H]^+$: 296.0102, found: 296.0111.
Melting Point:	151–152 °C (dec.).

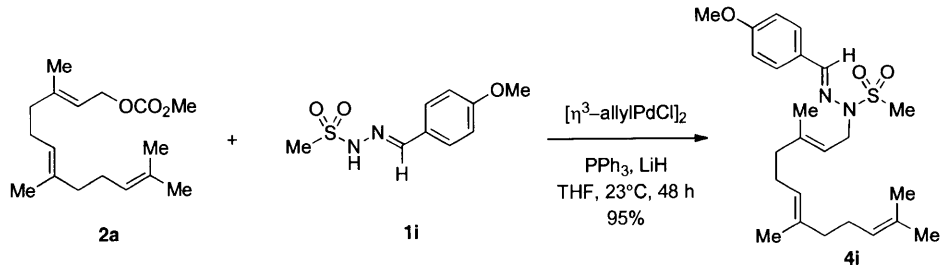


2a **1b** **4h**

2-Nitro-*N'*-(propan-2-ylidene)-*N*-((2*E*,6*E*)-3,7,11-trimethyldodeca-2,6,10-trienyl)benzenesulfonohydrazide (Table 3):

A solution of carbonate **2a** (38 mg, 0.16 mmol, 1 equiv), allylpalladiumchloride dimer (1.4 mg, 3.8 μmol, 2.5 mol%), and triphenylphosphine (4.2 mg, 16 μmol, 10 mol%) in anhydrous THF (700 μL) was added to solid potassium sulfonylhydrazide **1b** (47 mg, 0.16 mmol, 1.0 equiv) via cannula at 23 °C and the reaction mixture was stirred under an atmosphere of argon. After 24 h, the volatiles were removed under reduced pressure and the residue was purified by flash column chromatography (eluent: 30% EtOAc in hexanes; SiO_2: 12 × 3 cm) to give the hydrazone **4h** as a pale-yellow oil (54 mg, 87%).

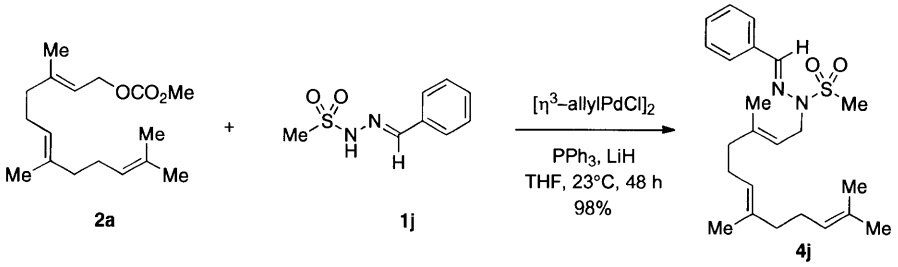
^{1}H NMR (500 MHz, $CDCl_3$, 20 °C) δ:	7.98–7.96 (m, 1H, Ar**H**), 7.73–7.68 (m, 2H, Ar**H**), 7.55–7.54 (m, 1H, Ar**H**), 5.08–5.04 (m, 3H, C=C**H**), 3.84 (d, 2H, J = 7.0, N**CH**$_2$), 2.12 (s, 3H, ((N=C)**CH**$_3$), 2.11 (s, 3H, ((N=C)**CH**$_3$), 2.07–2.01 (m, 4H, (**CH**$_2$)$_2$), 1.98–1.94 (m, 4H, (**CH**$_2$)$_2$), 1.68 (s, 3H, **CH**$_3$), 1.62 (s, 3H, **CH**$_3$), 1.60 (s, 3H, **CH**$_3$), 1.58 (s, 3H, **CH**$_3$).
^{13}C NMR (125 MHz, $CDCl_3$, 20 °C) δ:	182.8, 149.7, 142.5, 135.6, 134.1, 131.9, 131.5, 130.9, 128.3, 124.3, 123.7, 123.6, 117.0, 49.5, 39.9, 39.7, 26.6, 26.5, 25.9, 25.2, 21.2, 17.8, 16.5, 16.1.
FTIR (neat) cm^{-1}:	2918 (br s), 1644 (m), 1589 (m), 1547 (s), 1439 (s), 1372 (s).
HRMS (ESI):	calc'd for $C_{24}H_{36}N_3O_4S$ $[M+H]^+$: 462.2421, found: 462.2412.
TLC (40% EtOAc in hexanes), R_f:	0.40 (UV, $KMnO_4$).



(*E*)-*N'*-(4-Methoxybenzylidene)-*N*-((2*E*,6*E*)-3,7,11-trimethyldodeca-2,6,10-trienyl)methanesulfonohydrazide (Table 3):

A solution of hydrazone **1i** (34 mg, 0.15 mmol, 1.0 equiv) in anhydrous THF (350 μL) was added via cannula to solid lithium hydride (1.2 mg, 0.15 mmol, 1.0 equiv) at 23 °C. After 15 min, a solution of carbonate **2a** (41 mg, 0.15 mmol, 1 equiv), allylpalladiumchloride dimer (1.3 mg, 3.6 μmol, 2.5 mol%), and triphenylphosphine (3.8 mg, 14 μmol, 9.9 mol%) in anhydrous THF (300 μL) was added via cannula to the yellow solution of the lithium sulfonnylhydrazide, and the mixture was stirred under an argon atmosphere. After 48 h, the volatiles were removed under reduced pressure and the residue was purified by flash column chromatography (eluent: 40% EtOAc in hexanes; SiO_2: 18 × 2 cm) to give the hydrazone **4i** as a pale yellow oil (60 mg, 95%).

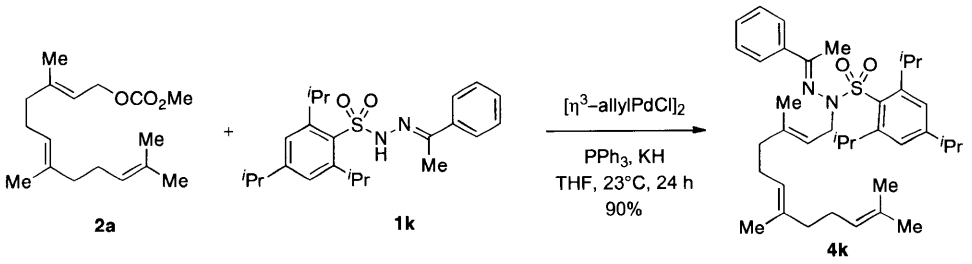
^{1}H NMR (500 MHz, $CDCl_3$, 20 °C) δ:	7.82 (s, 1H, N=C**H**), 7.63 (dt, 2H, *J* = 6.5, 2.0 Hz, Ar**H**), 6.92 (dt, 2H, *J* = 7.0, 2.0 Hz, Ar**H**), 5.23–5.21 (m, 1H, C=C**H**), 5.06–5.03 (m, 2H, C=C**H**), 4.41 (d, 2H, *J* = 6.5 Hz, NC**H**$_2$), 3.85 (s, 3H, OC**H**$_3$), 3.06 (s, 3H, SO_2C**H**$_3$), 2.09–1.90 (m, 8H, (C**H**$_2$)$_2$), 1.77 (s, 3H, C=CC**H**$_3$), 1.68 (s, 3H, C=CC**H**$_3$), 1.59 (s, 3H, C=CC**H**$_3$), 1.57 (s, 3H, C=CC**H**$_3$).
^{13}C NMR (125 MHz, $CDCl_3$, 20 °C) δ:	161.6, 148.1, 141.1, 135.8, 131.5, 129.3, 126.9, 124.4, 123.6, 117.6, 114.3, 55.6, 45.3, 39.9, 39.7, 37.5, 26.9, 26.4, 25.9, 17.9, 16.7, 16.2.
FTIR (neat) cm^{-1}:	2924 (s), 1747 (m), 1607 (m), 1514 (s), 1441(m), 1253 (s), 1161 (s).
HRMS (ESI):	calc'd for $C_{24}H_{37}N_2O_3S$ $[M+H]^+$: 433.2519, found: 433.2534.
TLC (25% EtOAc in hexanes), R_f:	0.31 (UV, $KMnO_4$).



(*E*)-*N'*-Benzylidene-*N*-((2*E*,6*E*)-3,7,11-trimethyldodeca-2,6,10-trienyl)methanesulfonohydrazide (Table 3):

A solution of hydrazone **1j** (25 mg, 0.12 mmol, 1.0 equiv) in anhydrous THF (300 μL) was added via cannula to solid lithium hydride (1.0 mg, 0.12 mmol, 1.0 equiv) at 23 °C. After 15 min, a solution of carbonate **2a** (35 mg, 0.12 mmol, 1 equiv), allylpalladiumchloride dimer (1.1 mg, 3.0 μmol, 2.5 mol%), and triphenylphosphine (3.2 mg, 12 μmol, 10 mol%) in anhydrous THF (300 μL) was added via cannula to the yellow lithium sulfonamide solution and the mixture was stirred under an argon atmosphere. After 48 h, the volatiles were removed under reduced pressure and the residue was purified by flash column chromatography (eluent: 20% EtOAc in hexanes; SiO_2: 16 × 2.0 cm) to afford the hydrazone **4j** as a pale yellow oil (49 mg, 98%).

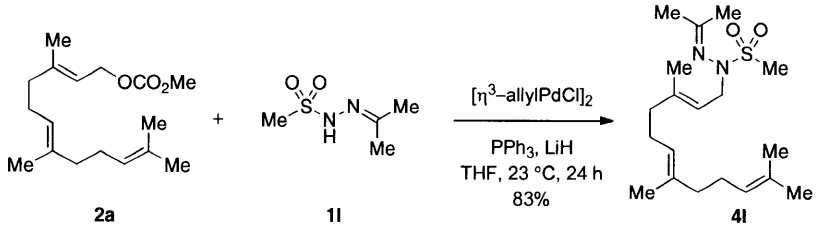
^{1}H NMR (500 MHz, $CDCl_3$, 20 °C) δ:	7.77 (s, 1H, N=C**H**), 7.68–7.67 (m, 2H, Ar**H**), 7.41–7.40 (m, 3H, Ar**H**), 5.23–5.20 (m, 1H, C=C**H**), 5.06–5.04 (m, 2H, C=C**H**), 4.49 (d, 2H, J = 6.5 Hz, N**C**H_2), 3.09 (s, 3H, SO_2CH_3), 2.10–1.90 (m, 8H, $(CH_2)_2$), 1.79 (s, 3H, C=CCH_3), 1.67 (s, 3H, C=CCH_3), 1.58 (s, 3H, C=CCH_3), 1.57 (s, 3H, C=CCH_3).
^{13}C NMR (100 MHz, $CDCl_3$, 20 °C) δ:	145.2, 141.2, 135.9, 134.2, 131.5, 130.3, 128.9, 127.5, 124.4, 123.5, 117.3, 44.5, 39.8, 39.7, 38.2, 26.9, 26.4, 25.9, 17.9, 16.7, 16.2.
FTIR (neat) cm^{-1}:	2918 (s), 1667 (w), 1436 (m), 1349 (s), 1162 (s), 693 (m).
HRMS (ESI):	calc'd for $C_{23}H_{34}N_2NaO_2S$ $[M+Na]^+$: 425.2233, found: 425.2224.
TLC (10% EtOAc in hexanes), R_f:	0.13 (UV, $KMnO_4$).



(*E*)-2,4,6-Triisopropyl-*N'*-(1-phenylethylidene)-*N*-((2*E*,6*E*)-3,7,11-trimethyldodeca-2,6,10-trienyl)-benzenesulfonohydrazide (Table 3):

A solution of hydrazone **1k** (61 mg, 0.15 mmol, 1.0 equiv) in anhydrous THF (350 μL) was added via cannula to solid potassium hydride (6.1 mg, 15 μmol, 1.0 equiv) at 23 °C. After 15 min, a solution of carbonate **2a** (42 mg, 0.15 mmol, 1 equiv), allylpalladiumchloride dimer (1.4 mg, 38 μmol, 2.5 mol%), and triphenylphosphine (4.0 mg, 15 μmol, 10 mol%) in anhydrous THF (350 μL) was added to the potassium sulfonylhydrazide solution via cannula and the mixture was stirred under an argon atmosphere. After 24 h, the volatiles were removed under reduced pressure and the residue was purified by flash column chromatography (eluent: 10% EtOAc in hexanes; SiO_2: 10 × 3 cm) to give the hydrazone **4k** as a pale yellow oil (82 mg, 90%).

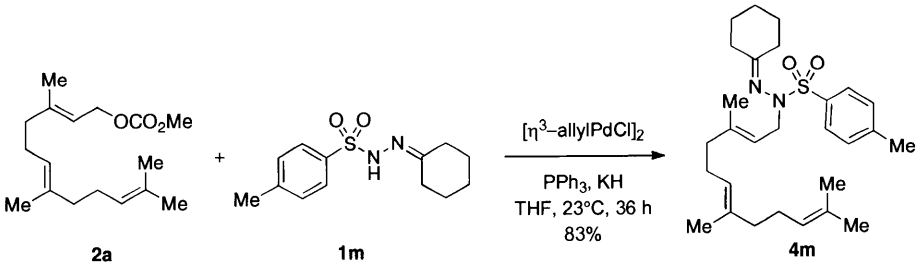
^{1}H NMR (500 MHz, $CDCl_3$, 20 °C) δ:	7.80–7.78 (m, 2H, Ar**H**), 7.43–7.41 (m, 1H, Ar**H**), 7.37–7.34 (m, 2H, Ar**H**), 7.13 (s, 2H, Ar**H**), 5.24–5.21 (m, 1H, C=C**H**), 5.08–5.02 (m, 2H, C=C**H**), 4.21 (septet, 2H, *J* = 7.0 Hz, ArC**H**$(CH_3)_2$), 4.13 (d, 2H, *J* = 7.5 Hz, NC$\mathbf{H}_2$), 2.88 (septet, 1H, *J* = 7.0 Hz, ArC**H**$(CH_3)_2$), 2.26 (s, 3H, (N=C)C$\mathbf{H}_3$), 2.03–1.89 (m, 8H, $(C\mathbf{H}_2)_2$), 1.68 (s, 3H, (C=C)C$\mathbf{H}_3$), 1.66 (s, 3H, (C=C)C$\mathbf{H}_3$), 1.65 (s, 3H, (C=C)C$\mathbf{H}_3$), 1.60 (s, 3H, (C=C)C$\mathbf{H}_3$), 1.24 (d, 6H, *J* = 7.0 Hz, ArCH$(C\mathbf{H}_3)_2$), 1.18 (d, 12H, *J* = 6.5 Hz, ArCH$(C\mathbf{H}_3)_2$).
^{13}C NMR (100 MHz, $CDCl_3$, 20 °C) δ:	175.0, 153.3, 152.4, 141.9, 137.2, 135.5, 131.5, 130.9, 130.7, 128.3, 127.4, 124.4, 124.0, 123.9, 118.1, 47.7, 39.8, 39.8, 34.3, 30.4, 26.9, 26.5, 25.9, 25.3, 23.7, 17.9, 17.5, 16.5, 16.1.
FTIR (neat) cm^{-1}:	2962 (s), 1600 (m), 1572 (w), 1446 (m), 1364 (m), 1165 (s).
HRMS (ESI):	calc'd for $C_{38}H_{57}N_2O_2S$ $[M+H]^+$: 605.4135, found: 605.4145.
TLC (40% EtOAc in hexanes), R_f:	0.61 (UV, $KMnO_4$).



_N'_-(Propan-2-ylidene)-_N_-((2_E_,6_E_)-3,7,11-trimethyldodeca-2,6,10-trienyl)methanesulfonohydrazide (Table 3):

A solution of hydrazone **1l** (23 mg, 0.16 mmol, 1.0 equiv) in anhydrous THF (350 μL) was added via cannula to solid lithium hydride (1.3 mg, 0.16 mmol, 1.0 equiv) at 23 °C. After 15 min, a solution of carbonate **2a** (44 mg, 0.16 mmol, 1 equiv), allylpalladiumchloride dimer (1.4 mg, 3.8 μmol, 2.5 mol%), and triphenylphosphine (4.2 mg, 16 μmol, 10 mol%) in THF (350 μL) was added to the lithium sulfonylhydrazide solution via cannula, and the mixture was stirred under an argon atmosphere. After 24 h, the volatiles were removed under reduced pressure and the residue was purified by flash column chromatography (eluent: 40% EtOAc in hexanes; SiO_2: 15 × 2.0 cm) to give the hydrazone **4l** as a pale yellow oil (47 mg, 83%).

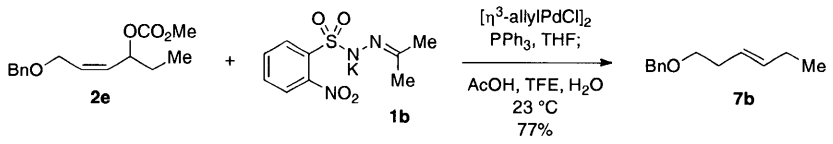
^{1}H NMR (500 MHz, $CDCl_3$, 20 °C) δ:	5.17–5.14 (m, 1H, C=C**H**), 5.11–5.07 (m, 2H, (C=C**H**)$_2$), 3.88 (d, 2H, J = 7.0 Hz, NC**H**$_2$), 2.88 (s, 3H, $SO_2C\mathbf{H}_3$), 2.08 (s, 3H, ((N=C)C**H**$_3$), 2.07 (s, 3H, ((N=C)C**H**$_3$), 2.06–1.96 (m, 8H, (C**H**$_2$)$_2$), 1.68 (s, 6H, (C=C)C**H**$_3$), 1.61 (s, 3H, (C=C)C**H**$_3$), 1.60 (s, 3H, (C=C)C**H**$_3$).
^{13}C NMR (125 MHz, $CDCl_3$, 20 °C) δ:	181.4, 141.9, 135.7, 131.6, 124.4, 123.8, 117.6, 49.8, 39.9, 39.8, 32.4, 26.9, 26.5, 25.9, 25.4, 20.9, 17.9, 16.6, 16.2.
FTIR (neat) cm^{-1}:	2919 (s), 1647 (m), 1437 (m), 1344 (s), 1161 (s).
HRMS (ESI):	calc'd for $C_{19}H_{34}N_2NaO_2S$ $[M+Na]^+$: 377.2233, found: 377.2237.
TLC (35% EtOAc in hexanes), R_f:	0.33 ($KMnO_4$).



***N'*-Cyclohexylidene-4-methyl-*N*-((2*E*,6*E*)-3,7,11-trimethyldodeca-2,6,10-trienyl)benzenesulfonohydrazide (Table 3):**

A solution of hydrazone **1m** (59 mg, 0.22 mmol, 1.0 equiv) in anhydrous THF (500 μL) was added via cannula to solid potassium hydride (8.8 mg, 0.22 mmol, 1.0 equiv) at 23 °C. After 15 min, a solution of carbonate **2a** (61 mg, 0.22 mmol, 1 equiv), allylpalladiumchloride dimer (2.0 mg, 5.5 μmol, 2.5 mol%), and triphenylphosphine (5.7 mg, 22 μmol, 10 mol%) in anhydrous THF (500 μL) was added to the potassium sulfonylhydrazide solution via cannula, and the mixture was stirred under an atmosphere of argon. After 36 h, the volatiles were removed under reduced pressure and the residue was purified by flash column chromatography (eluent: 10% EtOAc in hexanes; SiO_2: 16 × 2.5 cm) to provide the hydrazone **4m** as a pale yellow oil (85 mg, 83%).

^{1}H NMR (500 MHz, $CDCl_3$, 20 °C) δ:	7.69 (app. d, 2H, J = 8.5, Ar**H**), 7.30 (app. d, 2H, J = 8.5, Ar**H**), 5.09–5.01 (m, 3H, C=C**H**), 3.63 (d, 2H, J = 6.5 Hz, NC**H**$_2$), 2.70 (t, 2H, J = 5.5 Hz, (N=C)C**H**$_2$), 2.43 (s, 3H, ArC**H**$_3$), 2.35 (t, 2H, J = 6.0 Hz, C**H**$_2$), 2.07–1.95 (m, 8H, C**H**$_2$), 1.73–1.59 (m, 18H, C**H**$_2$, (C=C)C**H**$_3$).
^{13}C NMR (125 MHz, $CDCl_3$, 20 °C) δ:	186.0, 143.0, 141.5, 135.5, 132.4, 131.6, 129.5, 129.2, 124.4, 123.9, 117.9, 49.3, 39.9, 39.8, 36.1, 31.2, 27.8, 26.9, 26.8, 26.6, 25.9, 25.9, 21.8, 17.9, 16.7, 16.1.
FTIR (neat) cm^{-1}:	2928 (s), 2857 (m), 1634 (s), 1449 (m), 1351 (s), 1165 (s).
HRMS (ESI):	calc'd for $C_{28}H_{43}N_2O_2S$ $[M+H]^+$: 471.3040, found: 471.3049.
TLC (25% EtOAc in hexanes), R_f:	0.24 (UV, $KMnO_4$).

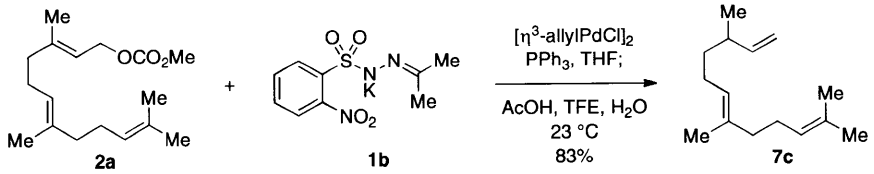


(*E*)-((Hex-3-enyloxy)methyl)benzene (Entry 1, Table 4):

A solution of carbonate **2e** (50 mg, 0.19 mmol, 1 equiv), allylpalladiumchloride dimer (1.7 mg, 4.6 μmol, 2.5 mol%), and triphenylphosphine (7.5 mg, 29 μmol, 10 mol%) in anhydrous THF (800 μL) was added via cannula to a flask containing the potassium sulfonylhydrazide **1b** (56 mg, 0.19 mmol, 1.0 equiv) at 23 °C and the mixture was stirred under an atmosphere of argon. After 24 h, glacial acetic acid (54 μL, 5.0 equiv) was added to quench excess base, and the reaction mixture was diluted with a mixture of trifluoroethanol and water (1:1, 400 μL). After 3 h, the reaction mixture was partitioned between aqueous saturated sodium bicarbonate solution (2 mL) and dichloromethane (10 mL). The organic layer was washed with water (10 mL) whereas the aqueous layer was extracted with dichloromethane (10 mL). The combined organic layers were washed with brine (10 mL), were dried over anhydrous sodium sulfate, and were filtered. The volatiles were removed under reduced pressure and the residue was purified by flash column chromatography (eluent: 4% Et_2O in ^{n}pentane; SiO_2: 13 × 2 cm) on silica gel to provide the alkene **7b** as a clear oil (42 mg, 77%, *E:Z*, 95:5). All spectroscopic data matched those previously reported for this compound.[5]

^{1}H NMR (500 MHz, $CDCl_3$, 20 °C) δ:	7.36–7.29 (m, 5H, Ar**H**), 5.56 (dtt, 1H, J = 15.5, 6.5, 1.5 Hz, C**H**=CH), 5.42 (dtt, 1H, J = 15.0, 7.0, 1.5 Hz, CH=C**H**), 4.53 (s, 2H, PhC**H**$_2$), 3.49 (t, 2H, J = 6.5 Hz, PhCH$_2$OC**H**$_2$), 2.32 (app. qq, 2H, J = 7.0, 1.5 Hz, C**H**$_2$), 2.02 (app. pq, 2H, J = 7.5, 1.0 Hz, C**H**$_2$), 0.98 (t, 3H, J = 7.5 Hz, CH$_2$C**H**$_3$).
^{13}C NMR (125 MHz, $CDCl_3$, 20 °C) δ:	138.8, 134.4, 128.6, 127.9, 127.7, 125.4, 73.0, 70.5, 33.3, 25.9, 14.0.
FTIR (neat) cm^{-1}:	2962 (s), 2932 (s), 2853 (s), 1454 (m), 1362 (m), 1103 (s).
HRMS (ESI):	calc'd for $C_{13}H_{18}NaO$ $[M+Na]^+$: 213.1250, found: 213.1248
TLC (40% EtOAc in hexanes), R_f:	0.70 (UV, anis).

[5] F. Azzena, F. Calvani, P. Crotti, C. Gardelli, F. Macchia, M. Pineschi *Tetrahedron* **1995**, *51*, 10601.

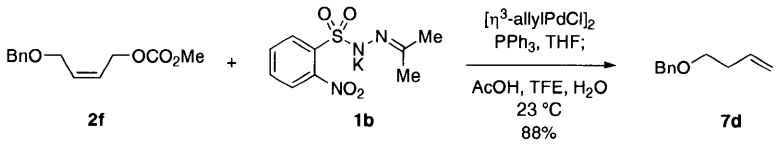


(*E*)-3,7,11-Trimethyldodeca-1,6,10-triene (Entry 2, Table 4):

A solution of carbonate **2a** (40 mg, 0.14 mmol, 1 equiv), allylpalladiumchloride dimer (1.3 mg, 3.6 μmol, 2.5 mol%), and triphenylphosphine (3.9 mg, 15 μmol, 10 mol%) in anhydrous THF (600 μL) was added via cannula to a flask containing the potassium sulfonylhydrazide **1b** (43 mg, 0.15 mmol, 1.0 equiv) at 23 °C, and the reaction mixture was sealed and stirred under an argon atmosphere. After 24 h, glacial acetic acid (41 μL, 5.0 equiv) was added to quench excess base, and the reaction mixture was diluted with a mixture of trifluoroethanol and water (1:1, 300 μL). After 4 h, the reaction mixture was partitioned between aqueous saturated sodium bicarbonate solution (2 mL) and dichloromethane (10 mL). The organic layer was washed with water (10 mL) whereas the aqueous layer was extracted with dichloromethane (10 mL). The combined organic layers were washed with brine (10 mL), were dried over anhydrous sodium sulfate, and were filtered. The volatiles were removed under reduced pressure and the residue was purified by flash column chromatography (eluent: ″pentane; SiO_2: 12 × 2 cm) on silica gel to give the volatile triene **7c** as a clear oil (27 mg, 83%). All spectroscopic data matched those previously reported for this compound.[6]

^{1}H NMR (400 MHz, $CDCl_3$, 20 °C) δ:	5.75–5.68 (m, 1H, C=C**H**), 5.13–5.10 (m, 2H, C=C**H**), 4.98–4.91 (m, 2H, C=C**H**), 2.14–1.98 (m, 7H, C**H**$_2$, C**H**), 1.69 (s, 3H, C**H**$_3$), 1.61 (s, 3H, C**H**$_3$), 1.60 (s, 3H, C**H**$_3$), 1.36–1.33 (m, 2H, C**H**$_2$), 0.99 (d, 3H, J = 8 Hz, (CH)C**H**$_3$).
^{13}C NMR (125 MHz, $CDCl_3$, 20 °C) δ:	145.0, 135.1, 131.5, 124.7, 124.6, 112.7, 39.9, 37.5, 36.9, 26.9, 25.9, 25.8, 20.4, 17.9, 16.2.
FTIR (neat) cm^{-1}:	3077 (m), 2966 (s), 2915 (s), 2856 (s), 1640 (m), 1453 (s), 1376 (s).
MS (*m/z*):	calc'd for $C_{15}H_{26}$ $[M]^+$: 206, found: 206.
TLC (40% EtOAc in hexanes), R_f:	0.80 (CAM, $KMnO_4$).

[6] K. M. Saplay, R. Sahni, N. P. Damodaran, S. Dev *Tetrahedron* **1980**, *36*, 1455.

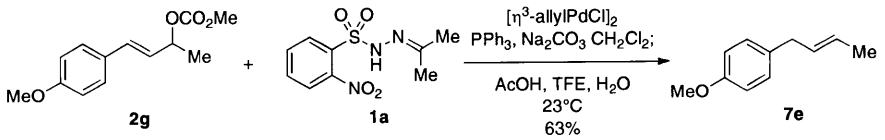


((But-3-enyloxy)methyl)benzene (Entry 3, Table 4):

A solution of carbonate **2f** (45 mg, 0.19 mmol, 1 equiv), allylpalladiumchloride dimer (1.8 mg, 4.9 μmol, 2.5 mol%), and triphenylphosphine (5.0 mg, 19 μmol, 10 mol%) in anhydrous THF (800 μL) was added via cannula to a flask containing the potassium sulfonylhydrazide **1b** (57 mg, 0.19 mmol, 1.0 equiv) at 23 °C, and the reaction mixture was sealed and stirred under an atmosphere of argon. After 24 h, glacial acetic acid (55 μL, 5.0 equiv) was added to quench excess base, and the reaction mixture was diluted with a mixture of trifluoroethanol and water (1:1, 400 μL). After 4 h, the reaction mixture was partitioned between aqueous saturated sodium bicarbonate solution (2 mL), water (10 mL), and dichloromethane (10 mL). The aqueous layer was extracted with dichloromethane (10 mL). The combined organic layers were washed with brine (10 mL), were dried over anhydrous sodium sulfate, and were filtered. The volatiles were removed under reduced pressure and the residue was purified by flash column chromatography (eluent: 4% Et_2O in ^{n}pentane; SiO_2: 15 × 2.0 cm) on silica gel to give the alkene **7d** as a clear oil (28 mg, 88%). All spectroscopic data matched those previously reported for this compound.[7]

^{1}H NMR (500 MHz, $CDCl_3$, 20 °C) δ:	7.38–7.27 (m, 5H, Ar**H**), 5.86 (ddt, J = 17.0, 10.5, 6.5 Hz, 1H, $CH_2C\mathbf{H}=CH_2$), 5.12 (ddt, J = 17.5, 2.0, 1.5 Hz, 1H, trans-$CH_2CH=C\mathbf{H}_2$), 5.06 (ddt, J = 10.5, 2.0, 1.5 Hz, 1H, cis-$CH_2CH=C\mathbf{H}_2$), 4.54 (s, 2H, Ar$C\mathbf{H}_2$), 3.54 (t, J = 6.5 Hz, 2H, $OC\mathbf{H}_2CH_2$), 2.40 (app. qt, J = 6.5, 1.5 Hz, 2H, $C\mathbf{H}_2CH=CH_2$).
^{13}C NMR (125 MHz, $CDCl_3$, 20 °C) δ:	138.7, 135.5, 128.6, 127.9, 127.8, 116.6, 73.1, 69.8, 34.5.
FTIR (neat) cm^{-1}:	3031 (m), 2926 (s), 2855 (s), 1642 (m), 1454 (m), 1362 (m), 1101 (s).
HRMS (ESI):	calc'd for $C_{11}H_{14}NaO$ $[M+Na]^+$: 185.0937, found: 185.0938.
TLC (40% EtOAc in hexanes), R_f:	0.65 (UV, anis).

[7] P. A. Cleary, K. A. Woerpel *Org. Lett.* **2005**, *7*, 5531.

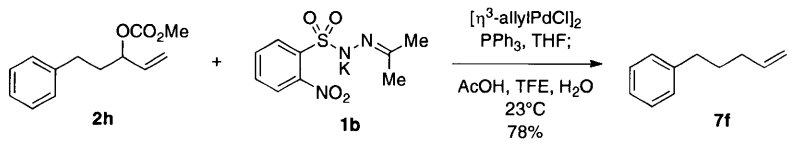


(*E*)-1-(But-2-enyl)-4-methoxybenzene (Entry 4, Table 4):

A solution of allylic carbonate **2g** (30 mg, 0.13 mmol, 1 equiv), allylpalladiumchloride dimer (1.2 mg, 3.3 μmol, 2.5 mol%), and triphenylphosphine (3.4 mg, 13 μmol, 10 mol%) in anhydrous dichloromethane (700 μL) was added via cannula to a mixture of solid IPNBSH **1a** (33 mg, 0.13 mmol, 1.0 equiv) and anhydrous sodium carbonate (1.4 mg, 13 μmol, 10 mol%) at 23 °C, and the reaction mixture was stirred under an argon atmosphere. After 24 h, glacial acetic acid (4 μL, 0.5 equiv) was added to quench excess base, and the reaction mixture was diluted with a mixture of trifluoroethanol and water (1:1, 350 μL). After 12 h, the reaction mixture was partitioned between aqueous saturated sodium bicarbonate solution (1 mL), dichloromethane (5 mL), and water (5 mL). The aqueous layer was extracted with dichloromethane (5 mL). The combined organic layers were washed with brine (5 mL), were dried over anhydrous sodium sulfate, and were filtered. The volatiles were removed under reduced pressure and the residue was purified by flash column chromatography (eluent: 4% Et_2O in ^{n}pentane; SiO_2: 15 × 1.5 cm) on silica gel to give the olefin **7e** as a clear oil (13 mg, 63%, *E*:*Z*, 95:5). All spectroscopic data matched those previously reported for this compound.[8]

^{1}H NMR (500 MHz, $CDCl_3$, 20 °C) δ:	7.11 (app. d, 2H, J = 9.0 Hz, Ar**H**), 6.84 (app. d, 2H, J = 8.5 Hz, Ar**H**), 5.58 (dtq, 1H, J = 15.0, 6.5, 1.0 Hz, CH=C**H**), 5.50 (dqt, 1H, J = 15.0, 6.0, 1.0 Hz, C**H**=CH), 3.80 (s, 3H, C**H**$_3$O), 3.27 (d, 2H, ArC**H**$_2$, J = 6.5 Hz), 1.69 (app. dq, 3H, J = 6.0, 1.0 Hz, CH=CHC**H**$_3$).
^{13}C NMR (100 MHz, $CDCl_3$, 20 °C) δ:	158.0, 133.3, 130.7, 129.6, 126.2, 114.0, 55.5, 38.3, 18.1.
FTIR (neat) cm^{-1}:	2999 (m), 2915 (m), 2843 (m), 1611 (m), 1512 (s), 1245 (s).
HRMS (ESI):	calc'd for $C_{11}H_{14}ONa$ $[M+Na]^+$: 185.0937, found: 185.0937.
TLC (40% EtOAc in hexanes), R_f:	0.65 (UV, anis).

[8] M. R. Heinrich, O. Blank, D. Ullrich, M. Kirschstein *J. Org. Chem.* **2007**, *72*, 9609.

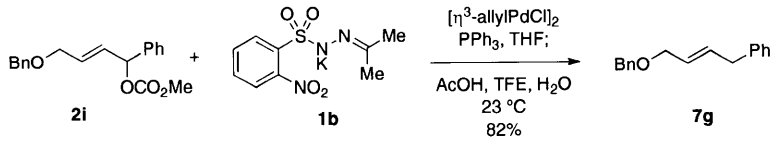


Pent-4-enylbenzene (Entry 5, Table 4):

A solution of carbonate **2h** (57 mg, 0.26 mmol, 1 equiv), allylpalladiumchloride dimer (2.4 mg, 6.5 μmol, 2.5 mol %), and triphenylphosphine (6.8 mg, 26 μmol, 10 mol %) in anhydrous THF (1.1 mL) was added via cannula to a flask containing solid potassium sulfonylhydrazide **1b** (76 mg, 0.26 mmol, 1.0 equiv) at 23 °C, and the reaction mixture was stirred under an atmosphere of argon. After 24 h, glacial acetic acid (64 μL, 5.0 equiv) was added to quench excess base, and the reaction mixture was diluted with a mixture of trifluoroethanol and water (1:1, 550 μL). After 3 h, the reaction mixture was partitioned between aqueous saturated sodium bicarbonate solution (2 mL), water (10 mL), and dichloromethane (10 mL). The aqueous layer was extracted with dichloromethane (10 mL). The combined organic layers were washed with brine (10 mL), were dried over anhydrous sodium sulfate, and were filtered. The volatiles were removed under reduced pressure and the residue was purified by flash column chromatography (eluent: ^{n}pentane; SiO_2: 11 × 2.0 cm) on silica gel to afford the alkene **7f** as a clear oil (30 mg, 78%). All spectroscopic data matched those previously reported for this compound.[9]

^{1}H NMR (500 MHz, $CDCl_3$, 20 °C) δ:	7.31–7.28 (m, 2H, Ar**H**), 7.20–7.19 (m, 3H, Ar**H**), 5.85 (ddt, 1H, J = 17.0, 10.5, 6.5 Hz, C**H**=CH$_2$), 5.06 (dtd, 1H, J = 17.5, 2.0, 0.5 Hz, trans-CH=C**H**$_2$), 4.99 (dtd, 1H, J = 10.5, 1.5, 0.5 Hz, cis-CH=C**H**$_2$), 2.64 (t, 2H, J = 7.5 Hz, PhC**H**$_2$), 2.13-2.09 (m, 2H, C**H**$_2$CH=CH$_2$), 1.77-1.70 (m, 2H, PhCH$_2$C**H**$_2$).
^{13}C NMR (100 MHz, $CDCl_3$, 20 °C) δ:	142.7, 138.8, 128.7, 128.5, 125.9, 114.9, 35.5, 33.5, 30.8.
FTIR (neat) cm^{-1}:	2923 (s), 2853 (m), 1640 (w), 1496 (m), 1454 (m), 910 (m).
HRMS (EI):	calc'd for $C_{11}H_{14}$ $[M]^+$: 146.1090, found: 146.1091.
TLC (4% Et_2O in ^{n}pentane), R_f:	0.25 (UV, $KMnO_4$).

[9] S. A. Gamage, R. A. J. Smith *Tetrahedron Lett.* **1990**, *46*, 2112.

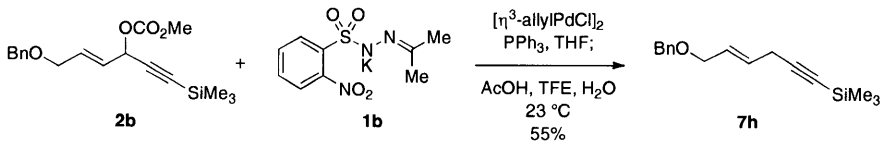


(*E*)-(4-(Benzyloxy)but-2-enyl)benzene (Entry 6, Table 4):

A solution of carbonate **2i** (67 mg, 0.22 mmol, 1 equiv), allylpalladiumchloride dimer (2.0 mg, 5.5 μmol, 2.5 mol%), and triphenylphosphine (5.6 mg, 21 μmol, 10 mol%) in anhydrous THF (0.9 mL) was added to a flask containing solid potassium sulfonylhydrazide **1b** (64 mg, 0.22 mmol, 1.0 equiv) at 23 °C and the mixture was stirred under an argon atmosphere. After 12 h, glacial acetic acid (62 μL, 5.0 equiv) was added to quench excess base, and the reaction mixture was diluted with a mixture of trifluoroethanol and water (1:1, 450 μL). After 3 h, the reaction mixture was partitioned between aqueous saturated sodium bicarbonate solution (2 mL), water (10 mL), and dichloromethane (10 mL). The aqueous layer was extracted with dichloromethane (10 mL). The combined organic layers were washed with brine (10 mL), were dried over anhydrous sodium sulfate, and were filtered. The volatiles were removed under reduced pressure, and the residue was purified by flash column chromatography (eluent: 5% Et_2O in ^{n}pentane; SiO_2: 15 × 2.5 cm) on silica gel to provide the alkene **7g** as a clear oil (42 mg, 82%, *E*:*Z*, 96:4). All spectroscopic data matched those previously reported for this compound.[10]

^{1}H NMR (500 MHz, $CDCl_3$, 20 °C) δ:	7.37–7.21 (m, 10H, Ar**H**), 5.91 (dtt, 1H, J = 15.5, 6.5, 1.5 Hz, CH=C**H**), 5.70 (dtt, 1H, J = 15.0, 6.0, 1.5 Hz, CH=C**H**), 4.54 (s, 2 H, Ph**CH$_2$**OCH$_2$), 4.04 (dd, 2H, J = 6.0, 1.0 Hz, PhCH$_2$O**CH$_2$**), 3.43 (d, 2H, J = 6.5 Hz, Ph**CH$_2$**CH=CH).
^{13}C NMR (125 MHz, $CDCl_3$, 20 °C) δ:	140.2, 138.5, 133.3, 128.8, 128.7, 128.6, 128.0, 128.0, 127.8, 126.3, 72.3, 70.9, 39.0.
FTIR (neat) cm^{-1}:	3028 (s), 2851 (s), 1721 (m), 1603 (m), 1495 (s), 1453 (s), 1115 (s).
HRMS (ESI):	calc'd for $C_{17}H_{18}NaO$ $[M+Na]^+$: 261.1250, found: 261.1246.
TLC (4% Et_2O in ^{n}pentane), R_f:	0.17 (UV, anis).

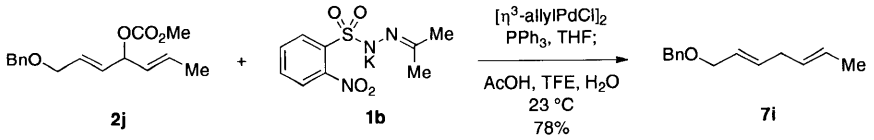
[10] J. D. Kim, M. H. Lee, G. Han. H. Park, O. P. Zee, Y. H. Jung *Tetrahedron* **2001**, 57, 8257.



(*E*)-(6-(Benzyloxy)hex-4-en-1-ynyl)trimethylsilane (Entry 7, Table 4):

A solution of carbonate **2b** (32 mg, 0.096 mmol, 1 equiv), allylpalladiumchloride dimer (0.9 mg, 2.5 μmol, 2.6 mol%), and triphenylphosphine (2.5 mg, 9.5 μmol, 10 mol%) in anhydrous THF (500 μL) was added via cannula to a flask containing solid potassium sulfonylhydrazide **1b** (28 mg, 0.095 mmol, 1.0 equiv) at 23 °C and the mixture was stirred under an atmosphere of argon. After 12 h, glacial acetic acid (28 μL, 5.0 equiv) was added to quench excess base, and the reaction mixture was diluted with a mixture of trifluoroethanol and water (1:1, 250 μL). After 3 h, the reaction mixture was partitioned between aqueous saturated sodium bicarbonate solution (2 mL), and dichloromethane (5 mL). The aqueous layer was extracted with dichloromethane (5 mL) and the combined organic layers were washed with brine (5 mL), were dried over anhydrous sodium sulfate, and were filtered. The volatiles were removed under reduced pressure, and the residue was purified by flash column chromatography (eluent: 5% Et_2O in ^{n}pentane; SiO_2: 18 × 2 cm) on silica gel to afford the eneyne **7h** as a clear oil (14 mg, 55%, *E*:*Z*, 96:4).

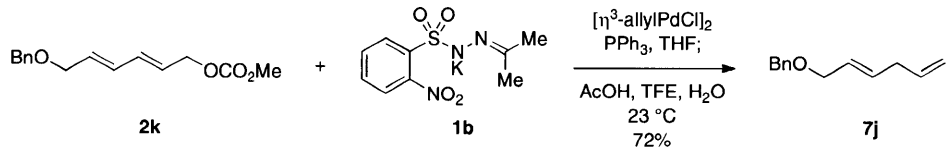
^{1}H NMR (500 MHz, $CDCl_3$, 20 °C) δ:	7.36–7.29 (m, 5H, Ar**H**), 5.89 (dtt, 1H, J = 15.5, 6.0, 1.5 Hz, CH=C**H**), 5.72 (dtt, 1H, J = 15.5, 5.5, 1.0 Hz, CH=C**H**), 4.53 (s, 2H, PhC**H**$_2$O), 4.04 (dd, 2H, J = 6.0, 1.5 Hz, PhCH$_2$OC**H**$_2$), 3.04 (dd, 2H, J = 5.0, 1.0 Hz, CHC**H**$_2$CCSi(CH$_3$)$_3$), 0.18 (s, 9H, Si(C**H**$_3$)$_3$).
^{13}C NMR (125 MHz, $CDCl_3$, 20 °C) δ:	138.5, 128.6, 128.4, 128.0, 127.8, 127.7, 103.7, 87.1, 72.3, 70.4, 23.1, 0.3.
FTIR (neat) cm^{-1}:	2959 (s), 2853 (m), 2177 (s), 1454 (w), 1250 (s) 843 (s).
HRMS (ESI):	calc'd for $C_{16}H_{22}NaOSi$ [M+Na]$^+$: 281.1332, found: 281.1343.
TLC (4% Et_2O in ^{n}pentane), R_f:	0.29 (UV, $KMnO_4$).



(((2*E*,5*E*)-Hepta-2,5-dienyloxy)methyl)benzene (Entry 8, Table 4):

A solution of carbonate **2j** (50 mg, 0.18 mmol, 1 equiv), allylpalladiumchloride dimer (1.7 mg, 4.6 μmol, 2.5 mol%), and triphenylphosphine (4.8 mg, 18 μmol, 10 mol%) in anhydrous THF (800 μL) was added via cannula to a flask containing solid potassium sulfonylhydrazide **1b** (54 mg, 0.18 mmol, 1.0 equiv) at 23 °C, and the mixture was stirred under an argon atmosphere. After 24 h, glacial acetic acid (52 μL, 5.0 equiv) was added to quench excess base, and the reaction mixture was diluted with a mixture of trifluoroethanol and water (1:1, 550 μL). After 3 h, the reaction mixture was partitioned between aqueous saturated sodium bicarbonate solution (2 mL) and dichloromethane (10 mL). The organic layer was washed with water (10 mL) whereas the aqueous layer was extracted with dichloromethane (10 mL). The combined organic layers were washed with brine (10 mL), were dried over anhydrous sodium sulfate, and were filtered. The volatiles were removed under reduced pressure and the residue was purified by flash column chromatography (eluent: 5% Et_2O in *n*pentane; SiO_2: 14 × 2.0 cm) on silica gel to give the diene **7i** as a clear oil (29 mg, 78%, C2-*E*:*Z*, 96:4, C5-*E*:*Z*, 95:5).

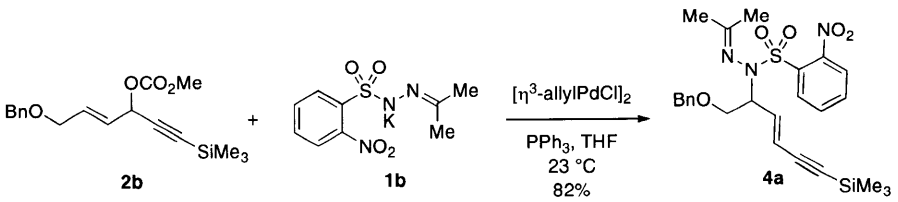
^{1}H NMR (500 MHz, $CDCl_3$, 20 °C) δ:	7.36–7.29 (m, 5H, Ar**H**), 5.74 (dtt, 1H, *J* = 15.5, 6.5, 1.5 Hz, C**H**=CH), 5.62 (dtt, 1H, *J* = 15.5, 6.0, 1.5 Hz, CH=C**H**), 5.51–5.41 (m, 2H, CH=C**H**), 4.52 (s, 2H, PhC**H**$_2$O), 3.99 (dd, 2H, J = 6.0, 1.0 Hz, PhCH$_2$OC**H**$_2$), 2.77–2.74 (m, 2H, CH=CHC**H**$_2$CH=CH), 1.67 (app. dt, 3H, *J* = 5.0, 1.5 Hz, CH=CHC**H**$_3$).
^{13}C NMR (125 MHz, $CDCl_3$, 20 °C) δ:	138.6, 133.4, 128.9, 128.6, 128.0, 127.8, 127.0, 126.4, 72.2, 71.1, 35.5, 18.2.
FTIR (neat) cm^{-1}:	2918 (s), 2854 (s), 1453 (m), 1361 (m), 1070 (s), 969 (s).
HRMS (ESI):	calc'd for $C_{14}H_{18}NaO$ $[M+Na]^+$: 225.1250, found: 225.1256.
TLC (4% Et_2O in *n*pentane), R_f:	0.28 (UV, $KMnO_4$).



(*E*)-((Hexa-2,5-dienyloxy)methyl)benzene (Entry 9, Table 4):

A solution of allylic carbonate **2k** (47 mg, 0.18 mmol, 1 equiv), allylpalladiumchloride dimer (1.6 mg, 4.4 μmol, 2.5 mol%), and triphenylphosphine (4.7 mg, 18 μmol, 10 mol%) in anhydrous THF (750 μL) was added via cannula to a flask containing solid potassium sulfonylhydrazide **1b** (53 mg, 0.18 mmol, 1.0 equiv) at 23 °C, and the mixture was stirred under an argon atmosphere. After 24 h, glacial acetic acid (50 μL, 5.0 equiv) was added to quench excess base, and the reaction mixture was diluted with a mixture of trifluoroethanol and water (1:1, 400 μL). After 4 h, the reaction mixture was partitioned between aqueous saturated sodium bicarbonate solution (2 mL), water (10 mL), and dichloromethane (10 mL). The aqueous layer was extracted with dichloromethane (10 mL). The combined organic layers were washed with brine (10 mL), were dried over anhydrous sodium sulfate, and were filtered. The volatiles were removed under reduced pressure and the residue was purified by flash column chromatography (eluent: 5% Et_2O in ^{n}pentane; SiO_2: 10 × 2.0 cm) on silica gel to provide the diene **7j** as a clear oil (28 mg, 72%).

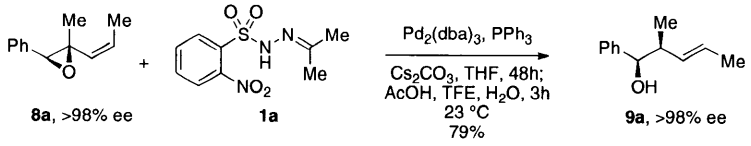
^{1}H NMR (500 MHz, $CDCl_3$, 20 °C) δ:	7.36–7.28 (m, 5H, Ar**H**), 5.85 (ddt, 1H, J = 17.0, 10.5, 6.5 Hz, C**H**=CH_2), 5.76 (dtt, 1H, J = 15.5, 6.5, 1.0 Hz, CH=C**H**), 5.65 (dtt, 1H, J = 15.5, 6.0, 1.0 Hz, CH=C**H**), 5.07 (app. dq, 1H, J = 17.0, 1.5 Hz, trans-CH=C**H**$_2$), 5.03 (app. dq, 1H, J = 10.0, 1.5 Hz, cis-CH=C**H**$_2$), 4.52 (s, 2H, PhC**H**$_2$O), 4.01 (app. dq, 2H, J = 6.0, 1.0 Hz, PhCH$_2$OC**H**$_2$), 2.85–2.82 (m, 2H, CH=CHC**H**$_2$CH=CH).
^{13}C NMR (125 MHz, $CDCl_3$, 20 °C) δ:	138.6, 136.5, 132.3, 128.6, 128.0, 127.8, 127.7, 115.8, 72.2, 70.9, 36.6.
FTIR (neat) cm^{-1}:	3030 (m), 2851 (s), 1638 (m), 1453 (m), 1361 (m), 1103 (s), 735 (s), 697 (s).
HRMS (ESI):	calc'd for $C_{13}H_{16}NaO$ $[M+Na]^+$: 211.1093, found: 211.1095.
TLC (40% EtOAc in hexanes), R_f:	0.67 (UV, anis).



(*E*)-*N*-(1-(Benzyloxy)-6-(trimethylsilyl)hex-3-en-5-yn-2-yl)-2-nitro-*N'*-(propan-2-ylidene)benzene-sulfonohydrazide (4a, Equation 3):

A solution of carbonate **2b** (59 mg, 0.18 mmol, 1 equiv), allylpalladiumchloride dimer (1.6 mg, 4.4 μmol, 2.5 mol%), and triphenylphosphine (4.7 mg, 18 μmol, 10 mol%) in anhydrous THF (900 μL) was added via cannula to a flask containing solid potassium sulfonylhydrazide **1b** (53 mg, 0.18 mmol, 1.0 equiv) at 23 °C and the mixture was stirred under an argon atmosphere. After 12 h, the volatiles were removed under reduced pressure, and the residue was purified by flash column chromatography on silica gel (eluent: 10→30% EtOAc in hexanes; SiO_2: 18 × 2 cm) to afford the hydrazone **4a** as a yellow viscous oil (75 mg, 82%).

^{1}H NMR (500 MHz, $CDCl_3$, 20 °C) δ:	7.96–7.94 (m, 1H, Ar**H**), 7.64–7.62 (m, 1H, Ar**H**), 7.51–7.49 (m, 1H, Ar**H**), 7.34–7.28 (m, 6H, Ar**H**), 5.97 (dd, 1H, *J* = 16.5, 9.0 Hz, C=C**H**), 5.58 (dd, 1H, *J* = 16.5, 1.0 Hz, C=C**H**), 4.83–4.79 (m, 1H, $ArSO_2NC\mathbf{H}$), 4.53 (d, 1H, *J* = 11.5 Hz, $PhC\mathbf{H}_2O$), 4.40 (d, 1H, *J* = 11.5 Hz, $PhC\mathbf{H}_2O$), 3.37 (dd, 1H, *J* = 11.0, 8.5 Hz, $PhCH_2OC\mathbf{H}_2$), 3.28 (dd, 1H, *J* = 10.5, 5.5 Hz, $PhCH_2OC\mathbf{H}_2$), 2.17 (s, 3H, (N=C)$C\mathbf{H}_3$), 2.16 (s, 3H, (N=C)$C\mathbf{H}_3$), 0.15 (s, 9H, $Si(C\mathbf{H}_3)_3$).
^{13}C NMR (125 MHz, $CDCl_3$, 20 °C) δ:	185.6, 149.1, 137.7, 136.5, 134.1, 131.5, 131.0, 130.8, 128.6, 128.0, 127.9, 123.5, 114.5, 102.7, 95.9, 72.7, 70.2, 61.5, 25.6, 21.6, 0.0.
FTIR (neat) cm^{-1}:	2917 (m), 2849 (m), 1627 (w), 1546 (s), 1373 (s) 844 (s).
HRMS (ESI):	calc'd for $C_{25}H_{31}N_3NaO_5SSi$ $[M+Na]^+$: 536.1646, found: 536.1648.
TLC (40% EtOAc in hexanes), R_f:	0.40 (UV, anis).



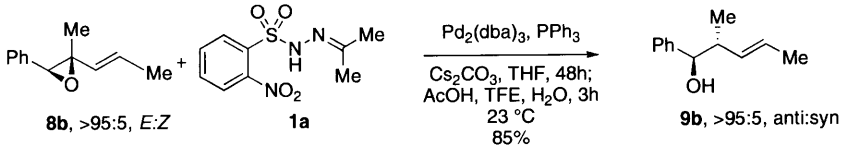
(1*R*,2*S*,*E*)-2-Methyl-1-phenylpent-3-en-1-ol (9a, Scheme 3):

A solution of epoxide **8a**[11] (60 mg, 0.34 mmol, 1 equiv), $Pd_2(dba)_3$ (7.8 mg, 0.0085 mmol, 0.025 equiv), and triphenylphosphine (14 mg, 0.051 mmol, 0.15 equiv) in anhydrous dichloromethane (1.4 mL) was added via cannula to a mixture of solid anhydrous cesium carbonate (11 mg, 0.034 mmol, 0.10 equiv) and IPNBSH **1a** (88 mg, 0.34 mmol, 1.0 equiv) at 23 °C and the mixture was stirred under an argon atmosphere. After 48 h, glacial acetic acid (98 μL, 5.0 equiv) was added to quench excess base, and the reaction mixture was diluted with a mixture of trifluoroethanol and water (1:1, 0.7 mL). After 3 h, the reaction mixture was partitioned between aqueous saturated sodium bicarbonate solution (2 mL), water (10 mL), and dichloromethane (10 mL). The aqueous layer was extracted with dichloromethane (10 mL). The combined organic layers were washed with brine (10 mL), were dried over anhydrous sodium sulfate, and were filtered. The volatiles were removed under reduced pressure, and the residue was purified by flash column chromatography (eluent: 1% acetone in dichloromethane; SiO_2: 19 × 2.0 cm) on silica gel to give the homoallylic alcohol **9a** (48 mg, 79%, *E:Z*, >98:2) as a single diastereomer. The enantiomeric excess was determined to be >98% by Mosher ester analysis. All spectroscopic data matched those previously reported for this compound.[12]

^{1}H NMR (500 MHz, $CDCl_3$, 20 °C) δ:	7.36-7.32 (m, 2H, Ar**H**), 7.31-7.27 (m, 3H, Ar**H**), 5.50 (dqd, 1H, J = 15.5, 6.5, 1.0 Hz, C**H**=CHCH$_3$), 5.37 (ddq, 1H, J = 15.5, 7.5, 2.0 Hz, CH=C**H**CH$_3$), 4.61 (app. t, 1H, J = 4.5, PhC**H**OH), 2.57-2.51 (m, 1H, CH(OH)C**H**CH$_3$), 1.94 (d, 1H, J = 4.5 Hz, O**H**), 1.67 (app. dq, 3H, J = 6.0, 1.0 Hz, CH=CHC**H**$_3$), 0.96 (d, 3H, J = 6.5 Hz, CH(OH)CHC**H**$_3$).
^{13}C NMR (125 MHz, $CDCl_3$, 20 °C) δ:	142.8, 133.0, 128.2, 127.4, 126.7, 126.6, 77.6, 43.9, 18.3, 14.7.
FTIR (neat) cm^{-1}:	3404 (br s), 3029 (m), 2965 (m), 1653 (w), 1452 (s), 968 (s).
HRMS (ESI):	calc'd for $C_{12}H_{16}NaO$ $[M+Na]^+$: 199.1093, found: 199.1094.

TLC (10% EtOAc, 45% PhMe, and 45% hexanes), R_f: 0.34 (UV, anis).

[11] Enantiomeric excess of epoxide **8** was determined to be >98% by Mosher ester analysis of a derivative.
[12] R. W. Hoffmann, K. Ditrich, G. Koester, R. Stuermer *Chem. Ber.* **1989**, *122*, 1783.

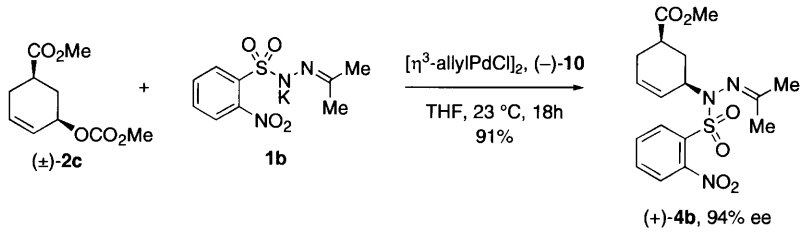


(*1R,2R,E*)-2-Methyl-1-phenylpent-3-en-1-ol (9b, Equation 4):

A solution of epoxide **8b** (12 mg, 0.069 mmol, 1 equiv), $Pd_2(dba)_3$ (1.6 mg, 0.0017 mmol, 0.025 equiv), and triphenylphosphine (2.7 mg, 0.010 mmol, 0.15 equiv) in anhydrous dichloromethane (0.70 mL) was added via cannula to a mixture of solid anhydrous cesium carbonate (2.2 mg, 0.0068 mmol, 0.10 equiv) and IPNBSH **1a** (18 mg, 0.069 mmol, 1.0 equiv) at 23 °C and the mixture was stirred under an argon atmosphere. After 48 h, glacial acetic acid (20 μL, 5.0 equiv) was added to quench excess base, and the reaction mixture was diluted with a mixture of trifluoroethanol and water (1:1, 0.35 mL). After 3 h, the reaction mixture was partitioned between aqueous saturated sodium bicarbonate solution (1 mL), water (5 mL), and dichloromethane (5 mL). The aqueous layer was extracted with dichloromethane (5 mL). The combined organic layers were washed with brine (5 mL), were dried over anhydrous sodium sulfate, and were filtered. The volatiles were removed under reduced pressure, and the residue was purified by flash column chromatography (eluent: 5% acetone, 3% iPrOH in hexanes, SiO_2: 15 × 1.5 cm) on silica gel to give the homoallylic alcohol **9b** (10 mg, 85%, *E:Z*, >98:2).

^{1}H NMR (500 MHz, $CDCl_3$, 20 °C) δ:	7.37-7.33 (m, 2H, Ar**H**), 7.30-7.27 (m, 3H, Ar**H**), 5.68 (dqd, 1H, *J* = 15.5, 6.5, 1.0 Hz, C**H**=CHCH$_3$), 5.40 (ddq, 1H, *J* = 15.5, 8.5, 1.5 Hz, CH=C**H**CH$_3$), 4.27 (dd, 1H, *J* = 8.5, 2.0 Hz, PhC**H**OH), 2.40 (app. sextet, 1H, *J* = 7.5 Hz, CH(OH)C**H**CH$_3$), 2.23 (d, 1H, *J* = 2.5 Hz, O**H**), 1.75 (ddd, 3H, *J* = 6.5, 1.5, 0.5 Hz, CH=CHC**H**$_3$), 0.83 (d, 3H, *J* = 7.0 Hz, CH(OH)CHC**H**$_3$).
^{13}C NMR (125 MHz, $CDCl_3$, 20 °C) δ:	142.7, 133.5, 128.4, 128.4, 127.8, 127.2, 78.3, 45.9, 18.4, 17.3.
FTIR (neat) cm^{-1}:	3423 (br s), 2966 (m), 1648 (m), 1451 (m), 969 (s), 700 (m).
HRMS (ESI):	calc'd for $C_{12}H_{16}NaO$ $[M+Na]^+$: 199.1093, found: 199.1099.

TLC (10% EtOAc, 45% PhMe, and 45% hexanes), R_f: 0.34 (UV, anis).

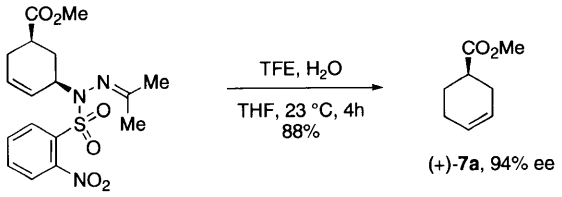


(*1R,5R*)-Methyl 5-(1-(2-nitrophenylsulfonyl)-2-(propan-2-ylidene)hydrazinyl)cyclohex-3-enecarboxylate ((+)-4b, Equation 6):

A solution of carbonate (±)-**2c** (271 mg, 1.27 mmol, 1 equiv) in anhydrous THF (4.5 mL) was added via cannula to a solution of allylpalladiumchloride dimer (12 mg, 0.032 mmol, 2.5 mol%), and (*1S,2S*)-(–)-1,2-diaminocyclohexane-*N,N'*-bis(2'-diphenylphosphinobenzoyl)[13] ((–)-**10**, 66 mg, 0.095 mmol, 7.5 mol%) in anhydrous THF (2.0 mL) at 23 °C via cannula. After 20 min, the resulting yellow solution was transferred via cannula to a flask containing solid potassium sufonylhydrazide **1b** (374 mg, 1.27 mmol, 1.00 equiv) and the mixture was stirred under an argon atmosphere. After 18 h, the reaction mixture was concentrated, and the residue was purified by flash column chromatography (eluent: 30→60% EtOAc in hexanes; SiO_2: 16 × 3.0 cm) on silica gel to give hydrazone (+)-**4b** ($[\alpha]^{22}_D$ = +18.7 (*c* 1.3, CH_2Cl_2) as a pale yellow, viscous oil (454 mg, 91%). The enantiomeric excess was determined to be 94% by chiral HPLC analysis [AD-H; 1.3 mL/min; 7% ^{i}PrOH in hexanes; t_R (minor) = 11.7 min, t_R (major) = 14.7 min].

^{1}H NMR (500 MHz, $CDCl_3$, 20 °C) δ:	7.96-7.94 (m, 1H, Ar**H**), 7.75–7.67 (m, 2H, Ar**H**), 7.56–7.54 (m, 1H, Ar**H**), 5.69–5.65 (m, 1H, C**H**=CH), 5.21 (d, 1H, *J* = 10.0 Hz, CH=C**H**), 4.96–4.93 (m, 1H, C**H**NSO_2Ar), 3.67 (s, 3H, CO_2CH_3), 2.78–2.72 (m, 1H, C**H**CO_2Me), 2.25–2.20 (m, 1H, C**H**), 2.18 (s, 3H, $NCCH_3$), 2.17 (s, 3H, $NCCH_3$), 2.14–2.04 (m, 2H, CH_2), 1.60–1.53 (m, 1H, C**H**).
^{13}C NMR (125 MHz, $CDCl_3$, 20 °C) δ:	185.1, 175.1, 148.7, 134.2, 131.8, 131.4, 131.2, 129.0, 126.4, 123.7, 58.0, 52.1, 39.0, 29.4, 27.3, 25.5, 21.6.
FTIR (neat) cm^{-1}:	2953 (m), 2919 (m), 1734 (s), 1547 (s), 1438 (m), 1373 (s), 1173 (s).
HRMS (ESI):	calc'd for $C_{17}H_{22}N_3O_6S$ $[M+H]^+$: 396.1224, found: 396.1224.
TLC (60% EtOAc in hexanes), R_f:	0.29 (UV, anis).

[13] a) B. M. Trost, D. L. Van Vranken, C. Bingel *J. Am. Chem. Soc.* **1992**, *114*, 9327. b) B. M. Trost, R. C. Bunt *J. Am. Chem. Soc.* **1994**, *116*, 4089.



(+)-**4b**, 94% ee

(+)-**7a**, 94% ee

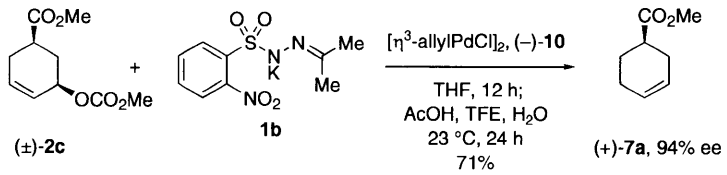
(*R*)-Methyl cyclohex-3-enecarboxylate ((+)-7a, equation 6):

A mixture of trifluoroethanol and water (1:1, 2.7 mL) was added to a solution of hydrazone (+)-**4b** (428 mg, 1.08 mmol, 1 equiv) in THF (5.4 mL) at 23 °C. After 4 h, the reaction mixture was diluted with dichloromethane (50 mL) and washed with water (50 mL). The yellow aqueous layer was extracted with dichloromethane (50 mL). The combined organic layers were washed with brine (20 mL), were dried over anhydrous sodium sulfate, and were filtered. The volatiles were removed under reduced pressure, and the residue was purified by flash column chromatography (eluent: 5% Et_2O in ^{n}pentane; SiO_2: 15 × 2.0 cm) on silica gel to give the ester (+)-**7a** ($[\alpha]^{22}_D$ = +80.0 (*c* 0.93, $CHCl_3$); lit.[14] $[\alpha]^{20}_D$ = +80.4 (*c* 1.06, $CHCl_3$); lit.[15] $[\alpha]^{20}_D$ = +86.5 (*c* 1.0, $CHCl_3$)) as a clear oil (133 mg, 88%). The enantiomeric excess was determined to be 94% by hydrolysis and iodolactonization of the product, followed by chiral HPLC analysis of the iodolactone [AD-H; 0.75 mL/min; 2.5% ^{i}PrOH in hexanes; t_R (minor) = 14.1 min, t_R (major) = 18.7 min].

^{1}H NMR (500 MHz, $CDCl_3$, 20 °C) δ:	5.72–5.65 (m, 2H, **CH=CH**), 3.70 (s, 3H, CO_2CH_3), 2.60–2.55 (m, 1H, **CH**CO_2Me), 2.26–2.25 (m, 2H, CH_2), 2.15–1.99 (m, 3H, CH_2), 1.73–1.65 (m, 1H, CH_2).
^{13}C NMR (125 MHz, $CDCl_3$, 20 °C) δ:	176.6, 126.9, 125.4, 51.9, 39.4, 27.7, 25.3, 24.7.
FTIR (neat) cm^{-1}:	3027 (s), 2951 (s), 2843 (s), 1737 (s), 1437 (s), 1306 (s), 1224 (s), 1167 (s).
HRMS (ESI):	calc'd for $C_8H_{13}O_2$ $[M+H]^+$: 141.0910, found: 141.0917.
TLC (5% Et_2O in ^{n}pentane), R_f:	0.27 ($KMnO_4$).

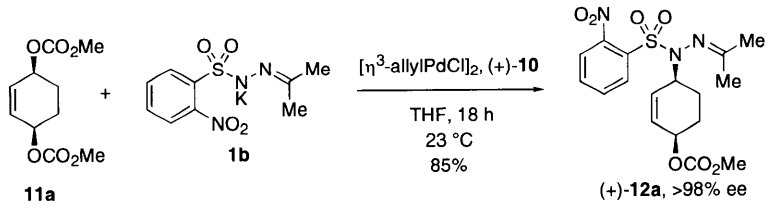
[14] G. Karig, A. Fuchs, A. Büsing, T. Brandstetter, S. Scherer, J. W. Bats, A. Eschenmoser, G. Quinkert *Helv. Chim. Acta* **2000**, *83*, 1049.

[15] C. Tanyeli, E. Turkut *Tetrahedron:* Asym. **2004**, *15*, 2057.



(*R*)-Methyl cyclohex-3-enecarboxylate ((+)-7a, Equation 7):

A solution of carbonate (±)-**2c** (67 mg, 0.31 mmol, 1 equiv) in anhydrous THF (800 μL) was added to a solution of allylpalladiumchloride dimer (2.9 mg, 7.9 μmol, 2.5 mol%), and (*1S,2S*)-(–)-1,2-diaminocyclohexane-*N,N'*-bis(2'-diphenylphosphinobenzoyl)[13] (**10**, 16 mg, 23 μmol, 7.5 mol%) in anhydrous THF (100 μL) at 23 °C via cannula. After 20 min the resulting yellow solution was transferred via cannula to a flask containing solid potassium sufonylhydrazide **1b** (92 mg, 0.31 mmol, 1.0 equiv) and the mixture was stirred under an argon atmosphere. After 12 h, the reaction mixture was diluted by the addition of trifluoroethanol and water (1:1, 600 μL), and excess base was quenched by the addition of glacial acetic acid (17 μL, 0.97 equiv). After 24 h, the reaction mixture was diluted with dichloromethane (10 mL) and washed with water (10 mL). The aqueous layer was extracted with dichloromethane (10 mL). The combined organic layers were washed with brine (10 mL), were dried over anhydrous sodium sulfate, and were filtered. The volatiles were removed under reduced pressure, and the residue was purified by flash column chromatography (eluent: 5% Et_2O in hexanes; SiO_2: 15 × 1.5 cm) on silica gel to give ester (+)–**7a** as a clear oil (35 mg, 79%). The enantiomeric excess was determined to be 94% by hydrolysis and iodolactonization of the product, followed by chiral HPLC analysis of the iodolactone [AD-H; 0.75 mL/min; 2.5% ^{i}PrOH in hexanes; t_R (minor) = 14.1 min, t_R (major) = 18.7 min].

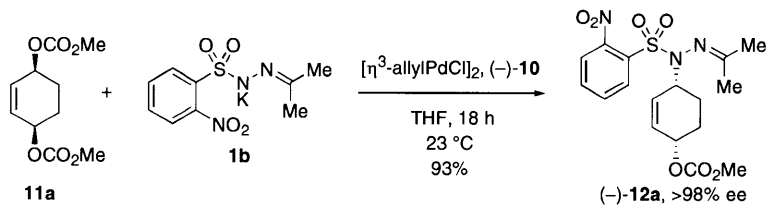


Methyl (*1S,4R*)-4-(1-(2-nitrophenylsulfonyl)-2-(propan-2-ylidene)hydrazinyl)cyclohex-2-enyl carbonate) ((+)-12a, Equation 8):

A solution of carbonate **11a** (64 mg, 0.28 mmol, 1 equiv) in anhydrous THF (1.2 mL) was added via cannula to a solution of allylpalladiumchloride dimer (2.6 mg, 0.0071 mmol, 2.5 mol%), and (*1R,2R*)-(+)-1,2-diaminocyclohexane-*N,N'*-bis(2'-diphenylphosphinobenzoyl)[16] ((+)-**10**, 15 mg, 0.021 mmol, 7.5 mol%) in anhydrous THF (0.2 mL) at 23 °C via cannula. After 30 min, the resulting yellow solution was transferred via cannula to a flask containing solid potassium sufonylhydrazide **1b** (83 mg, 0.28 mmol, 1.0 equiv) and the mixture was stirred under an argon atmosphere. After 18 h, the reaction mixture was concentrated, and the residue was purified by flash column chromatography (eluent: 50% EtOAc in hexanes; SiO_2: 14 × 2.5 cm) on silica gel to give hydrazone (+)-**12a** ($[\alpha]^{22}_D$ = +34.3 (*c* 1.5, CH_2Cl_2)) as a foamy white solid (98 mg, 85%). The enantiomeric excess was determined to be >98% by chiral HPLC analysis [AD-H; 1.3 mL/min; 7% ^{i}PrOH in hexanes; t_R (minor) = 12.8 min, t_R (major) = 14.3 min].

^{1}H NMR (500 MHz, $CDCl_3$, 20 °C) δ:	7.95-7. 93 (m, 1H, Ar**H**), 7.76–7.67 (m, 2H, Ar**H**), 7.56–7.55 (m, 1H, Ar**H**), 5.82–5.79 (m, 1H, C**H**=CH), 5.58 (d, 1H, *J* = 11 Hz, CH=C**H**), 4.78–4.74 (m, 1H, C**H**OCO_2Me), 4.96–4.95 (m, 1H, C**H**NSO_2Ar), 3.75 (s, 3H, OCO_2CH_3), 2.17 (s, 3H, $NCCH_3$), 2.16 (s, 3H, $NCCH_3$), 1.87–1.85 (m, 2H, CH_2), 1.65–1.63 (m, 2H, CH_2).
^{13}C NMR (125 MHz, $CDCl_3$, 20 °C) δ:	184.8, 155.3, 148.6, 134.3, 132.8, 131.8, 131.3, 130.6, 127.6, 123.6, 69.4, 56.8, 54.8, 26.8, 25.4, 22.4, 21.3.
FTIR (neat) cm^{-1}:	2958 (m), 1744 (s), 1633 (s), 1547 (s), 1442 (m), 1373 (s), 1269 (s), 1173 (s).
HRMS (ESI):	calc'd for $C_{17}H_{21}N_3NaO_7S$ $[M+Na]^+$: 434.0992, found: 434.0996.
TLC (50% EtOAc in hexanes), R_f:	0.32 (UV, CAM).

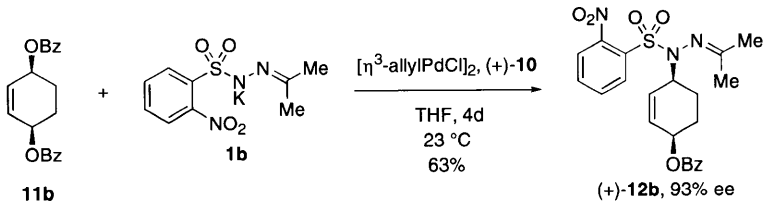
[16] a) B. M. Trost, D. L. Van Vranken, C. Bingel *J. Am. Chem. Soc.* **1992**, *114*, 9327. b) B. M. Trost, R. C. Bunt *J. Am. Chem. Soc.* **1994**, *116*, 4089.



Methyl (*1R,4S*)-4-(1-(2-nitrophenylsulfonyl)-2-(propan-2-ylidene)hydrazinyl)cyclohex-2-enyl carbonate) ((–)-12a, Equation 9):

A solution of carbonate **11a** (14 mg, 0.063 mmol, 1 equiv) in anhydrous THF (0.45 mL) was added via cannula to a solution of allylpalladiumchloride dimer (0.6 mg, 0.0016 mmol, 2.5 mol%), and (*1S,2S*)-(–)-1,2-diaminocyclohexane-*N,N'*-bis(2'-diphenylphosphinobenzoyl)[17] ((–)-**10**, 3.2 mg, 0.0046 mmol, 7.5 mol%) in anhydrous THF (0.1 mL) at 23 °C via cannula. After 30 min, the resulting yellow solution was transferred via cannula to a flask containing solid potassium sufonylhydrazide **1b** (19 mg, 0.064 mmol, 1.0 equiv) and the mixture was stirred under an argon atmosphere. After 18 h, the reaction mixture was concentrated, and the residue was purified by flash column chromatography (eluent: 50% EtOAc in hexanes; SiO_2: 11 × 2.0 cm) on silica gel to give hydrazone (–)-**12a** ($[\alpha]^{22}_D$ = –33.1 (*c* 1.5, CH_2Cl_2)) as a foamy white solid (24 mg, 93%). The enantiomeric excess was determined to be >98% by chiral HPLC analysis [AD-H; 1.3 mL/min; 7% ^{i}PrOH in hexanes; t_R (major) = 12.6 min, t_R (minor) = 14.1 min].

[17] a) B. M. Trost, D. L. Van Vranken, C. Bingel *J. Am. Chem. Soc.* **1992**, *114*, 9327. b) B. M. Trost, R. C. Bunt *J. Am. Chem. Soc.* **1994**, *116*, 4089.

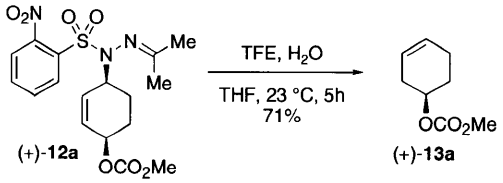


***(1S,4R)*-4-(1-(2-Nitrophenylsulfonyl)-2-(propan-2-ylidene)hydrazinyl)cyclohex-2-enyl benzoate ((+)-12b, Equation 10):**

A solution of benzoate **11b** (78 mg, 0.24 mmol, 1 equiv) in anhydrous THF (1.0 mL) was added via cannula to a solution of allylpalladiumchloride dimer (2.2 mg, 0.0060 mmol, 2.5 mol%), and (*1R,2R*)-(+)-1,2-diaminocyclohexane-*N,N'*-bis(2'-diphenylphosphinobenzoyl)[18] ((+)-**10**, 13 mg, 0.028 mmol, 7.5 mol%) in anhydrous THF (0.2 mL) at 23 °C via cannula. After 30 min, the resulting yellow solution was transferred via cannula to a flask containing solid potassium sufonylhydrazide **1b** (72 mg, 0.24 mmol, 1.0 equiv) and the mixture was stirred under an argon atmosphere. After 4 days, the reaction mixture was concentrated, and the residue was purified by flash column chromatography (eluent: 40% EtOAc in hexanes; SiO_2: 15 × 2.5 cm) on silica gel to give hydrazone (+)-**12b** ($[\alpha]^{22}_D$ = +39.6 (*c* 1.0, CH_2Cl_2)) as a foamy white solid (70 mg, 63%). The enantiomeric excess was determined to be 93% by chiral HPLC analysis [AD-H; 1.3 mL/min; 7% ^{i}PrOH in hexanes; t_R (minor) = 16.7 min, t_R (major) = 19.4 min].

^{1}H NMR (500 MHz, C_6D_6, 20 °C) δ:	8.05–8.03 (m, 2H, Ar**H**), 7.81 (dd, 1H, *J* = 7.5, 3.0 Hz, Ar**H**), 7.10–7. 07 (m, 1H, Ar**H**), 7.07–6.98 (m, 2H, Ar**H**), 6.72–6.57 (m, 3H, Ar**H**), 5.79–5.75 (m, 1H, C**H**=CH), 5.56 (dt, 1H, *J* = 10.0, 1.0 Hz, CH=C**H**), 5.22 (app. q, 1H, *J* = 4.0 Hz, C**H**OBz), 4.97–4.94 (m, 1H, C**H**NSO$_2$Ar), 1.82 (s, 3H, NCC**H**$_3$), 1.80–1.70 (m, 2H, C**H**$_2$), 1.69 (s, 3H, NCC**H**$_3$), 1.59–1.53 (m, 1H, C**H**$_2$), 1.48–1.44 (m, 1H, C**H**$_2$).
^{13}C NMR (125 MHz, $CDCl_3$, 20 °C) δ:	184.9, 166.0, 148.8, 134.2, 133.1, 132.5, 131.9, 131.4, 131.1, 130.6, 129.7, 128.7, 128.5, 123.8, 66.2, 57.2, 27.0, 25.4, 22.5, 21.5.
FTIR (neat) cm^{-1}:	2954 (m), 1713 (s), 1633 (w), 1547 (s), 1373 (s), 1272 (s), 1173 (s).
HRMS (ESI):	calc'd for $C_{22}H_{24}N_3O_6S$ $[M+H]^+$: 458.1320, found: 458.1398.
TLC (40% EtOAc in hexanes), R_f:	0.31 (UV, CAM).

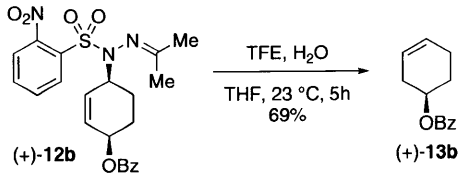
[18] a) B. M. Trost, D. L. Van Vranken, C. Bingel *J. Am. Chem. Soc.* **1992**, *114*, 9327. b) B. M. Trost, R. C. Bunt *J. Am. Chem. Soc.* **1994**, *116*, 4089.



***(S)*-Cyclohex-3-enyl methyl carbonate (13a, Equation 8):**

A mixture of trifluoroethanol and water (1:1, 0.65 mL) was added to a solution of hydrazone (+)-**12a** (105 mg, 0.26 mmol, 1 equiv) in THF (1.3 mL) at 23 °C. After 5 h, the reaction mixture was diluted with dichloromethane (10 mL) and washed with water (10 mL). The yellow aqueous layer was extracted with dichloromethane (10 mL). The combined organic layers were washed with brine (10 mL), were dried over anhydrous sodium sulfate, and were filtered. The volatiles were removed under reduced pressure, and the residue was purified by flash column chromatography (eluent: 8% Et_2O in ^{n}pentane; SiO_2: 10 × 1.5 cm) on silica gel to give the carbonate (+)-**13a** ($[a]^{22}_D$ = +20.4 (*c* 1.4, CH_2Cl_2)) as a clear oil (32 mg, 71%).

^{1}H NMR (500 MHz, $CDCl_3$, 20 °C) δ:	5.71–5.67 (m, 1H, **CH=CH**), 5.60–5.56 (m, 1H, **CH=CH**), 4.92–4.87 (m, 1H, **CH**OCO_2Me), 3.78 (s, 3H, CO_2CH_3), 2.46–2.41 (m, 1H, CH_2), 2.21–2.14 (m, 3H, CH_2), 1.97–1.94 (m, 1H, CH_2), 1.83–1.77 (m, 1H, CH_2).
^{13}C NMR (100 MHz, $CDCl_3$, 20 °C) δ:	155.5, 127.0, 123.5, 74.0, 54.7, 30.8, 27.4, 23.4.
FTIR (CH_2Cl_2) cm^{-1}:	2957 (m), 2254 (w), 1744 (s), 1444 (m), 1286 (m), 910 (s).
HRMS (ESI):	calc'd for $C_8H_{12}NaO_3$ $[M+Na]^+$: 179.0679, found: 179.0684.
TLC (8% Et_2O in ^{n}pentane), R_f:	0.30 ($KMnO_4$).



(*S*)-Cyclohex-3-enyl benzoate (13b, Equation 10):

A mixture of trifluoroethanol and water (1:1, 0.4 mL) was added to a solution of hydrazone (+)-**12b** (70 mg, 0.15 mmol, 1 equiv) in THF (0.8 mL) at 23 °C. After 5 h, the reaction mixture was diluted with dichloromethane (10 mL) and washed with water (10 mL). The yellow aqueous layer was extracted with dichloromethane (10 mL). The combined organic layers were washed with brine (10 mL), were dried over anhydrous sodium sulfate, and were filtered. The volatiles were removed under reduced pressure, and the residue was purified by flash column chromatography (eluent: 8% Et_2O in ^{n}pentane; SiO_2: 7 × 1.5 cm) on silica gel to give the benzoate (+)-**13b** ($[a]^{22}_D$ = +45.0 (*c* 1.1, CH_2Cl_2)) as a clear oil (22 mg, 69%).

^{1}H NMR (500 MHz, $CDCl_3$, 20 °C) δ:	8.05 (dd, 2H, *J* = 8.0, 1.0 Hz, Ar**H**), 7.55(t, 1H, *J* = 7.5 Hz, Ar**H**), 7.44 (app. t, 2H, *J* = 8.0 Hz, Ar**H**), 5.75–5.73 (m, 1H, C**H**=C**H**), 5.65–5.63 (m, 1H, C**H**=C**H**), 5.29–5.28 (m, 1H, C**H**OBz), 2.52–2.23 (m, 1H, C**H**$_2$), 2.28–2.22 (m, 3H, C**H**$_2$), 2.01–1.99 (m, 1H, C**H**$_2$), 1.90–1.88 (m, 1H, C**H**$_2$).
^{13}C NMR (100 MHz, $CDCl_3$, 20 °C) δ:	166.4, 133.0, 131.0, 130.0, 128.5, 127.0, 123.9, 70.4, 31.0, 27.5, 23.4.
FTIR (neat) cm^{-1}:	3028 (m), 2922 (m), 2846 (m), 1712 (s), 1650 (s), 1451 (m), 1274 (s), 1115 (m).
HRMS (ESI):	calc'd for $C_{13}H_{14}NaO_2$ $[M+Na]^+$: 225.0886, found: 225.0889.
TLC (8% Et_2O in ^{n}pentane), R_f:	0.44 (UV, $KMnO_4$).

Chapter III

Single-Step Synthesis of Pyridine Derivatives

Introduction and Background

The pyridine substructure is one of the most prevalent heterocyclic systems in natural products, pharmaceuticals, and functional materials.[1,2] BILN 2061,[3] a Hepatitis C virus (HCV) protease inhibitor, and indinavir sulfate,[4] a human immunodeficiency virus (HIV) protease inhibitor, are two of the many examples of pyridine derived pharmaceutical drug targets that have shown potent antiviral activity in humans (Figure 1). Imidacloprid,[5] which also contains a pyridine substructure, is a commonly used neuro-active insecticide. In nature, pyridines are found as important building blocks in the form of niacin and nicotine, as well as constituents of more complex alkaloids like chiapenine ES-II, isolated from the leaves of *Maytenis chiapensis*,[6] and phantasmidine that was recently isolated from the Ecuadorian poison frog *Epipedobates anthonyi*[7] (Figure 1).

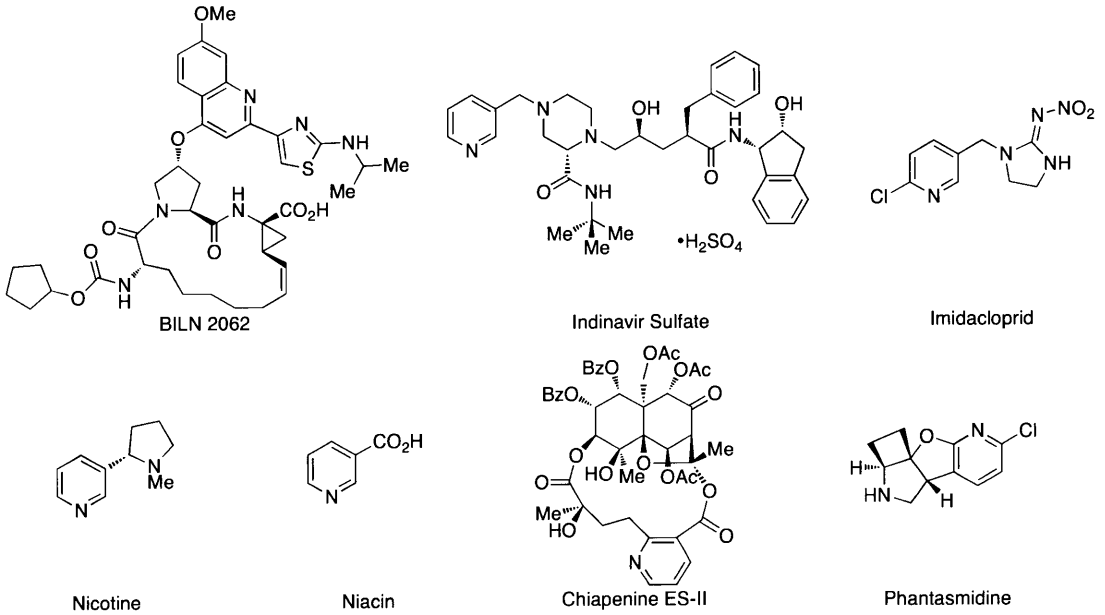
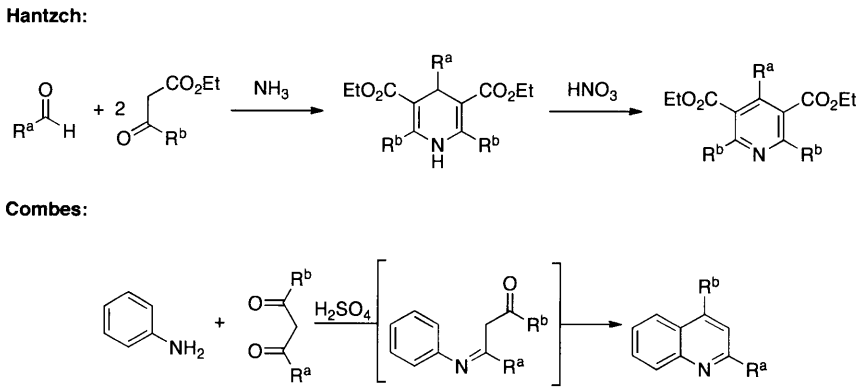


Figure 1. Representative examples of compounds containing a pyridine substructure.

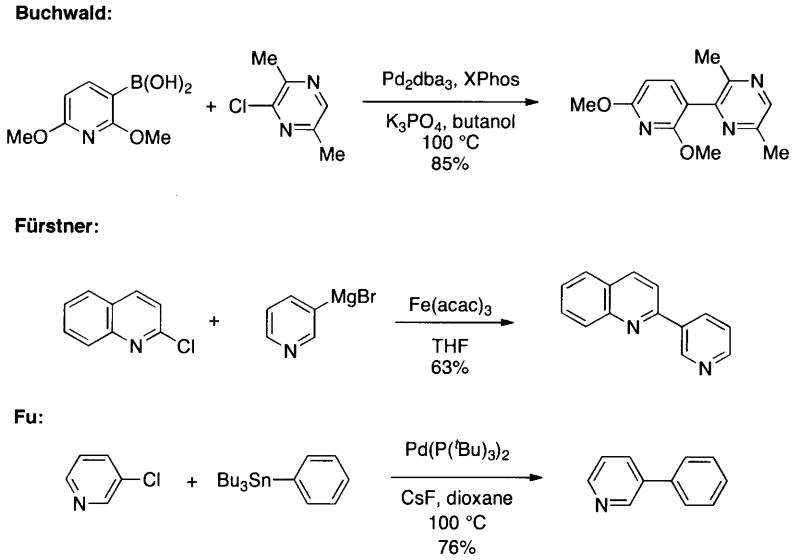
The majority of synthetic routes to pyridines and quinolines rely on condensation reactions of amines and carbonyl compounds.[8,9] The Hantzsch pyridine synthesis[10] is perhaps the most well known example of a route to this class of azaheterocycles. It relies on condensation of a 1,3-dicarbonyl derivative and an aldehyde in the presence of an ammonia equivalent (Scheme 1). Combes[11] pioneered the synthesis of quinolines that

utilizes a condensation reaction between an aniline and a 1,3-dicarbonyl derivative (Scheme 1).



Scheme 1. Synthesis of pyridines and quinolines.

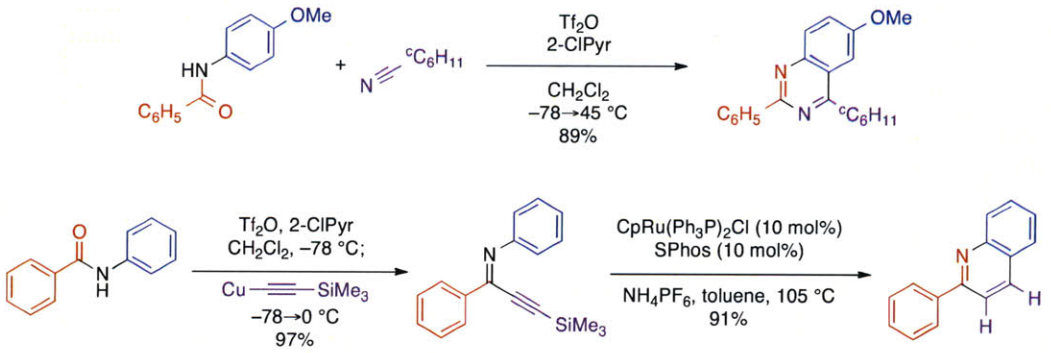
Advances in cross-coupling chemistry have recently permitted introduction of substituents on activated heterocycles (Scheme 2).[12] This substituent modification approach, utilizing, for instance, Suzuki-Miyaura,[13] Stille[14] and iron-catalyzed cross-coupling reactions,[15] has allowed access to a variety of structurally diverse pyridines.



Scheme 2. Cross-coupling of pyridine derivatives.

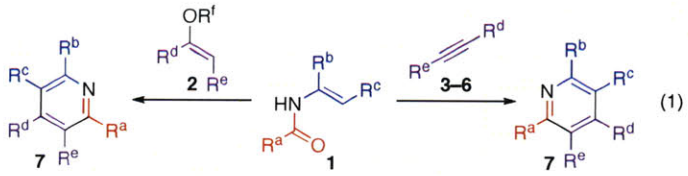
A mild procedure for electrophilic activation of structurally diverse amides en route to pyrimidine[16] derivatives and a two-step approach for the synthesis of a variety of pyridines[17] were developed previously in our laboratory (Scheme 3). These methods

exploit unique reactivity associated with electrophilic activation of amides using 2-chloropyridine (2-ClPyr)[18] in combination with trifluoromethanesulfonic anhydride (Tf_2O).[19,20]



Scheme 3. Synthesis of azaheterocycles using amides as precursors.

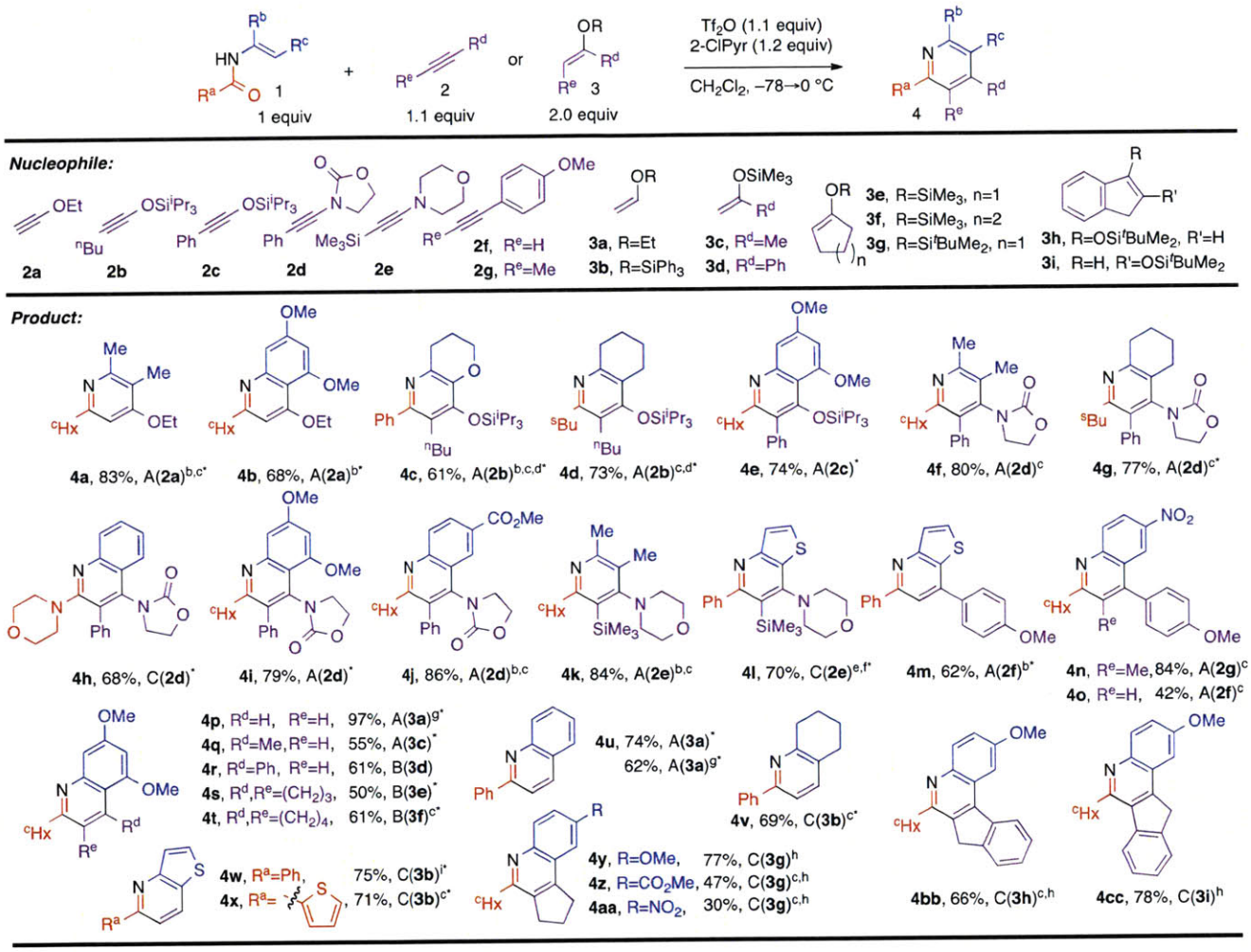
In this chapter we discuss a mild and efficient single-step procedure for the conversion of *N*-vinyl and *N*-aryl amides[21] to the corresponding substituted pyridines and quinolines (eq 1). The current study concerns trapping of highly activated amide derivatives **1** with π-nucleophiles (**2**–**6**) to directly provide the corresponding pyridine derivatives **7** (eq 1).



Results and Discussion

We began our studies by investigating the use of alkoxy and silyloxy acetylenes, which can be prepared directly from the corresponding acetylene precursors,[22] in direct condensation with amides. Under optimum reaction conditions, these electron-rich π-nucleophiles provided the desired pyridine and quinoline derivatives in a single-step from the corresponding *N*-vinyl and *N*-aryl amides, respectively (Table 1, **4a-e**). Similarly, the use of ynamide **2d** and ynamine **2e** readily provided the 4-amino pyridine derivatives in a single-step (Table 1, **4f-l**). While phenyl acetylene was not sufficiently nucleophilic, the more electron rich derivatives **2f** and **2g** served as nucleophiles in this pyridine synthesis (Table 1, **4m-o**). Importantly, both electron-rich and electron-deficient *N*-aryl amides can

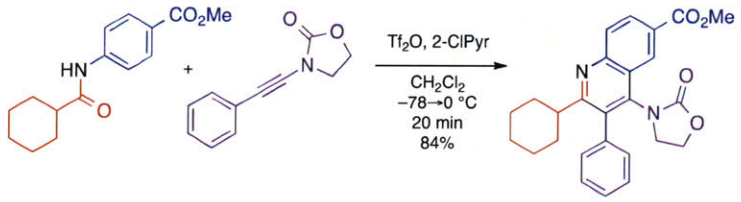
Table 1. Single-step synthesis of pyridine deriviatives.



[a] Average of two experiments. Uniform conditions unless otherwise noted: Tf_2O (1.1 equiv), 2-ClPyr (1.2 equiv), nucleophile (**2** or **3**), CH_2Cl_2, heating: A = 23 °C, 1 h; B = 45 °C, 1 h; C = 140 °C, 20 min. [b] nucleophile (2.0 equiv). [c] 2-ClPyr (2.0 equiv). [d] only10 min at 23 °C. [e] 2-ClPyr (5.0 equiv). [f] only 1 min heating, nucleophile (3.0 equiv). [g] nucleophile (1.1 equiv). [h] heated for 1 h. [i] 45% yield using **3a** with condition A. * Experiments performed by my colleague, Matthew D. Hill.

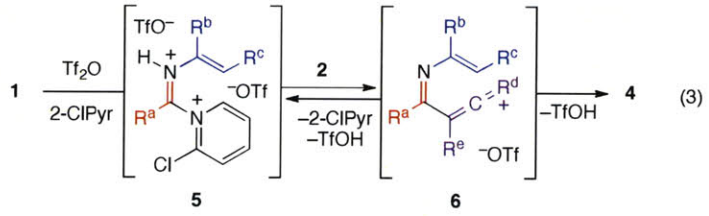
be condensed with nucleophiles **2a-g** with similar efficiency (Table 1, compare **4i** and **4j**).

The use of electron-rich acetylene derivatives as nucleophiles provide easy access to an array of highly substituted pyridines under mild conditions. Although we report a standard set of conditions that can be applied to a range of different amides and nucleophiles, it is important to note that most amide substrates can be activated and will undergo conversion to the corresponding pyridine product within a few minutes at sub-ambient temperatures. For example, conversion of amide **1f** to quinoline **4j** is complete within 20 minutes at 0 °C (eq 2). These mild conditions are in contrast to most other methods for synthesis of highly substituted azaheterocycles that require heating at high temperatures.[8,9,12]

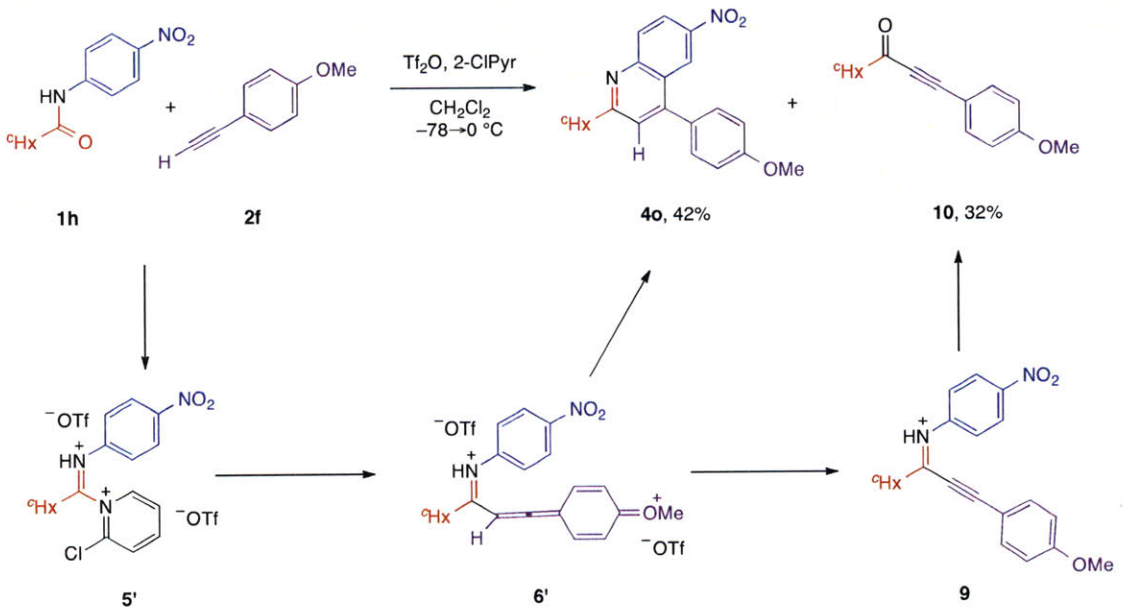


1f **2d** **4j** (2)

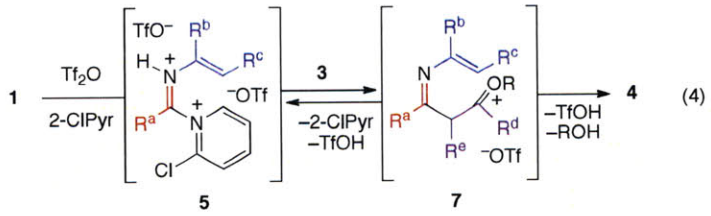
Based on mechanistic findings in the pyrimidine synthesis methodology developed in our laboratories,[16] we propose this single-step pyridine synthesis to occur by nucleophilic addition of acetylenes **2a-g** to an activated electrophile **5**[23] followed by expulsion of 2-ClPyr•HOTf and annulation of the highly reactive intermediate **6** (eq 3). The condensation of the terminal alkyne **2f** with amide **1h** gave the desired quinoline **4o** (Table 1, 42% yield) along with 32% yield of ynone **10**, which is the hydrolysis product of the corresponding alkynyl imine **9** (Scheme 4). This observation suggests competitive deprotonation of intermediate **6** (R^c=H) when cyclization to heterocycle **4** is slow.



(3)

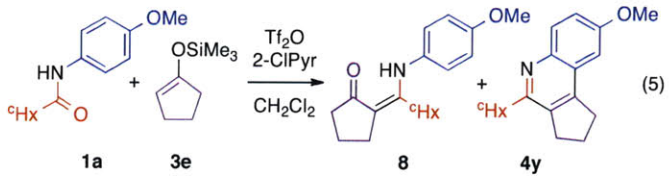


Scheme 4. Competitive deprotonation of activated intermediate.



We next examined the direct condensation of enol ethers with *N*-vinyl and *N*-aryl amides (eq 4). While ethyl vinyl ether (**3a**) could be used as a nucleophile in cases not requiring heating (Table 1, **4p** and **4u**), we found triphenylsilyl vinyl ether (**3b**) to provide superior results in more challenging cases (Table 1, **4v-x**). The use of excess nucleophile can be beneficial and provide an improved yield of the product (Table 1, **4u**). Importantly, the use of silyl ether **3b** in place of **3a** eliminates the competitive addition of EtOH, generated in conversion of **7** to **4** (eq 4), to the activated intermediate **5**. Both acyclic and cyclic trimethylsilyl enol ethers can be used in this direct condensation with amides (Table 1, **4q-t**). However, when desilylation competes with cyclization of oxonium **7** (eq 4), the use of more robust silyl enol ether derivatives is preferred. Condensation of amide **1a** with enol ether **3e** at 23 °C predominantly gave the vinylogous amide **8** (78%, **8**:**4y**, >99:1) while heating the reaction mixture at 140 °C for 2h provided

the desired quinoline (eq 5, 53%, **4y**:**8**, >99:1). Shorter reaction times gave a mixture of amide **8** and product **4y**.



1a **3e** **8** **4y** (5)

Consistent with cyclization of intermediate **7** (eq 4), exposure of uncyclized **8** to the standard reaction conditions provided <10% yield of **4y**. While the use of triisopropylsilyl ether derivatives was not optimal due to slow cyclization, the use of *t*butyldimethylsilyl ethers and microwave irradiation extends this chemistry to less reactive amide substrates (Table 1, **4y-cc**). While the use of a broad range of enol ethers is possible, the overall efficiency of this pyridine synthesis using enol ethers as the nucleophile in conjunction with electron deficient *N*-aryl amides (Table 1, compare **4y-aa**) is more sensitive as compared to the use of acetylenic nucleophiles (vide supra). Additionally, it should be noted that formamides do not give the corresponding pyridine derivatives due to rapid isocyanide formation.

Conclusion

We describe a single-step and convergent procedure for the synthesis of pyridine derivatives. This chemistry is compatible with a wide range of *N*-vinyl and *N*-aryl amides and π-nucleophiles. This methodology alleviates the need for isolation of activated amide derivatives and provides rapid access to highly substituted pyridines with predictable control of substituent introduction. The versatility of this chemistry offers a valuable addendum to methodology for azaheterocycle synthesis.

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[1] For recent reviews, see: (a) Henry, G. D. *Tetrahedron* **2004**, *60*, 6043. (b) Michael, J. P. *Nat. Prod. Rep.* **2005**, *22*, 627. (c) Abass, M. *Heterocycles* **2005**, *65*, 901.

[2] (a) Jones, G. In Comprehensive Heterocyclic Chemistry II; Katritzky, A. R.; Rees, C. W.; Scriven, E. F. V.; McKillop, A., Eds; Pergamon: Oxford, 1996; Vol. 5; p 167. (b) Larock, R. C. Comprehensive Organic Transformations: A Guide to Functional Group Preparations. Wiley-VCH, New York, 1999.

[3] Faucher, A.-M.; Bailey, M. D.; Beaulieu, P. L.; Brochu, C.; Duceppe, J.-S.; Ferland, J.-M.; Ghiro, E.; Gorys, V.; Halmos, T.; Kawai, S. H.; Poirier, M.; Simoneau, B.; Tsantrizos, Y. S.; Llinàs-Brunet, M. *Org. Lett.* **2004**, *6*, 2901.

[4] Deeks, S. G.; Smith, M.; Holodniy, M.; Kahn, J. O.; *J. Am. Med. Assoc.* **1997**, *277*, 145

[5] Moffat, A. S.; *Science* **1993**, *261*, 550.

[6] Núñez, M. J.;Guadaño, A.; Jiménez, I. A.; Ravelo,A. G.; González-Coloma, A.; Bazzocchi, I. L. *J. Nat. Prod.* **2004**, *67*, 14.

[7] Fitch, R. W.; Spande, T. F.; Garraffo, H. M.; Yeh. H. J. C.; Daly, J. W. *J. Nat. Prod.* **2010**, *73*, 331.

[8] For reviews on metal-catalyzed heterocycle synthesis, see: (a) Bönnemann, H.; Brijoux, W. Adv. Heterocycl. Chem. **1990**, 48, 177. (b) Nakamura, I.; Yamamoto, Y. Chem. Rev. **2004**, 104, 2127. (c) Zeni G.; Larock, R. C. Chem. Rev. **2004**, 104, 2285. (d) Varela, J. A.; Saá, C. Chem. Rev. **2004**, 104, 3787.

[9] For related recent metal-catalyzed azaheterocycle syntheses, see: (a) Roesch, K. R.; Larock, R. C. *Org. Lett.* **1999**, *1*, 553, (b) Varela, J. A.; Castedo, L.; Saá, C. *J. Org. Chem.* **2003**, *68*, 8595, (c) Sangu, K.; Fuchibe, K.; Akiyama, T. *Org. Lett.* **2004**, *6*, 353, (d) Zhang, X.; Campo, M. A.; Yao, T.; Larock, R. C. *Org. Lett.* **2005**, *7*, 763, (e) McCormick, M. M.; Duong, H. A.; Zuo, G.; Louie, J. *J. Am. Chem. Soc.* **2005**, *127*, 5030 and references cited therein.

[10] Hantzsch, A. *Liebigs Ann. Chem.* **1882**, *215*, 1.

[11] Combes, A. *Bull. Chim. Soc. France* **1888**, *49*, 89.

[12]For reviews, see: (a) Chinchilla, R.; Nájera, C.; Yus, M. *Chem. Rev.* **2004**, *104*, 2667. (b) Turck, A.; Plé, N.; Mongin, F.; Quéguiner, G. *Tetrahedron* **2001**, *57*, 4489.

[13] Billingsley, K.; Buchwald, S. L.; *J. Am. Chem. Soc.* **2007**,*129*, 3358.

[14] Littke, A. F.; Schwarz, L.; Fu, G. C. *J. Am. Chem. Soc.* **2002**,*124*, 6343.

[15] Fürstner, A.; Leitner, A.; Mendez, M.; Krause, H. *J. Am. Chem. Soc.* **2002**,*124*, 13856.

[16] Movassaghi, M.; Hill, M. D. *J. Am. Chem. Soc.* **2006**, *128*, 14254.

[17] (a) Movassaghi, M.; Hill, M. D. *J. Am. Chem. Soc.* **2006**, *128*, 4592. (b) Hill, M. D.; Movassaghi, M. *Synthesis* **2007**, 1115.

[18] (a) Myers, A. G.; Tom, N. J.; Fraley, M. E.; Cohen, S. B.; Madar, D. J. *J. Am. Chem. Soc.* **1997**, *119*, 6072. (b) Garcia, B. A.; Gin, D. Y. *J. Am. Chem. Soc.* **2000**, *122*, 4269.

[19] Baraznenok, I. L.; Nenajdenko, V. G.; Balenkova, E. S. *Tetrahedron* **2000**, *56*, 3077.

[20] For elegant studies on the activation of amides using Tf_2O and pyridine, see: (a) Charette, A. B.; Grenon, M. *Can. J. Chem.* **2001**, *79*, 1694. (b) Charette, A. B.; Mathieu, S.; Martel, J. *Org. Lett.* **2005**, *7*, 5401.

[21] (a) Muci, A. R.; Buchwald, S. L. *Top. Curr. Chem.* **2002**, *219*, 131. (b) Hartwig, J. F. In *Handbook of Organopalladium Chemistry for Organic Synthesis*; Negishi, E., Ed.; Wiley-Interscience: New York, 2002; p. 1051. (c) Beletskaya, I. P.; Cheprakov, A. V. *Coordin. Chem. Rev.* **2004**, *248*, 2337. (d) Dehli, J. R.; Legros, J.; Bolm, C. *Chem. Commun.* **2005**, 973.

[22] (a) Julia, M.; Saint-Jalmes, V. P.; Verpeaux, J.-N. *Synlett* **1993**, 233. (b) Austin, W. F.; Zhang, Y.; Danheiser, R. L. *Org. Lett.* **2005**, *7*, 3905.

[23] For further discussion on the structure and chemistry of **5**, see ref. 16.

Experimental Section

General Procedures. All reactions were performed in oven-dried or flame-dried round bottomed flasks, modified Schlenk (Kjeldahl shape) flasks, or glass pressure vessels. The flasks were fitted with rubber septa and reactions were conducted under a positive pressure of argon. Stainless steel syringes or cannulae were used to transfer air- and moisture-sensitive liquids. Flash column chromatography was performed as described by Still et al. using silica gel (60-Å pore size, 32–63 μm, standard grade, Sorbent Technologies) or non-activated alumina gel (80–325 mesh, chromatographic grade, EM Science).[1] Analytical thin–layer chromatography was performed using glass plates pre-coated with 0.25 mm 230–400 mesh silica gel or neutral alumina gel impregnated with a fluorescent indicator (254 nm). Thin layer chromatography plates were visualized by exposure to ultraviolet light and/or by exposure to an ethanolic phosphomolybdic acid (PMA), an acidic solution of *p*-anisaldehyde (anis), an aqueous solution of ceric ammonium molybdate (CAM), an aqueous solution of potassium permanganate ($KMnO_4$) or an ethanolic solution of ninhydrin followed by heating (<1 min) on a hot plate (~250 °C). Organic solutions were concentrated on Büchi R-200 rotary evaporators at ~10 Torr (house vacuum) at 25–35 °C, then at ~0.5 Torr (vacuum pump) unless otherwise indicated.

Materials. Commercial reagents and solvents were used as received with the following exceptions: Dichloromethane, diethyl ether, tetrahydrofuran, acetonitrile, and toluene were purchased from J.T. Baker (Cycletainer™) and were purified by the method of Grubbs et al. under positive argon pressure.[2] 2-chloropyridine was distilled from calcium hydride and stored sealed under an argon atmosphere. The starting amides were prepared by acylation of the corresponding anilines[3] or via previously reported copper–catalyzed C–N bond–forming reactions.[4,5] Ethoxy acetylene (**2a**) was purchased from Aldrich as a solution in hexanes and purified by kugelrohr distillation before use (% wt. in hexanes determined by ^{1}H NMR analysis, ~47% wt.). Silyloxy acetylenes **2b** and **2c** were prepared according to Sun, J.; Kozmin, S. A. *Angew. Chem. Int. Ed.* **2006**, *45*, 4991-4993. Ynamide **2d** was prepared according to Buissonneaud, D.; Cintrat, J.-C. *Tetrahedron Lett.* **2006**, *47*, 3139-3143. Silyl enol ether **3b** was prepared according to Schaumann, E.; Tries, F. *Synthesis* **2002**, 191–194.

Instrumentation. All reaction conducted at 140 °C were performed in a CEM Discover Lab Mate microwave reactor. Proton nuclear magnetic resonance (^{1}H NMR) spectra were recorded with a Varian inverse probe 500 INOVA spectrometer or a Bruker 400 AVANCE spectrometer. Chemical shifts are recorded in parts per million from internal tetramethylsilane on the δ scale and are referenced from the residual protium in the NMR solvent ($CHCl_3$: δ 7.27, C_6HD_5: δ 7.16). Data is reported as follows: chemical shift [multiplicity (s = singlet, d = doublet, q = quartet, m = multiplet), integration, coupling constant(s) in Hertz, assignment]. Carbon-13 nuclear magnetic resonance spectra were recorded with a Varian 500 INOVA spectrometer or a Bruker 400 AVANCE spectrometer and are recorded in parts per million from internal tetramethylsilane on the δ scale and are referenced from the carbon resonances of the solvent ($CDCl_3$: δ 77.2, benzene-d_6: δ 128.0). Data

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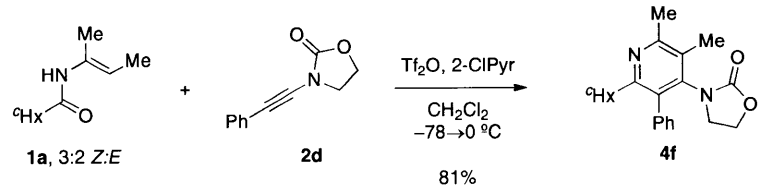
[1] Still, W. C.; Kahn, M.; Mitra, A. *J. Org. Chem.* **1978**, *43*, 2923–2925.
[2] Pangborn, A. B.; Giardello, M. A.; Grubbs, R. H.; Rosen, R. K.; Timmers, F. J. *Organometallics* **1996**, *15*, 1518–1520.
[3] For a general procedure, see: DeRuiter, J.; Swearingen, B. E,; Wandrekar, V.; Mayfield, C. A. *J. Med. Chem.* **1989**, *32*, 1033–1038.
[4] For the general procedure used for the synthesis of all *N*-vinyl amides, see: Jiang, L.; Job, G. E.; Klapars, A.; Buchwald, S. L. *Org. Lett.* **2003**, *5*, 3667–3669.
[5] For related reports, see: (a) Wolfe, J. P.; Wagaw, S.; Marcoux, J.-F.; Buchwald, S. L. *Acc. Chem. Res.* **1998**, *31*, 805–818. (b) Hartwig, J. F. *Acc. Chem. Res.* **1998**, *31*, 852–860. (c) Muci, A. R.; Buchwald, S. L. *Top. Curr. Chem.* **2002**, *219*, 131–209. (d) Beletskaya, I. P.; Cheprakov, A. V. *Coordin. Chem. Rev.* **2004**, *248*, 2337–2364. (e) Dehli, J. R.; Legros, J.; Bolm, C. *Chem. Commun.* **2005**, 973–986.

is reported as follows: chemical shift [multiplicity (s = singlet, d = doublet, q = quartet, m = multiplet), coupling constant(s) in Hertz, assignment]. Infrared data were obtained with a Perkin-Elmer 2000 FTIR and are reported as follows: [frequency of absorption (cm^{-1}), intensity of absorption (s = strong, m = medium, w = weak, br = broad), assignment]. Chiral HPLC analysis was performed on an Agilent 1100 Series HPLC with a Whelk-O1 (*S*,*S*) column. We thank Dr. Li Li at the Massachusetts Institute of Technology Department of Chemistry instrumentation facility for obtaining mass spectroscopic data.

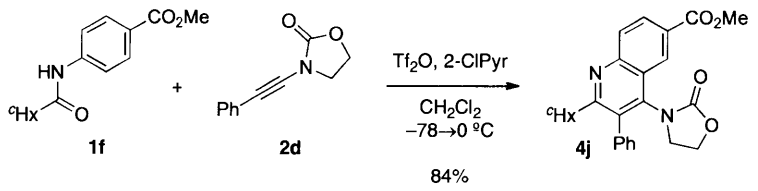


3-(2-Cyclohexyl-5,6-dimethyl-3-phenyl-pyridin-4-yl)-oxazolidin-2-one (4f, Table 1):

Trifluoromethanesulfonic anhydride (52 μL, 0.31 mmol, 1.1 equiv) was added via syringe drop-wise to a stirred mixture of amide **1a** (51 mg, 0.28 mmol, 1 equiv) and 2-chloropyridine (54 μL, 0.57 mmol, 2.0 equiv) in dichloromethane (700 μL) at –78 °C. After 5 min, the reaction mixture was placed in an ice-water bath and warmed to 0 °C, and a solution of ynamide **2d**[6] (59 mg, 0.32 mmol, 1.1 equiv) in dichloromethane (250 μL) was added via cannula. After 20 minutes, aqueous sodium hydroxide solution (1.0 mL, 1N) was introduced to neutralize the trifluoromethanesulfonate salts. The mixture was partitioned between dichloromethane (10 mL) and water (10 mL), and the layers were separated. The aqueous layer was extracted with dichloromethane (2 × 10 mL) and the combined organic layers were washed with brine (10 mL), were dried over anhydrous sodium sulfate, and were filtered. The volatiles were removed under reduced pressure and the residue was purified by flash column chromatography (eluent: 50% EtOAc and 1% Et_3N in hexanes; SiO_2: 15 × 2 cm) to give the pyridine derivative **4f** as a white solid (80 mg, 81%).

^{1}H NMR (500 MHz, $CDCl_3$, 20 °C) δ:	7.46–7.38 (m, 3H, Ar**H**), 7.31–7.27 (m, 1H, Ar**H**), 7.20–7.17 (m, 1H, Ar**H**), 4.24 (td, 1H, J = 8.8, 5.6 Hz, $NCH_2C\mathbf{H}_2O$), 3.79 (td, 1H, J = 8.4, 8.0 Hz, $NCH_2C\mathbf{H}_2O$), 3.52 (app. q, 1 H, J = 8.4 Hz, $NC\mathbf{H}_2CH_2O$), 3.08 (td, 1H, J = 9.0, 5.6 Hz, $NC\mathbf{H}_2CH_2O$), 2.57 (s, 3H, $ArC\mathbf{H}_3$), 2.48 (tt, 1H, J = 11.4, 3.4 Hz, $^cC_6\mathbf{H}_{11}$), 2.19 (s, 3H, $ArC\mathbf{H}_3$), 1.85–1.70 (m, 3H, $^cC_6\mathbf{H}_{11}$), 1.65–1.54 (m, 3H, $^cC_6\mathbf{H}_{11}$), 1.47–1.44 (m, 1H, $^cC_6\mathbf{H}_{11}$), 1.29–1.12 (m, 2H, $^cC_6\mathbf{H}_{11}$), 1.00 (qt, 1H, J = 12.4, 3.2 Hz, $^cC_6\mathbf{H}_{11}$).
^{13}C NMR (500 MHz, $CDCl_3$, 20 °C) δ:	161.9, 157.9, 156.7, 141.1, 136.4, 132.1, 129.7, 129.0, 128.8, 128.1, 127.9, 126.9, 62.8, 46.2, 42.1, 32.5, 32.4, 25.9, 23.6, 13.8
FTIR (neat) cm^{-1}:	2925 (s), 2852 (m), 1752 (s), 1643 (m), 1448 (m).
HRMS (ESI):	calc'd for $C_{22}H_{27}N_2O_2$ $[M+H]^+$: 351.2067, found: 351.2054.
TLC (50% EtOAc/1% Et_3N/hexanes), R_f:	0.25 (UV, CAM).

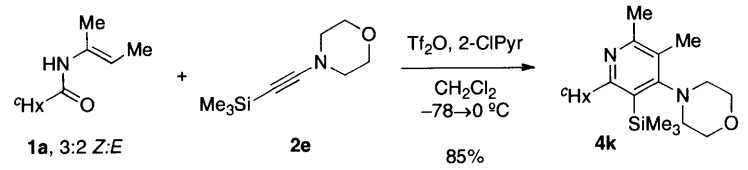
[6] For preparation of **2d** see Buissonneaud, D.; Cintrat, J.-C. *Tetrahedron Lett.* **2006**, *47*, 3139–3143.



Methyl 2-cyclohexyl-4-(2-oxooxazolidin-3-yl)-3-phenylquinoline-6-carboxylate (4j, Table 1):

Trifluoromethanesulfonic anhydride (36 μL, 0.21 mmol, 1.1 equiv) was added drop-wise via syringe to a stirred mixture of amide **1f** (50 mg, 0.19 mmol, 1 equiv) and 2-chloropyridine (36 μL, 0.38, 2.0 equiv) in dichloromethane (540 μL) at –78 °C. After five minutes, the reaction mixture was allowed to warm to 0 °C for five minutes, cooled back to –78°C, and, after five minutes, a solution of ynamide **2d** (72 mg, 0.38 mmol, 2.0 equiv) in dichloromethane (100 μL) was added via cannula. After an additional five minutes, the reaction mixture was allowed to warm back to 0°C. After 20 minutes, trifluoroacetic acid (150 μL) was added to the reaction mixture to remove excess ynamide. After 15 minutes, saturated aqueous sodium bicarbonate solution (7 mL) was added to quench excess acid. The mixture was diluted with water (10 mL) and extracted with dichloromethane (3 × 10 mL). The combined organic layers were washed with brine (10 mL), were dried over anhydrous sodium sulfate, and were filtered. The volatiles were removed under reduced pressure, and the residue was purified by flash column chromatography (eluent: 50% EtOAc and 2% Et_3N in hexanes; SiO_2: 15 × 3 cm) to give the quinoline derivative **4j** as a white solid (69 mg, 84%).

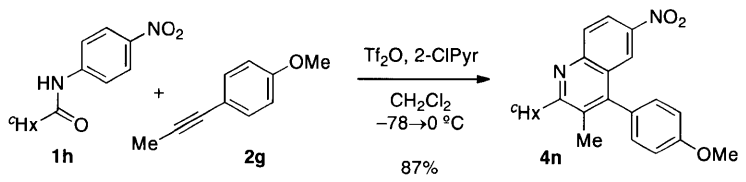
^{1}H NMR (500 MHz, $CDCl_3$, 20 °C) δ:	8.53 (d, 1H, J = 1.5 Hz, Ar**H**), 8.33 (dd, 1H, J = 9.0, 1.5 Hz Ar**H**), 8.20 (d, 1H, J = 9.0 Hz, Ar**H**), 7.56–7.46 (m, 4H, Ar**H**), 7.26–7.25 (m, 1H, Ar**H**), 4.49 (td, 1H, J = 9.0, 6.5 Hz, $NCH_2C\mathbf{H}_2O$), 4.06–3.98 (m, 4H, $NCH_2C\mathbf{H}_2O$, $OC\mathbf{H}_3$), 3.81 (td, 1H, J = 9.0, 7.0 Hz, $OCH_2C\mathbf{H}_2N$), 3.30 (td, 1H, J = 9.0, 6.5 Hz, $OCH_2C\mathbf{H}_2N$), 2.79–2.73 (m, 1H, $^cC_6\mathbf{H}_{11}$), 1.98–1.81 (m, 3H, $^cC_6\mathbf{H}_{11}$), 1.72–1.61 (m, 4H, $^cC_6\mathbf{H}_{11}$), 1.35–1.27 (m, 1H, $^cC_6\mathbf{H}_{11}$), 1.22–1.14 (m, 1H, $^cC_6\mathbf{H}_{11}$), 1.09–1.03 (m, 1H, $^cC_6\mathbf{H}_{11}$).
^{13}C NMR (125 MHz, $CDCl_3$, 20 °C) δ:	168.9, 166.8, 157.2, 150.8, 140.4, 135.5, 135.2, 130.4, 129.8, 129.5, 128.7, 128.6, 128.4, 125.6, 123.5, 63.2, 52.7, 47.2, 43.6, 32.7, 32.3, 26.5, 26.4, 26.0
FTIR (neat) cm^{-1}:	2928 (m), 2853 (w), 1758 (s), 1720 (s), 1451 (m), 1413 (m), 1259 (s).
HRMS (ESI):	calc'd for $C_{26}H_{27}N_2O_4$ $[M+H]^+$: 431.1965, found: 431.1958.
TLC (8% EtOAc/2% Et_3N/DCM), R_f:	0.26 (UV, CAM).



4-(2-Cyclohexyl-5,6-dimethyl-3-(trimethylsilyl)pyridin-4-yl)morpholine (4k, Table 1):

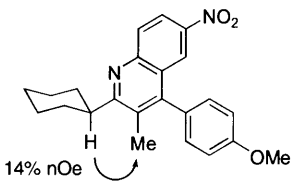
Trifluoromethanesulfonic anhydride (66 μL, 0.39 mmol, 1.1 equiv) was added drop-wise via syringe to a stirred mixture of amide **1a** (65 mg, 0.38 mmol, 1 equiv) and 2-chloropyridine (68 μL, 0.72, 2.0 equiv) in dichloromethane (1.0 mL) at –78 °C. After five minutes, the reaction mixture was placed in an ice-water bath, allowed to warm to 0 °C, and a solution of ynamine **2e** (143 μL, 0.72 mmol, 2.00 equiv) in dichloromethane (200 μL) was added via cannula. After 20 minutes, triethylamine (0.5 mL) was added to the reaction mixture to neutralize the trifluoromethanesulfonate salts. The mixture was partitioned between water (10 mL) and dichloromethane (10 mL), and the layers were separated. The aqueous layer was extracted with dichloromethane (2 × 10 mL). The combined organic layers were washed with brine (10 mL), were dried over anhydrous sodium sulfate, and were filtered. The volatiles were removed under reduced pressure, and the residue was purified by flash column chromatography (eluent: 9% EtOAc and 1% Et_3N in hexanes; SiO_2: 12 × 3 cm) to give the pyridine derivative **4k** as an off-white solid (106 mg, 85%).

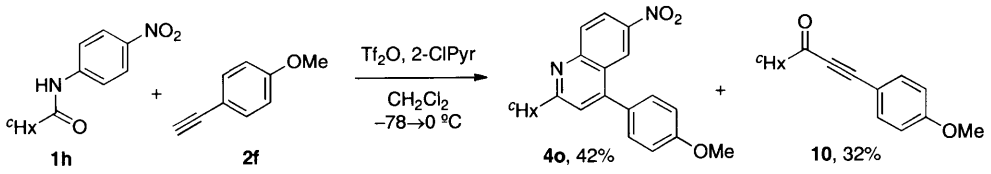
^{1}H NMR (500 MHz, $CDCl_3$, 20 °C) δ:	3.84 (t, 4H, J = 4.5 Hz, $N(CH_2C\mathbf{H}_2)_2O$), 3.16 (br s, 4H, $O(CH_2C\mathbf{H}_2)_2N$), 2.93 (tt, 1H, J = 11.5, 3.5 Hz, $^cC_6\mathbf{H}_{11}$), 2.46 (s, 3H, $C\mathbf{H}_3$), 2.30 (s, 3H, $C\mathbf{H}_3$), 1.82–1.71 (m, 7H, $^cC_6\mathbf{H}_{11}$), 1.36–1.34 (m, 3H, $^cC_6\mathbf{H}_{11}$), 0.39 (s, 9H, $Si(C\mathbf{H}_3)_3$).
^{13}C NMR (125 MHz, $CDCl_3$, 20 °C) δ:	170.1, 162.2, 159.9, 128.7, 126.9, 66.9, 49.7, 44.9, 33.4, 26.8, 26.1, 23.7, 16.1, 4.2.
FTIR (neat) cm^{-1}:	2923 (s), 2854 (m), 1529 (m), 1450 (m), 1367 (m), 1260 (s), 1115 (s).
HRMS (ESI):	calc'd for $C_{20}H_{35}N_2OSi$ $[M+H]^+$: 347.2513, found: 347.2507.
TLC (35% EtOAc/1% Et_3N/hexanes), R_f:	0.42 (UV, CAM).



2-cyclohexyl-4-(4-methoxyphenyl)-3-methyl-6-nitroquinoline (4n, Table 1):

Trifluoromethanesulfonic anhydride (65 μL, 0.39 mmol, 1.1 equiv) was added drop-wise via syringe to a stirred mixture of amide **1h** (87 mg, 0.35 mmol, 1 equiv) and 2-chloropyridine (66 μL, 0.70, 2.0 equiv) in dichloromethane (1.0 mL) at −78 °C. After five minutes, the reaction mixture was allowed to warm to 0 °C for five minutes, and a solution of alkyne **2g** (56 mg, 0.38 mmol, 1.1 equiv) in dichloromethane (200 μL) was added via cannula. After 20 minutes, aqueous sodium hydroxide solution (1.0 mL, 1 N) was added to the reaction mixture to neutralize the trifluoromethanesulfonate salts. The mixture was partitioned between water (10 mL) and dichloromethane (10 mL), and the layers were separated. The aqueous layer was extracted with dichloromethane (2 × 10 mL). The combined organic layers were washed with brine (10 mL), were dried over anhydrous sodium sulfate, and were filtered. The volatiles were removed under reduced pressure, and the residue was purified by flash column chromatography (eluent: 10% EtOAc and 1% Et_3N in hexanes; SiO_2: 14 × 3 cm) to give the quinoline **4n** as a white solid (116 mg, 87%).

^{1}H NMR (500 MHz, $CDCl_3$, 20 °C) δ:	8.36–8.23 (m, 2H, Ar**H**), 8.14 (dd, 1H, J = 9.0, 0.5 Hz Ar**H**), 7.17 (dt, 2H, J = 9.0, 2.5 Hz, Ar**H**), 7.10 (dt, 2H, J = 9.0, 2.5 Hz, Ar**H**), 3.95 (s, 3H, OC**H**$_3$), 3.13 (tt, 1H, J = 11.0, 3.5 Hz, ^{c}C$_6$**H**$_{11}$), 2.29 (s, 3H, ArC**H**$_3$), 1.96–1.82 (m, 7H, ^{c}C$_6$**H**$_{11}$), 1.51–1.41 (m, 3H, ^{c}C$_6$**H**$_{11}$).
^{13}C NMR (100 MHz, $CDCl_3$, 20 °C) δ:	169.9, 159.7, 148.7, 148.3, 145.0, 130.9, 130.7, 129.3, 128.6, 126.2, 123.4, 121.5, 114.5, 55.6, 43.7, 32.0, 26.9, 26.3, 16.6
FTIR (neat) cm^{-1}:	2929 (s), 2853 (m), 1609 (m), 1525 (s), 1483 (s), 1339 (s).
HRMS (ESI):	calcd for $C_{23}H_{25}N_2O_3$ $[M+H]^+$: 377.1860, found: 377.1858.
TLC (35% EtOAc/1% Et_3N/hexanes), R_f:	0.55 (UV, CAM).
nOe data :	



2-Cyclohexyl-4-(4-methoxy-phenyl)-6-nitro-quinoline (4o, Table 1):

Trifluoromethanesulfonic anhydride (42 μL, 0.25 mmol, 1.1 equiv) was added drop-wise via syringe to a stirred mixture of amide **1h** (56 mg, 0.23 mmol, 1 equiv) and 2-chloropyridine (43 μL, 0.45 mmol, 2.0 equiv) in dichloromethane (760 μL) at –78 °C. After 5 min, the reaction mixture was placed in an ice-water bath and warmed to 0 °C, and acetylene **2f** (33 μL, 0.25 mmol, 1.1 equiv) was added via syringe. After 20 minutes, aqueous sodium hydroxide solution (0.5 mL, 1N) was introduced to neutralize the trifluoromethanesulfonate salts. The mixture was partitioned between dichloromethane (10 mL) and water (10 mL), and the layers were separated. The aqueous layer was extracted with dichloromethane (2 × 10 mL) and the combined organic layers were washed with brine (10 mL), were dried over anhydrous sodium sulfate, and were filtered. The volatiles were removed under reduced pressure and the residue was purified by flash column chromatography (eluent: 9% EtOAc and 1% Et_3N in hexanes; SiO_2: 15 × 2 cm) to give the quinoline derivative **4o** as a yellow solid (34 mg, 42%) and the ynone **10** as a pale yellow oil (15.3 mg, 32%).

^{1}H NMR (500 MHz, $CDCl_3$, 20 °C) δ: 8.87 (m, 1H, J = 2.5 Hz, Ar**H**), 8.44 (dd, 1H, J = 9.5, 2.5 Hz, Ar**H**), 8.20 (d, 1H, J = 9.5 Hz Ar**H**), 7.46 (dt, 2H, J = 9.0, 2.5 Hz, Ar**H**), 7.39 (s, 1H, Ar**H**), 7.12 (dt, 2H, J = 9.0, 2.5 Hz, Ar**H**), 3.94 (s, 3H, $OC\mathbf{H}_3$), 2.98 (tt, 1H, J = 12.0, 3.5 Hz, $^cC_6\mathbf{H}_{11}$), 2.09–2.05 (m, 2H, $^cC_6\mathbf{H}_{11}$), 1.95–1.92 (m, 2H, $^cC_6\mathbf{H}_{11}$), 1.82–1.80 (m, 1H, $^cC_6\mathbf{H}_{11}$), 1.73–1.65 (m, 2H, $^cC_6\mathbf{H}_{11}$), 1.49 (qt, 2H, J = 12.5, 3.5 Hz, $^cC_6\mathbf{H}_{11}$), 1.35 (qt, 1H, J = 12.5, 3.5 Hz, $^cC_6\mathbf{H}_{11}$).

^{13}C NMR (125 MHz, $CDCl_3$, 20 °C) δ: 170.6, 160.6, 151.0, 150.6, 145.2, 131.3, 131.0, 129.4, 124.9, 123.2, 122.8, 121.8, 114.8, 55.7, 48.0, 32.8, 26.6, 26.2.

FTIR (neat) cm^{-1}: 2929 (s), 2853 (m), 1609 (s), 1530 (m), 1491 (s), 1340 (s).

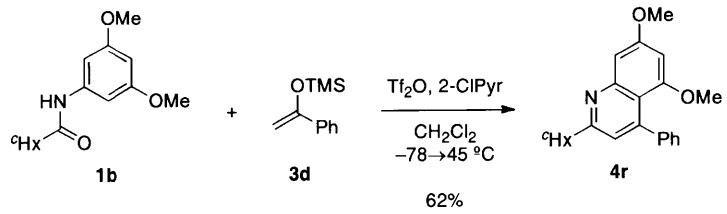
HRMS (ESI): calc'd for $C_{22}H_{23}N_2O_3$ $[M+H]^+$: 363.1703, found: 363.1708.

TLC (35% EtOAc/1% Et_3N/hexanes), R_f: 0.41 (UV, CAM).

Characterization of the byproduct **10**:

^{1}H NMR (500 MHz, $CDCl_3$, 20 °C) δ: 7.54 (dt, 2H, J = 8.5, 2.0 Hz, Ar**H**), 6.90 (dt, 2H, J = 9.0, 2.0 Hz, Ar**H**), 3.85 (s, 3H, $OC\mathbf{H}_3$), 2.50 (tt, 1H, J = 11.0, 3.5 Hz, $^cC_6\mathbf{H}_{11}$), 2.08–2.04 (m, 2H, $^cC_6\mathbf{H}_{11}$), 1.84–1.81 (m, 2H, $^cC_6\mathbf{H}_{11}$), 1.70–1.67 (m, 1H, $^cC_6\mathbf{H}_{11}$), 1.54–1.46 (m, 2H, $^cC_6\mathbf{H}_{11}$), 1.35 (qt, 2H, J = 12.5, 3.0 Hz, $^cC_6\mathbf{H}_{11}$), 1.25 (qt, 1H, J = 12.0, 3.0 Hz, $^cC_6\mathbf{H}_{11}$).

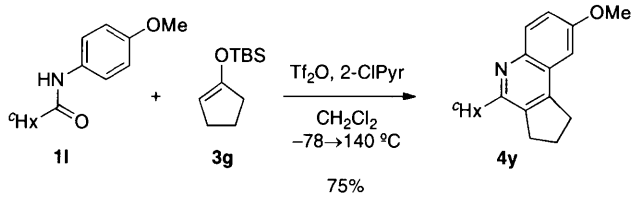
^{13}C NMR (125 MHz, $CDCl_3$, 20 °C) δ:	191.9, 161.7, 135.3, 114.5, 112.2, 92.7, 87.3, 55.6, 52.4, 28.6, 26.0, 25.7.
FTIR (neat) cm^{-1}:	2931 (s), 2854 (m), 2192 (s), 1658 (s), 1603 (s), 1510 (s), 1253 (s).
HRMS (ESI):	calcd for $C_{16}H_{18}NaO_2$ $[M+Na]^+$: 265.1199, found: 265.1209.
TLC (35% EtOAc/1% Et_3N/hexanes), R_f:	0.56 (UV, CAM).



2-Cyclohexyl-5,7-dimethoxy-4-phenylquinoline (4r, Table 1):

Trifluoromethanesulfonic anhydride (71 μL, 0.42 mmol, 1.1 equiv) was added drop-wise via syringe to a stirred mixture of amide **1b** (101 mg, 0.382 mmol, 1 equiv) and 2-chloropyridine (44 μL, 0.46, 1.2 equiv) in dichloromethane (1.3 mL) at –78 °C. After 5 min, the reaction mixture was placed in an ice-water bath, allowed to warm to 0 °C, and after five minutes silylenol ether **3d** (158 μL, 0.768 mmol, 2.01 equiv) was added via syringe. After 5 min, the reaction mixture was heated to 45 °C in an oil bath. After an hour, the reaction mixture was allowed to cool to ambient temperature and aqueous sodium hydroxide solution (2.0 mL, 1 N) was added to neutralize the trifluoromethanesulfonate salts. The reaction mixture was partitioned between water (10 mL) and dichloromethane (10 mL), and the aqueous layer was extracted with dichloromethane (2 × 10 mL). The combined organic layers were washed with brine (10 mL), were dried over anhydrous sodium sulfate, and were filtered. The volatiles were removed under reduced pressure, and the residue was purified by flash column chromatography (eluent: 10% EtOAc in hexanes; Al_2O_3: 15 × 3 cm) on neutral alumina to give the quinoline derivative **4r** as a white solid (90 mg, 62%).

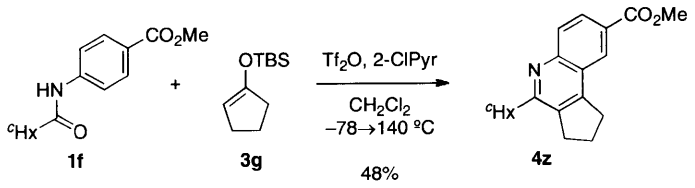
^{1}H NMR (500 MHz, $CDCl_3$, 20 °C) δ:	7.40–7.36 (m, 3H, Ar**H**), 7.32–7.30 (m, 2H, Ar**H**), 7.10 (d, 1H, J = 2.5 Hz, Ar**H**), 6.96 (s, 1H, Ar**H**), 6.42 (d, 1H, J = 2.5 Hz, Ar**H**), 3.96 (s, 3H, O**CH**$_3$), 3.48 (s, 3H, O**CH**$_3$), 2.87 (tt, 1H, J = 12.0, 3.5 Hz, ^{c}**C**$_6$**H**$_{11}$), 2.06–2.03 (m, 2H, ^{c}**C**$_6$**H**$_{11}$), 1.89–1.87 (m, 2H, ^{c}**C**$_6$**H**$_{11}$), 1.79–1.76 (m, 1H, ^{c}**C**$_6$**H**$_{11}$), 1.65–1.57 (m, 2H, ^{c}**C**$_6$**H**$_{11}$), 1.50–1.41 (m, 2H, ^{c}**C**$_6$**H**$_{11}$), 1.35–1.26 (m, 1H, ^{c}**C**$_6$**H**$_{11}$).
^{13}C NMR (125 MHz, $CDCl_3$, 20 °C) δ:	166.6, 160.9, 157.4, 151.4, 148.1, 143.2, 128.4, 127.0, 126.8, 119.6, 113.4, 100.6, 98.6, 55.7, 55.3, 47.6, 33.0, 26.7, 26.3.
FTIR (neat) cm^{-1}:	2927 (s), 2851 (m), 1619 (s), 1587 (s), 1563 (m), 1451 (m), 1403 (s), 1207 (s).
HRMS (ESI):	calcd for $C_{23}H_{26}NO_2$ $[M+H]^+$: 348.1958, found: 348.1957.
TLC (35% EtOAc/1% Et_3N/hexanes), R_f:	0.57 (UV, CAM).



4-Cyclohexyl-8-methoxy-2,3-dihydro-*1H*-cyclopenta[c]quinoline (4y, Table 1):

Trifluoromethanesulfonic anhydride (81 μL, 0.48 mmol, 1.1 equiv) was added drop-wise via syringe to a stirred mixture of amide **1l** (101 mg, 0.434 mmol, 1 equiv) and 2-chloropyridine (50 μL, 0.52, 1.2 equiv) in dichloromethane (1.5 mL) at –78°C. After five minutes, the reaction mixture was allowed to warm to 0°C for five minutes, and silylenol ether **3g** (198 μL, 0.868 mmol, 2.00 equiv) was added via syringe. The reaction vessel was placed in a microwave reactor and heated to 140 °C. After one hour, the reaction vessel was removed from the microwave reactor and allowed to cool to ambient temperature. Aqueous sodium hydroxide solution (1 mL, 1 N) was added to the reaction mixture to neutralize the trifluoromethanesulfonate salts. The mixture was partitioned between water (10 mL) and dichloromethane (10 mL), and the aqueous layer was extracted with dichloromethane (2 × 10 mL). The combined organic layers were washed with brine (10 mL), were dried over anhydrous sodium sulfate, and were filtered. The solution was concentrated under reduced pressure, and the residue was purified by flash column chromatography (eluent: 9% EtOAc and 1% Et_3N in hexanes; SiO_2: 15 × 3 cm) on neutralized silica gel to give the quinoline derivative **4y** as a white solid (91 mg, 75%).

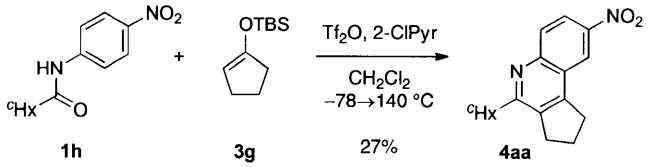
^{1}H NMR (400 MHz, $CDCl_3$, 20 °C) δ:	7.98 (d, 1H, J = 9.5 Hz, Ar**H**), 7.27–7.25 (m, 1H, Ar**H**), 6.98 (d, 1H, J = 3.0 Hz, Ar**H**), 3.93 (s, 3H, O**CH$_3$**), 3.22 (t, 2H, J = 7.5 Hz, **CH$_2$**CH$_2$CH$_2$), 3.13 (t, 2H, J = 7.5 Hz, CH$_2$CH$_2$**CH$_2$**), 2.86 (tt, 1H, J = 11.5, 3.5 Hz, ^{c}C$_6$**H$_{11}$**), 2.27 (p, 2H, J = 7.5 Hz, CH$_2$**CH$_2$**CH$_2$), 1.91–1.89 (m, 4H, ^{c}C$_6$**H$_{11}$**), 1.83–1.76 (m, 3H, ^{c}C$_6$**H$_{11}$**), 1.45-1.39 (m, 3H, ^{c}C$_6$**H$_{11}$**).
^{13}C NMR (125 MHz, $CDCl_3$, 20 °C) δ:	160.9, 157.1, 148.4, 143.3, 135.4, 131.0, 125.8, 120.2, 102.2, 55.6, 44.7, 31.8, 31.5, 31.3, 26.9, 26.3, 24.2.
FTIR (neat) cm^{-1}:	3323 (w), 2924 (s), 2855 (s), 1621 (s), 1592 (s), 1505 (s), 1459 (s), 1344 (m).
HRMS (ESI):	calcd for $C_{19}H_{24}NO$ $[M+H]^+$: 282.1852, found: 282.1866.
TLC (35% EtOAc/1% Et_3N/hexanes), R_f:	0.62 (UV, CAM).



Methyl 4-cyclohexyl-2,3-dihydro-*1H*-cyclopenta[c]quinoline-8-carboxylate (4z, Table 1):

Trifluoromethanesulfonic anhydride (62 μL, 0.37 mmol, 1.1 equiv) was added drop-wise via syringe to a stirred mixture of amide **1f** (87 mg, 0.33 mmol, 1 equiv) and 2-chloropyridine (63 μL, 0.67, 2.0 equiv) in dichloromethane (800 μL) at –78°C. After five minutes, the reaction mixture was allowed to warm to 0 °C for five minutes, cooled back to –78 °C, and after an additional five minutes a solution of silylenol ether **3g** (134 μL, 0.67 mmol, 2.0 equiv) in dichloromethane (300 μL) was added via cannula. The reaction mixture was allowed to warm to 0 °C for five minutes, and the reaction vessel was placed in a microwave reactor and heated to 140 °C. After one hour, the reaction mixture was allowed to cool to ambient temperature and aqueous sodium hydroxide solution (1 mL, 1N) was added to neutralize the trifluoromethanesulfonate salts. The mixture was partitioned between water (10 mL) and dichloromethane (10 mL). The layers were separated and the aqueous layer extracted with dichloromethane (2 × 10 mL). The combined organic layers were washed with brine (10 mL), were dried over anhydrous sodium sulfate, and were filtered. The volatiles were removed under reduced pressure, and the residue was purified by flash column chromatography (eluent: 9% EtOAc and 1% Et_3N in hexanes; SiO_2: 15 × 3 cm) to give the quinoline derivative **4z** as an off-white solid (49 mg, 48%).

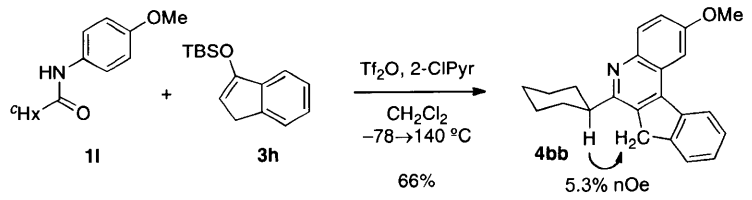
^{1}H NMR (500 MHz, $CDCl_3$, 20 °C) δ:	8.52 (d, 1H, J = 2.0 Hz, Ar**H**), 8.19 (dd, 1H, J = 9.0, 2.0 Hz, Ar**H**), 8.09 (d, 1H, J = 8.5 Hz, Ar**H**), 3.99 (s, 3H, $OC\mathbf{H}_3$), 3.33 (t, 2H, J = 7.0 Hz, $C\mathbf{H}_2CH_2CH_2$), 3.15 (t, 2H, J = 7.0 Hz, $CH_2CH_2CH_2$), 2.91 (tt, 1H, J = 12.0, 3.0 Hz, $^cC_6\mathbf{H}_{11}$), 2.30 (p, 2H, J = 7.0 Hz, $CH_2C\mathbf{H}_2CH_2$), 1.92–1.91 (m, 4H, $^cC_6\mathbf{H}_{11}$), 1.84–1.77 (m, 3H, $^cC_6\mathbf{H}_{11}$), 1.49-1.37 (m, 3H, $^cC_6\mathbf{H}_{11}$).
^{13}C NMR (125 MHz, $CDCl_3$, 20 °C) δ:	167.3, 165.9, 151.2, 149.5, 136.2, 129.8, 127.6, 127.5, 126.7, 124.4, 52.4, 45.0, 31.7, 31.4, 31.4, 26.8, 26.2, 24.2.
FTIR (neat) cm^{-1}:	2926 (s), 2850 (m), 1722 (s), 1452 (m), 1262 (s), 1250 (s).
HRMS (ESI):	calc'd for $C_{20}H_{24}NO_2$ $[M+H]^+$: 310.1802, found: 310.1801.
TLC (35% EtOAc/1% Et_3N/hexanes), R_f:	0.51 (UV, CAM).



4-cyclohexyl-8-nitro-2,3-dihydro-1H-cyclopenta[c]quinoline (4aa, Table 1):

Trifluoromethanesulfonic anhydride (77 μL, 0.45 mmol, 1.1 equiv) was added via syringe drop-wise to a stirred mixture of amide **1h** (103 mg, 0.413 mmol, 1 equiv) and 2-chloropyridine (78 μL, 0.82 mmol, 2.0 equiv) in dichloromethane (1.0 mL) at –78 °C. After five minutes, the reaction mixture was allowed to warm to 0 °C for five minutes, cooled back to –78°C, and, after five minutes, a solution of silyl ether **3g** (163 mg, 0.822 mmol, 1.99 equiv) in dichloromethane (400 μL) was added via cannula. The reaction mixture was allowed to warm to 0 °C for five minutes, and the reaction vessel was placed in a microwave reactor and heated to 140 °C. After one hour, the reaction mixture was allowed to cool to ambient temperature and aqueous sodium hydroxide solution (1 mL, 1N) was added to neutralize the trifluoromethanesulfonate salts. The mixture was partitioned between dichloromethane (10 mL) and water (10 mL), and the layers were separated. The aqueous layer was extracted with dichloromethane (2 × 10 mL) and the combined organic layers were washed with brine (10 mL), were dried over anhydrous sodium sulfate, and were filtered. The volatiles were removed under reduced pressure and the residue was purified by flash column chromatography (eluent: 9% EtOAc and 1% Et_3N in hexanes; SiO_2: 15 × 3 cm) to give the quinoline derivative **4aa** as a yellow solid (33 mg, 27%).

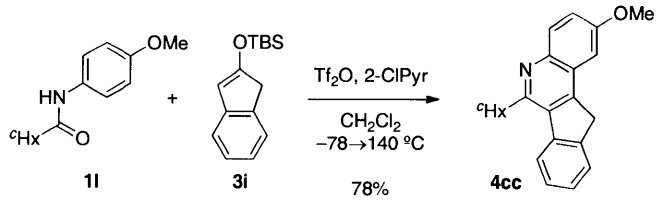
^{1}H NMR (400 MHz, $CDCl_3$, 20 °C) δ:	8.67 (d, 1H, J = 2.8, Ar**H**), 8.33 (dd, 1H, J = 9.2 Hz, 2.8 Hz Ar**H**), 8.11 (m, 1H, J = 9.2 Hz, Ar**H**), 3.32 (t, 2H, J = 7.6 Hz, $CH_2CH_2C\mathbf{H}_2$), 3.14 (t, 2H, J = 7.4 Hz, $C\mathbf{H}_2CH_2CH_2$), 2.89 (tt, 1H, J = 11.6, 3.2 Hz, $^cC_6\mathbf{H}_{11}$), 2.30 (p, 2H, J = 7.6 Hz, $CH_2C\mathbf{H}_2CH_2$), 1.91–1.86 (m, 4H, $^cC_6\mathbf{H}_{11}$), 1.81–1.71 (m, 3H, $^cC_6\mathbf{H}_{11}$), 145.–1.27 (m, 3H, $^cC_6\mathbf{H}_{11}$).
^{13}C NMR (125 MHz, $CDCl_3$, 20 °C) δ:	167.6, 152.0, 149.8, 144.7, 137.6, 131.2, 124.1, 121.6, 121.4, 45.1, 31.8, 31.5, 31.4, 26.8, 26.2, 24.2.
FTIR (neat) cm^{-1}:	2929 (s), 2853 (m), 1600 (m), 1528 (m), 1492 (m), 1340 (s).
HRMS (ESI):	calcd for $C_{18}H_{21}N_2O_2$ $[M+H]^+$: 297.1598, found: 297.1592.
TLC (9% EtOAc/1% Et_3N/hexanes), R_f:	0.37 (UV, CAM).



6-Cyclohexyl-2-methoxy-7*H*-indeno[2,1-c]quinoline (4bb, Table 1):

Trifluoromethanesulfonic anhydride (81 μL, 0.48 mmol, 1.1 equiv) was added drop-wise via syringe to a stirred mixture of amide **1l** (102 mg, 0.438 mmol, 1 equiv) and 2-chloropyridine (83 μL, 0.88, 2.0 equiv) in dichloromethane (1.0 mL) at –78 °C. After 5 min, the reaction mixture was placed in an ice-water bath and warmed to 0 °C. After 5 min, the mixture was cooled back to –78 °C and after another 5 min a solution of the silylenol ether **3h** (216 μL, 0.875 mmol, 2.00 equiv) in dichloromethane (460 μL) was added via cannula. After 5 min, the reaction vessel was placed in an ice-water bath and warmed to 0 °C, and after an additional 5 min, the reaction vessel was placed in the microwave reactor and heated to 140°C. After an hour, the reaction vessel was removed from the microwave reactor and cooled to ambient temperature before adding aqueous sodium hydroxide (1 mL) to the reaction mixture to neutralize the trifluoromethanesulfonate salts. The mixture was partitioned between water (10 mL) and dichloromethane (10 mL), and the aqueous layer was extracted with dichloromethane (2 × 10 mL). The combined organic layers were washed with brine (10 mL), were dried over anhydrous sodium sulfate, and were filtered. The volatiles were removed under reduced pressure, and the residue was purified by flash column chromatography (eluent: 9% EtOAc and 1% Et_3N in hexanes; SiO_2: 15 × 3 cm) to give the quinoline derivative **4bb** as an off-white solid (95 mg, 66%).

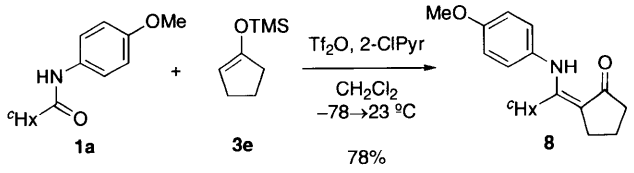
^{1}H NMR (500 MHz, $CDCl_3$, 20 °C) δ:	8.34 (d, 1H, J = 8.0 Hz, Ar**H**), 8.11 (d, 1H, J = 9.0 Hz Ar**H**), 7.93 (d, 1H, J = 2.5 Hz, Ar**H**), 7.72 (d, 1H, J = 7.5, Ar**H**), 7.55 (td, 1H, J = 7.5, 1.0 Hz, Ar**H**), 7.48 (td, 1H, J = 7.5, 1.0 Hz, Ar**H**), 7.39 (dd, 1H, J = 9.5, 2.5 Hz, Ar**H**), 4.07 (s, 2H, C**H**$_2$), 4.06 (s, 3H, OC**H**$_3$), 3.11–3.06 (m, 1H, ^{c}C$_6$**H**$_{11}$), 2.00–1.89 (m, 6H, ^{c}C$_6$**H**$_{11}$), 1.85–1.81 (m, 1H, ^{c}C$_6$**H**$_{11}$), 1.55–1.43 (m, 3H, ^{c}C$_6$**H**$_{11}$).
^{13}C NMR (125 MHz, $CDCl_3$, 20 °C) δ:	160.6, 157.5, 144.6, 144.4, 143.1, 141.6, 134.8, 131.7, 127.7, 127.3, 125.4, 124.4, 123.8, 120.0, 102.4, 55.7, 44.4, 36.0, 31.9, 27.0, 26.3
FTIR (neat) cm^{-1}:	2929 (s), 2848 (m), 1643 (w), 1625 (m), 1568 (m), 1508 (s), 1221 (s).
HRMS (ESI):	calc'd for $C_{23}H_{24}NO$ $[M+H]^+$: 330.1852, found: 330.1845.
TLC (35% EtOAc/1% Et_3N/hexanes), R_f:	0.42 (UV, CAM).



6-Cyclohexyl-2-methoxy-*11H*-indeno[1,2-c]quinoline (4cc, Table 1):

Trifluoromethanesulfonic anhydride (81 μL, 0.48 mmol, 1.1 equiv) was added drop-wise via syringe to a stirred mixture of amide **1l** (101 mg, 0.433 mmol, 1 equiv) and 2-chloropyridine (49 μL, 0.52, 1.2 equiv) in dichloromethane (1.5 mL) at –78 °C. After five minutes, the reaction mixture was placed in an ice-water bath, allowed to warm to 0 °C for five minutes, and a solution of the silylenol ether **3i** (220 μL, 0.866 mmol, 2.00 equiv) in dichloromethane (200 μL) was added via cannula. The reaction vessel was placed in a microwave reactor and heated to 140 °C. After one hour, the reaction mixture was allowed to cool to ambient temperature and sodium hydroxide solution (1 mL, 1 N) was added to neutralize the trifluoromethanesulfonate salts. The mixture was partitioned between dichloromethane (10 mL) and water (10 mL), and the aqueous layer was extracted with dichloromethane (2 × 10 mL). The combined organic layers were washed with brine (10 mL), were dried over anhydrous sodium sulfate, and were filtered. The solution was concentrated under reduced pressure, and the residue was purified by flash column chromatography (eluent: 9% EtOAc and 1% Et_3N in hexanes; SiO_2: 15 × 3 cm) to give the quinoline derivative **4cc** as an off-white solid (112 mg, 78%).

^{1}H NMR (500 MHz, $CDCl_3$, 20 °C) δ:	8.03 (d, 1H, J = 9.0 Hz, Ar**H**), 7.96 (d, 1H, J = 7.5 Hz Ar**H**), 7.67 (d, 1H, J = 8.0 Hz, Ar**H**), 7.48 (td, 1H, J = 7.5, 0.5 Hz, Ar**H**), 7.38 (td, 1H, J = 7.5, 0.5 Hz, Ar**H**), 7.32 (dd, 1H, J = 9.0, 2.5 Hz, Ar**H**), 7.20 (d, 1H, J = 3.0 Hz, Ar**H**), 4.17 (s, 2H, C**H**$_2$), 3.98 (s, 3H, OC**H**$_3$), 3.52 (tt, 1H, J = 11.5, 3.0 Hz, ^{c}C$_6$**H**$_{11}$), 2.17–2.15 (m, 2H, ^{c}C$_6$**H**$_{11}$), 2.03–1.99 (m, 2H, ^{c}C$_6$**H**$_{11}$), 1.96–1.87 (m, 3H, ^{c}C$_6$**H**$_{11}$), 1.66–1.57 (m, 2H, ^{c}C$_6$**H**$_{11}$), 1.50–1.41 (m, 1H, ^{c}C$_6$**H**$_{11}$).
^{13}C NMR (125 MHz, $CDCl_3$, 20 °C) δ:	159.7, 157.6, 148.5, 143.5, 142.5, 141.3, 133.3, 131.5, 127.5, 126.6, 125.6, 125.2, 123.3, 121.1, 101.7, 55.8, 43.9, 36.0, 31.5, 27.1, 26.5.
FTIR (neat) cm^{-1}:	3432 (br), 2927 (s), 2850 (m), 1622 (m), 1574 (w), 1477 (w), 1220 (s).
HRMS (ESI):	calc'd for $C_{23}H_{24}NO$ $[M+H]^+$: 330.1852, found: 330.1843.
TLC (35% EtOAc/1% Et_3N/hexanes), R_f:	0.44 (UV, CAM).



(Z)-2-(Cyclohexyl(4-methoxyphenylamino)methylene)cyclopentanone (8, equation 4):

Trifluoromethanesulfonic anhydride (82 μL, 0.49 mmol, 1.1 equiv) was added drop-wise via syringe to a stirred mixture of amide **1f** (103 mg, 0.439 mmol, 1 equiv) and 2-chloropyridine (50 μL, 0.53, 1.2 equiv) in dichloromethane (1.5 mL) at –78°C. After five minutes, the reaction mixture was placed in an ice-water bath, allowed to warm to 0°C for five minutes, and silylenol ether **3e** (158 μL, 0.885 mmol, 2.01 equiv) was added via syringe. After five minutes, the reaction mixture was allowed to warm to ambient temperature. After 20 minutes, aqueous sodium hydroxide solution (2 mL) was added to the reaction mixture to neutralize the trifluoromethanesulfonate salts. The mixture was partitioned between water (10 mL) and dichloromethane (10 mL), and the layers were separated. The aqueous layer was extracted with dichloromethane (2 × 10 mL). The combined organic layers were washed with brine (10 mL), were dried over anhydrous sodium sulfate, and were filtered. The volatiles were removed under reduced pressure, and the residue was purified by flash column chromatography (eluent: 19% EtOAc and 1% Et_3N in hexanes; SiO_2: 13 × 3 cm) to give the vinylogous amide **8** as a pale-yellow oil (102 mg, 78%).

^{1}H NMR (500 MHz, $CDCl_3$, 20 °C) δ:	12.48 (br s, 1H, N**H**), 7.00 (d, 2H, J = 8.5 Hz, Ar**H**), 6.88 (d, 2H, J = 8.5 Hz, Ar**H**), 3.83 (s, 3H, OC**H**$_3$), 2.77 (t, 2H, J = 7.0 Hz, $CH_2CH_2C\mathbf{H}_2$), 2.50–2.46 (m, 1H, $^cC_6\mathbf{H}_{11}$), 2.35 (t, 2H, J = 8.0 Hz, $CH_2CH_2C\mathbf{H}_2$), 1.88 (p, 2H, J = 7.5 Hz, $CH_2C\mathbf{H}_2CH_2$), 1.74–1.58 (m, 7H, $^cC_6\mathbf{H}_{11}$), 1.15–1.06 (m, 3H, $^cC_6\mathbf{H}_{11}$).
^{13}C NMR (125 MHz, $CDCl_3$, 20 °C) δ:	204.6, 164.9, 157.9, 132.3, 127.8, 114.3, 103.1, 55.7, 40.5, 38.8, 28.9, 28.7, 26.4, 25.9, 21.5.
FTIR (neat) cm^{-1}:	2930 (s), 2852 (m), 1618 (s), 1576 (s), 1512 (s), 1450 (m), 1240 (s), 1211 (s).
HRMS (ESI):	calcd for $C_{19}H_{26}NO_2$ $[M+H]^+$: 300.1958, found: 300.1947.
TLC (20% EtOAc/1% Et_3N/hexanes), R_f:	0.25 (UV, CAM).

Crystal Structure of quinoline 4j (Table 1).

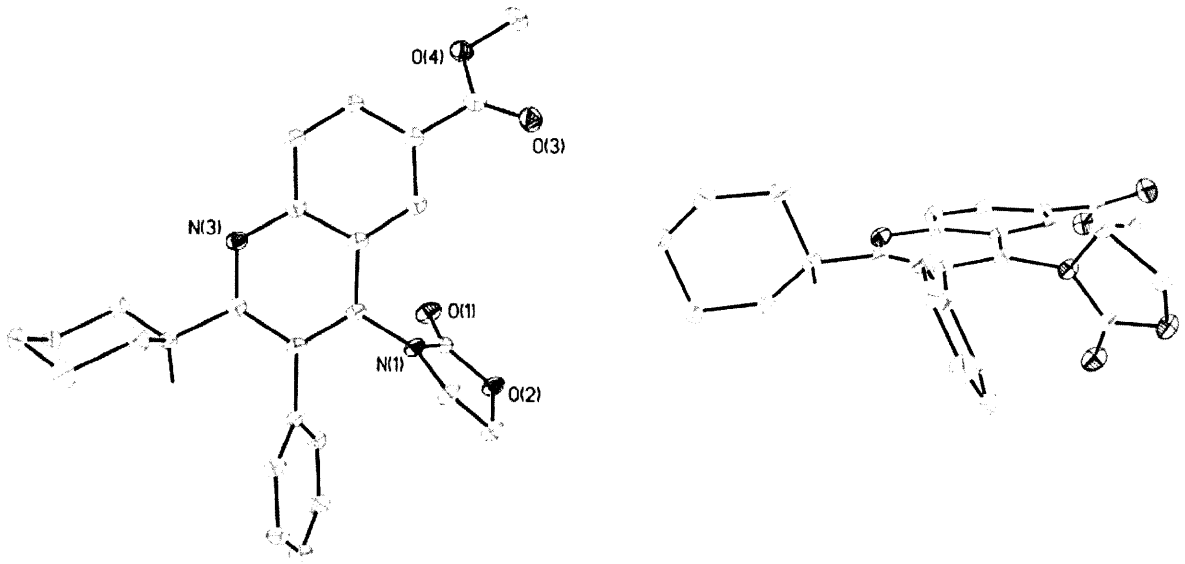


Table S1. Crystal data and structure refinement for **4j**.

Identification code	07069	
Empirical formula	C26 H26 N2 O4	
Formula weight	430.49	
Temperature	100(2) K	
Wavelength	0.71073 ≈	
Crystal system	Monoclinic	
Space group	P2(1)/n	
Unit cell dimensions	a = 16.767(13) ≈	α= 90∞.
	b = 6.055(5) ≈	β= 97.944(14)∞.
	c = 20.972(16) ≈	γ = 90∞.
Volume	2109(3) ≈^{3}	
Z	4	
Density (calculated)	1.356 Mg/m^3	
Absorption coefficient	0.092 mm^{-1}	
F(000)	912	
Crystal size	0.40 x 0.10 x 0.05 mm^3	
Theta range for data collection	1.96 to 29.57∞.	
Index ranges	-23<=h<=23, -8<=k<=8, -29<=l<=29	
Reflections collected	43401	
Independent reflections	5922 [R(int) = 0.0672]	
Completeness to theta = 29.57∞	100.0 %	
Absorption correction	Semi-empirical from equivalents	
Max. and min. transmission	0.9954 and 0.9642	
Refinement method	Full-matrix least-squares on F^2	
Data / restraints / parameters	5922 / 0 / 290	
Goodness-of-fit on F^2	1.032	
Final R indices [I>2sigma(I)]	R1 = 0.0415, wR2 = 0.0997	
R indices (all data)	R1 = 0.0617, wR2 = 0.1107	
Largest diff. peak and hole	0.412 and -0.238 e.≈$^{-3}$	

Table S2. Atomic coordinates (x 10^4) and equivalent isotropic displacement parameters ($\approx^2$x 10^3) for **4j**. U(eq) is defined as one third of the trace of the orthogonalized U^{ij} tensor.

	x	y	z	U(eq)
C(1)	177(1)	5105(2)	2289(1)	14(1)
C(2)	204(1)	4446(2)	2912(1)	14(1)
C(3)	822(1)	5357(2)	3373(1)	14(1)
C(4)	1280(1)	7561(2)	2609(1)	15(1)
C(5)	1794(1)	9275(2)	2466(1)	18(1)
C(6)	1759(1)	10043(2)	1857(1)	18(1)
C(7)	1237(1)	9063(2)	1356(1)	16(1)
C(8)	741(1)	7375(2)	1478(1)	15(1)
C(9)	733(1)	6652(2)	2111(1)	14(1)
C(10)	-1044(1)	5488(2)	1535(1)	16(1)
C(11)	-1328(1)	1920(2)	1262(1)	19(1)
C(12)	-468(1)	2003(2)	1587(1)	18(1)
C(21)	-427(1)	2949(2)	3090(1)	15(1)
C(22)	-1224(1)	3624(2)	2990(1)	17(1)
C(23)	-1829(1)	2233(2)	3125(1)	20(1)
C(24)	-1642(1)	145(2)	3360(1)	22(1)
C(25)	-852(1)	-536(2)	3464(1)	21(1)
C(26)	-248(1)	850(2)	3330(1)	18(1)
C(31)	926(1)	4662(2)	4065(1)	15(1)
C(32)	1654(1)	3147(2)	4215(1)	21(1)
C(33)	1770(1)	2439(2)	4914(1)	25(1)
C(34)	1845(1)	4415(2)	5359(1)	23(1)
C(35)	1126(1)	5918(2)	5213(1)	22(1)
C(36)	1013(1)	6642(2)	4517(1)	20(1)
N(1)	-420(1)	4267(2)	1812(1)	14(1)
N(3)	1327(1)	6868(2)	3226(1)	16(1)
O(1)	-1157(1)	7422(1)	1608(1)	22(1)
O(2)	-1551(1)	4209(1)	1145(1)	18(1)
O(3)	929(1)	8872(2)	219(1)	25(1)
O(4)	1343(1)	12056(1)	689(1)	22(1)
C(13)	1158(1)	9920(2)	692(1)	17(1)
C(14)	1217(1)	13123(2)	73(1)	26(1)

Table 3. Bond lengths [≈] and angles [∞] for **4j**.

C(1)-C(2)	1.3626(19)
C(1)-C(9)	1.4070(17)
C(1)-N(1)	1.4088(16)
C(2)-C(3)	1.4265(17)
C(2)-C(21)	1.4789(17)
C(3)-N(3)	1.3117(16)
C(3)-C(31)	1.498(2)
C(4)-N(3)	1.3514(18)
C(4)-C(9)	1.4032(18)
C(4)-C(5)	1.4073(18)
C(5)-C(6)	1.353(2)
C(6)-C(7)	1.4040(18)
C(7)-C(8)	1.3632(18)
C(7)-C(13)	1.475(2)
C(8)-C(9)	1.3999(19)
C(10)-O(1)	1.1994(17)
C(10)-O(2)	1.3405(15)
C(10)-N(1)	1.3448(16)
C(11)-O(2)	1.4472(18)
C(11)-C(12)	1.507(2)
C(12)-N(1)	1.4481(18)
C(21)-C(26)	1.3852(19)
C(21)-C(22)	1.3855(19)
C(22)-C(23)	1.3777(19)
C(23)-C(24)	1.377(2)
C(24)-C(25)	1.376(2)
C(25)-C(26)	1.3744(19)
C(31)-C(36)	1.5226(19)
C(31)-C(32)	1.5245(19)
C(32)-C(33)	1.514(2)

C(33)-C(34)	1.511(2)	O(2)-C(11)-C(12)	104.65(10)
C(34)-C(35)	1.507(2)	N(1)-C(12)-C(11)	100.69(9)
C(35)-C(36)	1.511(2)	C(26)-C(21)-C(22)	118.79(11)
O(3)-C(13)	1.1942(17)		
O(4)-C(13)	1.3303(18)	C(26)-C(21)-C(2)	121.82(11)
O(4)-C(14)	1.4342(18)	C(22)-C(21)-C(2)	119.34(12)
		C(23)-C(22)-C(21)	120.75(13)
C(2)-C(1)-C(9)	120.88(11)	C(24)-C(23)-C(22)	119.82(13)
C(2)-C(1)-N(1)	120.17(11)	C(25)-C(24)-C(23)	119.86(12)
C(9)-C(1)-N(1)	118.95(11)	C(26)-C(25)-C(24)	120.39(13)
C(1)-C(2)-C(3)	117.53(11)	C(25)-C(26)-C(21)	120.38(12)
C(1)-C(2)-C(21)	119.38(10)	C(3)-C(31)-C(36)	111.72(11)
C(3)-C(2)-C(21)	122.98(11)	C(3)-C(31)-C(32)	110.60(10)
N(3)-C(3)-C(2)	122.76(12)	C(36)-C(31)-C(32)	109.93(11)
N(3)-C(3)-C(31)	115.60(10)	C(33)-C(32)-C(31)	111.25(11)
C(2)-C(3)-C(31)	121.63(11)	C(34)-C(33)-C(32)	111.21(12)
N(3)-C(4)-C(9)	122.39(11)	C(35)-C(34)-C(33)	110.96(11)
N(3)-C(4)-C(5)	118.43(11)	C(34)-C(35)-C(36)	111.23(11)
C(9)-C(4)-C(5)	119.17(12)	C(35)-C(36)-C(31)	111.17(12)
C(6)-C(5)-C(4)	120.44(12)	C(10)-N(1)-C(1)	122.86(11)
C(5)-C(6)-C(7)	120.19(12)	C(10)-N(1)-C(12)	112.02(10)
C(8)-C(7)-C(6)	120.61(12)	C(1)-N(1)-C(12)	125.04(10)
C(8)-C(7)-C(13)	117.63(11)	C(3)-N(3)-C(4)	119.24(11)
C(6)-C(7)-C(13)	121.61(12)	C(10)-O(2)-C(11)	108.87(10)
C(7)-C(8)-C(9)	119.94(11)	C(13)-O(4)-C(14)	115.84(11)
C(8)-C(9)-C(4)	119.45(12)	O(3)-C(13)-O(4)	124.19(12)
C(8)-C(9)-C(1)	123.56(11)	O(3)-C(13)-C(7)	124.98(12)
C(4)-C(9)-C(1)	116.94(12)	O(4)-C(13)-C(7)	110.78(11)
O(1)-C(10)-O(2)	122.90(11)		
O(1)-C(10)-N(1)	127.54(12)		
O(2)-C(10)-N(1)	109.56(11)		

Symmetry transformations used to generate equivalent atoms

Table 4. Anisotropic displacement parameters ($\approx^2$x 10^3)for **4j**. The anisotropic displacement factor exponent takes the form: $-2\pi^2[h^2a^{*2}U^{11} + ... + 2\ h\ k\ a^*\ b^*\ U^{12}]$

	U^{11}	U^{22}	U^{33}	U^{23}	U^{13}	U^{12}
C(1)	11(1)	11(1)	20(1)	-1(1)	0(1)	0(1)
C(2)	11(1)	11(1)	19(1)	1(1)	2(1)	1(1)
C(3)	12(1)	13(1)	18(1)	0(1)	1(1)	2(1)
C(4)	12(1)	13(1)	20(1)	1(1)	1(1)	1(1)
C(5)	14(1)	17(1)	21(1)	1(1)	1(1)	-3(1)
C(6)	14(1)	16(1)	23(1)	2(1)	3(1)	-3(1)
C(7)	14(1)	14(1)	20(1)	2(1)	3(1)	2(1)
C(8)	13(1)	14(1)	19(1)	1(1)	1(1)	1(1)
C(9)	12(1)	11(1)	20(1)	1(1)	1(1)	1(1)
C(10)	14(1)	14(1)	19(1)	2(1)	1(1)	-1(1)
C(11)	18(1)	12(1)	24(1)	-1(1)	-2(1)	0(1)
C(12)	17(1)	12(1)	25(1)	-4(1)	0(1)	1(1)
C(21)	14(1)	14(1)	16(1)	-1(1)	1(1)	-3(1)
C(22)	17(1)	16(1)	19(1)	0(1)	1(1)	0(1)
C(23)	14(1)	23(1)	23(1)	-1(1)	2(1)	-2(1)
C(24)	20(1)	21(1)	24(1)	1(1)	4(1)	-8(1)
C(25)	24(1)	14(1)	23(1)	2(1)	2(1)	-4(1)
C(26)	16(1)	15(1)	21(1)	0(1)	1(1)	0(1)
C(31)	13(1)	16(1)	18(1)	1(1)	1(1)	-1(1)
C(32)	20(1)	21(1)	23(1)	4(1)	3(1)	6(1)
C(33)	27(1)	24(1)	24(1)	6(1)	1(1)	8(1)

C(34)	19(1)	28(1)	21(1)	5(1)	-2(1)	-2(1)
C(35)	24(1)	22(1)	18(1)	0(1)	-1(1)	0(1)
C(36)	24(1)	17(1)	20(1)	0(1)	-2(1)	2(1)
N(1)	14(1)	10(1)	19(1)	0(1)	-1(1)	-1(1)
N(3)	13(1)	15(1)	19(1)	2(1)	1(1)	0(1)
O(1)	21(1)	11(1)	33(1)	1(1)	-2(1)	1(1)
O(2)	18(1)	12(1)	23(1)	1(1)	-4(1)	-1(1)
O(3)	34(1)	20(1)	20(1)	1(1)	4(1)	-2(1)
O(4)	28(1)	15(1)	22(1)	5(1)	3(1)	-3(1)
C(13)	14(1)	15(1)	23(1)	3(1)	4(1)	1(1)
C(14)	34(1)	19(1)	24(1)	9(1)	5(1)	2(1)

Table 5. Hydrogen coordinates (x 10^4) and isotropic displacement parameters ($\approx^2$x 10^3) for **4j**.

	x	y	z	U(eq)
H(5)	2167	9897	2800	21
H(6)	2090	11248	1769	22
H(8)	402	6690	1134	19
H(11A)	-1368	1090	852	22
H(11B)	-1679	1209	1544	22
H(12A)	-373	942	1948	22
H(12B)	-83	1712	1279	22
H(22)	-1354	5062	2827	21
H(23)	-2373	2713	3056	24
H(24)	-2058	-823	3451	26
H(25)	-724	-1973	3629	25
H(26)	296	365	3403	21
H(31)	436	3817	4142	19
H(32A)	1579	1823	3936	26
H(32B)	2143	3928	4120	26
H(33A)	1307	1525	4999	30
H(33B)	2263	1524	5003	30
H(34A)	1887	3905	5811	27
H(34B)	2341	5242	5308	27
H(35A)	1202	7235	5495	26
H(35B)	637	5136	5306	26
H(36A)	1481	7540	4434	25
H(36B)	525	7577	4431	25
H(14A)	1617	12593	-190	38
H(14B)	1273	14724	131	38
H(14C)	675	12781	-143	38

Chapter IV

Synthesis of Densely Subsitututed Pyrimidine Derivatives

Introduction and Background

Pyrimidine derivatives are a significant class of azaheterocycles that are found in many natural products and pharmaceuticals.[1] Cytosine and thymine are key DNA building blocks and are prevalent in nature (Figure 1), as are more complex pyrimidine containing alkaloids like cylindrospermopsin,[2] hyrantinadine A,[3] and dehydrobatzelladine C.[4] Some examples of pharmaceutically relevant compounds containing the pyrimidine core structure are Gleevec[5] and sulfadiazine.[6]

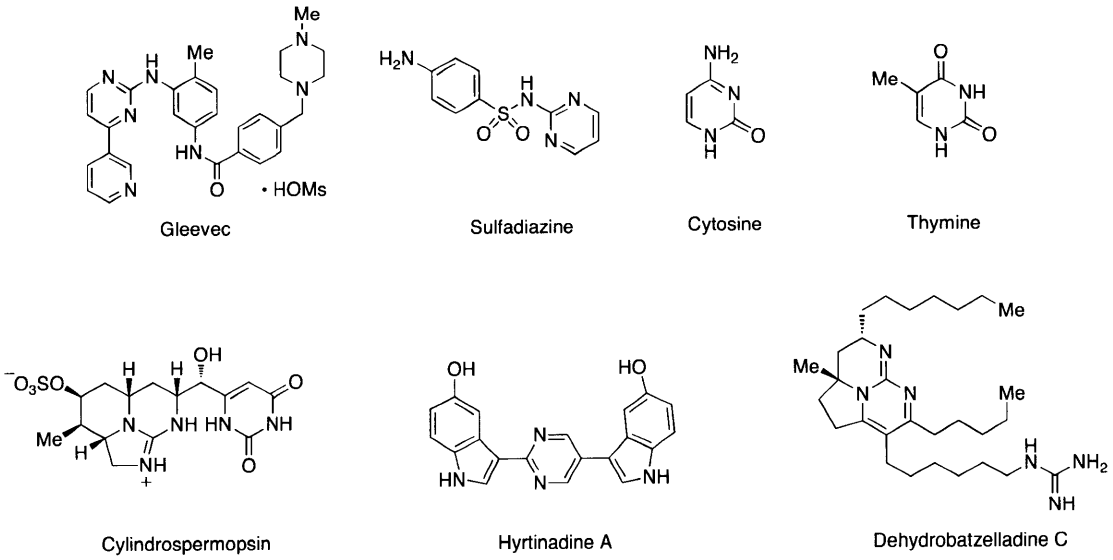
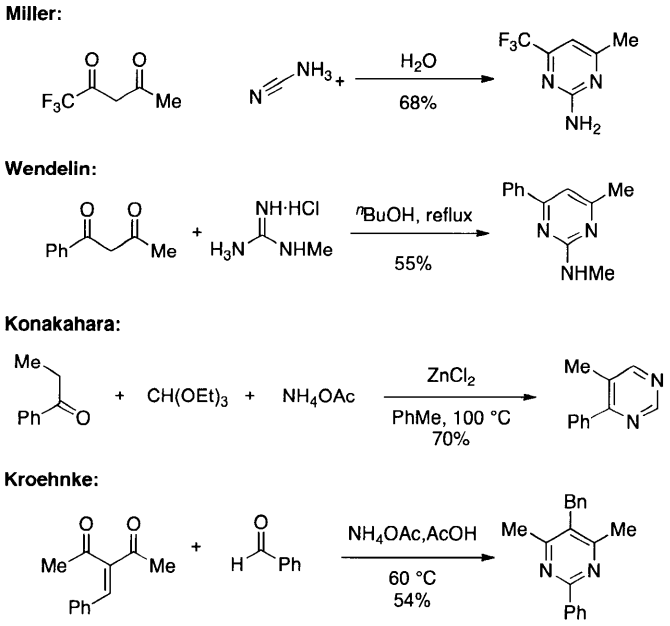
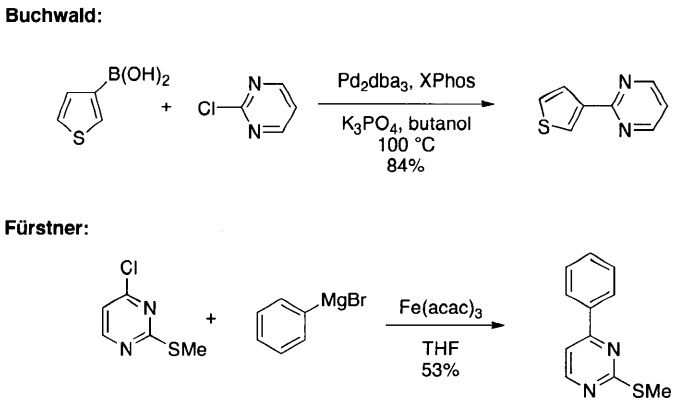


Figure 1. Representative organic compounds containing pyrimidine substructure.

Pyrimidines have inspired the development of new methodologies for their chemical synthesis for over a century. In addition to reports concerning variation of established protocols,[7] new methods[8] are also described that rely on the union of amine- and carbonyl-containing fragments to assemble the important pyrimidine substructures of interest (Scheme 1). Additionally, the advancement of transition-metal catalyzed methodologies for cross-coupling of activated azaheterocycles offers complementary access to substituted azaheterocycles[9] (Scheme 2).



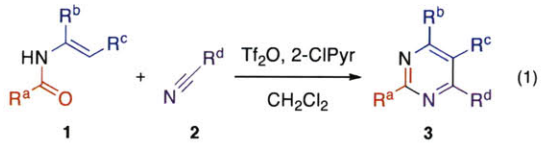
Scheme 1. Representative examples of pyrimidine syntheses.



Scheme 2. Cross-coupling with pyrimidine derivatives.

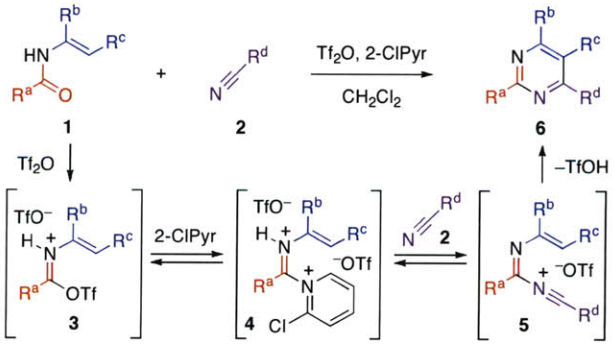
In chapter III, we discussed the development of a methodology[10] for the convergent synthesis of pyridine derivatives in a single step from the corresponding *N*-vinyl/aryl[11] amides. This methodology relies on electrophilic amide activation[12] using the reagent combination of trifluoromethanesulfonic anhydride[13] (Tf_2O) and 2-chloropyridine[14] (2-ClPyr). In this chapter, we discuss the use of cyanic acid derivatives as nucleophiles for rapid synthesis of versatile C4-heteroatom substituted pyrimidines (eq 1). Furthermore, we discuss the utility of this chemistry in the synthesis of a variety of pyrimidine

derivatives that are not directly accessible due to functional group incompatibility with the condensation reaction conditions. In addition, we describe the use of various amide analogues that provide access to a variety of C2-substituents on the pyrimidine core.



Results and Discussion

Scheme 3 illustrates a plausible mechanism for the union of an *N*-vinyl/aryl amide **1** with nitrile **2** by interception of an activated intermediate[15] followed by cyclization of the nitrilium ion **5** to give the corresponding substituted pyrimidine **6**. Amongst the various nucleophiles we have explored for this chemistry, nitriles proved to be most sensitive to conditions for amide activation, their addition being inhibited even by the excess 2-ClPyr additive. The prevalence of C4-heteroatom substituted pyrimidine derivatives in fine chemicals and pharmaceuticals coupled with our observations that more electron rich nucleophiles served as excellent condensation partners prompted our investigation of cyanic acid derivatives in the context of our pyrimidine synthesis methodology.



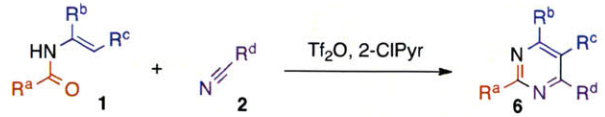
Scheme 3. Synthesis of pyrimidine derivatives.

The use of a variety of cyanic acid derivatives in the direct synthesis of C4-heteroatom substituted pyrimidine derivatives is shown in Table 1. Synthesis of the 4-morpholinopyrimidine **6a** is illustrative: introduction of Tf_2O to a solution of *N*-vinyl

amide **1a**, morpholine-4-carbonitrile (**2a**), and 2-ClPyr in dichloromethane at –78 °C followed by warming to 23 °C gave the desired azaheterocycle **6a** in 87% yield. Both *N*-vinyl and *N*-aryl amides serve as effective coupling partners with various cyanic acid derivatives to give the corresponding azaheterocycles. We recommend either simple warming to 23 °C after electrophilic activation or heating at 140 °C in a microwave reactor to accelerate the rate of cyclization. The union of morpholine-4-carbonitrile (**2a**) with amides **1a**, **1b** and **1c** gave the corresponding pyrimidines **6a** and **6b,** and quinazoline **6c**, respectively, within an hour at 23 °C (Condition A). The use of the less nucleophilic 1,3-dioxoisoindoline-2-carbonitrile (**2b**) necessitated the use of more forcing cyclization conditions (Condition B) to deliver the desired azaheterocycles. Interestingly, while cyanatobenzene (**2c**) afforded the targeted pyrimidine **6f** and quinazoline **6g** in moderate yield (Table 1), the use of thiocyanatobenzene failed to provide the corresponding 4-thiophenyl substituted azaheterocycles in synthetically useful yields.[16] Based on our interest in the synthesis of 4-thio-derivatives as versatile precursors to other compounds of interest[17] we were delighted to see the formation of the desired products **6h-k** (Table 1) in good yield using thiocyanatomethane (**2d**) as the nucleophile in this chemistry. Importantly, even cyanic bromide (**2e**) can be used as a starting material in this azaheterocycle synthesis illustrated by 4-bromo-quinazolines **6l** and **6m** (Table 1).[18] The direct synthesis of azaheterocycles **6h-6m** is noteworthy as they offer exciting options for introduction of a wide range of other substituents at C4.[19]

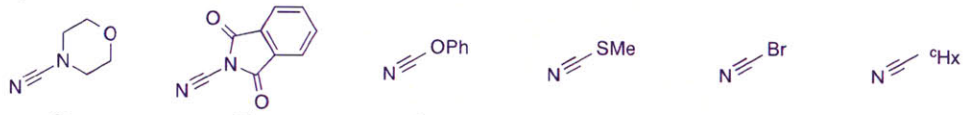
Similar to the examples discussed in chapter III, warming to room temperature or heating in the microwave is only necessary for more recalcitrant substrates. For instance, the addition of thiocyanatomethane **2d** to a solution of *N*-vinyl amide **1b** leads to complete conversion and formation of the corresponding pyridine derivative **6j** in 81% yield at sub-ambient temperature (Scheme 2). It is noteworthy that most other protocols for synthesis of highly substituted azaheterocycles, on the other hand, require heating at high temperatures.[7,8,9]

Table 1. Synthesis of Pyrimidines and Quinazolines.[a]



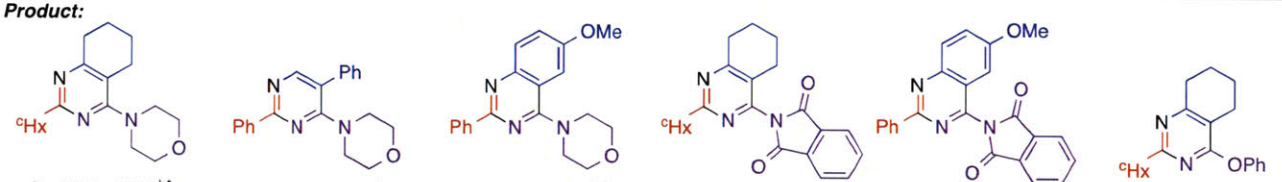
1 + 2 → 6

Nucleophile:



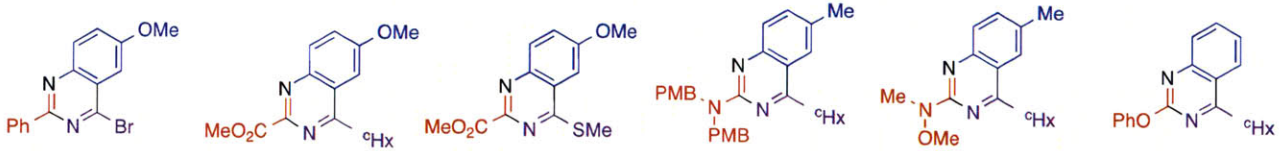
2a **2b** **2c** **2d** **2e** **2f**

Product:



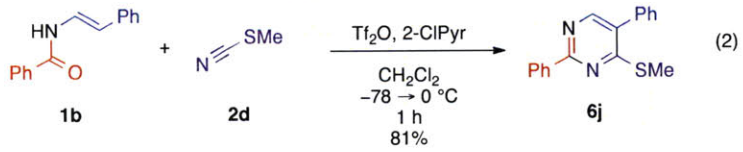
6a, 87%, A(**2a**)[b*] **6b**, 77%, A(**2a**)[b] **6c**, 77%, A(**2a**)[b*] **6d**, 54%, B(**2b**) **6e**, 64%, B(**2b**)[c*] **6f**, 63%, B(**2c**)*

6g, 54%, B(**2c**)* **6h**, 92%, B(**2d**)* **6i**, 99%, A(**2d**)* **6j**, 82%, A(**2a**) **6k**, 62%, A(**2d**) **6l**, 72%, C(**2e**)

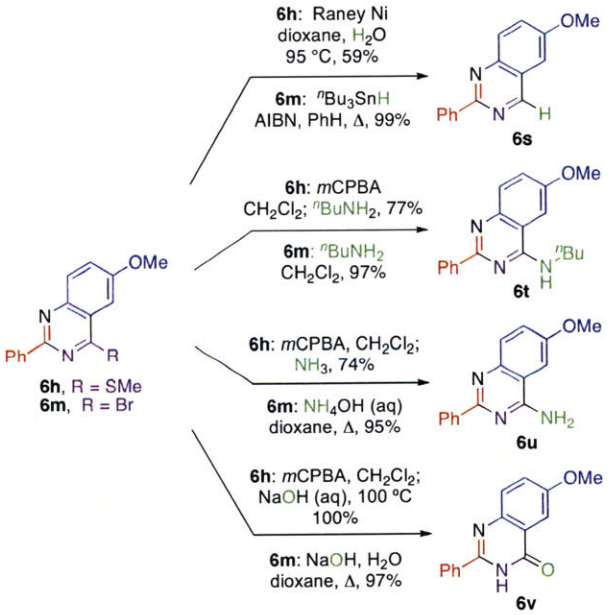


6m, 68%, C(**2e**) **6n**, 54%, B(**2f**) **6o**, 71%, A(**2d**) **6p**, 84%, B(**2f**) **6q**, 70%, B(**2f**) **6r**, 59%, B(**2f**)*

[a]All yields are average of two experiments. ^{c}Hx = cyclohexyl. PMB = *p*-methoxybenzyl. Uniform reaction conditions unless otherwise noted: Tf_2O (1.1 equiv), 2-ClPyr (1.2 equiv), nucleophile (2.0 equiv), CH_2Cl_2. Heating: A = 23 °C, 1 h; B = microwave, 140 °C, 5 min; C = 1,2-dichloroethane, reflux, 2h, nucleophile. [b]Nucleophile (1.1 equiv). [c]Heat in the microwave for 10 min. * Experiments carried out by my colleague, Matthew D. Hill.



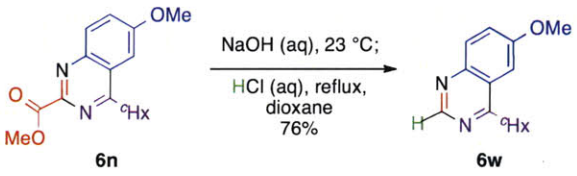
The conversion of 4-bromoquinazoline **6m** to azaheterocycles **6s-6v** (Scheme 4) is illustrative of the versatility of the products accessed using cyanic bromide (**2e**), as the nucleophilic component in this chemistry. Tin hydride based reduction[20] of C4-Br **6m** proceeded cleanly to give product **6s** in 99% yield. It is important to note that the use of trimethylsilyl cyanide in our condensative synthesis of pyrimidines did not proceed under optimal conditions.[21] Furthermore, treatment of 4-bromoquinazoline **6m** with butylamine, ammonia, or aqueous sodium hydroxide gave the corresponding 4-butylaminoquinazoline **6t**, 4-aminoquinazoline **6u**, and the quinazoline-4(*3H*)-one **6v**, respectively (Scheme 4). It should be noted that products **6t-6v** could not be accessed directly by condensation of amide **1c** with the respective cyanamide or cyanate nucleophiles.[22]



Scheme 4. Derivatization reactions of pyrimidines.

We have also been interested in expansion of our chemistry to address the need for synthesis of pyrimidines with maximum flexibility for the C2-substituent. In prior studies we have demonstrated the use of various benzoic, heteroaromatic, alkanoic, and alk-2-enoic amide derivatives in our condensative synthesis of azaheterocycles. These

substrates offer the corresponding 2-alkyl, aryl, heteroaryl, and vinyl azaheterocycles. However, we have that formamides are not substrates for this azaheterocycles synthesis methodology due to competing formation of isonitriles during the activation of the substrates.[23] The rapid decarboxylation of pyrimidine-2-carboxylic acids[24] prompted exploration of oxamates as substrates for our azaheterocycle synthesis. Simple acylation of amines using the commercially available methyl 2-chloro-2-oxoacetate provides the necessary substrates for condensative union with various nucleophiles. As an illustration, the coupling of amide **1f** with cyclohexylnitrile (**2f**) and thiocyanatomethane (**2d**) provided the corresponding quinazolines **6n** and **6o**, respectively (Table 1). The simple decarboxylation of quinazoline-2-carboxylate **6n** to the corresponding quinazoline **6w** is shown in equation 3. The use of readily available oxamates in our azaheterocycle synthesis followed by decarboxylation affords access to products that are not viable using formamides as discussed above. Notably, (2*H*)-quinazolines are important kinase inhibitors and are of value in the development of anti-cancer drugs.[25]



6n **6w** (3)

The synthesis of 2-aminoazaheterocycles is of interest due to their prevalence in a variety of pharmacological drug targets.[26] Typically, their synthesis involves condensation of guanidine derivatives with appropriate coupling partners. We had previously noted that trisubstituted ureas function effectively under activation conditions for both pyridine and pyrimidine synthesis using our methodology. However, less substituted ureas simply undergo dehydration under the activation conditions.[27] In this regard the use of *para*-methoxybenzyl amine derived ureas as substrates provides a solution for rapid access to the desired 2-aminoazaheterocycles by simple unraveling of the C2-amino group post azaheterocycle synthesis. For example, the direct condensation of methoxybenzylurea derivative **1g** with cyclohexanecarbonitrile (**2f**) gave the desired methoxybenzylquinazoline **6p** in 84% yield (Table 1). Treatment of the quinazoline **6p**

with hydrogen bromide in toluene at reflux results in the desired 2-aminoquinazoline **6x** as shown in equation 4.

6p **6x** (4)

Similarly, use of the methoxy-3-(4-methoxyphenyl)-1-methylurea **1h** and the phenyl carbamate **1i** in this methodology affords the corresponding 2-dimethylhydroxyaminoquinazoline **6q** and 2-phenoxy **6r**, respectively (Table 1). It should be noted that carbamothioates did not provide 2-thiopyrimidines in synthetically useful yields.[28]

Conclusion

In summary, the direct condensation of cyanic acid derivatives with *N*-vinyl/aryl amides affords the corresponding C4-heteroatom substituted pyrimidines. In particular, the use of cyanic bromide and thiocyanatomethane in this chemistry yields versatile azaheterocycles ready for further C4 derivatization. Additionally, we describe the use oxamates and benzylated ureas to access C2-H and C2-amino azaheterocycles, compounds previously inaccessible using this methodology. This chemistry provides densely substituted and functionalized pyrimidine derivatives and extends the scope of this condensative strategy for azaheterocycle synthesis.

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[1] For reviews, see: (a) Undheim, K.; Benneche, T. In *Comprehensive Heterocyclic Chemistry II*; Katritzky, A. R.; Rees, C. W.; Scriven, E. F. V.; McKillop, A., Eds; Pergamon: Oxford, 1996; Vol. 6; p 93. (b) Lagoja, I. M. *Chem. & Biodiversity* **2005**, *2*, 1. (c) Michael, J. P. *Nat. Prod. Rep.* **2005**, *22*, 627. (d) Joule, J. A.; Mills, K. In *Heterocyclic Chemistry*, 4th ed.; Blackwell Science Ltd.: Cambridge, MA, 2000; p 194. (e) Hill, M. D.; Movassaghi, M. *Chem. Eur. J.* **2008**, *14*, 6836.

[2] Ohtani, I.; Moore, R. E. *J. Am. Chem. Soc.* **1992**, *114*, 7941.

[3] Endo, T.; Tsuda, M.; Fromont, J.; Kobayashi, J. *J. Nat. Prod.* **2007**, *70*, 423.

[4] Braekman, J. C.; Daloze, D.; Tavares, R.; Hajdu, E.; Van Soest, R. W. M. *J. Nat. Prod.* **2000**, *63*, 193.

[5] Nadal, E.; Olavarria, E. *Int. J. Clin. Pract.* **2004**, *58*, 511.

[6] Petersen, E.; Schmidt, D. R. *Expert. Rev. Anti-infective Ther.* **2003**, *1*, 175.

[7] (a) Kroehnke, F.; Schmidt, E.; Zecher, W. *Chem. Ber.* **1964**, *97*, 1163. (b) Wendelin, W.; Schermantz, K.; Fuchsgruber, A. *Montash, Chem.* **1983**, *114*, 1371. (c) Miller, A. *J. Org. Chem.* **1984**, *49*, 4072.

[8] For representative reports, see: (a) Madroñero, R.; Vega, S. *Synthesis* **1987**, 628. (a) Martínez, A. G.; Fernández, A. H.; Fraile, A. G.; Subramanian, L. R.; Hanack, M. *J. Org. Chem.* **1992**, *57*, 1627. (b) Kofanov, E. R.; Sosnina, V. V.; Danilova, A. S.; Korolev, P. V. *Zh. Prik. Khim.* **1999**, *72*, 813. (c) Ghosez, L.; Jnoff, E.; Bayard, P.; Sainte, F.; Beaudegnies, R. *Tetrahedron* **1999**, *55*, 3387. (d) Kotsuki, H.; Sakai, H.; Morimoto, H.; Suenaga H. *Synlett* **1999**, 1993. (e) Zielinski, W.; Kudelko, A. *Monatsh. Chem.* **2000**, *131*, 895. (f) Kakiya, H.; Yagi, K.; Shinokubo, H.; Oshima, K. *J. Am. Chem. Soc.* **2002**, *124*, 9032. (g) Yoon, D. S.; Han, Y.; Stark, T. M.; Haber, J. C.; Gregg, B. T.; Stankovich, S. B. *Org. Lett.* **2004**, *6*, 4775. (h) Sakai, N.; Youichi, A.; Sasada, T.; Konakahara, T. *Org. Lett.* **2005**, *7*, 4705. (i) Blangetti, M.; Deagostino, A.; Prandi, C.; Zavattaro, C; Venturello, P. *Chem. Commun.* **2008**, 1689. (j) Sasada, T; Kobayashi, F; Sakai, N; Konakahara, T. *Org. Lett.* **2009**, *11*, 2161. (k) Bannwarth, P.; Valleix, A.; Grée, D.; Grée, R. *J. Org. Chem.* **2009**, *74*, 4646.

[9] For reviews, see: (a) Turck, A.; Plé, N.; Mongin, F.; Quéguiner, G. *Tetrahedron* **2001**, *57*, 4489. (b) Chinchilla, R.; Nájera, C.; Yus, M. *Chem. Rev.* **2004**, *104*, 2667. (c) Schröter, S.; Stock, C.; Bach, T. *Tetrahedron*, **2005**, *61*, 2245. (d) Martin, R.; Buchwald, S. L. *Acc. Chem. Res.* **2008**, *41*, 1461. (e) Surry, D. S.; Buchwald, S. L. *Angew. Chem. Int. Ed.* **2008**, *47*, 6338.

[10] (a) Movassaghi, M.; Hill, M. D. *J. Am. Chem. Soc.* **2006**, *128*, 14254. (b) Movassaghi, M.; Hill, M. D.; Ahmad, O. K. *J. Am. Chem. Soc.* **2007**, *129*, 10096.

[11] (a) Muci, A. R.; Buchwald, S. L. *Top. Curr. Chem.* **2002**, *219*, 131. (b) Hartwig, J. F. In *Handbook of Organopalladium Chemistry for Organic Synthesis*; Negishi, E., Ed.; Wiley-Interscience; New York, 2002; p. 1051. (c) Beletskaya, I. P.; Cheprakov, A. V. *Coordin. Chem. Rev.* **2004**, *248*, 2337. (d) Dehli, J. R.; Legros, J.; Bolm, C. *Chem. Commun.* **2005**, 973.

[12] For elegant prior studies on the activation of amides using Tf_2O and pyridine, see: (a) Charette, A. B.; Grenon, M. *Can. J. Chem.* **2001**, *79*, 1694. (b) Charette, A. B.; Mathieu, S.; Martel, J. *Org. Lett.* **2005**, *7*, 5401.

[13] Baraznenok, I. L.; Nenajdenko, V. G.; Balenkova, E. S. *Tetrahedron* **2000**, *56*, 3077.

[14] (a) Myers, A. G.; Tom, N. J.; Fraley, M. E.; Cohen, S. B.; Madar, D. J. *J. Am. Chem. Soc.* **1997**, *119*, 6072. (b) Garcia, B. A.; Gin, D. Y. *J. Am. Chem. Soc.* **2000**, *122*, 4269.

[15] For a discussion on the nature of the activated amide as a function of amide structure, please see Medley, J. W.; Movassaghi, M. *J. Org. Chem.* **2009**, *74*, 1341.

[16] Treatment of amide **1b** with thiocyanatobenzene provided the corresponding quinazoline in <15% under various reaction conditions.

[17] Jang, M.-Y.; De Jonghe, S.; Gao, L.–J.; Rozenski, J.; Herdewijn, P. *Eur. J. Org. Chem.* **2006**, *18*, 4257.

[18] 4-Bromopyrimidine derivatives could be formed by treatment of amide **1a** with cyanic bromide in low yields (37–56%).

[19] We have considered mechanisms other than direct nucleophilic addition of **2e** to an electrophilic intermediate; however, in the absence of any contrary data, a plausible mechanism based on our prior studies is used here.

[20] Bennasar, M.-L.; Roca, T.; Ferrando, F. *Org. Lett.* **2006**, *8*, 561.

[21] The use of trimethylsilyl cyanide led to decomposition of the activated amide.

[22] Cyanamide, bis(trimethylsilyl)carbodiimide, and potassium cyanate do not serve as competent nucleophiles under our condensative pyrimidine synthesis reaction conditions; for example, amide **1b** and cyanamide did not afford **6r**.

[23] Baldwin, J. E.; O'Neil, I. A. *Tetrahedron Lett.* **1990**, *3*, 2047.

[24] Boger, D. L.; Dang, Q. *Tetrahedron* **1988**, *44*, 3379.

[25] (a) Thompson, A. M.; Bridges, A. J.; Fry, D. W.; Kraker, A. J.; Denny, W. A. *J. Med. Chem.* **1995**, *38*, 3780. (b) Gibson, K. H.; Grundy, W.; Godfrey, A. A.; Woodburn, J. R.; Ashton, S. E.; Curry, B. J.; Scarlett, L.; Barker, A. J.; Brown, D. S. *Bioorg. Med. Chem. Lett.* **1997**, *7*, 2723. (c) Fry, D. W. *Exp. Cell. Res.* **2003**, *284*, 131. (d) Cascone, T. Morelli, M. P.; Ciardiello, F. *Ann. Oncol.* **2006**, *17 Suppl 2*, 44.

[26] For recent studies, see: (a) Collis , A. J.; Foster, M. L.; Halley, F.; Maslen, C.; McLay, I. M.; Page, K. M.; Redford, E. J.; Souness, J. E.; Wilsher, N. E. *Bioorg. Med. Chem. Lett.* **2001**, *11*, 693. (b) Gangjee, A.; Adair, O. O.; Pagley, M.; Queener, S. F. *J. Med. Chem.* **2008**, *51*, 6195. (c) Fujiwara, N.; Nakajima, T.; Ueda, T.; Fujita, H.; Kawakami, H. *Bioorg, Med. Chem.* **2008**, *16*, 9804.

[27] Stevens, C. L.; Singhal, G. P.; Ash, A. B. *J. Org. Chem.* **1967**, *32*, 2895.

[28] A variety of 2-thiopyrimidine derivatives were synthesized in low yield (<20%) primarily due to the incomplete activation of the carbamothioates.

Experimental Section

General Procedures. All reactions were performed in oven-dried or flame-dried round bottomed flasks, modified Schlenk (Kjeldahl shape) flasks, or glass pressure vessels. The flasks were fitted with rubber septa and reactions were conducted under a positive pressure of argon. Stainless steel syringes or cannulae were used to transfer air- and moisture-sensitive liquids. Flash column chromatography was performed as described by Still et al. using silica gel (60-Å pore size, 32–63 μm, standard grade) or non-activated alumina gel (80–325 mesh, chromatographic grade).[1] Analytical thin–layer chromatography was performed using glass plates pre-coated with 0.25 mm 230–400 mesh silica gel or neutral alumina gel impregnated with a fluorescent indicator (254 nm). Thin layer chromatography plates were visualized by exposure to ultraviolet light and/or by exposure to an ethanolic phosphomolybdic acid (PMA), an acidic solution of *p*-anisaldehyde (anis), an aqueous solution of ceric ammonium molybdate (CAM), an aqueous solution of potassium permanganate ($KMnO_4$) or an ethanolic solution of ninhydrin followed by heating (<1 min) on a hot plate (~250 °C). Organic solutions were concentrated on rotary evaporators at ~10 Torr (house vacuum) at 25–35 °C, then at ~0.5 Torr (vacuum pump) unless otherwise indicated.

Materials. Commercial reagents and solvents were used as received with the following exceptions: Dichloromethane, diethyl ether, tetrahydrofuran, acetonitrile, and toluene were purified by the method of Grubbs et al. under positive argon pressure.[2] 2-Chloropyridine, 1,2-dichloroethane, 1,4-dioxane, and *n*-butylamine were distilled from calcium hydride and stored sealed under an argon atmosphere. The starting amides were prepared by acylation of the corresponding anilines[3] or via previously reported copper–catalyzed C–N bond–forming reactions.[4,5] The starting ureas and carbamate were prepared by addition of the corresponding amines and phenol, respectively, to the corresponding isocyanates.

Instrumentation. All reaction conducted at 140 °C were performed in a microwave reactor. Proton nuclear magnetic resonance (^{1}H NMR) spectra were recorded with an inverse probe 500 MHz spectrometer. Chemical shifts are recorded in parts per million from internal tetramethylsilane on the δ scale and are referenced from the residual protium in the NMR solvent ($CHCl_3$: δ 7.24; DMSO-d_5: δ 2.50). Data is reported as follows: chemical shift [multiplicity (s = singlet, d = doublet, q = quartet, m = multiplet), integration, coupling constant(s) in Hertz, assignment]. Carbon-13 nuclear magnetic resonance spectra were recorded with a 500 MHz spectrometer and are recorded in parts per million from internal tetramethylsilane on the δ scale and are referenced from the carbon resonances of the solvent ($CDCl_3$: δ 77.23; DMF-d_7: 163.15, DMSO-d_6: 39.51). Data is reported as follows: chemical shift [multiplicity (s = singlet, d = doublet, q = quartet, m = multiplet), coupling constant(s) in Hertz, assignment]. Infrared data were obtained with an FTIR and are reported as follows: [frequency of absorption (cm^{-1}), intensity of absorption (s = strong, m = medium, w = weak, br = broad), assignment].

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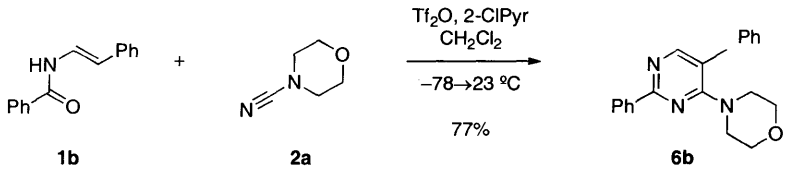
[1] Still, W. C.; Kahn, M.; Mitra, A. *J. Org. Chem.* **1978**, *43*, 2923–2925.
[2] Pangborn, A. B.; Giardello, M. A.; Grubbs, R. H.; Rosen, R. K.; Timmers, F. J. *Organometallics* **1996**, *15*, 1518–1520.
[3] For a general procedure, see: DeRuiter, J.; Swearingen, B. E,; Wandrekar, V.; Mayfield, C. A. *J. Med. Chem.* **1989**, *32*, 1033–1038.
[4] For the general procedure used for the synthesis of all *N*-vinyl amides, see: Jiang, L.; Job, G. E.; Klapars, A.; Buchwald, S. L. *Org. Lett.* **2003**, *5*, 3667–3669.
[5] For related reports, see: (a) Wolfe, J. P.; Wagaw, S.; Marcoux, J.-F.; Buchwald, S. L. *Acc. Chem. Res.* **1998**, *31*, 805–818. (b) Hartwig, J. F. *Acc. Chem. Res.* **1998**, *31*, 852–860. (c) Muci, A. R.; Buchwald, S. L. *Top. Curr. Chem.* **2002**, *219*, 131–209. (d) Beletskaya, I. P.; Cheprakov, A. V. *Coordin. Chem. Rev.* **2004**, *248*, 2337–2364. (e) Dehli, J. R.; Legros, J.; Bolm, C. *Chem. Commun.* **2005**, 973–986.

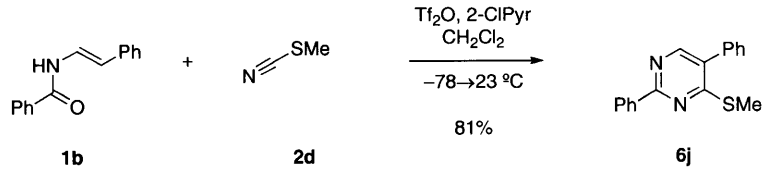


1b 2a 6b

4-(2,5-Diphenylpyrimidin-4-yl)morpholine (6b, Table 1):

Trifluoromethanesulfonic anhydride (43 μL, 0.26 mmol, 1.1 equiv) was added via syringe over 1 min to a stirred mixture of amide **1b** (52 mg, 0.23 mmol, 1 equiv), nucleophile **2a** (26 μL, 0.26 mmol, 1.1 equiv) and 2-chloropyridine (26 μL, 0.28 mmol, 1.2 equiv) in dichloromethane (800 μL) at –78 °C. After 5 min, the reaction mixture was placed in an ice-water bath for 5 min and warmed to 0 °C. The resulting solution was allowed to warm to ambient temperature. After 1 h, saturated aqueous sodium bicarbonate solution (1 mL) was introduced to neutralize the trifluoromethanesulfonate salts. The mixture was diluted with H_2O (5 mL) and extracted with dichloromethane (3 × 10 mL). The combined organic layers were washed with brine (10 mL), were dried over anhydrous sodium sulfate and were concentrated. The residue was purified by flash column chromatography (eluent: 15% EtOAc in hexanes; SiO_2: 11 × 2.0 cm) on silica gel to give pyrimidine derivative **6b** as a white solid (57 mg, 77%).

^{1}H NMR (500 MHz, $CDCl_3$, 20 °C) δ:	8.42–8.40 (m, 2H), 8.30 (s, 1H), 7.48–7.42 (m, 7H), 7.37–7.33 (m, 1H), 3.65 (t, 4H, J = 5.0 Hz), 3.39 (t, 4H, J = 5.0 Hz).
^{13}C NMR (125 MHz, $CDCl_3$, 20 °C) δ:	162.4, 162.3, 158.3, 138.1, 137.7, 130.6, 129.3, 128.6, 128.2, 128.0, 127.9, 119.5, 66.7, 47.9.
FTIR (neat) cm^{-1}:	2962 (m), 2853 (m), 1587 (m), 1565 (s), 1527 (s), 1429 (s), 1119 (s), 965 (s).
HRMS (ESI):	calc'd for $C_{20}H_{20}N_3O$ $[M+H]^+$: 318.1601, found: 318.1611.
mp:	94-95 °C
TLC (15% EtOAc in hexanes), R_f:	0.30 (UV).

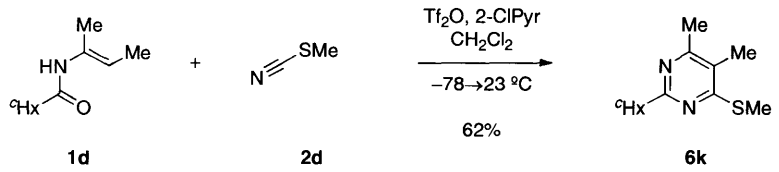


1b **2d** **6j**

4-(Methylthio)-2,5-diphenylpyrimidine (6j, Table 1):

Trifluoromethanesulfonic anhydride (47 μL, 0.28 mmol, 1.1 equiv) was added via syringe over 1 min to a stirred mixture of amide **1b** (56 mg, 0.25 mmol, 1 equiv), nucleophile **2d** (37 μL, 0.51 mmol, 2.0 equiv) and 2-chloropyridine (29 μL, 0.30 mmol, 1.2 equiv) in dichloromethane (900 μL) at –78 °C. After 5 min, the reaction mixture was placed in an ice-water bath for 5 min and warmed to 0 °C. The resulting solution was allowed to warm to ambient temperature. After 1 h, saturated aqueous sodium bicarbonate solution (1 mL) was introduced to neutralize the trifluoromethanesulfonate salts. The mixture was diluted with H_2O (5 mL) and extracted with dichloromethane (3 × 10 mL). The combined organic layers were washed with brine (10 mL), were dried over anhydrous sodium sulfate and were concentrated. The residue was purified by flash column chromatography (eluent: 15% EtOAc in hexanes; SiO_2: 11 × 2.0 cm) on silica gel to give pyrimidine derivative **6j** as a white solid (57 mg, 81%).

^{1}H NMR (500 MHz, $CDCl_3$, 20 °C) δ:	8.51–8.49 (m, 2H), 8.34 (s, 1H), 7.50–7.44 (m, 8H), 2.64 (s, 3H).
^{13}C NMR (125 MHz, $CDCl_3$, 20 °C) δ:	168.5, 162.4, 154.0, 137.7, 135.0, 131.3, 130.9, 129.2, 128.9, 128.7, 128.3, 128.3, 13.3.
FTIR (neat) cm^{-1}:	3057 (m), 2919 (m), 1558 (s), 1508 (s), 1416 (s), 1404 (s), 1355.
HRMS (ESI):	calc'd for $C_{17}H_{15}N_2S$ $[M+H]^+$: 279.0950, found: 279.0960.
TLC (15% EtOAc in hexanes), R_f:	0.60 (UV).

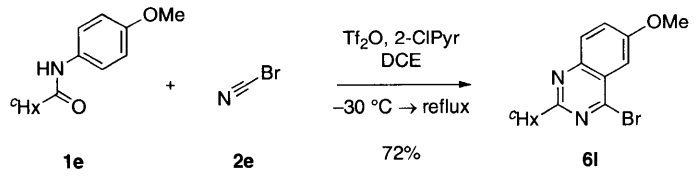


1d **2d** **6k**

2-Cyclohexyl-4,5-dimethyl-6-(methylthio)pyrimidine (6k, Table 1):

Trifluoromethanesulfonic anhydride (27 μL, 0.16 mmol, 1.1 equiv) was added via syringe over 1 min to a stirred mixture of amide **1d** (26 mg, 0.14 mmol, 1 equiv), nucleophile **2d** (21 μL, 0.29 mmol, 2.0 equiv) and 2-chloropyridine (17 μL, 0.17 mmol, 1.2 equiv) in dichloromethane (500 μL) at –78 °C. After 5 min, the reaction mixture was placed in an ice-water bath for 5 min and warmed to 0 °C. The resulting solution was allowed to warm to ambient temperature. After 1 h, saturated aqueous sodium bicarbonate solution (1 mL) was introduced to neutralize the trifluoromethanesulfonate salts. The mixture was diluted with H_2O (5 mL) and extracted with dichloromethane (3 × 10 mL). The combined organic layers were washed with brine (10 mL), were dried over anhydrous sodium sulfate and were concentrated. The residue was purified by flash column chromatography (eluent: 10% EtOAc in hexanes; SiO_2: 8 × 1.5 cm) on silica gel to give pyrimidine derivative **6k** as a white solid (21 mg, 62%).

^{1}H NMR (500 MHz, $CDCl_3$, 20 °C) δ:	2.70 (tt, 1H, *J* = 11.5, 3.5 Hz), 2.53 (s, 3H), 2.37 (s, 3H), 2.12 (s, 3H), 1.96–1.91 (m, 2H), 1.81–1.77 (m, 2H), 1.71–1.68 (m, 1H), 1.60 (qd, 2H, *J* = 12.5, 3.5 Hz), 1.37 (qt, 2H, *J* = 12.5, 3.5 Hz), 1.25 (qd, 1H, *J* = 12.5, 3.0 Hz),
^{13}C NMR (125 MHz, $CDCl_3$, 20 °C) δ:	170.3, 167.8, 161.6, 122.7, 47.4, 32.2, 26.5, 26.3, 22.2, 13.6, 13.0.
FTIR (neat) cm^{-1}:	2926 (s), 2853 (s), 1538 (s), 1447 (m), 1404 (m).
HRMS (ESI):	calc'd for $C_{13}H_{21}N_2S$ $[M+H]^+$: 237.1420, found: 237.1423.
TLC (15% EtOAc in hexanes), R_f:	0.40 (UV).

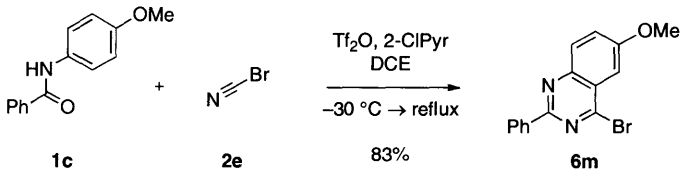


1e 2e 6l

4-Bromo-2-cyclohexyl-6-methoxyquinazoline (6l, Table 1):

Trifluoromethanesulfonic anhydride (79 μL, 0.47 mmol, 1.1 equiv) was added drop wise to a mixture of amide **1e** (100 mg, 0.429 mmol, 1 equiv) and 2-chloropyridine (49 μL, 0.52 mmol, 1.2 equiv) in 1,2-dichloroethane (0.75 mL) at –30 °C. After 5 min, the reaction mixture was allowed to warm to 0 °C, and after another 5 min, a solution of cyanic bromide **2e** (193 mg, 1.82 mmol, 4.24 equiv) in 1,2-dichloroethane (0.75 mL) was added via cannula. After 5 min the reaction mixture was heated to reflux. After 1 h, the reaction mixture was allowed to cool to ambient temperature, the volatiles were removed under reduced pressure, and the residue was purified by flash column chromatography (eluent: 8% EtOAc and 2% Et_3N in hexanes; SiO_2: 7.5 × 2.5 cm) on neutralized silica gel to afford the desired quinazoline derivative **6l** (100 mg, 72%) as a white solid.

^{1}H NMR (500 MHz, DMSO-d_6, 20 °C) δ:	7.84 (d, 1H, J = 9.0 Hz), 7.50 (dd, 1H, J = 9.5, 3.0 Hz), 7.34 (d, 1H, J = 3.0 Hz), 3.96 (s, 3H), 2.95 (tt, 1H, J = 12.0, 3.5 Hz), 2.06–2.03 (m, 2H), 1.88–1.84 (m, 2H), 1.75–1.66 (m, 3H), 1.46–1.30 (m, 3H).
^{13}C NMR (125 MHz, $CDCl_3$, 20 °C) δ:	130.9, 130.8, 128.8, 128.6, 128.0, 125.6, 105.5, 105.3, 56.1, 47.1, 32.0, 26.4, 26.1.
FTIR (neat) cm^{-1}:	2920 (s), 2848 (m), 1621 (m), 1567 (s), 1490 (m), 1218 (s), 830 (s).
HRMS (ESI):	calc'd for $C_{15}H_{18}BrN_2O$ $[M+H]^+$: 321.0597, found: 321.0599.
TLC (8% EtOAc in hexanes), R_f:	0.30 (UV)

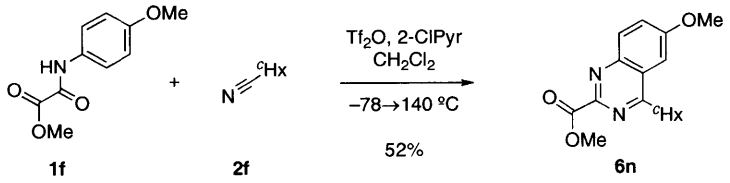


1c 2e 6m

4-Bromo-6-methoxy-2-phenylquinazoline (6m, Table 1):

Trifluoromethanesulfonic anhydride (450 μL, 2.67 mmol, 1.10 equiv) was added drop wise to a mixture of amide **1c** (552 mg, 2.43 mmol, 1 equiv) and 2-chloropyridine (275 μL, 2.91 mmol, 1.20 equiv) in 1,2-dichloroethane (4.0 mL) at –30 °C. After 5 min, the reaction mixture was allowed to warm to 0 °C, and after another 5 min, a solution of cyanic bromide **2e** (1.072 g, 10.12 mmol, 4.17 equiv) in 1,2-dichloroethane (4.1 mL) was added via cannula. After five minutes the reaction mixture was heated to reflux. After 1 h, the reaction mixture was allowed to cool to ambient temperature, the volatiles were removed under reduced pressure, and the residue was purified by flash column chromatography (eluent: 10% EtOAc and 1% Et_3N in hexanes; SiO_2: 18 × 3.0 cm) on neutralized silica gel to afford the desired quinazoline derivative **6m** (633 mg, 83%) as a white solid.

^{1}H NMR (500 MHz, DMSO-d_6, 20 °C) δ:	8.49 (app. dt, 2H, J = 7.5 Hz, 2.0 Hz), 7.92 (d, 1H, J = 9.0 Hz), 7.52 (dd, 1H, J = 9.0, 3.0 Hz), 7.49–7.44 (m, 3H), 7.36 (d, 1H, J = 2.5 Hz), 3.96 (s, 3H).
^{13}C NMR (125 MHz, DMSO-d_6, 20 °C) δ:	159.3, 158.4, 155.4, 147.5, 136.8, 130.9, 130.6, 128.8, 128.5, 127.8, 125.8, 105.3, 56.0.
FTIR (nujol) cm^{-1}:	2855 (s), 2828 (s), 1619 (m), 1553 (m), 1482 (s), 1391 (s).
HRMS (ESI):	calc'd for $C_{15}H_{12}BrN_2O$ $[M+H]^+$: 315.0128, found: 315.0136.
mp:	141-142 °C
TLC (10% EtOAc in hexanes), R_f:	0.30 (UV)

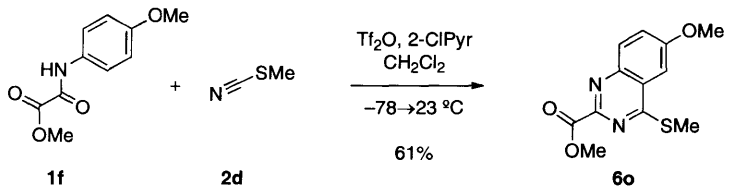


Methyl 4-cyclohexyl-6-methoxyquinazoline-2-carboxylate (6n, Table 1):

Trifluoromethanesulfonic anhydride (69 μL, 0.41 mmol, 1.1 equiv) was added via syringe over 1 min to a stirred mixture of oxamate **1f** (77 mg, 0.37 mmol, 1 equiv) and 2-chloropyridine (70 μL, 0.74 mmol, 2.0 equiv) in dichloromethane (1.3 mL) at –78 °C. After 5 min, the reaction mixture was placed in an ice-water bath and warmed to 0 °C. After 5 min, nitrile **2f** (175 μL, 1.47 mmol, 4.00 equiv) was added via syringe. After 5 min, the resulting solution was allowed to warm to ambient temperature for 5 min before the reaction vessel was placed into a microwave reactor and heated to 140 °C. After 20 min, the reaction vessel was removed from the microwave reactor and allowed to cool to ambient temperature. Aqueous saturated sodium bicarbonate solution (1.0 mL) was introduced to neutralize the trifluoromethanesulfonate salts and the reaction mixture was partitioned between dichloromethane (10 mL) and water (10 mL). The aqueous layer was extracted with dichloromethane (2 × 10 mL). The combined organic layers were washed with brine (10 mL), were dried over anhydrous sodium sulfate, and were filtered. The volatiles were removed under reduced pressure, and the residue was purified by flash column chromatography (eluent: 50% EtOAc and 2% Et_3N in hexanes; SiO_2: 17 × 2.5 cm) on neutralized silica gel to give the quinazoline derivative **6n** as a white solid (58 mg, 52%).

^{1}H NMR (500 MHz, $CDCl_3$, 20 °C) δ:	8.12 (d, 1H, J = 9.0 Hz), 7.55 (dd, 1H, J = 9.0, 3.0 Hz), 7.36 (d, 1H, J = 2.5 Hz), 4.05 (s, 3H), 3.98 (s, 3H), 3.47–3.41 (m, 1H), 1.97–1.86 (m, 6H), 1.80–1.78 (m, 1H), 1.54–1.37 (m, 3H).
^{13}C NMR (125 MHz, $CDCl_3$, 20 °C) δ:	174.4, 165.3, 159.9, 150.7, 146.1, 132.1, 126.5, 124.7, 102.1, 56.0, 53.6, 41.9, 31.7, 26.6, 26.0.
FTIR (neat) cm^{-1}:	3347 (m), 2927 (m), 1724 (s), 1699 (s), 1513 (s), 1253 (s), 1170 (s).
HRMS (ESI):	calc'd for $C_{17}H_{21}N_2O_3$ $[M+H]^+$: 301.1547, found: 301.1542.

TLC (50% EtOAc and 2% Et_3N in hexanes), R_f: 0.35 (UV, CAM).



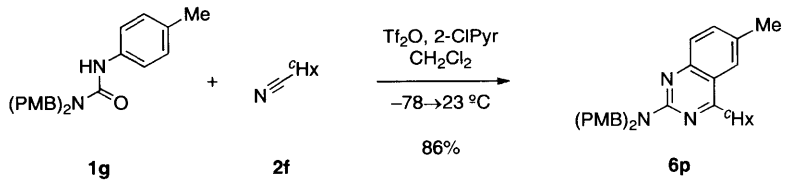
1f **2d** **6o**

Methyl 4-(methylthio)-6-methoxyquinazoline-2-carboxylate (6o, Table 1):

Trifluoromethanesulfonic anhydride (85 μL, 0.51 mmol, 1.1 equiv) was added via syringe over 1 min to a stirred mixture of oxamate **1f** (96 mg, 0.46 mmol, 1 equiv), 2-chloropyridine (52 μL, 0.55 mmol, 1.2 equiv) and nitrile (62 μL, 0.92 mmol, 2.0 equiv) in dichloromethane (1.5 mL) at –78 °C. After 5 min, the reaction mixture was placed in an ice-water bath and warmed to 0 °C. After 5 min, nitrile **2d** was added via syringe. After an additional 5 min, the resulting solution was allowed to warm to ambient temperature. After 1 h, aqueous saturated sodium bicarbonate solution (1.0 mL) was introduced to neutralize the trifluoromethanesulfonate salts and the reaction mixture was partitioned between dichloromethane (10 mL) and water (10 mL). The aqueous layer was extracted with dichloromethane (2 × 10 mL). The combined organic layers were washed with brine (10 mL), were dried over anhydrous sodium sulfate, and were filtered. The volatiles were removed under reduced pressure, and the residue was purified by flash column chromatography (eluent: 60% EtOAc and 1% Et_3N in hexanes; SiO_2: 18 × 2.0 cm) on neutralized silica gel to give the quinazoline derivative **6o** as a white solid (75 mg, 61%).

^{1}H NMR (500 MHz, $CDCl_3$, 20 °C) δ:	8.06 (d, 1H, J = 9.0 Hz), 7.53 (dd, 1H, J = 9.0, 3.0 Hz), 7.29 (d, 1H, J = 3.0 Hz), 4.06 (s, 3H), 3.97 (s, 3H), 2.81 (s, 3H).
^{13}C NMR (125 MHz, $CDCl_3$, 20 °C) δ:	171.1, 164.9, 160.0, 149.7, 143.4, 131.7, 127.0, 125.3, 101.8, 56.1, 53.6, 13.0.
FTIR (neat) cm^{-1}:	2917 (m), 2849 (w), 1732 (s), 1614 (m), 1495 (s), 1393 (s), 1219 (s).
HRMS (ESI):	calc'd for $C_{12}H_{12}N_2NaO_3S$ $[M+Na]^+$: 265.0641, found: 265.0650.

TLC (50% EtOAc and 1% Et_3N in hexanes), R_f: 0.25 (UV, CAM).

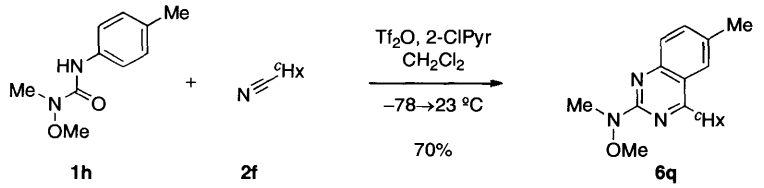


1g **2f** **6p**

4-Cyclohexyl-*N*,*N*-bis(4-methoxybenzyl)-6-methylquinazolin-2-amine (6p, Table 1):

Trifluoromethanesulfonic anhydride (24 μL, 0.14 mmol, 1.1 equiv) was added drop wise to a mixture of urea **1g** (49 mg, 0.13 mmol, 1 equiv), cyclohexanecarbonitrile **2f** (45 μL, 0.34 mmol, 3.0 equiv) and 2-chloropyridine (24 μL, 0.25 mmol, 1.2 equiv) in dichloromethane (0.50 mL) at –78 °C. After 5 min, the reaction mixture was allowed to warm to 0 °C, and after another 5 min, the reaction mixture was allowed to warm to ambient temperature. After 1 h, saturated aqueous sodium bicarbonate solution (1.0 mL) was added to the reaction mixture to quench excess trifluoromethanesulfonate salts, and the mixture was partitioned between water (10 mL) and dichloromethane (10 mL). The aqueous layer was extracted with dichloromethane (2 × 10 mL). The combined organic layers were washed with brine (10 mL), were dried over anhydrous sodium sulfate, and were filtered. The volatiles were removed under reduced pressure, and the residue was purified by flash column chromatography (eluent: 10% EtOAc and 1% Et_3N in hexanes; SiO_2: 15 × 2 cm) on neutralized silica gel to afford the desired quinazolinone derivative **6p** (52 mg, 86%) as a white solid.

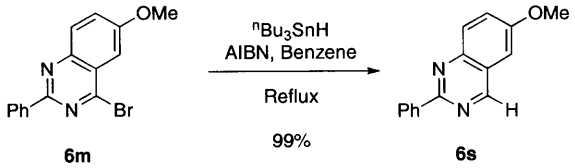
^{1}H NMR (500 MHz, $CDCl_3$, 20 °C) δ:	7.64 (d, 1H, J = 2.0 Hz), 7.48 (d, 1H, J = 8.5 Hz), 7.42 (dd, 1H, J = 8.5, 2.0 Hz), 7.22 (d, 4H, J = 8.5 Hz), 6.81 (d, 4H, J = 8.5 Hz), 4.86 (s, 4H), 3.77 (s, 6H), 3.36 (tt, 1H, J = 11.5, 3.5 Hz), 2.44 (s, 3H), 1.90–1.83 (m, 3H), 1.76–1.64 (m, 3H), 1.52–1.40 (m, 3H), 1.30–1.24 (m, 1H).
^{13}C NMR (125 MHz, $CDCl_3$, 20 °C) δ:	175.0, 159.0, 158.8, 151.5, 135.2, 131.6, 131.1, 129.6, 126.7, 123.4, 117.8, 113.9, 55.5, 48.0, 41.3, 32.1, 26.7, 26.4, 21.7
FTIR (neat) cm^{-1}:	2966 (s), 2934 (m), 1711 (s), 1638 (m), 1493 (m), 1454 (s), 1162 (m).
HRMS (ESI):	calc'd for $C_{31}H_{36}N_3O_2$ $[M+H]^+$: 482.2802, found: 482.2790.
TLC (10% EtOAc in hexanes), R_f:	0.30 (UV)



4-Cyclohexyl-*N*,*N*-bis(4-methoxybenzyl)-6-methylquinazolin-2-amine (6q, Table 1):

Trifluoromethanesulfonic anhydride (78 μL, 0.46 mmol, 1.1 equiv) was added via syringe over 1 min to a stirred mixture of urea **1h** (82 mg, 0.42 mmol, 1 equiv) and 2-chloropyridine (48 μL, 0.51 mmol, 1.2 equiv) in dichloromethane (1.4 mL) at –78 °C. After 5 min, the reaction mixture was placed in an ice-water bath and warmed to 0 °C. After 5 min nitrile **2f** (100 μL, 0.842 mmol, 2.00 equiv) was added via syringe. After 5 min, the resulting solution was allowed to warm to ambient temperature for 5 min before the reaction vessel was placed into a microwave reactor and heated to 140 °C. After 10 min, the reaction vessel was removed from the microwave reactor and allowed to cool to ambient temperature. Aqueous sodium hydroxide solution (1.0 mL, 1 N) was added to neutralize the trifluoromethanesulfonate salts and the reaction mixture was partitioned between dichloromethane (10 mL) and water (10 mL). The aqueous layer was extracted with dichloromethane (2 × 10 mL). The combined organic layers were washed with brine (10 mL), were dried over anhydrous sodium sulfate, and were filtered. The volatiles were removed under reduced pressure, and the residue was purified by flash column chromatography (eluent: 14% EtOAc and 1% Et_3N in hexanes; SiO_2: 15 × 2.5 cm) on neutralized silica gel to give the quinazoline derivative **6q** as a white solid (84 mg, 70%).

^{1}H NMR (500 MHz, $CDCl_3$, 20 °C) δ:	7.72–7.70 (m, 2H), 7.50 (dd, 1H, J = 8.5, 1.5 Hz), 3.90 (s, 3H), 3.45 (s, 3H), 3.39 (tt, 1H, J = 6.5, 3.0 Hz), 2.46 (s, 3H), 1.92–1.86 (m, 4H), 1.80–1.70 (m, 3H), 1.52–1.45 (m, 2H), 1.33 (tt, 1H, J = 13.0, 3.0 Hz).
^{13}C NMR (125 MHz, $CDCl_3$, 20 °C) δ:	175.6, 161.8, 150.5, 135.4, 133.4, 127.7, 123.3, 119.1, 61.7, 41.3, 38.7, 32.0, 26.6, 26.3, 21.8.
FTIR (neat) cm^{-1}:	2959 (m), 1753 (s), 1442 (m), 1265 (s), 955 (m), 845 (s).
HRMS (ESI):	calc'd for $C_{17}H_{24}N_3O$ $[M+H]^+$: 286.1914, found: 286.1914.
TLC (15% EtOAc in hexanes), R_f:	0.30 (UV, CAM).

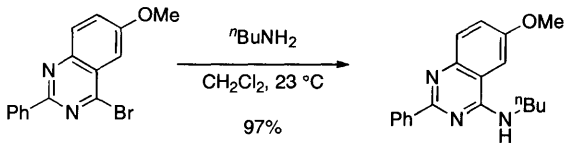


6-Methoxy-2-phenylquinazoline (6s, Scheme 2):

A degassed mixture of quinazoline **6m** (23 mg, 0.072 mmol, 1 equiv), tributyltin hydride (48 μL, 0.18, 2.5 equiv) and AIBN (1.8 mg, 0.011, 15 mol%) in anhydrous benzene (750 μL) was heated to reflux. After 2 h, the reaction mixture was allowed to cool to ambient temperature, the volatiles were removed under reduced pressure, and the residue was purified by flash column chromatography (eluent: 20% EtOAc and 1% Et_3N in hexanes; SiO_2: 13 × 1.5 cm) on neutralized silica gel to give quinazoline derivative **6s**[6] as a white solid (17 mg, 99%).

^{1}H NMR (500 MHz, $CDCl_3$, 20 °C) δ:	9.36 (s, 1H), 8.56–8.53 (m, 2H), 7.98 (d, 1H, J = 10 Hz), 7.55–7.45 (m, 4H), 7.15 (d, 1H, J = 3.0 Hz), 3.96 (s, 3H).
^{13}C NMR (125 MHz, $CDCl_3$, 20 °C) δ:	159.6, 159.0, 158.4, 147.2, 138.4, 130.4, 130.3, 128.8, 128.4, 127.4, 124.7, 104.1, 55.9.
FTIR (neat) cm^{-1}:	3387 (w), 2916 (w), 1640 (s), 1490 (m), 1225 (m), 1165 (m).
HRMS (ESI):	calc'd for $C_{15}H_{13}N_2O$ $[M+H]^+$: 237.1022, found: 237.1028.
TLC (20% EtOAc in hexanes), R_f:	0.47 (UV)

[6] For prior syntheses, see Tsizin, Y. S.; Karpova, N. B.; Efimova, O. V. *Khimiya Geterotsiklicheskikh Soedinenii* **1971**, 418 and Rossi, E.; Stradi, R. *Synthesis* **1989**, *3*, 214.

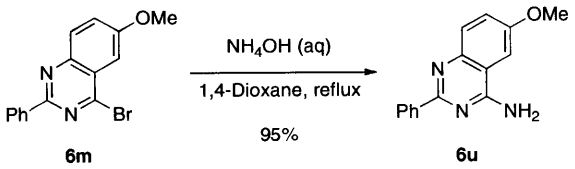


N-Butyl-6-methoxy-2-phenylquinazolin-4-amine (6t, Scheme 2):

^{n}Butylamine (180 μL, 1.8, 15 equiv) was added to a solution of quinazoline **6m** (39 mg, 0.12, 1 equiv) in CH_2Cl_2 at 23 °C. After 2h, the reaction mixture was diluted with CH_2Cl_2 (15 mL) and washed with water (10 mL). The aqueous layer was extracted with EtOAc (15 mL). Combined organic layers were washed with brine (10 mL), were dried over anhydrous sodium sulfate and were concentrated. The volatiles were removed under reduced pressure, and the residue was purified by flash column chromatography (eluent: 30% EtOAc and 1% Et_3N in hexanes; SiO_2: 6 × 1.5 cm) on neutralized silica gel to give quinazoline derivative **6t**[7] as a white solid (37 mg, 97%).

^{1}H NMR (500 MHz, $CDCl_3$, 20 °C) δ:	8.53–8.51 (m, 2H), 7.85 (d, 1H, J = 9.0 Hz), 7.48–7.40 (m, 3H), 7.37 (dd, 1H, J = 9.0, 3.0 Hz), 6.91 (d, 1H, J = 2.5 Hz), 5.45 (br s, 1H), 3.92 (s, 3H), 3.80 (app. q, 2H, J = 7.0 Hz), 3.78 (app. p, 2H, J = 7.0 Hz), 1.54–1.49 (m, 2H), 1.00 (t, 3H, J = 7.5 Hz).
^{13}C NMR (125 MHz, $CDCl_3$, 20 °C) δ:	159.1, 159.0, 157.3, 146.0, 139.3, 130.6, 129.6, 128.4, 128.3, 123.4, 114.2, 100.5, 55.9, 41.3, 31.8, 20.5, 14.1
FTIR (neat) cm^{-1}:	2958 (m), 1626 (s), 1574 (s), 1536 (s), 1368 (s), 1241 (s).
HRMS (ESI):	calc'd for $C_{19}H_{22}N_3O$ $[M+H]^+$: 308.1757, found: 308.1758.
TLC (30% EtOAc in hexanes), R_f:	0.30 (UV)

[7] For a prior synthesis, see Tsizin, Y. S.; Karpova, N. B.; Efimova, O. V. *Khimiya Geterotsiklicheskikh Soedinenii* **1971**, 418.



6m **6u**

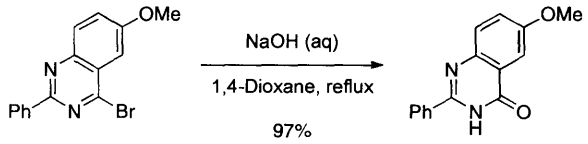
6-Methoxy-2-phenylquinazolin-4-amine (6u, Scheme 2):

A mixture of quinazoline **6m** (33 mg, 0.11 mmol, 1 equiv) and saturated ammonium hydroxide solution (3.0 mL) in 1,4-dioxane was heated to 100 °C in a sealed pressure vessel. After 9 h, the reaction vessel was allowed to cool to ambient temperature. The reaction mixture was diluted with water (25 mL) and extracted with EtOAc (2 × 25 mL). The combined organic layers were washed with brine (25 mL), were dried over anhydrous sodium sulfate and were concentrated. The volatiles were removed under reduced pressure, and the residue was purified by flash column chromatography (eluent: 65% EtOAc and 1% Et_3N in hexanes; SiO_2: 5.5 × 2.0 cm) on neutralized silica gel to give quinazoline derivative **6u**[8] as a white solid (25 mg, 95%).

^{1}H NMR (500 MHz, $CDCl_3$, 20 °C) δ:	8.45–8.44 (m, 2H), 7.88 (d, 1H, J = 9.0 Hz), 7.48–7.41 (m, 4H), 6.96 (d, 1H, J = 2.0 Hz), 5.55 (br s, 2H), 3.93 (s, 3H).
^{13}C NMR (125 MHz, $CDCl_3$, 20 °C) δ:	160.9, 159.2, 157.5, 146.8, 138.8, 130.6, 130.0, 128.6, 128.3, 124.8, 113.6, 100.9, 55.9.
FTIR (neat) cm^{-1}:	3335 (m), 3185 (w), 1636 (s), 1548 (s), 1509 (s), 1237 (s).
HRMS (ESI):	calc'd for $C_{15}H_{14}N_3O$ $[M+H]^+$: 252.1131, found: 252.1129.

TLC (65% EtOAc and 1% Et_3N in hexanes), R_f: 0.42 (UV).

[8] For a prior synthesis, see Zielinski, W.; Kudelko, A. *Monatshefte für Chem.* **2000**, *131*, 895.



6m **6v**

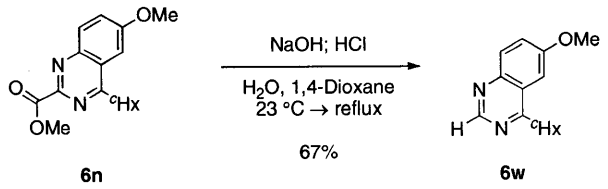
6-Methoxy-2-phenylquinazolin-4(3*H*)-one (6v, Scheme 2):

A mixture of quinazoline **6m** (52 mg, 0.16 mmol, 1 equiv) and aqueous sodium hydroxide solution (2.0 mL, 1.25 N) in 1,4-dioxane (1.6 mL) was heated to reflux. After 2.5 h, the reaction mixture was allowed to cool to ambient temperature, diluted with water (5.0 mL) and extracted with EtOAc (25 mL). Aqueous HCl solution (1.5 mL, 1 N) was added to the aqueous layer to quench excess base, and the aqueous layer was extracted with EtOAc (30 mL). Combined organic layers were dried over anhydrous sodium sulfate, were filtered and were concentrated. The volatiles were removed under reduced pressure, and the residue was purified by flash column chromatography (eluent: 3% MeOH and 1% AcOH in CH_2Cl_2; SiO_2: 8 × 1.5 cm) on silica gel to afford the desired quinazolinone derivative **6v**[9] (40 mg, 97%) as a white solid.

^{1}H NMR (500 MHz, DMSO-d_6, 20 °C) δ:	12.33 (br s, 1H), 8.14 (dd, 2H, J = 8.0, 1.5 Hz), 7.66 (d, 1H, J = 9.0 Hz), 7.53–7.48 (m, 4H), 7.40 (dd, 1H, J = 9.0, 3.0 Hz), 3.86 (s, 3H).
^{13}C NMR (125 MHz, DMSO-d_6, 20 °C) δ:	162.4, 157.6, 150.5, 143.3, 133.1, 131.0, 129.1, 128.6, 127.5, 124.0, 121.8, 105.8, 55.6.
FTIR (neat) cm^{-1}:	2928 (w), 1669 (s), 1607 (m), 1484 (w), 1289 (w), 1147 (m), 847 (s), 685 (s).
HRMS (ESI):	calc'd for $C_{15}H_{13}N_2O_2$ $[M+H]^+$: 253.0972, found: 253.0962.

TLC (3% MeOH and 1% AcOH in CH_2Cl_2), R_f: 0.29 (UV)

[9] For prior syntheses, see Tsizin, Y. S.; Karpova, N. B.; Efimova, O. V. *Khimiya Geterotsiklicheskikh Soedinenii* **1971**, 418 and Zhou, J.; Fu, L.; Lv, M.; Liu, J.; Pei, D.; Ding, K. *Synthesis* **2008**, 3974.



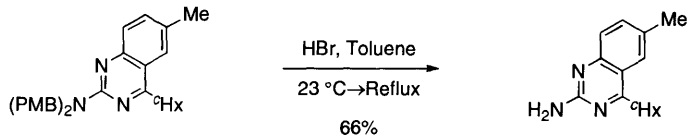
6n **6w**

4-cyclohexyl-6-methoxyquinazoline (6w, equation 2):

Aqueous sodium hydroxide solution (2.0 mL, 1.25 N) was added to a solution of quinazoline **6n** (23 mg, 0.075 mmol, 1 equiv) in 1,4-dioxane (500 μL). After 1 h, concentrated hydrochloric acid was added to the reaction mixture until the pH dropped to 1, and the reaction mixture was heated to reflux. After 16 hours, the reaction mixture was allowed to cool to ambient temperature and was extracted with ethyl acetate (3 × 10 mL). Aqueous sodium hydroxide (1 N) was added to the aqueous layer until the pH increased to 7 and the aqueous layer was extracted with ethyl acetate (3 × 10 mL). The pH of the aqueous layer was adjusted to 14 by addition of aqueous sodium hydroxide solution (1 N), and the aqueous layer was extracted again with ethyl acetate (3 × 10 mL). The combined organic layers were dried over anhydrous sodium sulfate and were filtered. The volatiles were removed under reduced pressure, and the residue was purified by flash column chromatography (eluent: 20% EtOAc and 2% Et_3N in hexanes; SiO_2: 10 × 2 cm) on neutralized silica gel to afford the desired quinazoline derivative **6w** (12 mg, 67%) as a white solid.

^{1}H NMR (500 MHz, $CDCl_3$, 20 °C) δ:	9.12 (s, 1H), 7.93 (d, 1H, J = 9.0 Hz), 7.51 (dd, 1H, J = 9.0, 3.0 Hz), 7.33 (d, 1H, J = 3.0 Hz), 3.96 (s, 3H), 3.42 (tt, 1H, J = 11.5, 3.5 Hz), 1.96–1.92 (m, 4H), 1.84–1.77 (m, 3H), 1.53–1.47 (m, 2H), 1.49–1.36 (m, 1H).
^{13}C NMR (125 MHz, $CDCl_3$, 20 °C) δ:	173.3, 158.3, 153.1, 146.4, 131.0, 125.8, 124.2, 102.1, 55.9, 41.5, 32.0, 26.7, 26.2.
FTIR (neat) cm^{-1}:	2928 (m), 2851 (w), 1620 (w), 1552 (m), 1501 (s), 1226 (s), 1026 (m).
HRMS (ESI):	calc'd for $C_{15}H_{19}N_2O$ $[M+H]^+$: 243.1492, found: 243.1499.

TLC (20% EtOAc and 2% Et_3N in hexanes), R_f: 0.21 (UV, CAM).



6p **6x**

4-Cyclohexyl-6-methylquinazolin-2-amine (6x, equation 3):

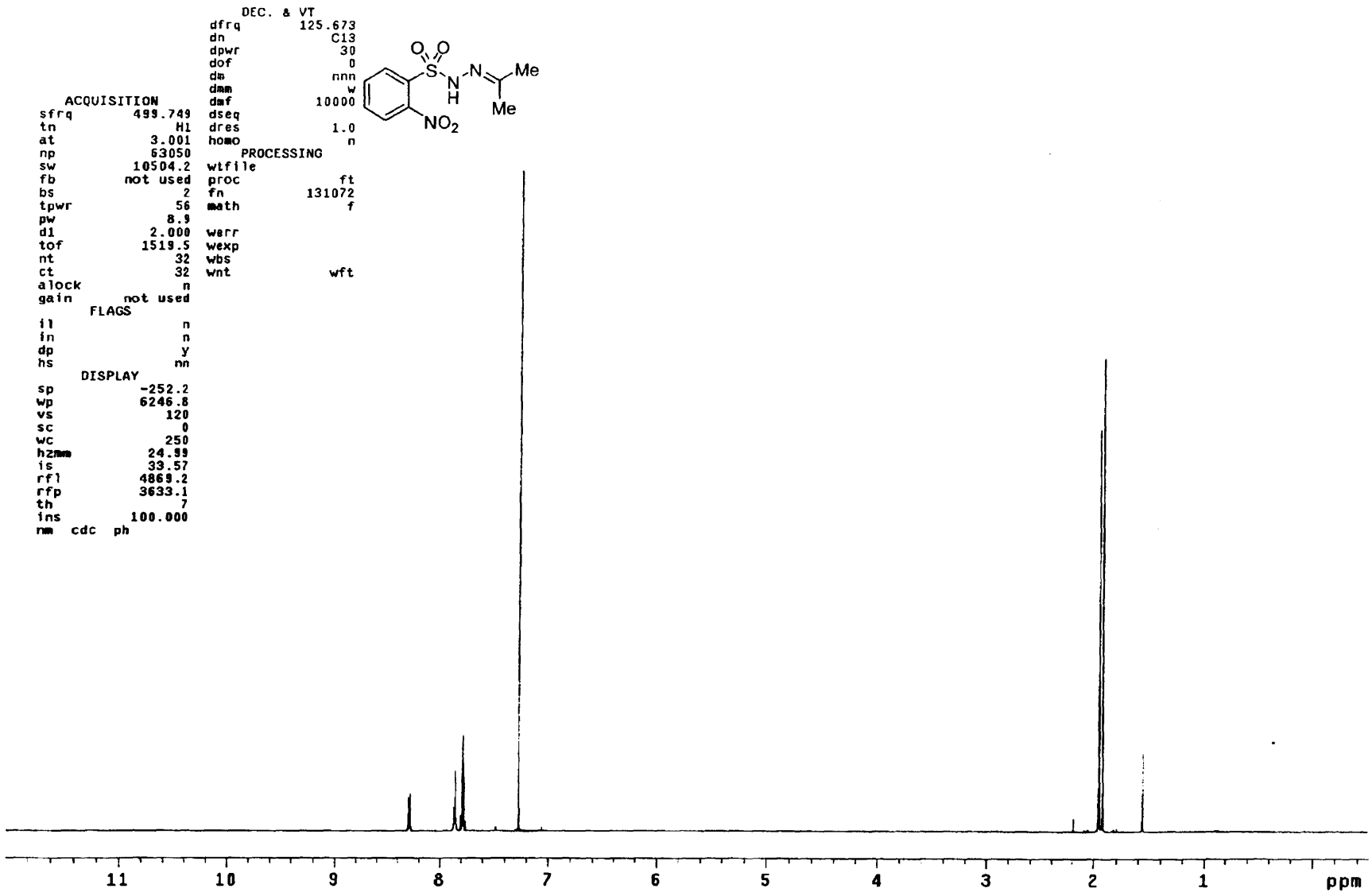
A solution of HBr in acetic acid (500 μL, 5.7 M) was added to a solution of quinazoline **6p** (54 mg, 0.11, 1 equiv) in toluene at 23 °C. The resulting bright yellow solution was heated to reflux. After 8 h, the reaction mixture was allowed to cool to ambient temperature and aqueous sodium hydroxide solution (3 mL, 1 N) was added to quench excess acid. The reaction mixture was diluted with water (10 mL), and extracted first with dichloromethane (2 × 10 mL), then with EtOAc (2 × 10 mL). Combined organic layers were washed with brine (10 mL), were dried over anhydrous sodium sulfate and were filtered. The volatiles were removed under reduced pressure, and the residue was purified by flash column chromatography (eluent: 40% EtOAc and 1% Et_3N in hexanes; SiO_2: 10 × 1.5 cm) on neutralized silica gel to give quinazoline derivative **6x** as a white solid (18 mg, 66%).

^{1}H NMR (500 MHz, $CDCl_3$, 20 °C) δ:	7.68 (d, 1H, J = 1.0 Hz), 7.47–7.46 (m, 2H), 5.01 (br s, 2H), 3.37 (tt, 1H, J = 11.5, 3.0 Hz), 2.45 (s, 3H), 1.91–1.86 (m, 4H), 1.80–1.66 (m, 3H), 1.52–1.44 (m, 2H), 1.3 (app. qt, 1H, J = 13.0, 3.0 Hz).
^{13}C NMR (125 MHz, $CDCl_3$, 20 °C) δ:	176.6, 159.5, 150.6, 135.7, 132.5, 126.2, 123.6, 118.6, 41.1, 32.0, 26.7, 26.3, 21.8.
FTIR (neat) cm^{-1}:	3326 (s), 3201 (s), 2929 (s), 2853 (m), 1621 (s), 1563 (s), 1445 (s).
HRMS (ESI):	calc'd for $C_{15}H_{20}N_3$ $[M+H]^+$: 242.1652, found: 242.1652.

TLC (40% EtOAc and 1% Et_3N in hexanes), R_f: 0.30 (UV, CAM)

Appendix A

Spectra for Chapter I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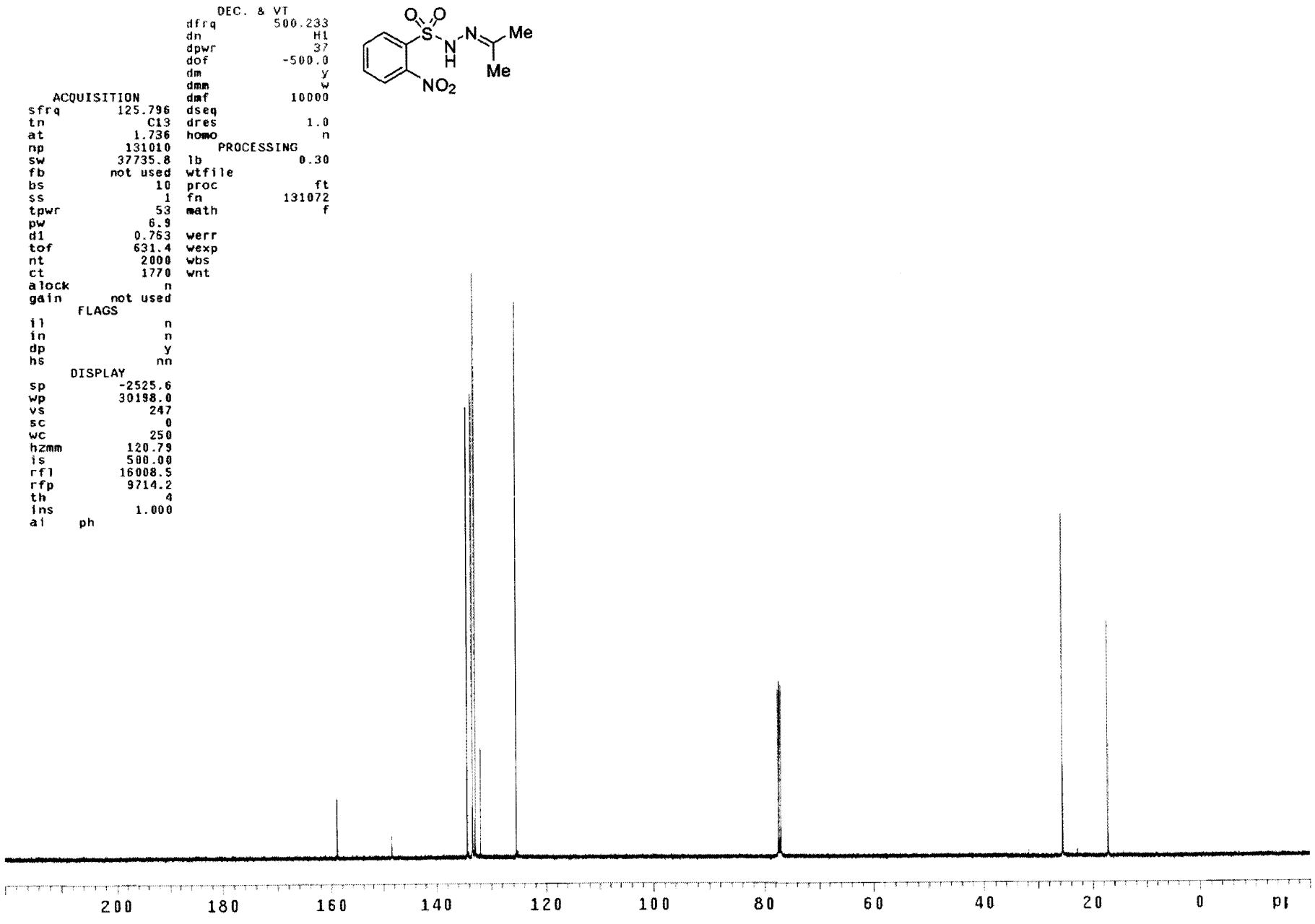
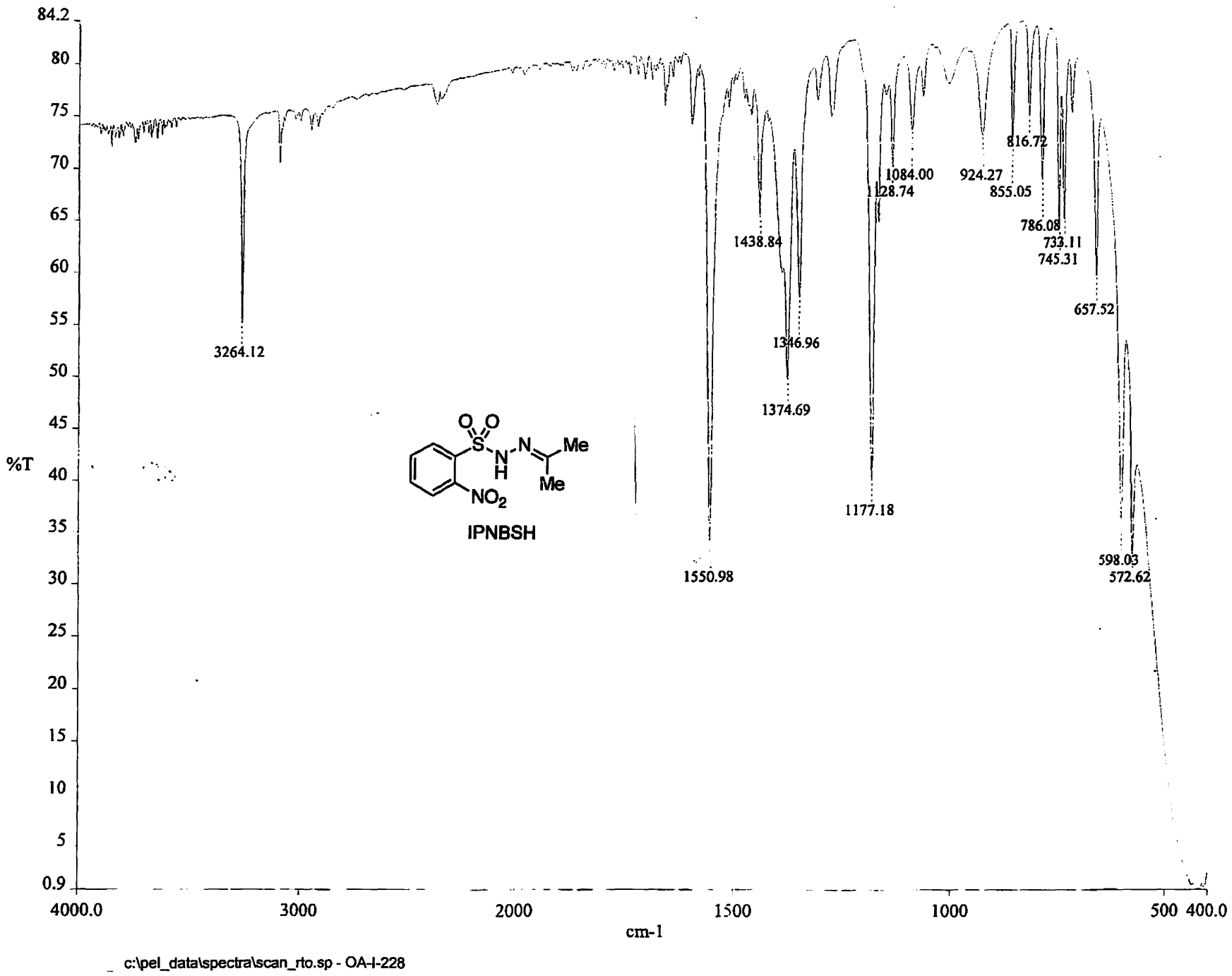
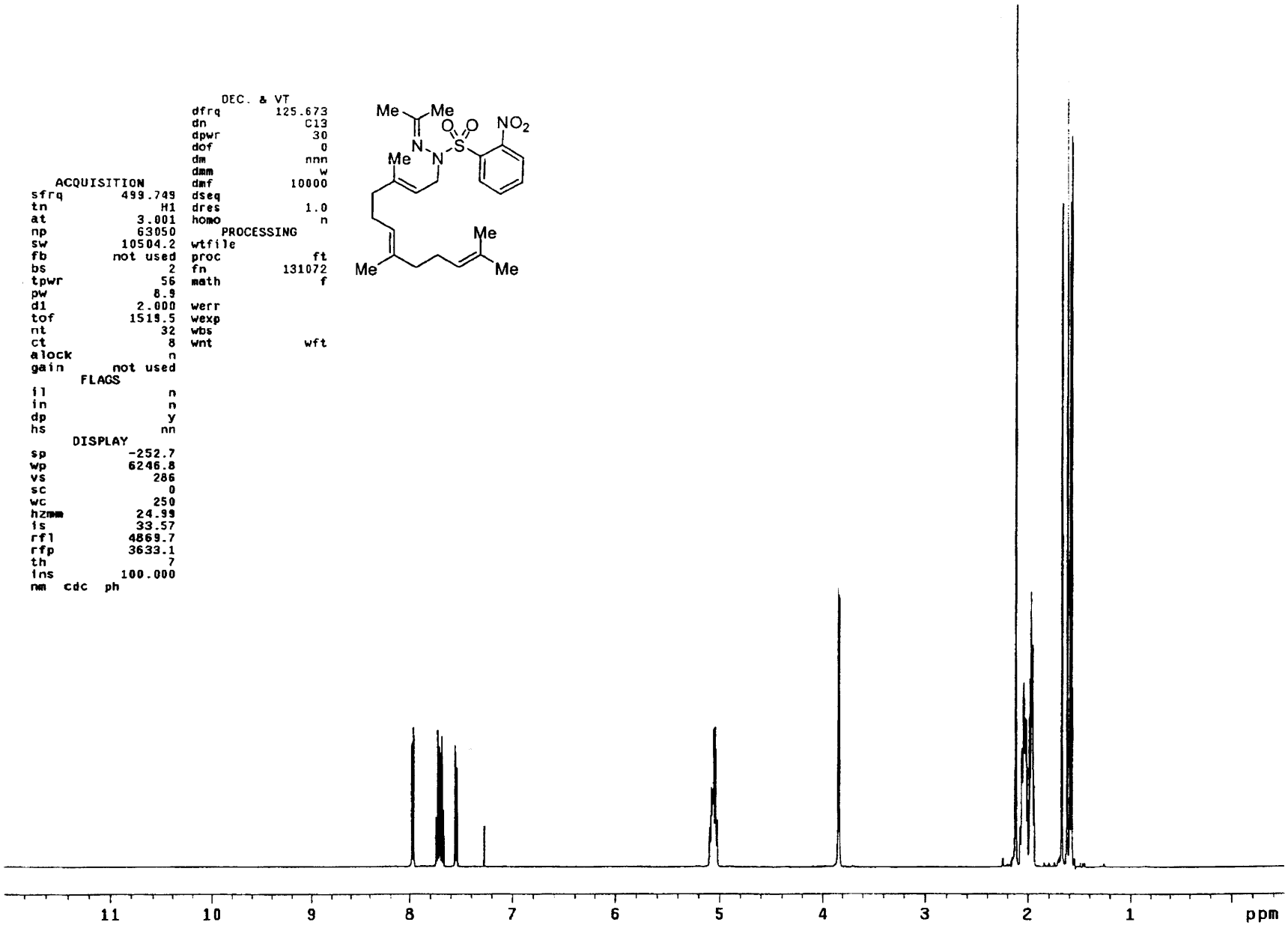
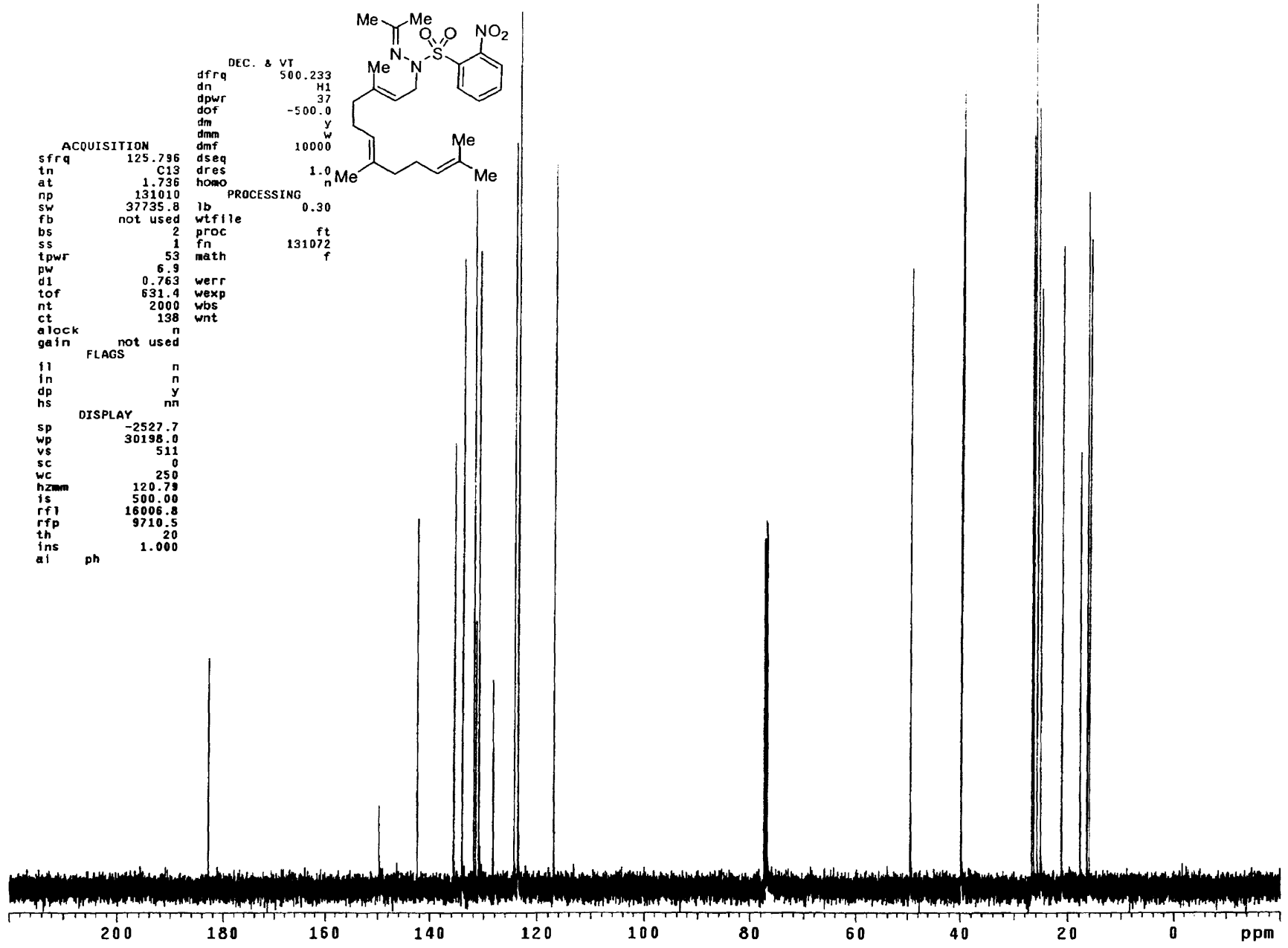
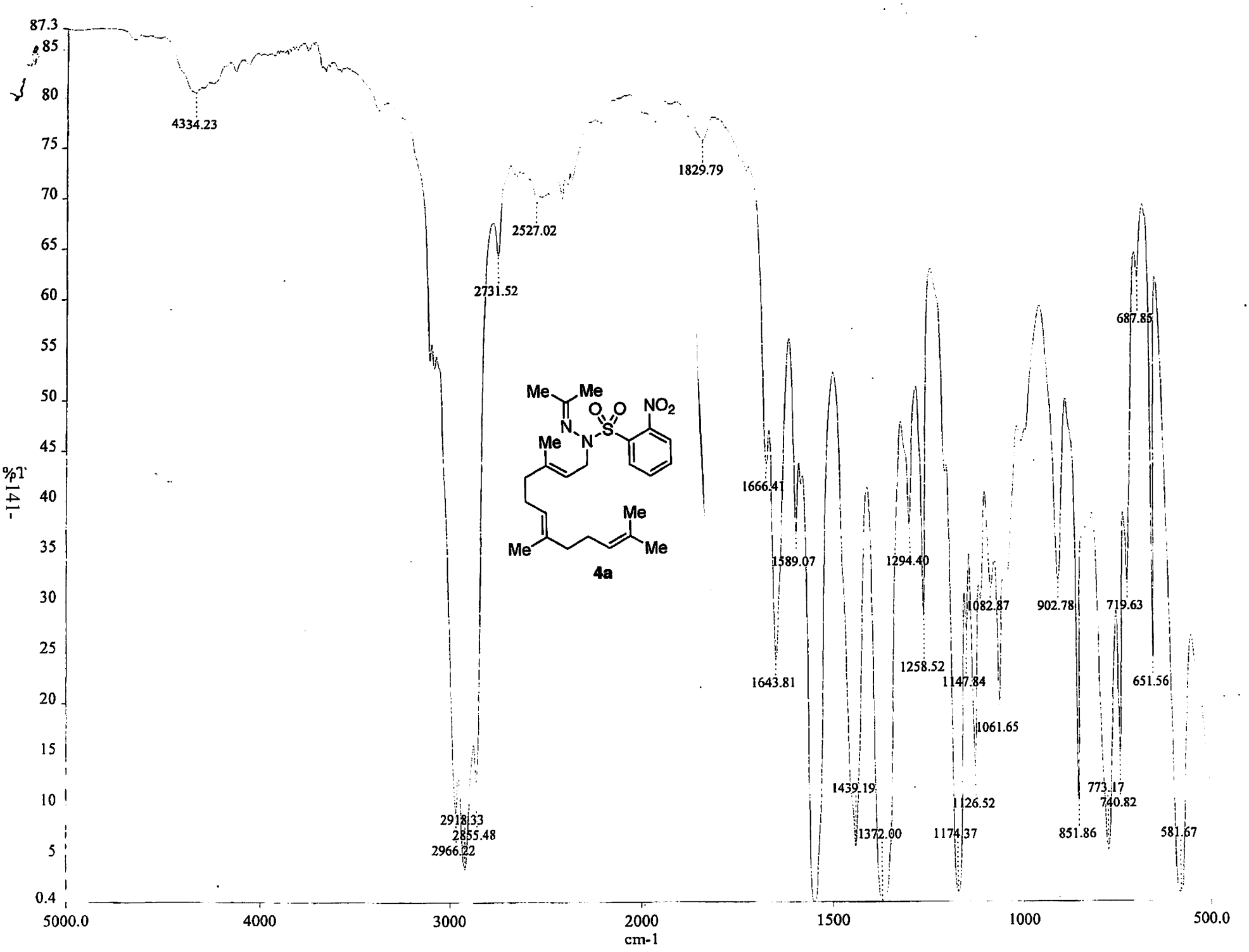
dmf 10000
dseq
dres 1.0
homo n
PROCESSING
wtfile
proc ft
fn 131072
math f
werr
wexp
wbs
wnt wft
O
O
S
N
H
N
Me
Me
NO2
11
10
9
8
7
6
5
4
3
2
1
ppm


ACQUISITION
sfrq 125.796
tn C13
at 1.736
np 131010
sw 37735.8
fb not used
bs 10
ss 1
tpwr 53
pw 6.9
d1 0.763
tof 631.4
nt 2000
ct 1770
alock n
gain not used
FLAGS
il n
in n
dp y
hs nn
DISPLAY
sp -2525.6
wp 30198.0
vs 247
sc 0
wc 250
hzmm 120.79
is 500.00
rfl 16008.5
rfp 9714.2
th 4
ins 1.000
ai ph
DEC. & VT
dfrq 500.233
dn H1
dpwr 37
dof -500.0
dm y
dmm w
dmf 10000
dseq
dres 1.0
homo n
PROCESSING
lb 0.30
wtfile
proc ft
fn 131072
math f
werr
wexp
wbs
wnt
O
O
S
N
H
N
Me
Me
NO2
200
180
160
140
120
100
80
60
40
20
0
pp


84.2
80
75
70
65
60
55
50
45
40
35
30
25
20
15
10
5
0.9
%T
3264.12
1550.98
1438.84
1374.69
1346.96
1177.18
1128.74
1084.00
924.27
855.05
816.72
786.08
745.31
733.11
657.52
598.03
572.62
O
O
S
N
H
N
Me
Me
NO2
IPNBSH
4000.0
3000
2000
1500
1000
500
400.0
cm-1
c:\pel_data\spectra\scan_rto.sp - OA-I-228


ACQUISITION
sfrq 499.749
tn H1
at 3.001
np 63050
sw 10504.2
fb not used
bs 2
tpwr 56
pw 8.9
d1 2.000
tof 1519.5
nt 32
ct 8
alock n
gain not used
FLAGS
il n
in n
dp y
hs nn
DISPLAY
sp -252.7
wp 6246.8
vs 286
sc 0
wc 250
hzmm 24.99
is 33.57
rfl 4869.7
rfp 3633.1
th 7
ins 100.000
nm cdc ph
DEC. & VT
dfrq 125.673
dn C13
dpwr 30
dof 0
dm nnn
dmm w
dmf 10000
dseq
dres 1.0
homo n
PROCESSING
wtfile
proc ft
fn 131072
math f
werr
wexp
wbs
wnt wft
Me
Me
O
O
NO2
N
N
S
Me
Me
Me
Me
11
10
9
8
7
6
5
4
3
2
1
ppm

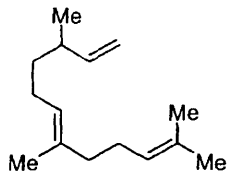

ACQUISITION
sfrq 125.796
tn C13
at 1.736
np 131010
sw 37735.8
fb not used
bs 2
ss 1
tpwr 53
pw 6.9
d1 0.763
tof 631.4
nt 2000
ct 138
alock n
gain not used
FLAGS
fl n
in n
dp y
hs nn
DISPLAY
sp -2527.7
wp 30198.0
vs 511
sc 0
wc 250
hzmm 120.78
is 500.00
rfl 16006.8
rfp 9710.5
th 20
ins 1.000
ai ph
DEC. & VT
dfrq 500.233
dn H1
dpwr 37
dof -500.0
dm y
dmm w
dmf 10000
dseq
dres 1.0
homo n
PROCESSING
lb 0.30
wtfile
proc ft
fn 131072
math f
werr
wexp
wbs
wnt
Me
Me
O
O
NO2
Me
N
N
S
Me
Me
Me
200
180
160
140
120
100
80
60
40
20
0
ppm

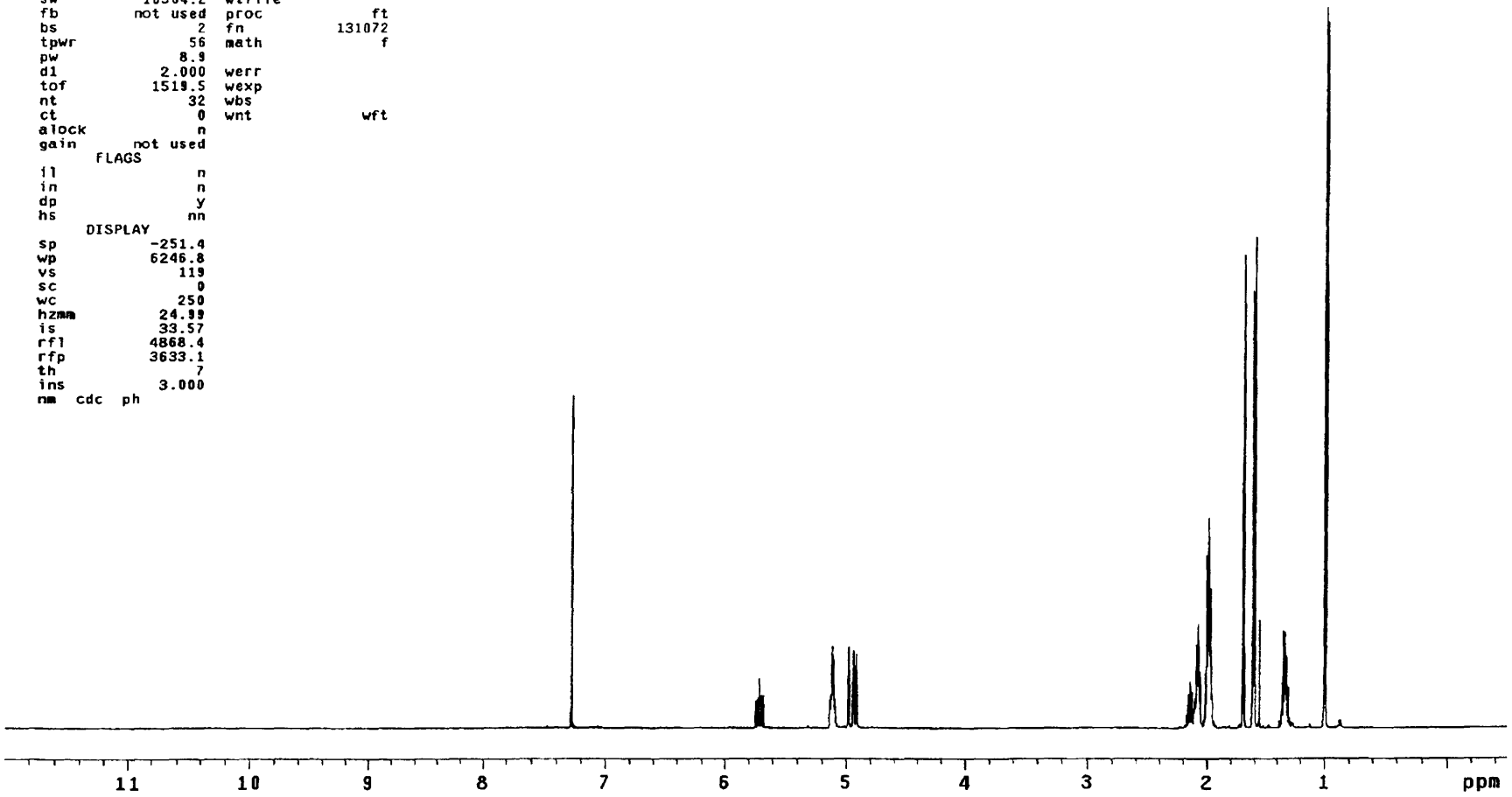

87.3
85
80
75
70
65
60
55
50
45
40
35
30
25
20
15
10
5
0.4
%T
4334.23
2731.52
2527.02
1829.79
1666.41
1589.07
1643.81
1294.40
1258.52
1147.84
1082.87
1061.65
902.78
719.63
687.85
651.56
1439.19
1372.00
1174.37
1126.52
773.17
740.82
851.86
581.67
2918.33
2855.48
2966.22
Me
Me
Me
N
N
O
O
S
NO2
Me
Me
Me
4a
5000.0
4000
3000
2000
1500
1000
500.0
cm-1

c

ACQUISITION	
sfrq	499.749
tn	H1
at	3.001
np	63050
sw	10504.2
fb	not used
bs	2
tpwr	56
pw	8.9
d1	2.000
tof	1519.5
nt	32
ct	0
alock	n
gain	not used
FLAGS	
il	n
in	n
dp	y
hs	nn
DISPLAY	
sp	-251.4
wp	6246.8
vs	119
sc	0
wc	250
hzmm	24.99
is	33.57
rfl	4868.4
rfp	3633.1
th	7
ins	3.000
nm	cdc ph

DEC. & VT	
dfrq	125.673
dn	C13
dpwr	30
dof	0
dm	nnn
dmm	w
dmf	10000
dseq	
dres	1.0
homo	n
PROCESSING	
wtfile	
proc	ft
fn	131072
math	f
werr	
wexp	
wbs	
wnt	wft

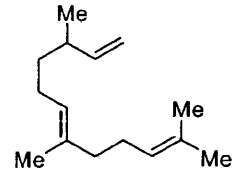


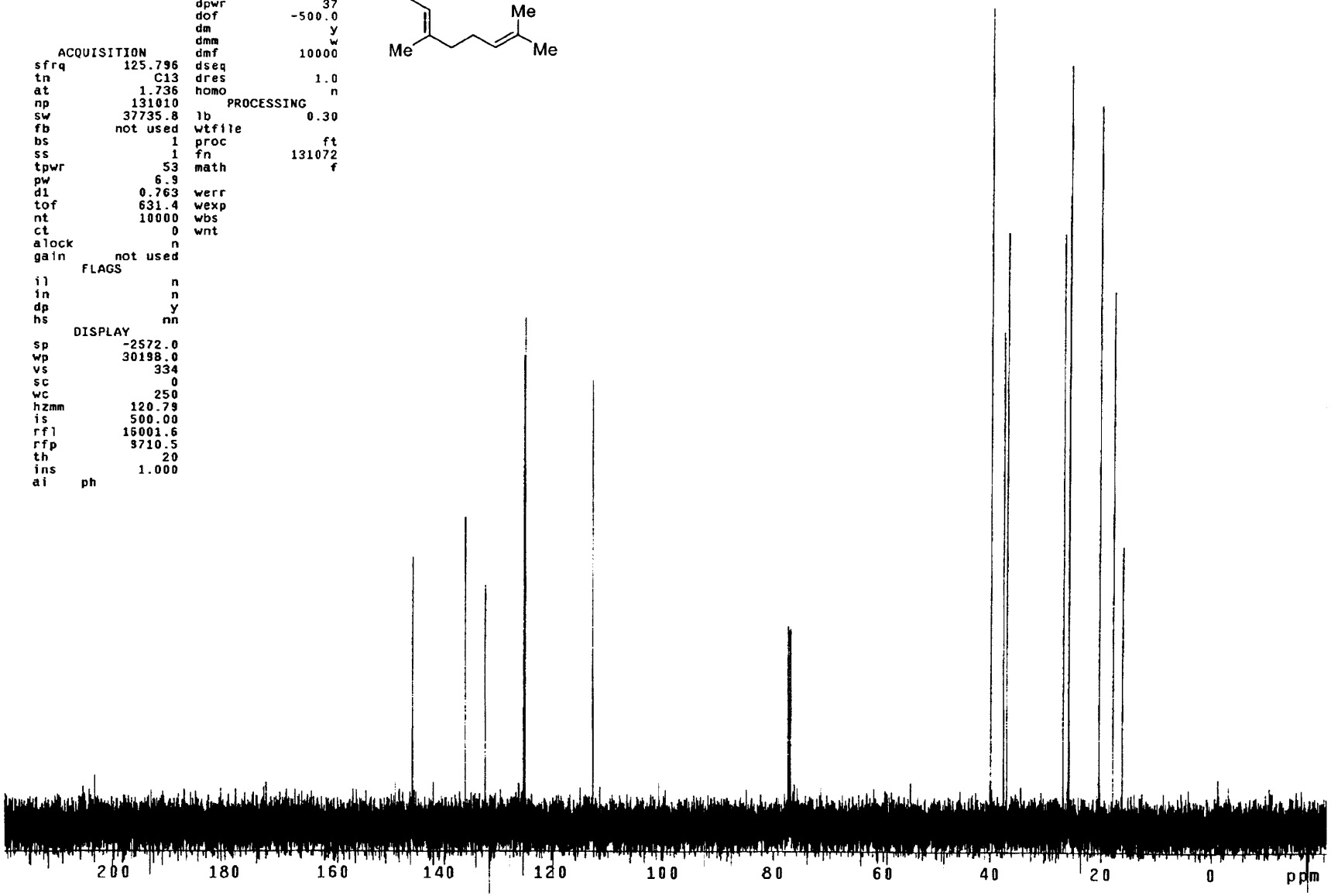


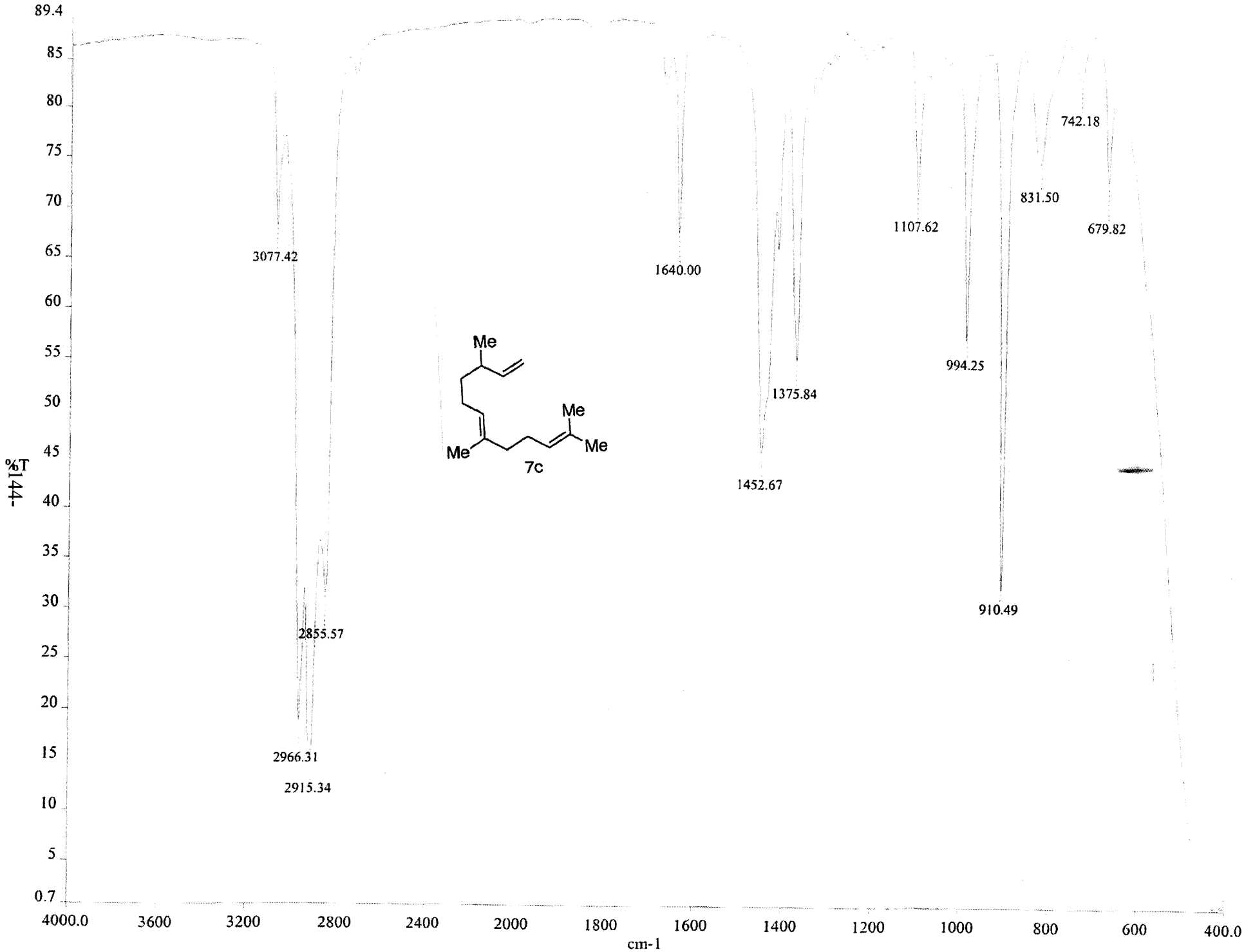
STANDARD CARBON PARAMETERS

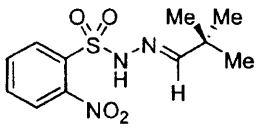
expl s2pul

ACQUISITION		DEC. & VT	
sfrq	125.796	dfrq	500.233
tn	C13	dn	H1
at	1.736	dpwr	37
np	131010	dof	-500.0
sw	37735.8	dm	y
fb	not used	dmm	w
bs	1	dmf	10000
ss	1	dseq	
tpwr	53	dres	1.0
pw	6.9	homo	n
d1	0.763	PROCESSING	
tof	631.4	lb	0.30
nt	10000	wtfile	
ct	0	proc	ft
alock	n	fn	131072
gain	not used	math	f
FLAGS		werr	
il	n	wexp	
in	n	wbs	
dp	y	wnt	
hs	nn		
DISPLAY			
sp	-2572.0		
wp	30198.0		
vs	334		
sc	0		
wc	250		
hzmm	120.79		
is	500.00		
rfl	16001.6		
rfp	9710.5		
th	20		
ins	1.000		
ai	ph		






89.4
85
80
75
70
65
60
55
50
45
40
35
30
25
20
15
10
5
0.7
%T
144-
3077.42
2966.31
2915.34
2855.57
1640.00
1452.67
1375.84
1107.62
994.25
910.49
831.50
742.18
679.82
Me
Me
Me
Me
7c
4000.0
3600
3200
2800
2400
2000
1800
1600
1400
1200
1000
800
600
400.0
cm-1



F2 - Acquisition Parameters

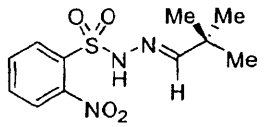
INSTRUM	spect	
PROBHD	5 mm QNP 1H/1	
PULPROG	zg30	
TD	65536	
SOLVENT	CDCl3	
NS	3	
DS	2	
SWH	8278.146	Hz
FIDRES	0.126314	Hz
AQ	3.9584243	sec
RG	287.4	
DW	60.400	usec
DE	6.00	usec
TE	293.7	K
D1	1.00000000	sec
MCREST	0.00000000	sec
MCWRK	0.01500000	sec
======== CHANNEL f1 ========		
NUC1	1H	
P1	9.88	usec
PL1	3.00	dB
SFO1	400.1324710	MHz

F2 - Processing parameters

SI	32768	
SF	400.1300059	MHz
WDW	EM	
SSB	0	
LB	0.30	Hz
GB	0	
PC	1.00	

STANDARD CARBON PARAMETERS

expl s2pul



ACQUISITION	
sfrq	125.673
tn	C13
at	2.001
np	125638
sw	31397.2
fb	not used
bs	2
tpwr	58
pw	6.7
d1	3.000
tof	0
nt	10000
ct	106
alock	n
gain	not used

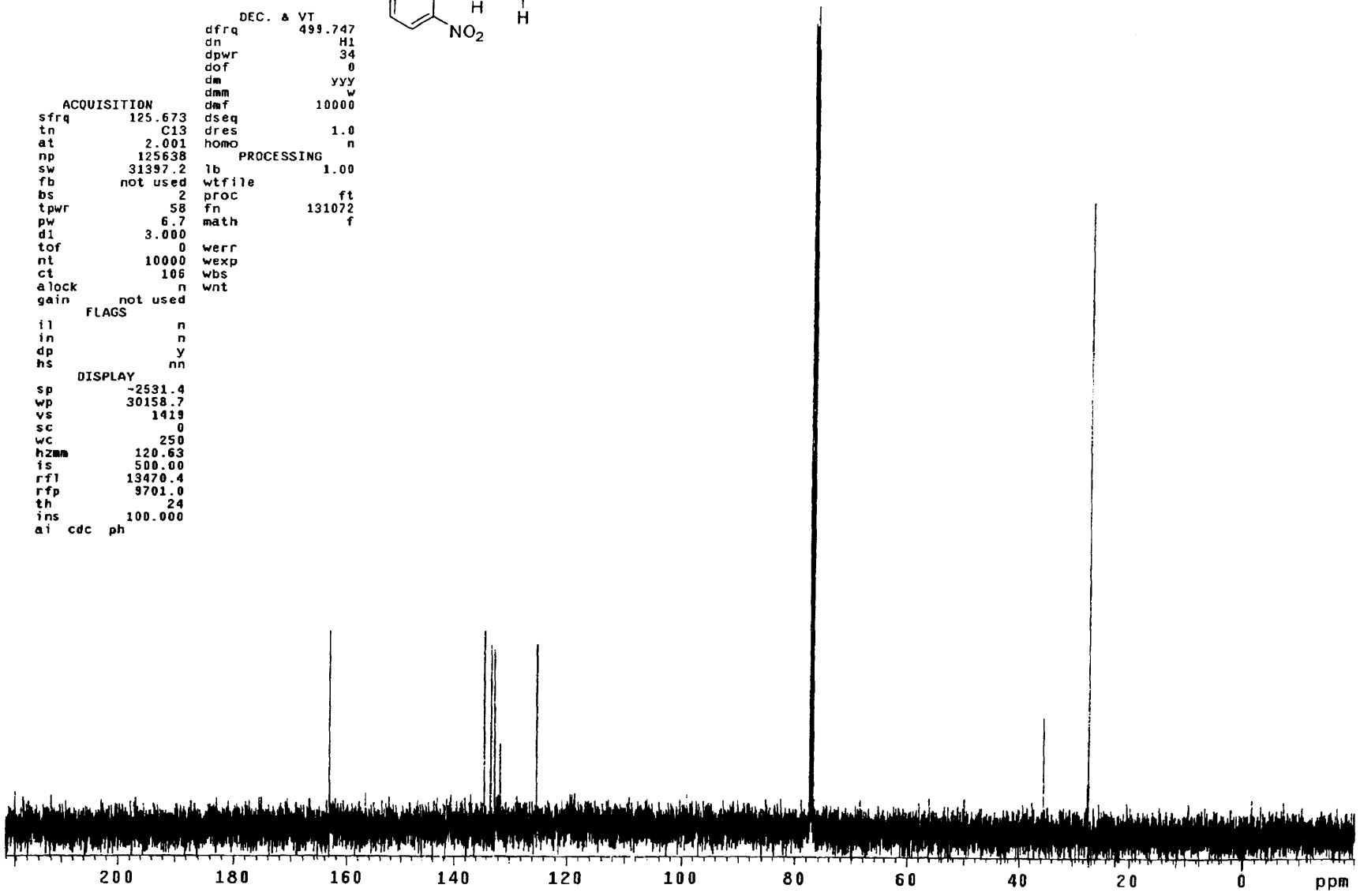
FLAGS	
il	n
in	n
dp	y
hs	nn

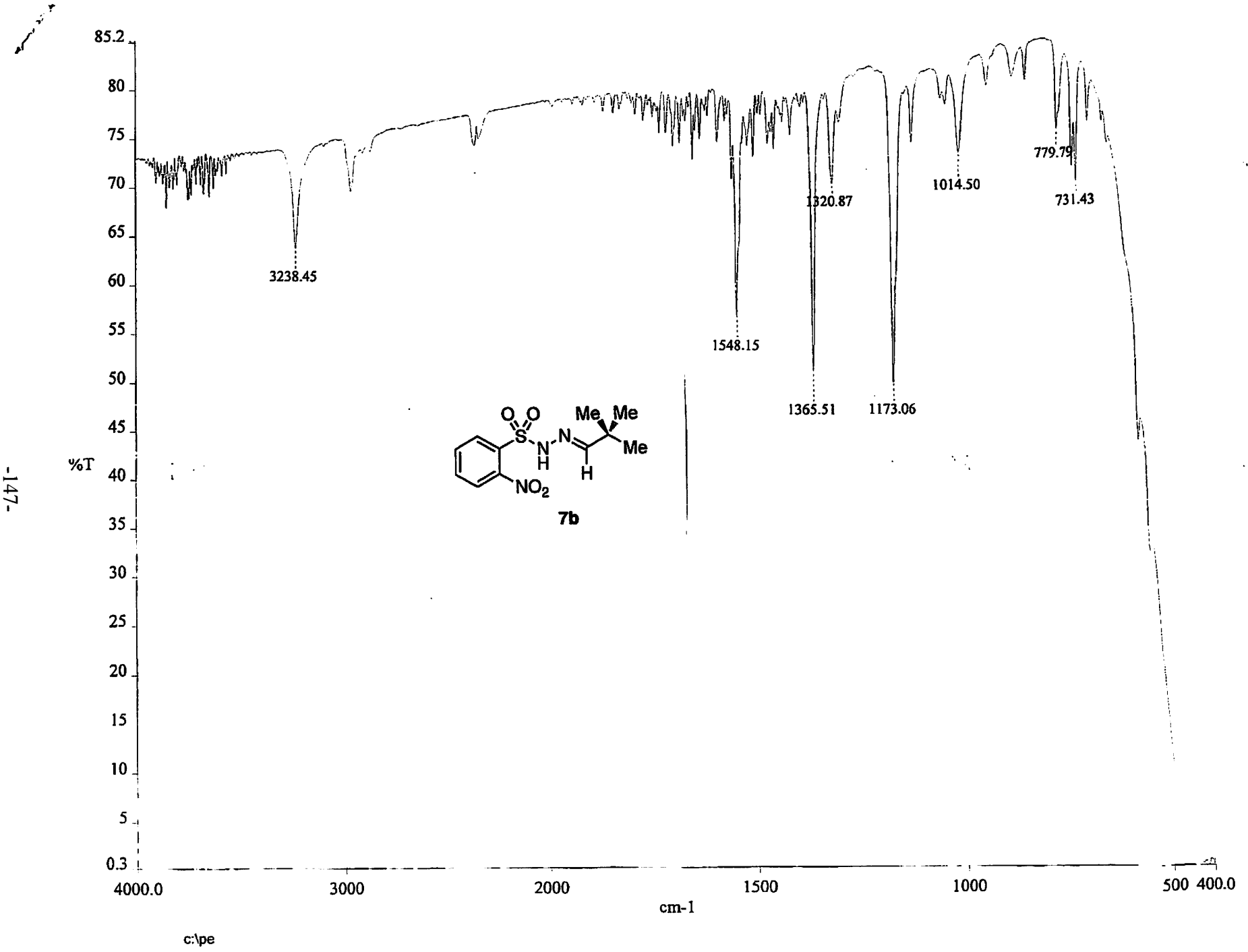
DISPLAY	
sp	-2531.4
wp	30158.7
vs	1419
sc	0
wc	250
hzmm	120.63
is	500.00
rfl	13470.4
rfp	9701.0
th	24
ins	100.000

ai cdc ph

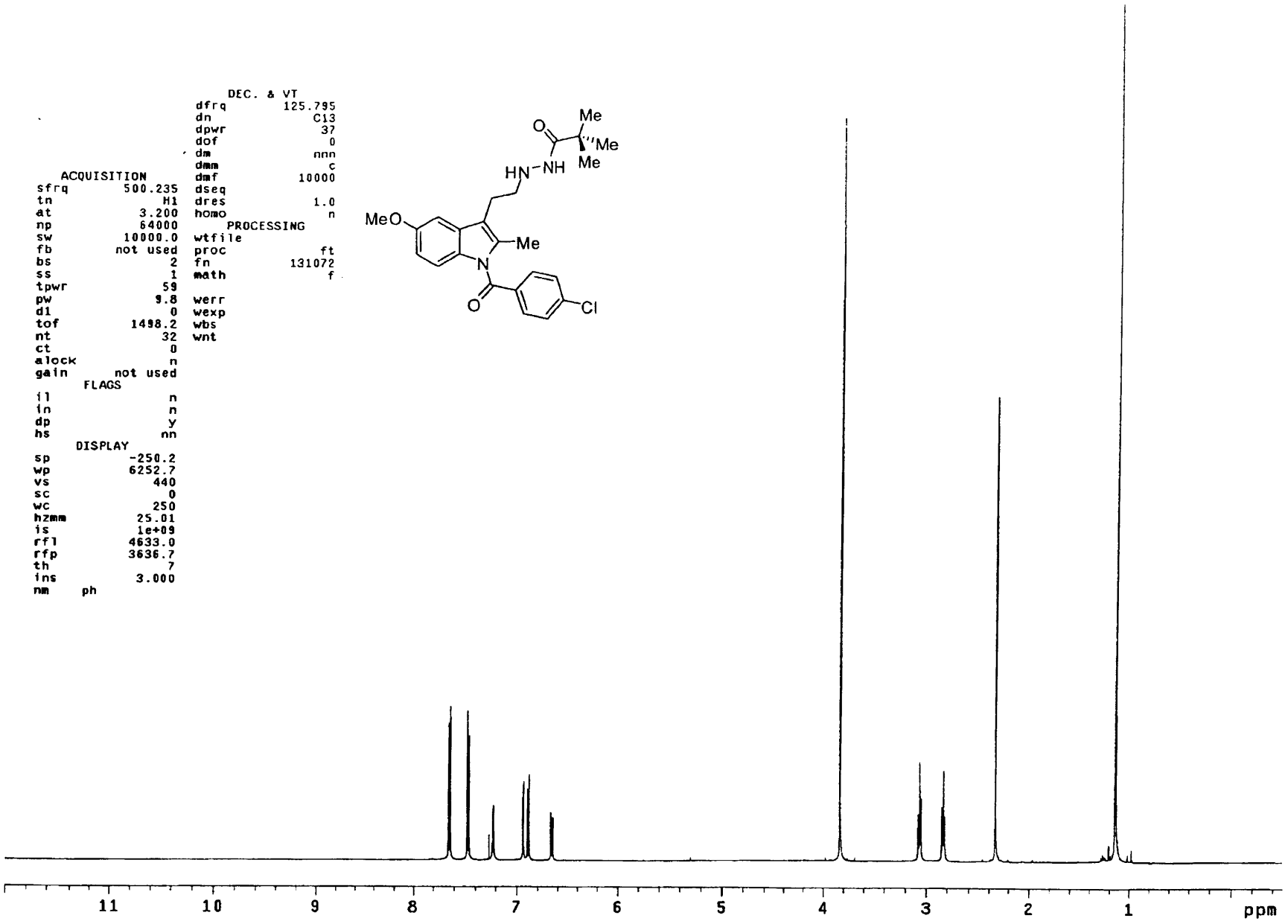
DEC. & VT	
dfrq	499.747
dn	H1
dpwr	34
dof	0
dm	yyy
dmm	w
dmf	10000
dseq	
dres	1.0
homo	n

PROCESSING	
lb	1.00
wtfile	
proc	ft
fn	131072
math	f
werr	
wexp	
wbs	
wnt	




85.2
80
75
70
65
60
55
50
45
40
35
30
25
20
15
10
5
0.3
%T
3238.45
1548.15
1365.51
1320.87
1173.06
1014.50
779.79
731.43
4000.0
3000
2000
1500
1000
500 400.0
cm-1
c:\pe
O O
S
N
H
N
Me Me
Me
H
NO2

7b


ACQUISITION
sfrq 500.235
tn H1
at 3.200
np 64000
sw 10000.0
fb not used
bs 2
ss 1
tpwr 59
pw 9.8
d1 0
tof 1498.2
nt 32
ct 0
alock n
gain not used
FLAGS
il n
in n
dp y
hs nn
DISPLAY
sp -250.2
wp 6252.7
vs 440
sc 0
wc 250
hzmm 25.01
is 1e+09
rfl 4633.0
rfp 3636.7
th 7
ins 3.000
nm ph
DEC. & VT
dfrq 125.795
dn C13
dpwr 37
dof 0
dm nnn
dmm c
dmf 10000
dseq
dres 1.0
homo n
PROCESSING
wtfile
proc ft
fn 131072
math f
werr
wexp
wbs
wnt
Me
O
Me
HN
NH
Me
MeO
Me
N
O
Cl
11
10
9
8
7
6
5
4
3
2
1
ppm

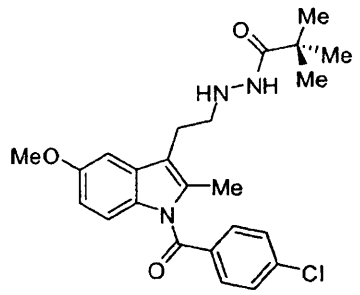
ACQUISITION	
sfrq	125.796
tn	C13
at	1.736
np	131010
sw	37735.8
fb	not used
bs	1
ss	1
tpwr	53
pw	6.9
d1	0.763
tof	631.4
nt	10000
ct	0
alock	n
gain	not used

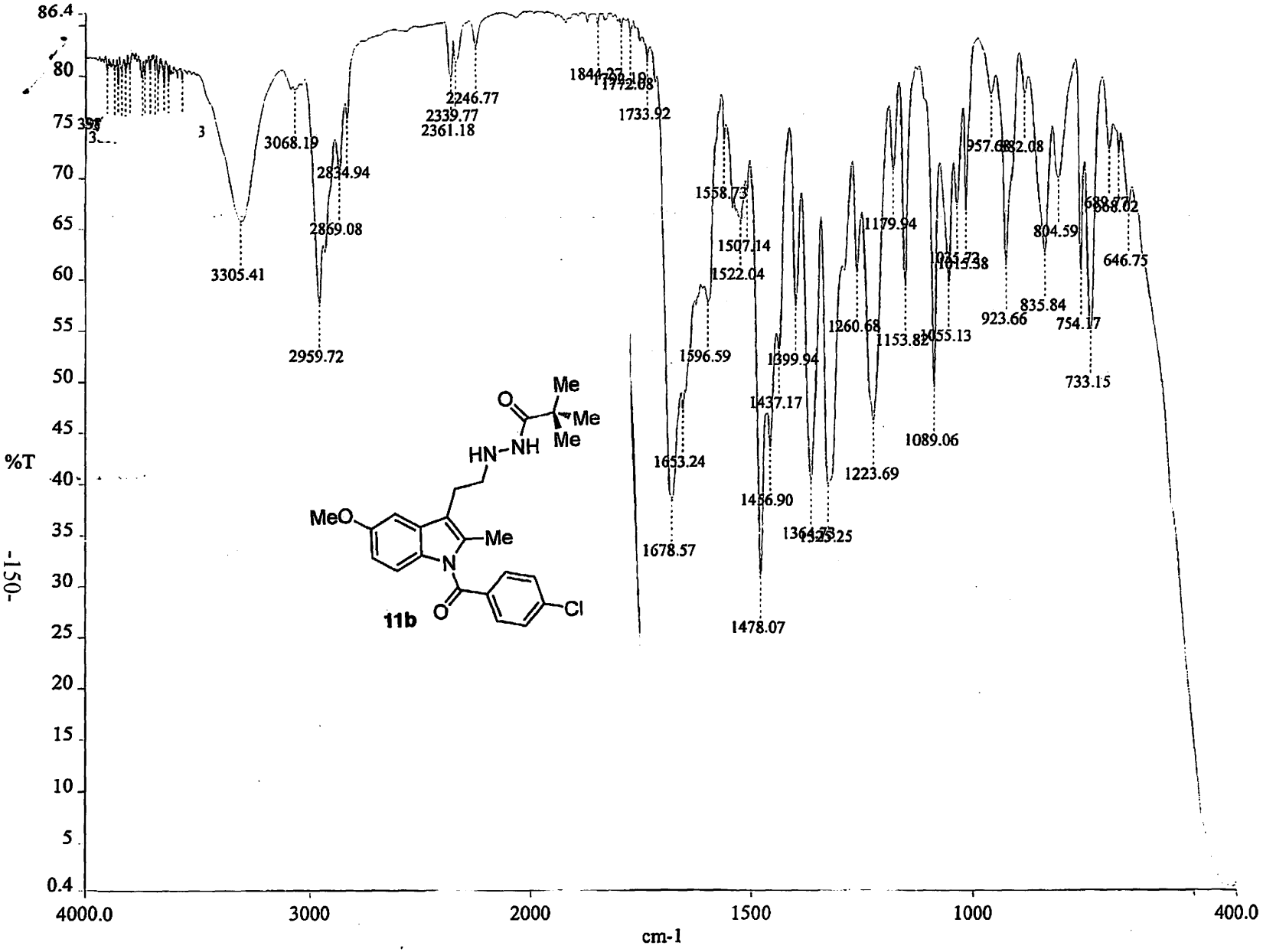
FLAGS	
il	n
in	n
dp	y
hs	nn

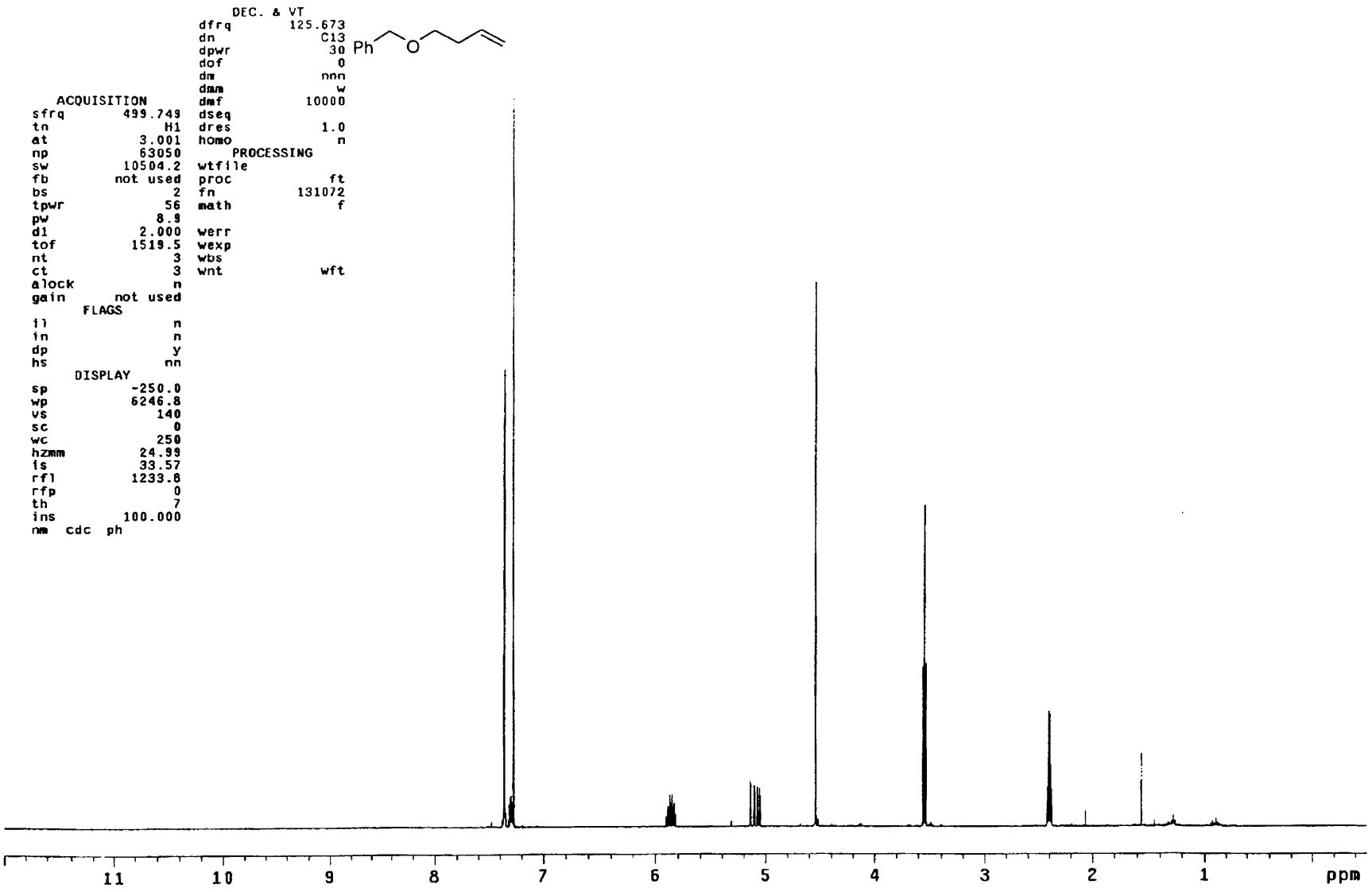
DISPLAY	
sp	-2528.8
wp	30198.6
vs	232
sc	0
wc	250
hzmm	120.79
is	500.00
rfl	16007.3
rfp	9710.5
th	20
ins	1.000
ai	ph

DEC. & VT	
dfrq	500.233
dn	H1
dpwr	37
dof	-500.0
dm	y
dmm	w
dmf	10000
dseq	
dres	1.0
homo	n

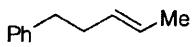
PROCESSING	
lb	0.30
wtfile	
proc	ft
fn	131072
math	f
werr	
wexp	
wbs	
wnt	




86.4
80
75
70
65
60
55
50
45
40
35
30
25
20
15
10
5
0.4
%T
4000.0
3000
2000
1500
1000
400.0
cm-1
3305.41
3068.19
2959.72
2869.08
2834.94
2361.18
2339.77
2246.77
1733.92
1678.57
1653.24
1596.59
1558.73
1522.04
1507.14
1478.07
1456.90
1437.17
1399.94
1364.75
1325.25
1260.68
1223.69
1179.94
1153.82
1089.06
1055.13
1015.38
957.68
923.66
882.08
835.84
804.59
754.17
733.15
688.02
646.75
MeO
Me
HN-NH
O
Me
Me
Me
N
O
Cl
11b


ACQUISITION
sfrq 499.749
tn H1
at 3.001
np 63050
sw 10504.2
fb not used
bs 2
tpwr 56
pw 8.9
d1 2.000
tof 1519.5
nt 3
ct 3
alock n
gain not used
FLAGS
il n
in n
dp y
hs nn
DISPLAY
sp -250.0
wp 6246.8
vs 140
sc 0
wc 250
hzmm 24.99
is 33.57
rfl 1233.8
rfp 0
th 7
ins 100.000
nm cdc ph
DEC. & VT
dfrq 125.673
dn C13
dpwr 30
dof 0
dm nnn
dmm w
dmf 10000
dseq
dres 1.0
homo n
PROCESSING
wtfile
proc ft
fn 131072
math f
werr
wexp
wbs
wnt wft
Ph
O
11
10
9
8
7
6
5
4
3
2
1
ppm

F2 - Acquisition Parameters



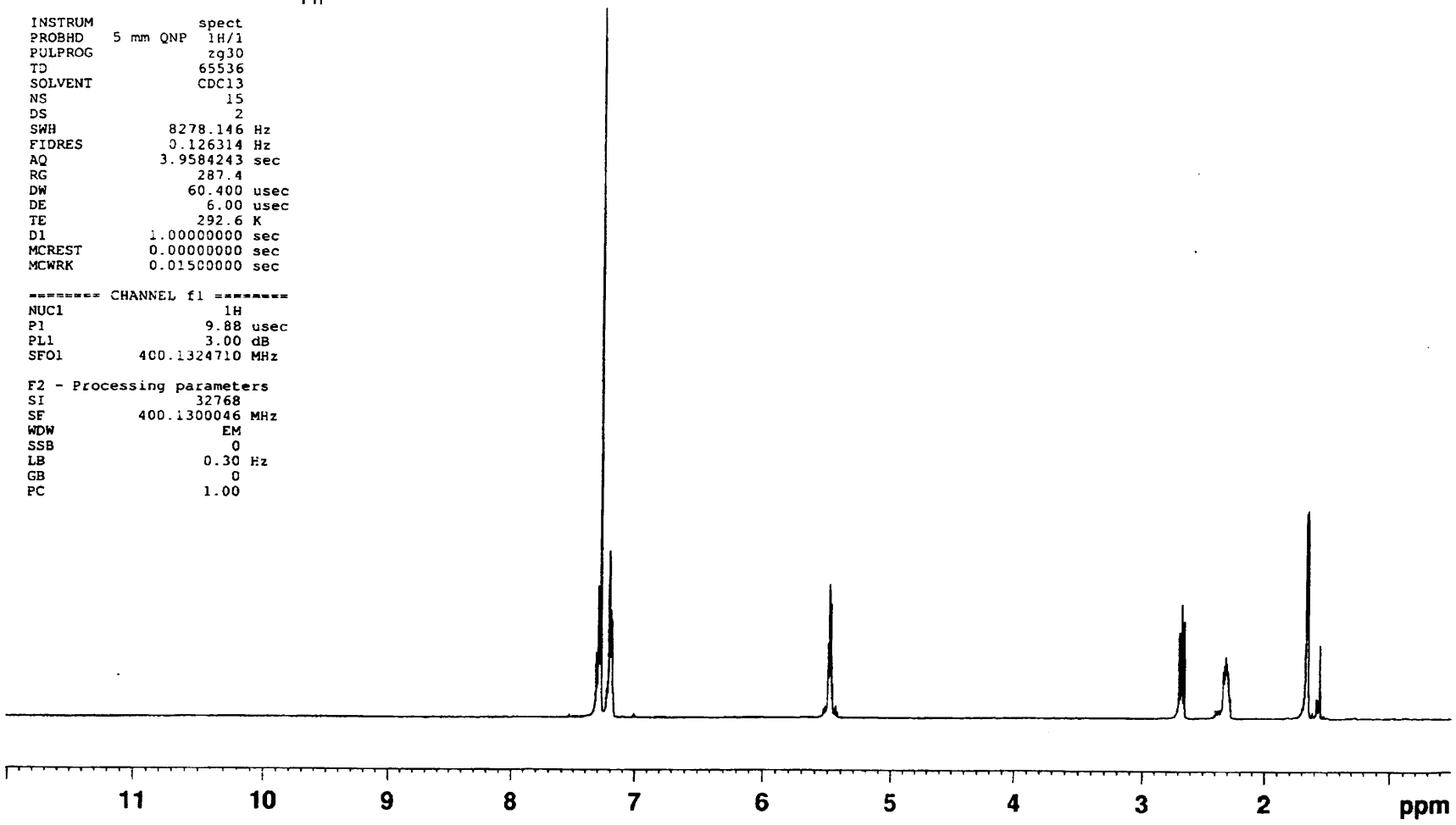
INSTRUM	spect	
PROBHD	5 mm QNP 1H/1	
PULPROG	zg30	
TD	65536	
SOLVENT	CDCl3	
NS	15	
DS	2	
SWH	8278.146	Hz
FIDRES	0.126314	Hz
AQ	3.9584243	sec
RG	287.4	
DW	60.400	usec
DE	6.00	usec
TE	292.6	K
D1	1.00000000	sec
MCREST	0.00000000	sec
MCWRK	0.01500000	sec

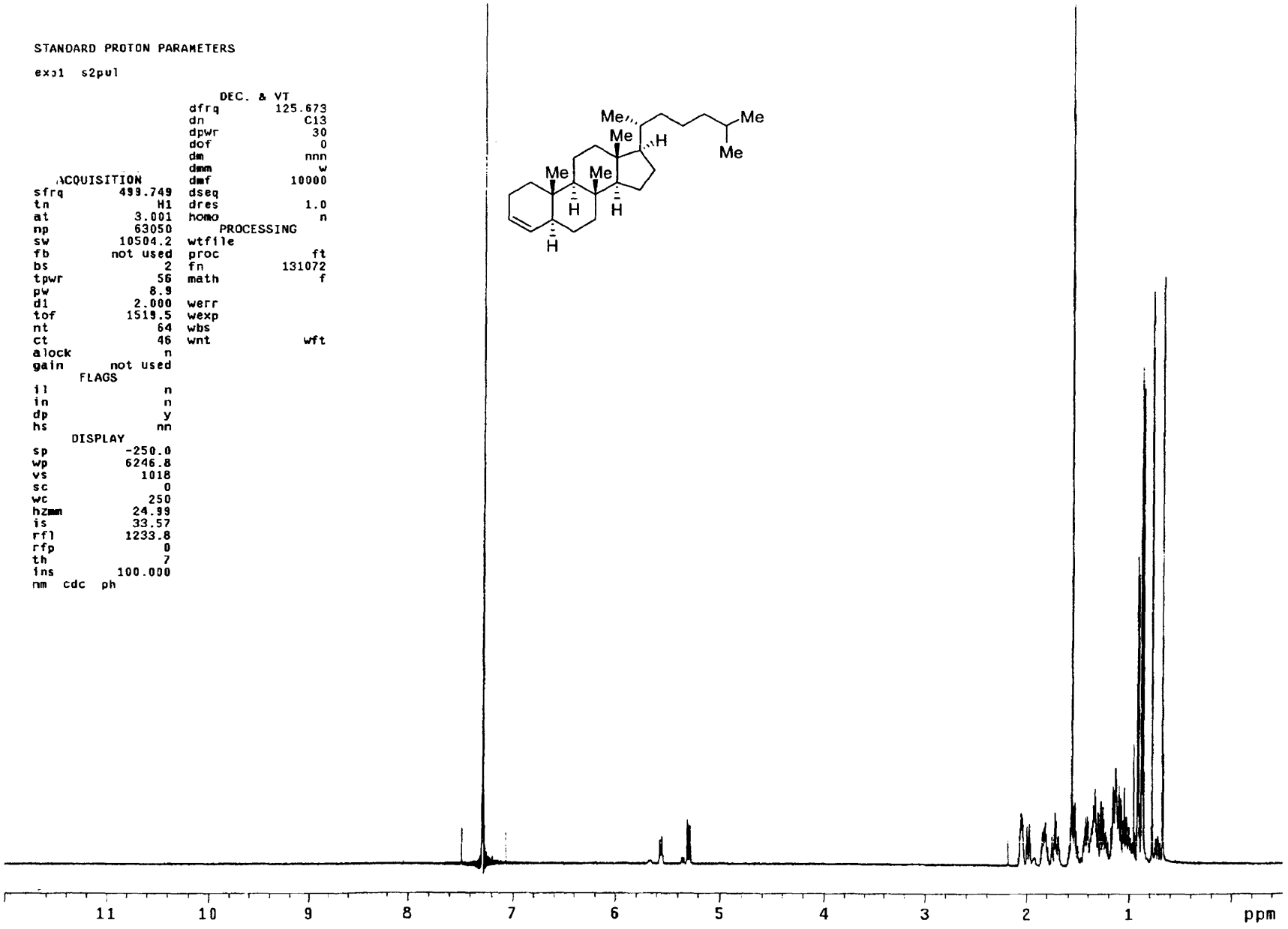
======== CHANNEL f1 ========

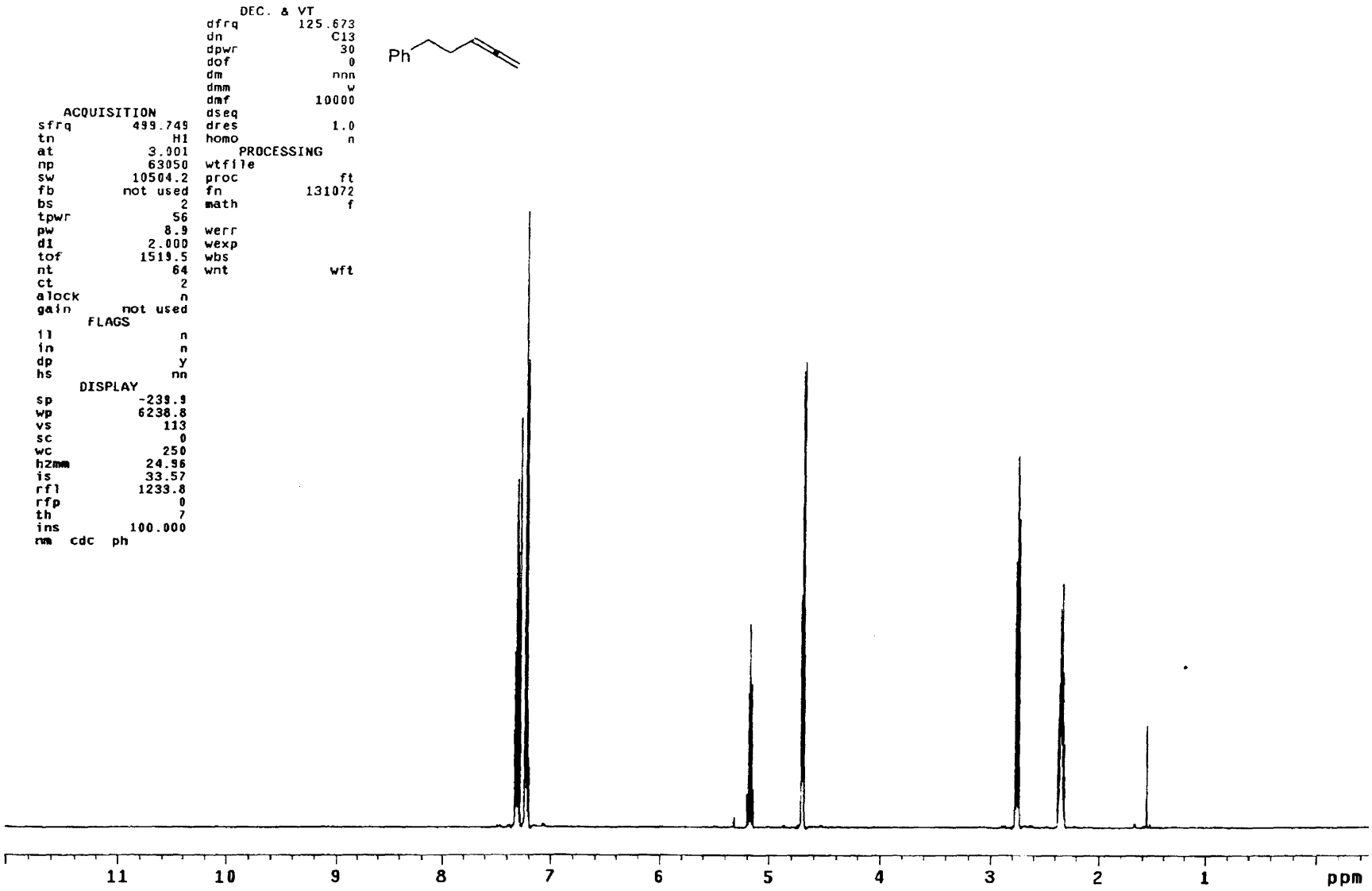
NUC1	1H	
P1	9.88	usec
PL1	3.00	dB
SFO1	400.1324710	MHz

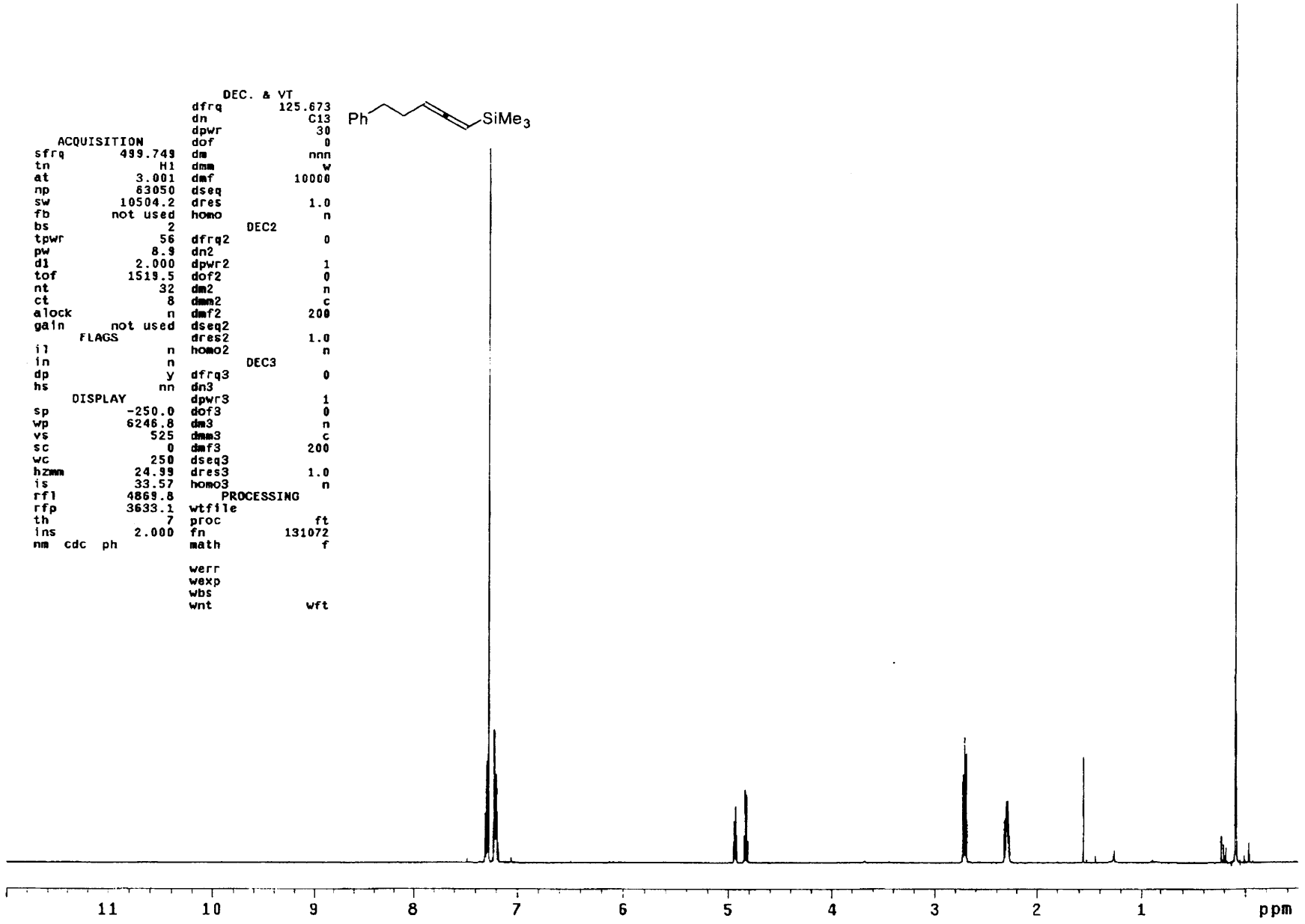
F2 - Processing parameters

SI	32768	
SF	400.1300046	MHz
WDW	EM	
SSB	0	
LB	0.30	Hz
GB	0	
PC	1.00	

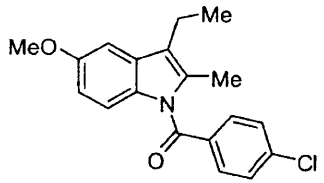



STANDARD PROTON PARAMETERS
exp1 s2pul
ACQUISITION
sfrq 499.749
tn H1
at 3.001
np 63050
sw 10504.2
fb not used
bs 2
tpwr 56
pw 8.9
d1 2.000
tof 1519.5
nt 64
ct 46
alock n
gain not used
FLAGS
il n
in n
dp y
hs nn
DISPLAY
sp -250.0
wp 6246.8
vs 1018
sc 0
wc 250
hzmm 24.99
is 33.57
rfl 1233.8
rfp 0
th 7
ins 100.000
nm cdc ph
DEC. & VT
dfrq 125.673
dn C13
dpwr 30
dof 0
dm nnn
dmm w
dmf 10000
dseq
dres 1.0
homo n
PROCESSING
wtfile
proc ft
fn 131072
math f
werr
wexp
wbs
wnt wft
Me
Me
H
Me
Me
Me
Me
H
H
H
11
10
9
8
7
6
5
4
3
2
1
ppm


ACQUISITION
sfrq 499.749
tn H1
at 3.001
np 63050
sw 10504.2
fb not used
bs 2
tpwr 56
pw 8.9
d1 2.000
tof 1519.5
nt 64
ct 2
alock n
gain not used
FLAGS
il n
in n
dp y
hs nn
DISPLAY
sp -239.9
wp 6238.8
vs 113
sc 0
wc 250
hzmm 24.96
is 33.57
rfl 1233.8
rfp 0
th 7
ins 100.000
nm cdc ph
DEC. & VT
dfrq 125.673
dn C13
dpwr 30
dof 0
dm nnn
dmm w
dmf 10000
dseq
dres 1.0
homo n
PROCESSING
wtfile
proc ft
fn 131072
math f
werr
wexp
wbs
wnt wft
Ph
11
10
9
8
7
6
5
4
3
2
1
ppm


ACQUISITION
sfrq 499.749
tn H1
at 3.001
np 63050
sw 10504.2
fb not used
bs 2
tpwr 56
pw 8.9
d1 2.000
tof 1519.5
nt 32
ct 8
alock n
gain not used
FLAGS
il n
in n
dp y
hs nn
DISPLAY
sp -250.0
wp 6246.8
vs 525
sc 0
wc 250
hzmm 24.99
is 33.57
rfl 4869.8
rfp 3633.1
th 7
ins 2.000
nm cdc ph
DEC. & VT
dfrq 125.673
dn C13
dpwr 30
dof 0
dm nnn
dmm w
dmf 10000
dseq
dres 1.0
homo n
DEC2
dfrq2 0
dn2
dpwr2 1
dof2 0
dm2 n
dmm2 c
dmf2 200
dseq2
dres2 1.0
homo2 n
DEC3
dfrq3 0
dn3
dpwr3 1
dof3 0
dm3 n
dmm3 c
dmf3 200
dseq3
dres3 1.0
homo3 n
PROCESSING
wtfile
proc ft
fn 131072
math f
werr
wexp
wbs
wnt wft
Ph
SiMe3
11
10
9
8
7
6
5
4
3
2
1
ppm

F2 - Acquisition Parameters



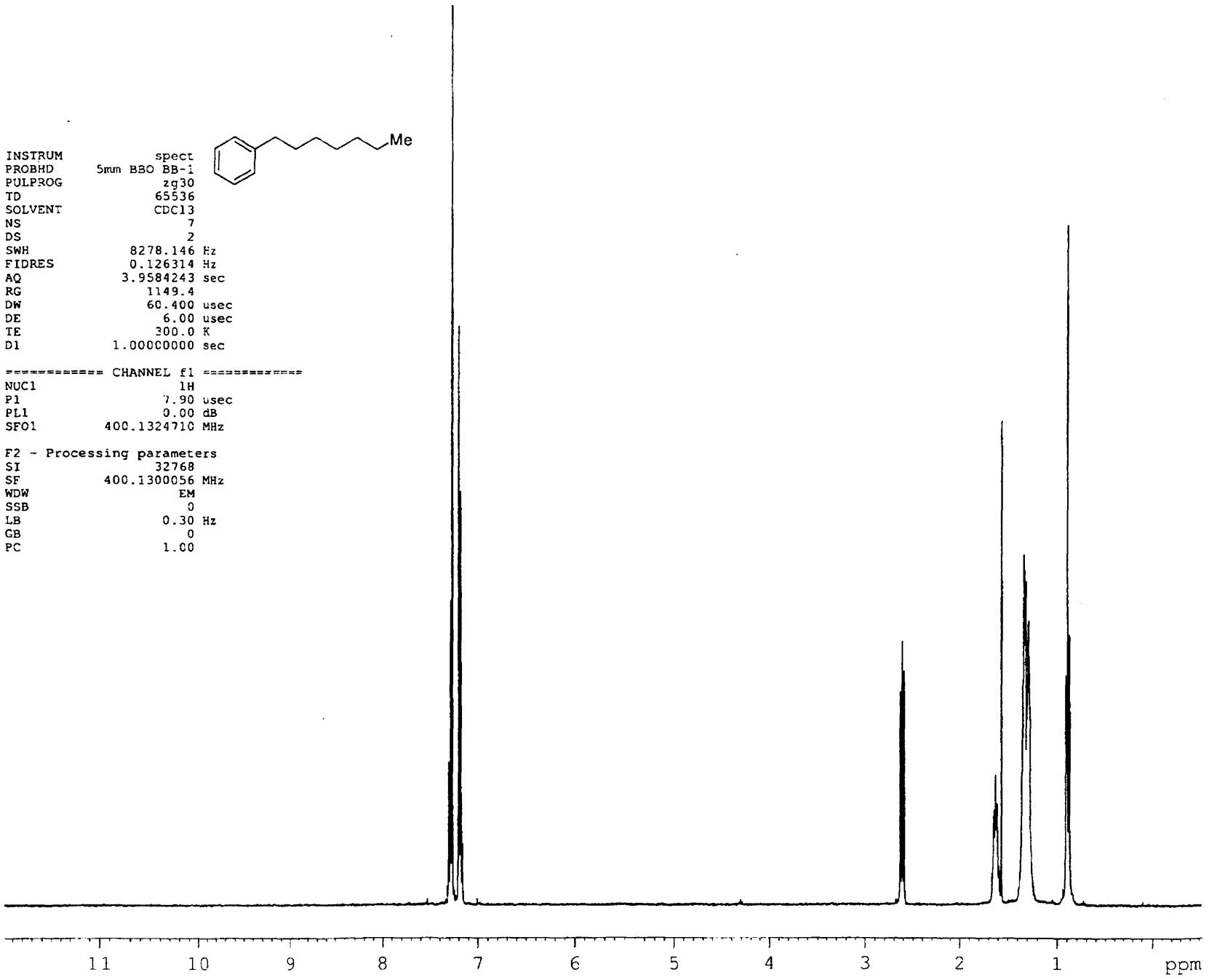
INSTRUM	spect
PROBHD	5mm BBO BB-1
PULPROG	zg30
TD	65536
SOLVENT	CDCl3
NS	6
DS	2
SWH	8278.146 Hz
FIDRES	0.126314 Hz
AQ	3.9584243 sec
RG	256
DW	60.400 usec
DE	6.00 usec
TE	300.0 K
D1	1.00000000 sec

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

NUC1	1H
P1	7.90 usec
PL1	0.00 dB
SFO1	400.1324710 MHz

F2 - Processing parameters

SI	32768
SF	400.1300056 MHz
WDW	EM
SSB	0
LB	0.30 Hz
GB	0
PC	1.00


Me
INSTRUM spect
PROBHD 5mm BBO BB-i
PULPROG zg30
TD 65536
SOLVENT CDC13
NS 7
DS 2
SWH 8278.146 Hz
FIDRES 0.126314 Hz
AQ 3.9584243 sec
RG 1149.4
DW 60.400 usec
DE 6.00 usec
TE 300.0 K
D1 1.00000000 sec
========== CHANNEL f1 ==========
NUC1 1H
P1 7.90 usec
PL1 0.00 dB
SFO1 400.1324710 MHz
F2 - Processing parameters
SI 32768
SF 400.1300056 MHz
WDW EM
SSB 0
LB 0.30 Hz
GB 0
PC 1.00
11
10
9
8
7
6
5
4
3
2
1
ppm

Appendix B

Spectra for Chapter II

ACQUISITION	
sfrq	499.749
tn	H1
at	3.001
np	63050
sw	10504.2
fb	not used
bs	2
tpwr	56
pw	8.9
d1	2.000
tof	1519.5
nt	32
ct	32
alock	n
gain	not used

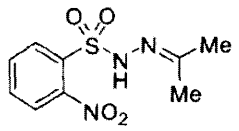
FLAGS	
il	n
in	n
dp	y
hs	nn

DISPLAY	
sp	-252.2
wp	6246.8
vs	120
sc	0
wc	250
hzmm	24.99
is	33.57
rfl	4869.2
rfp	3633.1
th	7
ins	100.000

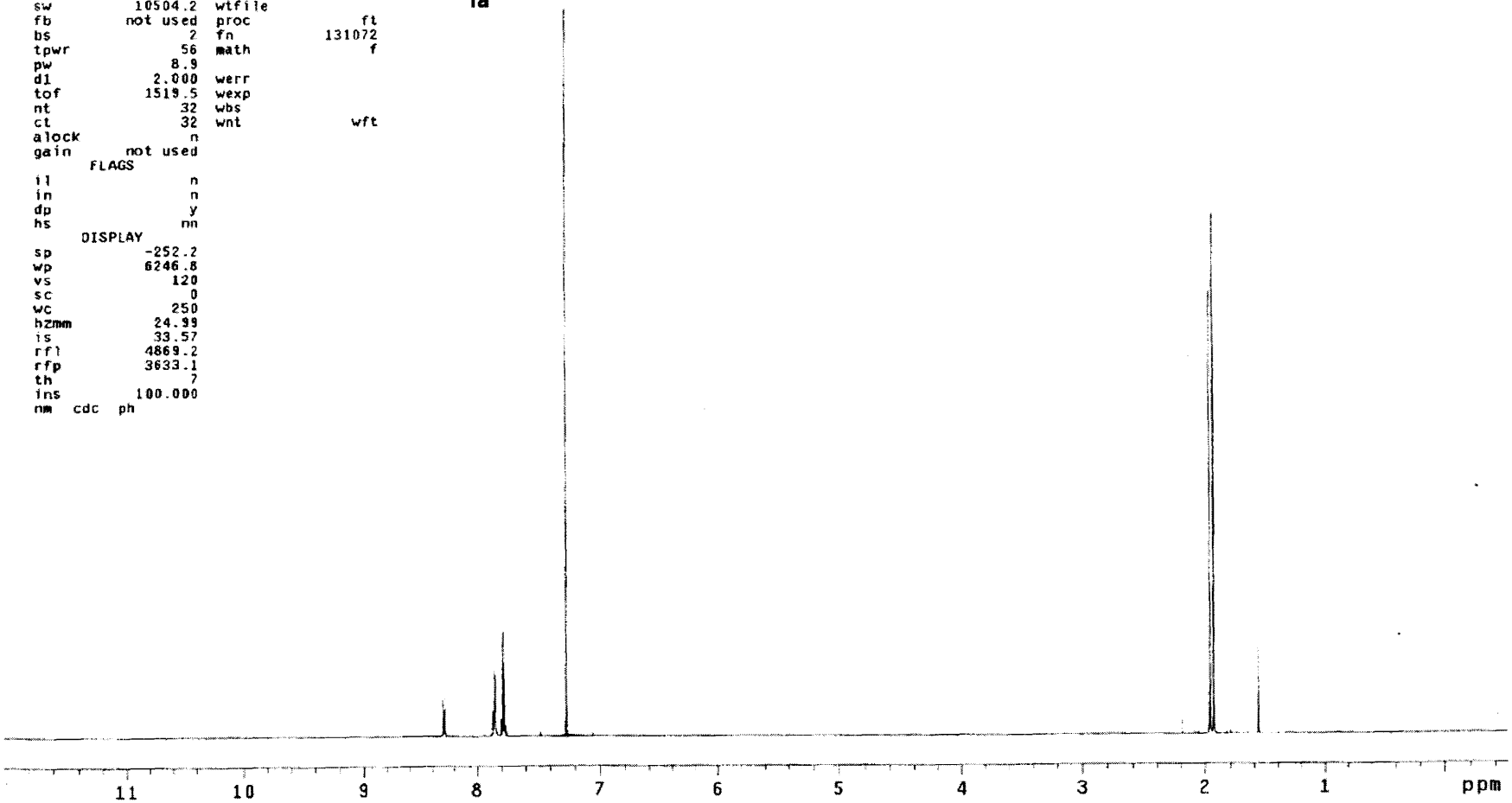
nm cdc ph

DEC. & VT	
dfrq	125.673
dn	C13
dpwr	30
dof	0
dm	nnn
dmm	w
dmf	10000
dseq	
dres	1.0
homo	n

PROCESSING	
wtfile	
proc	ft
fn	131072
math	f
werr	
wexp	
wbs	
wnt	wft



1a



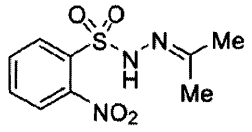
ACQUISITION	
sfrq	125.796
tn	C13
at	1.736
np	131010
sw	37735.8
fb	not used
bs	10
ss	1
tpwr	53
pw	6.5
d1	0.763
tof	631.4
nt	2000
ct	1770
alock	n
gain	not used

FLAGS	
il	n
in	n
dp	y
hs	nn

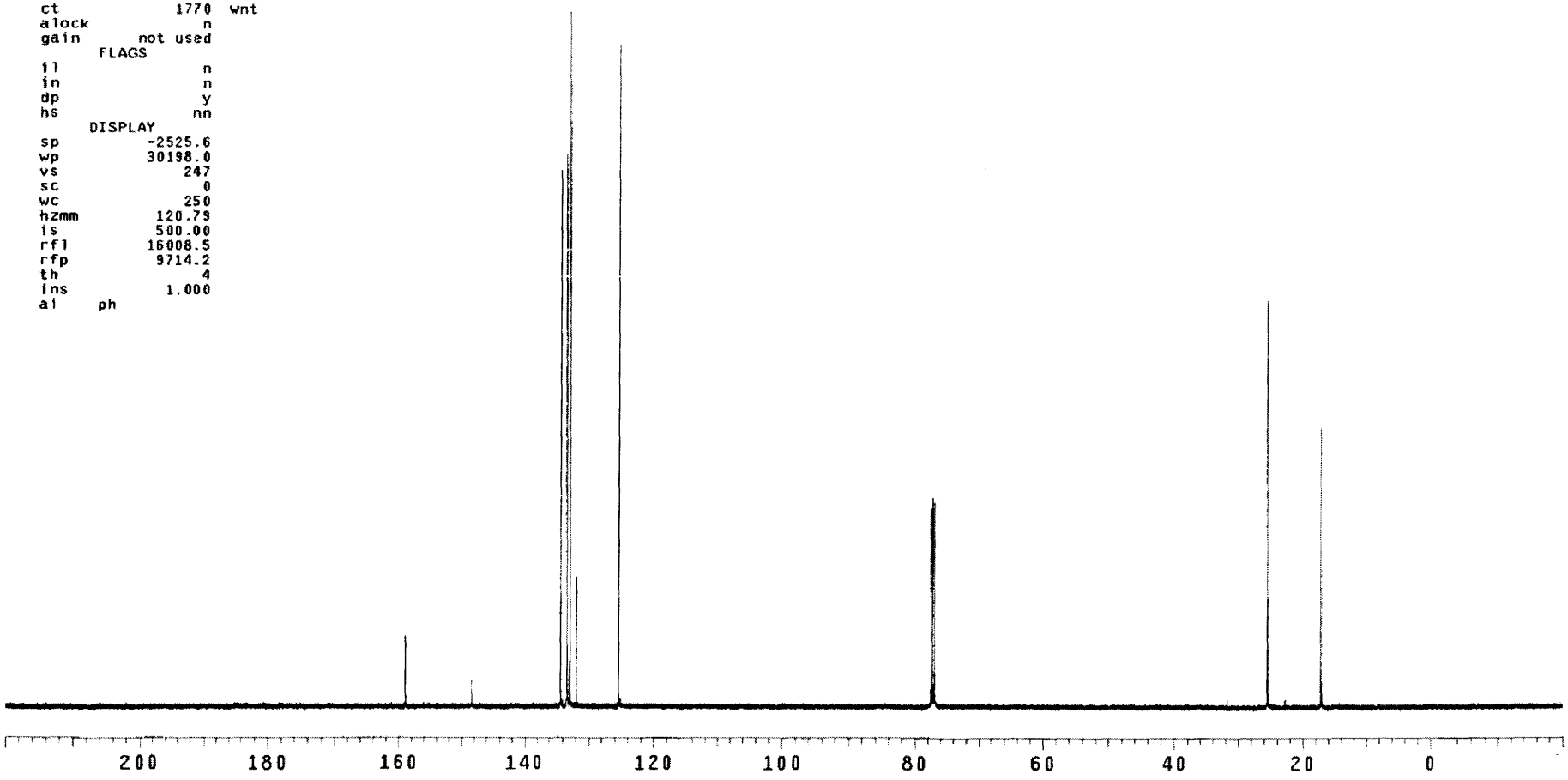
DISPLAY	
sp	-2525.6
wp	30198.0
vs	247
sc	0
wc	250
hzmm	120.79
is	500.00
rfl	16008.5
rfp	9714.2
th	4
ins	1.000
ai	ph

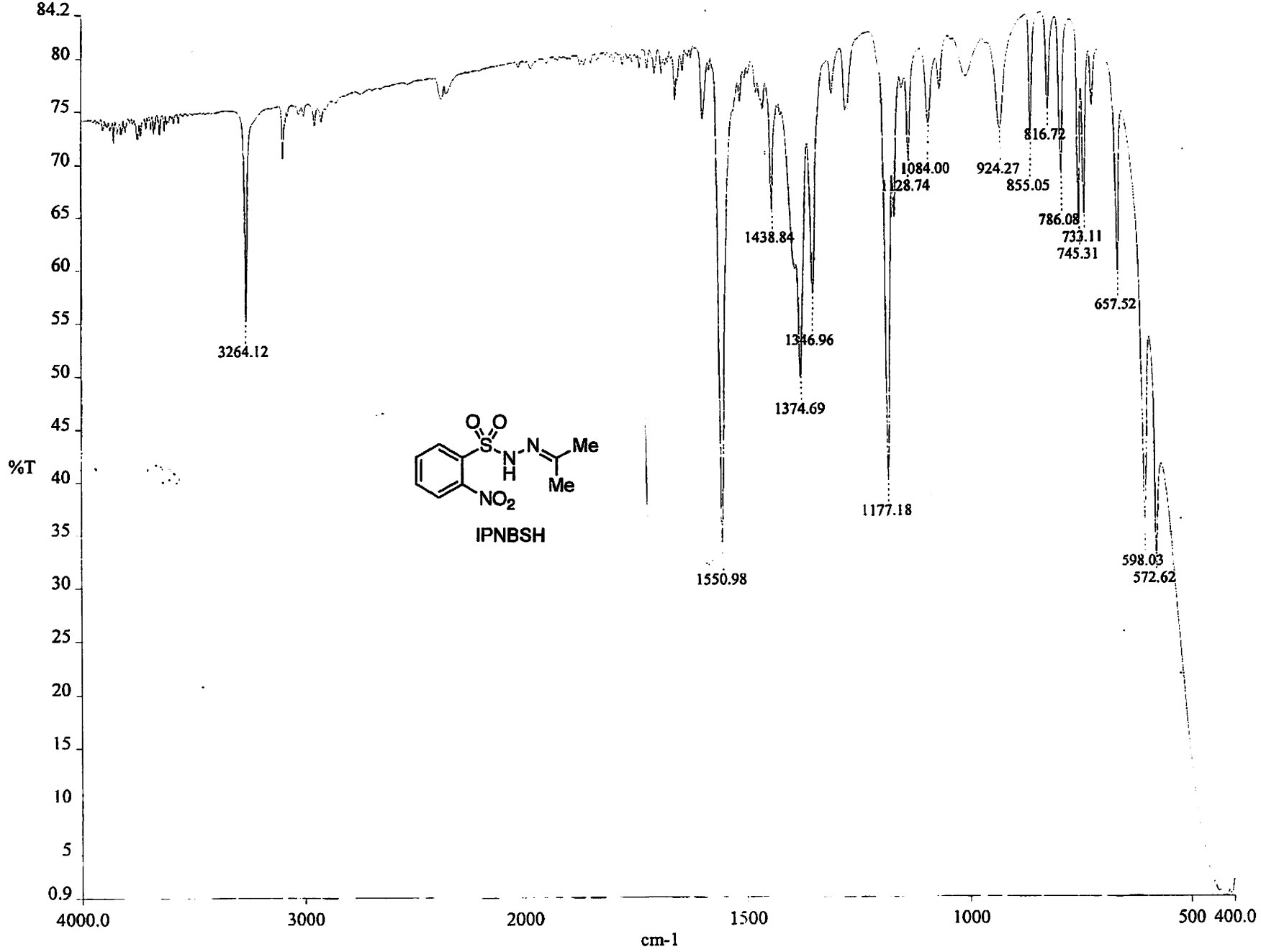
DEC. & VT	
dfrq	500.233
dn	H1
dpwr	37
dof	-500.0
dm	y
dmm	w
dmf	10000
dseq	
dres	1.0
homo	n

PROCESSING	
lb	0.30
wtfile	
proc	ft
fn	131072
math	f
werr	
wexp	
wbs	
wnt	



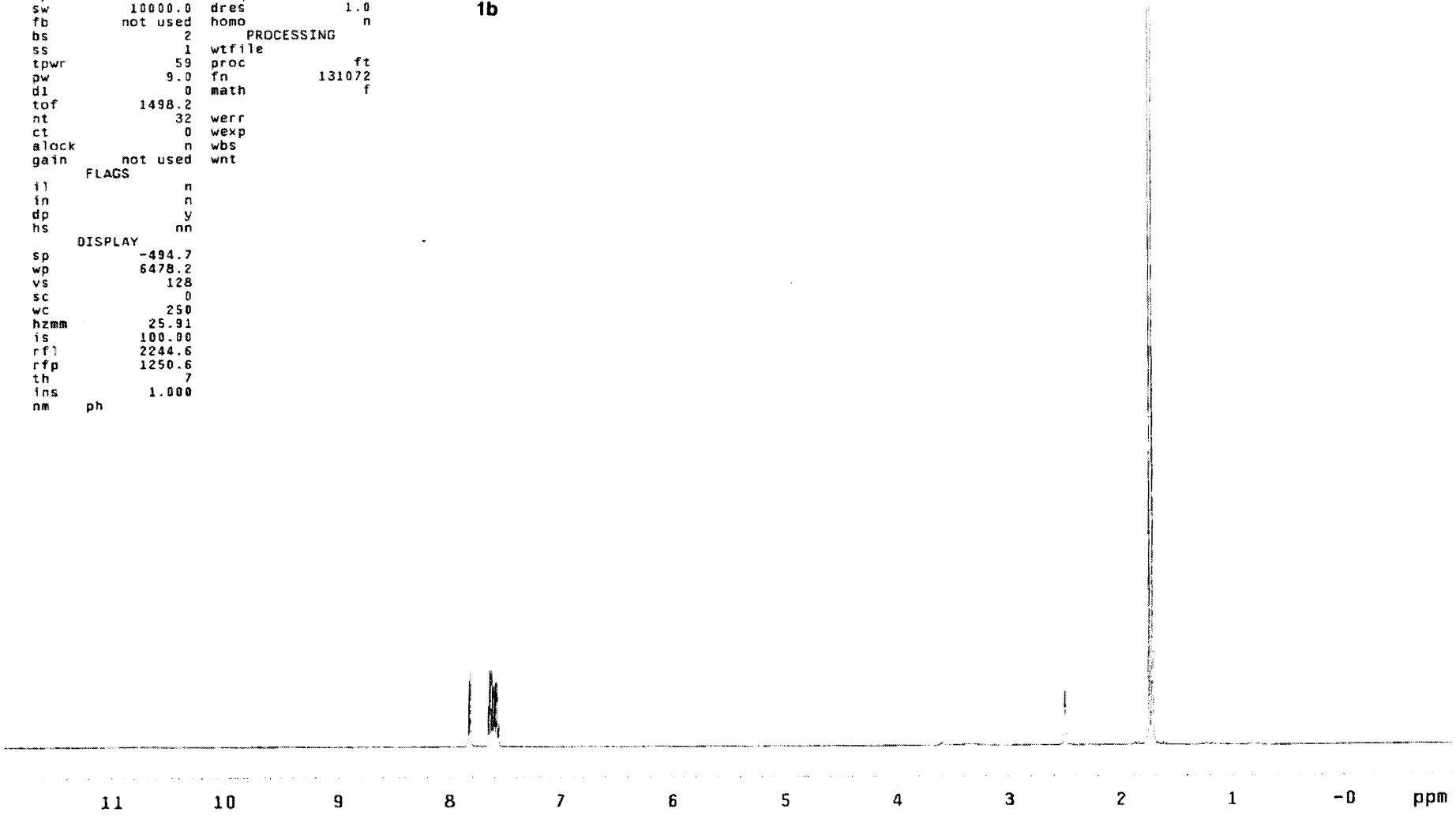
1a

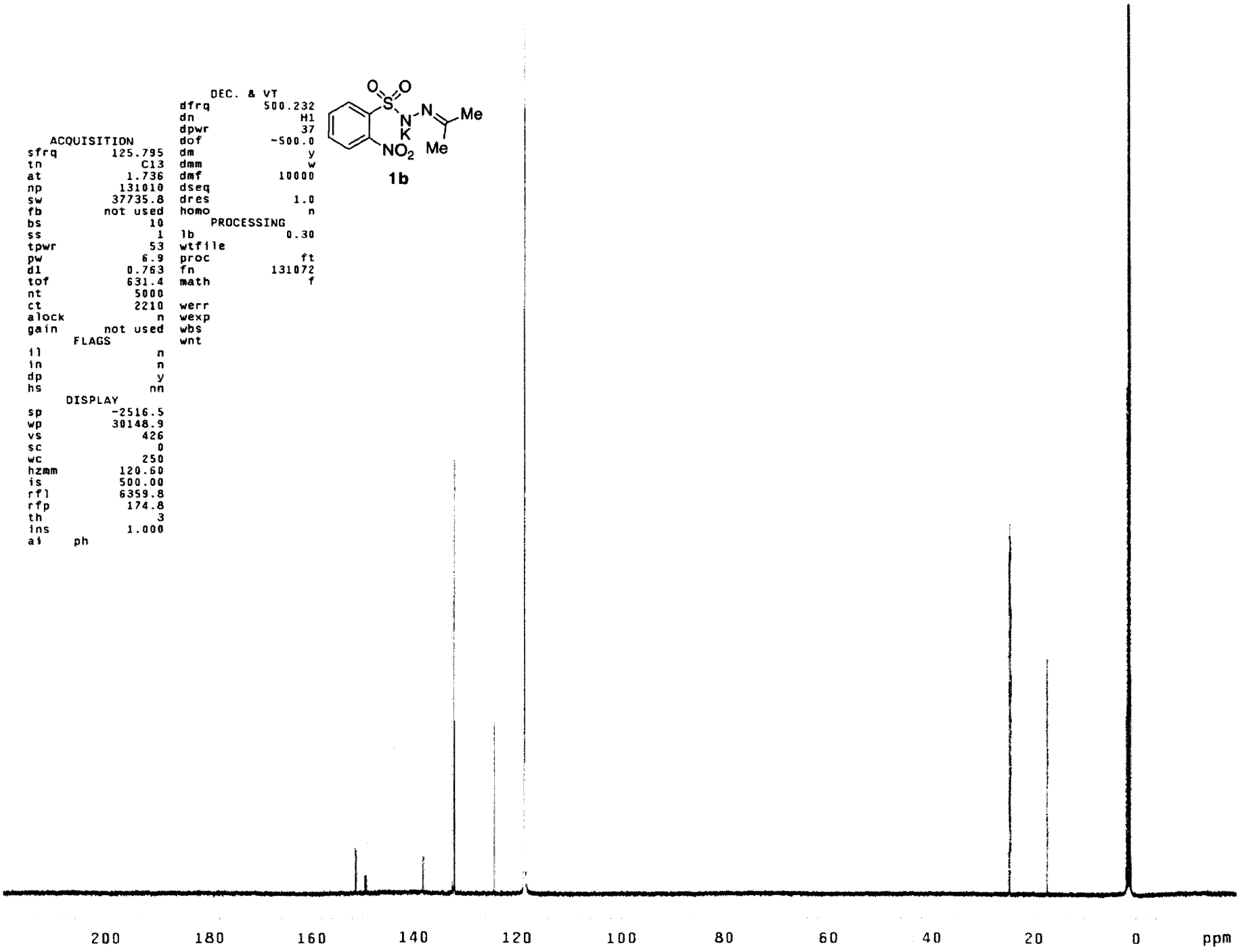


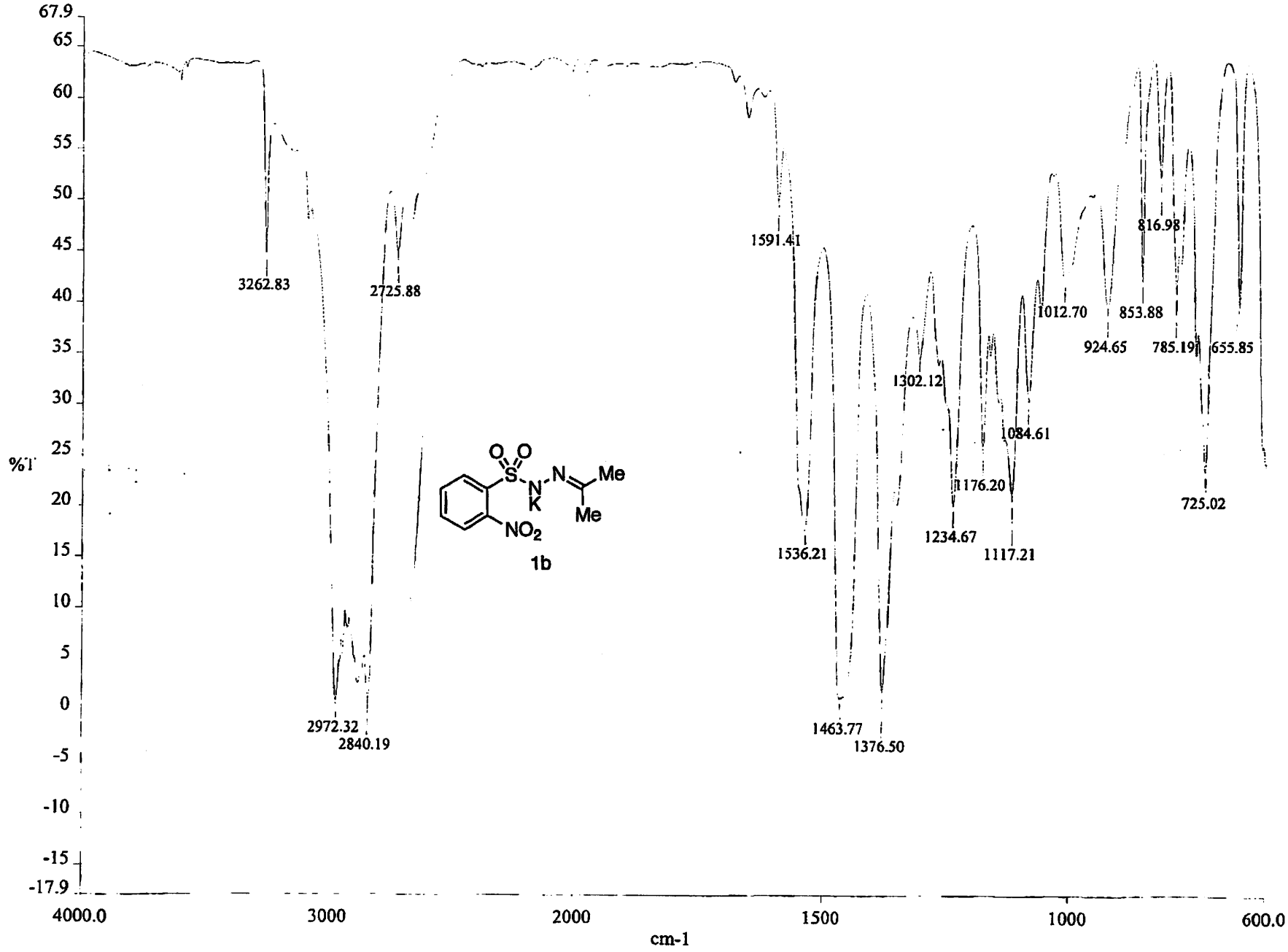

84.2
80
75
70
65
60
55
50
45
40
35
30
25
20
15
10
5
0.9
%T
4000.0
3000
2000
1500
1000
500 400.0
cm-1
3264.12
1550.98
1438.84
1374.69
1346.96
1177.18
1128.74
1084.00
924.27
855.05
816.72
786.08
745.31
733.11
657.52
598.03
572.62
O
O
S
N
H
N
Me
Me
NO2
IPNBSH
c:\pel_data\spectra\scan_rto.sp - OA-I-228

ACQUISITION		DEC. & VT	
sfrq	500.234	dfrq	125.795
tn	H1	dn	C13
at	3.200	dpwr	37
np	64000	dof	0
sw	10000.0	dm	nnn
fb	not used	dmm	c
bs	2	dmf	10000
ss	1	dseq	
tpwr	59	dres	1.0
pw	9.0	homo	n
dl	0	PROCESSING	
tof	1498.2	wtfile	
nt	32	proc	ft
ct	0	fn	131072
alock	n	math	f
gain	not used	werr	
FLAGS		wexp	
il	n	wbs	
in	n	wnt	
dp	y		
hs	nn		
DISPLAY			
sp	-494.7		
wp	6478.2		
vs	128		
sc	0		
wc	250		
hzmm	25.91		
is	100.00		
rfl	2244.6		
rfp	1250.6		
th	7		
ins	1.000		
nm	ph		

1b




ACQUISITION
sfrq 125.795
tn C13
at 1.736
np 131010
sw 37735.8
fb not used
bs 10
ss 1
tpwr 53
pw 6.9
d1 0.763
tof 631.4
nt 5000
ct 2210
alock n
gain not used
FLAGS
il n
in n
dp y
hs nn
DISPLAY
sp -2516.5
wp 30148.9
vs 426
sc 0
wc 250
hzmm 120.60
is 500.00
rfl 6359.8
rfp 174.8
th 3
ins 1.000
ai ph
DEC. & VT
dfrq 500.232
dn H1
dpwr 37
dof -500.0
dm y
dmm w
dmf 10000
dseq
dres 1.0
homo n
PROCESSING
lb 0.30
wtfile
proc ft
fn 131072
math f
werr
wexp
wbs
wnt
O
O
S
N
N
K
Me
NO2
Me
1b
200
180
160
140
120
100
80
60
40
20
0
ppm


67.9
65
60
55
50
45
40
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30
25
%T
20
15
10
5
0
-5
-10
-15
-17.9
3262.83
2725.88
2972.32
2840.19
1591.41
1536.21
1463.77
1376.50
1302.12
1234.67
1176.20
1117.21
1084.61
1012.70
924.65
853.88
816.98
785.19
725.02
655.85
O
O
S
N
K
N
Me
Me
NO2
1b
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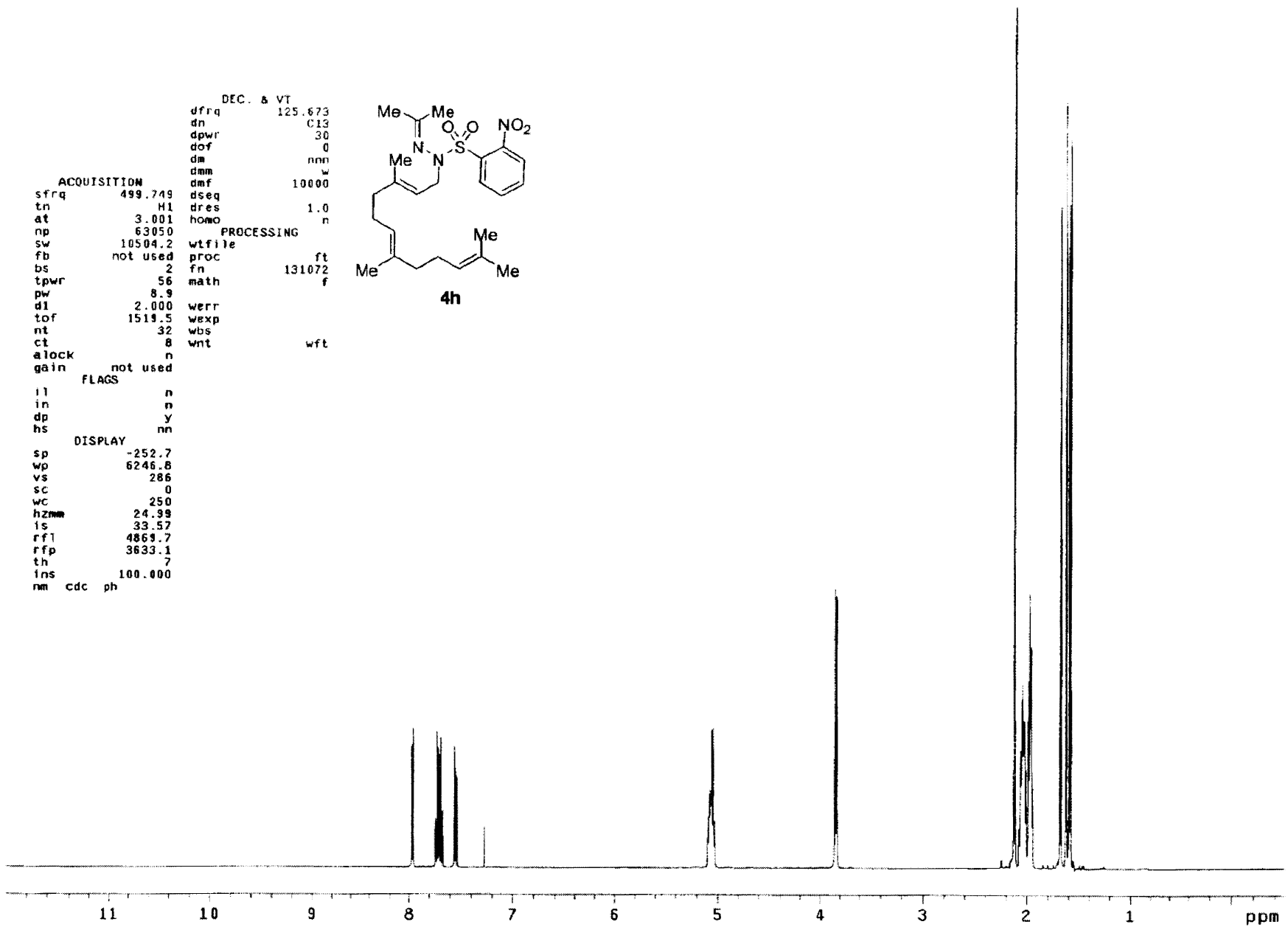
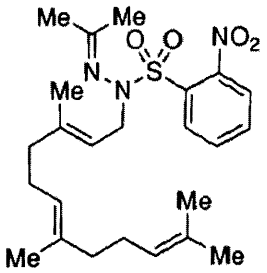
3000
2000
1500
1000
600.0
cm-1

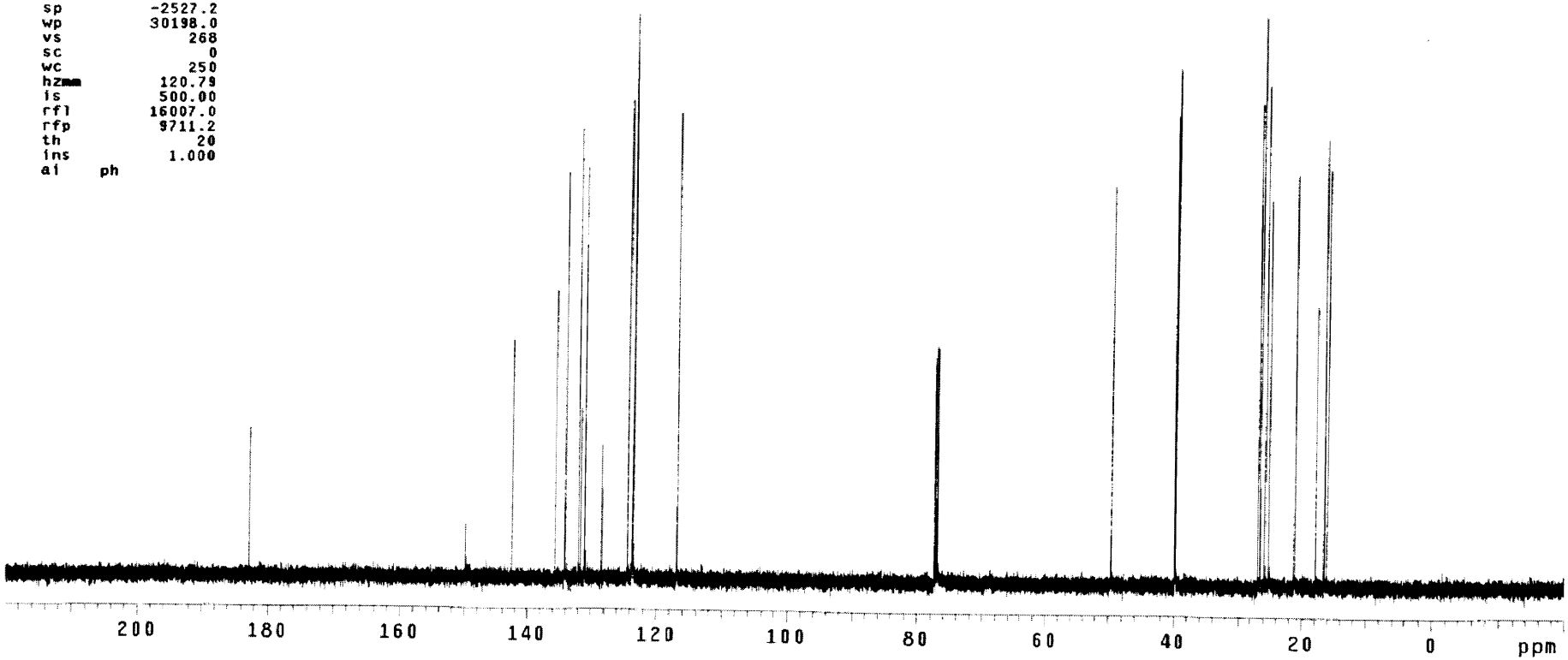

ACQUISITION
sfrq 499.749
tn H1
at 3.001
np 63050
sw 10504.2
fb not used
bs 2
tpwr 56
pw 8.9
d1 2.000
tof 1519.5
nt 32
ct 8
alock n
gain not used
FLAGS
il n
in n
dp y
hs nn
DISPLAY
sp -252.7
wp 6246.8
vs 286
sc 0
wc 250
hzmm 24.99
is 33.57
rfl 4869.7
rfp 3633.1
th 7
ins 100.000
nm cdc ph
DEC. & VT
dfrq 125.673
dn C13
dpwr 30
dof 0
dm nnn
dmm w
dmf 10000
dseq
dres 1.0
homo n
PROCESSING
wtfile
proc ft
fn 131072
math f
werr
wexp
wbs
wnt wft
Me
Me
O
O
NO2
N
N
S
Me
Me
Me
Me
4h
11
10
9
8
7
6
5
4
3
2
1
ppm

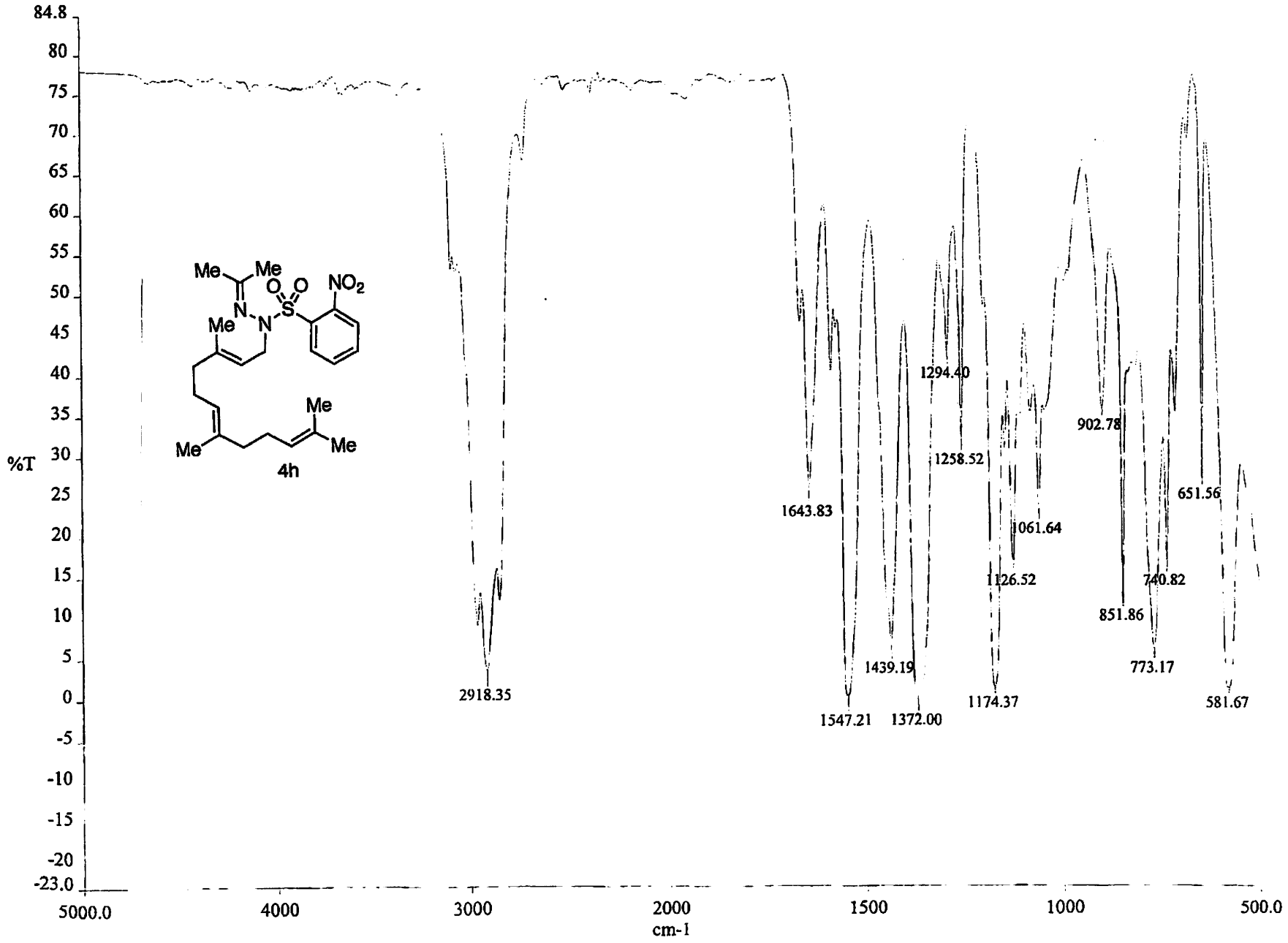
STANDARD CARBON PARAMETERS

ACQUISITION		DEC. & VT	
sfrq	125.796	dfrq	500.233
tn	C13	dn	H1
at	1.736	dpwr	37
np	131010	dof	-500.0
sw	37735.8	dm	y
fb	not used	dmm	w
bs	2	dmf	10000
ss	1	dseq	
tpwr	53	dres	1.0
pw	6.9	homo	n
dl	0.763	PROCESSING	
tof	631.4	lb	0.30
nt	2000	wtfile	
ct	138	proc	ft
alock	n	fn	131072
gain	not used	math	f
FLAGS		werr	
il	n	wexp	
in	n	wbs	
dp	y	wnt	
hs	nn		
DISPLAY			
sp	-2527.2		
wp	30198.0		
vs	268		
sc	0		
wc	250		
hzmm	120.79		
is	500.00		
rfl	16007.0		
rfp	9711.2		
th	20		
ins	1.000		
ai	ph		



4h




84.8
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60
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50
45
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30
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10
5
0
-5
-10
-15
-20
-23.0
%T
5000.0
4000
3000
2000
1500
1000
500.0
cm-1
Me
Me
O
O
NO2
N
N
S
Me
Me
Me
Me
4h
2918.35
1643.83
1547.21
1439.19
1372.00
1294.40
1258.52
1174.37
1126.52
1061.64
902.78
851.86
773.17
740.82
651.56
581.67

ACQUISITION	
sfrq	499.746
tn	H1
at	3.001
np	63050
sw	10504.2
fb	not used
bs	2
tpwr	56
pw	8.6
d1	2.000
tof	1519.5
nt	32
ct	4
alock	n
gain	not used

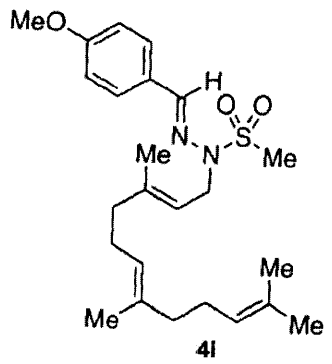
FLAGS	
il	n
in	n
dp	y
hs	nn

DISPLAY	
sp	-249.9
wp	6246.7
vs	45
sc	0
wc	250
hzmm	24.99
is	33.57
rfl	4865.3
rfp	3633.1
th	7
ins	2.000

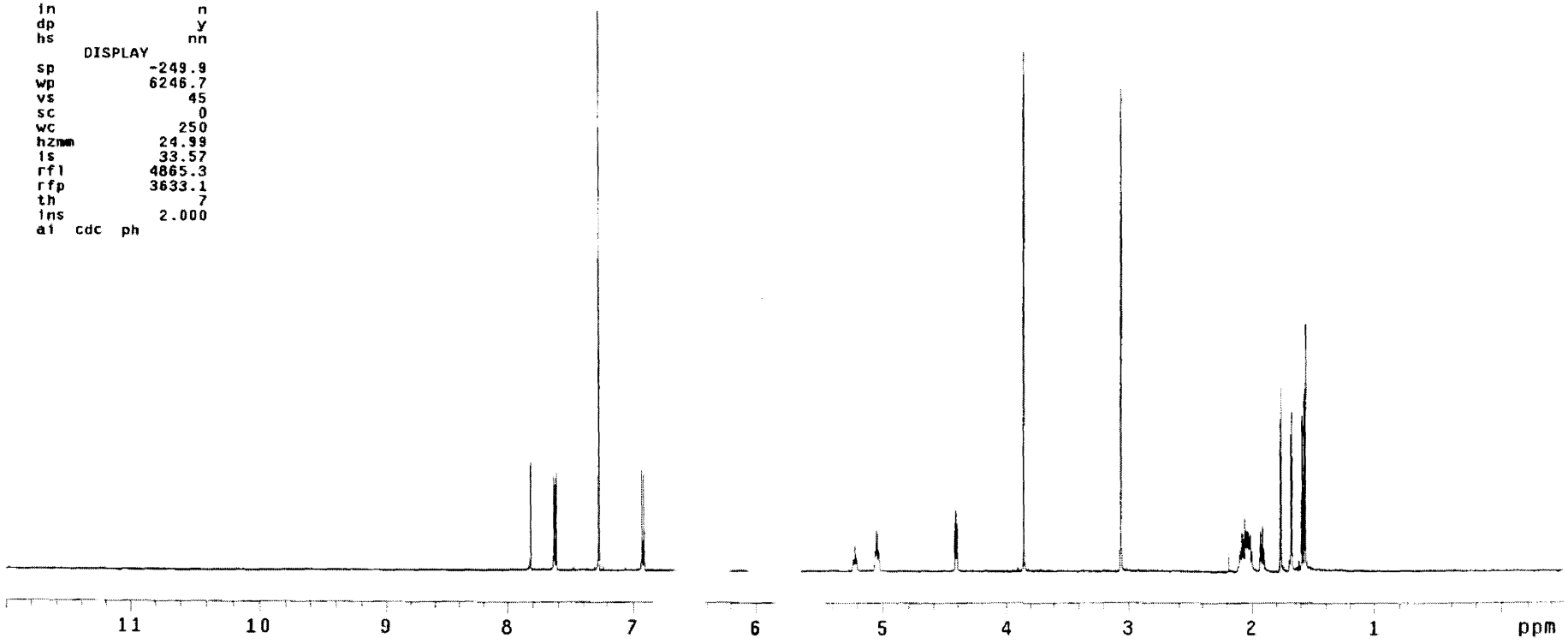
ai cdc ph

DEC. & VT	
dfrq	125.672
dn	C13
dpwr	30
dof	0
dm	nnn
dmm	w
dmf	10000
dseq	
dres	1.0
homo	n

PROCESSING	
wtfile	
proc	ft
fn	262144
math	f
werr	
wexp	
wbs	
wnt	wft



4l

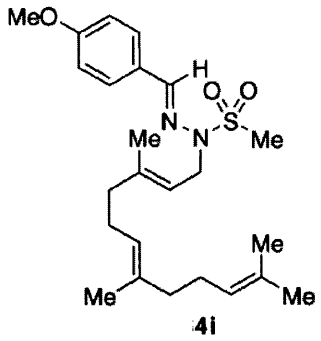


STANDARD CARBON PARAMETERS

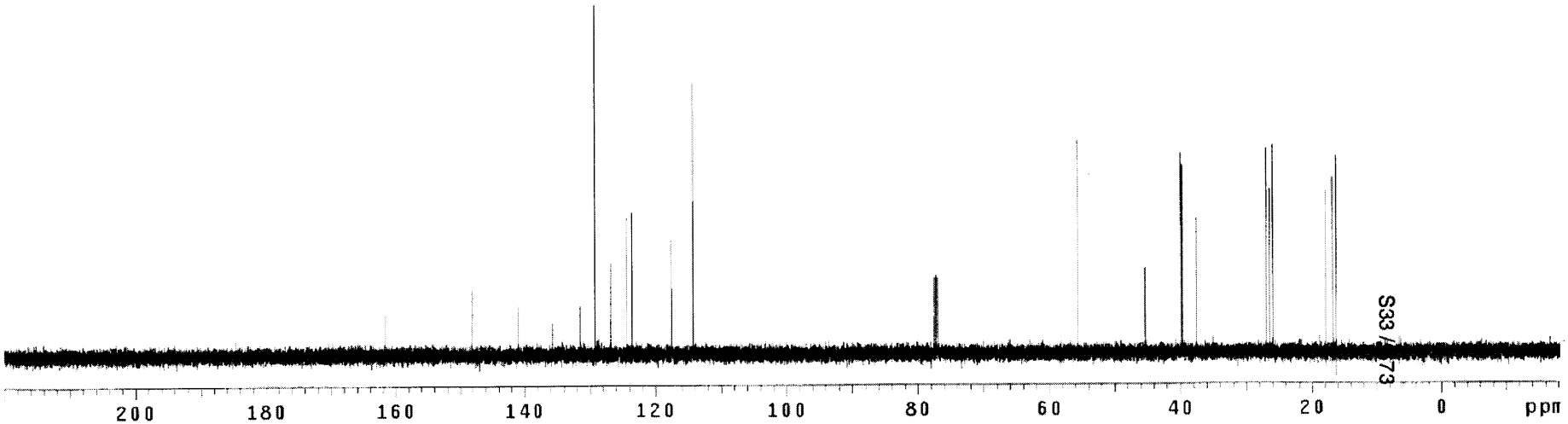
ACQUISITION		DEC. & VT		PROCESSING	
sfrq	125.795	dfrq	500.229	lb	0.00
tn	C13	dn	H1	wtfile	
at	1.736	dpwr	37	proc	ft
np	131010	dof	-500.0	fn	131072
sw	37735.8	dm	y	math	f
fb	not used	dmm	w		
bs	10	dmf	10000		
ss	1	dseq			
tpwr	53	dres	1.0		
pw	6.9	homo	n		
d1	0.763				
tof	631.4				
nt	20				
ct	20				
alock	n				
gain	not used				

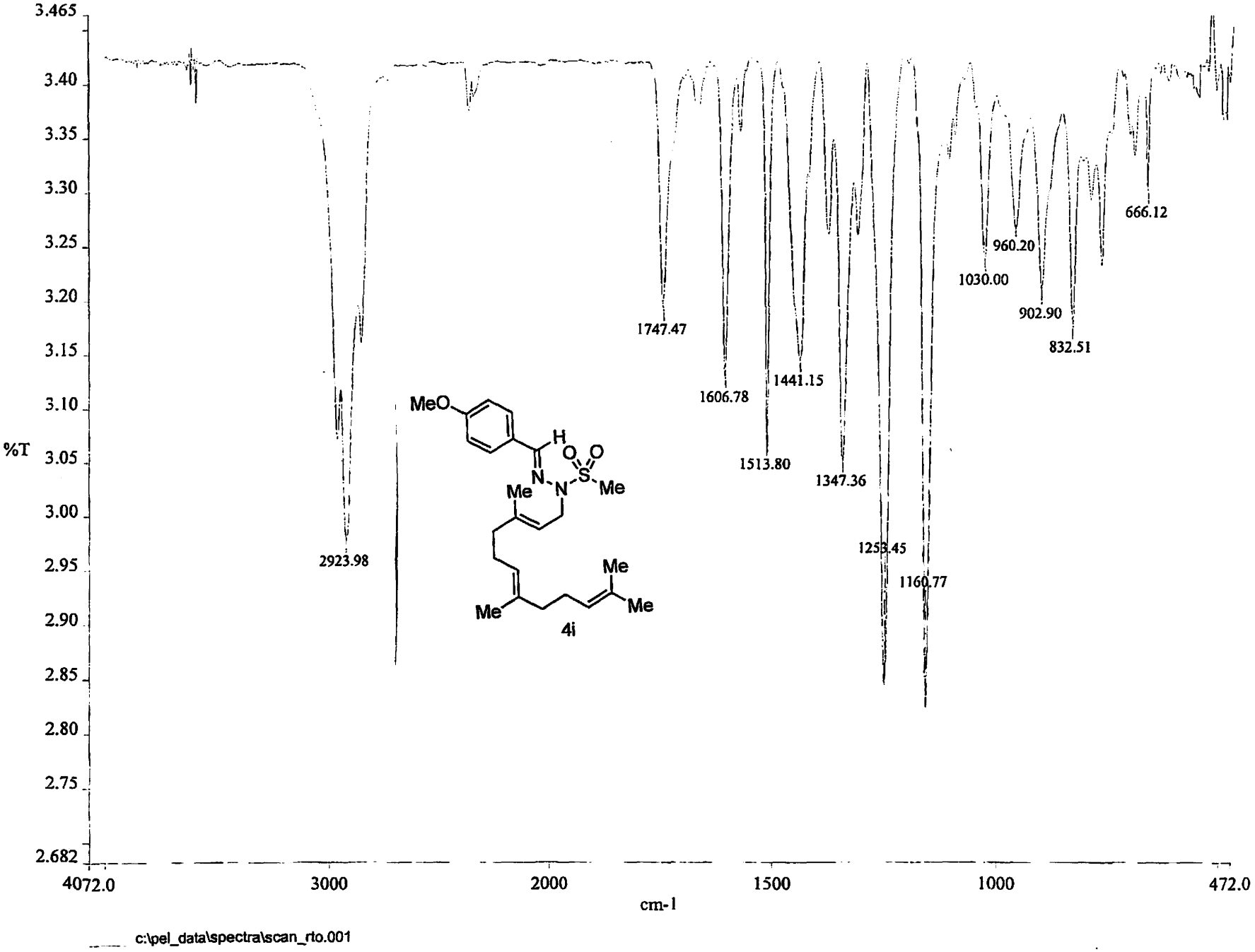
FLAGS	
il	n
in	n
dp	y
hs	nn

DISPLAY	
sp	-2516.0
wp	30189.9
vs	48
sc	0
wc	250
hzmm	120.76
is	500.00
rfl	16009.3
rfp	9714.9
th	6
ins	1.000
ai	ph



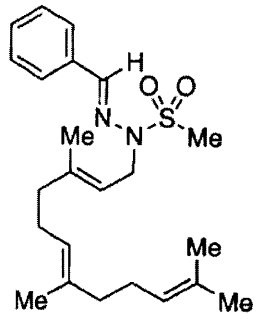
4i



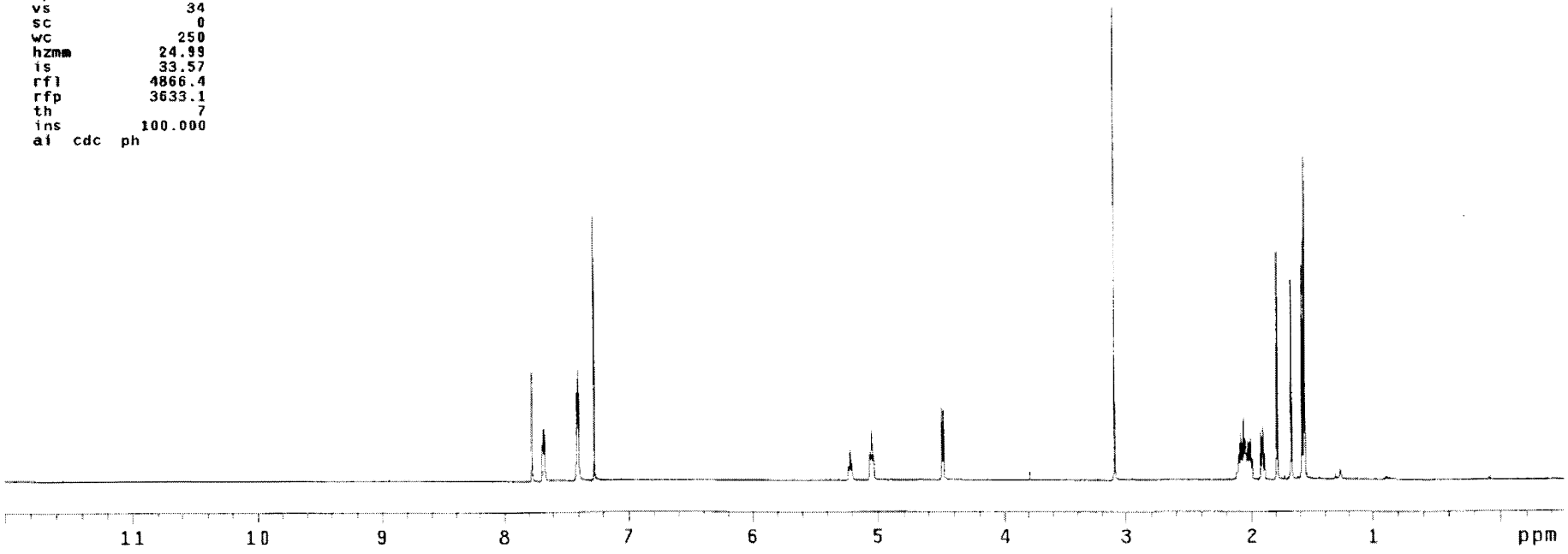

3.465
3.40
3.35
3.30
3.25
3.20
3.15
3.10
3.05
3.00
2.95
2.90
2.85
2.80
2.75
2.682
%T
4072.0
3000
2000
1500
1000
472.0
cm-1
2923.98
1747.47
1606.78
1513.80
1441.15
1347.36
1253.45
1160.77
1030.00
960.20
902.90
832.51
666.12
MeO
H
O
O
N
N
S
Me
Me
Me
Me
Me
4i
c:\pel_data\spectra\scan_rto.001

ACQUISITION	
sfrq	499.746
tn	H1
at	3.001
np	63050
sw	10504.2
fb	not used
bs	2
tpwr	56
pw	8.6
d1	2.000
tof	1519.5
nt	32
ct	6
alock	n
gain	not used
FLAGS	
il	n
in	n
dp	y
hs	nn
DISPLAY	
sp	-249.9
wp	6246.7
vs	34
sc	0
wc	250
hzmm	24.99
is	33.57
rfl	4866.4
rfp	3633.1
th	7
ins	100.000
ai cdc ph	

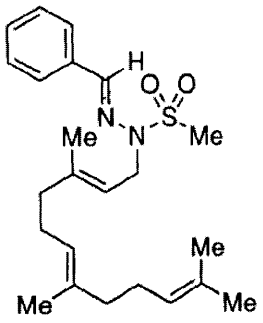
DEC. & VT	
dfrq	125.672
dn	C13
dpwr	30
dof	0
dm	nnn
dmm	w
dmf	10000
dseq	
dres	1.0
homo	n
temp	22.0
PROCESSING	
wtfile	
proc	ft
fn	262144
math	f
werr	
wexp	
wbs	
wnt	wft



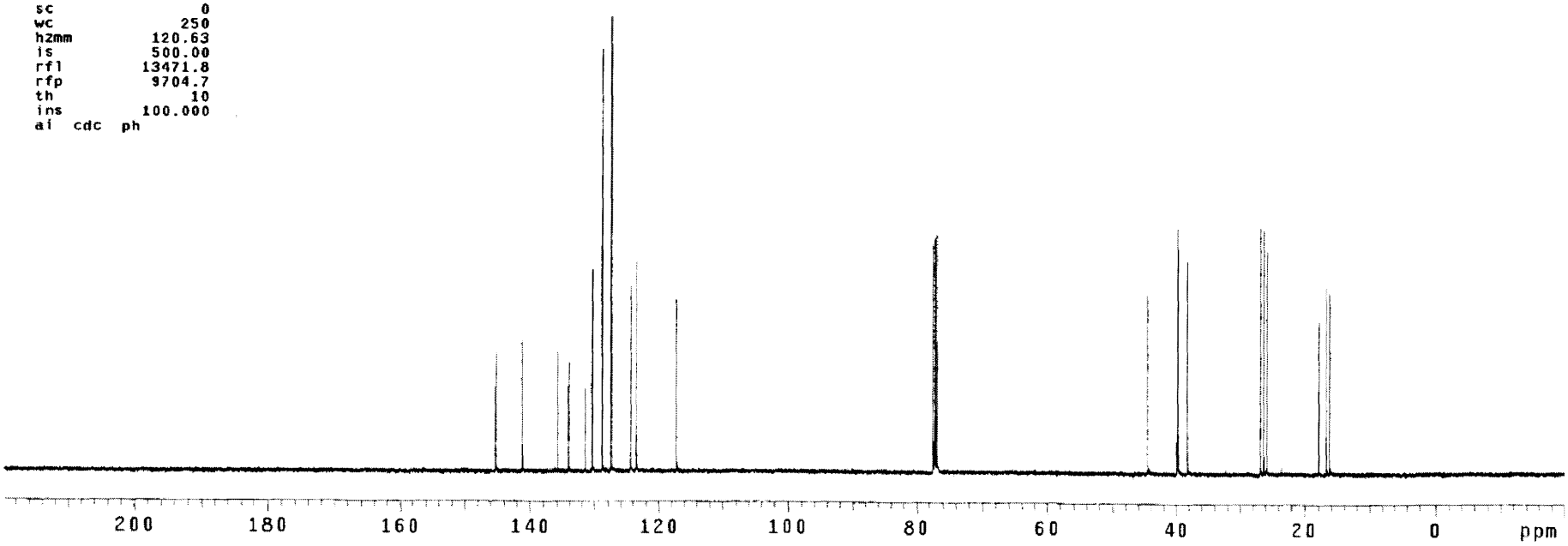
4j

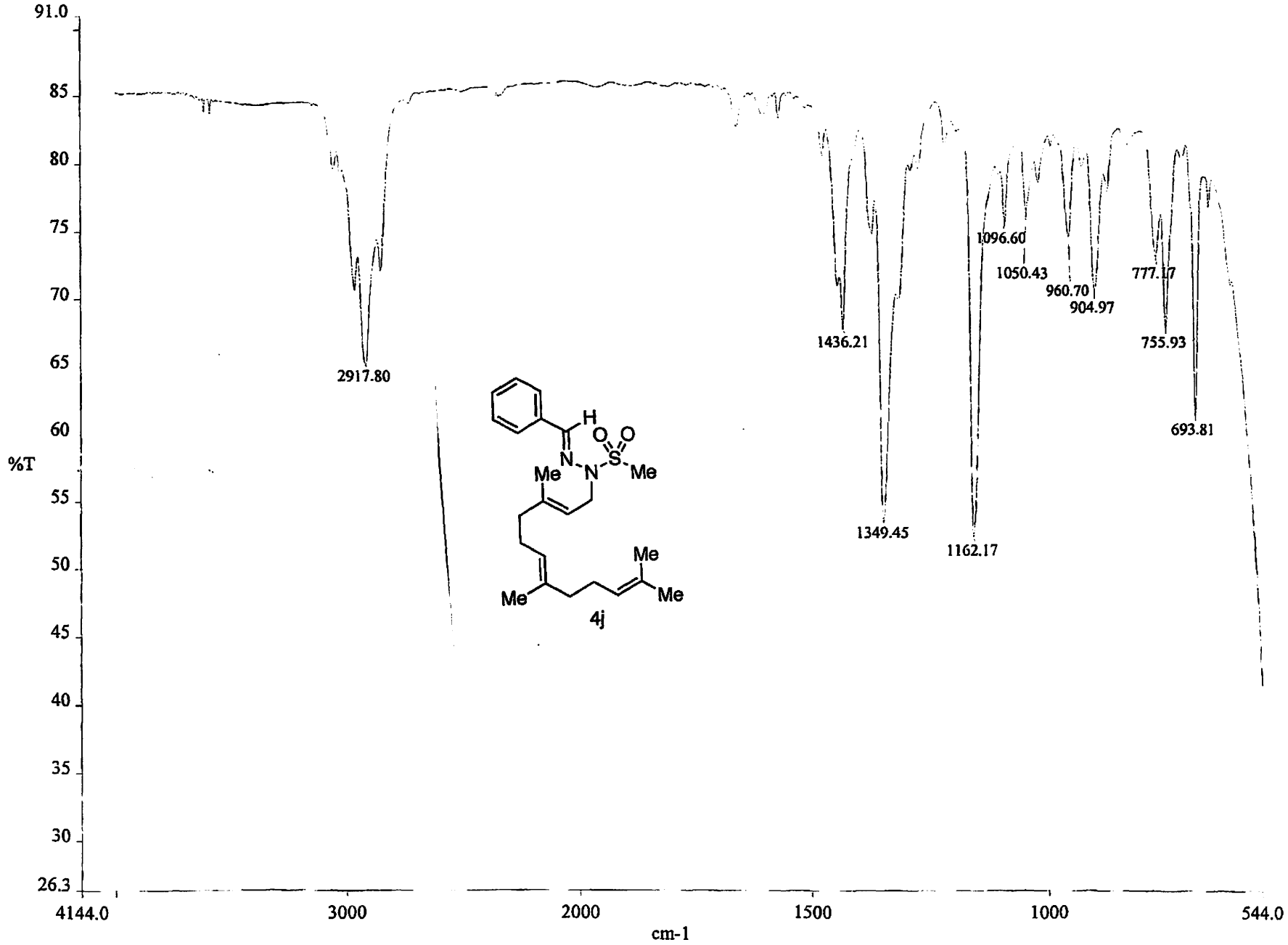


ACQUISITION		DEC. & VT	
sfrq	125.672	dfrq	499.744
tn	C13	dn	H1
at	2.000	dpwr	41
np	125588	dof	0
sw	31397.2	dm	yyy
fb	not used	dmm	w
bs	8	dmf	10000
tpwr	57	dseq	
pw	6.7	dres	1.0
d1	3.000	homo	n
tof	0	PROCESSING	
nt	1000	lb	1.00
ct	280	wtfile	
alock	n	proc	ft
gain	not used	fn	131072
FLAGS		math	f
il	n	werr	
in	n	wexp	
dp	y	wbs	
hs	nn	wnt	
DISPLAY			
sp	-2528.6		
wp	30158.3		
vs	216		
sc	0		
wc	250		
hzmm	120.63		
is	500.00		
rfl	13471.8		
rfp	9704.7		
th	10		
ins	100.000		
ai cdc ph			



4j

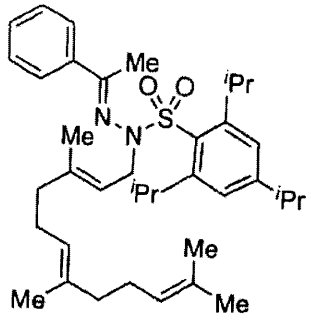



91.0
85
80
75
70
65
60
55
50
45
40
35
30
26.3
%T
2917.80
1436.21
1349.45
1162.17
1096.60
1050.43
960.70
904.97
777.17
755.93
693.81
4144.0
3000
2000
1500
1000
544.0
cm-1
H
O
O
N
N
S
Me
Me
Me
Me
Me
4j

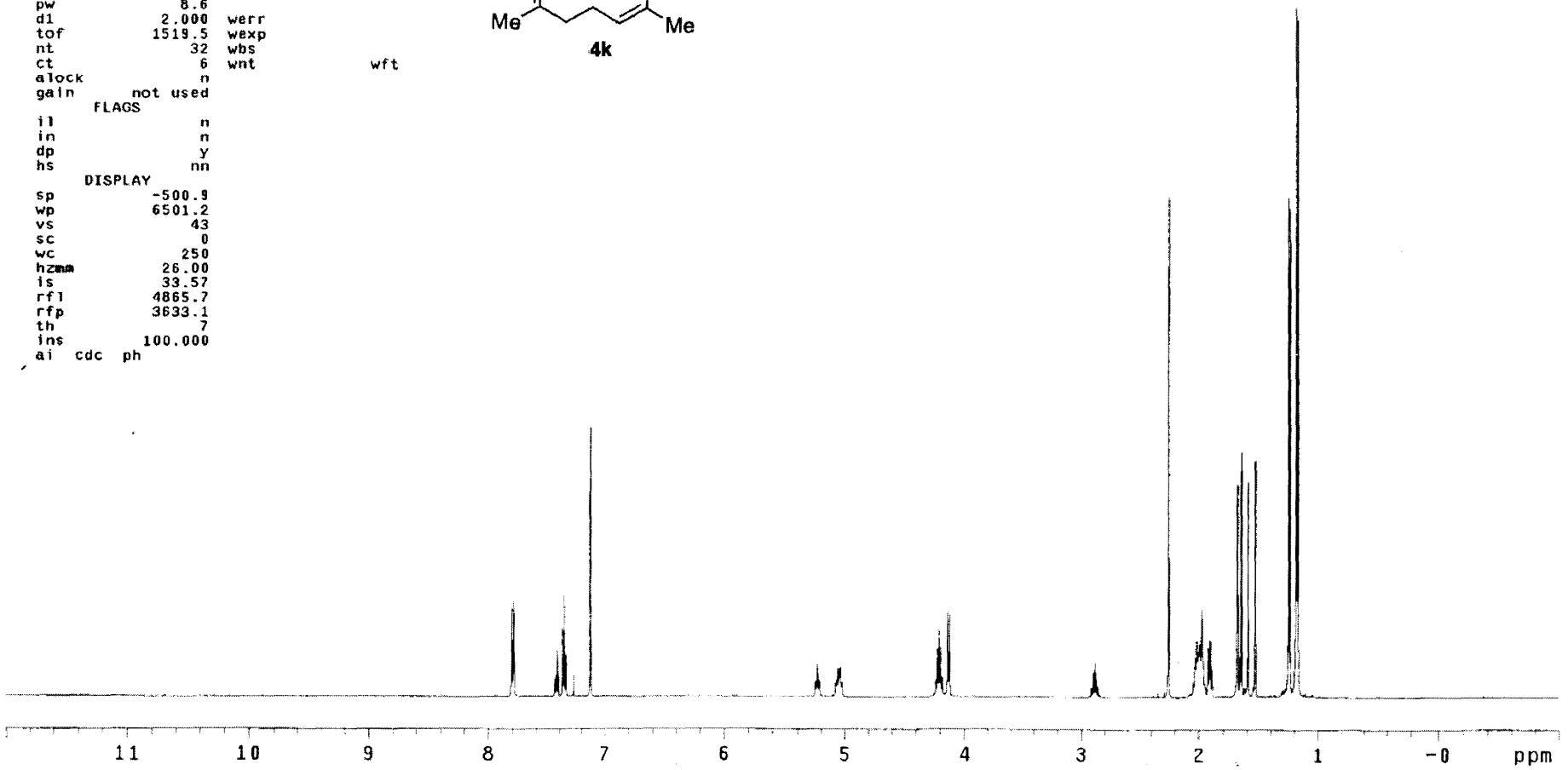
ACQUISITION	
sfrq	499.746
tn	H1
at	3.001
np	63050
sw	10504.2
fb	not used
bs	2
tpwr	56
pw	8.6
d1	2.000
tof	1519.5
nt	32
ct	6
alock	n
gain	not used
FLAGS	
il	n
in	n
dp	y
hs	nn
DISPLAY	
sp	-500.9
wp	6501.2
vs	43
sc	0
wc	250
hzmm	26.00
is	33.57
rfl	4865.7
rfp	3633.1
th	7
ins	100.000

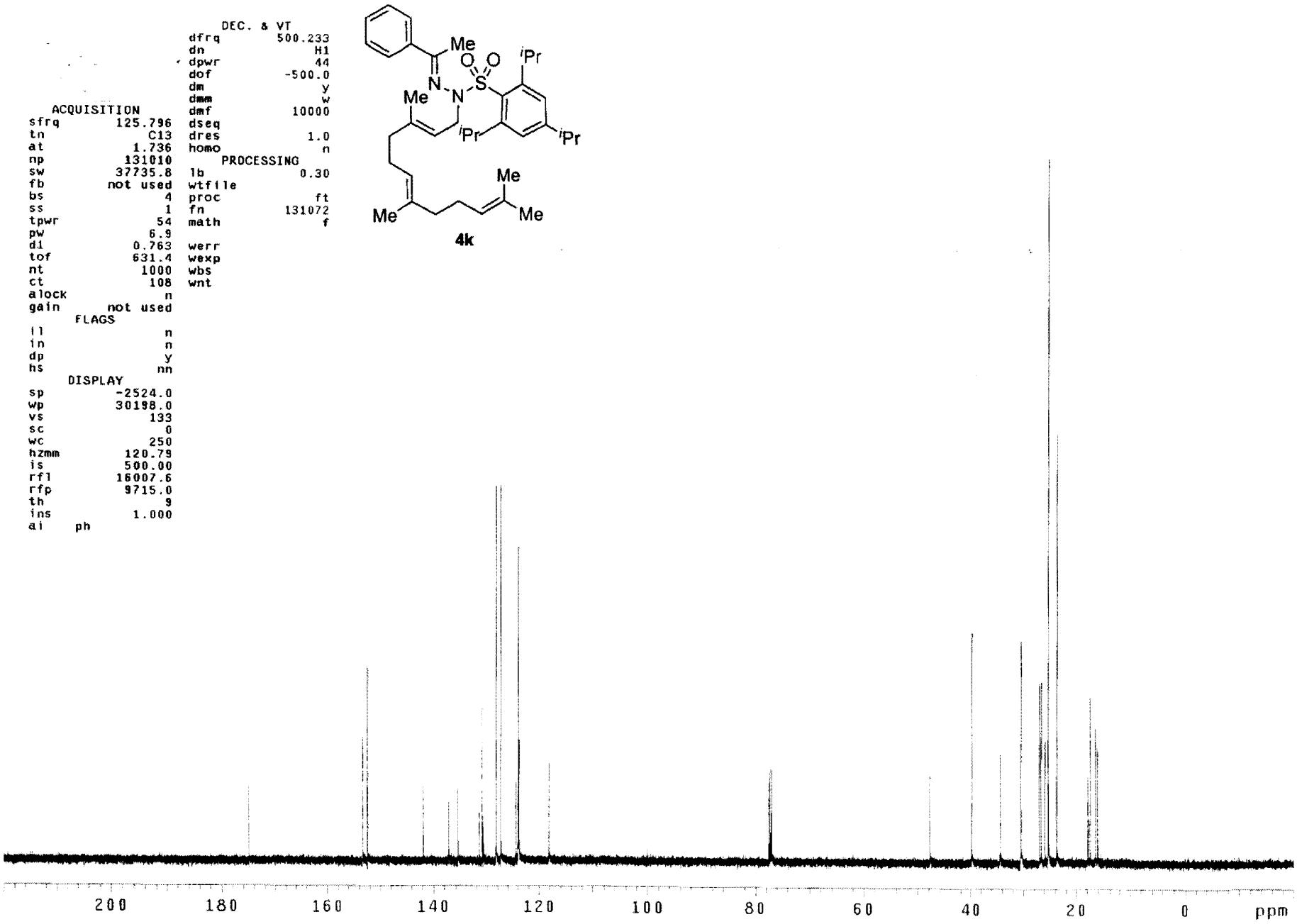
ai cdc ph

DEC. & VT	
dfrq	125.672
dn	C13
dpwr	30
dof	0
dm	nnn
dmm	w
dmf	10000
dseq	
dres	1.0
homo	n
PROCESSING	
wtfile	
proc	ft
fn	262144
math	f
werr	
wexp	
wbs	
wnt	wft



4k

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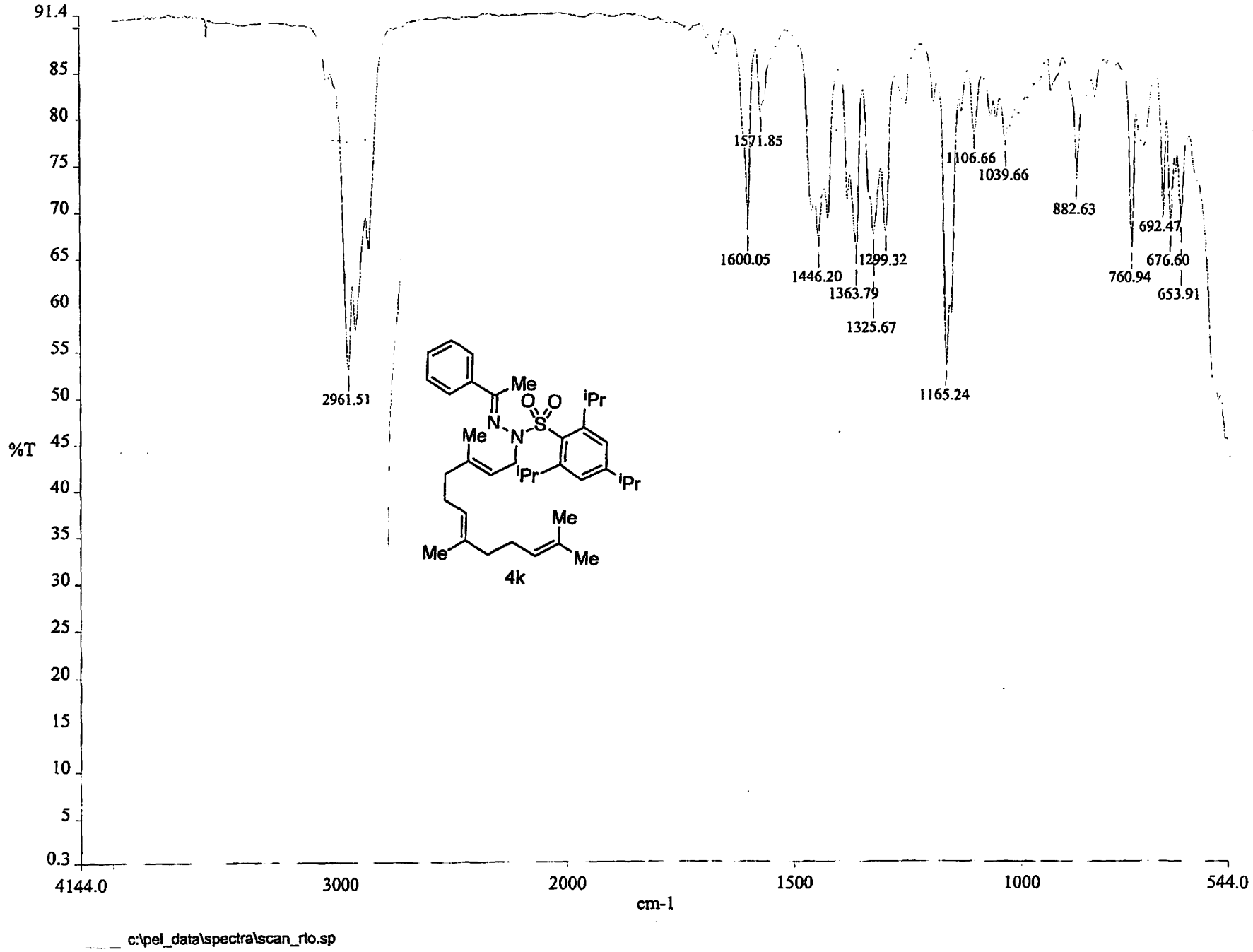
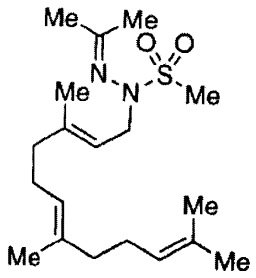
sfrq 125.796
tn C13
at 1.736
np 131010
sw 37735.8
fb not used
bs 4
ss 1
tpwr 54
pw 6.9
d1 0.763
tof 631.4
nt 1000
ct 108
alock n
gain not used
FLAGS
il n
in n
dp y
hs nn
DISPLAY
sp -2524.0
wp 30198.0
vs 133
sc 0
wc 250
hzmm 120.79
is 500.00
rfl 16007.6
rfp 9715.0
th 9
ins 1.000
ai ph
DEC. & VT
dfrq 500.233
dn H1
dpwr 44
dof -500.0
dm y
dmm w
dmf 10000
dseq
dres 1.0
homo n
PROCESSING
lb 0.30
wtfile
proc ft
fn 131072
math f
werr
wexp
wbs
wnt
Me
O
O
iPr
N
S
Me
N
iPr
iPr
Me
Me
Me
4k
200
180
160
140
120
100
80
60
40
20
0
ppm

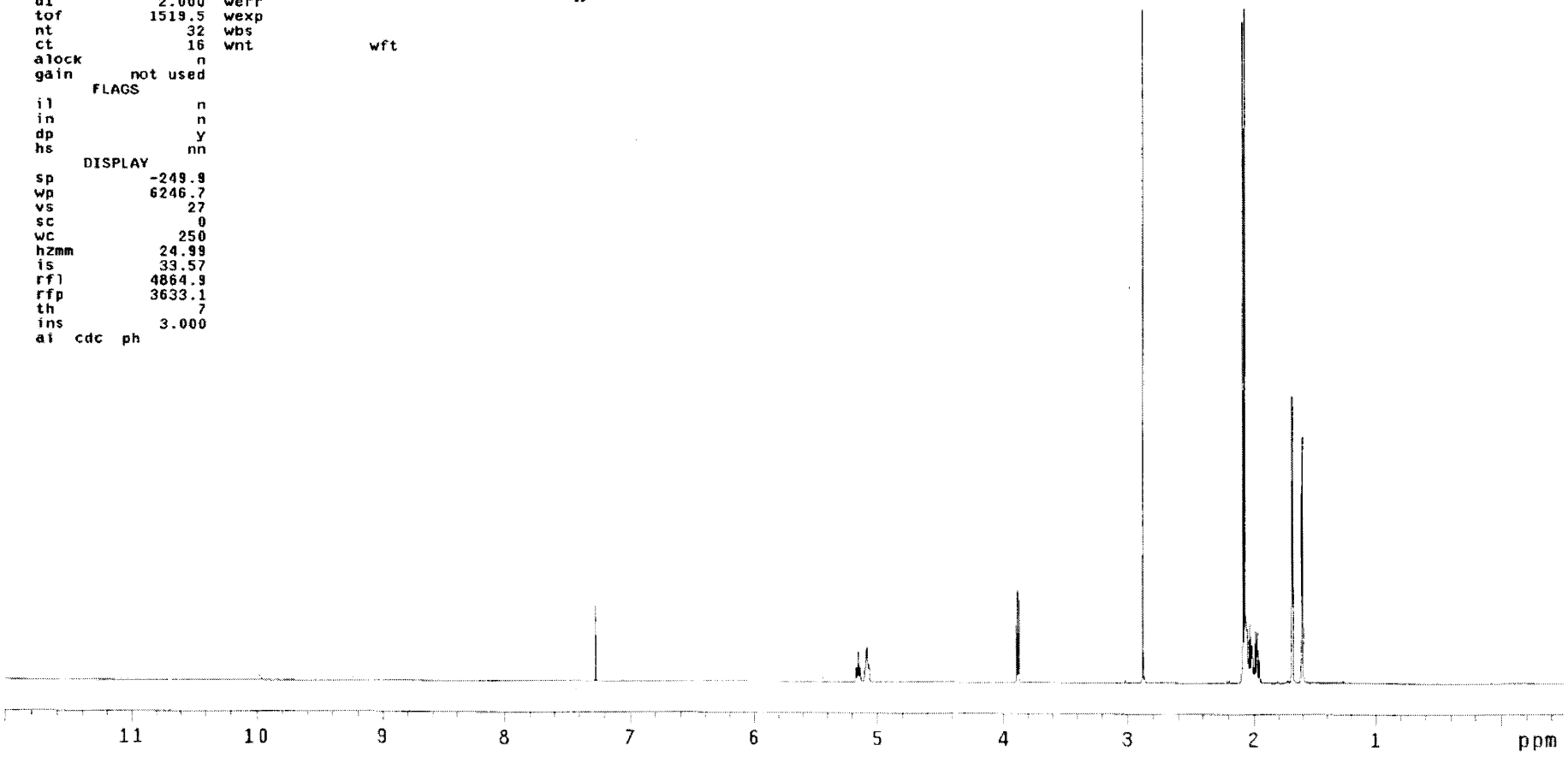

91.4
85
80
75
70
65
60
55
50
45
40
35
30
25
20
15
10
5
0.3
%T
2961.51
1600.05
1571.85
1446.20
1363.79
1325.67
1299.32
1165.24
1106.66
1039.66
882.63
760.94
692.47
676.60
653.91
Me
O
O
N
N
S
Me
iPr
iPr
iPr
Me
Me
Me
4k
4144.0
3000
2000
1500
1000
544.0
cm-1
c:\pel_data\spectra\scan_rto.sp

ACQUISITION	
sfrq	499.746
tn	H1
at	3.001
np	63050
sw	10504.2
fb	not used
bs	2
tpwr	56
pw	8.6
d1	2.000
tof	1519.5
nt	32
ct	16
alock	n
gain	not used
FLAGS	
il	n
in	n
dp	y
hs	nn
DISPLAY	
sp	-249.9
wp	6246.7
vs	27
sc	0
wc	250
hzmm	24.99
is	33.57
rfl	4864.9
rfp	3633.1
th	7
ins	3.000
ai cdc ph	

DEC. & VT	
dfrq	125.672
dn	C13
dpwr	30
dof	0
dm	nnn
dmm	w
dmf	10000
dseq	
dres	1.0
homo	n
PROCESSING	
wtfile	
proc	ft
fn	262144
math	f
werr	
wexp	
wbs	
wnt	wft



4l



ACQUISITION	
sfrq	125.672
tn	C13
at	2.000
np	125588
sw	31397.2
fb	not used
bs	8
tpwr	57
pw	6.7
d1	3.000
tof	0
nt	1000
ct	176
alock	n
gain	not used

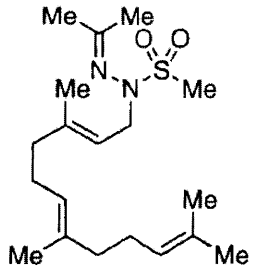
FLAGS	
il	n
in	n
dp	y
hs	nn

DISPLAY	
sp	-2527.2
wp	30158.7
vs	348
sc	0
wc	250
hzmm	120.63
is	500.00
rfl	13469.9
rfp	9704.7
th	13
ins	100.000

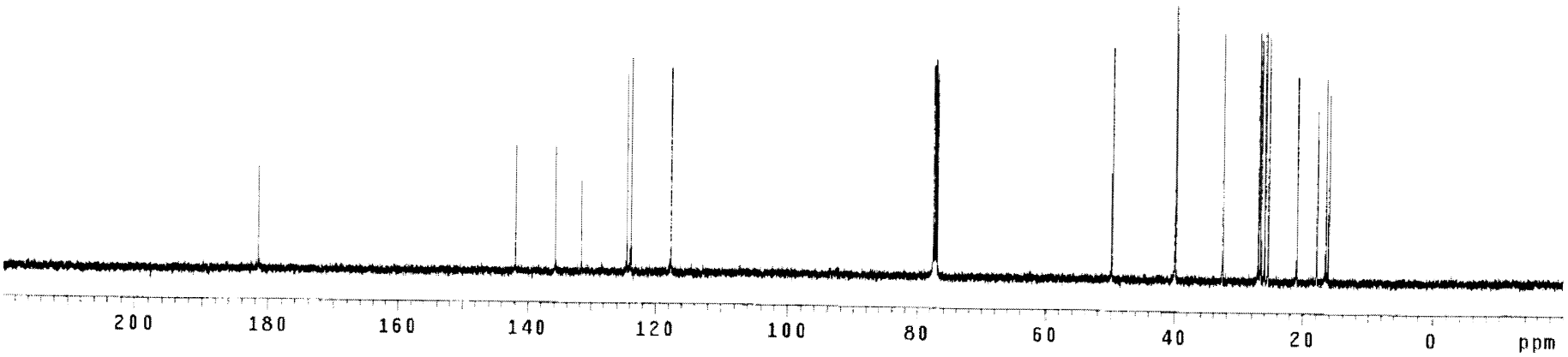
ai cdc ph

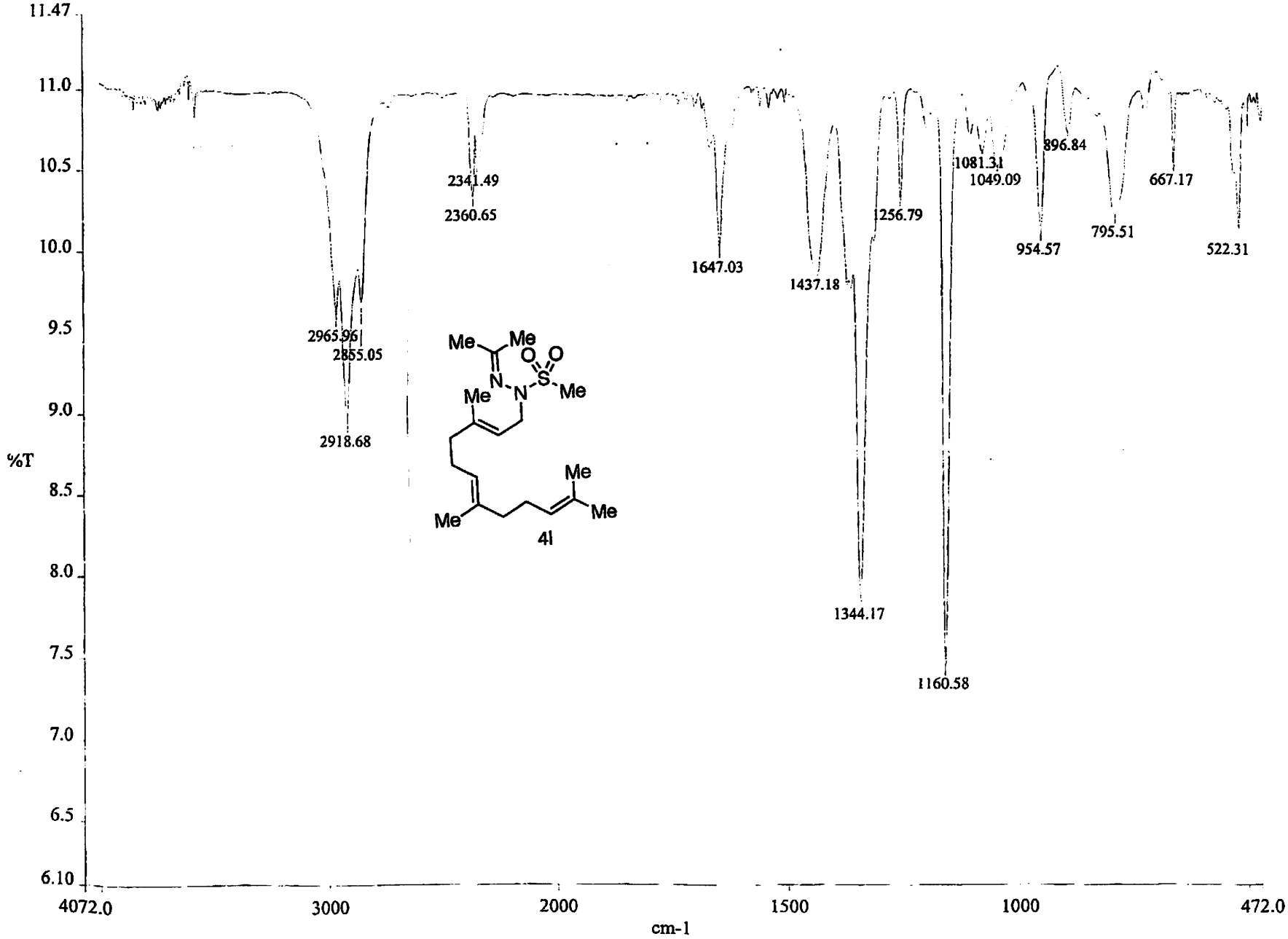
DEC. & VT	
dfrq	499.744
dn	H1
dpwr	41
dof	0
dm	yyy
dmm	w
dmf	10000
dseq	
dres	1.0
homo	n

PROCESSING	
lb	1.00
wtfile	
proc	ft
fn	131072
math	f
werr	
wexp	
wbs	
wnt	



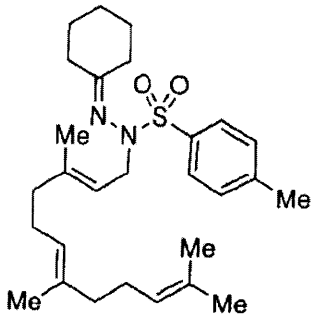
4l



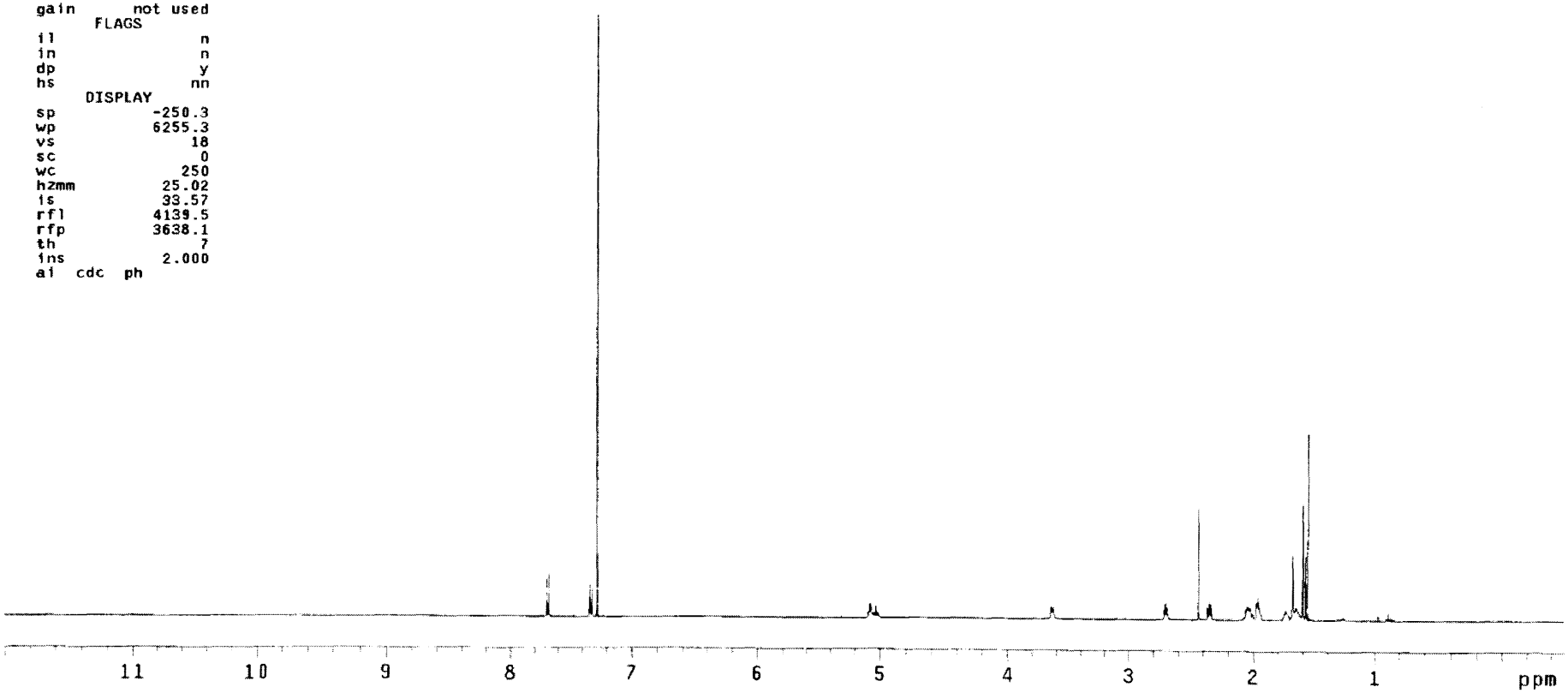

11.47
11.0
10.5
10.0
9.5
9.0
8.5
8.0
7.5
7.0
6.5
6.10
%T
4072.0
3000
2000
1500
1000
472.0
cm-1
2965.96
2855.05
2918.68
2341.49
2360.65
1647.03
1437.18
1344.17
1256.79
1160.58
1081.31
1049.09
896.84
954.57
795.51
667.17
522.31
Me
Me
O
O
N
S
Me
Me
N
Me
Me
Me
Me
4l

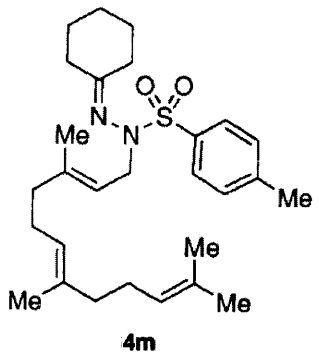
ACQUISITION	
sfrq	500.435
tn	H1
at	4.999
np	120102
sw	12012.0
fb	not used
bs	2
tpwr	56
pw	8.0
d1	0.100
tof	3003.2
nt	32
ct	14
alock	n
gain	not used
FLAGS	
il	n
in	n
dp	y
hs	nn
DISPLAY	
sp	-250.3
wp	6255.3
vs	18
sc	0
wc	250
hzmm	25.02
is	33.57
rfl	4139.5
rfp	3638.1
th	7
ins	2.000
ai cdc ph	

DEC. & VT	
dfrq	125.845
dn	C13
dpwr	30
dof	0
dm	nnn
dmm	c
dmf	200
dseq	
dres	1.0
homo	n
PROCESSING	
wtfile	
proc	ft
fn	262144
math	f
werr	
wexp	
wbs	
wnt	wft



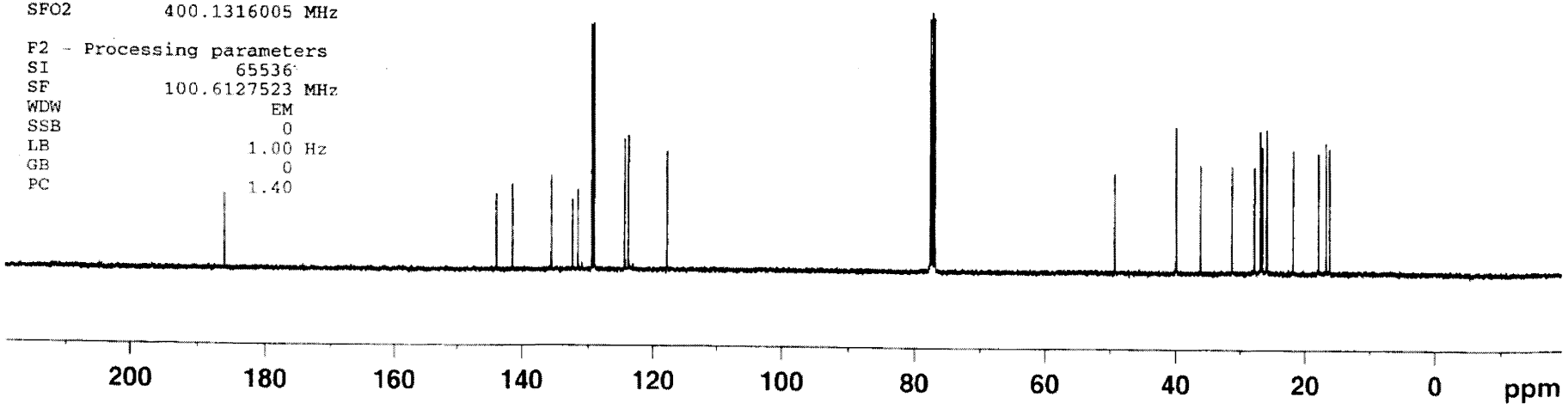
4m

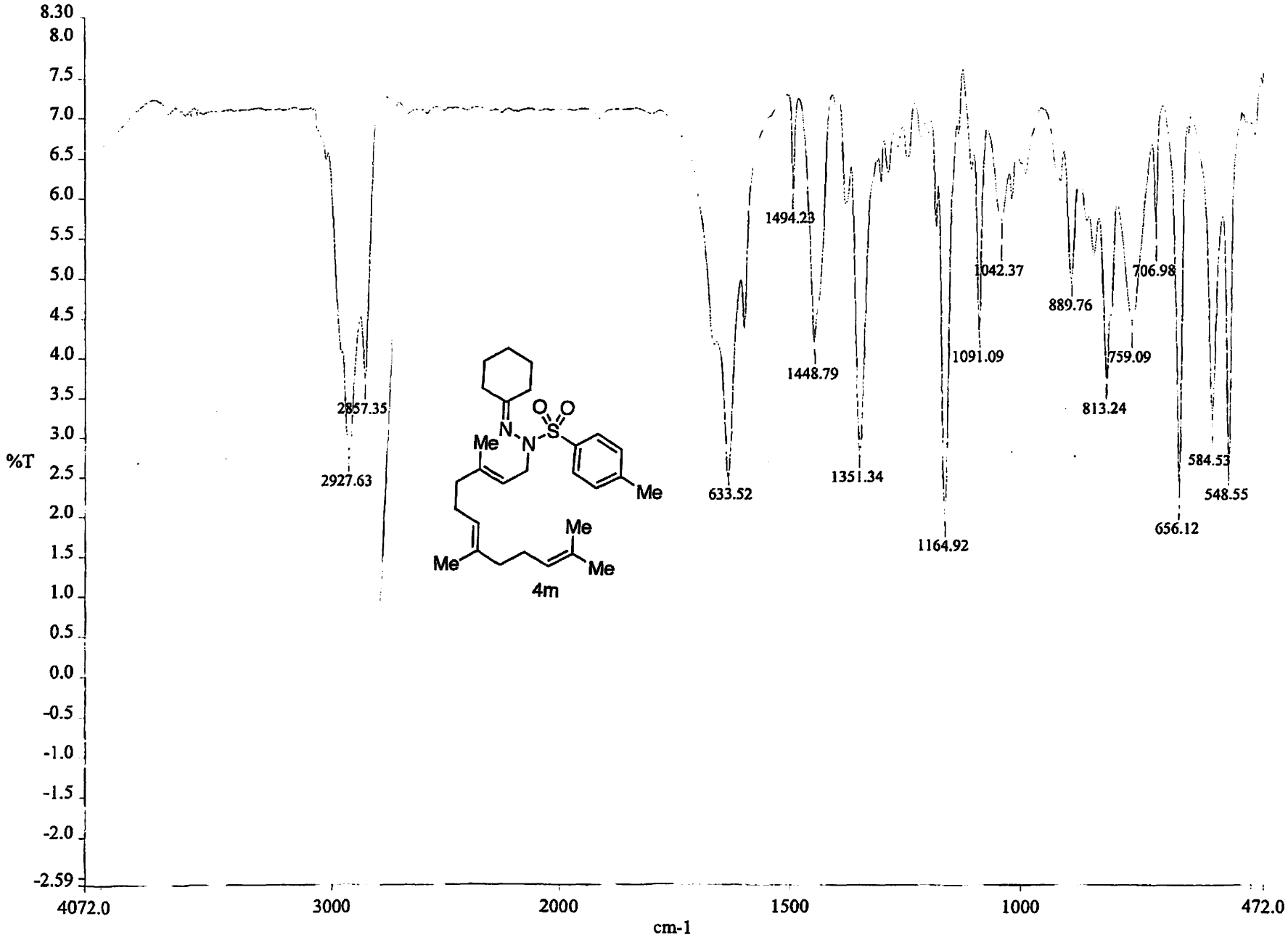




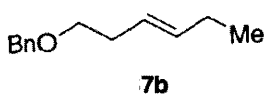
4m

```
F2 - Acquisition Parameters
Date_            20070622
Time                19.01
INSTRUM             spect
PROBHD   5 mm BBO BB-1H
PULPROG           zgpg30
TD                 65536
SOLVENT            CDCl3
NS                   478
DS                     2
SWH            23980.814 Hz
FIDRES          0.365918 Hz
AQ             1.3664756 sec
RG                 16384
DW                20.850 usec
DE                 6.00 usec
TE                293.2 K
D1            2.00000000 sec
d11           0.03000000 sec
DELTA         1.89999998 sec
TD0                    1

======== CHANNEL f1 ========
NUC1                13C
P1                 8.75 usec
PL1               -3.00 dB
SFO1         100.6228298 MHz

======== CHANNEL f2 ========
CPDPRG2          waltz16
NUC2                1H
PCPD2              90.00 usec
PL2                -1.00 dB
PL12               14.52 dB
PL13               18.00 dB
SFO2         400.1316005 MHz

F2 - Processing parameters
SI                 65536
SF           100.6127523 MHz
WDW                   EM
SSB                    0
LB                  1.00 Hz
GB                     0
PC                  1.40
```




8.30
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
-0.5
-1.0
-1.5
-2.0
-2.59
%T
2927.63
2857.35
1494.23
1448.79
1351.34
1164.92
1091.09
1042.37
889.76
813.24
759.09
706.98
656.12
633.52
584.53
548.55
Me
Me
Me
Me
4m
4072.0
3000
2000
1500
1000
472.0
cm-1

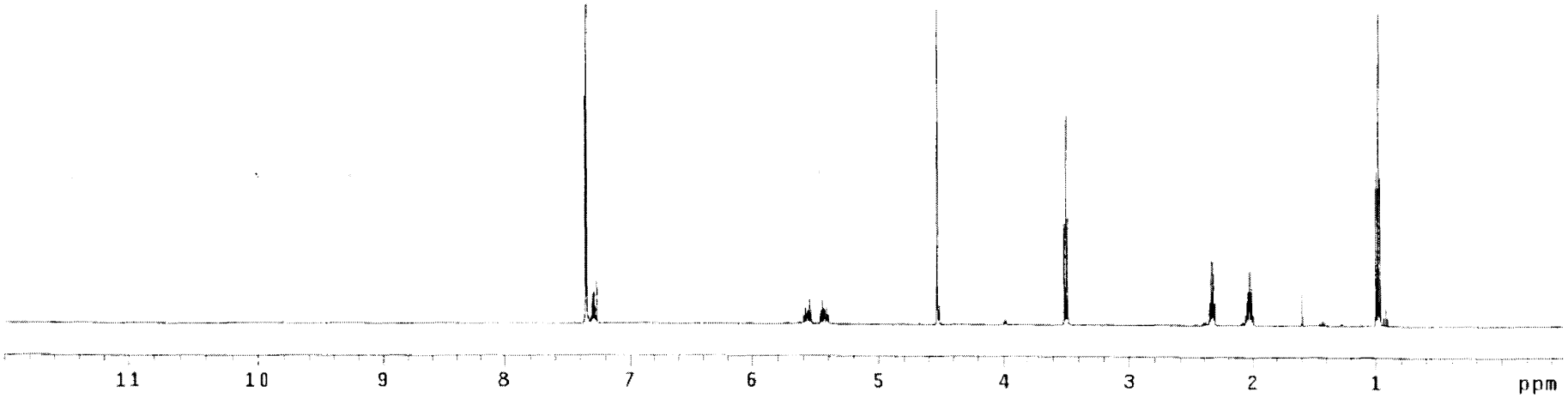
STANDARD PROTON PARAMETERS

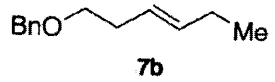


7b

ACQUISITION		DEC. & VT	
sfrq	499.746	dfrq	125.672
tn	H1	dn	C13
at	3.001	dpwr	30
np	63050	dof	0
sw	10504.2	dm	nnn
fb	not used	dmm	w
bs	2	dmf	10000
tpwr	59	dseq	
pw	8.6	dres	1.0
d1	2.000	homo	n
tof	1519.5	PROCESSING	
nt	32	wtfile	
ct	18	proc	ft
alock	n	fn	262144
gain	not used	math	f
FLAGS		werr	
il	n	wexp	
in	n	wbs	
dp	y	wnt	wft
hs	nn		
DISPLAY			
sp	-249.9		
wp	6246.7		
vs	23		
sc	0		
wc	250		
hzmm	24.99		
is	33.57		
rfl	1233.8		
rfp	0		
th	7		
ins	100.000		

ai cdc ph





7b

ACQUISITION	
sfrq	125.672
tn	C13
at	2.000
np	125588
sw	31397.2
fb	not used
bs	10
tpwr	57
pw	6.7
d1	3.000
tof	0
nt	1000
ct	120
alock	n
gain	not used

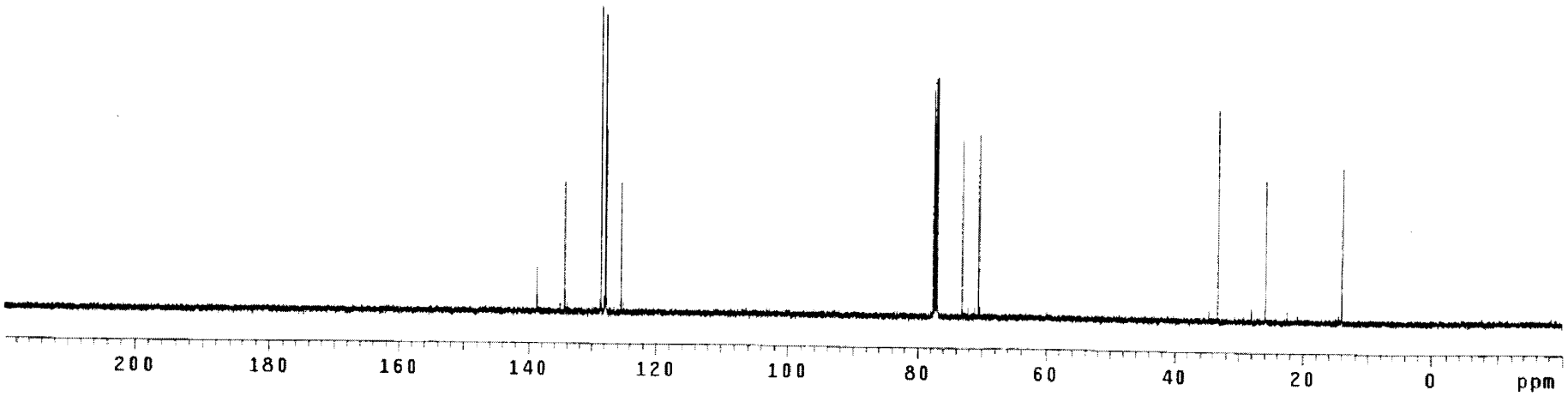
FLAGS	
il	n
in	n
dp	y
hs	nn

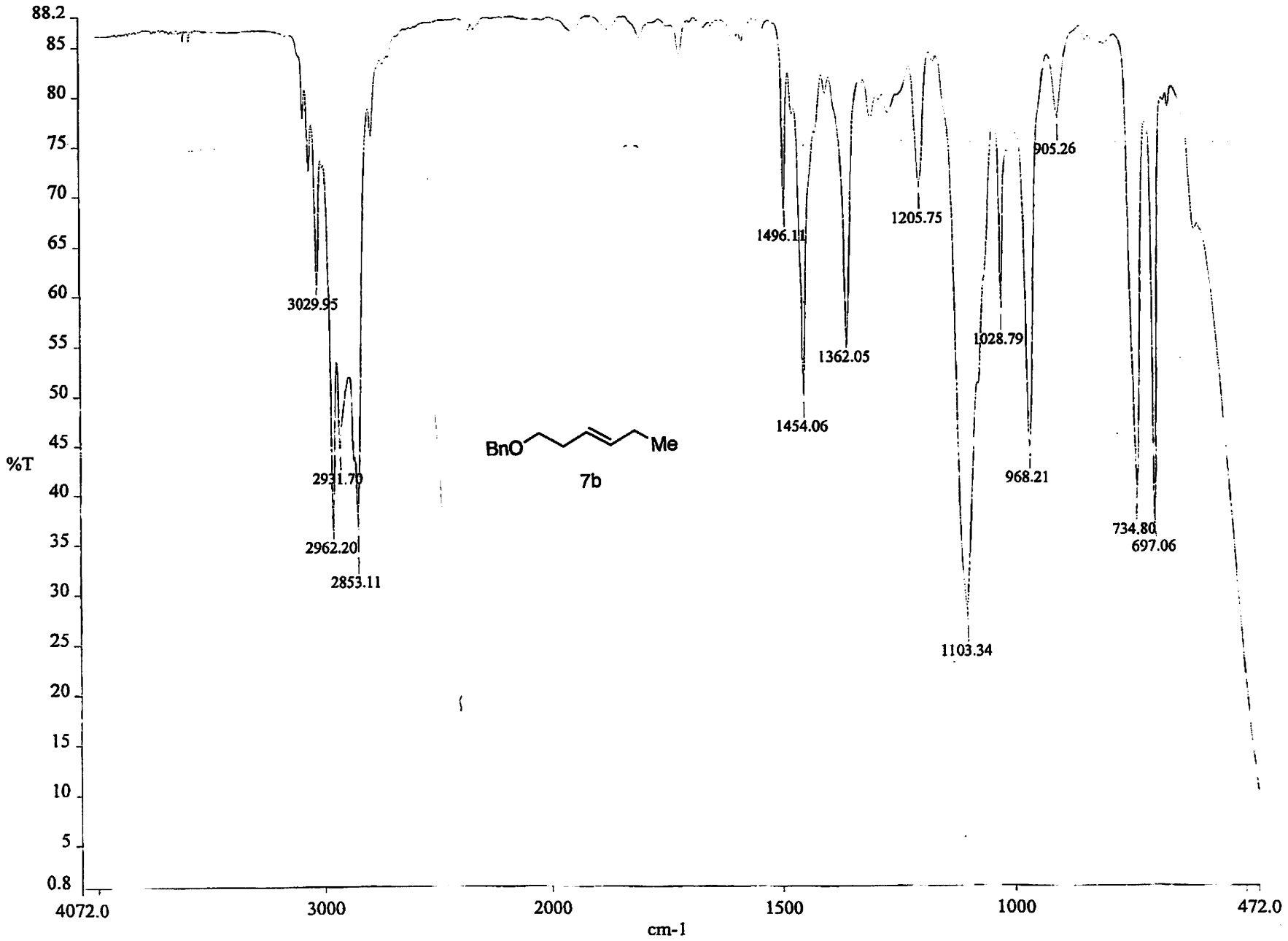
DISPLAY	
sp	-2525.3
wp	30158.3
vs	201
sc	0
wc	250
hzmm	120.63
is	500.00
rfl	13468.5
rfp	9704.7
th	9
ins	100.000

ai cdc ph

DEC. & VT	
dfrq	499.744
dn	H1
dpwr	41
dof	0
dm	yyy
dmm	w
dmf	10000
dseq	
dres	1.0
homo	n

PROCESSING	
lb	1.00
wtfile	
proc	ft
fn	131072
math	f
werr	
wexp	
wbs	
wnt	




88.2
85
80
75
70
65
60
55
50
45
40
35
30
25
20
15
10
5
0.8
%T
3029.95
2931.70
2962.20
2853.11
1496.11
1454.06
1362.05
1205.75
1103.34
1028.79
968.21
905.26
734.80
697.06
BnO
Me
7b
4072.0
3000
2000
1500
1000
472.0
cm-1

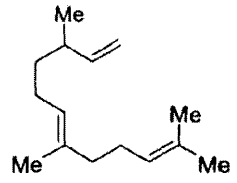
ACQUISITION	
sfrq	499.749
tn	H1
at	3.001
np	63050
sw	10504.2
fb	not used
bs	2
tpwr	56
pw	8.9
d1	2.000
tof	1519.5
nt	32
ct	0
alock	n
gain	not used

FLAGS	
il	n
in	n
dp	y
hs	nn

DISPLAY	
sp	-251.4
wp	6246.8
vs	119
sc	0
wc	250
hzmm	24.98
is	33.57
rfl	4868.4
rfp	3633.1
th	7
ins	3.000
nm	cdc ph

DEC. & VT	
dfrq	125.673
dn	C13
dpwr	30
dof	0
dm	nnn
dmm	w
dmf	10000
dseq	
dres	1.0
homo	n

PROCESSING	
wtfile	
proc	ft
fn	131072
math	f
werr	
wexp	
wbs	
wnt	wft



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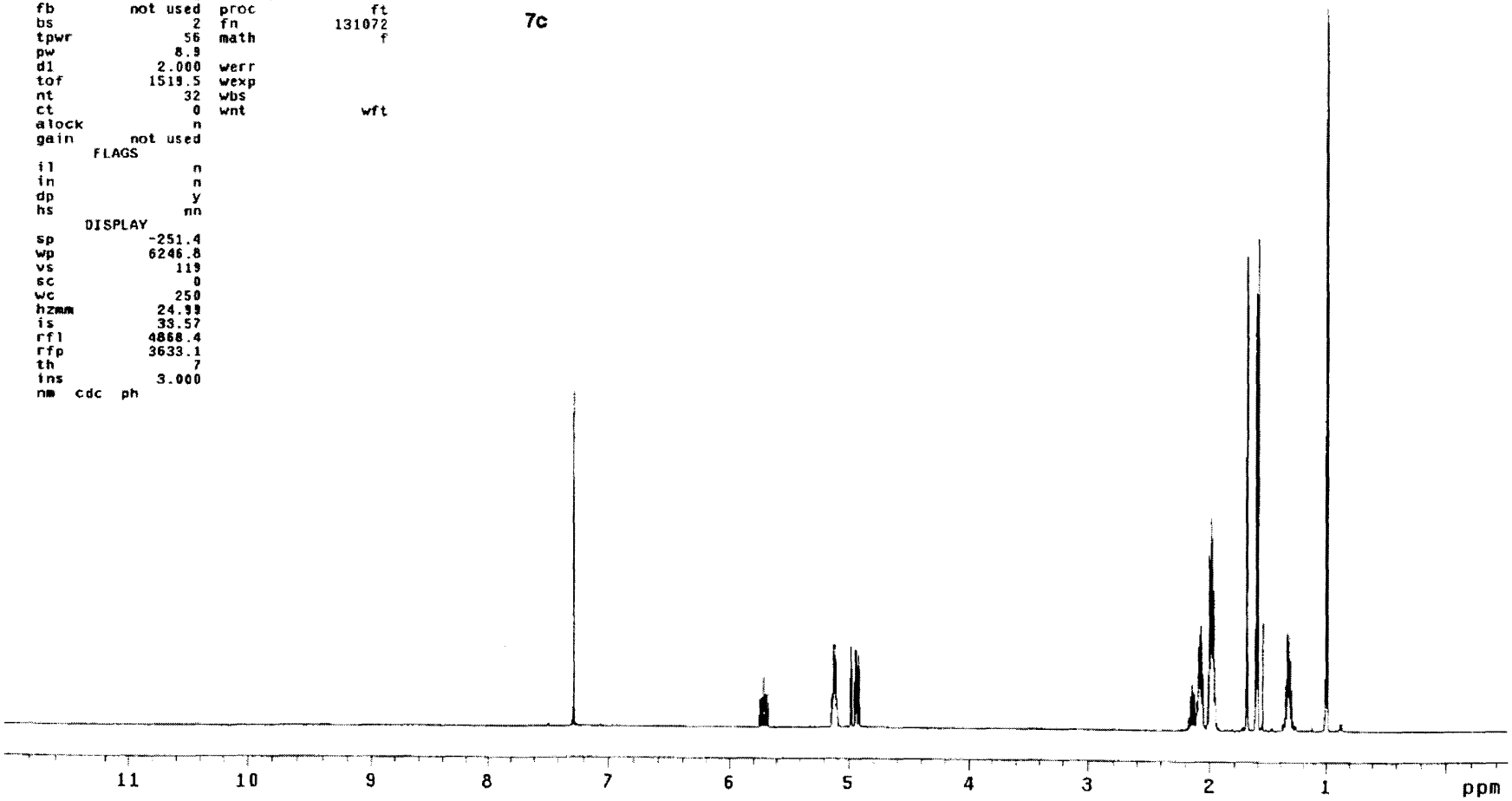
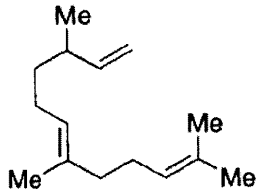


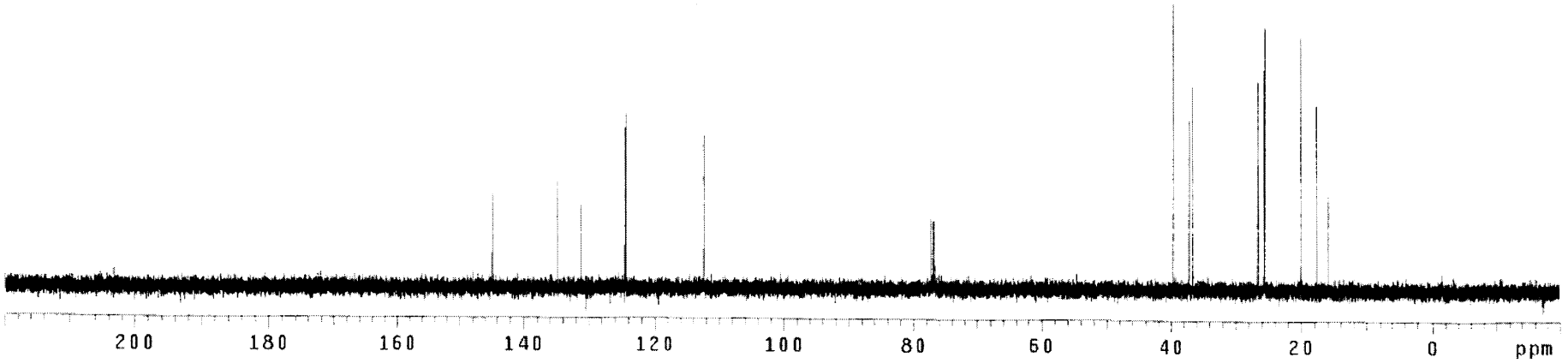
STANDARD CARBON PARAMETERS

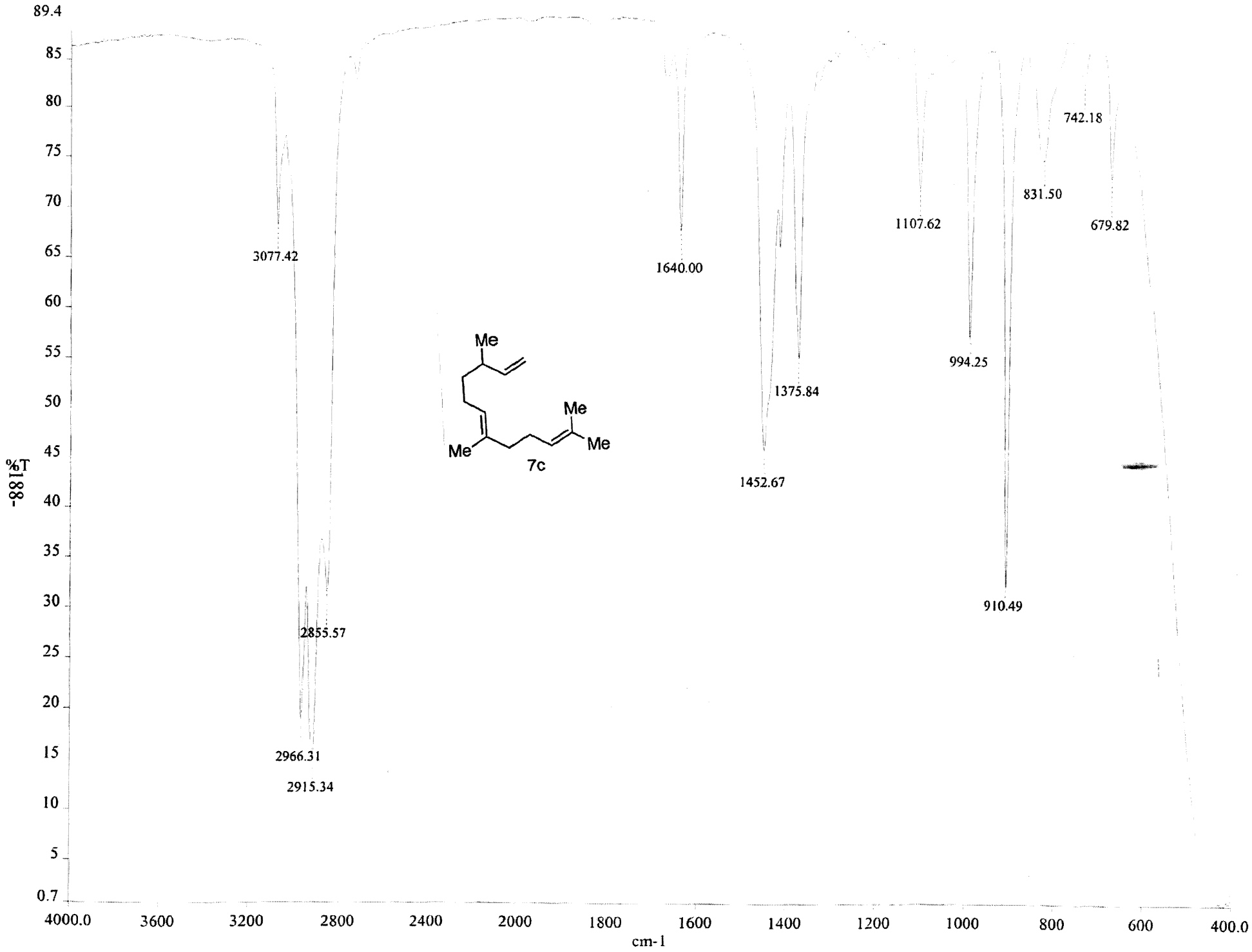
e

		DEC. & VT	
		dfrq	500.233
		dn	H1
		dpwr	37
		dof	-500.0
		dm	y
		dmm	w
ACQUISITION		dmf	10000
sfrq	125.796	dseq	
tn	C13	dres	1.0
at	1.736	homo	n
np	131010	PROCESSING	
sw	37735.8	lb	0.30
fb	not used	wtfile	
bs	1	proc	ft
ss	1	fn	131072
tpwr	53	math	f
pw	6.9		
d1	0.763	werr	
tof	631.4	wexp	
nt	10000	wbs	
ct	0	wnt	
alock	n		
gain	not used		
FLAGS			
il	n		
in	n		
dp	y		
hs	nn		
DISPLAY			
sp	-2516.2		
wp	30189.9		
vs	98		
sc	0		
wc	250		
hzmm	120.76		
is	500.00		
rfl	16034.1		
rfp	9711.2		
th	20		
ins	1.000		
ai	ph		



7c




89.4
85
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75
70
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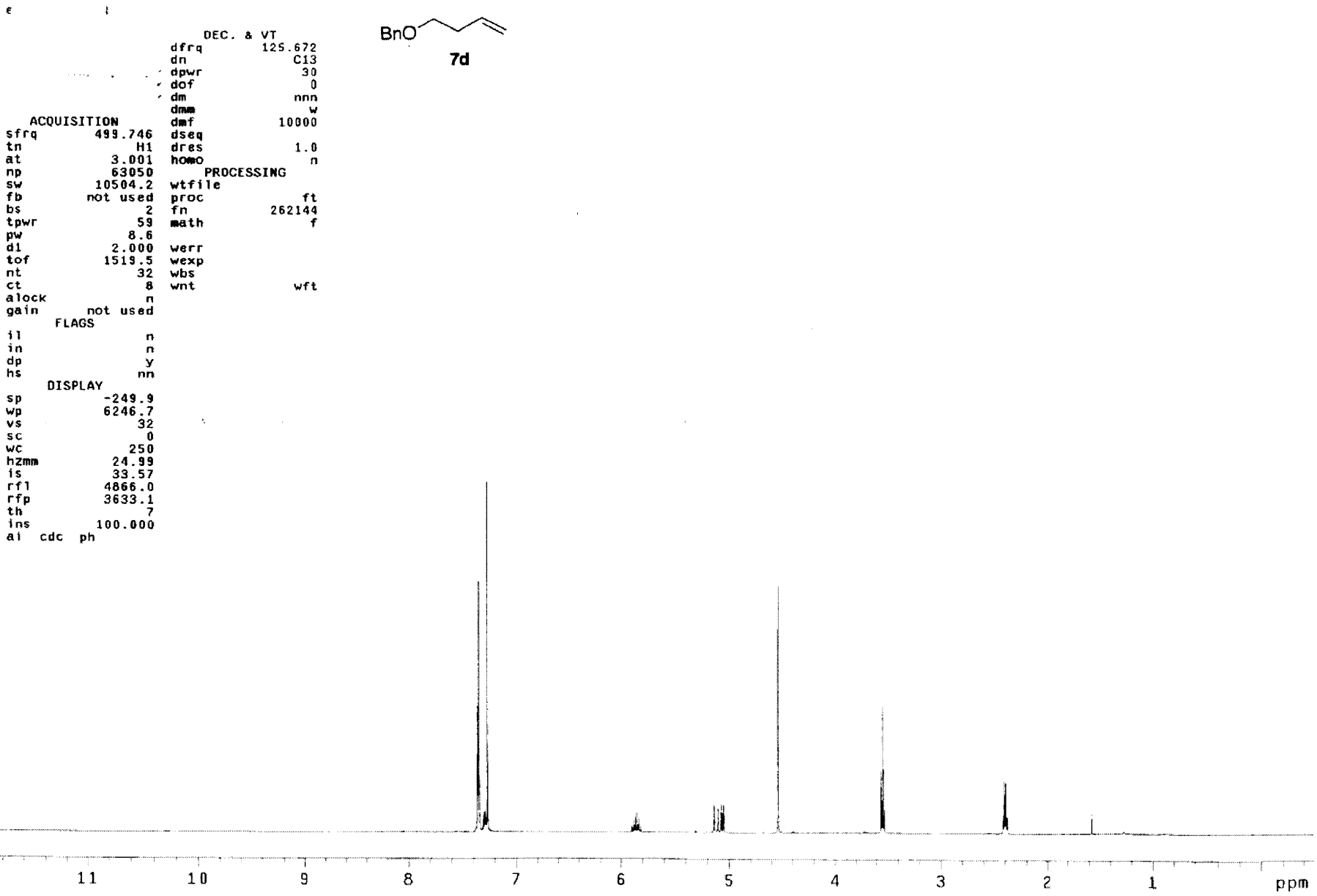
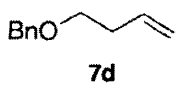
60
55
50
45
40
35
30
25
20
15
10
5
0.7
%T
-188-
3077.42
2855.57
2966.31
2915.34
1640.00
1452.67
1375.84
1107.62
994.25
910.49
831.50
742.18
679.82
Me
Me
Me
Me
7c
4000.0
3600
3200
2800
2400
2000
1800
1600
1400
1200
1000
800
600
400.0
cm-1


BnO
7d
DEC. & VT
dfrq 125.672
dn C13
dpwr 30
dof 0
dm nnn
dmm w
dmf 10000
dseq
dres 1.0
homo n
PROCESSING
wtfile
proc ft
fn 262144
math f
werr
wexp
wbs
wnt wft
ACQUISITION
sfrq 499.746
tn H1
at 3.001
np 63050
sw 10504.2
fb not used
bs 2
tpwr 59
pw 8.6
d1 2.000
tof 1519.5
nt 32
ct 8
alock n
gain not used
FLAGS
il n
in n
dp y
hs nn
DISPLAY
sp -249.9
wp 6246.7
vs 32
sc 0
wc 250
hzmm 24.99
is 33.57
rfl 4866.0
rfp 3633.1
th 7
ins 100.000
ai cdc ph
11
10
9
8
7
6
5
4
3
2
1
ppm



7d

ACQUISITION	
sfrq	125.672
tn	C13
at	2.000
np	125588
sw	31397.2
fb	not used
bs	10
tpwr	57
pw	6.7
d1	3.000
tof	0
nt	2000
ct	470
alock	n
gain	not used

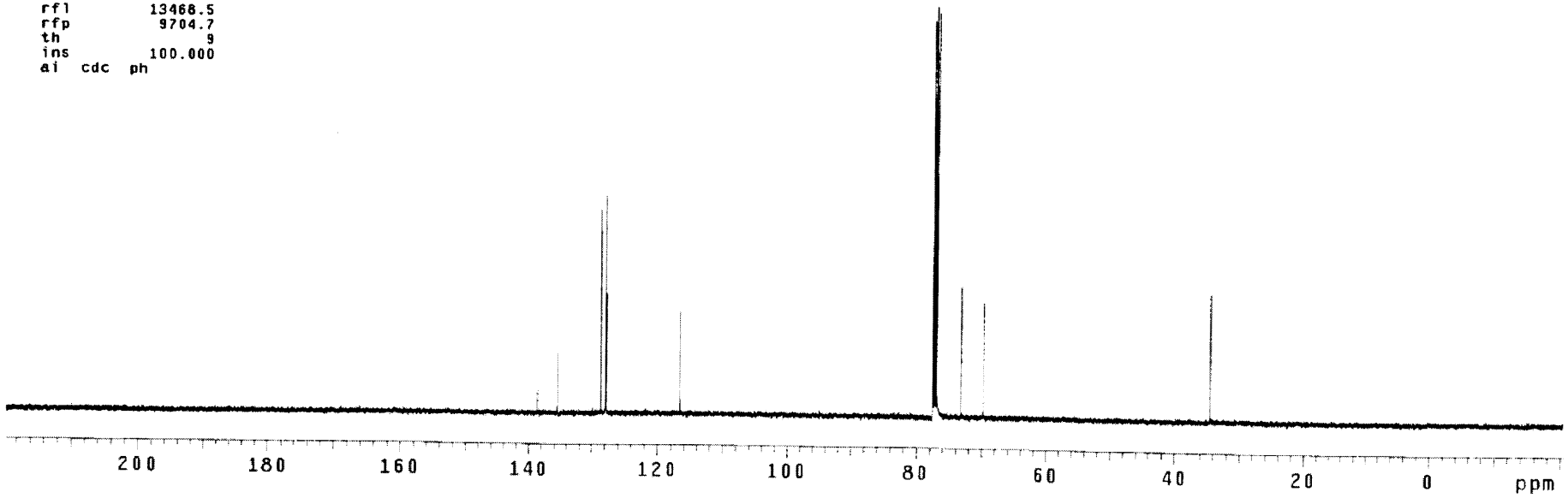
FLAGS	
il	n
in	n
dp	y
hs	nn

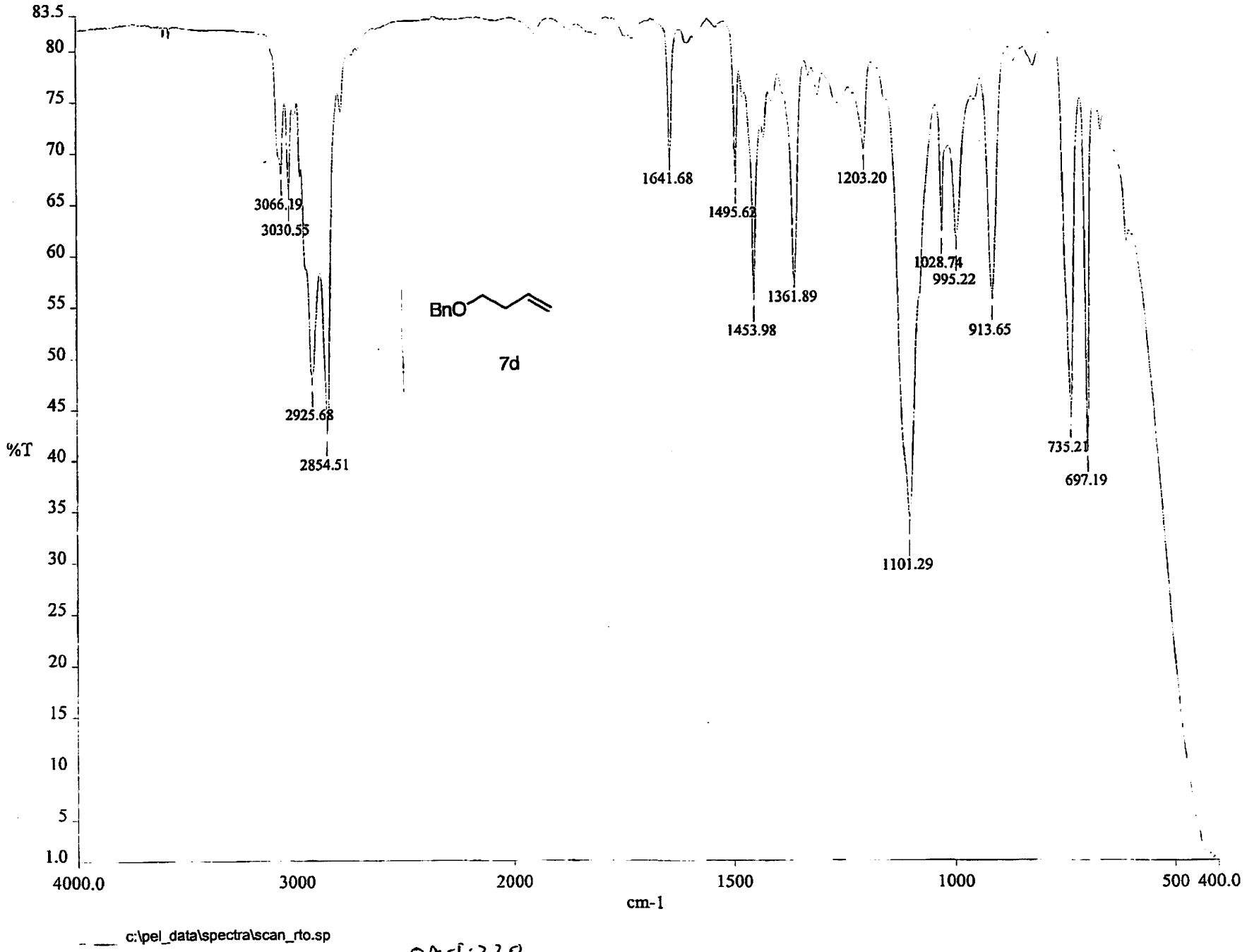
DISPLAY	
sp	-2567.0
wp	30158.3
vs	355
sc	0
wc	250
hzmm	120.63
is	500.00
rfl	13468.5
rfp	9704.7
th	9
ins	100.000

ai cdc ph

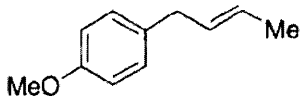
DEC. & VT	
dfrq	499.744
dn	H1
dpwr	41
dof	0
dm	yyy
dmm	w
dmf	10000
dseq	
dres	1.0
homo	n

PROCESSING	
lb	1.00
wtfile	
proc	ft
fn	131072
math	f
werr	
wexp	
wbs	
wnt	




83.5
80
75
70
65
60
55
50
45
40
35
30
25
20
15
10
5
1.0
%T
4000.0
3000
2000
1500
1000
500 400.0
cm-1
3066.19
3030.55
2925.68
2854.51
1641.68
1495.62
1453.98
1361.89
1203.20
1101.29
1028.74
995.22
913.65
735.21
697.19
BnO
7d
c:\pel_data\spectra\scan_rto.sp

04-I-220



7e

ACQUISITION	
sfrq	499.746
tn	H1
at	3.001
np	63050
sw	10504.2
fb	not used
bs	2
tpwr	56
pw	8.6
d1	2.000
tof	1519.5
nt	32
ct	8
alock	n
gain	not used

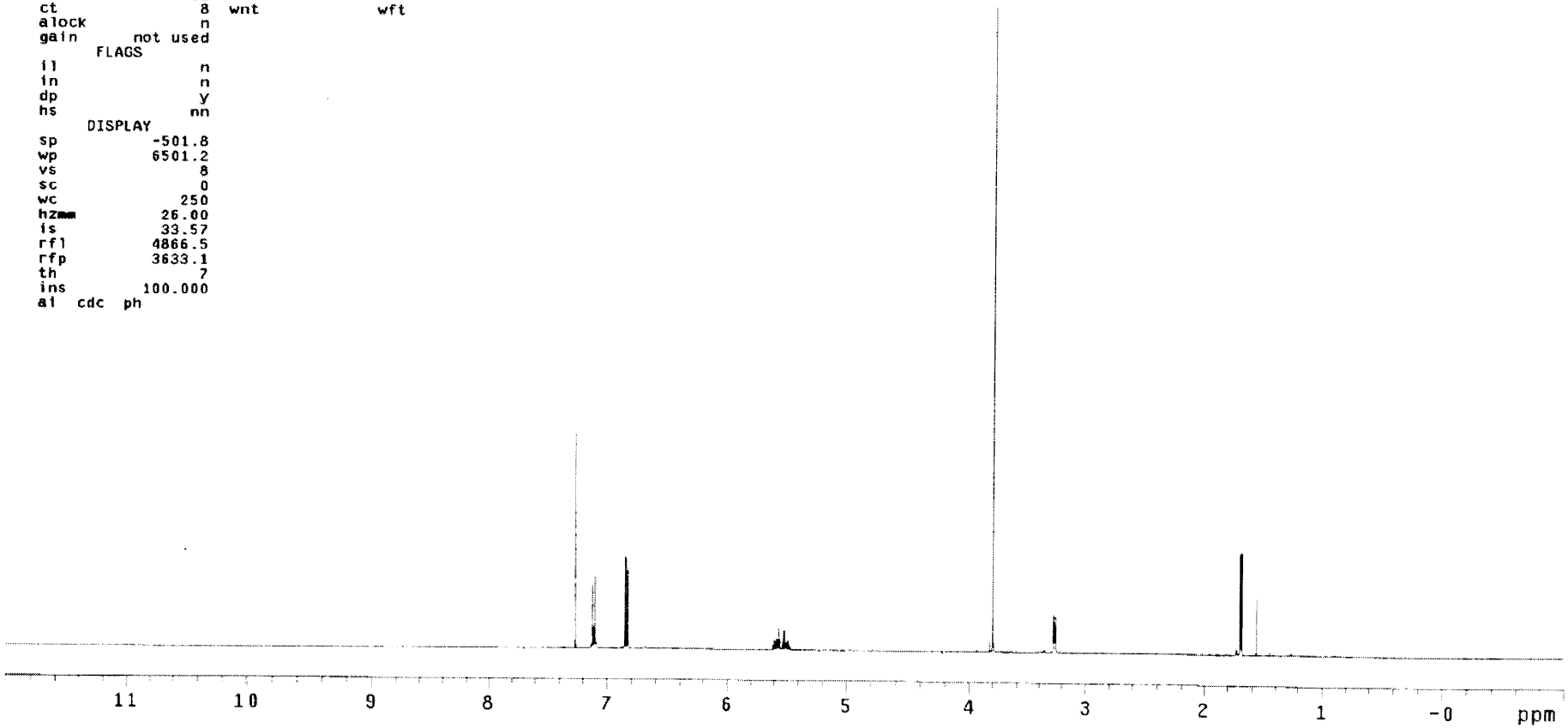
FLAGS	
il	n
in	n
dp	y
hs	nn

DISPLAY	
sp	-501.8
wp	6501.2
vs	8
sc	0
wc	250
hzmm	26.00
is	33.57
rfl	4866.5
rfp	3633.1
th	7
ins	100.000

ai cdc ph

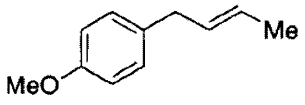
DEC. & VT	
dfrq	125.672
dn	C13
dpwr	30
dof	0
dm	nnn
dmm	w
dmf	10000
dseq	
dres	1.0
homo	n

PROCESSING	
wtfile	
proc	ft
fn	262144
math	f
werr	
wexp	
wbs	
wnt	wft

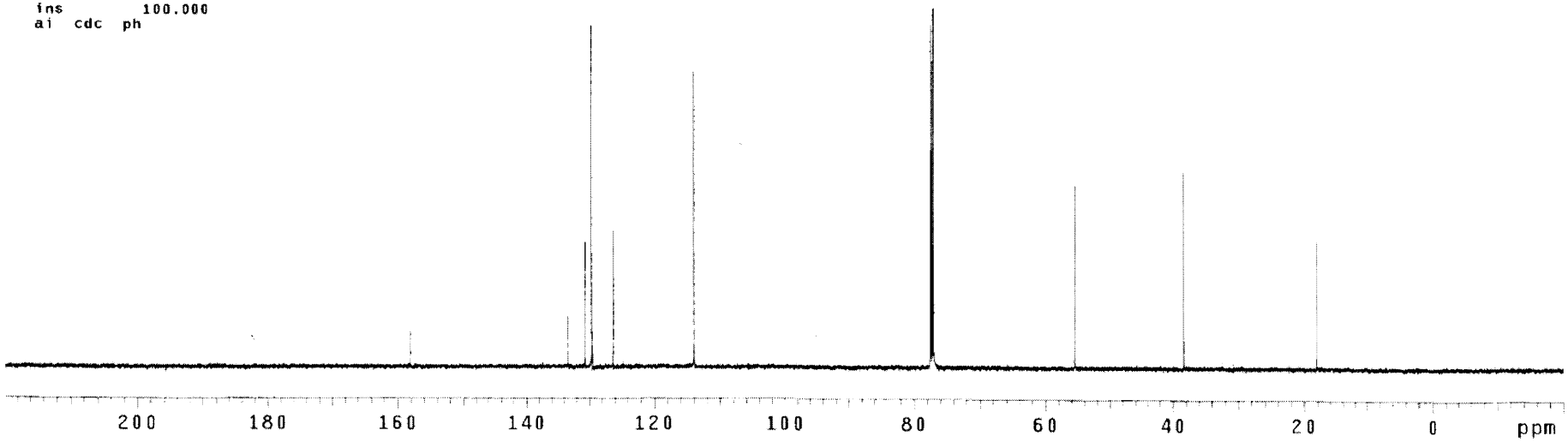


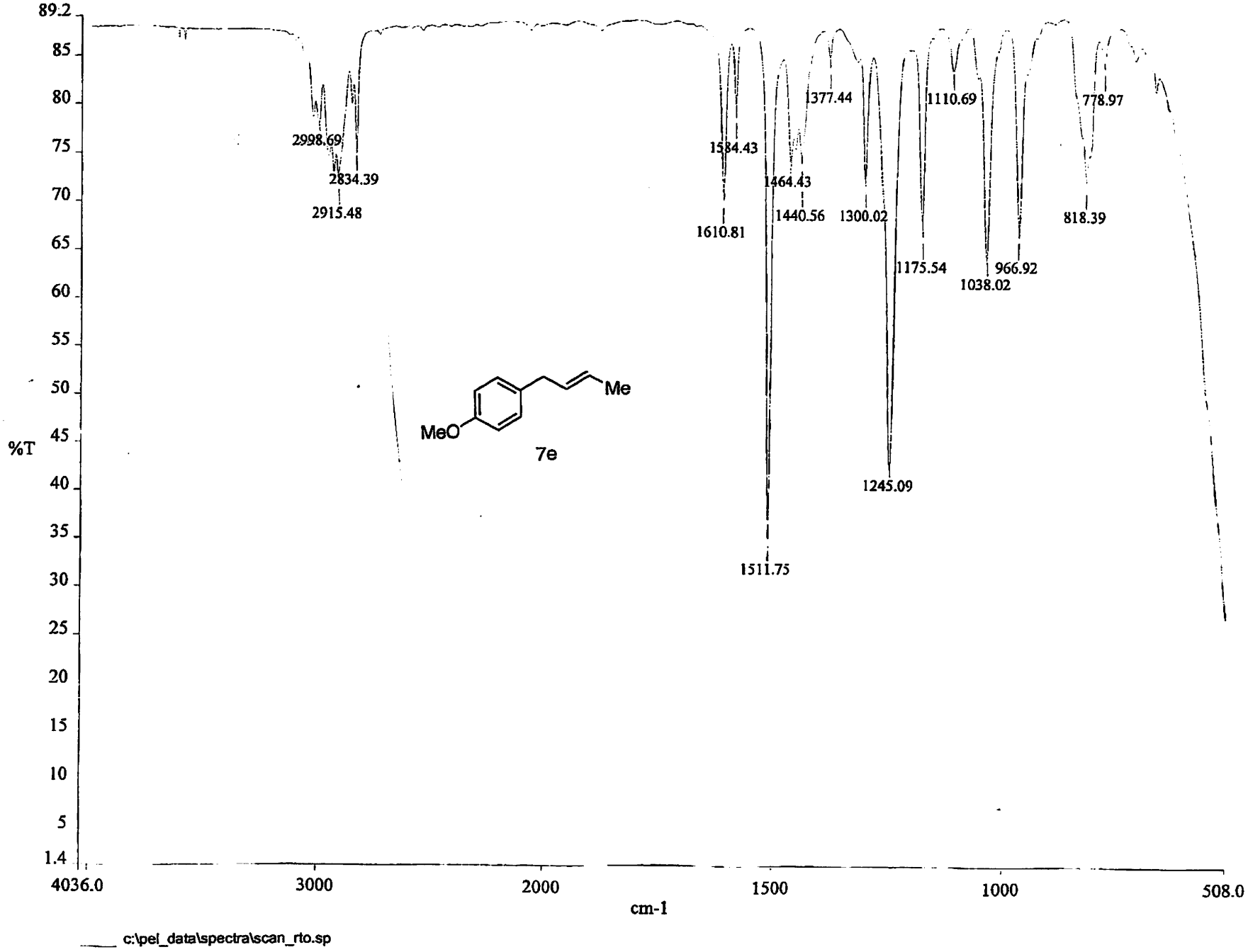
STANDARD CARBON PARAMETERS

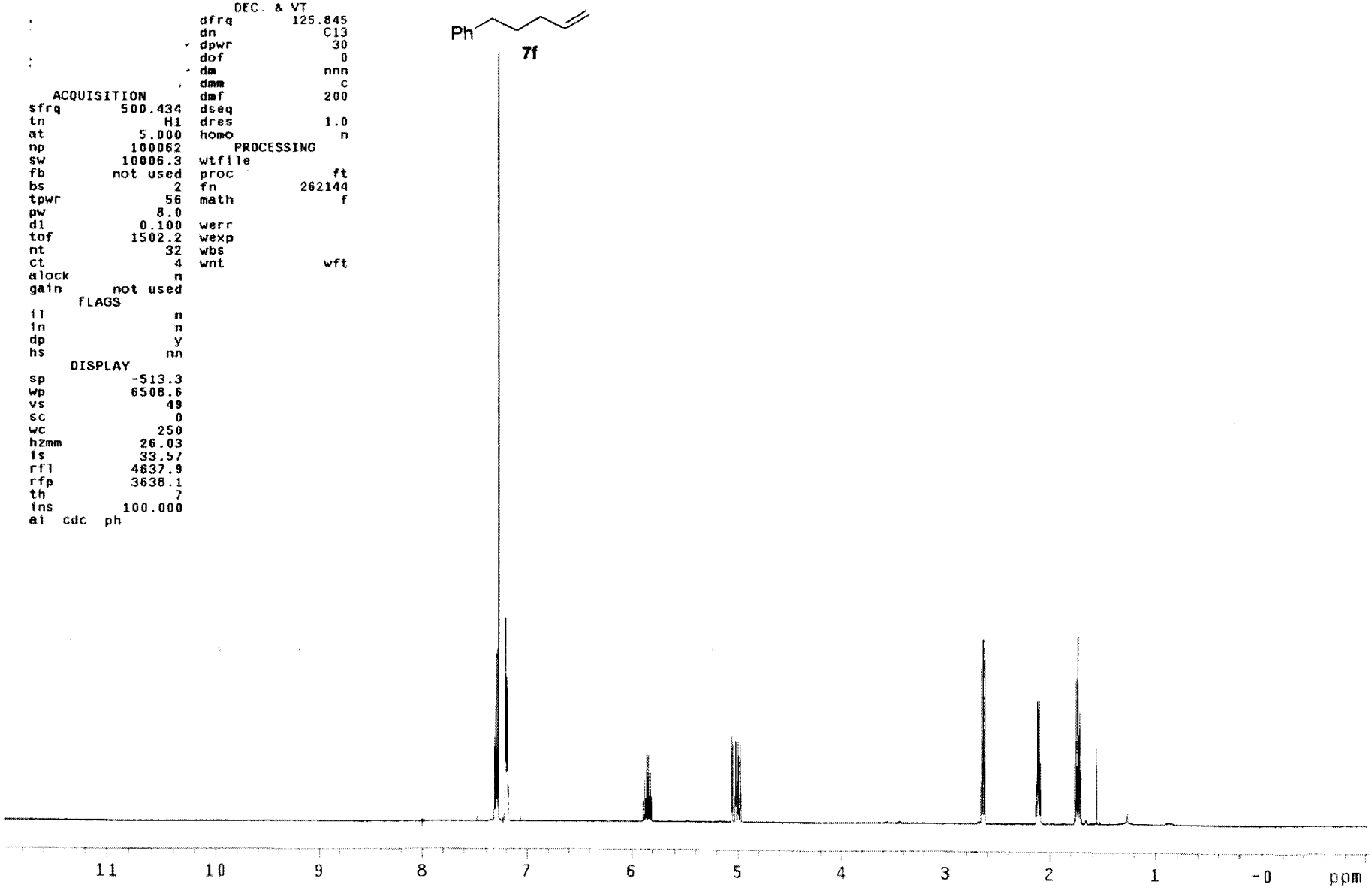
ACQUISITION		DEC. & VT	
sfrq	125.672	dfrq	499.744
tn	C13	dn	H1
at	2.000	dpwr	41
np	125588	dof	0
sw	31397.2	dm	yyy
fb	not used	dmm	w
bs	10	dmf	10000
tpwr	57	dseq	
pw	6.7	dres	1.0
d1	3.000	homo	n
tof	0	PROCESSING	
nt	2000	lb	1.00
ct	460	wtfile	
alock	n	proc	ft
gain	not used	fn	131072
FLAGS		math	f
il	n	werr	
in	n	wexp	
dp	y	wbs	
hs	nn	wnt	
DISPLAY			
sp	-2525.8		
wp	30158.3		
vs	295		
sc	0		
wc	250		
hzmm	120.63		
is	500.00		
rfl	13468.9		
rfp	9704.7		
th	4		
ins	100.000		
ai cdc ph			

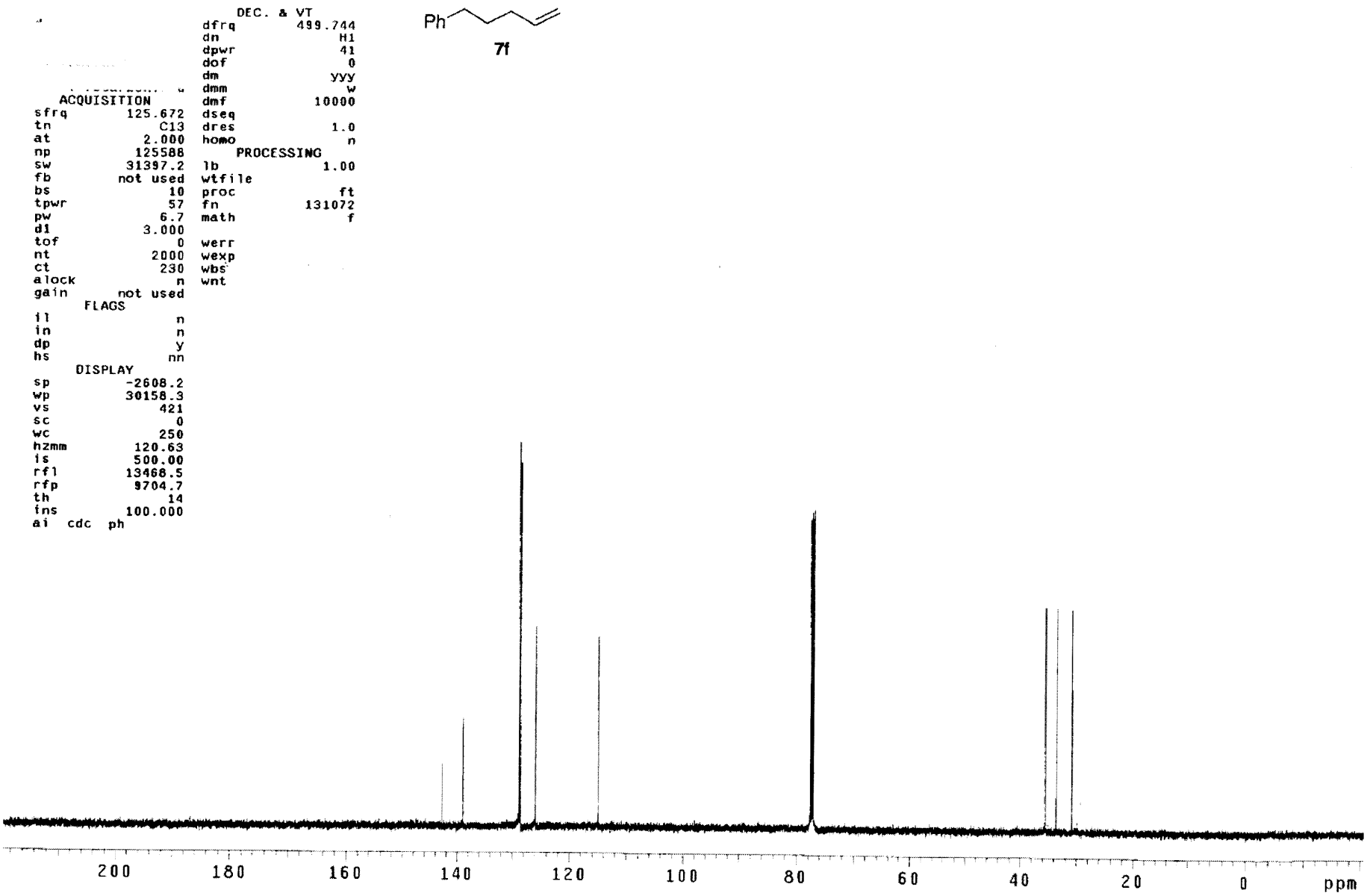


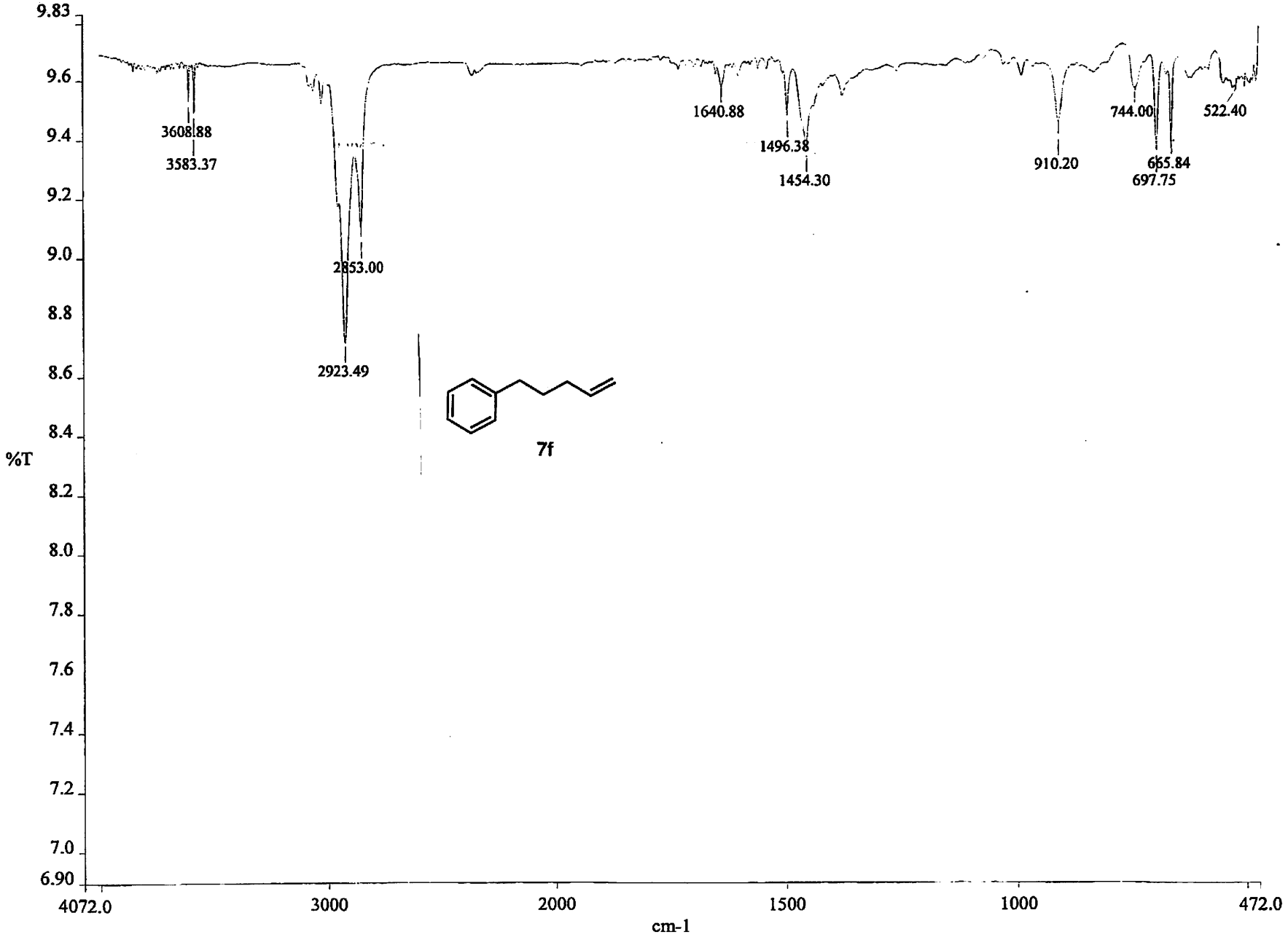
7e




89.2
85
80
75
70
65
60
55
50
45
40
35
30
25
20
15
10
5
1.4
%T
2998.69
2915.48
2834.39
1610.81
1584.43
1511.75
1464.43
1440.56
1377.44
1300.02
1245.09
1175.54
1110.69
1038.02
966.92
818.39
778.97
MeO
Me
7e
4036.0
3000
2000
1500
1000
508.0
cm-1
c:\pel_data\spectra\scan_rto.sp


ACQUISITION
sfrq 500.434
tn H1
at 5.000
np 100062
sw 10006.3
fb not used
bs 2
tpwr 56
pw 8.0
d1 0.100
tof 1502.2
nt 32
ct 4
alock n
gain not used
FLAGS
il n
in n
dp y
hs nn
DISPLAY
sp -513.3
wp 6508.6
vs 49
sc 0
wc 250
hzmm 26.03
is 33.57
rfl 4637.9
rfp 3638.1
th 7
ins 100.000
ai cdc ph
DEC. & VT
dfrq 125.845
dn C13
dpwr 30
dof 0
dm nnn
dmm c
dmf 200
dseq
dres 1.0
homo n
PROCESSING
wtfile
proc ft
fn 262144
math f
werr
wexp
wbs
wnt wft
Ph
7f
11
10
9
8
7
6
5
4
3
2
1
-0
ppm


ACQUISITION
sfrq 125.672
tn C13
at 2.000
np 125588
sw 31397.2
fb not used
bs 10
tpwr 57
pw 6.7
d1 3.000
tof 0
nt 2000
ct 230
alock n
gain not used
FLAGS
il n
in n
dp y
hs nn
DISPLAY
sp -2608.2
wp 30158.3
vs 421
sc 0
wc 250
hzmm 120.63
is 500.00
rfl 13468.5
rfp 9704.7
th 14
ins 100.000
ai cdc ph
DEC. & VT
dfrq 499.744
dn H1
dpwr 41
dof 0
dm yyy
dmm w
dmf 10000
dseq
dres 1.0
homo n
PROCESSING
lb 1.00
wtfile
proc ft
fn 131072
math f
werr
wexp
wbs
wnt
Ph
7f
200
180
160
140
120
100
80
60
40
20
0
ppm


9.83
9.6
9.4
9.2
9.0
8.8
8.6
8.4
8.2
8.0
7.8
7.6
7.4
7.2
7.0
6.90
%T
3608.88
3583.37
2923.49
2853.00
1640.88
1496.38
1454.30
910.20
744.00
697.75
655.84
522.40
4072.0
3000
2000
1500
1000
472.0
cm-1

7f

ACQUISITION	
sfrq	500.434
tn	H1
at	5.000
np	100062
sw	10006.3
fb	not used
bs	2
tpwr	56
pw	8.0
d1	0.100
tof	1502.2
nt	32
ct	20
alock	n
gain	not used

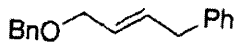
FLAGS	
il	n
in	n
dp	y
hs	nn

DISPLAY	
sp	-250.3
wp	6255.4
vs	30
sc	0
wc	250
hzmm	25.02
is	33.57
rfl	4637.0
rfp	3638.1
th	6
ins	100.000

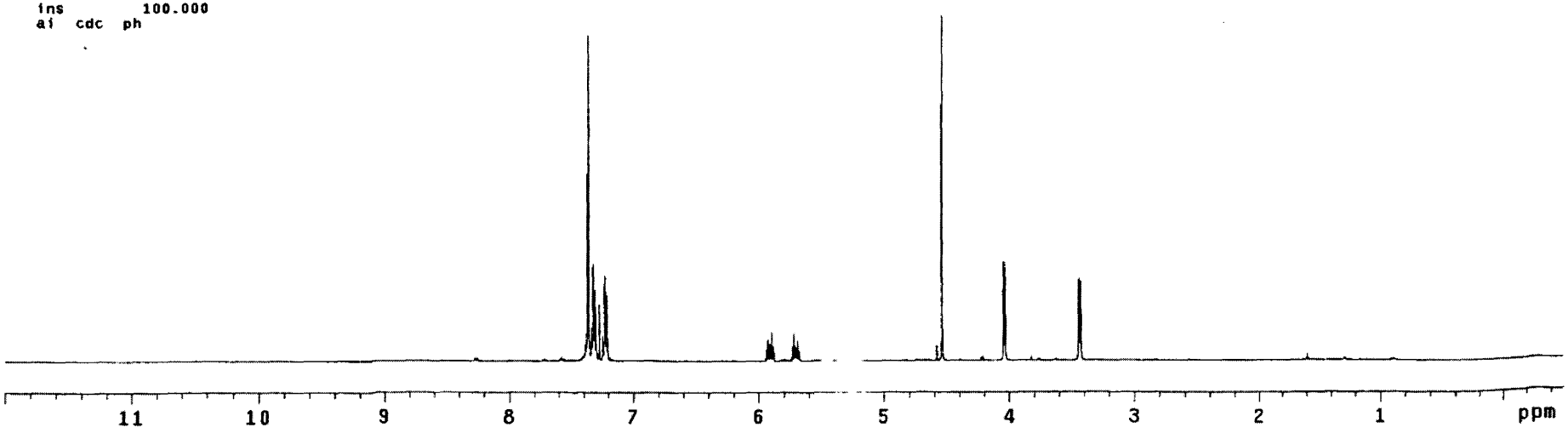
ai cdc ph

DEC. & VT	
dfrq	125.845
dn	C13
dpwr	30
dof	0
dm	nnn
dmm	c
dmf	200
dseq	
dres	1.0
homo	n

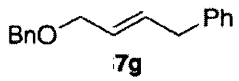
PROCESSING	
wtfile	
proc	ft
fn	262144
math	f
werr	
wexp	
wbs	
wnt	wft



7g



ACQUISITION		DEC. & VT	
sfrq	125.672	dfrq	499.744
tn	C13	dn	H1
at	2.000	dpwr	41
np	125588	dof	0
sw	31397.2	dm	yyy
fb	not used	dmm	w
bs	10	dmf	10000
tpwr	57	dseq	
pw	6.7	dres	1.0
d1	3.000	homo	n
tof	0	PROCESSING	
nt	1000	lb	1.00
ct	270	wtfile	
alock	n	proc	ft
gain	not used	fn	131072
FLAGS		math	f
il	n	werr	
in	n	wexp	
dp	y	wbs	
hs	nn	wnt	
DISPLAY			
sp	-2525.3		
wp	30158.3		
vs	406		
sc	0		
wc	250		
hzmm	120.63		
is	500.00		
rfl	13468.5		
rfp	9704.7		
th	6		
ins	100.000		
ai cdc ph			



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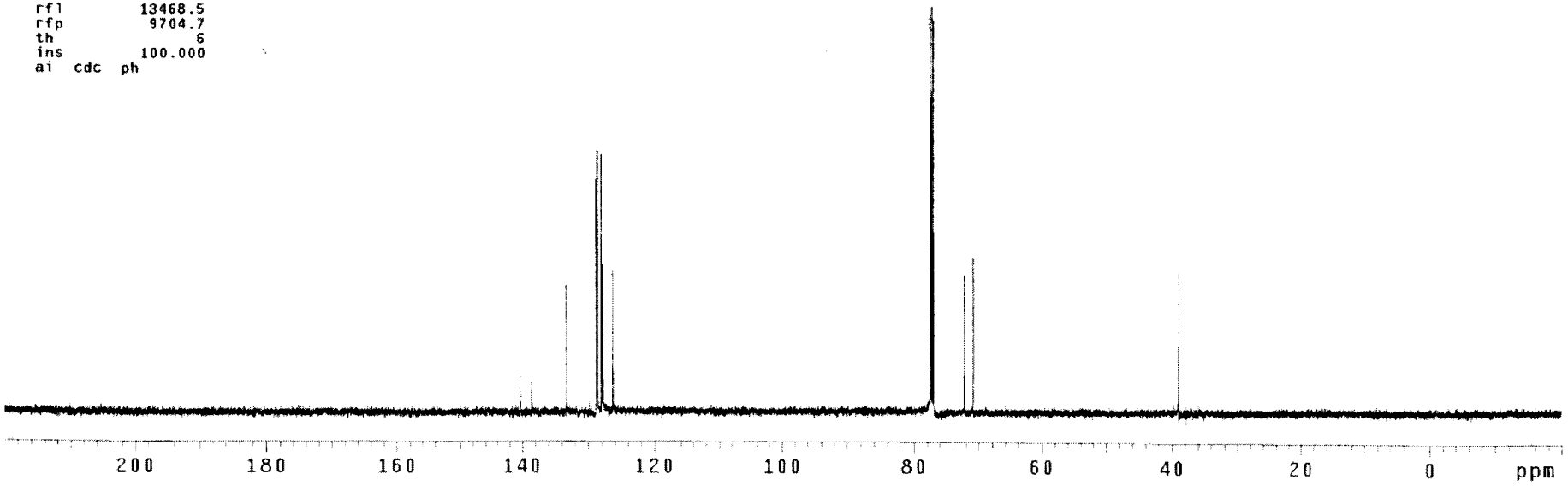

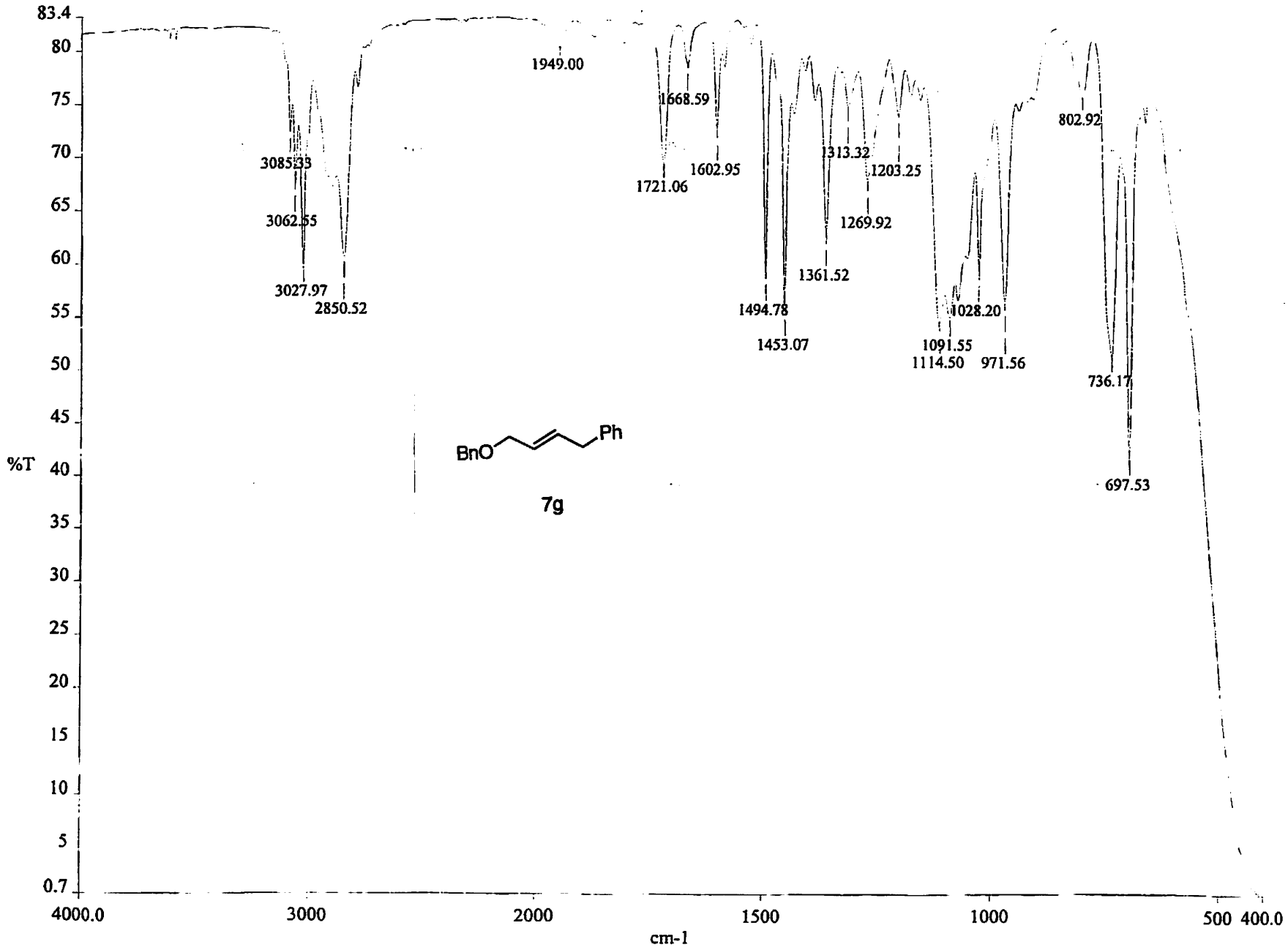
83.4
80
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70
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60
55
50
45
40
35
30
25
20
15
10
5
0.7
%T
4000.0
3000
2000
1500
1000
500 400.0
cm-1
3085.33
3062.55
3027.97
2850.52
1949.00
1721.06
1668.59
1602.95
1494.78
1453.07
1361.52
1313.32
1269.92
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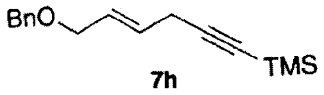
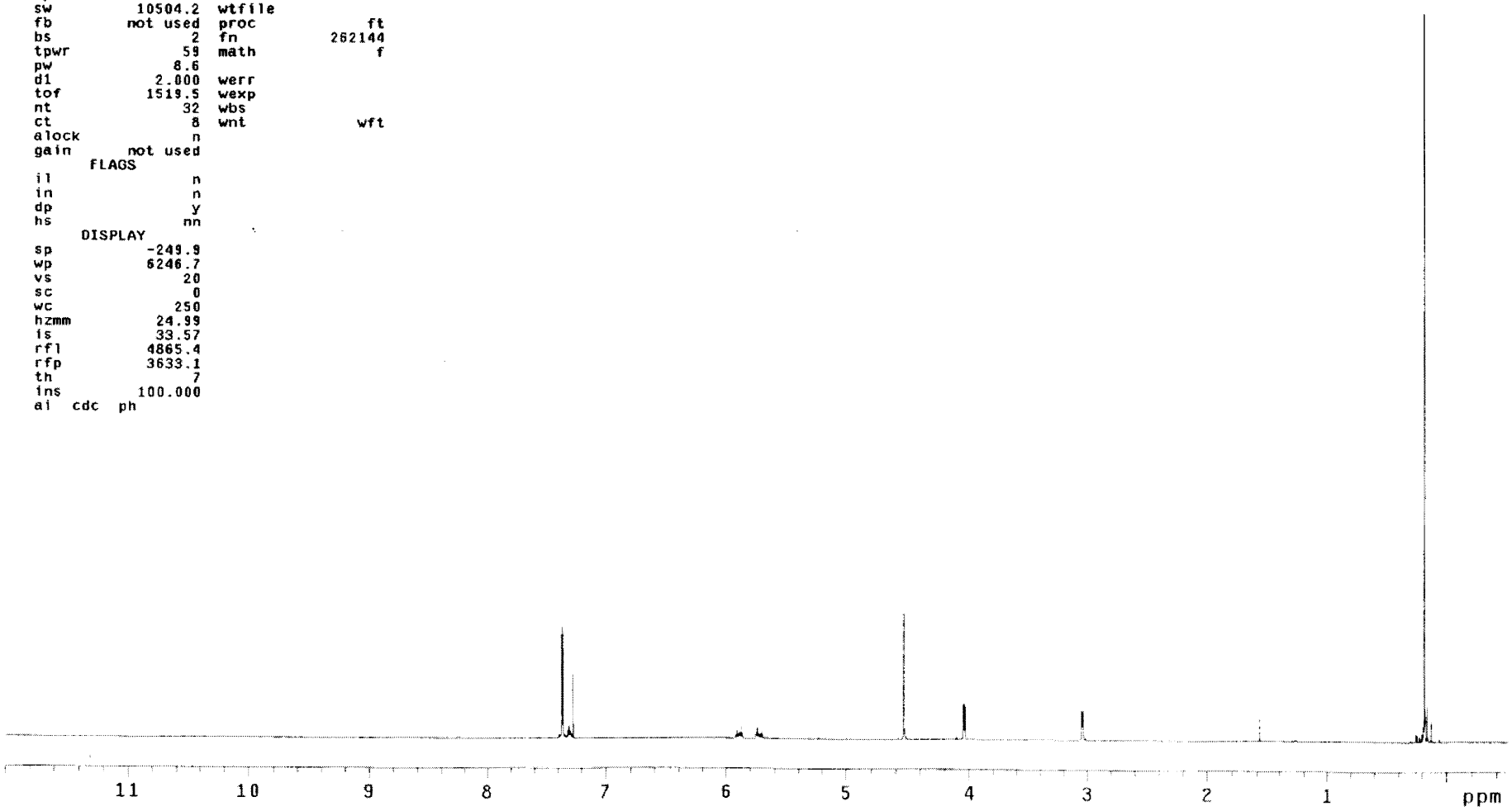
1114.50
1028.20
971.56
802.92
736.17
697.53
BnO
Ph
7g

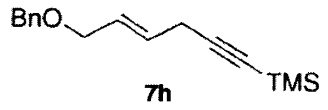


7h

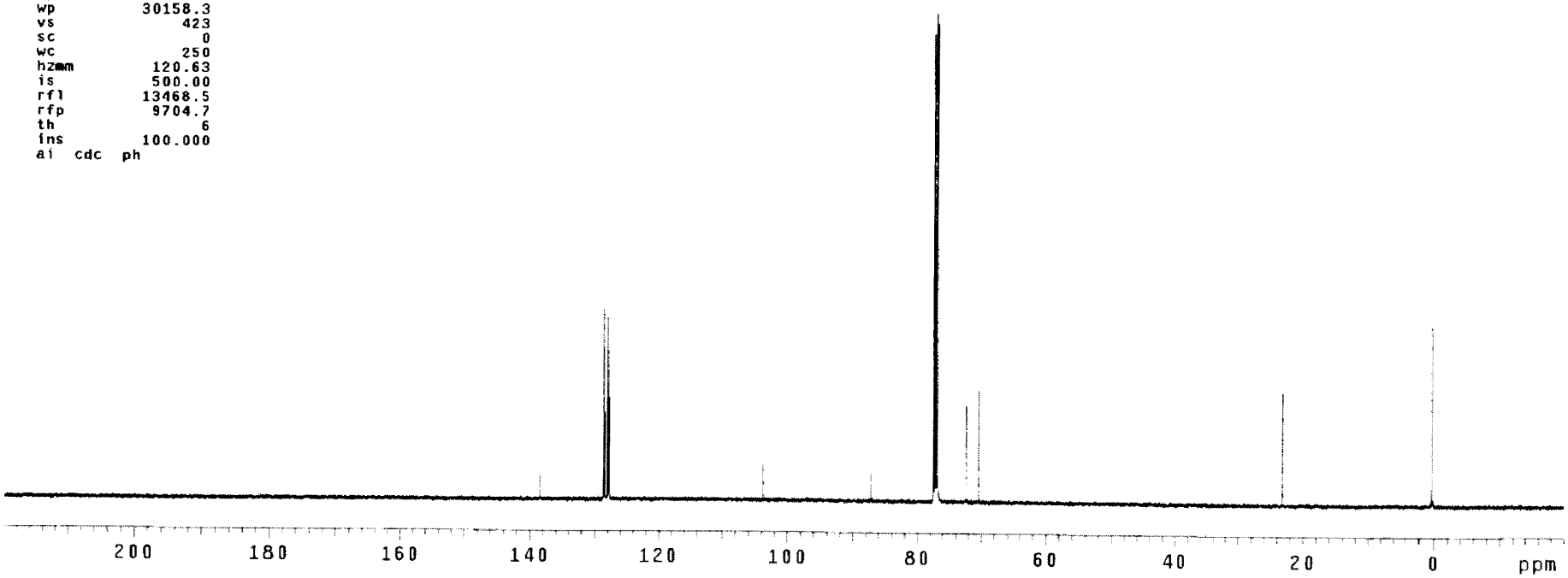
ACQUISITION		DEC. & VT	
sfrq	499.746	dfrq	125.672
tn	H1	dn	C13
at	3.001	dpwr	30
np	63050	dof	0
sw	10504.2	dm	nnn
fb	not used	dmm	w
bs	2	dmf	10000
tpwr	59	dseq	
pw	8.6	dres	1.0
d1	2.000	homo	n
tof	1519.5	PROCESSING	
nt	32	wtfile	
ct	8	proc	ft
alock	n	fn	262144
gain	not used	math	f
FLAGS		werr	
il	n	wexp	
in	n	wbs	
dp	y	wnt	wft
hs	nn		
DISPLAY			
sp	-249.9		
wp	6246.7		
vs	20		
sc	0		
wc	250		
hzmm	24.99		
is	33.57		
rfl	4865.4		
rfp	3633.1		
th	7		
ins	100.000		
ai cdc ph			

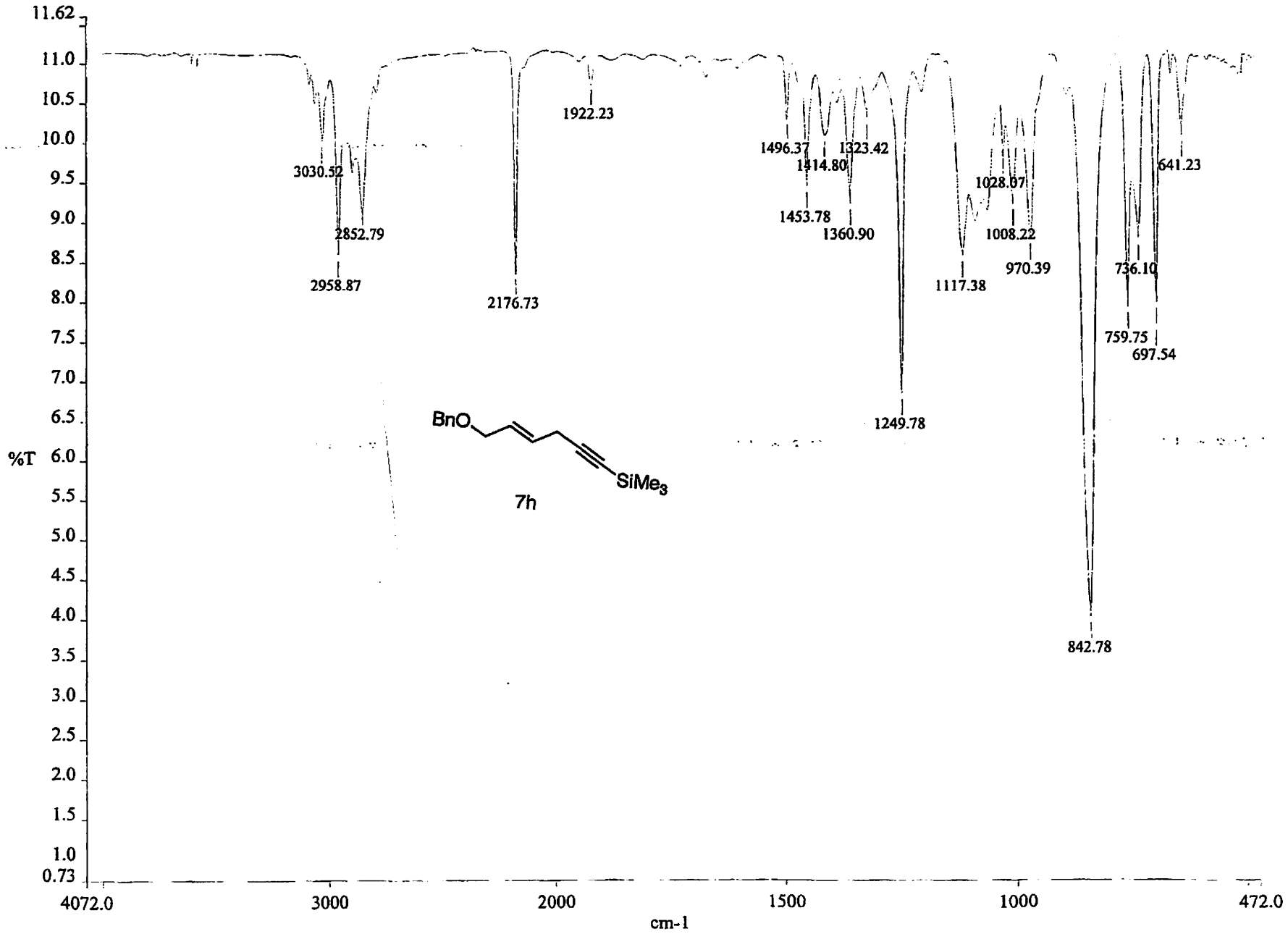


ACQUISITION		DEC. & VT	
sfrq	125.672	dfrq	499.744
tn	C13	dn	H1
at	2.000	dpwr	41
np	125588	dof	0
sw	31397.2	dm	yyy
fb	not used	dmm	w
bs	10	dmf	10000
tpwr	57	dseq	
pw	6.7	dres	1.0
d1	3.000	homo	n
tof	0	PROCESSING	
nt	2500	lb	1.00
ct	1200	wtfile	
alock	n	proc	ft
gain	not used	fn	131072
FLAGS		math	f
fl	n	werr	
in	n	wexp	
dp	y	wbs	
hs	nn	wnt	
DISPLAY			
sp	-2525.3		
wp	30158.3		
vs	423		
sc	0		
wc	250		
hzmm	120.63		
is	500.00		
rfl	13468.5		
rfp	9704.7		
th	6		
ins	100.000		
ai cdc ph			



7h

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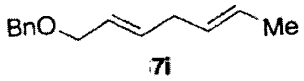
9.0
8.5
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.73
%T
4072.0
3000
2000
1500
1000
472.0
cm-1
3030.52
2852.79
2958.87
2176.73
1922.23
1496.37
1414.80
1453.78
1323.42
1360.90
1249.78
1117.38
1028.07
1008.22
970.39
842.78
759.75
736.10
697.54
641.23
BnO
SiMe3
7h



7i

ACQUISITION	
sfrq	499.746
tn	H1
at	3.001
np	63050
sw	10504.2
fb	not used
bs	2
tpwr	56
pw	8.6
d1	2.000
tof	1519.5
nt	32
ct	8
alock	n
gain	not used

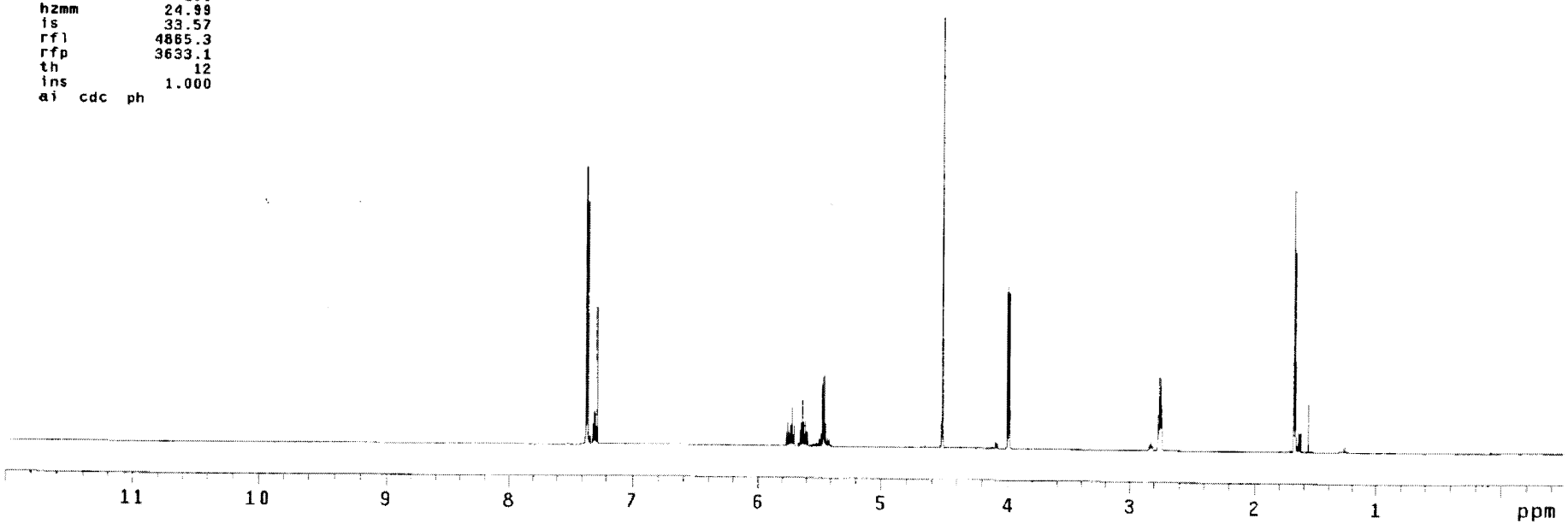
FLAGS	
il	n
in	n
dp	y
hs	nn

DISPLAY	
sp	-249.9
wp	6246.7
vs	21
sc	0
wc	250
hzmm	24.99
is	33.57
rfl	4865.3
rfp	3633.1
th	12
ins	1.000

ai cdc ph

DEC. & VT	
dfrq	125.672
dn	C13
dpwr	30
dof	0
dm	nnn
dmm	w
dmf	10000
dseq	
dres	1.0
homo	n

PROCESSING	
wtfile	
proc	ft
fn	262144
math	f
werr	
wexp	
wbs	
wnt	wft



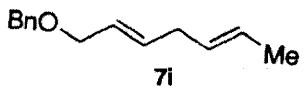
ACQUISITION	
sfrq	125.795
tn	C13
at	1.736
np	131010
sw	37735.8
fb	not used
bs	10
ss	1
tpwr	53
pw	6.9
d1	0.763
tof	631.4
nt	4000
ct	1770
alock	n
gain	not used

FLAGS	
il	n
in	n
dp	y
hs	nn

DISPLAY	
sp	-2519.9
wp	30198.5
vs	219
sc	0
wc	250
hzmm	120.79
is	500.00
rfl	16003.0
rfp	9714.9
th	5
ins	1.000
ai	ph

DEC. & VT	
dfrq	500.229
dn	H1
dpwr	37
dof	-500.0
dm	y
dmm	w
dmf	10000
dseq	
dres	1.0
homo	n

PROCESSING	
lb	0.30
wtfile	
proc	ft
fn	131072
math	f
werr	
wexp	
wbs	
wnt	



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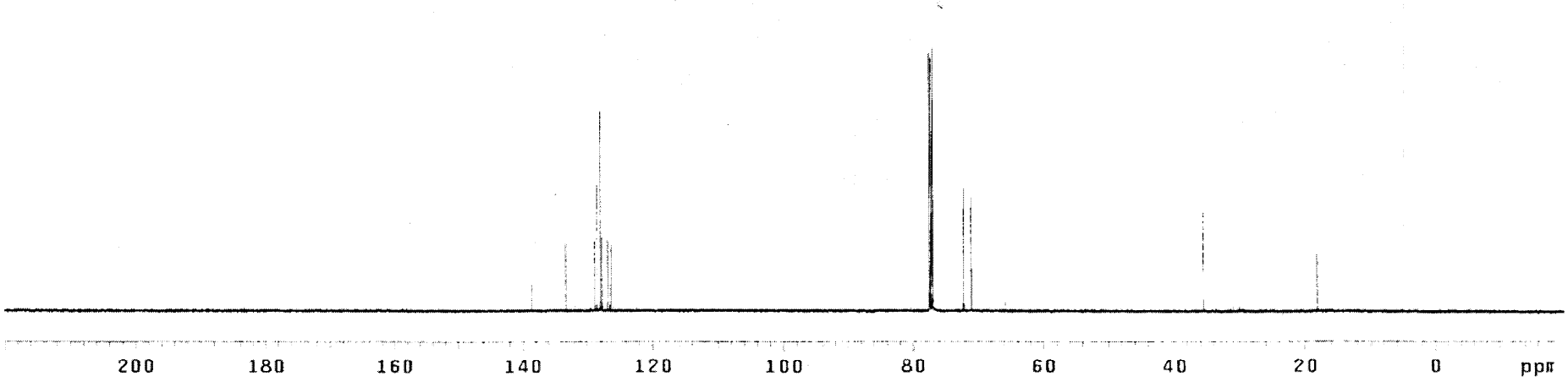

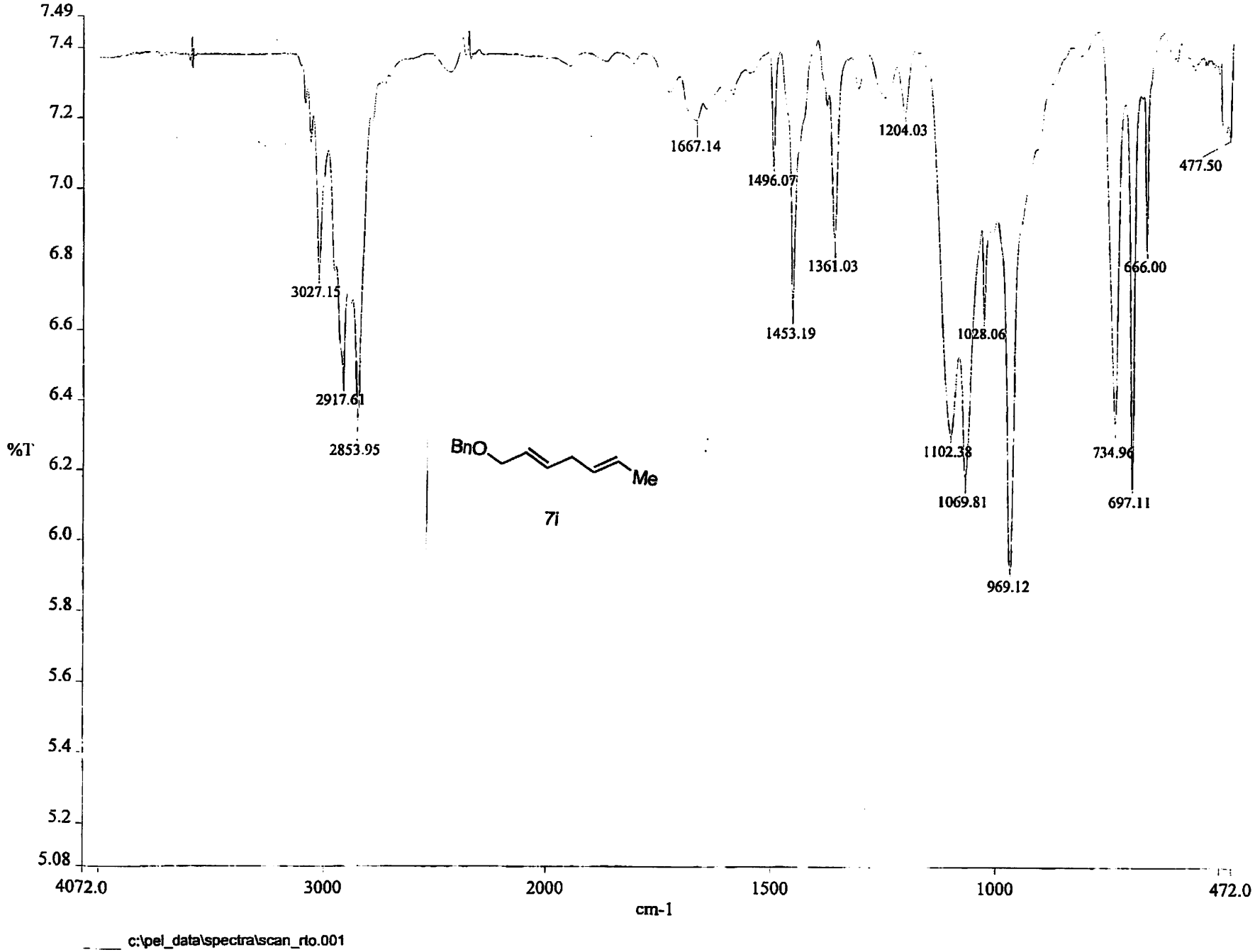
7.49
7.4
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6.8
6.6
6.4
6.2
6.0
5.8
5.6
5.4
5.2
5.08
%T
3027.15
2917.61
2853.95
1667.14
1496.07
1453.19
1361.03
1204.03
1102.38
1069.81
1028.06
969.12
734.96
697.11
666.00
477.50
BnO
Me
7i
4072.0
3000
2000
1500
1000
472.0
cm-1
c:\pel_data\spectra\scan_rto.001

ACQUISITION	
sfrq	500.434
tn	H1
at	5.000
np	100062
sw	10006.3
fb	not used
bs	2
tpwr	56
pw	8.0
d1	0.100
tof	1502.2
nt	32
ct	4
alock	n
gain	not used

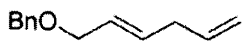
FLAGS	
il	n
in	n
dp	y
hs	nn

DISPLAY	
sp	-500.2
wp	6508.6
vs	35
sc	0
wc	250
hzmm	26.03
is	33.57
rfl	4638.0
rfp	3638.1
th	11
ins	100.000

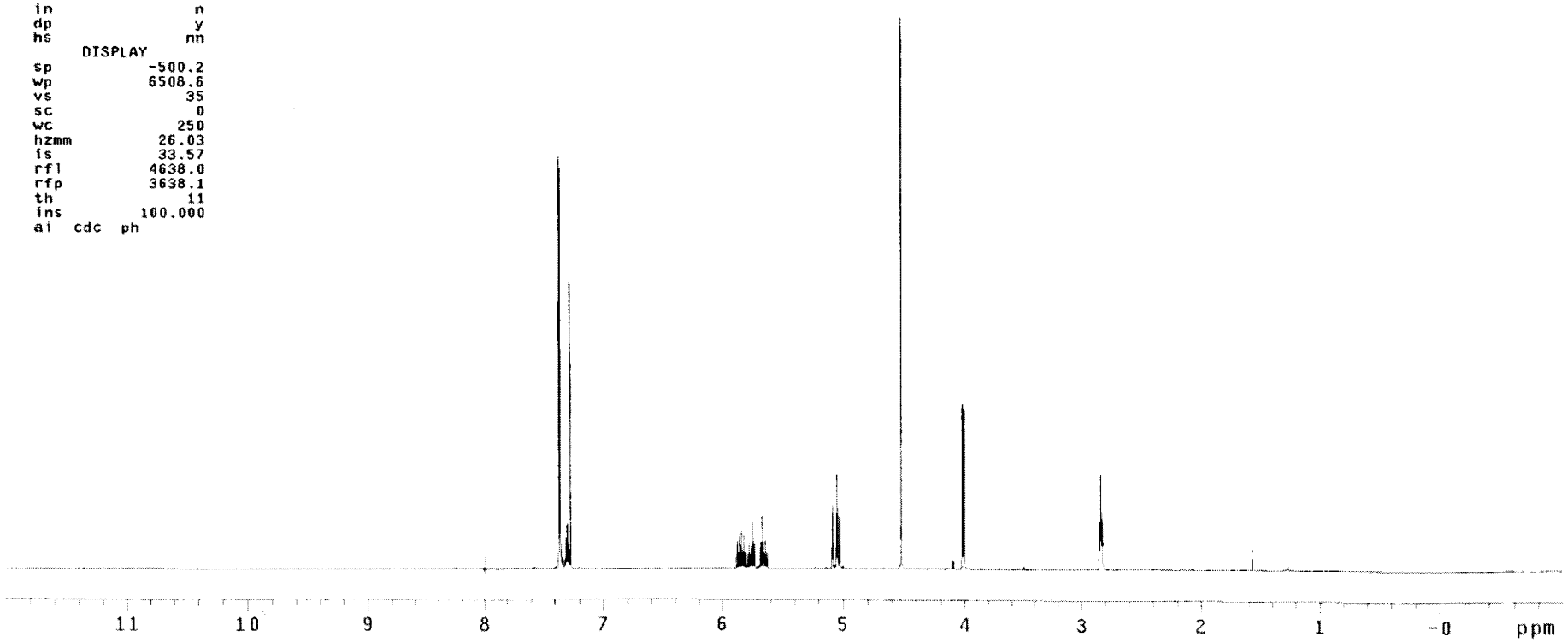
ai cdc ph

DEC. & VT	
dfrq	125.845
dn	C13
dpwr	30
dof	0
dm	nnn
dmm	c
dmf	200
dseq	
dres	1.0
homo	n

PROCESSING	
wtfile	
proc	ft
fn	262144
math	f
werr	
wexp	
wbs	
wnt	wft



7j



ACQUISITION	
sfrq	125.672
tn	C13
at	2.000
np	125588
sw	31397.2
fb	not used
bs	10
tpwr	59
pw	6.7
d1	3.000
tof	0
nt	2000
ct	420
alock	n
gain	not used

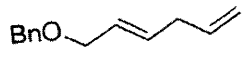
FLAGS	
il	n
in	n
dp	y
hs	nn

DISPLAY	
sp	-2525.8
wp	30158.3
vs	743
sc	0
wc	250
hzmm	120.63
is	500.00
rfl	13468.9
rfp	9704.7
th	10
ins	100.000

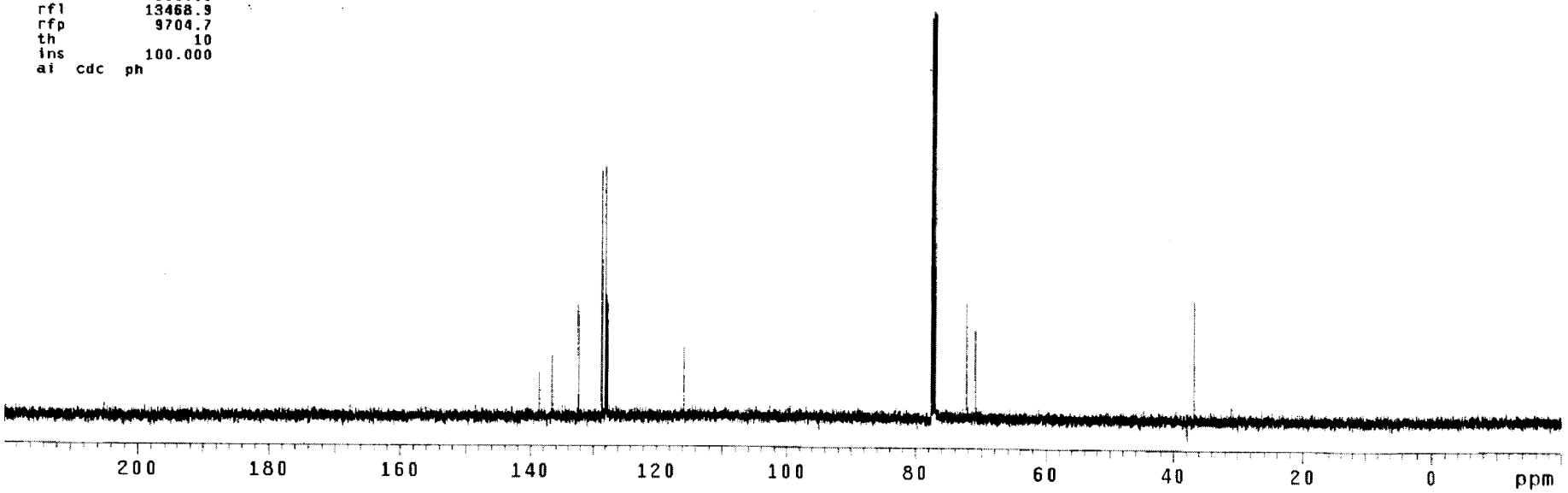
ai cdc ph

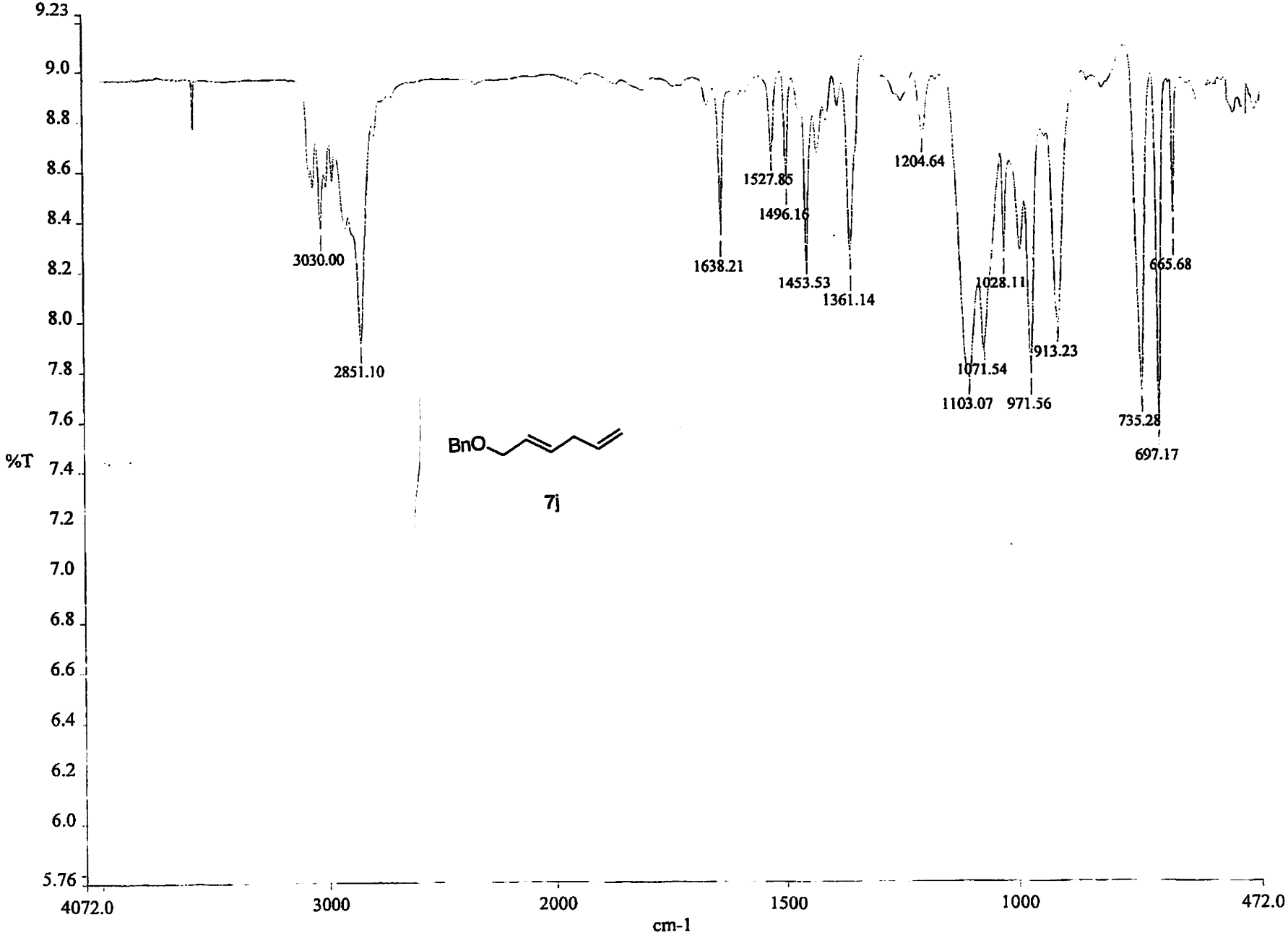
DEC. & VT	
dfrq	499.744
dn	H1
dpwr	34
dof	0
dm	yyy
dmm	w
dmf	10400
dseq	
dres	1.0
homo	n

PROCESSING	
lb	1.00
wtfile	
proc	ft
fn	131072
math	f
werr	
wexp	
wbs	
wnt	



7j

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7.4
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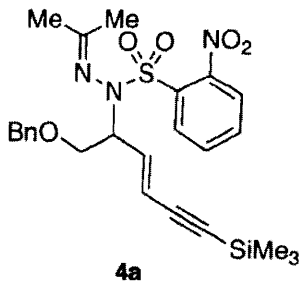
7.0
6.8
6.6
6.4
6.2
6.0
5.76
%T
4072.0
3000
2000
1500
1000
472.0
cm-1
3030.00
2851.10
1638.21
1527.85
1496.16
1453.53
1361.14
1204.64
1103.07
1071.54
1028.11
971.56
913.23
735.28
697.17
665.68
BnO

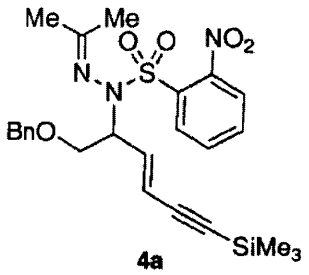
7j

ACQUISITION		DEC. & VT	
sfrq	499.746	dfrq	125.672
tn	H1	dn	C13
at	3.001	dpwr	30
np	63050	dof	0
sw	10504.2	dm	nnn
fb	not used	dmm	w
bs	2	dmf	10000
tpwr	59	dseq	
pw	8.6	dres	1.0
d1	2.000	homo	n
tof	1519.5	DEC2	
nt	32	dfrq2	0
ct	16	dn2	
alock	n	dpwr2	1
gain	not used	dof2	0
FLAGS		dm2	n
il	n	dmm2	c
in	n	dmf2	200
dp	y	dseq2	
hs	nn	dres2	1.0
DISPLAY		homo2	n
sp	-249.9	DEC3	
wp	6246.7	dfrq3	0
vs	47	dn3	
sc	0	dpwr3	1
wc	250	dof3	0
hzmm	24.99	dm3	n
is	33.57	dmm3	c
rfl	1233.8	dmf3	200
rfp	0	dseq3	
th	7	dres3	1.0
ins	100.000	homo3	n
ai cdc ph		PROCESSING	
		wtfile	
		proc	ft
		fn	262144
		math	f
		werr	
		wexp	
		wbs	
		wnt	wft

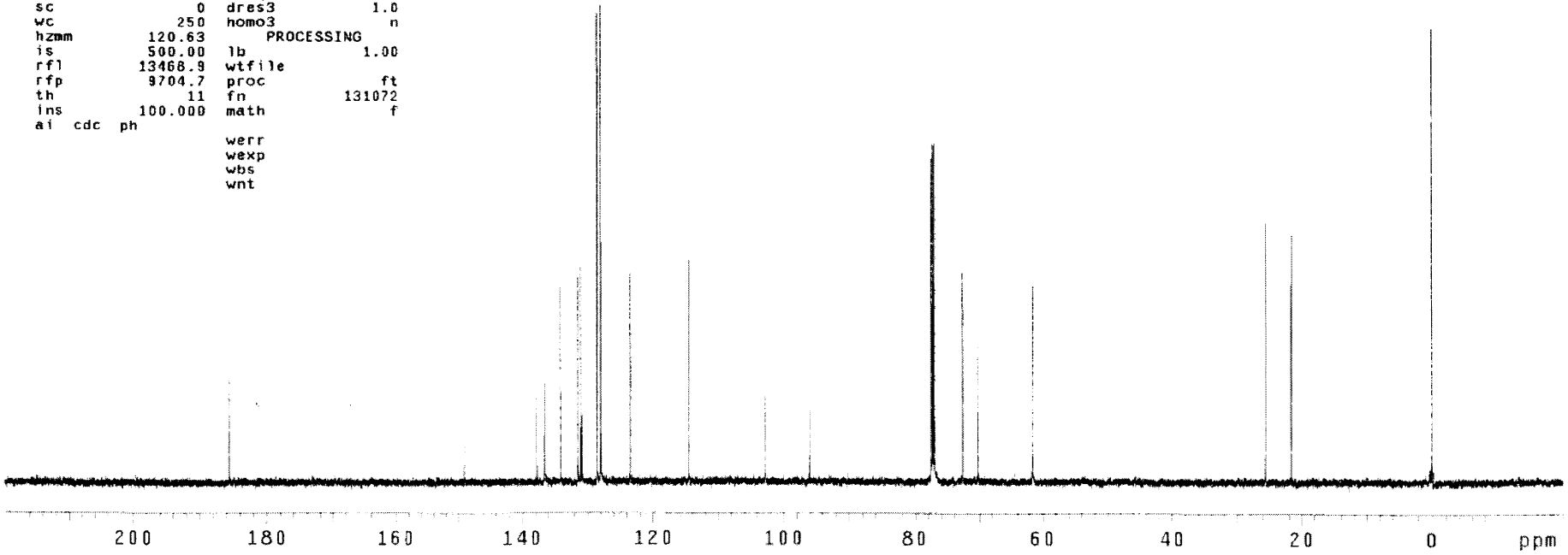


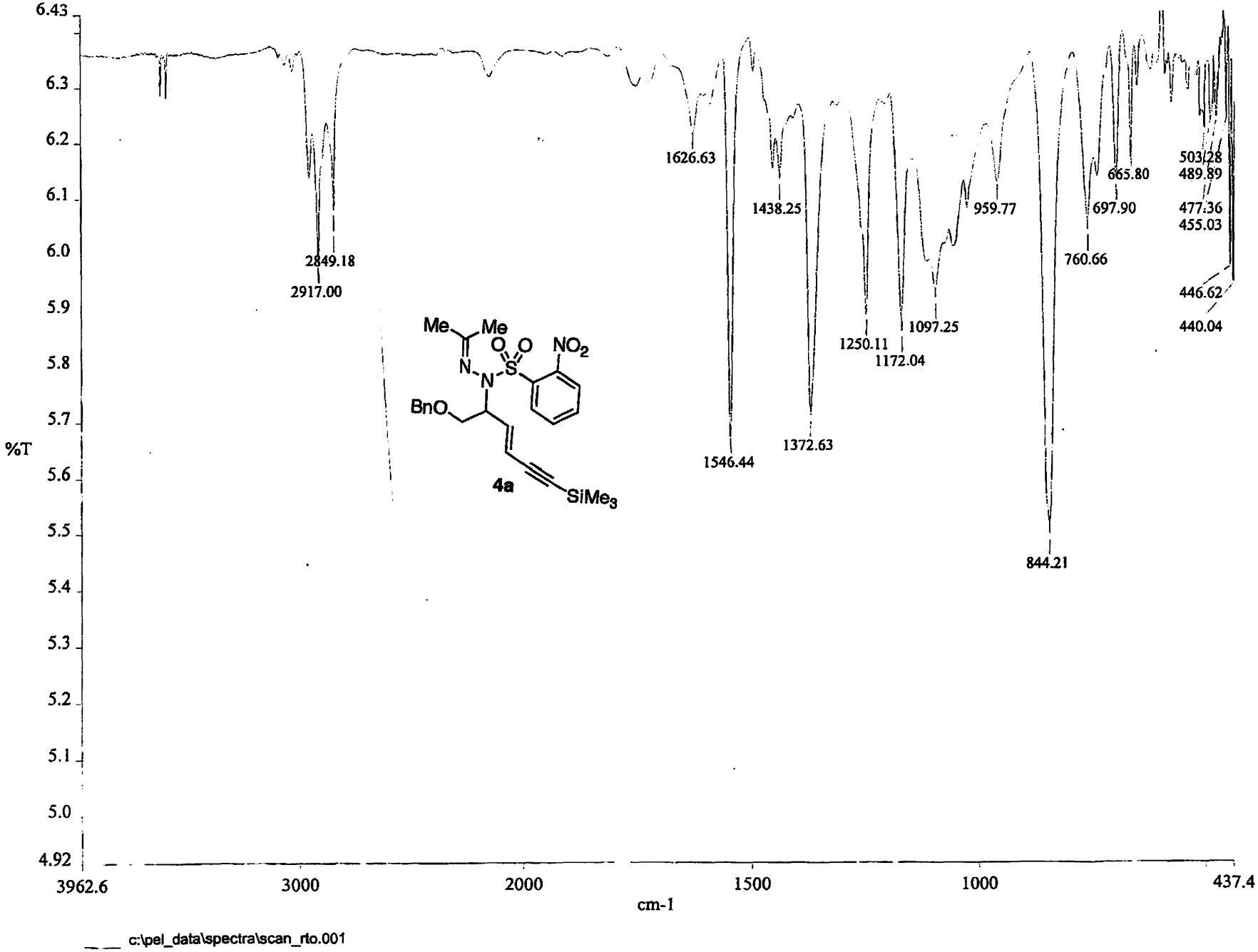
4a

ACQUISITION		DEC. & VT	
sfrq	125.672	dfrq	499.744
tn	C13	dn	H1
at	2.000	dpwr	41
np	125588	dof	0
sw	31397.2	dm	yyy
fb	not used	dmm	w
bs	10	dmf	10000
tpwr	57	dseq	
pw	6.7	dres	1.0
d1	3.000	homo	n
tof	0	DEC2	
nt	1000	dfrq2	0
ct	390	dn2	
alock	n	dpwr2	1
gain	not used	dof2	0
FLAGS		dm2	n
il	n	dmm2	c
in	n	dmf2	10000
dp	y	dseq2	
hs	nn	dres2	1.0
DISPLAY		homo2	n
sp	-2526.3	DEC3	
wp	30158.3	dfrq3	0
vs	550	dn3	
sc	0	dpwr3	1
wc	250	dof3	0
hzmm	120.63	dm3	n
is	500.00	dmm3	c
rfl	13468.9	dmf3	10000
rfp	9704.7	dseq3	
th	11	dres3	1.0
ins	100.000	homo3	n
ai cdc ph		PROCESSING	
		lb	1.00
		wtfile	
		proc	ft
		fn	131072
		math	f
		werr	
		wexp	
		wbs	
		wnt	



4a

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5.8
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5.5
5.4
5.3
5.2
5.1
5.0
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%T
3962.6
3000
2000
1500
1000
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cm-1
2917.00
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1626.63
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1438.25
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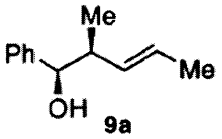
1250.11
1172.04
1097.25
959.77
844.21
760.66
697.90
665.80
503.28
489.89
477.36
455.03
446.62
440.04
Me
Me
O
O
NO2
N
N
S
BnO
SiMe3
4a
c:\pel_data\spectra\scan_rto.001

ACQUISITION		DEC. & VT	
sfrq	500.434	dfrq	125.845
tn	H1	dn	C13
at	5.000	dpwr	30
np	100062	dof	0
sw	10006.3	dm	nnn
fb	not used	dmm	c
bs	2	dmf	200
tpwr	56	dseq	
pw	8.0	dres	1.0
d1	0.100	homo	n
tof	1502.2	DEC2	
nt	32	dfrq2	0
ct	4	dn2	
alock	n	dpwr2	1
gain	not used	dof2	0
FLAGS		dm2	n
il	n	dmm2	c
in	n	dmf2	200
dp	y	dseq2	
hs	nn	dres2	1.0
DISPLAY		homo2	n
sp	-250.3	DEC3	
wp	6255.4	dfrq3	0
vs	18	dn3	
sc	0	dpwr3	1
wc	250	dof3	0
hzmm	25.02	dm3	n
is	33.57	dmm3	c
rfl	999.1	dmf3	200
rfp	0	dseq3	
th	5	dres3	1.0
ins	1.000	homo3	n
ai cdc ph		PROCESSING	
		wtfile	
		proc	ft
		fn	262144
		math	f
		werr	
		wexp	
		wbs	
		wnt	wft



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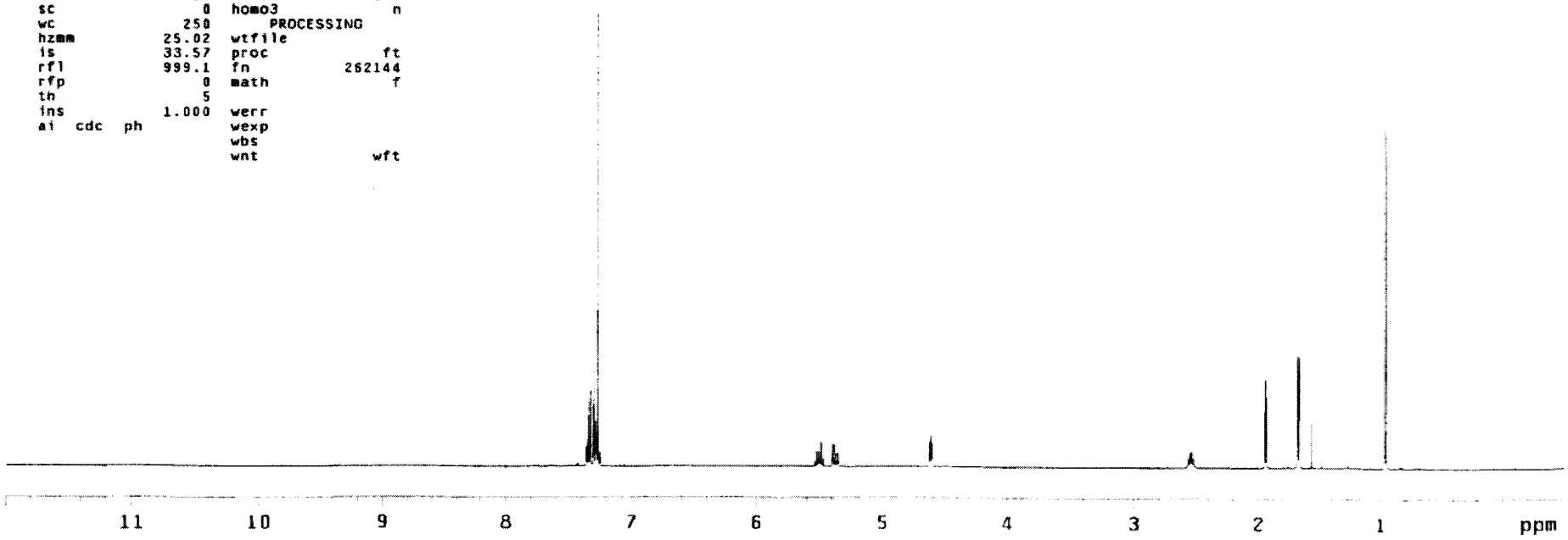
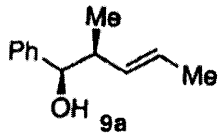
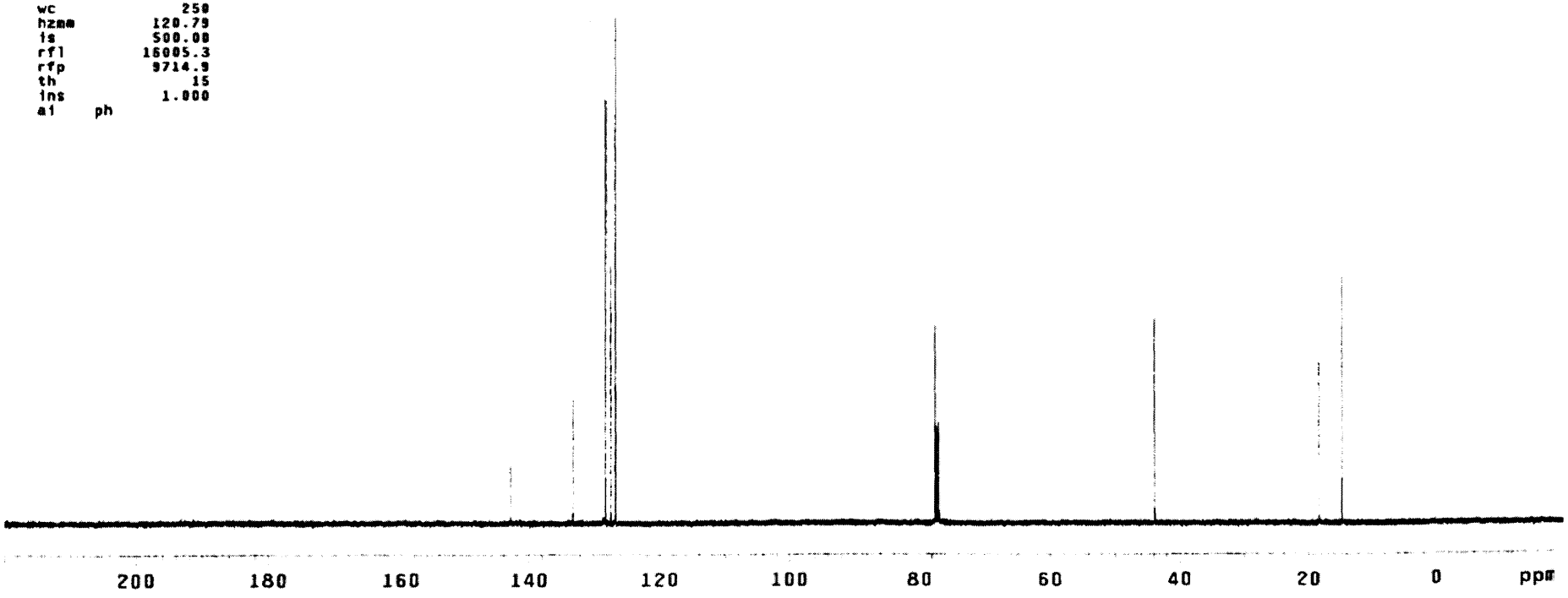
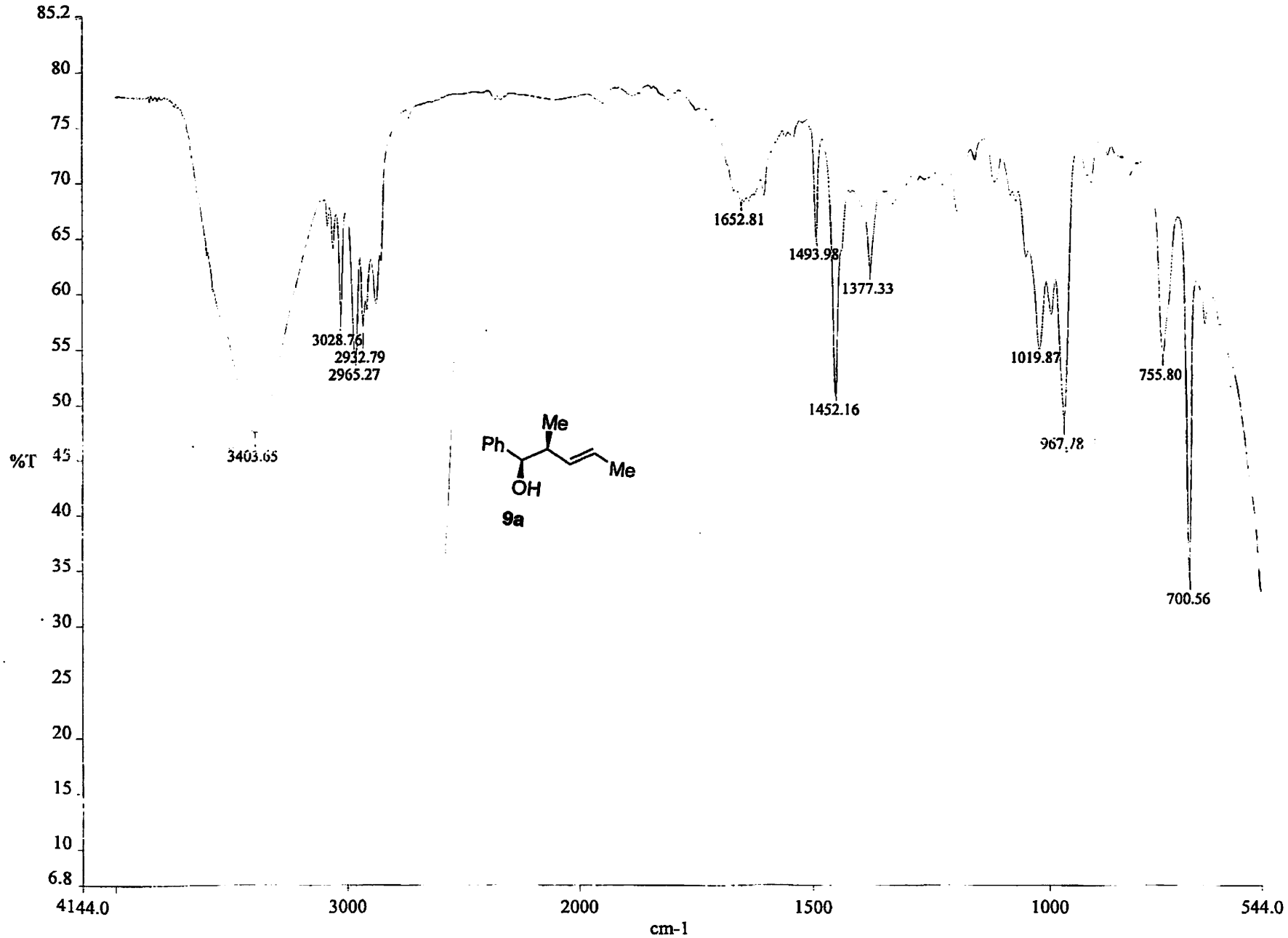


ACQUISITION		DEC. & VT	
sfrq	125.795	dfrq	500.229
tn	C13	dn	H1
at	1.736	dpwr	37
np	131010	dof	-500.0
sw	37735.8	dm	y
fb	not used	dmm	w
bs	8	dmf	10000
ss	1	dseq	
tpwr	53	dres	1.0
pw	6.9	homo	n
d1	0.763	PROCESSING	
tof	631.4	lb	0.30
nt	1008	wtfile	
ct	104	proc	ft
alock	n	fn	131072
gain	not used	math	f
FLAGS		werr	
il	n	wexp	
in	n	wbs	
dp	y	wnt	
hs	nn		
DISPLAY			
sp	-2522.8		
wp	30198.5		
vs	83		
sc	0		
wc	250		
hzmm	120.79		
is	500.00		
rfl	16085.3		
rfp	9714.9		
th	15		
ins	1.000		
ai	ph		



9a

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6.8
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3000
2000
1500
1000
544.0
cm-1
3403.65
3028.76
2932.79
2965.27
1652.81
1493.98
1377.33
1452.16
1019.87
967.78
755.80
700.56
Me
Ph
Me
OH
9a

ACQUISITION	
sfrq	500.434
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at	5.000
np	100062
sw	10006.3
fb	not used
bs	2
tpwr	56
pw	8.0
d1	0.100
tof	1502.2
nt	32
ct	14
alock	n
gain	not used
FLAGS	
il	n
in	n
dp	y
hs	nn
DISPLAY	
sp	-499.7
wp	6508.6
vs	7
sc	0
wc	250
hzmm	26.03
is	33.57
rfl	4637.5
rfp	3638.1
th	16
ins	1.000
ai cdc ph	

DEC. & VT	
dfrq	125.845
dn	C13
dpwr	30
dof	0
dm	nnn
dmm	c
dmf	200
dseq	
dres	1.0
homo	n
PROCESSING	
wtfile	
proc	ft
fn	262144
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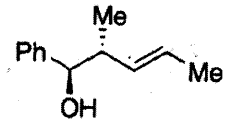
werr	
wexp	
wbs	
wnt	wft



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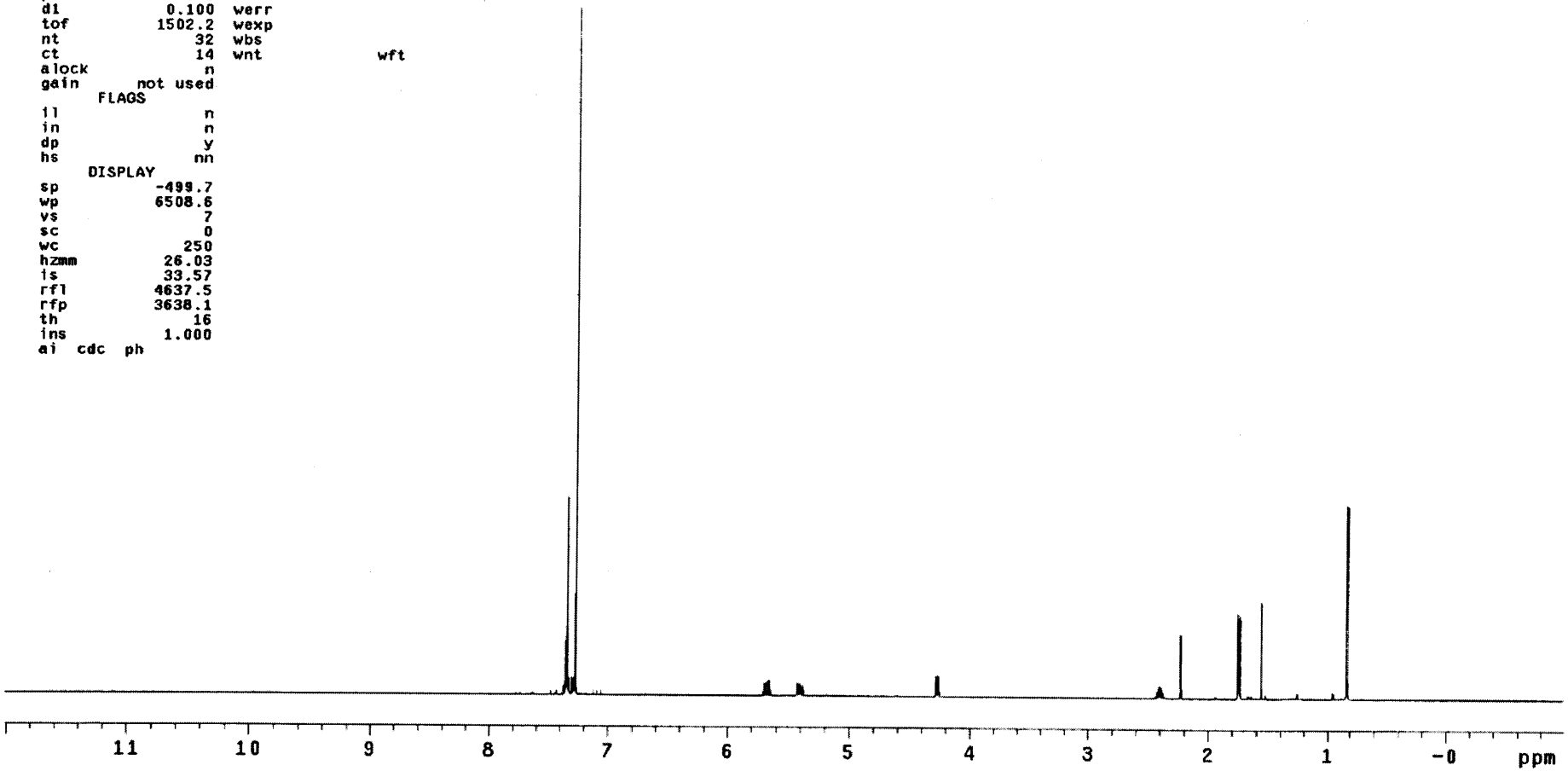

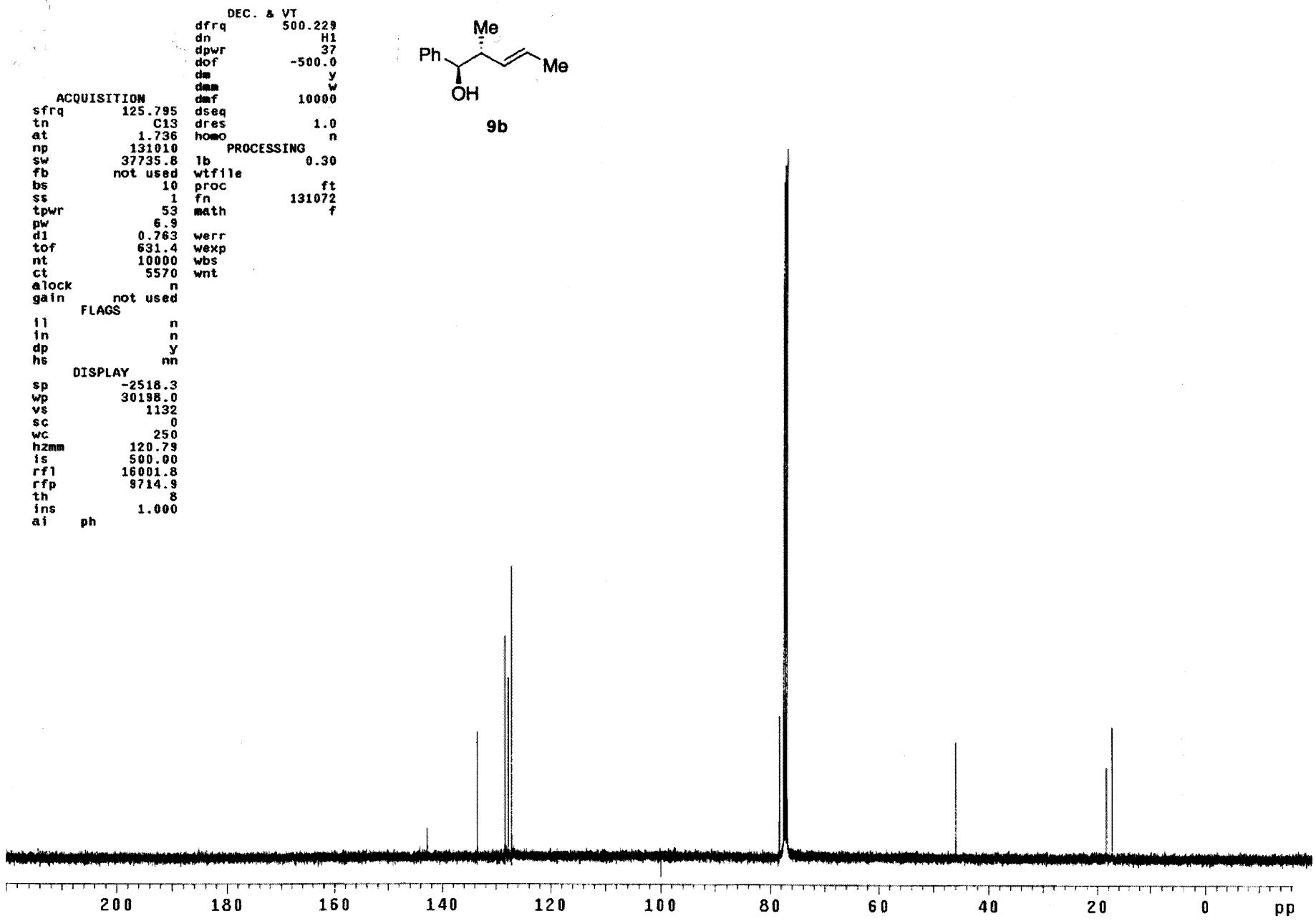
ACQUISITION
sfrq 125.795
tn C13
at 1.736
np 131010
sw 37735.8
fb not used
bs 10
ss 1
tpwr 53
pw 6.9
d1 0.763
tof 631.4
nt 10000
ct 5570
alock n
gain not used
FLAGS
il n
in n
dp y
hs nn
DISPLAY
sp -2518.3
wp 30198.0
vs 1132
sc 0
wc 250
hzmm 120.79
is 500.00
rfl 16001.8
rfp 9714.9
th 8
ins 1.000
ai ph
DEC. & VT
dfrq 500.229
dn H1
dpwr 37
dof -500.0
dm y
dmm w
dmf 10000
dseq
dres 1.0
homo n
PROCESSING
lb 0.30
wtfile
proc ft
fn 131072
math f
werr
wexp
wbs
wnt
Me
Ph
Me
OH
9b
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140
120
100
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40
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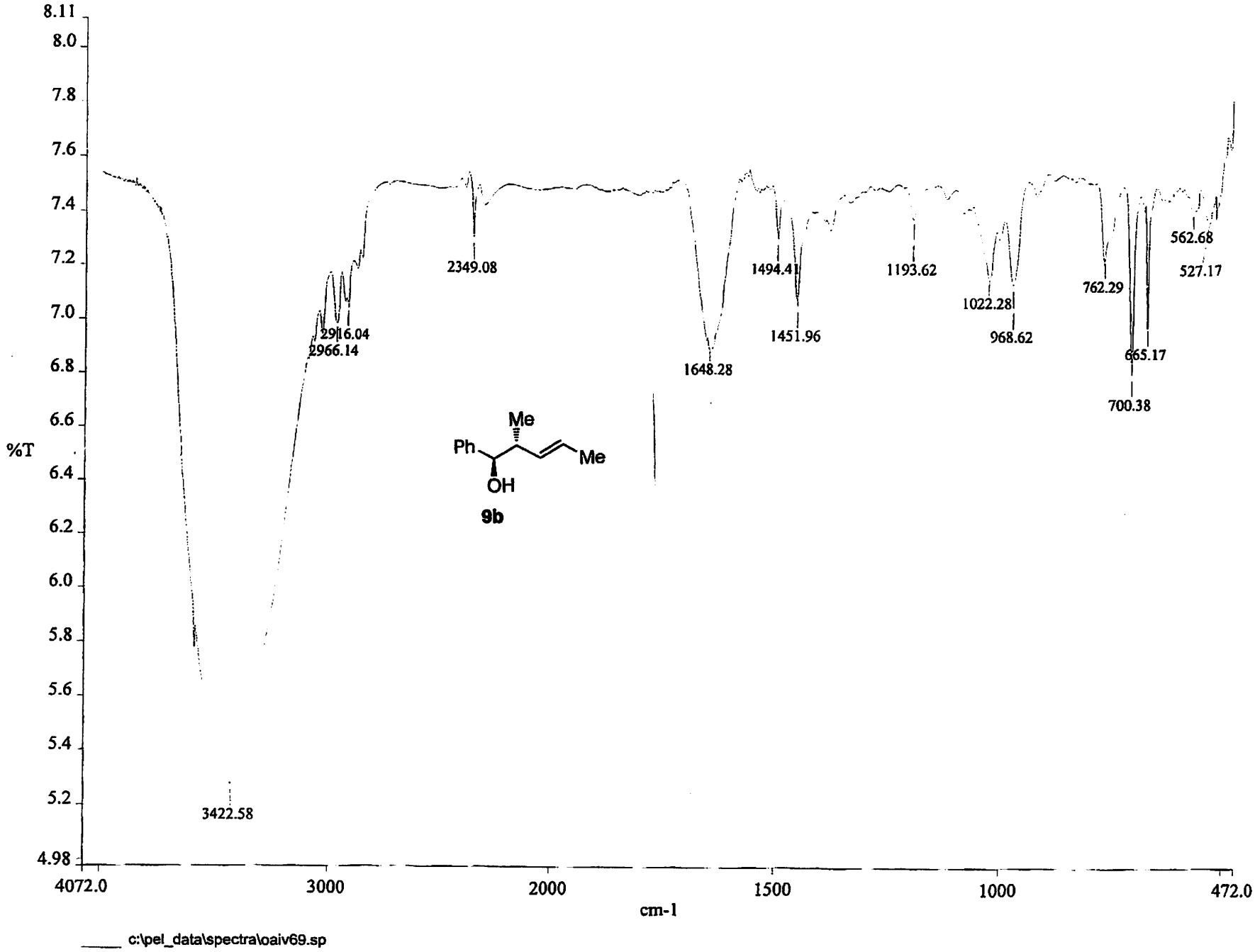
0
pp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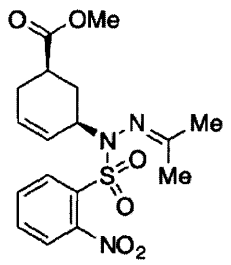
7.4
7.2
7.0
6.8
6.6
6.4
6.2
6.0
5.8
5.6
5.4
5.2
4.98
%T
3422.58
2966.14
2916.04
2349.08
1648.28
1494.41
1451.96
1193.62
1022.28
968.62
762.29
700.38
665.17
562.68
527.17
Me
Ph
Me
OH
9b
4072.0
3000
2000
1500
1000
472.0
cm-1
c:\pel_data\spectra\oaiv69.sp

ACQUISITION		DEC. & VT	
sfrq	500.435	dfrq	125.845
tn	H1	dn	C13
at	4.999	dpwr	30
np	120102	dof	0
sw	12012.0	dm	nnn
fb	not used	dmm	c
bs	2	dmf	200
tpwr	56	dseq	
pw	8.0	dres	1.0
d1	0.100	homo	n
tof	3003.2	DEC2	
nt	32	dfrq2	0
ct	10	dn2	
alock	n	dpwr2	1
gain	not used	dof2	0
FLAGS		dm2	n
il	n	dmm2	c
in	n	dmf2	200
dp	y	dseq2	
hs	nn	dres2	1.0
DISPLAY		homo2	n
sp	-252.3	DEC3	
wp	6255.3	dfrq3	0
vs	39	dn3	
sc	0	dpwr3	1
wc	250	dof3	0
hzmm	25.02	dm3	n
is	33.57	dmm3	c
rfl	4138.2	dmf3	200
rfp	3638.1	dseq3	
th	7	dres3	1.0
ins	100.000	homo3	n
ai cdc ph		PROCESSING	
		wtfile	
		proc	ft
		fn	262144
		math	f
		werr	
		wexp	
		wbs	
		wnt	wft



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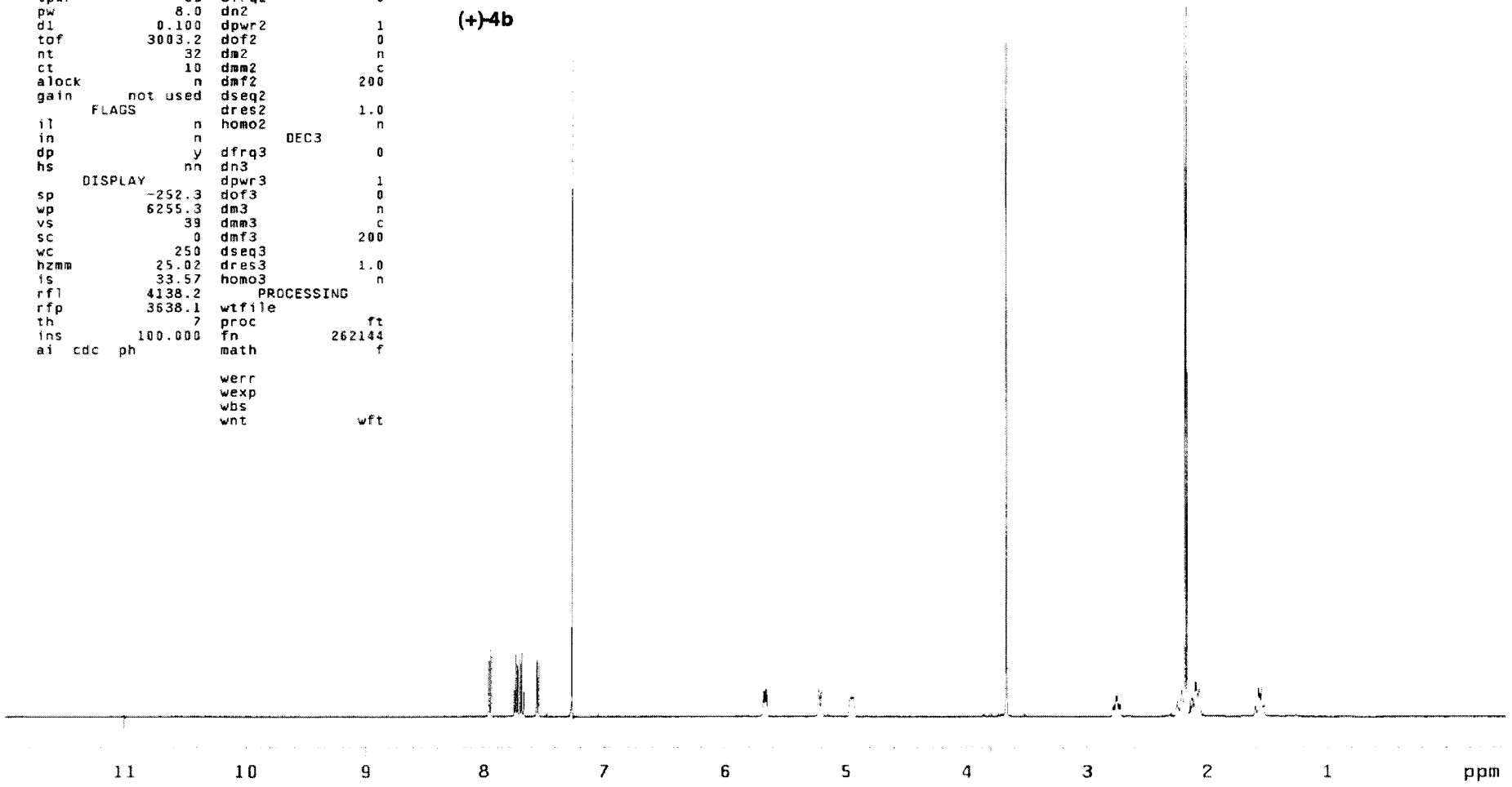
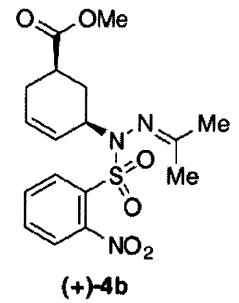


ACQUISITION		DEC. & VT	
sfrq	125.795	dfrq	500.229
tn	C13	dn	H1
at	1.736	dpwr	37
np	131010	dof	-500.0
sw	37735.8	dm	y
fb	not used	dmm	w
bs	10	dmf	10000
ss	1	dseq	
tpwr	53	dres	1.0
pw	6.9	homo	n
d1	0.763	PROCESSING	
tof	631.4	lb	0.30
nt	3000	wtfile	
ct	1350	proc	ft
alock	n	fn	131072
gain	not used	math	f
FLAGS		werr	
il	n	wexp	
in	n	wbs	
dp	y	wnt	
hs	nn		
DISPLAY			
sp	-2525.8		
wp	30198.6		
vs	428		
sc	0		
wc	250		
hzmm	120.79		
is	500.00		
rfl	16004.7		
rfp	9714.9		
th	4		
ins	1.000		
ai	ph		



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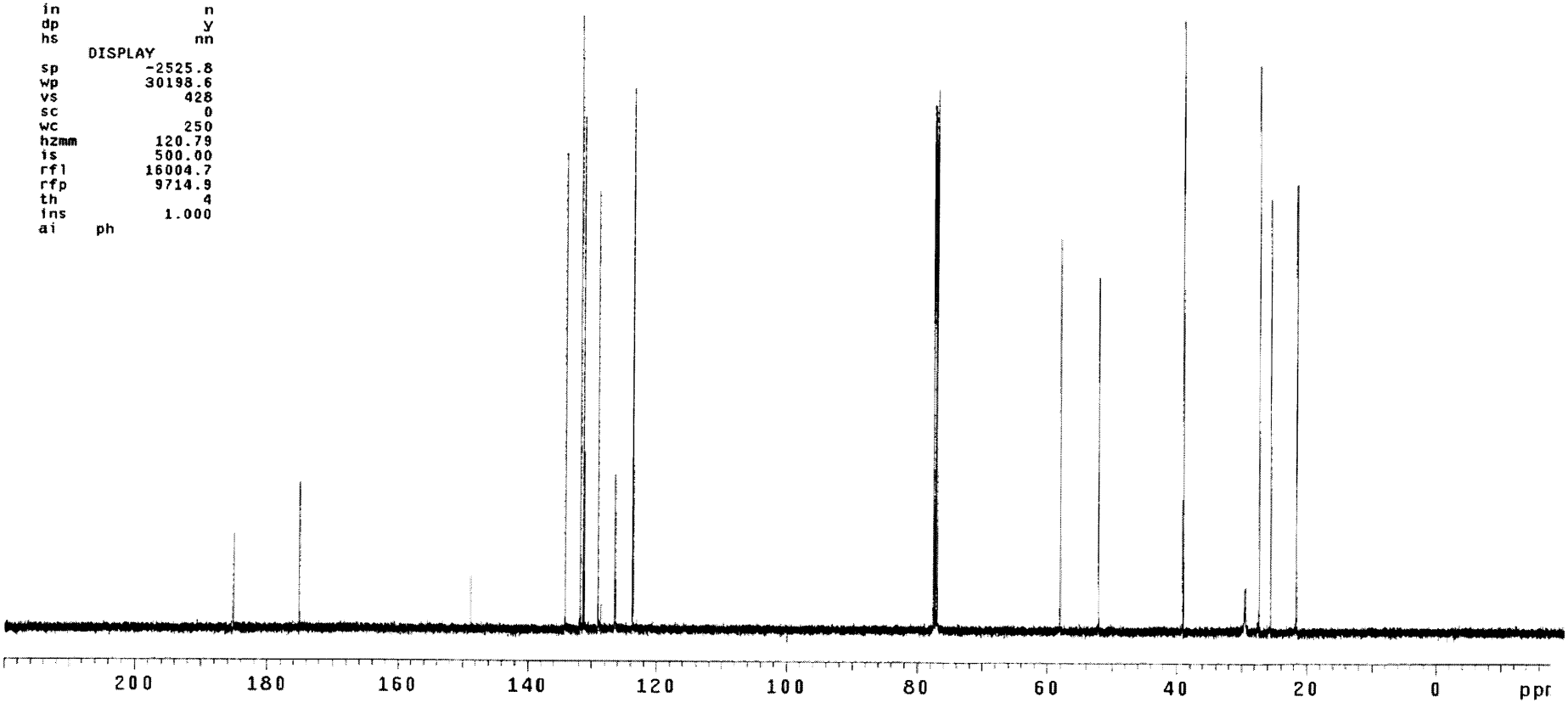

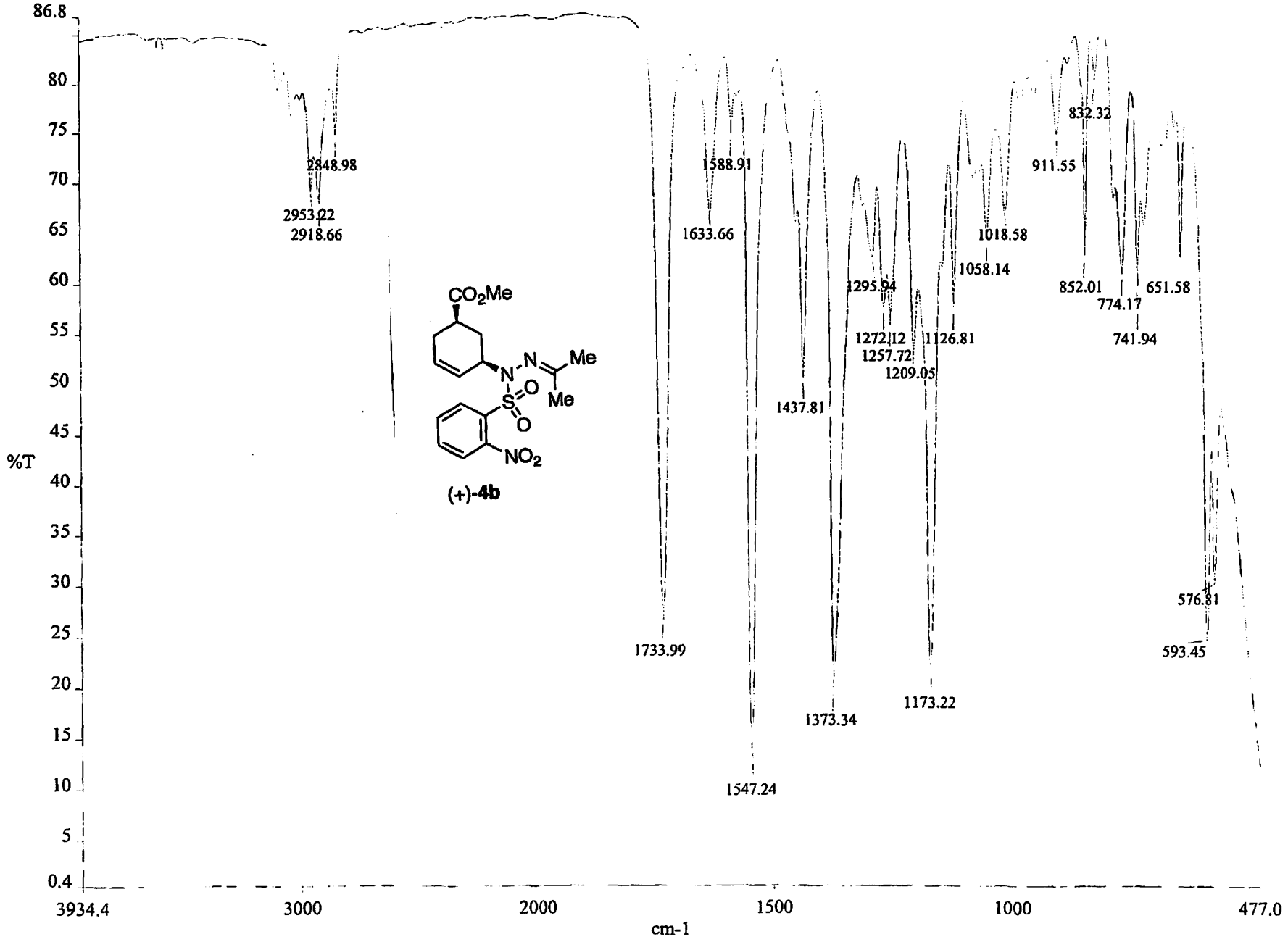
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5
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3000
2000
1500
1000
477.0
cm-1
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2918.66
2848.98
1633.66
1588.91
1733.99
1547.24
1437.81
1373.34
1295.94
1272.12
1257.72
1209.05
1173.22
1126.81
1058.14
1018.58
911.55
852.01
832.32
774.17
741.94
651.58
593.45
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Me
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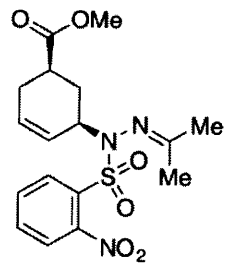

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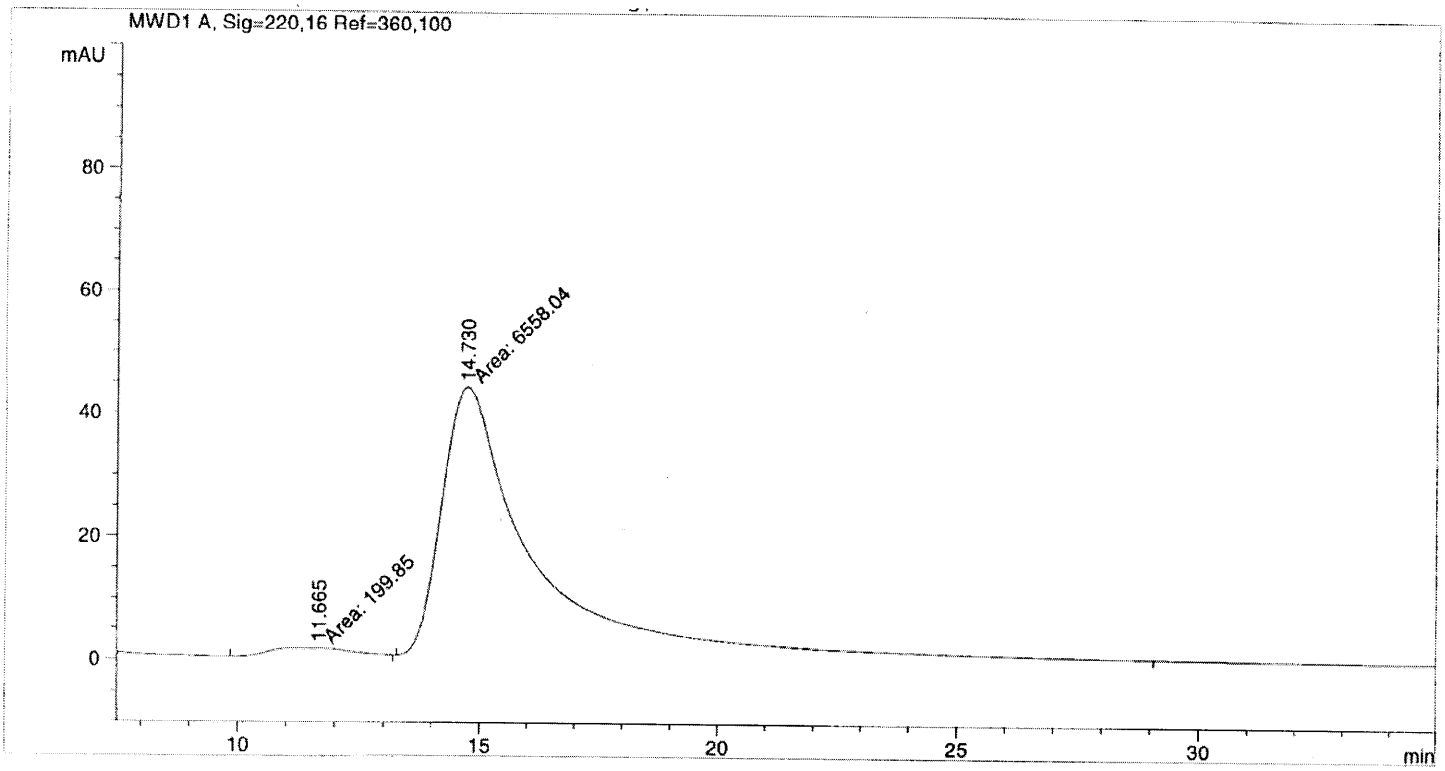
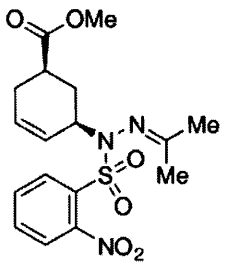
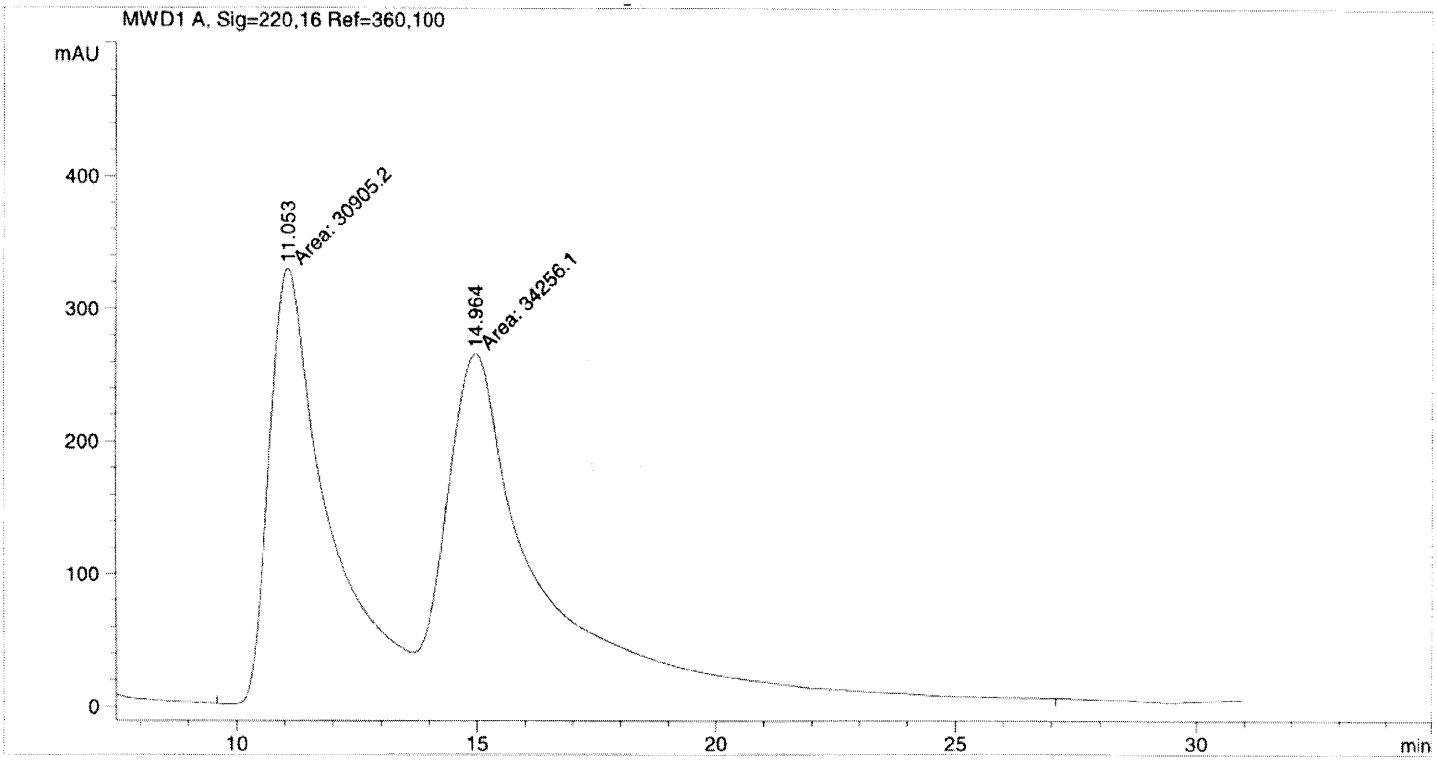



```
================================================================================
                          Area Percent Report
================================================================================

Sorted By             :      Signal
Multiplier            :      1.0000
Dilution              :      1.0000
Use Multiplier & Dilution Factor with ISTDs


Signal 1: MWD1 A, Sig=220,16 Ref=360,100

Peak RetTime Type  Width     Area      Height     Area
  #   [min]        [min]   [mAU*s]     [mAU]       %
----|-------|----|-------|----------|----------|--------|
   1  11.665 MM    2.1624  199.85022    1.54032   2.9573
   2  14.730 MM    2.4697 6558.04346   44.25581  97.0427

Totals :                  6757.89368   45.79613

 Results obtained with enhanced integrator!
================================================================================
                          *** End of Report ***
```



(±)-4b




```
=====================================================================
                        Area Percent Report
=====================================================================

Sorted By             :      Signal
Multiplier            :      1.0000
Dilution              :      1.0000
Use Multiplier & Dilution Factor with ISTDs


Signal 1: MWD1 A, Sig=220,16 Ref=360,100

Peak RetTime Type  Width     Area      Height     Area
  #   [min]        [min]   [mAU*s]     [mAU]       %
----|-------|----|-------|----------|----------|--------|
   1  11.053 MM    1.5662 3.09052e4   328.86630  47.4287
   2  14.964 MM    2.1648 3.42561e4   263.73654  52.5713

Totals :                  6.51613e4   592.60284

 Results obtained with enhanced integrator!
=====================================================================
                        *** End of Report ***
```

ACQUISITION	
sfrq	499.746
tn	H1
at	3.001
np	63050
sw	10504.2
fb	not used
bs	2
tpwr	56
pw	8.6
d1	2.000
tof	1519.5
nt	32
ct	12
alock	n
gain	not used

FLAGS	
il	n
in	n
dp	y
hs	nn

DISPLAY	
sp	-249.9
wp	6246.7
vs	10
sc	0
wc	250
hzmm	24.99
is	33.57
rfl	4865.2
rfp	3633.1
th	7
ins	1.000

ai cdc ph

DEC. & VT	
dfrq	125.672
dn	C13
dpwr	30
dof	0
dm	nnn
dmm	w
dmf	10000
dseq	
dres	1.0
homo	n

PROCESSING	
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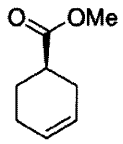
proc	ft
fn	262144
math	f
werr	
wexp	
wbs	
wnt	wft



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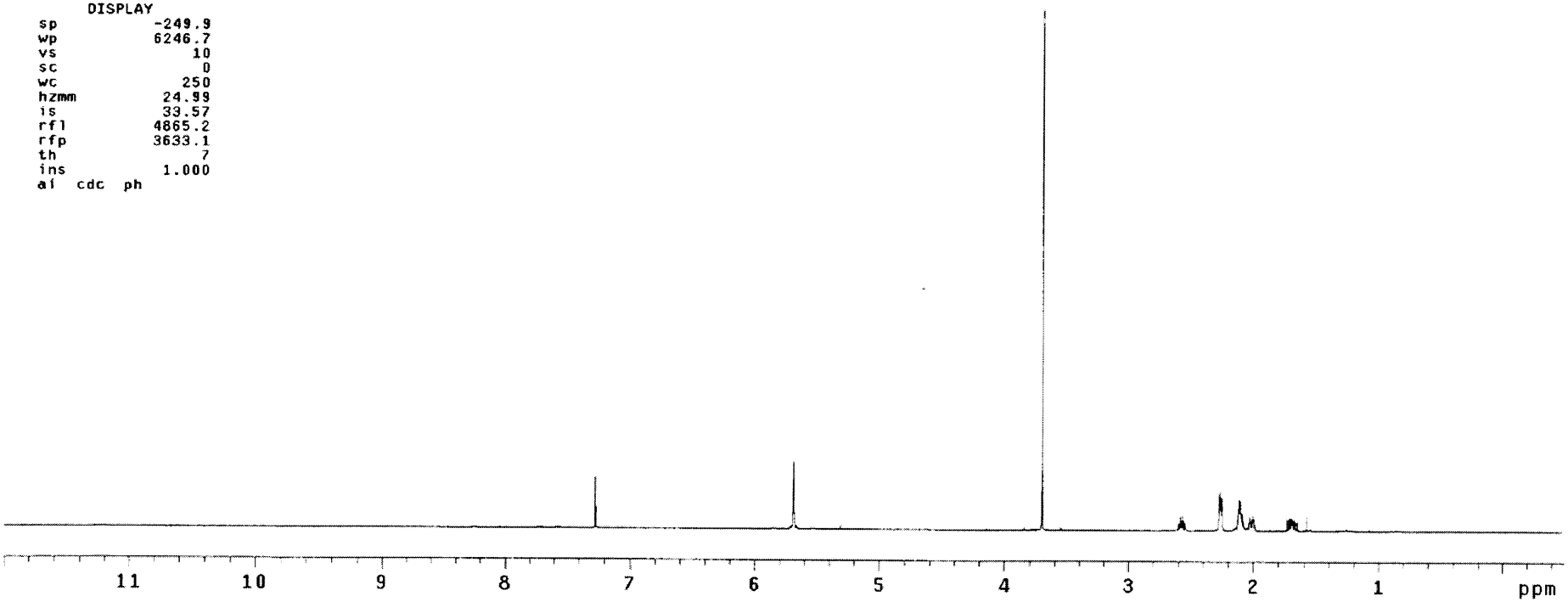

ACQUISITION		DEC. & VT	
sfrq	125.795	dfrq	500.229
tn	C13	dn	H1
at	1.736	dpwr	37
np	131010	dof	-500.0
sw	37735.8	dm	y
fb	not used	dmm	w
bs	10	dmf	10000
ss	1	dseq	
tpwr	53	dres	1.0
pw	6.9	homo	n
d1	0.763	PROCESSING	
tof	631.4	lb	0.30
nt	1000	wtfile	
ct	700	proc	ft
alock	n	fn	131072
gain	not used	math	f
FLAGS		werr	
il	n	wexp	
in	n	wbs	
dp	y	wnt	
hs	nn		
DISPLAY			
sp	-2516.0		
wp	30189.9		
vs	448		
sc	0		
wc	250		
hzmm	120.76		
is	500.00		
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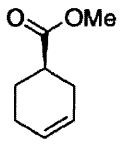
rfp	9714.9		
th	6		
ins	1.000		
ai	ph		



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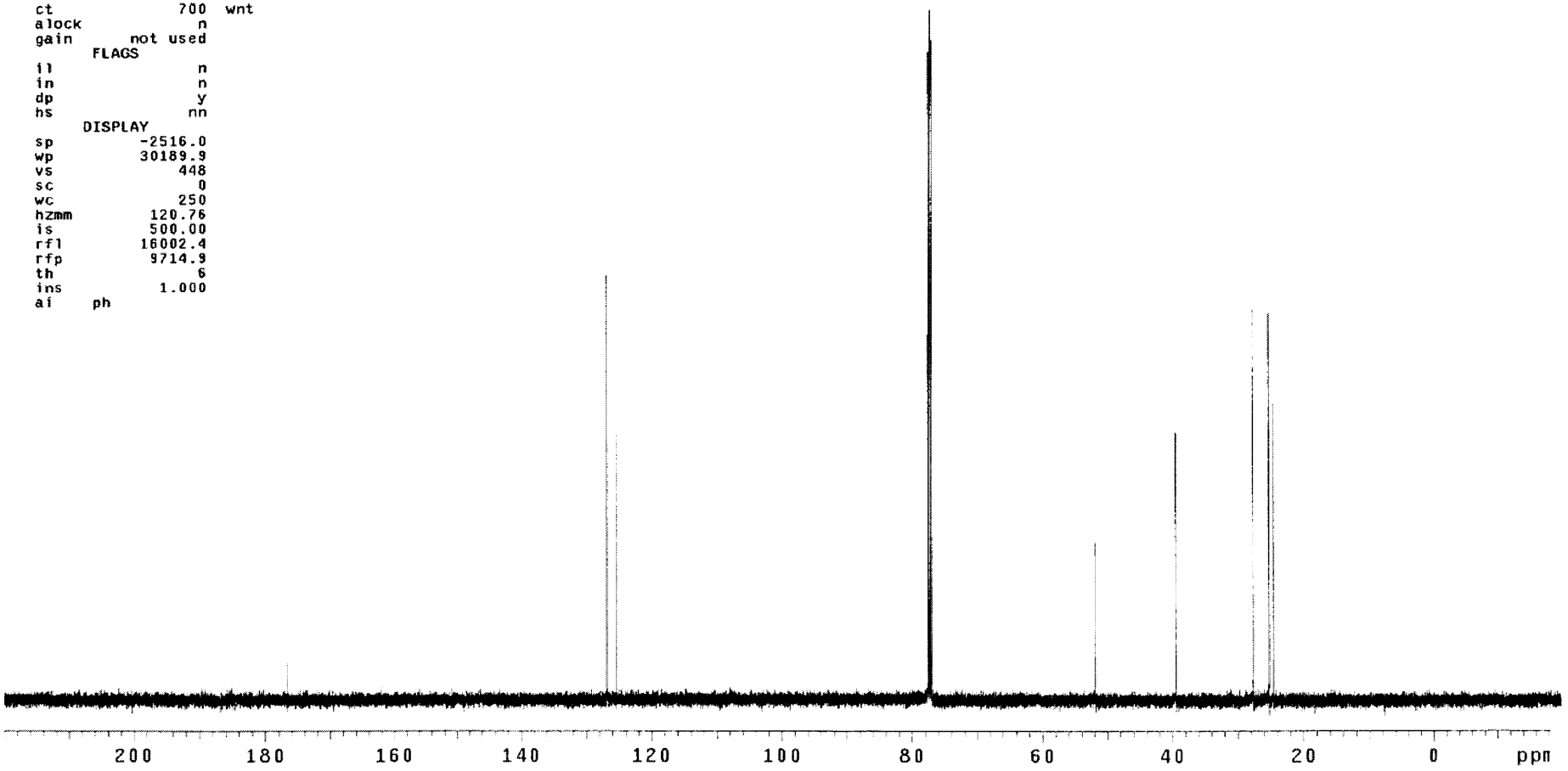

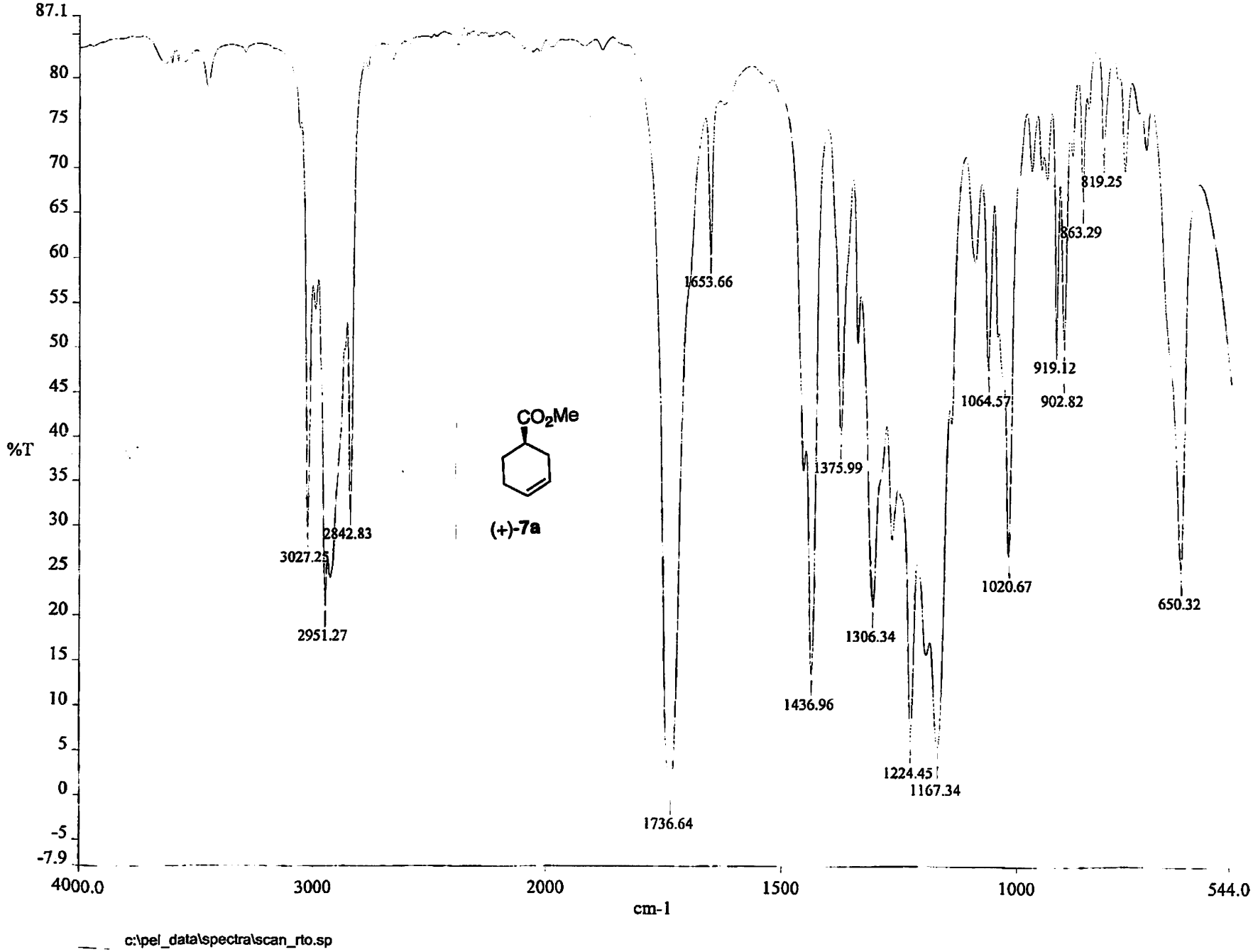
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-7.9
%T
4000.0
3000
2000
1500
1000
544.0
cm-1
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2842.83
2951.27
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1167.34
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650.32
CO2Me
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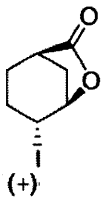
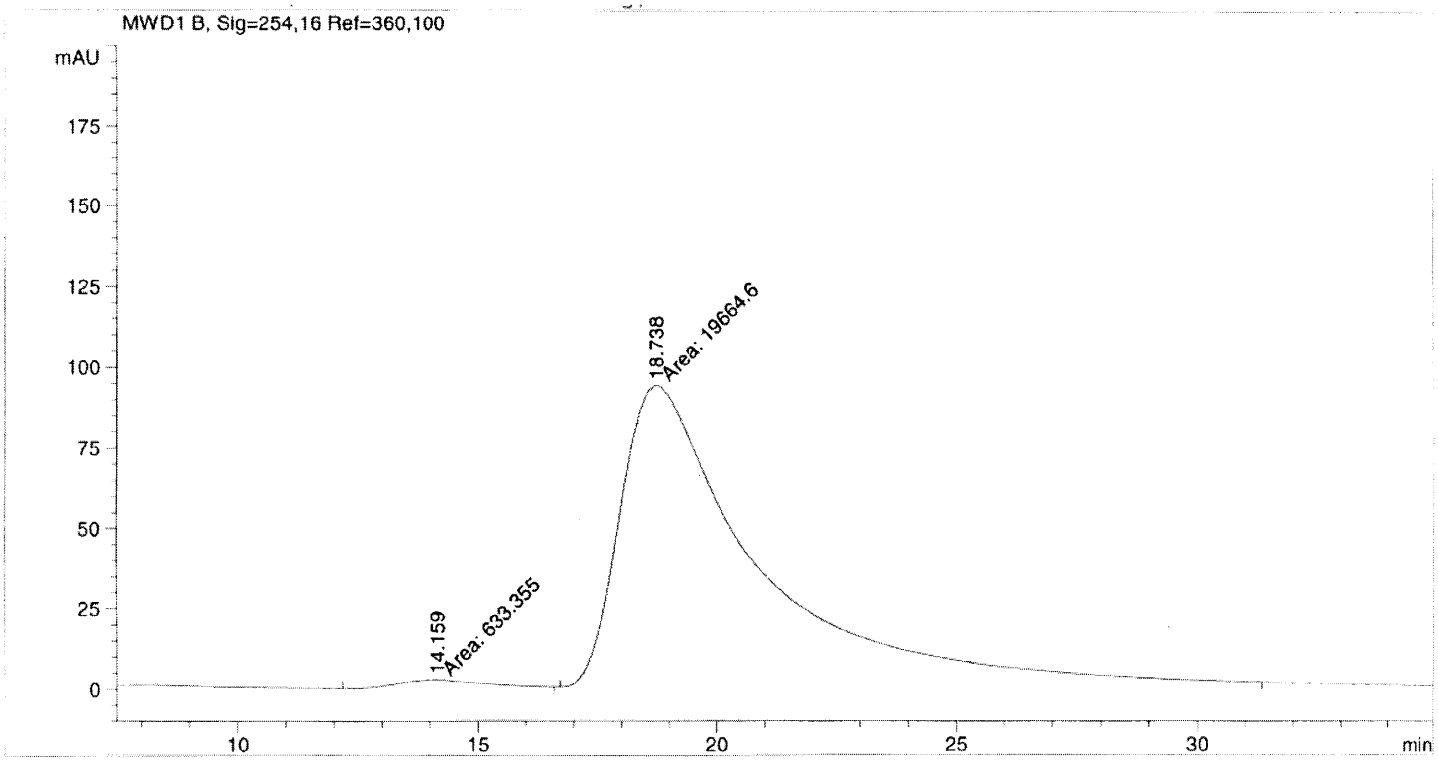
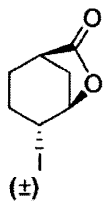
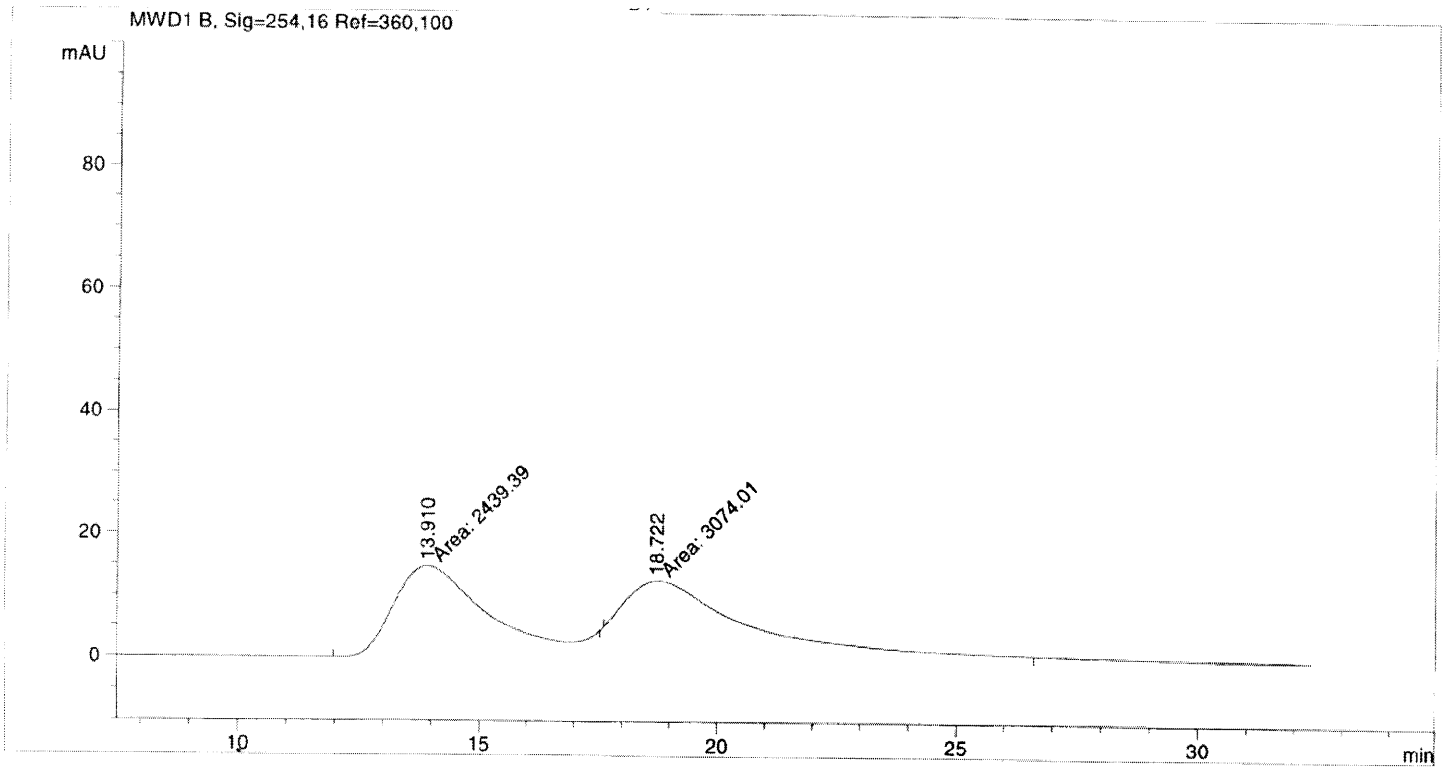





```
================================================================================
                            Area Percent Report
================================================================================

Sorted By             :      Signal
Multiplier            :      1.0000
Dilution              :      1.0000
Use Multiplier & Dilution Factor with ISTDs


Signal 1: MWD1 B, Sig=254,16 Ref=360,100

Peak RetTime Type  Width     Area      Height     Area
  #   [min]        [min]   [mAU*s]     [mAU]       %
----|-------|----|-------|----------|----------|--------|
   1  14.159 MM    2.8693  633.35461    3.67888   3.1203
   2  18.738 MM    3.4587 1.96646e4    94.75866  96.8797

Totals :                  2.02979e4    98.43754

 Results obtained with enhanced integrator!
================================================================================
                            *** End of Report ***
```





==========

Area Percent Report

==========

Sorted By : Signal
Multiplier : 1.0000
Dilution : 1.0000
Use Multiplier & Dilution Factor with ISTDs

Signal 1: MWD1 B, Sig=254,16 Ref=360,100

Peak #	RetTime [min]	Type	Width [min]	Area [mAU*s]	Height [mAU]	Area %
1	13.910	MM	2.5885	2439.39063	15.70683	44.2448
2	18.722	MM	3.6981	3074.00903	13.85405	55.7552

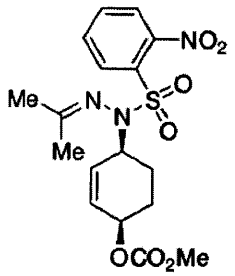
Totals : 5513.39966 29.56088

Results obtained with enhanced integrator!

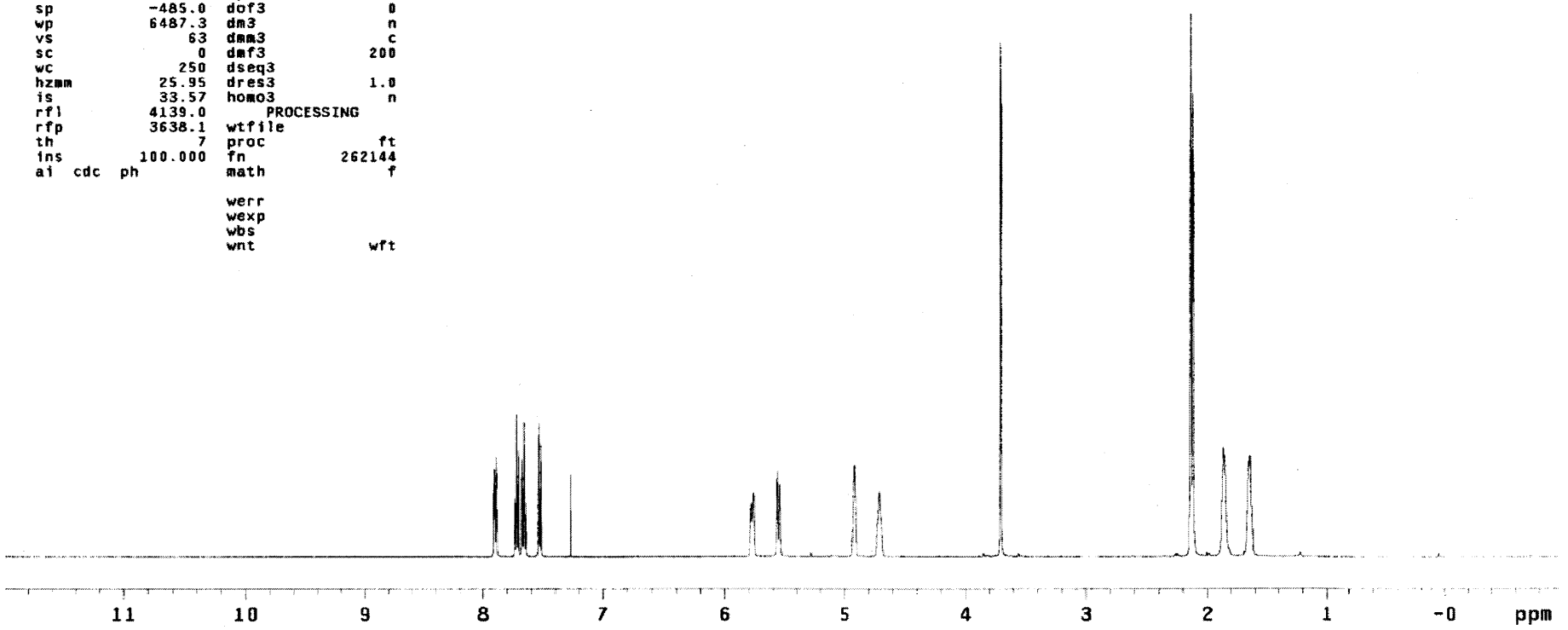
==========

*** End of Report ***

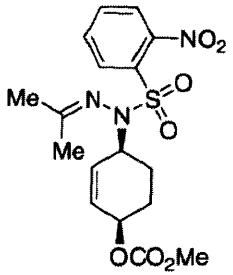
ACQUISITION		DEC. & VT	
sfrq	500.435	dfrq	125.845
tn	H1	dn	C13
at	4.999	dpwr	30
np	120102	dof	0
sw	12012.0	dm	nnn
fb	not used	dmm	c
bs	2	dmf	200
tpwr	56	dseq	
pw	8.0	dres	1.0
d1	0.100	homo	n
tof	3003.2	DEC2	
nt	32	dfrq2	0
ct	10	dn2	
alock	n	dpwr2	1
gain	not used	dof2	0
FLAGS		dm2	n
il	n	dmm2	c
in	n	dmf2	200
dp	y	dseq2	
hs	nn	dres2	1.0
DISPLAY		homo2	n
sp	-485.0	DEC3	
wp	6487.3	dfrq3	0
vs	63	dn3	
sc	0	dpwr3	1
wc	250	dof3	0
hzmm	25.95	dm3	n
is	33.57	dmm3	c
rfl	4139.0	dmf3	200
rfp	3638.1	dseq3	
th	7	dres3	1.0
ins	100.000	homo3	n
ai cdc ph		PROCESSING	
		wtfile	
		proc	ft
		fn	262144
		math	f
		werr	
		wexp	
		wbs	
		wnt	wft



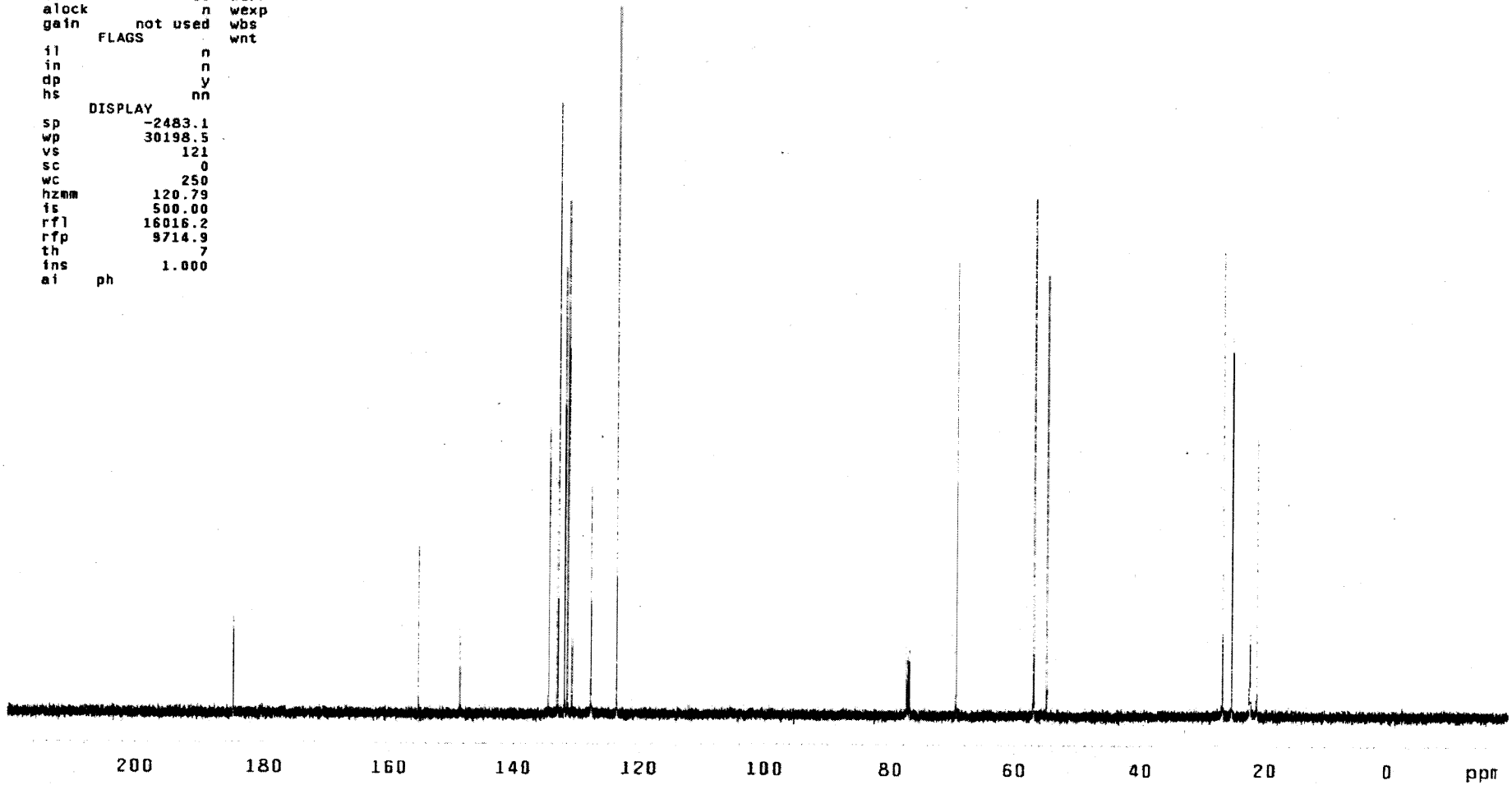
12a

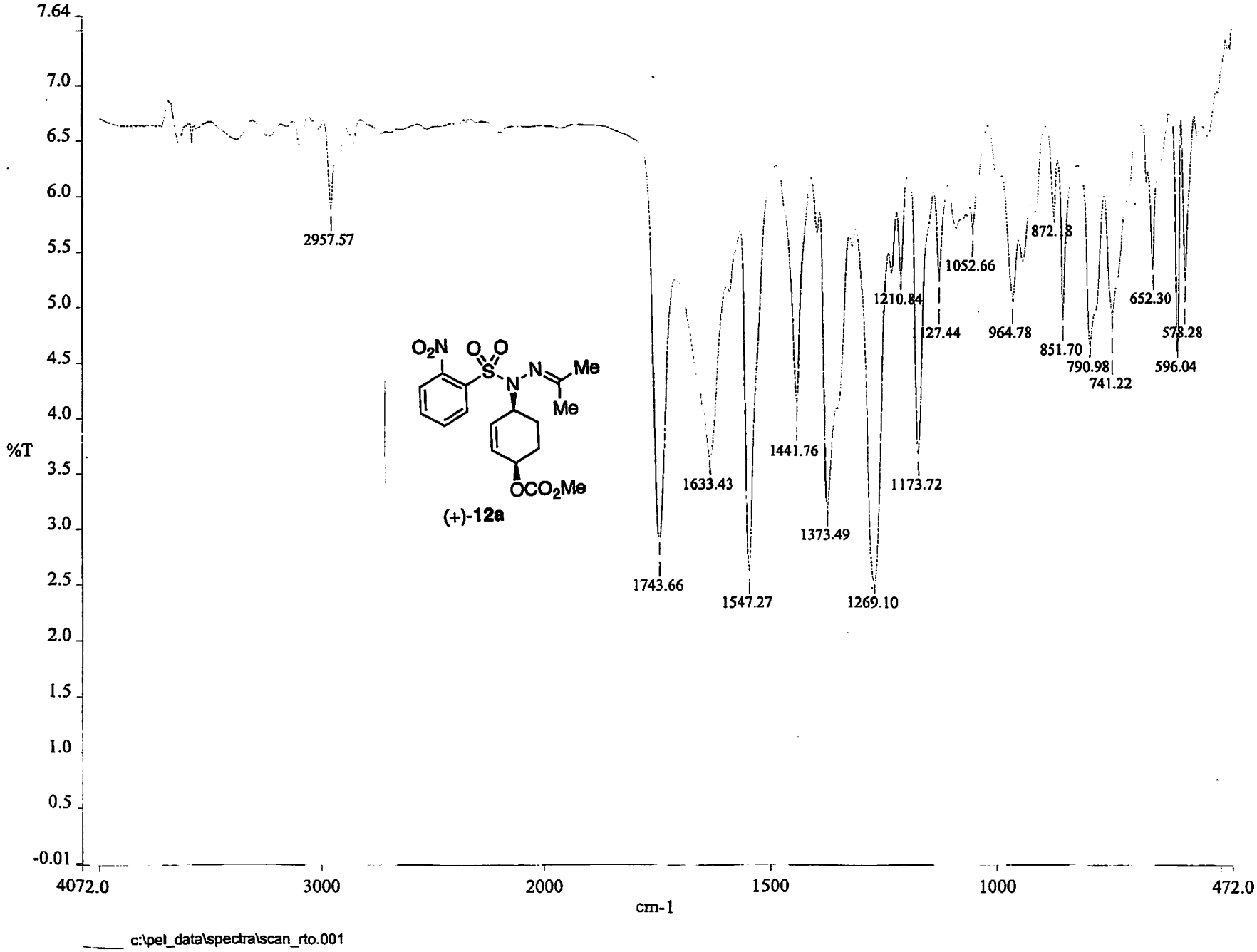


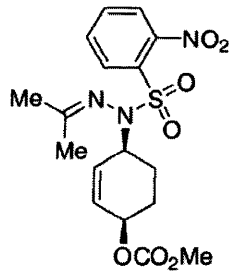
ACQUISITION		DEC. & VT	
sfrq	125.795	dfrq	500.229
tn	C13	dn	H1
at	1.736	dpwr	37
np	131010	dof	-500.0
sw	37735.8	dm	y
fb	not used	dmm	w
bs	10	dmf	10000
ss	1	dseq	
tpwr	53	dres	1.0
pw	6.9	homo	n
dl	0.763	PROCESSING	
tof	631.4	lb	0.30
nt	1000	wtfile	
ct	80	proc	ft
alock	n	fn	131072
gain	not used	math	f
FLAGS		werr	
il	n	wexp	
in	n	wbs	
dp	y	wnt	
hs	nn		
DISPLAY			
sp	-2483.1		
wp	30198.5		
vs	121		
sc	0		
wc	250		
hzmm	120.79		
is	500.00		
rfl	16016.2		
rfp	9714.9		
th	7		
ins	1.000		
ai	ph		



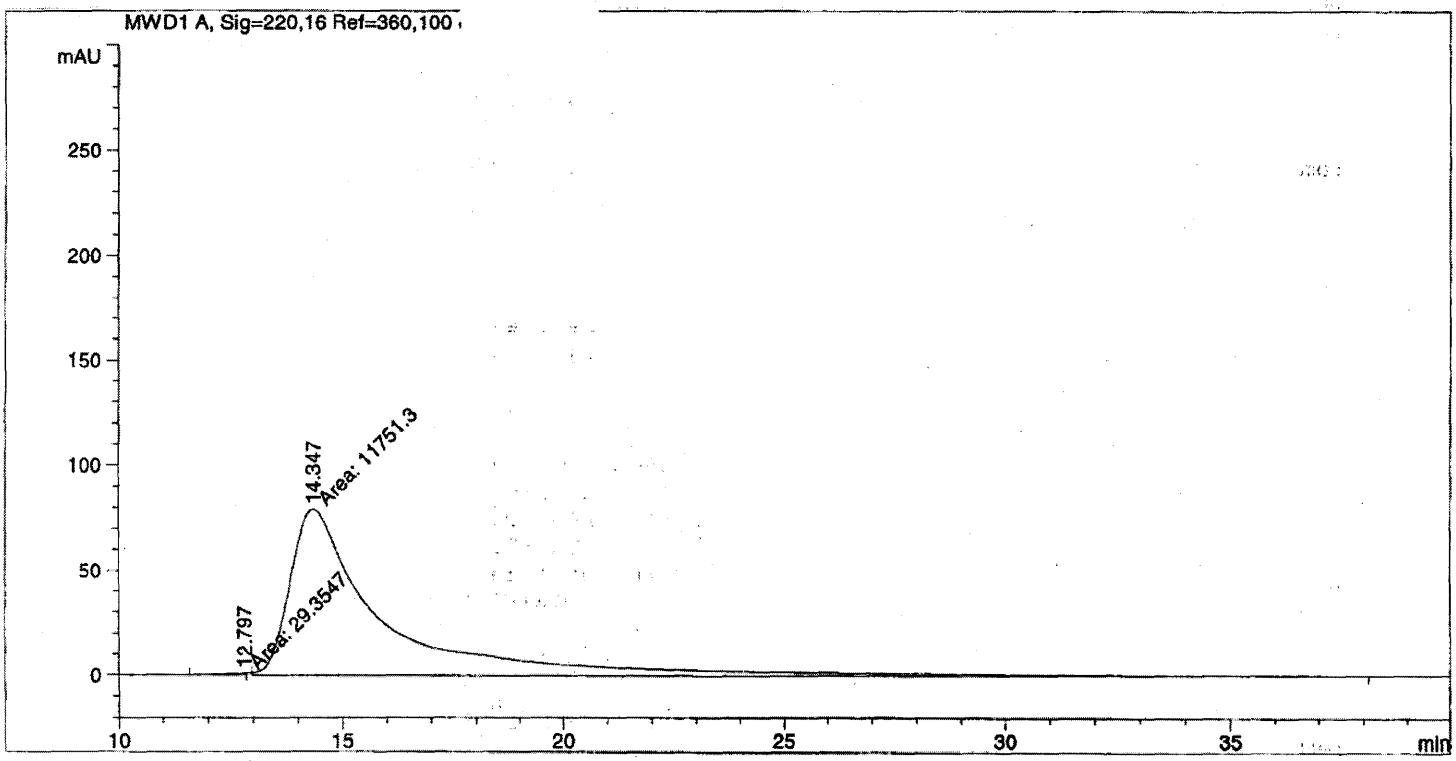
12a



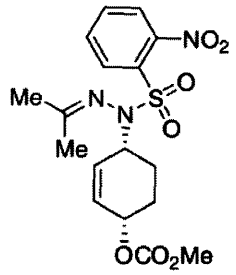

7.64
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
-0.01
%T
4072.0
3000
2000
1500
1000
472.0
cm-1
2957.57
1743.66
1633.43
1547.27
1441.76
1373.49
1269.10
1210.84
1173.72
1127.44
1052.66
964.78
872.18
851.70
790.98
741.22
652.30
596.04
578.28
O2N
O
O
S
N
N
Me
Me
OCO2Me
(+)-12a
c:\pel_data\spectra\scan_rto.001



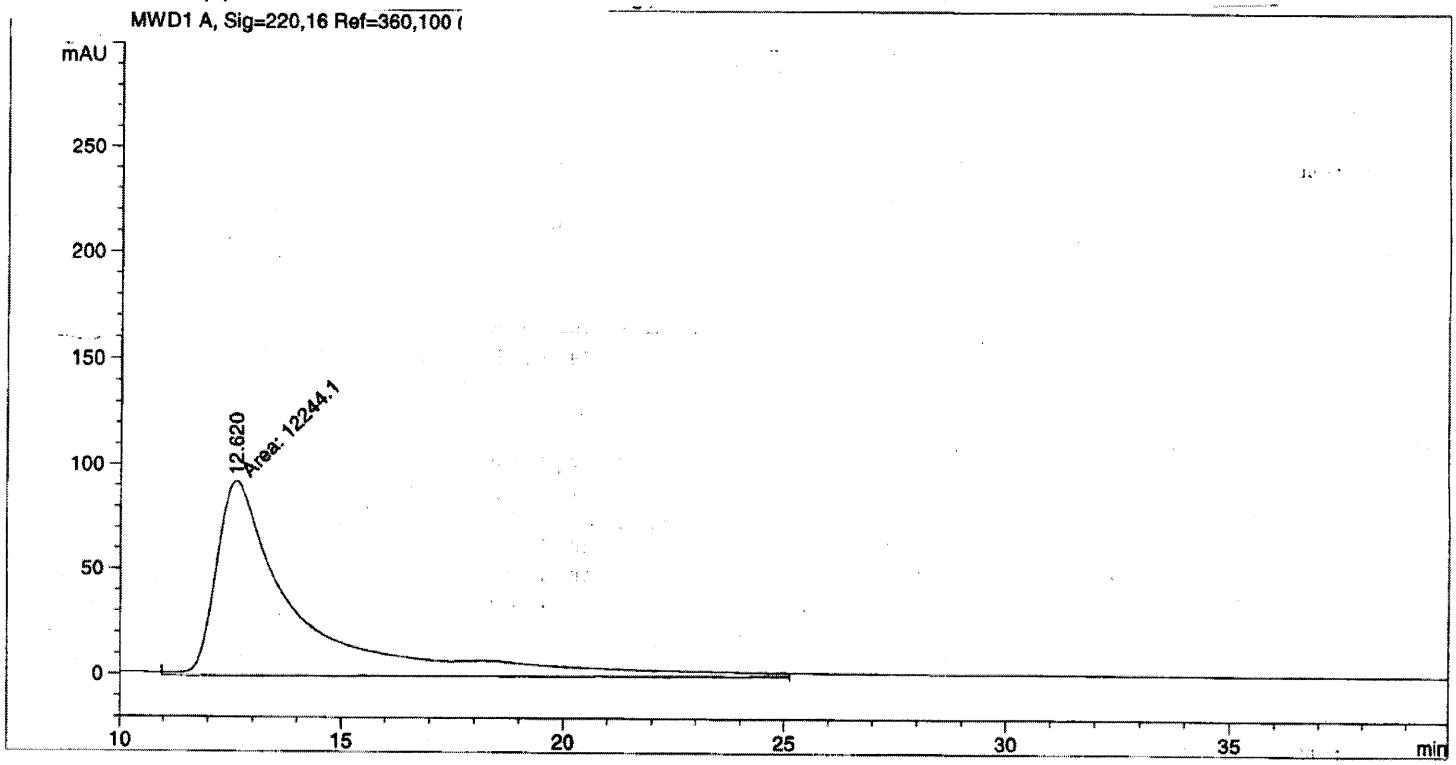
(+)-12a



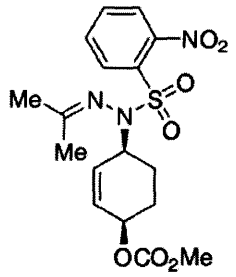

```
================================================================================
                          Area Percent Report
================================================================================

Sorted By             :      Signal
Multiplier            :      1.0000
Dilution              :      1.0000
Use Multiplier & Dilution Factor with ISTDs


Signal 1: MWD1 A, Sig=220,16 Ref=360,100

Peak RetTime Type  Width     Area      Height     Area
  #   [min]        [min]   [mAU*s]     [mAU]       %
----|-------|----|-------|----------|----------|--------|
   1  12.797 MM    0.6653   29.35473 7.35369e-1   0.2492
   2  14.347 MM    2.4682 1.17513e4    79.35277  99.7508

Totals :                  1.17806e4    80.08814

 Results obtained with enhanced integrator!
================================================================================
                          *** End of Report ***
```



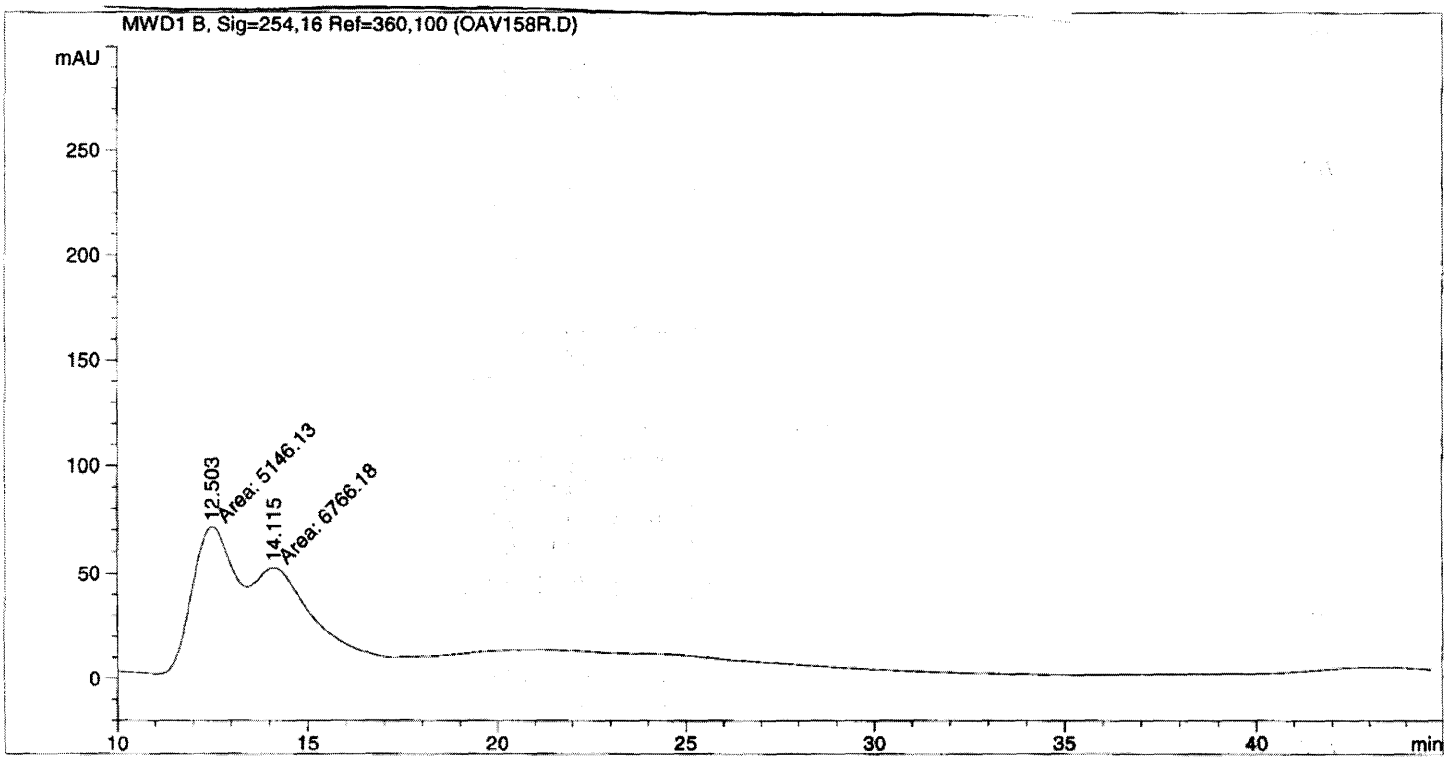
(−)-12a




```
================================================================================
                            Area Percent Report
================================================================================

Sorted By             :      Signal
Multiplier            :      1.0000
Dilution              :      1.0000
Use Multiplier & Dilution Factor with ISTDs


Signal 1: MWD1 A, Sig=220,16 Ref=360,100

Peak RetTime Type  Width     Area      Height     Area
  #   [min]        [min]   [mAU*s]     [mAU]       %
----|-------|----|-------|----------|----------|--------|
   1  12.620 MM    2.1945 1.22441e4    92.99144 100.0000

Totals :                  1.22441e4    92.99144

 Results obtained with enhanced integrator!
================================================================================
                            *** End of Report ***
```



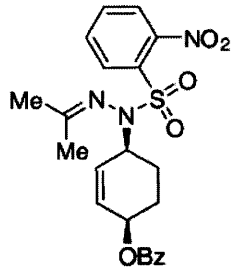
(±)-12a



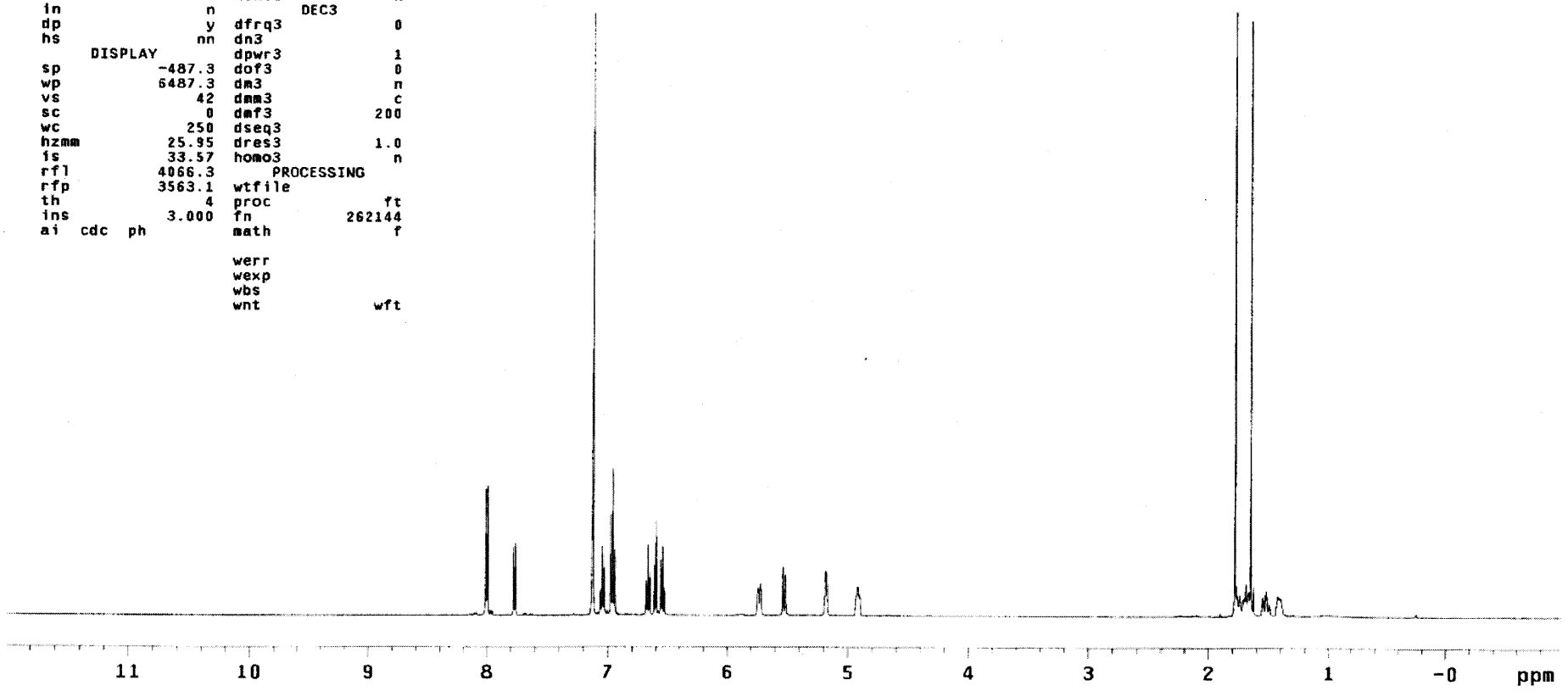

```
=====================================================================
                        Area Percent Report
=====================================================================

Sorted By             :      Signal
Multiplier            :      1.0000
Dilution              :      1.0000
Use Multiplier & Dilution Factor with ISTDs


Signal 1: MWD1 B, Sig=254,16 Ref=360,100

Peak RetTime Type  Width     Area      Height     Area
  #   [min]        [min]   [mAU*s]     [mAU]       %
----|-------|----|-------|----------|----------|--------|
   1  12.503 MM    1.2403 5146.12842   69.15303  43.2001
   2  14.115 MM    2.2838 6766.18213   49.37721  56.7999

Totals :                  1.19123e4   118.53024

 Results obtained with enhanced integrator!
=====================================================================
                        *** End of Report ***
```

ACQUISITION	
sfrq	500.435
tn	H1
at	4.999
np	120102
sw	12012.0
fb	not used
bs	2
tpwr	56
pw	8.0
d1	0.100
tof	3003.2
nt	32
ct	24
alock	n
gain	not used
FLAGS	
il	n
in	n
dp	y
hs	nn
DISPLAY	
sp	-487.3
wp	6487.3
vs	42
sc	0
wc	250
hzmm	25.95
is	33.57
rfl	4066.3
rfp	3563.1
th	4
ins	3.000
ai cdc ph	

DEC. & VT	
dfrq	125.845
dn	C13
dpwr	30
dof	0
dm	nnn
dmm	c
dmf	200
dseq	
dres	1.0
homo	n
DEC2	
dfrq2	0
dn2	
dpwr2	1
dof2	0
dm2	n
dmm2	c
dmf2	200
dseq2	
dres2	1.0
homo2	n
DEC3	
dfrq3	0
dn3	
dpwr3	1
dof3	0
dm3	n
dmm3	c
dmf3	200
dseq3	
dres3	1.0
homo3	n
PROCESSING	
wtfile	
proc	ft
fn	262144
math	f
werr	
wexp	
wbs	
wnt	wft



12b



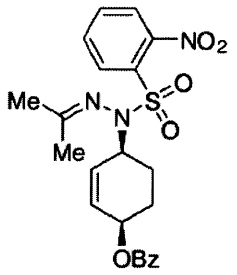
ACQUISITION	
sfrq	125.795
tn	C13
at	1.736
np	131010
sw	37735.8
fb	not used
bs	10
ss	1
tpwr	53
pw	6.9
d1	0.763
tof	631.4
nt	3000
ct	1810
alock	n
gain	not used

FLAGS	
il	n
in	n
dp	y
hs	nn

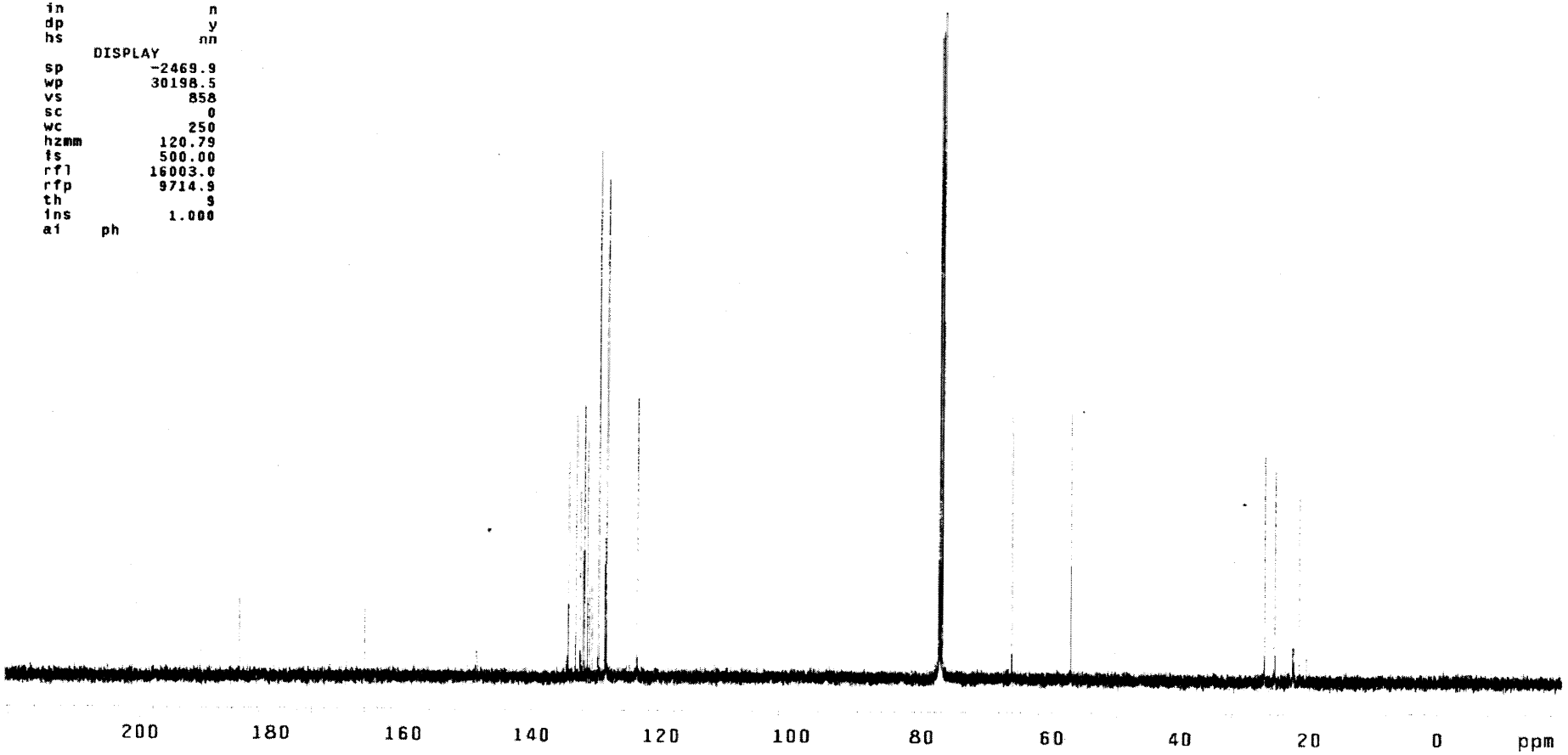
DISPLAY	
sp	-2469.9
wp	30198.5
vs	858
sc	0
wc	250
hzmm	120.79
is	500.00
rfl	16003.0
rfp	9714.9
th	9
ins	1.000
ai	ph

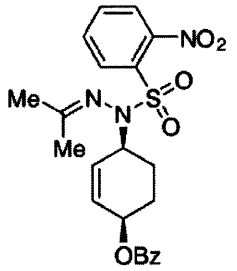
DEC. & VT	
dfrq	500.229
dn	H1
dpwr	37
dof	-500.0
dm	y
dmm	w
dmf	10000
dseq	
dres	1.0
homo	n

PROCESSING	
lb	0.30
wtfile	
proc	ft
fn	131072
math	f
werr	
wexp	
wbs	
wnt	

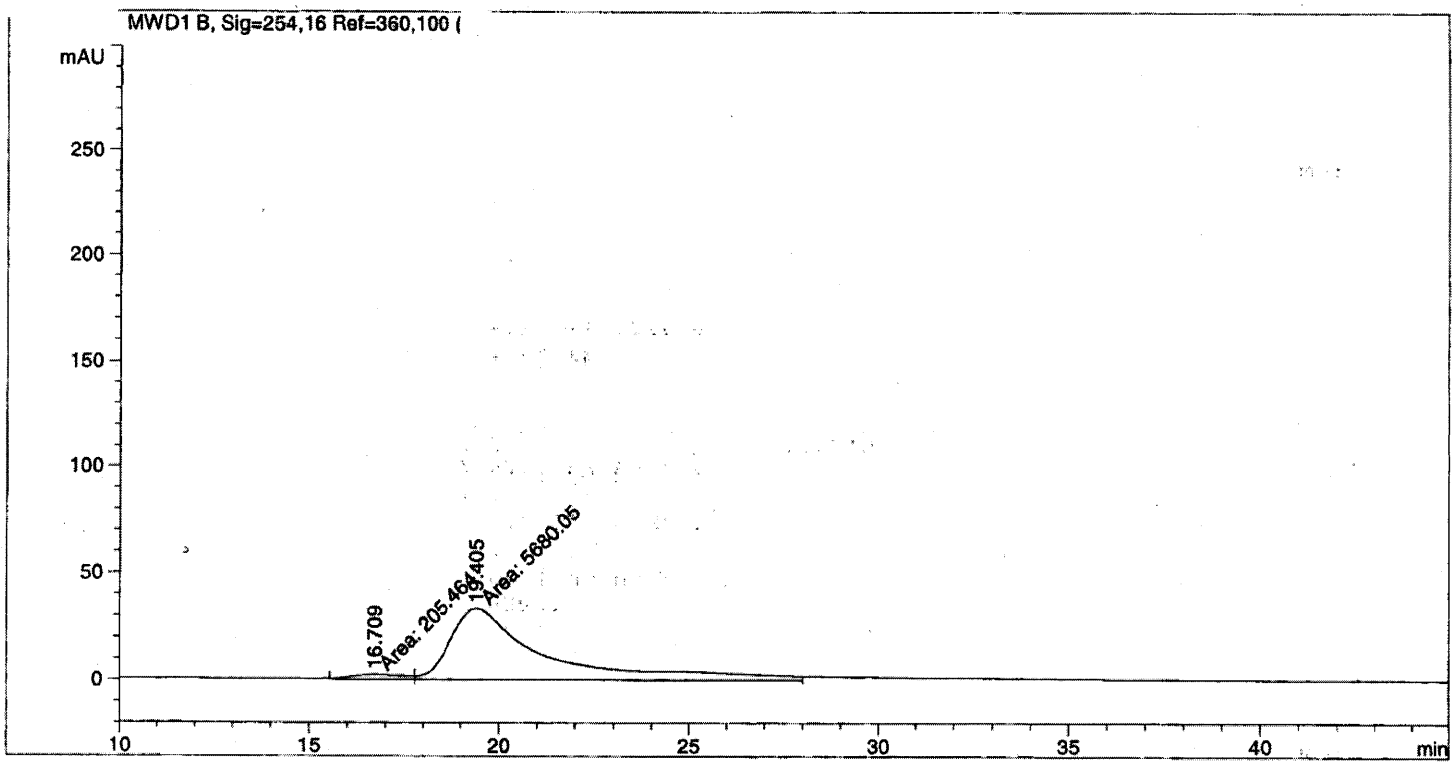


12b

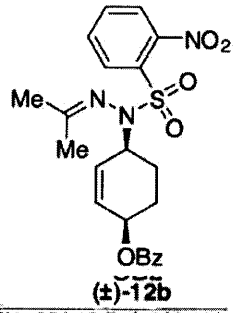




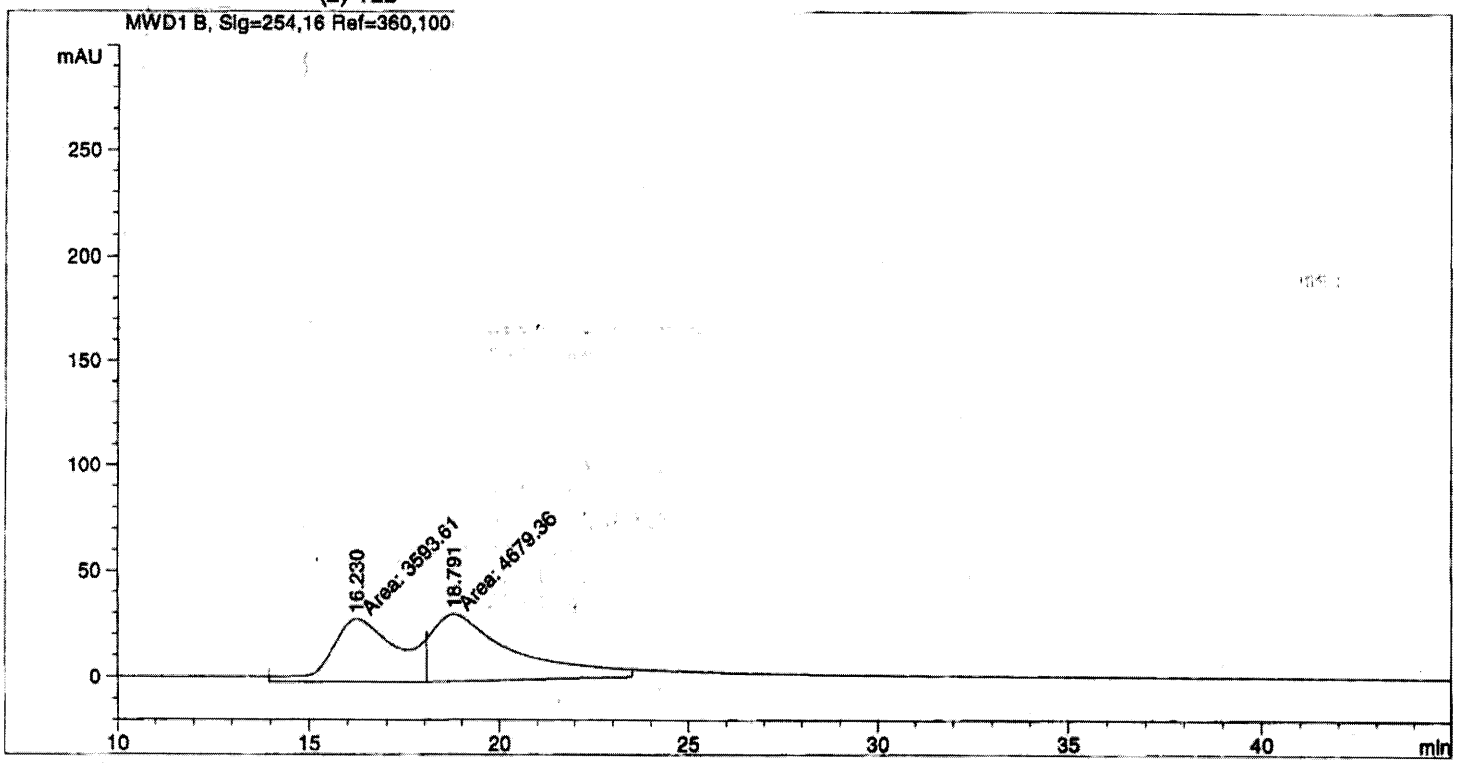
(+)-12b




```
=====================================================================
                        Area Percent Report
=====================================================================

Sorted By             :      Signal
Multiplier            :      1.0000
Dilution              :      1.0000
Use Multiplier & Dilution Factor with ISTDs


Signal 1: MWD1 B, Sig=254,16 Ref=360,100

Peak RetTime Type  Width     Area      Height     Area
  #   [min]        [min]   [mAU*s]     [mAU]       %
----|-------|----|-------|----------|----------|--------|
   1  16.709 MM    1.5934  205.46378    2.14912   3.4910
   2  19.405 MM    2.8421 5680.05371   33.30911  96.5090

Totals :                  5885.51749   35.45824

 Results obtained with enhanced integrator!
=====================================================================
                        *** End of Report ***
```



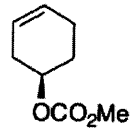
(±)-12b




```
=====================================================================
                        Area Percent Report
=====================================================================

Sorted By             :      Signal
Multiplier            :      1.0000
Dilution              :      1.0000
Use Multiplier & Dilution Factor with ISTDs


Signal 1: MWD1 B, Sig=254,16 Ref=360,100

Peak RetTime Type  Width     Area      Height     Area
  #   [min]        [min]   [mAU*s]     [mAU]       %
----|-------|----|-------|----------|----------|--------|
   1  16.230 MM    2.0120 3593.60986   29.76879  43.4380
   2  18.791 MM    2.4602 4679.36084   31.69983  56.5620

Totals :                  8272.97070   61.46862

 Results obtained with enhanced integrator!
=====================================================================
                        *** End of Report ***
```

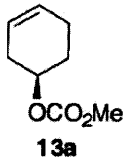
ACQUISITION	
$frq	499.746
tn	H1
at	3.001
np	63050
sw	10504.2
fb	not used
bs	2
tpwr	56
pw	8.6
d1	2.000
tof	1519.5
nt	32
ct	10
alock	n
gain	not used
FLAGS	
il	n
in	n
dp	y
hs	nn
DISPLAY	
sp	-252.4
wp	6251.4
vs	24
sc	0
wc	250
hzmm	25.01
is	33.57
rfl	1233.8
rfp	0
th	7
ins	1.000
al cdc ph	

DEC. & VT	
dfrq	125.672
dn	C13
dpwr	30
dof	0
dm	nnn
dmm	w
dmf	10000
dseq	
dres	1.0
homo	n
DEC2	
dfrq2	0
dn2	
dpwr2	1
dof2	0
dm2	n
dmm2	c
dmf2	200
dseq2	
dres2	1.0
homo2	n
DEC3	
dfrq3	0
dn3	
dpwr3	1
dof3	0
dm3	n
dmm3	c
dmf3	200
dseq3	
dres3	1.0
homo3	n
PROCESSING	
wtfile	
proc	ft
fn	262144
math	f
werr	
wexp	
wbs	
wnt	wft



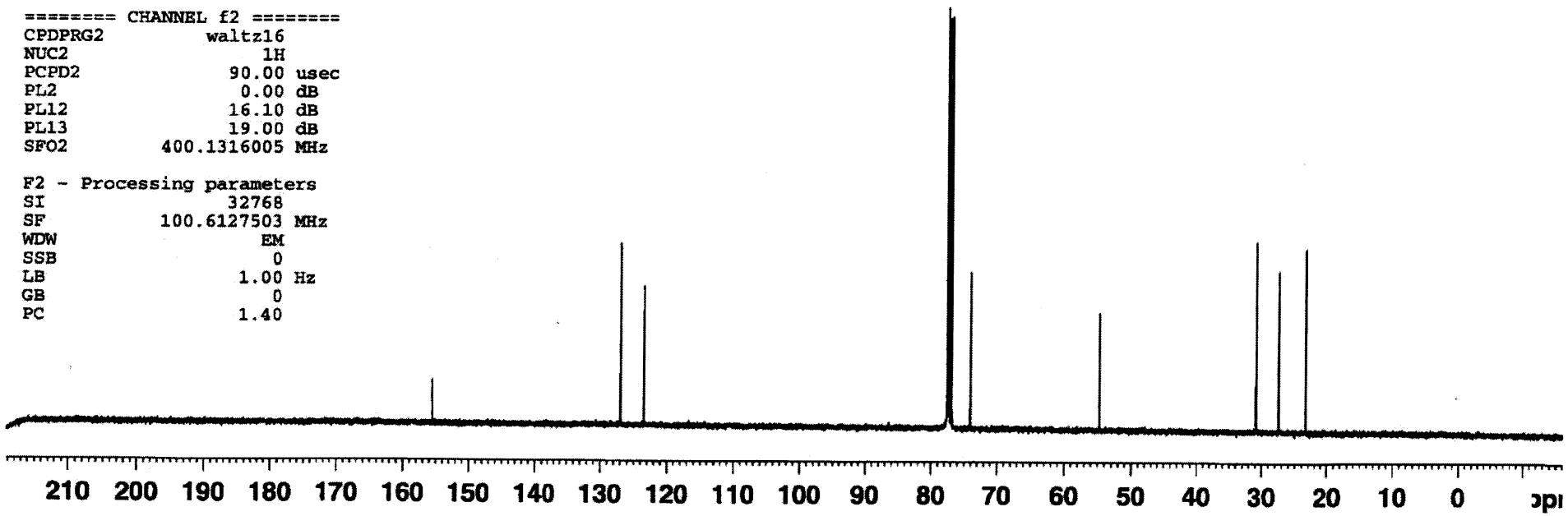
13a

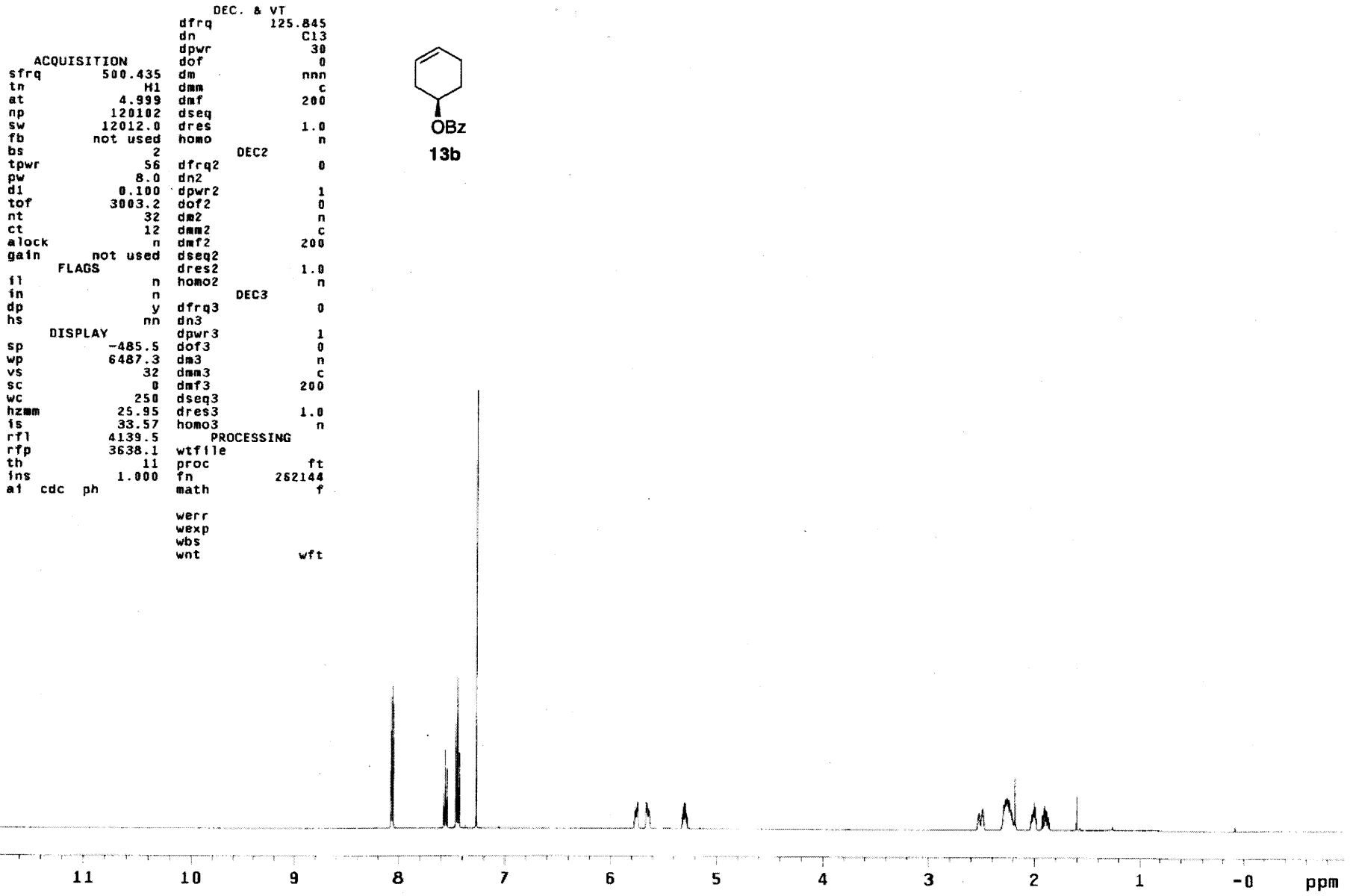
F2 - Acquisition Parameters



13a

INSTRUM	spect	
PROBHD	5 mm QNP 1H/13	
PULPROG	zgpg30	
TD	65536	
SOLVENT	CDCl3	
NS	993	
DS	0	
SWH	23980.814	Hz
FIDRES	0.365918	Hz
AQ	1.3664756	sec
RG	2896.3	
DW	20.850	usec
DE	6.00	usec
TE	291.2	K
D1	2.00000000	sec
d11	0.03000000	sec
DELTA	1.89999998	sec
TD0	1	
======== CHANNEL f1 ========		
NUC1	13C	
P1	9.38	usec
PL1	0.00	dB
SFO1	100.6228298	MHz
======== CHANNEL f2 ========		
CPDPRG2	waltz16	
NUC2	1H	
PCPD2	90.00	usec
PL2	0.00	dB
PL12	16.10	dB
PL13	19.00	dB
SFO2	400.1316005	MHz
F2 - Processing parameters		
SI	32768	
SF	100.6127503	MHz
WDW	EM	
SSB	0	
LB	1.00	Hz
GB	0	
PC	1.40	




ACQUISITION
sfrq 500.435
tn H1
at 4.999
np 120102
sw 12012.0
fb not used
bs 2
tpwr 56
pw 8.0
d1 0.100
tof 3003.2
nt 32
ct 12
alock n
gain not used
FLAGS
il n
in n
dp y
hs nn
DISPLAY
sp -485.5
wp 6487.3
vs 32
sc 0
wc 250
hzmm 25.95
is 33.57
rfl 4139.5
rfp 3638.1
th 11
ins 1.000
ai cdc ph
DEC. & VT
dfrq 125.845
dn C13
dpwr 30
dof 0
dm nnn
dmm c
dmf 200
dseq
dres 1.0
homo n
DEC2
dfrq2 0
dn2
dpwr2 1
dof2 0
dm2 n
dmm2 c
dmf2 200
dseq2
dres2 1.0
homo2 n
DEC3
dfrq3 0
dn3
dpwr3 1
dof3 0
dm3 n
dmm3 c
dmf3 200
dseq3
dres3 1.0
homo3 n
PROCESSING
wtfile
proc ft
fn 262144
math f
werr
wexp
wbs
wnt wft
OBz
13b
11
10
9
8
7
6
5
4
3
2
1
-0
ppm

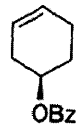
ACQUISITION	
sfrq	125.795
tn	C13
at	1.736
np	131010
sw	37735.8
fb	not used
bs	8
ss	1
tpwr	53
pw	6.9
d1	0.763
tof	631.4
nt	5000
ct	872
alock	n
gain	not used

FLAGS	
il	n
in	n
dp	y
hs	nn

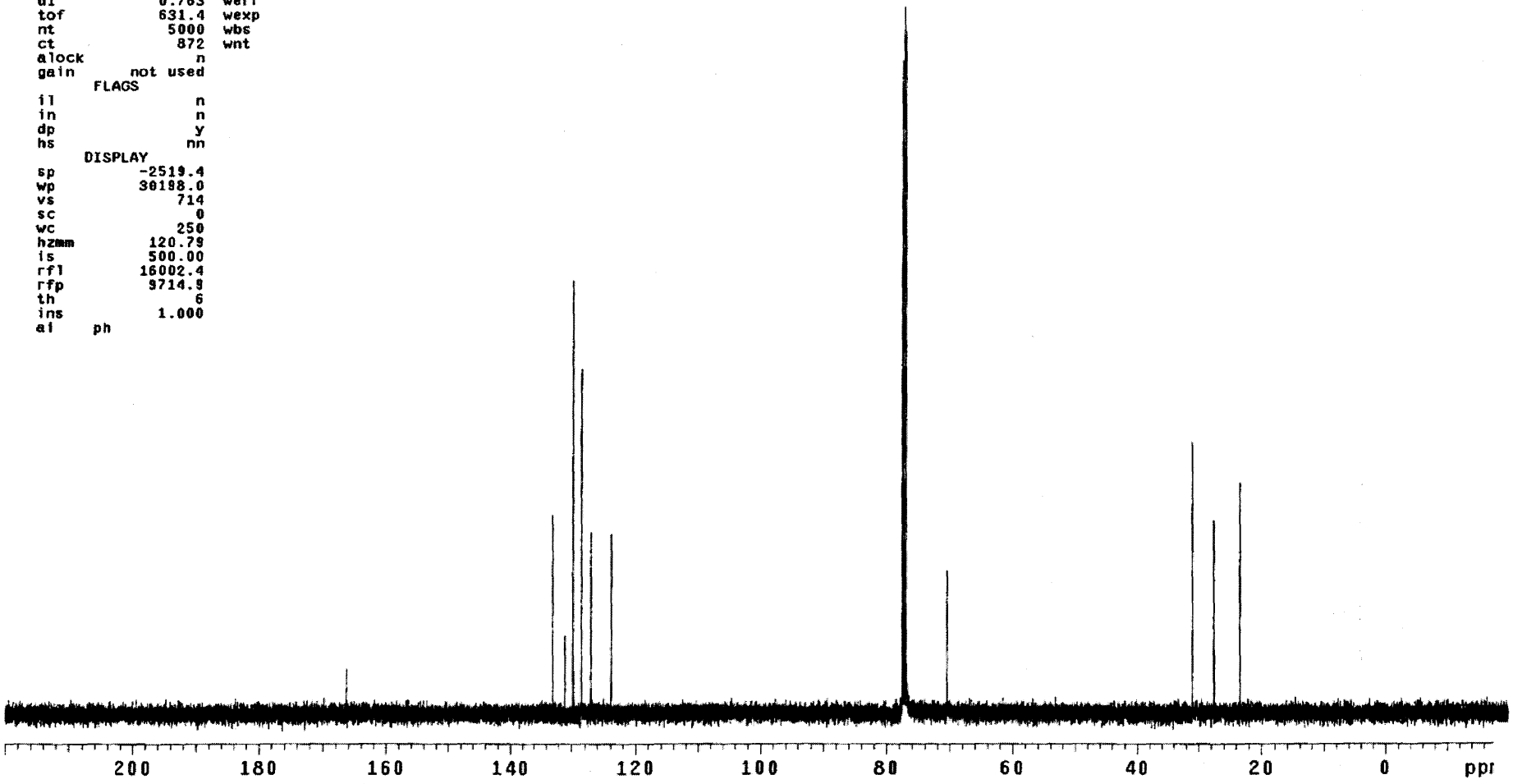
DISPLAY	
sp	-2519.4
wp	30198.0
vs	714
sc	0
wc	250
hzmm	120.79
is	500.00
rfl	16002.4
rfp	9714.9
th	6
ins	1.000
ai	ph

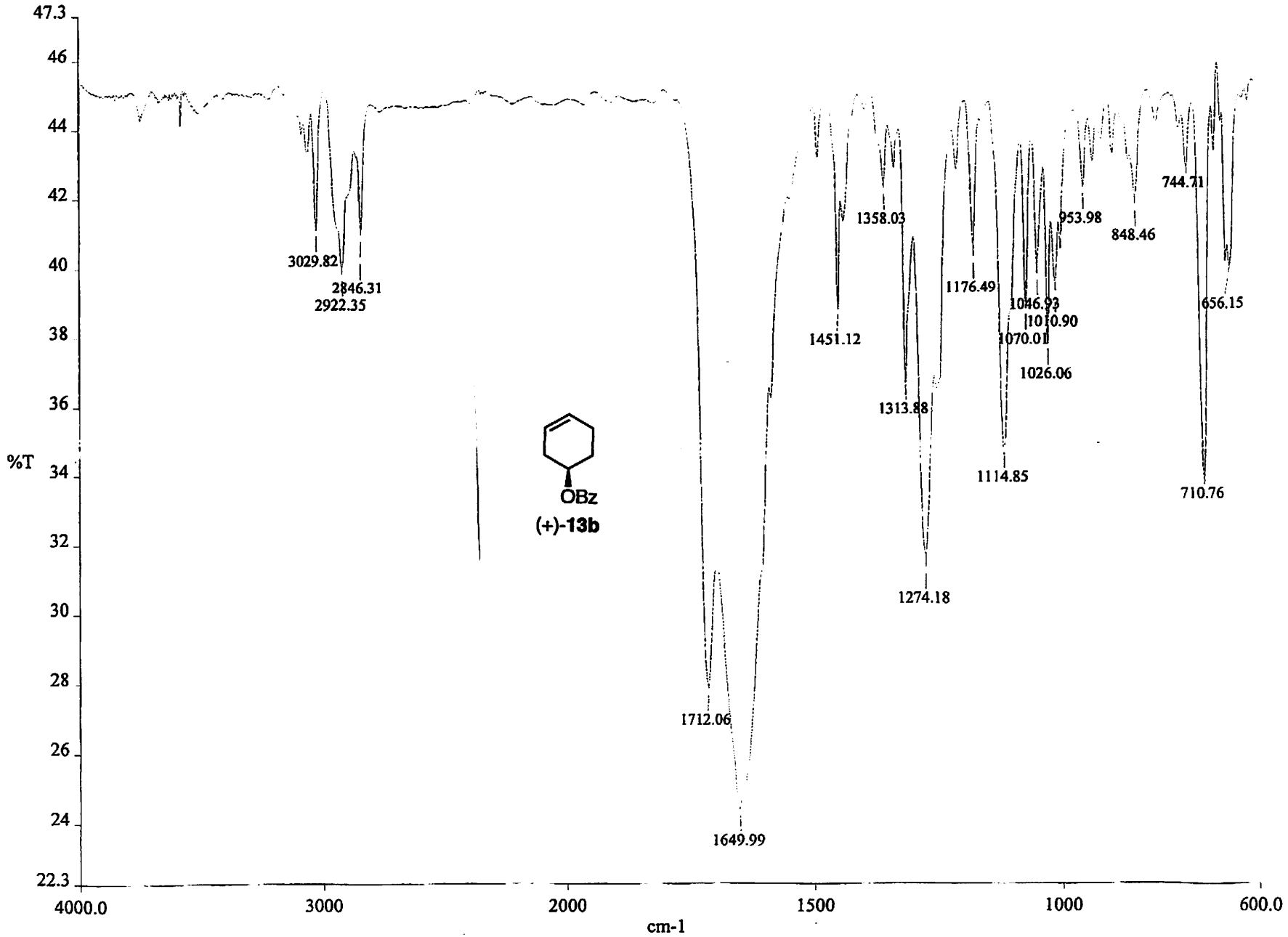
DEC. & VT	
dfrq	500.229
dn	H1
dpwr	37
dof	-500.0
dm	y
dmm	w
dmf	10000
dseq	
dres	1.0
homo	n

PROCESSING	
lb	0.30
wtfile	
proc	ft
fn	131072
math	f
werr	
wexp	
wbs	
wnt	



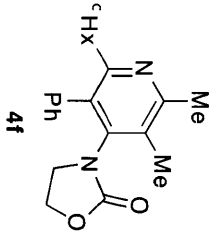
13b




47.3
46
44
42
40
38
36
34
32
30
28
26
24
22.3
%T
4000.0
3000
2000
1500
1000
600.0
cm-1
3029.82
2922.35
2846.31
1712.06
1649.99
1451.12
1358.03
1313.88
1274.18
1176.49
1114.85
1070.01
1046.93
1026.06
1010.90
953.98
848.46
744.71
710.76
656.15
OBz
(+)-13b

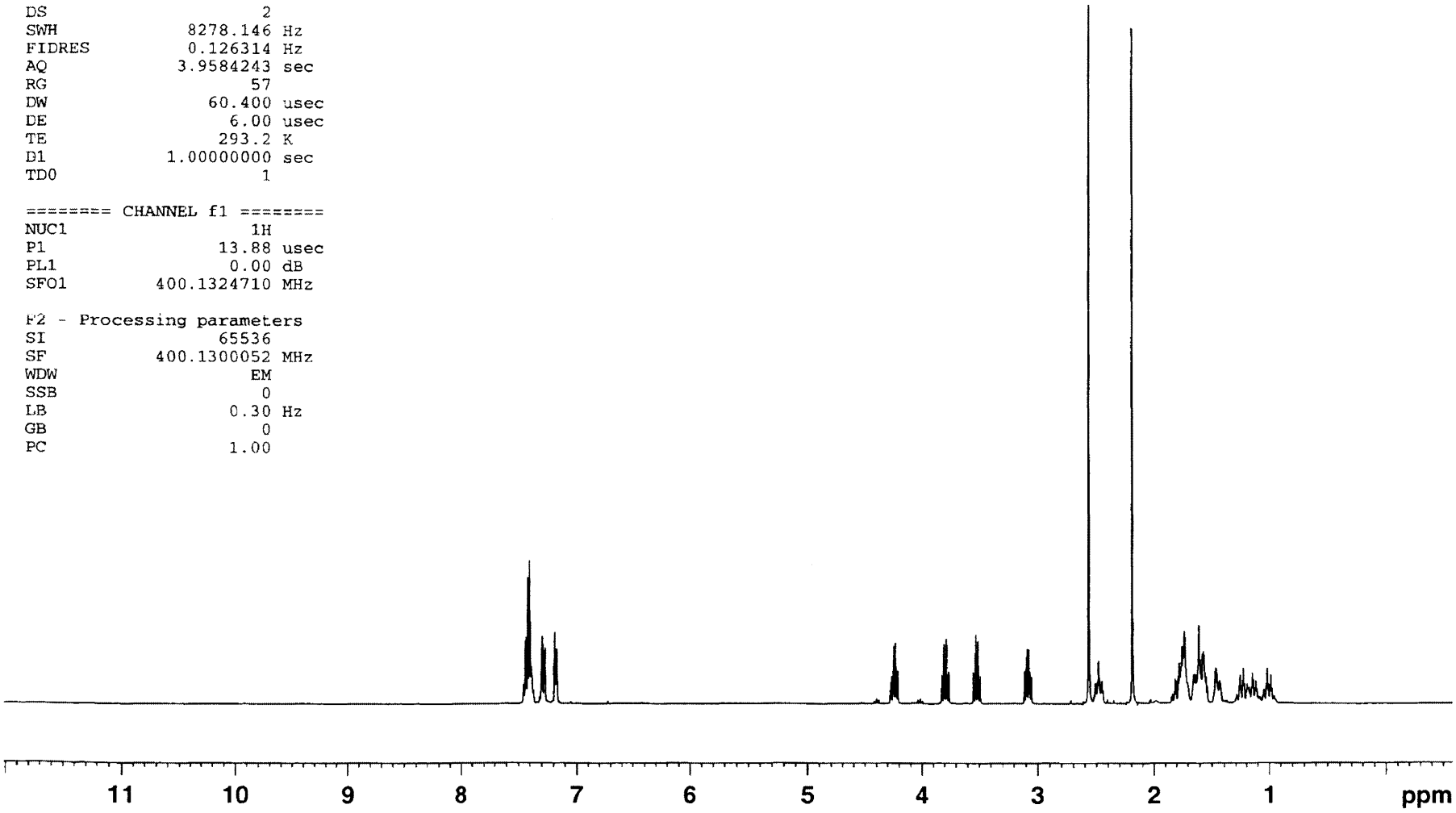
Appendix C

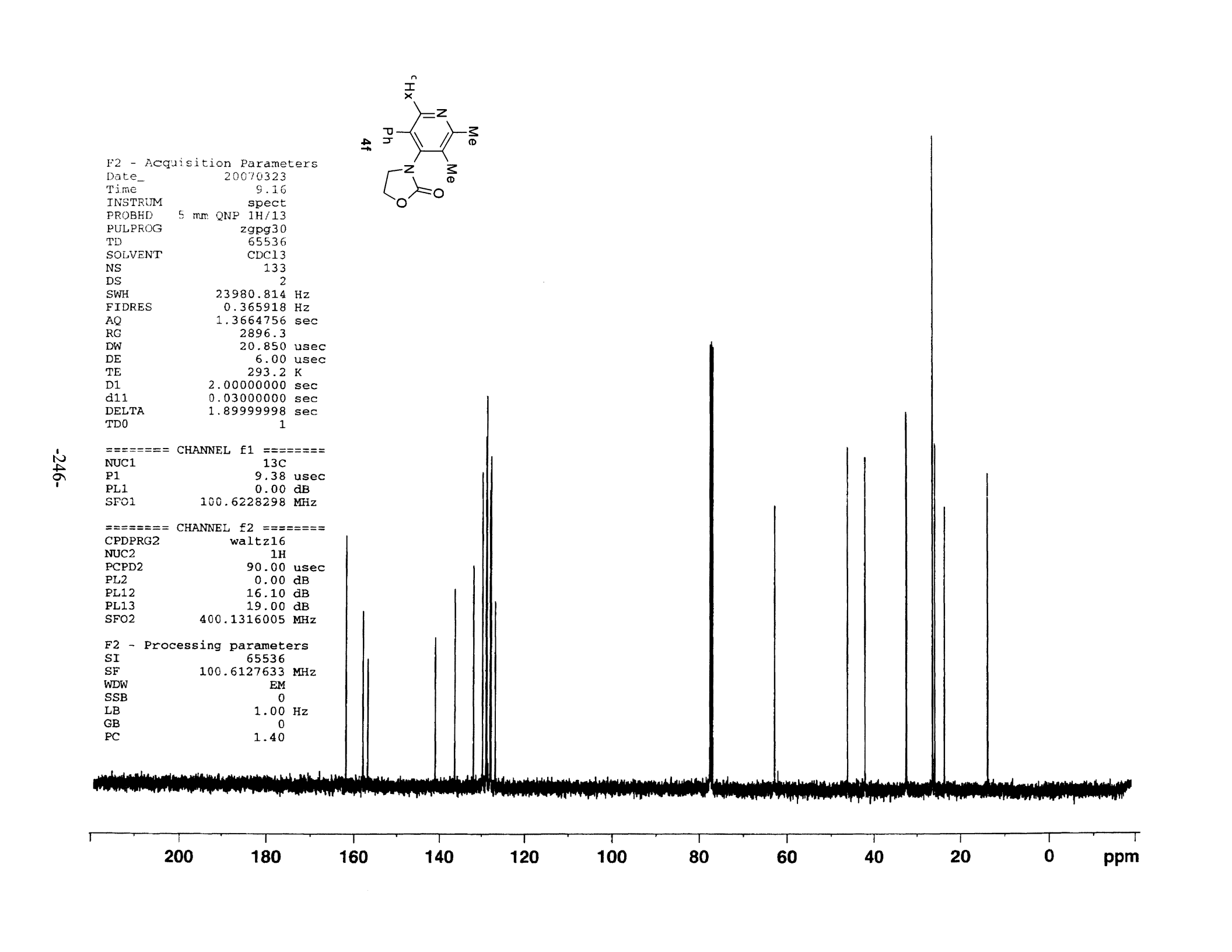
Spectra for Chapter III

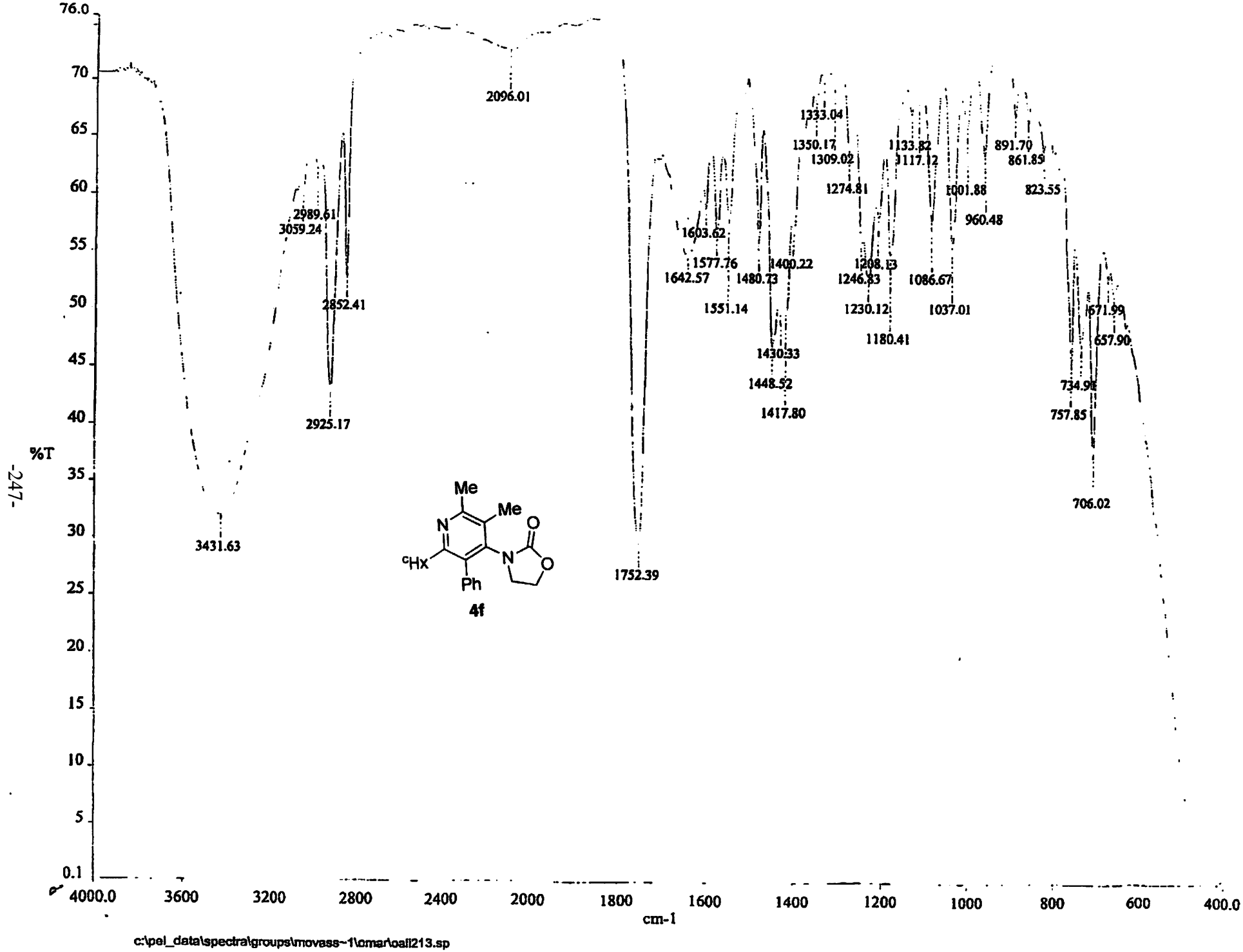


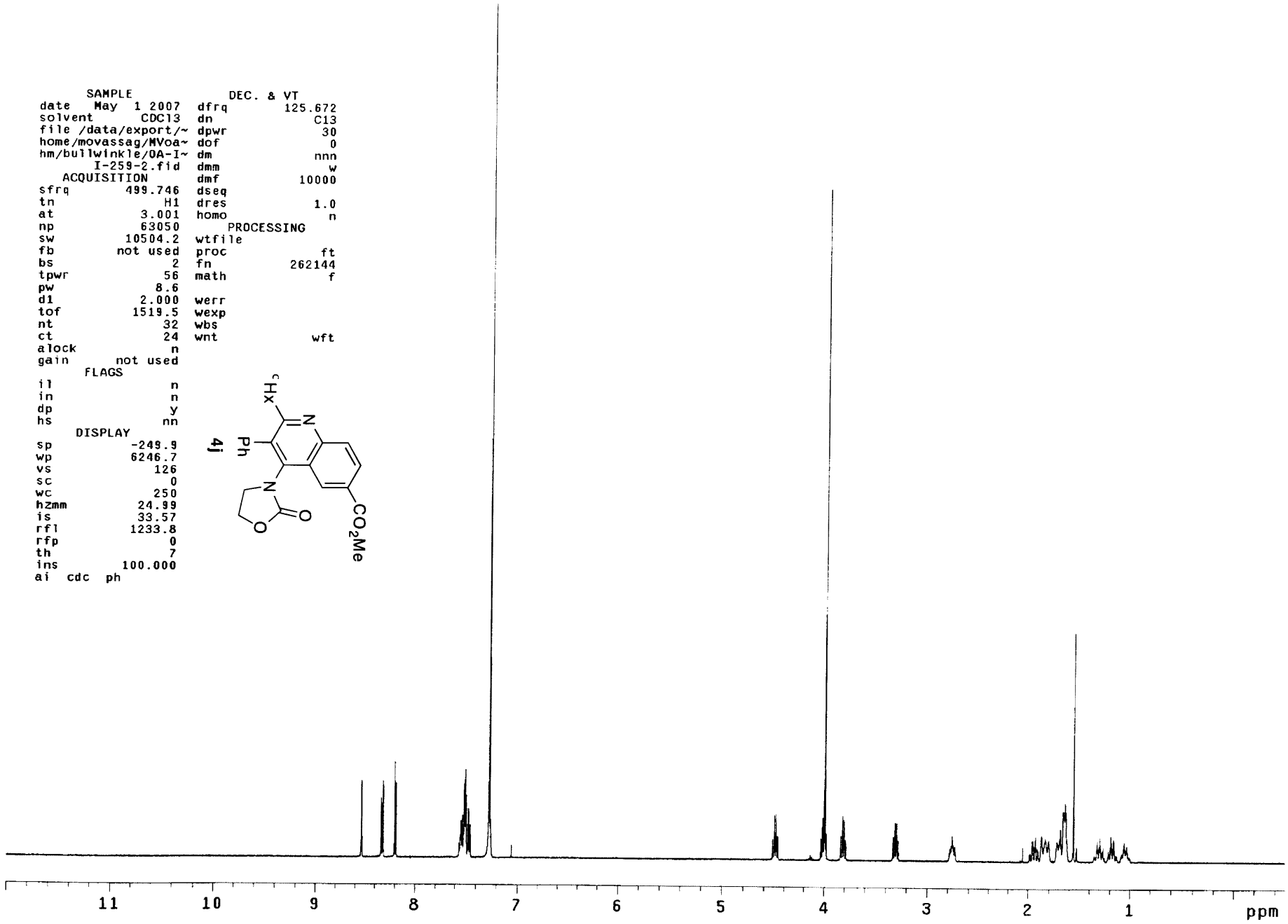
4f

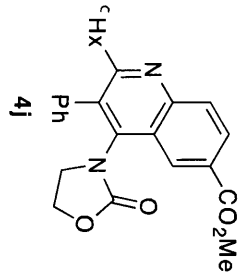
```
F2 - Acquisition Parameters
Date_            20070323
Time                9.11
INSTRUM            spect
PROBHD   5 mm QNP 1H/13
PULPROG             zg30
TD                 65536
SOLVENT            CDCl3
NS                     8
DS                     2
SWH             8278.146 Hz
FIDRES          0.126314 Hz
AQ              3.9584243 sec
RG                    57
DW                60.400 usec
DE                 6.00 usec
TE                293.2 K
D1           1.00000000 sec
TD0                    1

======== CHANNEL f1 ========
NUC1                  1H
P1                13.88 usec
PL1                0.00 dB
SFO1         400.1324710 MHz

F2 - Processing parameters
SI                 65536
SF          400.1300052 MHz
WDW                   EM
SSB                    0
LB                  0.30 Hz
GB                     0
PC                  1.00
```




F2 - Acquisition Parameters
Date_ 20070323
Time 9.16
INSTRUM spect
PROBHD 5 mm QNP 1H/13
PULPROG zgpg30
TD 65536
SOLVENT CDCl3
NS 133
DS 2
SWH 23980.814 Hz
FIDRES 0.365918 Hz
AQ 1.3664756 sec
RG 2896.3
DW 20.850 usec
DE 6.00 usec
TE 293.2 K
D1 2.00000000 sec
d11 0.03000000 sec
DELTA 1.89999998 sec
TD0 1
======== CHANNEL f1 ========
NUC1 13C
P1 9.38 usec
PL1 0.00 dB
SFO1 100.6228298 MHz
======== CHANNEL f2 ========
CPDPRG2 waltz16
NUC2 1H
PCPD2 90.00 usec
PL2 0.00 dB
PL12 16.10 dB
PL13 19.00 dB
SFO2 400.1316005 MHz
F2 - Processing parameters
SI 65536
SF 100.6127633 MHz
WDW EM
SSB 0
LB 1.00 Hz
GB 0
PC 1.40
Me
Ph
Me
O
O
4f
200
180
160
140
120
100
80
60
40
20
0
ppm

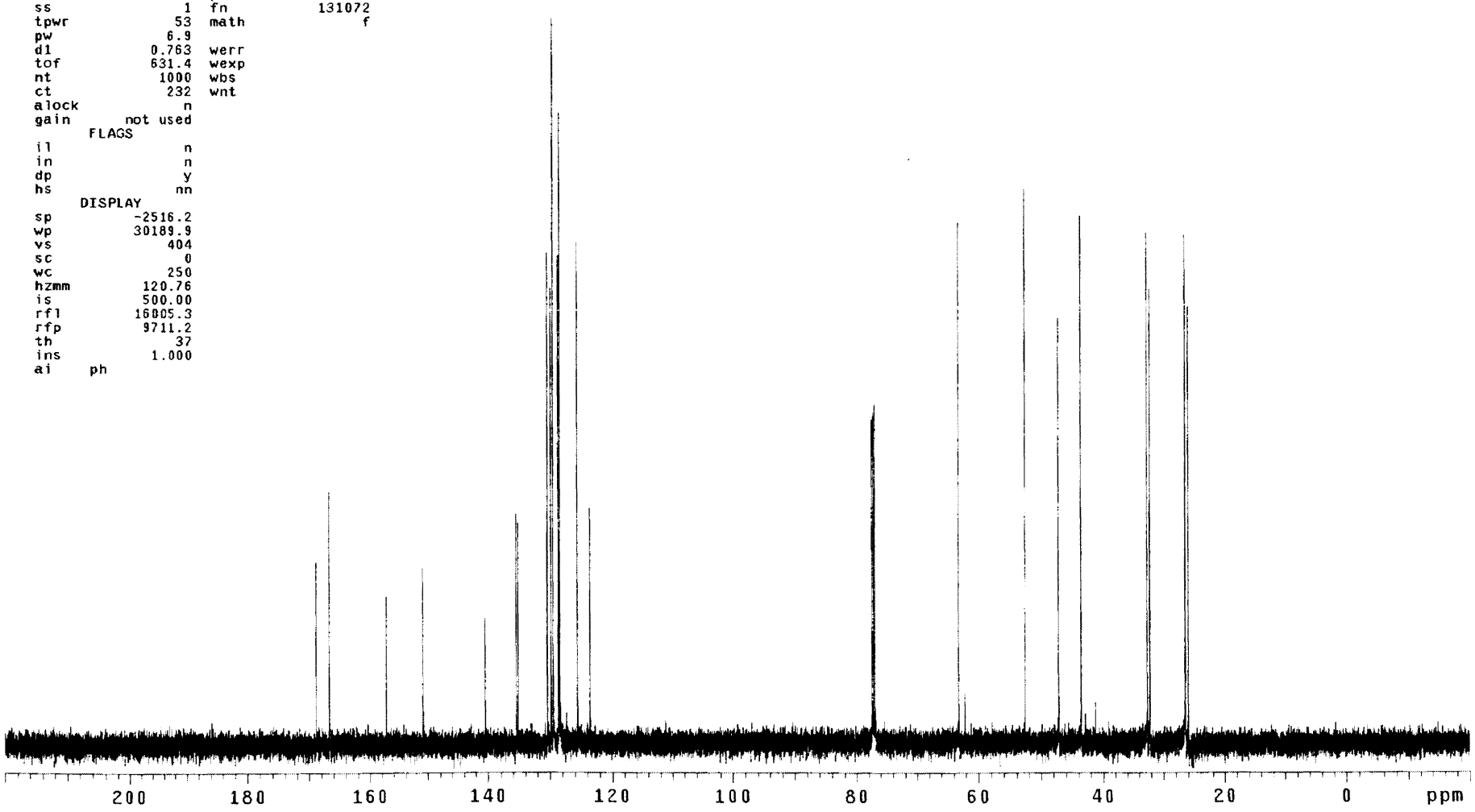

76.0
70
65
60
55
50
45
40
35
30
25
20
15
10
5
0.1
%T
4000.0
3600
3200
2800
2400
2000
1800
1600
1400
1200
1000
800
600
400.0
cm-1
3431.63
2989.61
3059.24
2925.17
2852.41
2096.01
1752.39
1642.57
1603.62
1577.76
1551.14
1480.73
1448.52
1430.33
1417.80
1400.22
1350.17
1333.04
1309.02
1274.81
1246.83
1230.12
1208.13
1180.41
1133.82
1117.12
1086.67
1037.01
1001.88
960.48
891.70
861.85
823.55
757.85
734.98
706.02
671.99
657.90
Me
Me
N
O
N
O
cHx
Ph
4f
-247-
c:\pel_data\spectra\groups\movass~1\cmar\oall213.sp

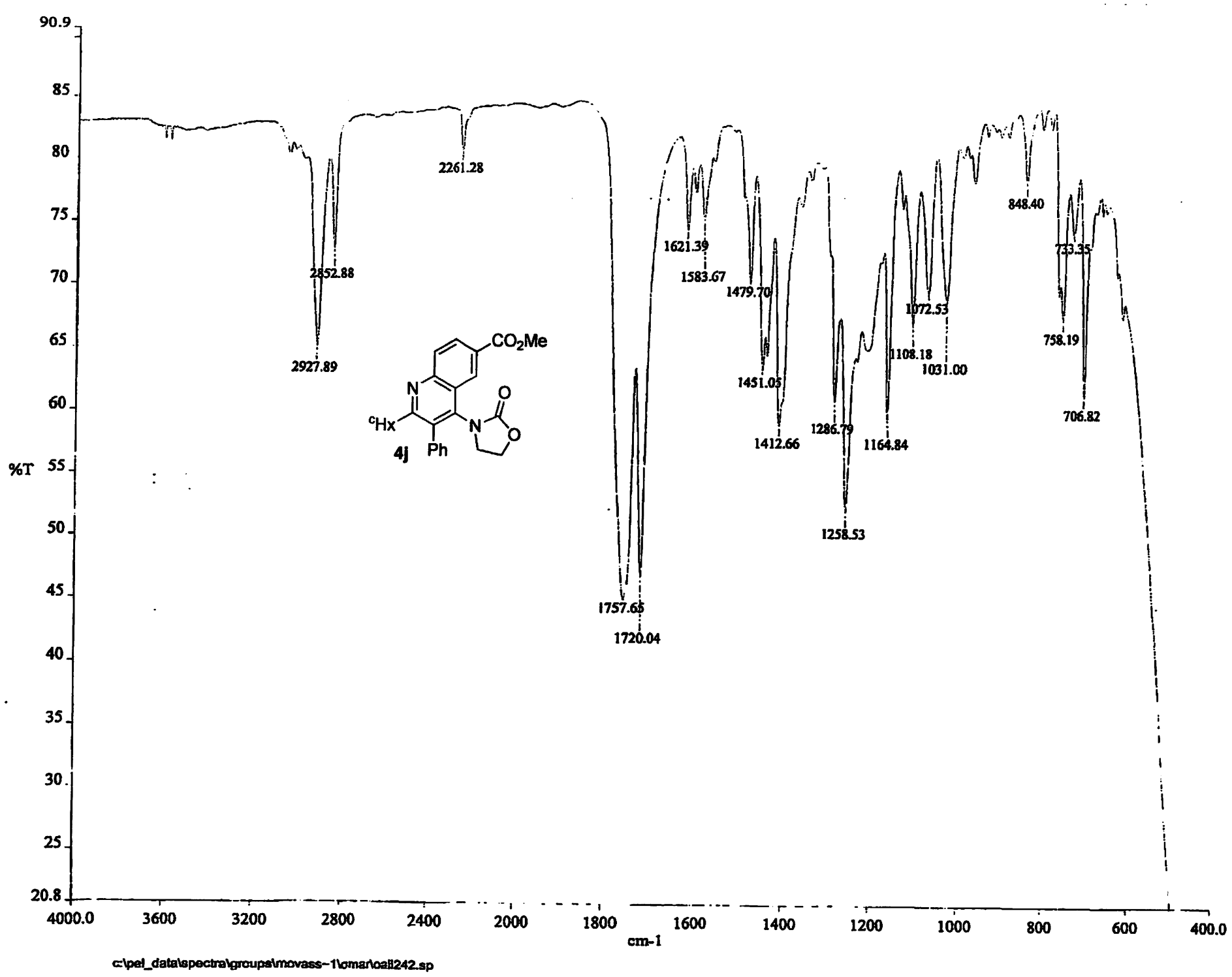

SAMPLE
date May 1 2007
solvent CDCl3
file /data/export/~
home/movassag/MVoa~
hm/bullwinkle/OA-I~
I-259-2.fid
ACQUISITION
sfrq 499.746
tn H1
at 3.001
np 63050
sw 10504.2
fb not used
bs 2
tpwr 56
pw 8.6
d1 2.000
tof 1519.5
nt 32
ct 24
alock n
gain not used
FLAGS
il n
in n
dp y
hs nn
DISPLAY
sp -249.9
wp 6246.7
vs 126
sc 0
wc 250
hzmm 24.99
is 33.57
rfl 1233.8
rfp 0
th 7
ins 100.000
ai cdc ph
DEC. & VT
dfrq 125.672
dn C13
dpwr 30
dof 0
dm nnn
dmm w
dmf 10000
dseq
dres 1.0
homo n
PROCESSING
wtfile
proc ft
fn 262144
math f
werr
wexp
wbs
wnt wft
4j
CH3
N
Ph
N
O
O
CO2Me
11
10
9
8
7
6
5
4
3
2
1
ppm

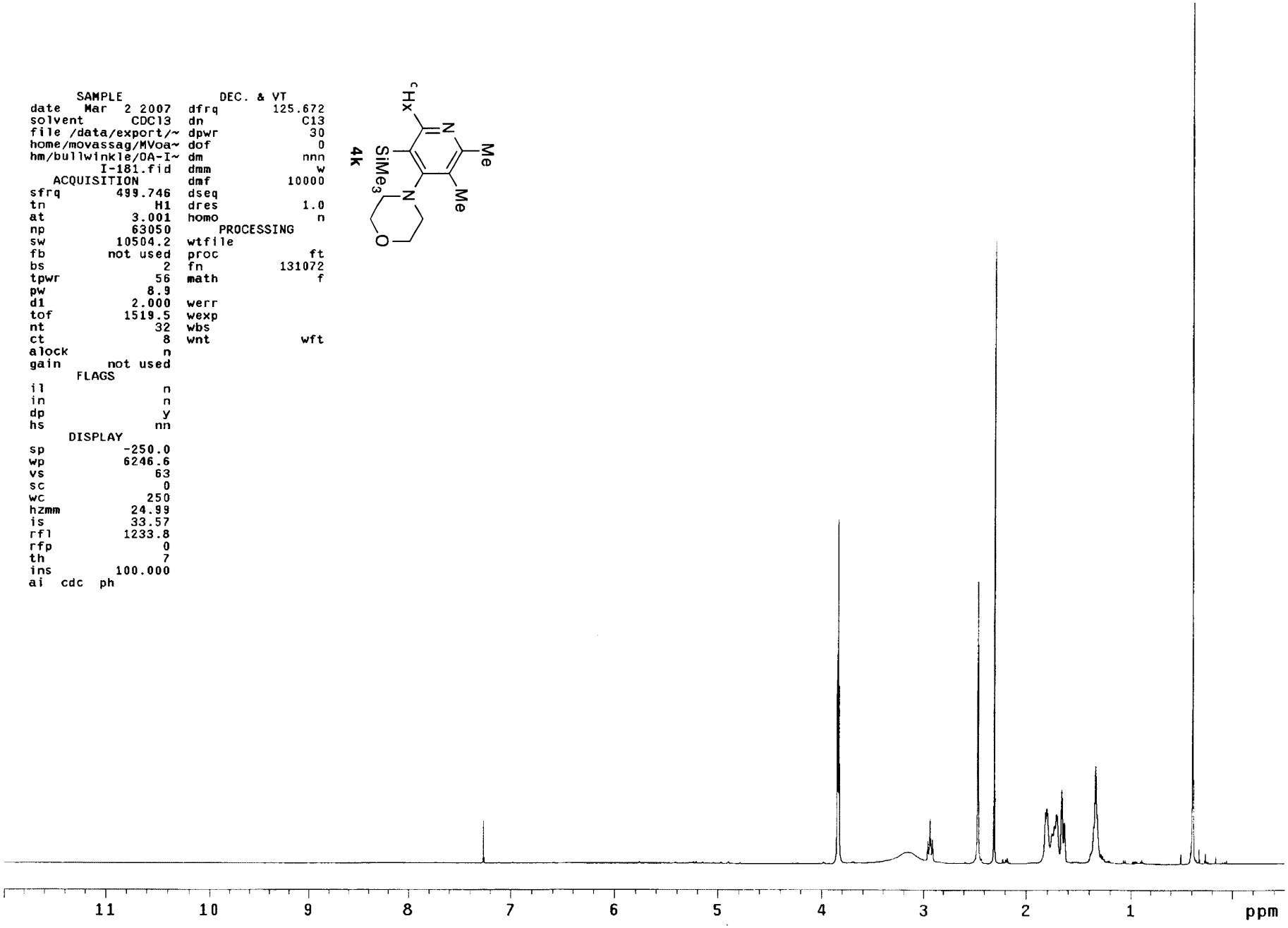


4j

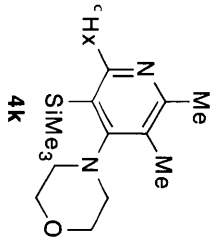
SAMPLE		DEC. & VT	
date	Apr 26 2007	dfrq	500.233
solvent	CDCl3	dn	H1
file	/data/export/~	dpwr	37
home/movassag/MVoa~		dof	-500.0
hm/rocky/OA-II-242~		dm	y
	carbon.fid	dmm	w
ACQUISITION		dmf	10000
sfrq	125.796	dseq	
tn	C13	dres	1.0
at	1.736	homo	n
np	131010	PROCESSING	
sw	37735.8	lb	0.30
fb	not used	wtfile	
bs	4	proc	ft
ss	1	fn	131072
tpwr	53	math	f
pw	6.9		
d1	0.763	werr	
tof	631.4	wexp	
nt	1000	wbs	
ct	232	wnt	
alock	n		
gain	not used		
FLAGS			
il	n		
in	n		
dp	y		
hs	nn		
DISPLAY			
sp	-2516.2		
wp	30189.9		
vs	404		
sc	0		
wc	250		
hzmm	120.76		
is	500.00		
rfl	16805.3		
rfp	9711.2		
th	37		
ins	1.000		
ai	ph		



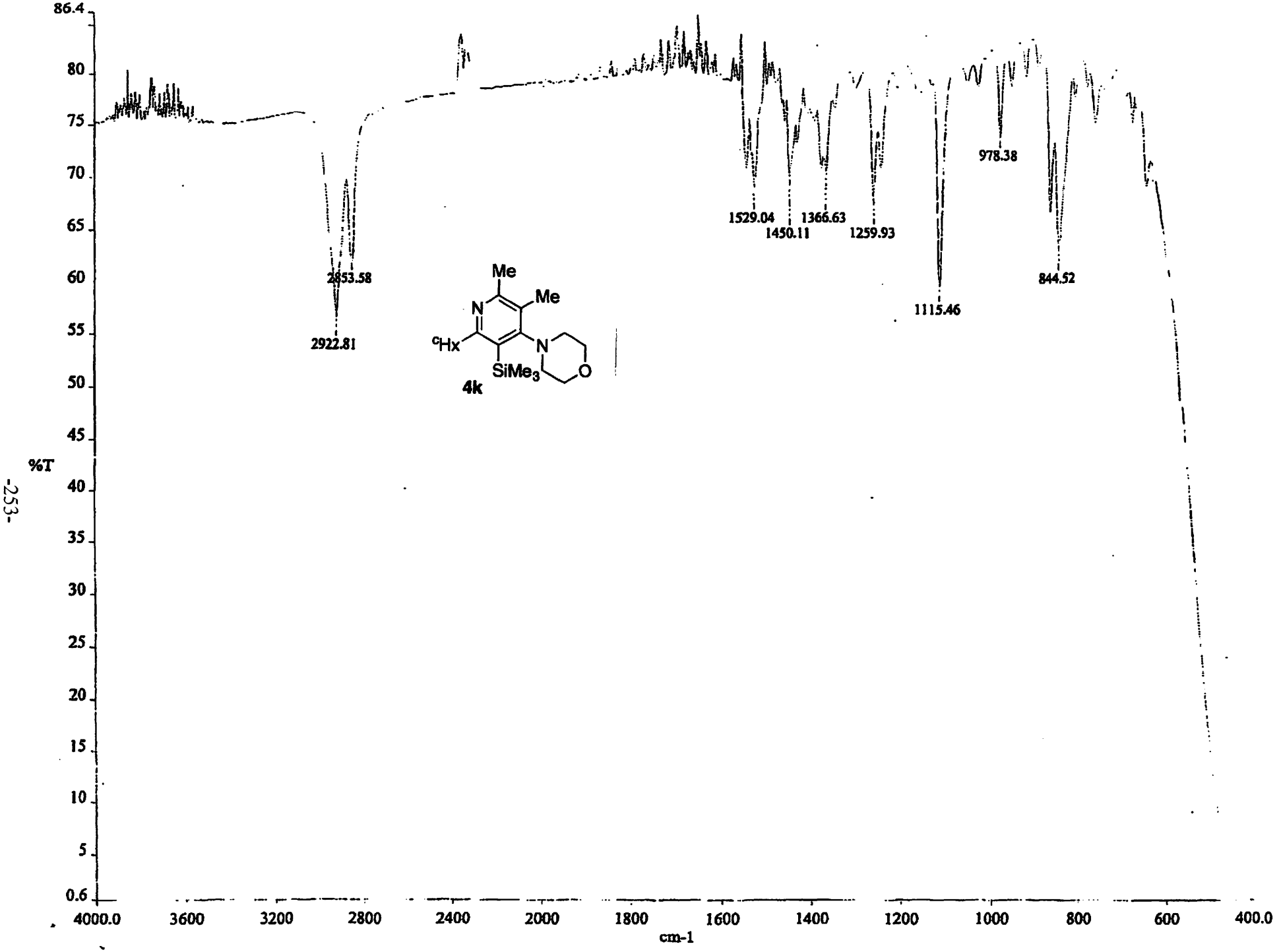

90.9
85
80
75
70
65
60
55
50
45
40
35
30
25
20.8
%T
2927.89
2852.88
2261.28
1757.65
1720.04
1621.39
1583.67
1479.70
1451.05
1412.66
1286.79
1258.53
1164.84
1108.18
1072.53
1031.00
848.40
758.19
733.35
706.82
CO2Me
N
O
N
O
cHx
Ph
4j
4000.0
3600
3200
2800
2400
2000
1800
1600
1400
1200
1000
800
600
400.0
cm-1
c:\pel_data\spectra\groups\novass-1\omar\oall242.sp

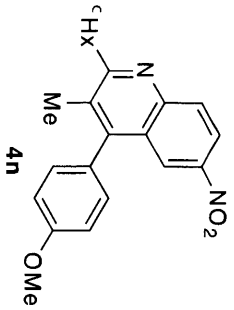

SAMPLE
date Mar 2 2007
solvent CDCl3
file /data/export/~
home/movassag/MVoa~
hm/bullwinkle/OA-I~
I-181.fid
ACQUISITION
sfrq 499.746
tn H1
at 3.001
np 63050
sw 10504.2
fb not used
bs 2
tpwr 56
pw 8.9
d1 2.000
tof 1519.5
nt 32
ct 8
alock n
gain not used
FLAGS
il n
in n
dp y
hs nn
DISPLAY
sp -250.0
wp 6246.6
vs 63
sc 0
wc 250
hzmm 24.99
is 33.57
rfl 1233.8
rfp 0
th 7
ins 100.000
ai cdc ph
DEC. & VT
dfrq 125.672
dn C13
dpwr 30
dof 0
dm nnn
dmm w
dmf 10000
dseq
dres 1.0
homo n
PROCESSING
wtfile
proc ft
fn 131072
math f
werr
wexp
wbs
wnt wft
4k
cHx
N
Me
SiMe3
N
Me
O
11
10
9
8
7
6
5
4
3
2
1
ppm

SAMPLE		DEC. & VT	
date	Mar 2 2007	dfrq	500.233
solvent	CDCl3	dn	H1
file	/data/export/~	dpwr	38
	home/movassag/MVoa~	dof	-500.0
	hm/rocky/OA-II-181~	dm	y
	carbon.fid	dmm	w
ACQUISITION		dmf	10000
sfrq	125.796	dseq	
tn	C13	dres	1.0
at	1.736	homo	n
np	131010	PROCESSING	
sw	37735.8	lb	0.30
fb	not used	wtfile	
bs	4	proc	ft
ss	1	fn	131072
tpwr	53	math	f
pw	6.9		
d1	0.763	werr	
tof	631.4	wexp	
nt	1000	wbs	
ct	0	wnt	
alock	n		
gain	not used		
FLAGS			
il	n		
in	n		
dp	y		
hs	nn		
DISPLAY			
sp	-2516.2		
wp	30189.9		
vs	161		
sc	0		
wc	250		
hzmm	120.76		
is	500.00		
rfl	16007.6		
rfp	9711.2		
th	8		
ins	1.000		
ai	ph		

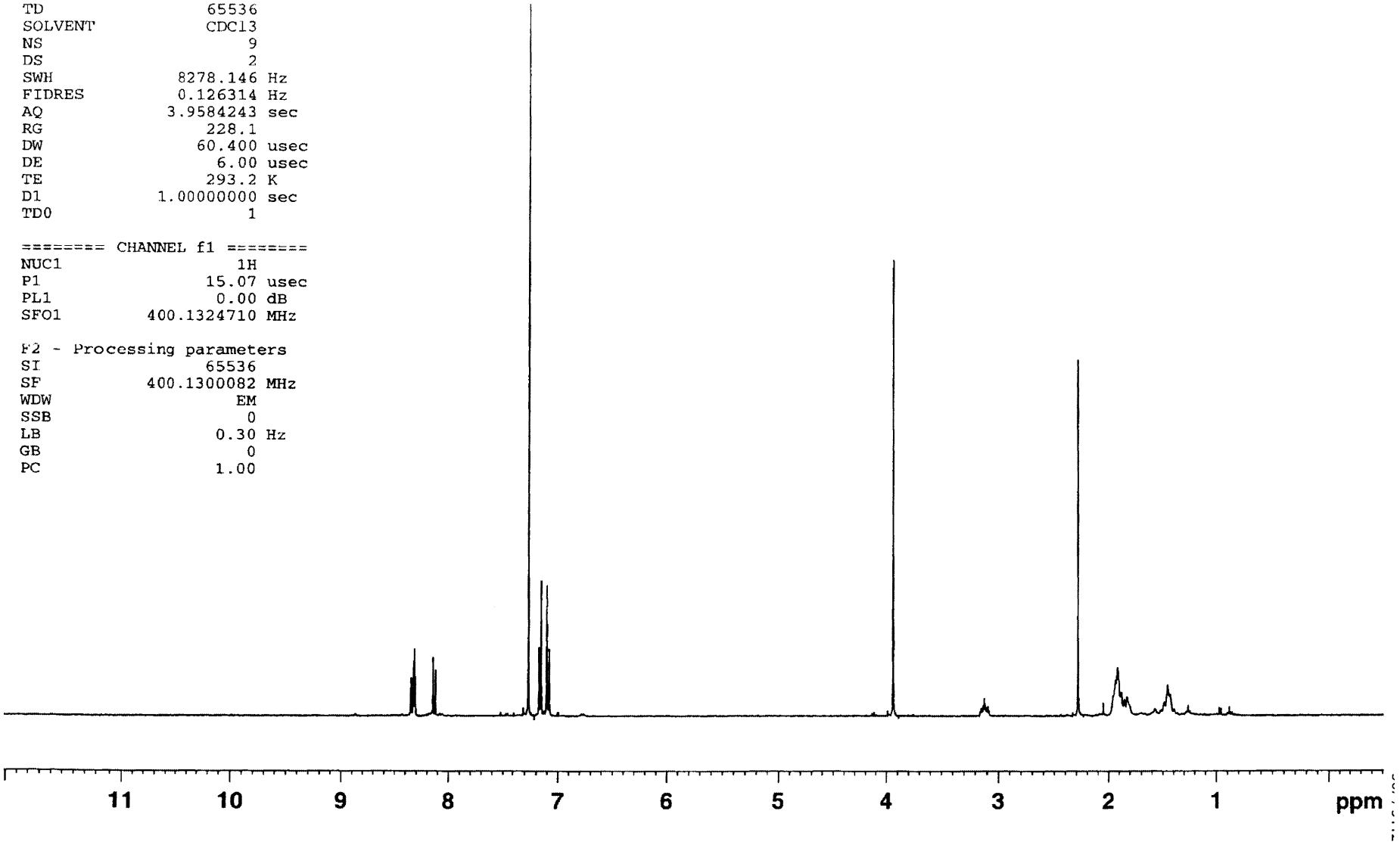


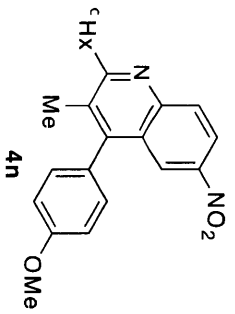
4k


86.4
80
75
70
65
60
55
50
45
%T
40
35
30
25
20
15
10
5
0.6
2922.81
2853.58
1529.04
1450.11
1366.63
1259.93
1115.46
978.38
844.52
Me
Me
N
cHx
N
SiMe3
O
4k
4000.0
3600
3200
2800
2400
2000
1800
1600
1400
1200
1000
800
600
400.0
cm-1
c:\pel_data\spectra\groups\movass~1\omar\oali181.sp

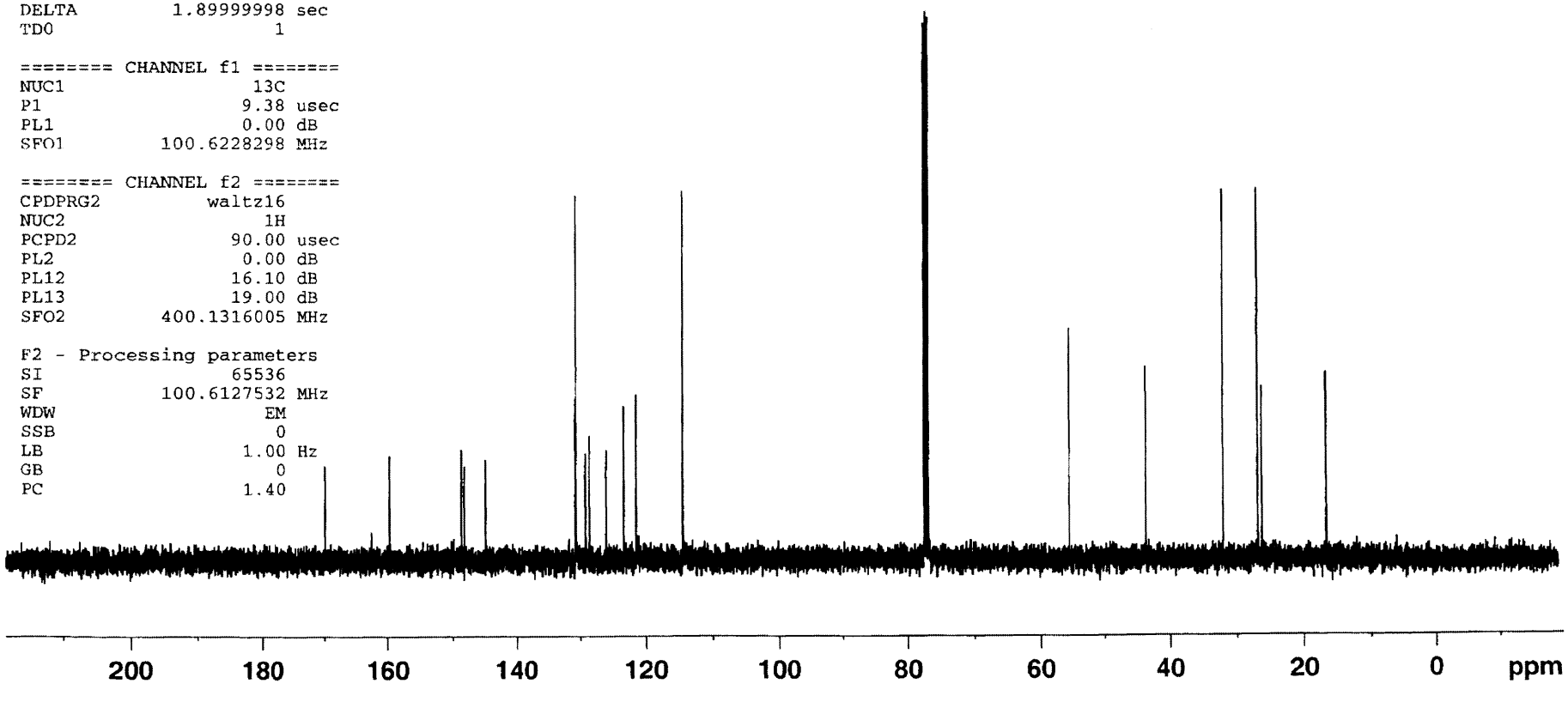


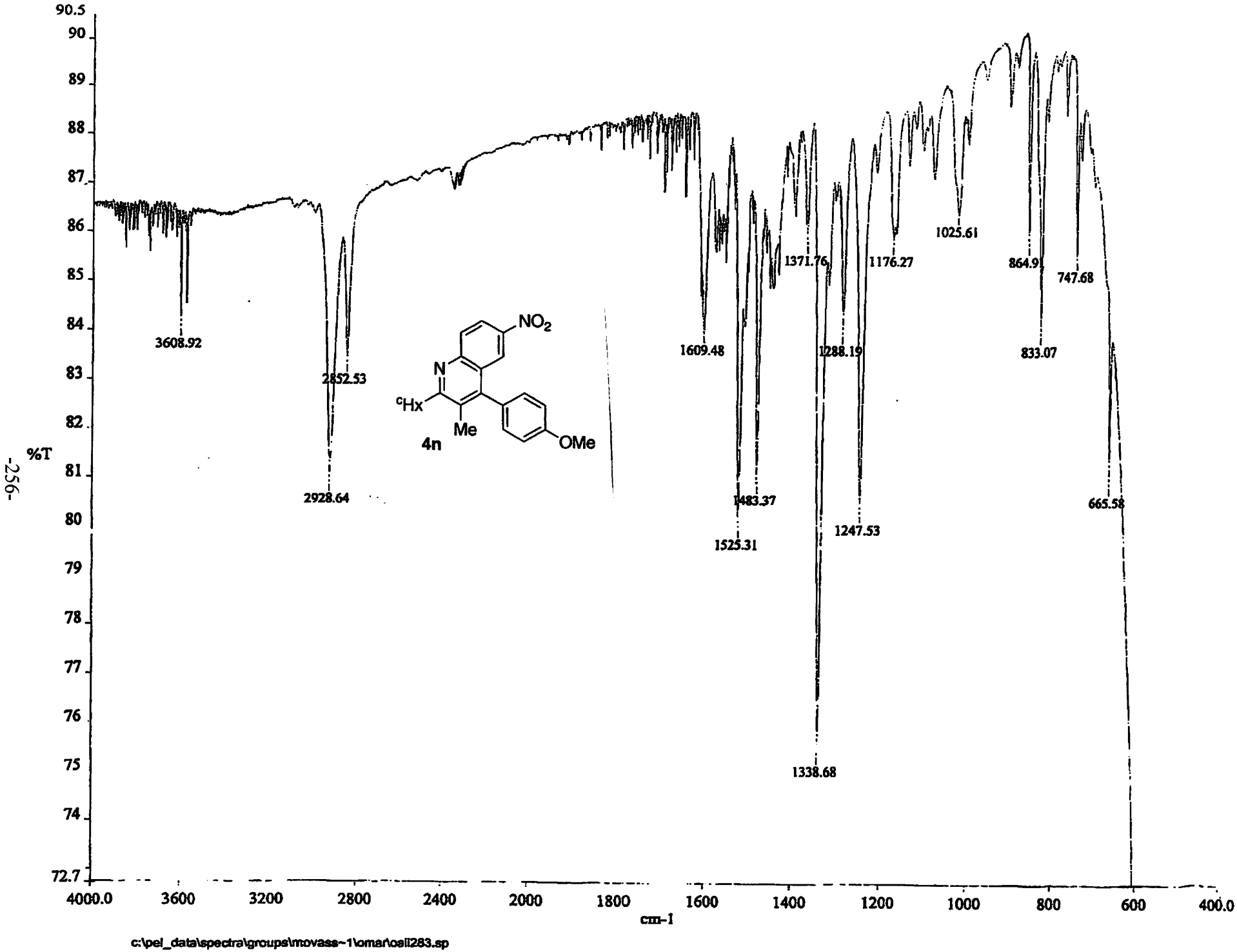

```
F2 - Acquisition Parameter:
Date_            20070503
Time                10.24
INSTRUM             spect
PROBHD    5 mm BBO BB-1H
PULPROG              zg30
TD                  65536
SOLVENT             CDCl3
NS                      9
DS                      2
SWH              8278.146 Hz
FIDRES           0.126314 Hz
AQ               3.9584243 sec
RG                  228.1
DW                 60.400 usec
DE                  6.00 usec
TE                 293.2 K
D1              1.00000000 sec
TD0                     1

======== CHANNEL f1 ========
NUC1                   1H
P1                  15.07 usec
PL1                  0.00 dB
SFO1          400.1324710 MHz

F2 - Processing parameters
SI                  65536
SF            400.1300082 MHz
WDW                    EM
SSB                     0
LB                   0.30 Hz
GB                      0
PC                   1.00
```






```
F2 - Acquisition Parameters
Date_            20070503
Time                20.14
INSTRUM             spect
PROBHD   5 mm QNP 1H/13
PULPROG           zgpg30
TD                 65536
SOLVENT            CDCl3
NS                   117
DS                     2
SWH            23980.814 Hz
FIDRES          0.365918 Hz
AQ             1.3664756 sec
RG                  6502
DW                20.850 usec
DE                 6.00 usec
TE                293.2 K
D1            2.00000000 sec
d11           0.03000000 sec
DELTA         1.89999998 sec
TD0                    1

======== CHANNEL f1 ========
NUC1                13C
P1                 9.38 usec
PL1                0.00 dB
SFO1         100.6228298 MHz

======== CHANNEL f2 ========
CPDPRG2          waltz16
NUC2                1H
PCPD2              90.00 usec
PL2                0.00 dB
PL12               16.10 dB
PL13               19.00 dB
SFO2         400.1316005 MHz

F2 - Processing parameters
SI                 65536
SF           100.6127532 MHz
WDW                   EM
SSB                    0
LB                  1.00 Hz
GB                     0
PC                  1.40
```




90.5
90
89
88
87
86
85
84
83
82
81
80
79
78
77
76
75
74
72.7
%T
3608.92
2852.53
2928.64
1609.48
1525.31
1483.37
1371.76
1338.68
1288.19
1247.53
1176.27
1025.61
864.91
833.07
747.68
665.58
NO2
N
cHx
Me
OMe
4n
4000.0
3600
3200
2800
2400
2000
1800
1600
1400
1200
1000
800
600
400.0
cm-1
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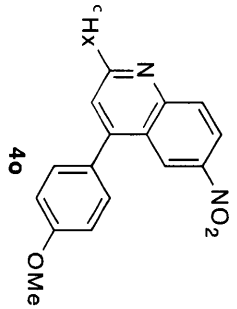
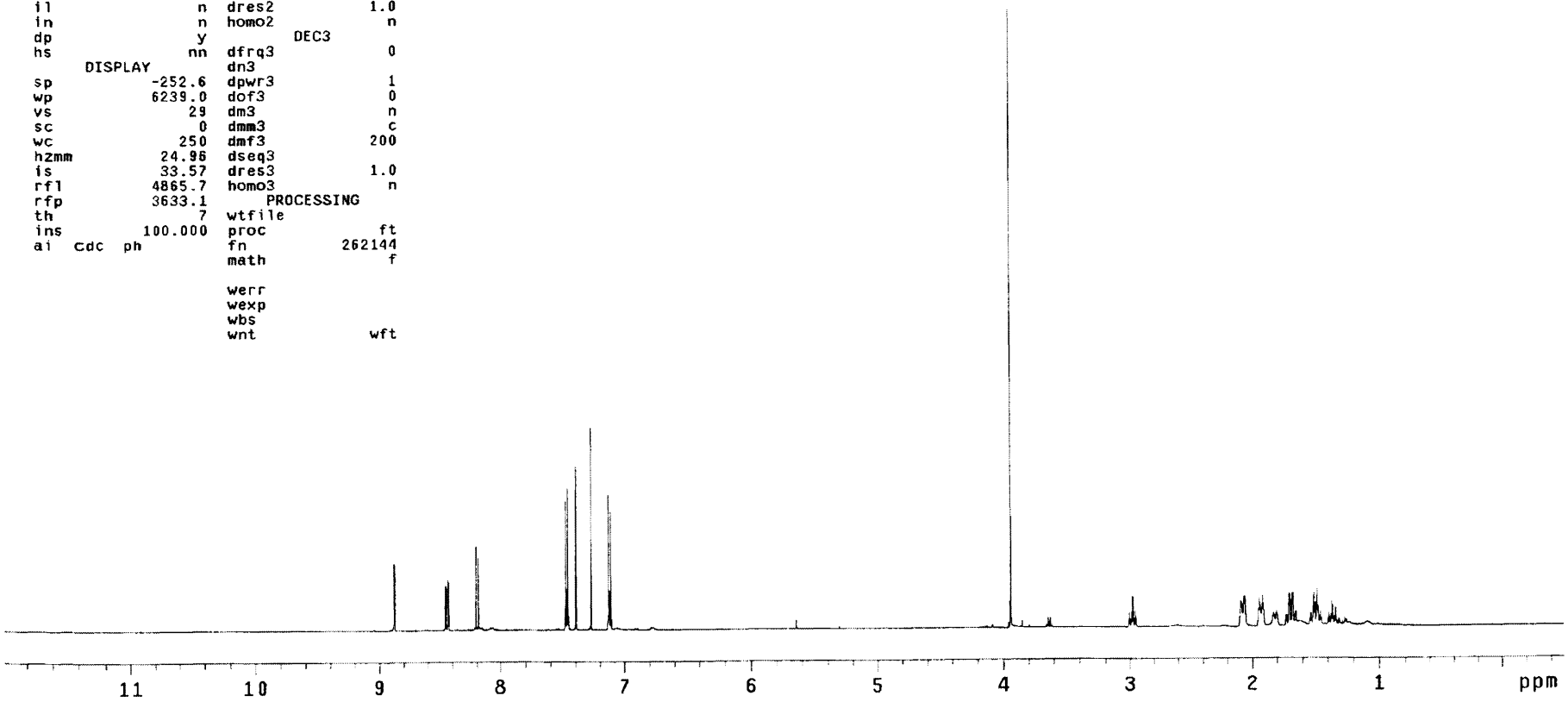
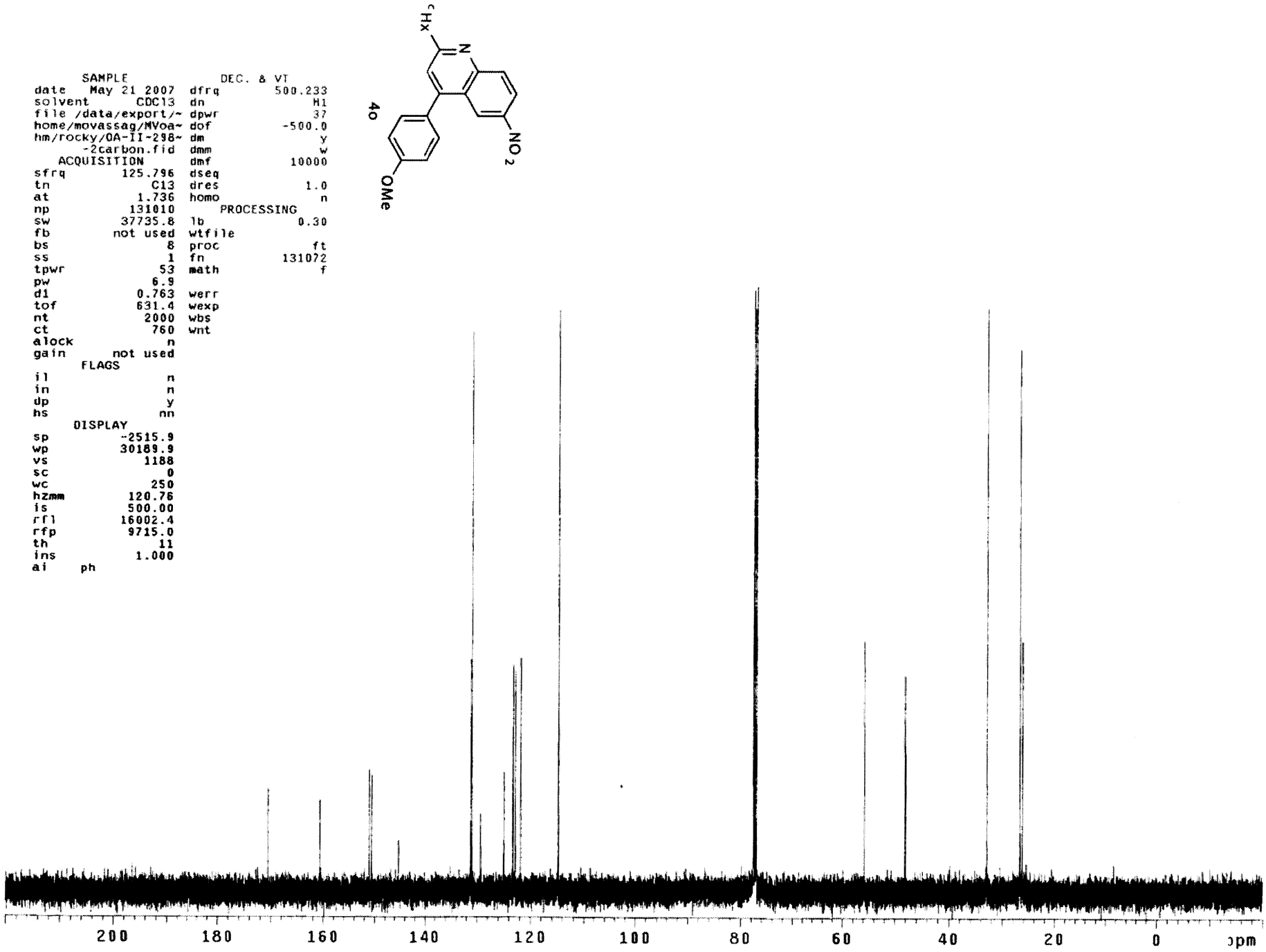
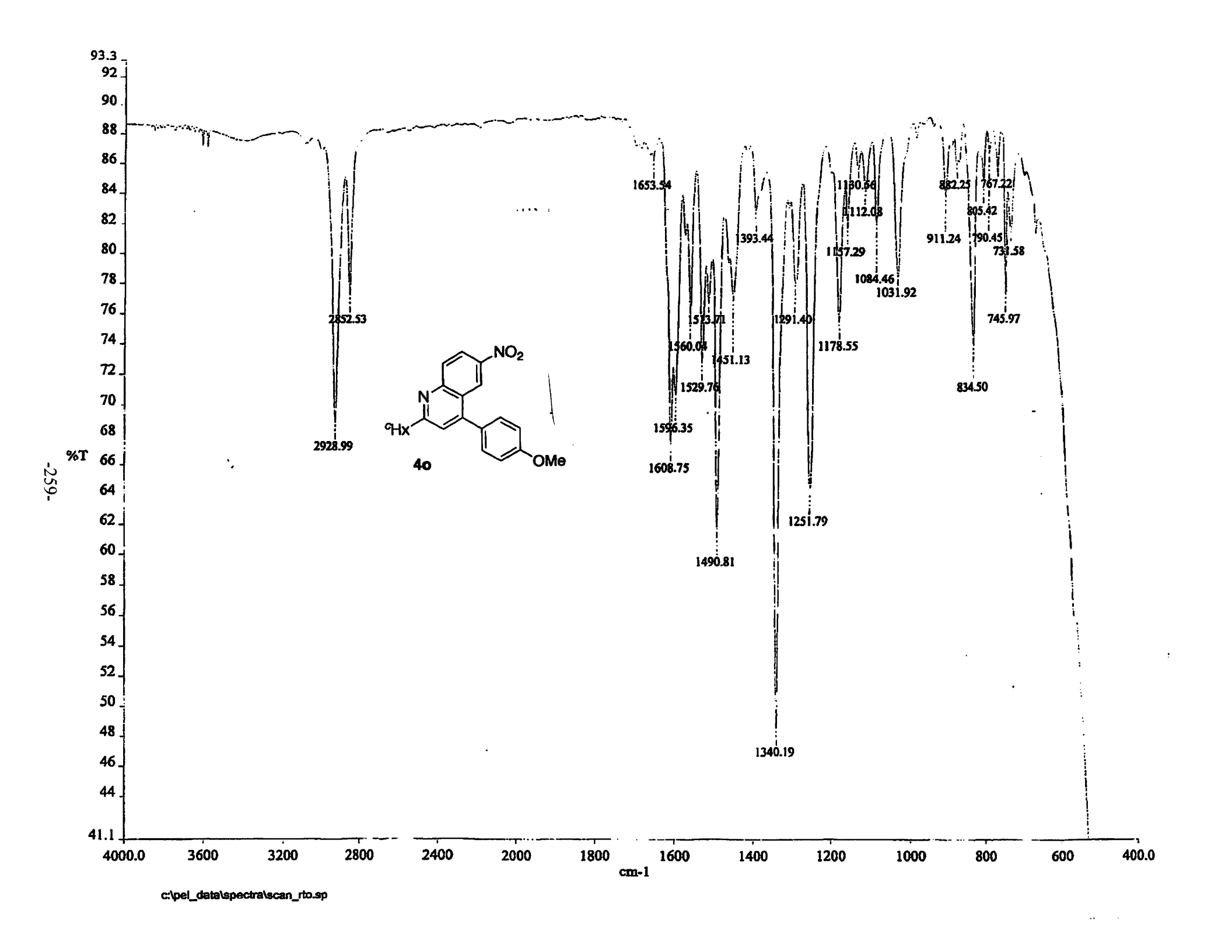


4o

SAMPLE		DEC. & VT	
date	May 21 2007	dfrq	125.672
solvent	CDCl3	dn	C13
file	exp	dpwr	30
ACQUISITION		dof	0
sfrq	499.746	dm	nnn
tn	H1	dmm	w
at	3.001	dmf	10000
np	63050	dseq	
sw	10504.2	dres	1.0
fb	not used	homo	n
bs	4	temp	22.0
tpwr	56	DEC2	
pw	8.6	dfrq2	0
d1	2.000	dn2	
tof	1519.5	dpwr2	1
nt	32	dof2	0
ct	8	dm2	n
alock	n	dmm2	c
gain	not used	dmf2	200
FLAGS		dseq2	
il	n	dres2	1.0
in	n	homo2	n
dp	y	DEC3	
hs	nn	dfrq3	0
DISPLAY		dn3	
sp	-252.6	dpwr3	1
wp	6239.0	dof3	0
vs	29	dm3	n
sc	0	dmm3	c
wc	250	dmf3	200
hzmm	24.96	dseq3	
is	33.57	dres3	1.0
rfl	4865.7	homo3	n
rfp	3633.1	PROCESSING	
th	7	wtfile	
ins	100.000	proc	ft
ai cdc ph		fn	262144
		math	f
		werr	
		wexp	
		wbs	
		wnt	wft




SAMPLE
date May 21 2007
solvent CDCl3
file /data/export/~
home/movassag/MVoa~
hm/rocky/OA-II-298~
-2carbon.fid
ACQUISITION
sfrq 125.796
tn C13
at 1.736
np 131010
sw 37735.8
fb not used
bs 8
ss 1
tpwr 53
pw 6.9
d1 0.763
tof 631.4
nt 2000
ct 760
alock n
gain not used
FLAGS
il n
in n
dp y
hs nn
DISPLAY
sp -2515.9
wp 30189.9
vs 1188
sc 0
wc 250
hzmm 120.76
is 500.00
rfl 16002.4
rfp 9715.0
th 11
ins 1.000
ai ph
DEC. & VT
dfrq 500.233
dn H1
dpwr 37
dof -500.0
dm y
dmm w
dmf 10000
dseq
dres 1.0
homo n
PROCESSING
lb 0.30
wtfile
proc ft
fn 131072
math f
werr
wexp
wbs
wnt
CH3
N
NO2
OMe
40
200
180
160
140
120
100
80
60
40
20
0
ppm


93.3
92
90
88
86
84
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76
74
72
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68
66
64
62
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58
56
54
52
50
48
46
44
41.1
%T
4000.0
3600
3200
2800
2400
2000
1800
1600
1400
1200
1000
800
600
400.0
cm-1
2928.99
2852.53
1653.54
1608.75
1596.35
1560.04
1529.76
1490.81
1451.13
1393.44
1340.19
1291.40
1251.79
1178.55
1157.29
1130.66
1112.08
1084.46
1031.92
911.24
882.25
834.50
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790.45
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745.97
731.58
NO2
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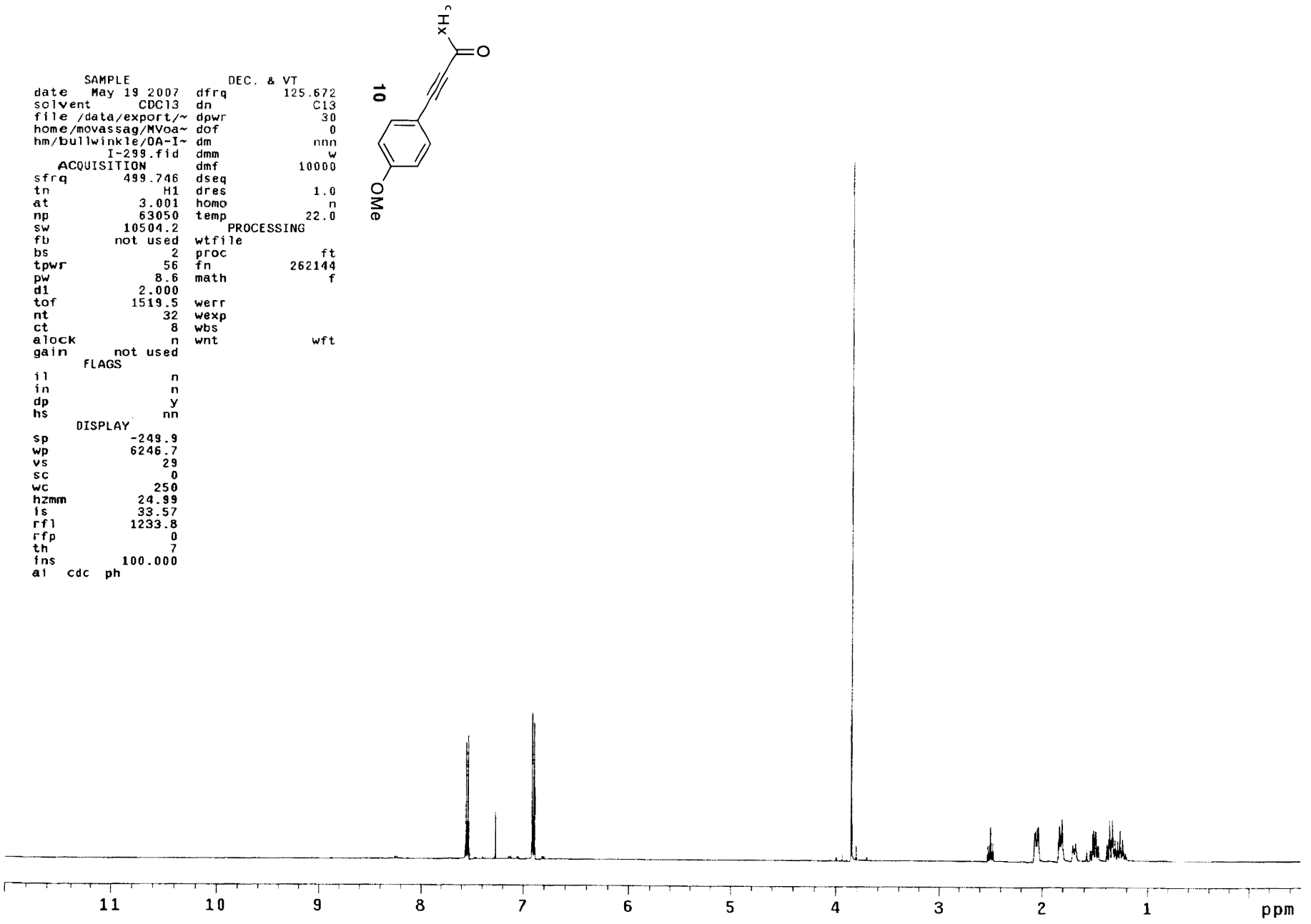
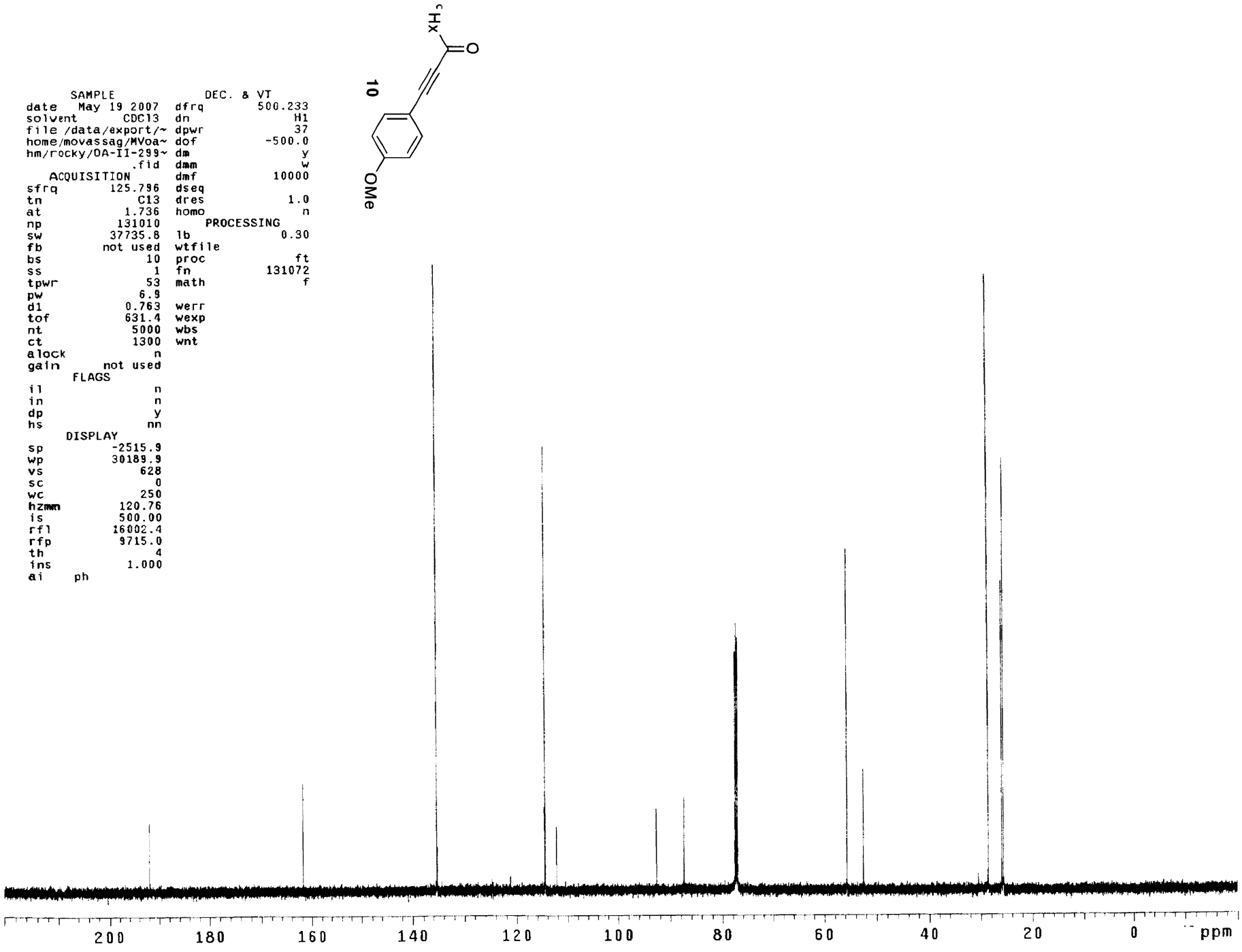
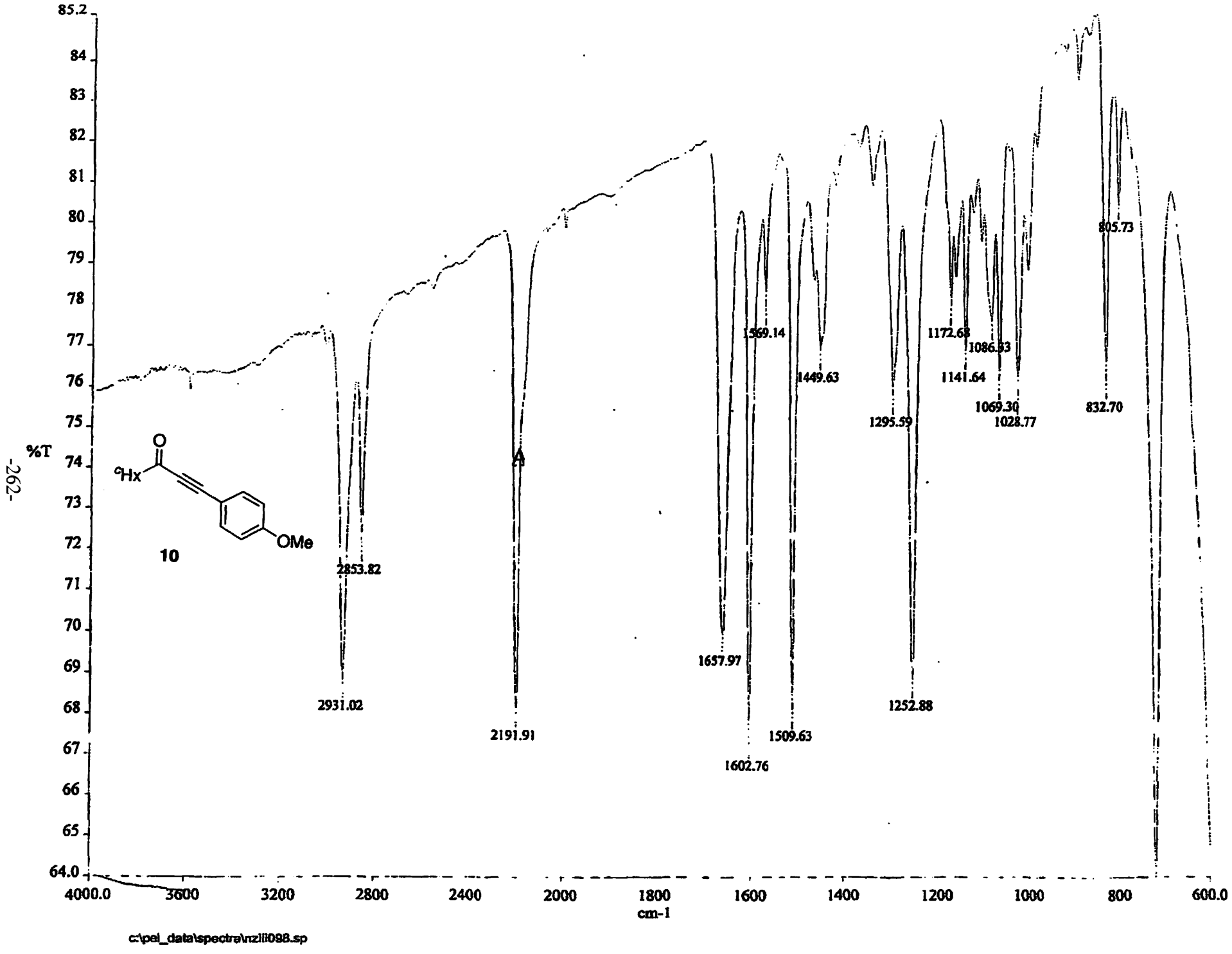
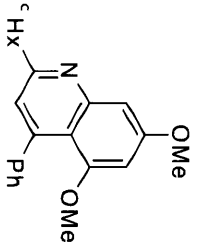
cHx
OMe
4o
c:\pel_data\spectra\scan_rto.sp


SAMPLE
date May 19 2007
solvent CDCl3
file /data/export/~
home/movassag/MVoa~
hm/bullwinkle/OA-I~
I-299.fid
ACQUISITION
sfrq 499.746
tn H1
at 3.001
np 63050
sw 10504.2
fb not used
bs 2
tpwr 56
pw 8.6
d1 2.000
tof 1519.5
nt 32
ct 8
alock n
gain not used
FLAGS
il n
in n
dp y
hs nn
DISPLAY
sp -249.9
wp 6246.7
vs 29
sc 0
wc 250
hzmm 24.99
is 33.57
rfl 1233.8
rfp 0
th 7
ins 100.000
ai cdc ph
DEC. & VT
dfrq 125.672
dn C13
dpwr 30
dof 0
dm nnn
dmm w
dmf 10000
dseq
dres 1.0
homo n
temp 22.0
PROCESSING
wtfile
proc ft
fn 262144
math f
werr
wexp
wbs
wnt wft
10
OMe
O
CH3
11
10
9
8
7
6
5
4
3
2
1
ppm

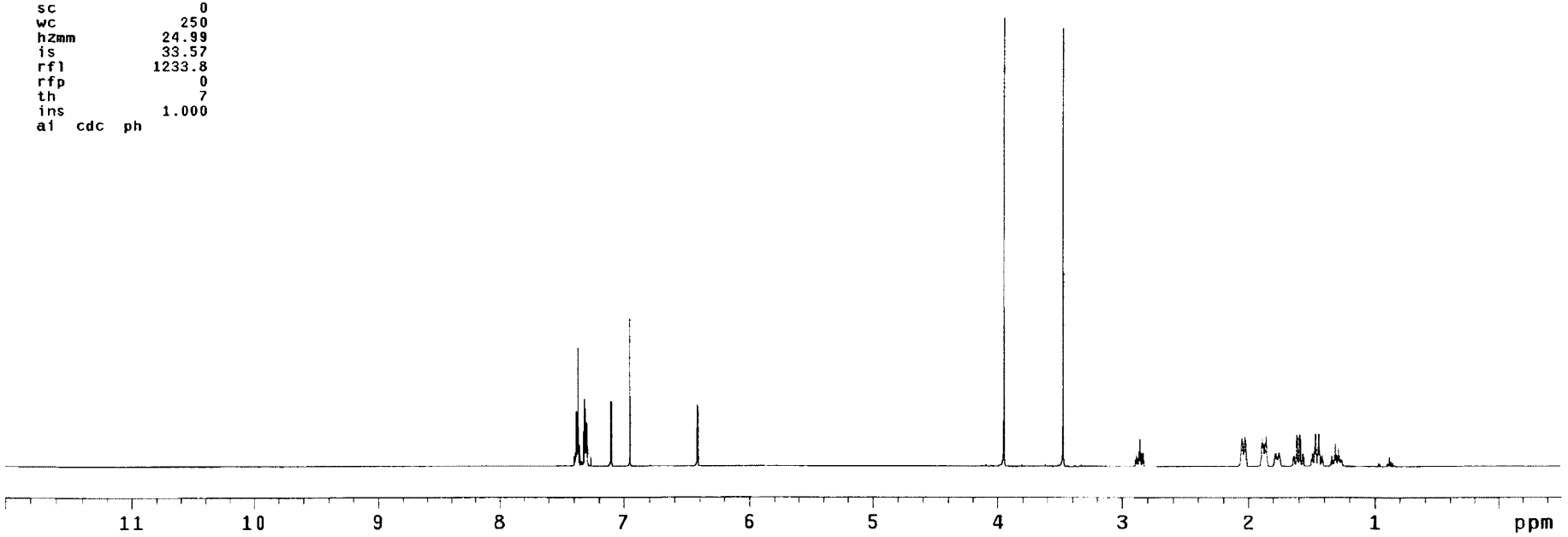

SAMPLE
date May 19 2007
solvent CDCl3
file /data/export/~
home/movassag/MVoa~
hm/rocky/OA-II-299~
.fid
ACQUISITION
sfrq 125.796
tn C13
at 1.736
np 131010
sw 37735.8
fb not used
bs 10
ss 1
tpwr 53
pw 6.9
d1 0.763
tof 631.4
nt 5000
ct 1300
alock n
gain not used
FLAGS
il n
in n
dp y
hs nn
DISPLAY
sp -2515.9
wp 30189.9
vs 628
sc 0
wc 250
hzmm 120.76
is 500.00
rfl 16002.4
rfp 9715.0
th 4
ins 1.000
ai ph
DEC. & VT
dfrq 500.233
dn H1
dpwr 37
dof -500.0
dm y
dmm w
dmf 10000
dseq
dres 1.0
homo n
PROCESSING
lb 0.30
wtfile
proc ft
fn 131072
math f
werr
wexp
wbs
wnt
10
OMe
200
180
160
140
120
100
80
60
40
20
0
ppm

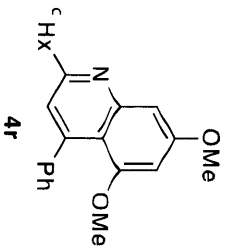

85.2
84
83
82
81
80
79
78
77
76
75
74
73
72
71
70
69
68
67
66
65
64.0
%T
4000.0
3600
3200
2800
2400
2000
1800
1600
1400
1200
1000
800
600.0
cm-1
2931.02
2853.82
2191.91
1657.97
1602.76
1569.14
1509.63
1449.63
1295.59
1252.88
1172.68
1141.64
1086.33
1069.30
1028.77
832.70
805.73
nHx
O
OMe
10
c:\pel_data\spectra\nzli\098.sp

SAMPLE		DEC. & VT	
date	Apr 26 2007	dfrq	125.672
solvent	CDCl3	dn	C13
file	/data/export/~	dpwr	30
	home/movassag/MVOa~	dof	0
	hm/bullwinkle/OA-I~	dm	nnn
	I-270.fid	dmm	w
ACQUISITION		dmf	10000
sfrq	499.746	dseq	
tn	H1	dres	1.0
at	3.001	homo	n
np	63050	PROCESSING	
sw	10504.2	wtfile	
fb	not used	proc	ft
bs	2	fn	262144
tpwr	56	math	f
pw	8.6		
d1	2.000	werr	
tof	1519.5	wexp	
nt	32	wbs	
ct	8	wnt	wft
alock	n		
gain	not used		
FLAGS			
il	n		
in	n		
dp	y		
hs	nn		
DISPLAY			
sp	-249.9		
wp	6246.7		
vs	24		
sc	0		
wc	250		
hzmm	24.99		
is	33.57		
rfl	1233.8		
rfp	0		
th	7		
ins	1.000		
al cdc ph			



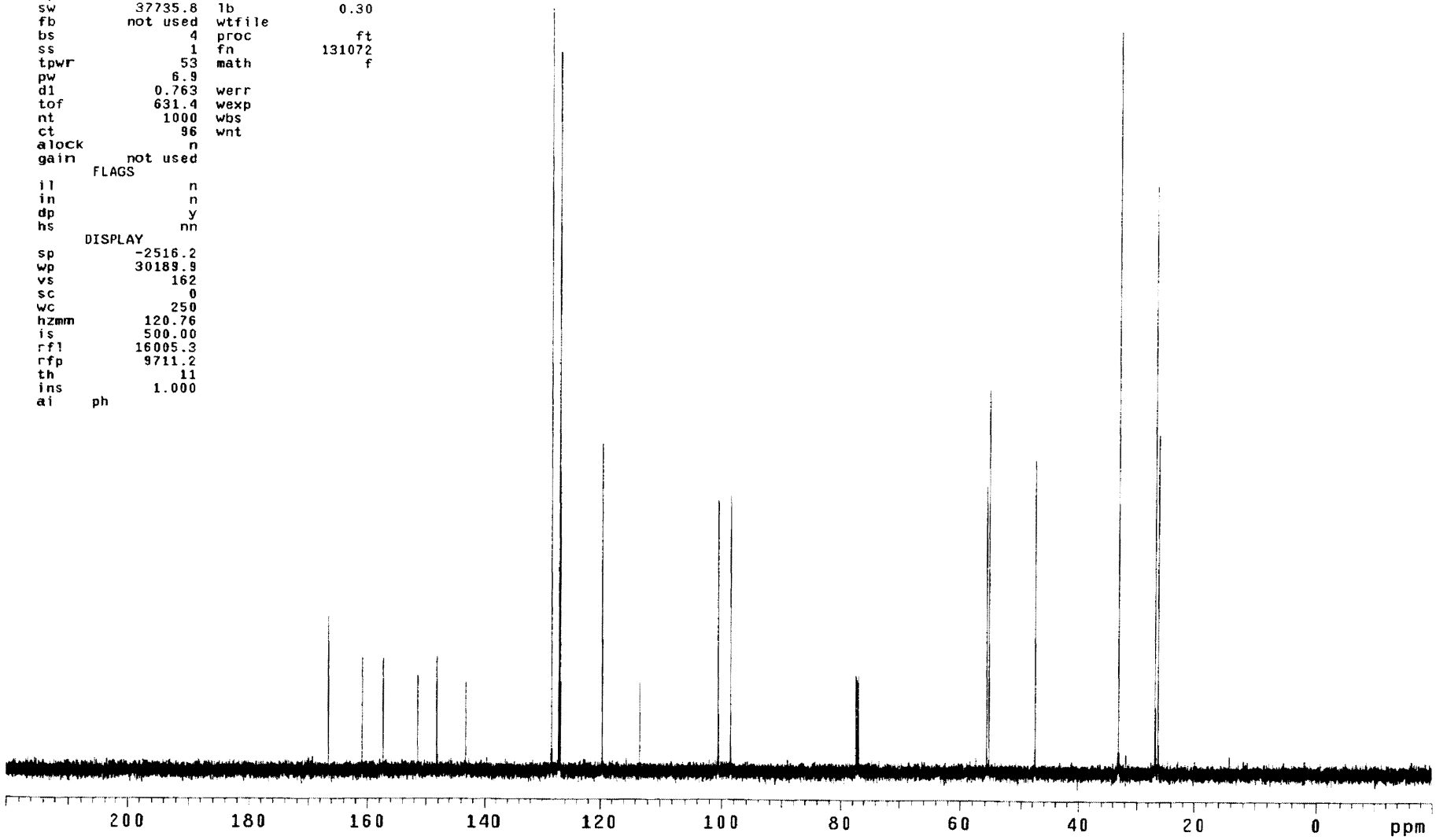
4r

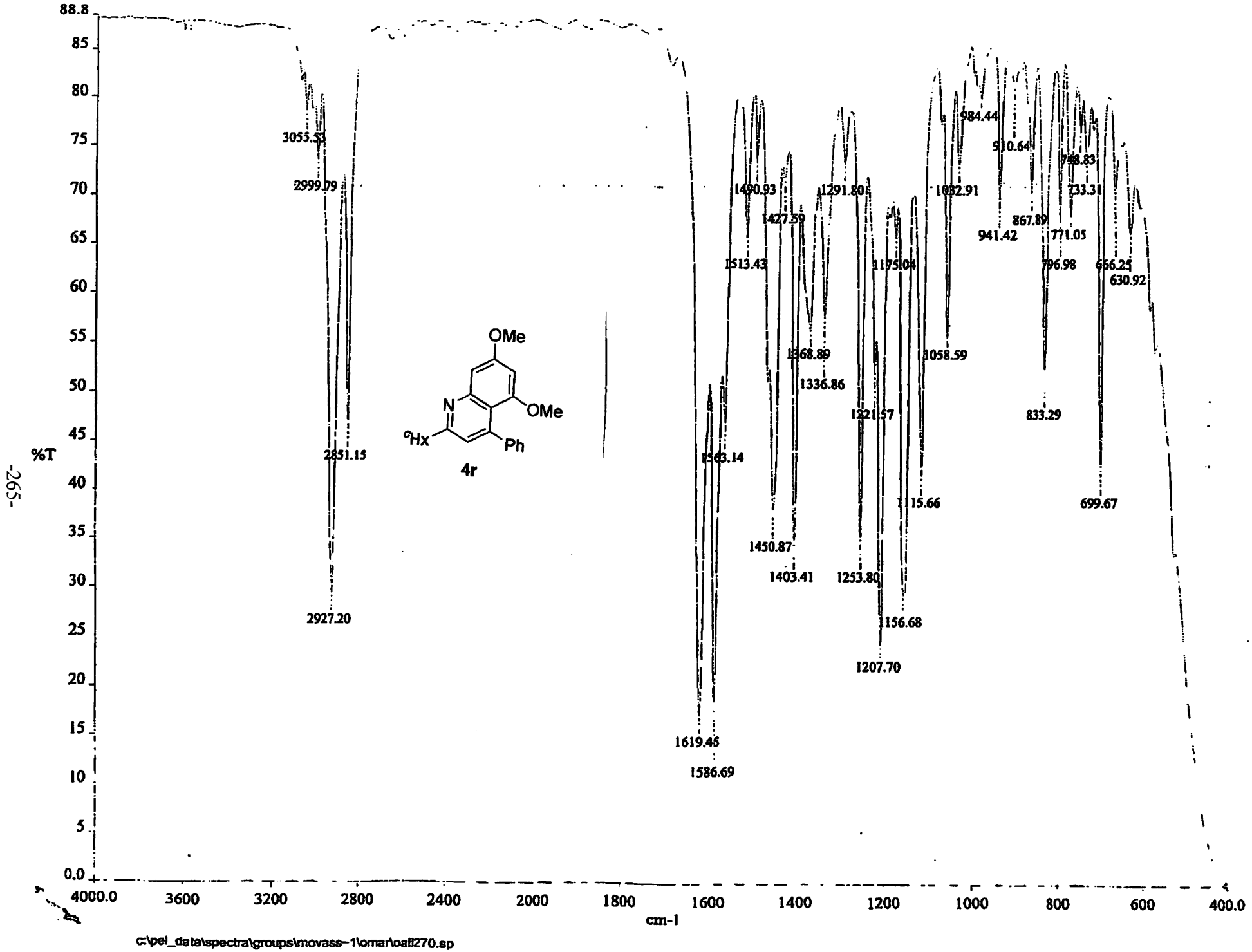




4r

SAMPLE		DEC. & VT	
date	Apr 26 2007	dfrq	500.233
solvent	CDCl3	dn	H1
file	/data/export/~	dpwr	37
	home/movassag/MVoa~	dof	-500.0
	hm/rocky/OA-II-270~	dm	y
	carbon.fid	dmm	w
ACQUISITION		dmf	10000
sfrq	125.796	dseq	
tn	C13	dres	1.0
at	1.736	homo	n
np	131010	PROCESSING	
sw	37735.8	lb	0.30
fb	not used	wtfile	
bs	4	proc	ft
ss	1	fn	131072
tpwr	53	math	f
pw	6.9		
d1	0.763	werr	
tof	631.4	wexp	
nt	1000	wbs	
ct	96	wnt	
alock	n		
gain	not used		
FLAGS			
il	n		
in	n		
dp	y		
hs	nn		
DISPLAY			
sp	-2516.2		
wp	30189.9		
vs	162		
sc	0		
wc	250		
hzmm	120.76		
is	500.00		
rfl	16005.3		
rfp	9711.2		
th	11		
ins	1.000		
ai	ph		




%T
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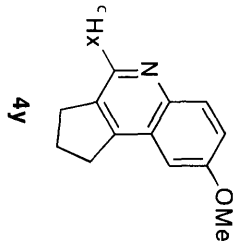
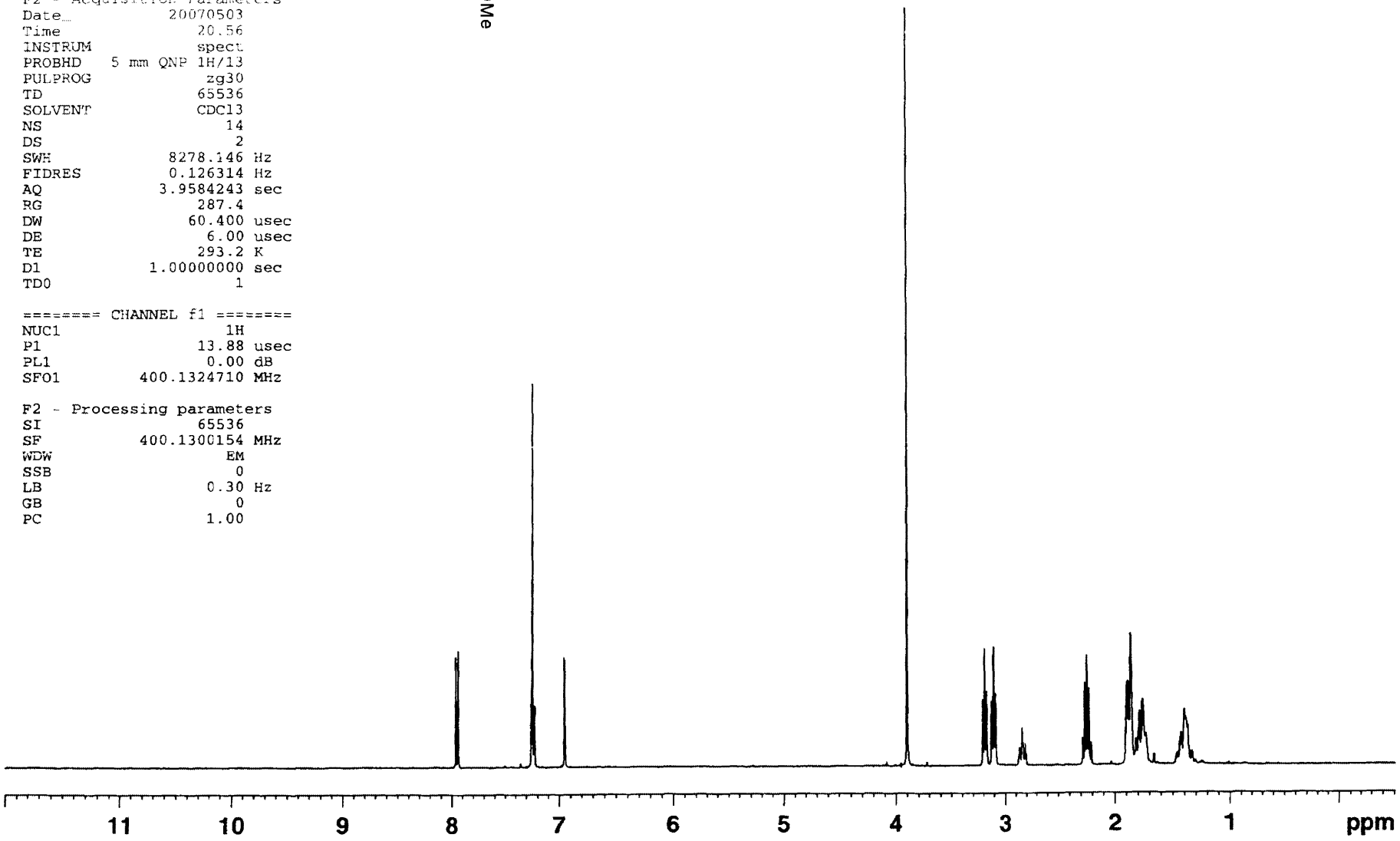
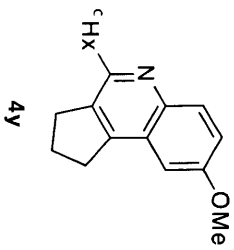
3200
2800
2400
2000
1800
1600
1400
1200
1000
800
600
400.0
88.8
85
80
75
70
65
60
55
50
45
40
35
30
25
20
15
10
5
0.0
3055.53
2999.79
2927.20
2851.15
1619.45
1586.69
1563.14
1513.43
1490.93
1450.87
1427.59
1403.41
1368.89
1336.86
1291.80
1253.80
1221.57
1207.70
1175.04
1156.68
1115.66
1058.59
1032.91
984.44
941.42
910.64
867.89
833.29
796.98
771.05
748.83
733.31
699.67
666.25
630.92
OMe
OMe
N
Ph
4r
c:\pel_data\spectra\groups\movass-1\omar\oall270.sp



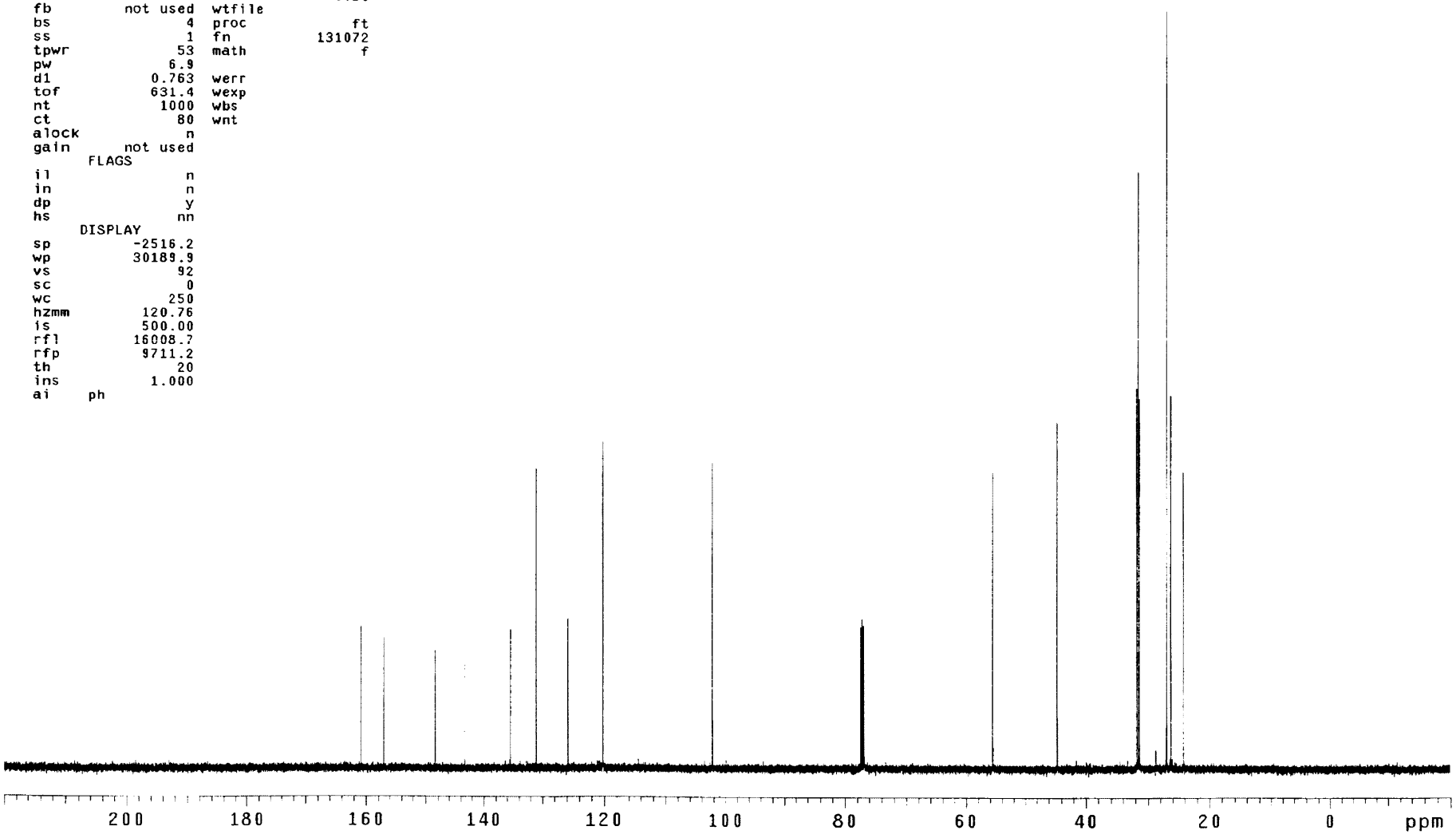

```
F2 - Acquisition Parameters
Date_           20070503
Time               20.56
INSTRUM            spect
PROBHD   5 mm QNP 1H/13
PULPROG             zg30
TD                 65536
SOLVENT            CDCl3
NS                    14
DS                     2
SWH             8278.146 Hz
FIDRES          0.126314 Hz
AQ              3.9584243 sec
RG                 287.4
DW                60.400 usec
DE                 6.00 usec
TE                293.2 K
D1             1.00000000 sec
TD0                    1

======== CHANNEL f1 ========
NUC1                  1H
P1                 13.88 usec
PL1                 0.00 dB
SFO1         400.1324710 MHz

F2 - Processing parameters
SI                 65536
SF           400.1300154 MHz
WDW                   EM
SSB                    0
LB                  0.30 Hz
GB                     0
PC                  1.00
```

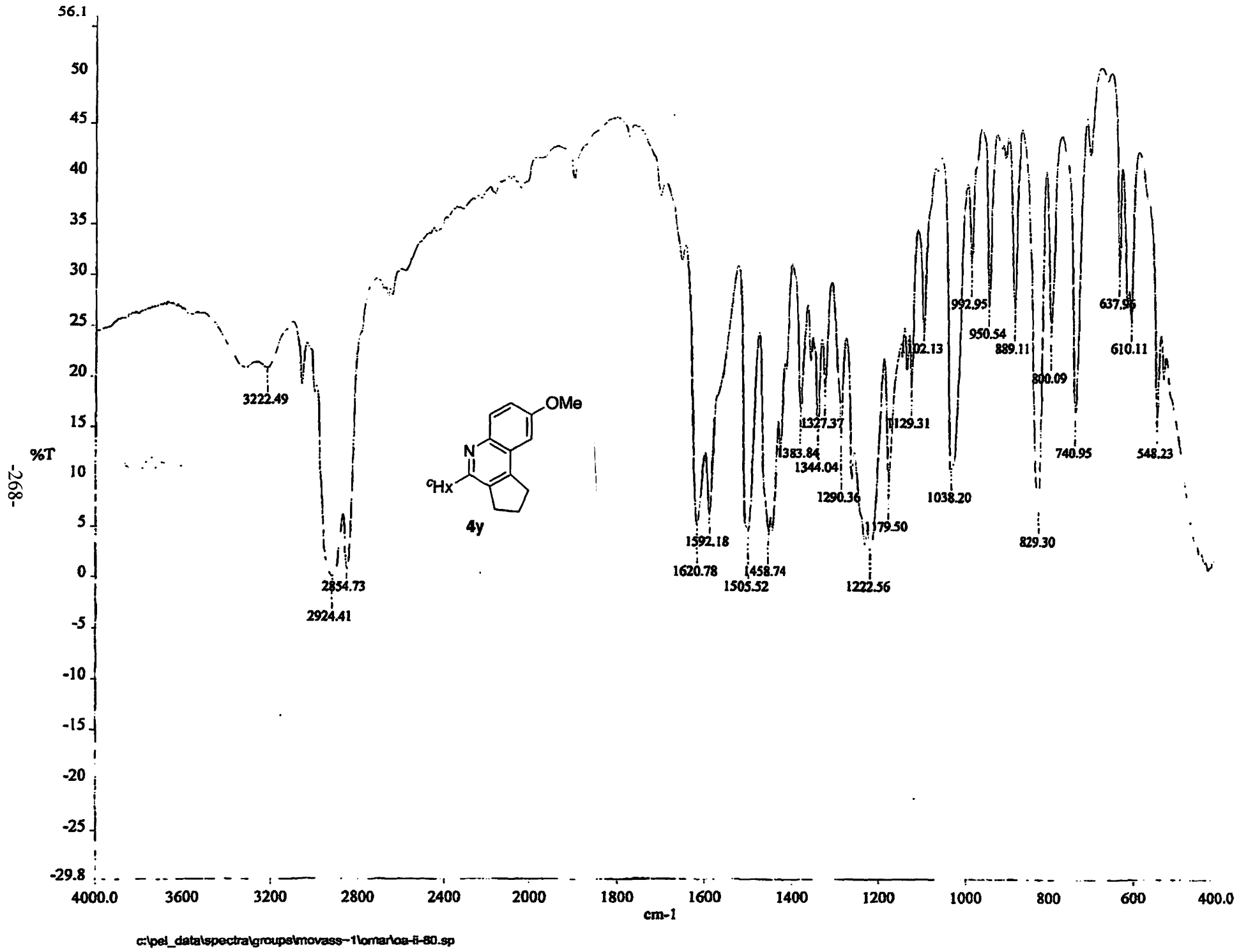




4y

SAMPLE		DEC. & VT	
date	Feb 26 2007	dfrq	500.233
solvent	CDCl3	dn	H1
file	/data/export/~	dpwr	38
home/movassag/MVoa~		dof	-500.0
hm/rocky/OA-II-95c~		dm	y
arbon.fid		dmm	w
ACQUISITION		dmf	10000
sfrq	125.796	dseq	
tn	C13	dres	1.0
at	1.736	homo	n
np	131010	PROCESSING	
sw	37735.8	lb	0.30
fb	not used	wtfile	
bs	4	proc	ft
ss	1	fn	131072
tpwr	53	math	f
pw	6.9		
d1	0.763	werr	
tof	631.4	wexp	
nt	1000	wbs	
ct	80	wnt	
alock	n		
gain	not used		
FLAGS			
il	n		
in	n		
dp	y		
hs	nn		
DISPLAY			
sp	-2516.2		
wp	30189.9		
vs	92		
sc	0		
wc	250		
hzmm	120.76		
is	500.00		
rfl	16008.7		
rfp	9711.2		
th	20		
ins	1.000		
ai	ph		

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25
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%T
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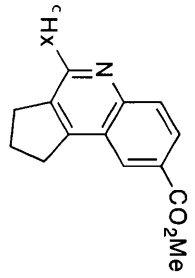
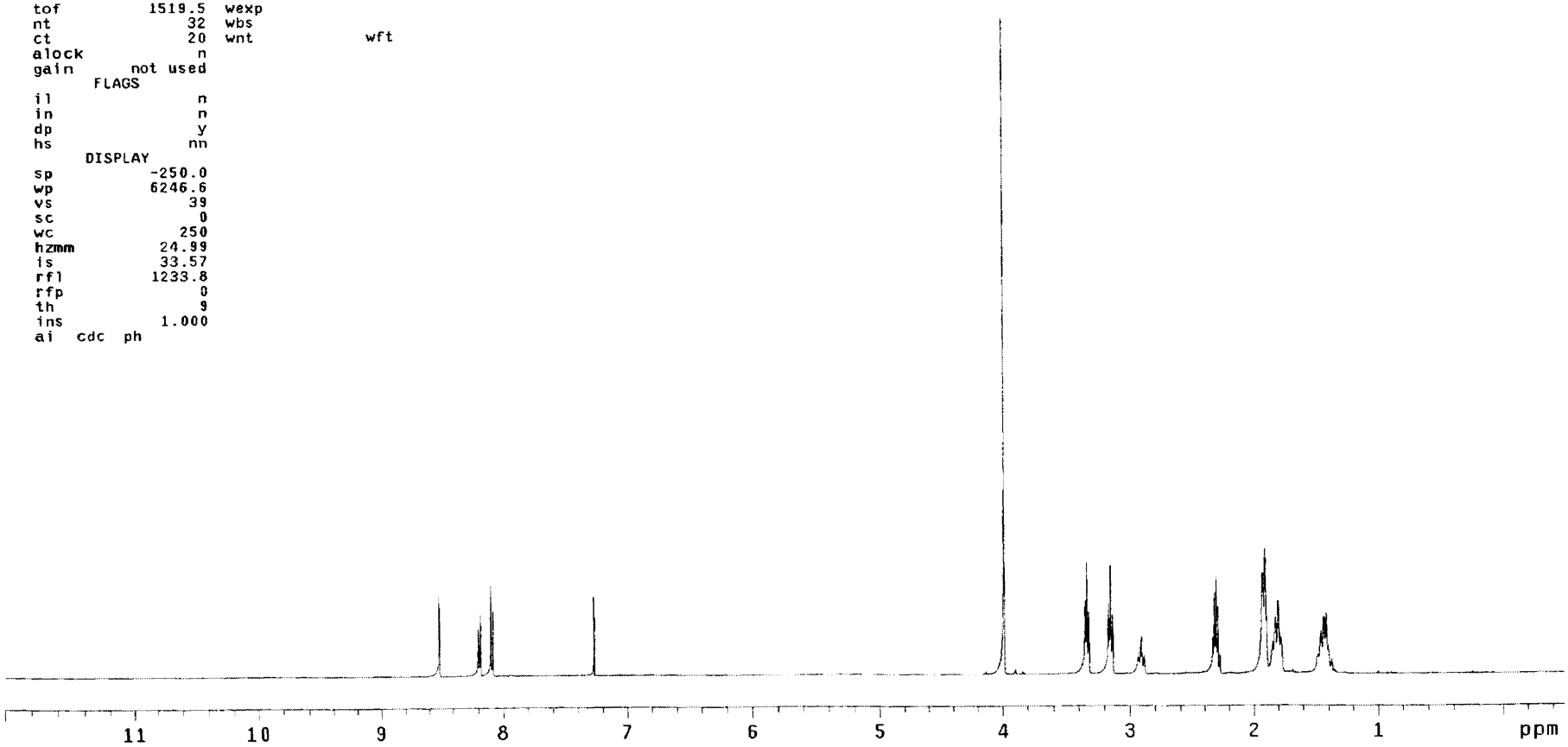
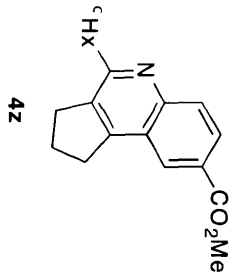
-10
-15
-20
-25
-29.8
-268-
4000.0
3600
3200
2800
2400
2000
1800
1600
1400
1200
1000
800
600
400.0
cm-1
3222.49
2924.41
2854.73
1620.78
1592.18
1505.52
1458.74
1383.84
1344.04
1327.37
1290.36
1222.56
1179.50
1129.31
1102.13
1038.20
992.95
950.54
889.11
829.30
800.09
740.95
637.96
610.11
548.23
OMe
N
cHx
4y
c:\pel_data\spectra\groups\movass-1\omar\oa-ii-80.sp

4z



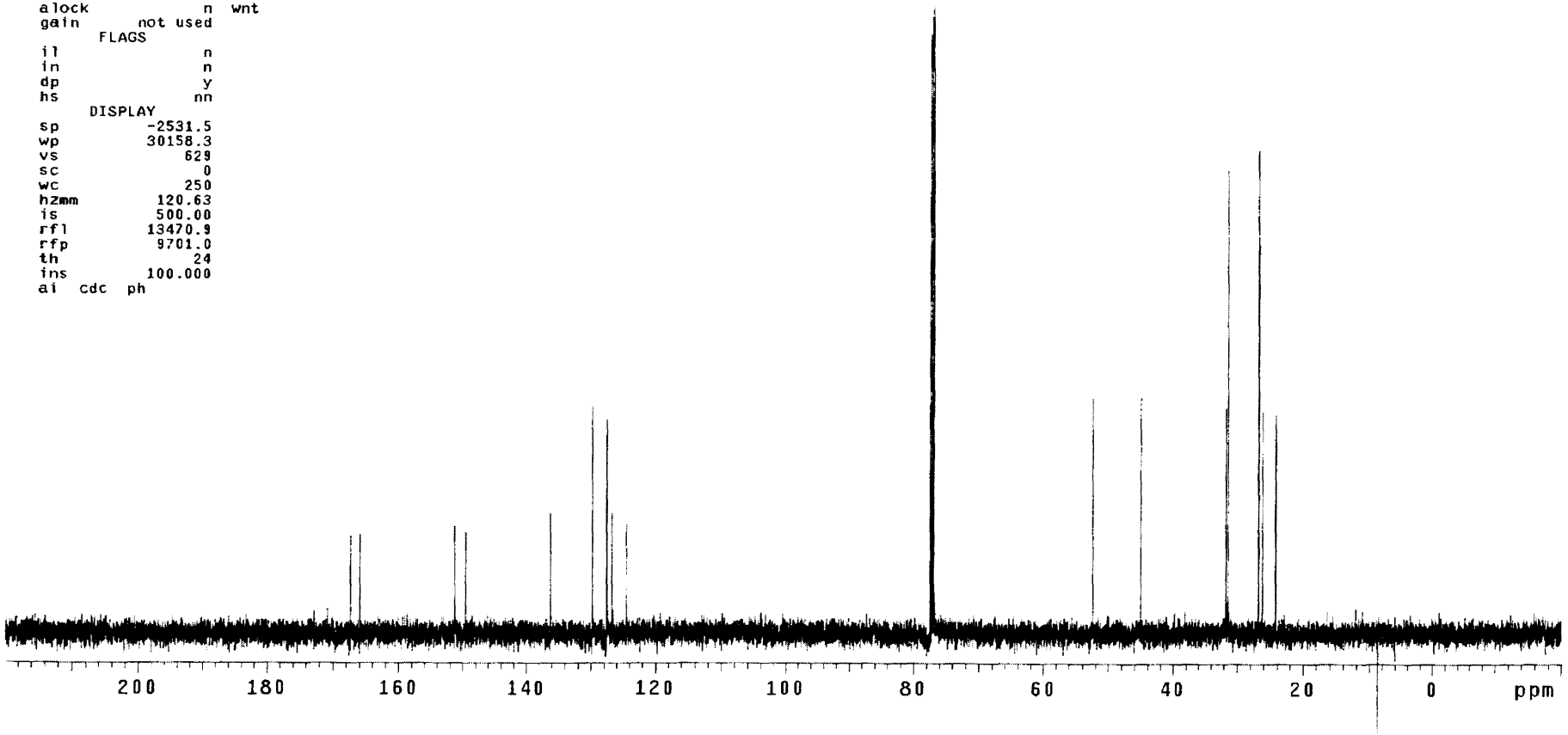
SAMPLE		DEC. & VT	
date	Feb 17 2007	dfrq	125.672
solvent	CDCl3	dn	C13
file	/data/export/~	dpwr	30
	home/movassag/MVoa~	dof	0
	hm/bullwinkle/OA-I~	dm	nnn
	I-166fr13-20.fid	dmm	w
ACQUISITION		dmf	10000
sfrq	499.746	dseq	
tn	H1	dres	1.0
at	3.001	homo	n
np	63050	PROCESSING	
sw	10504.2	wtfile	
fb	not used	proc	ft
bs	2	fn	131072
tpwr	56	math	f
pw	8.9		
d1	2.000	werr	
tof	1519.5	wexp	
nt	32	wbs	
ct	20	wnt	wft
alock	n		
gain	not used		
FLAGS			
il	n		
in	n		
dp	y		
hs	nn		
DISPLAY			
sp	-250.0		
wp	6246.6		
vs	39		
sc	0		
wc	250		
hzmm	24.99		
is	33.57		
rfl	1233.8		
rfp	0		
th	9		
ins	1.000		
ai cdc ph			

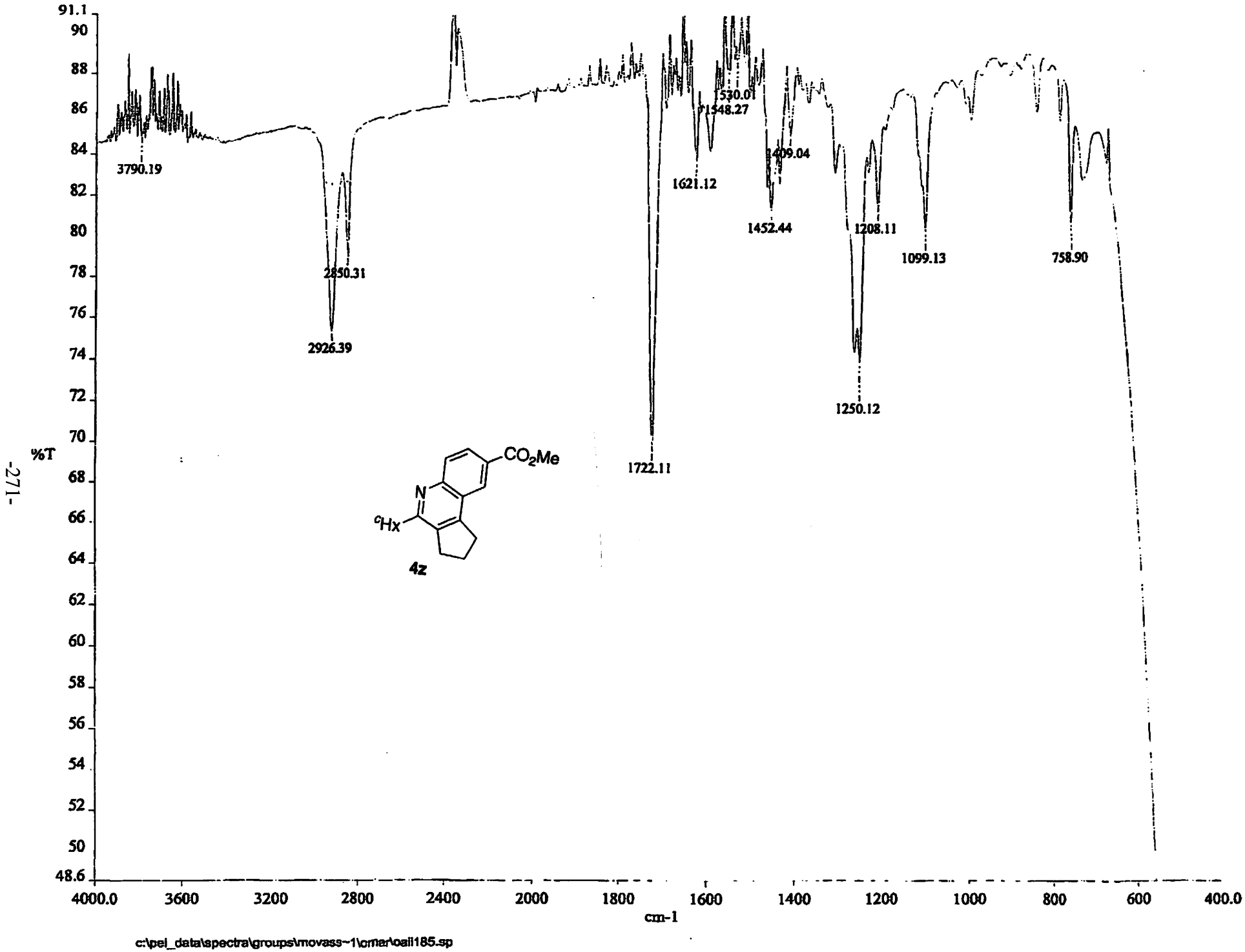




42

SAMPLE		DEC. & VT	
date	Mar 2 2007	dfrq	499.744
solvent	CDCl3	dn	H1
file	/data/export/~	dpwr	34
	home/movassag/MVoa~	dof	0
	hm/bullwinkle/OA-I~	dm	yyy
	I-185carbon.fid	dmm	w
ACQUISITION		dmf	10000
sfrq	125.672	dseq	
tn	C13	dres	1.0
at	2.000	homo	n
np	125588	PROCESSING	
sw	31397.2	lb	1.00
fb	not used	wtfile	
bs	4	proc	ft
tpwr	58	fn	131072
pw	6.7	math	f
d1	3.000		
tof	0	werr	
nt	1000	wexp	
ct	76	wbs	
alock	n	wnt	
gain	not used		
FLAGS			
il	n		
in	n		
dp	y		
hs	nn		
DISPLAY			
sp	-2531.5		
wp	30158.3		
vs	629		
sc	0		
wc	250		
hzmm	120.63		
is	500.00		
rfl	13470.9		
rfp	9701.0		
th	24		
ins	100.000		
ai cdc ph			

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86
84
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76
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64
62
60
58
56
54
52
50
48.6
%T
3790.19
2850.31
2926.39
1722.11
1621.12
1548.27
1530.01
1452.44
1409.04
1250.12
1208.11
1099.13
758.90
CO2Me
N
cHx
4z
4000.0
3600
3200
2800
2400
2000
1800
1600
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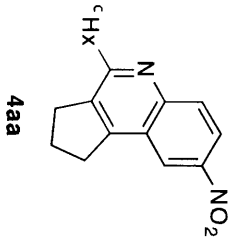
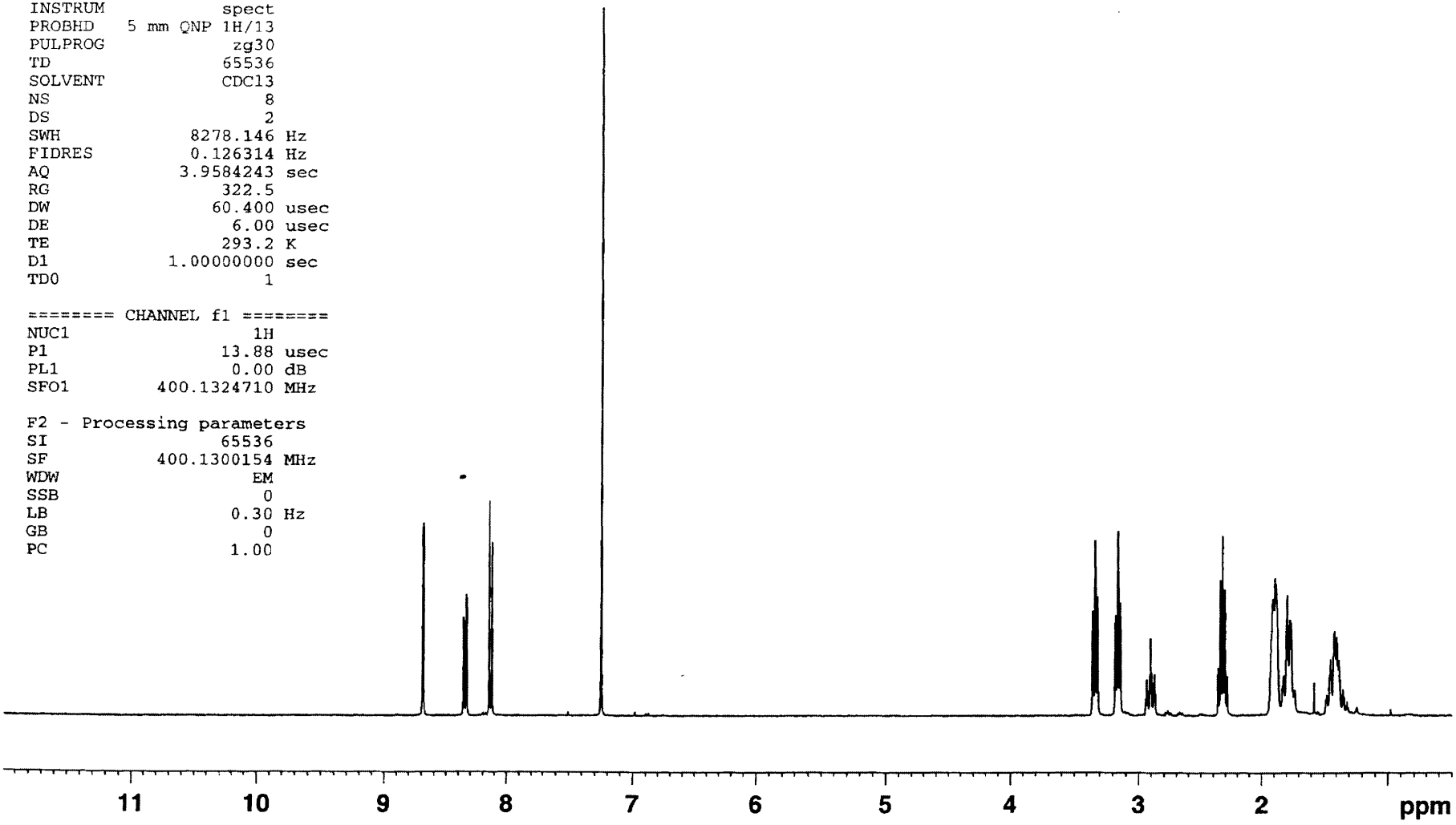
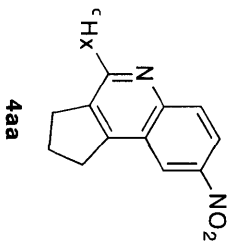
1200
1000
800
600
400.0
cm-1
c:\pel_data\spectra\groups\movass~1\cmar\oail185.sp



4aa

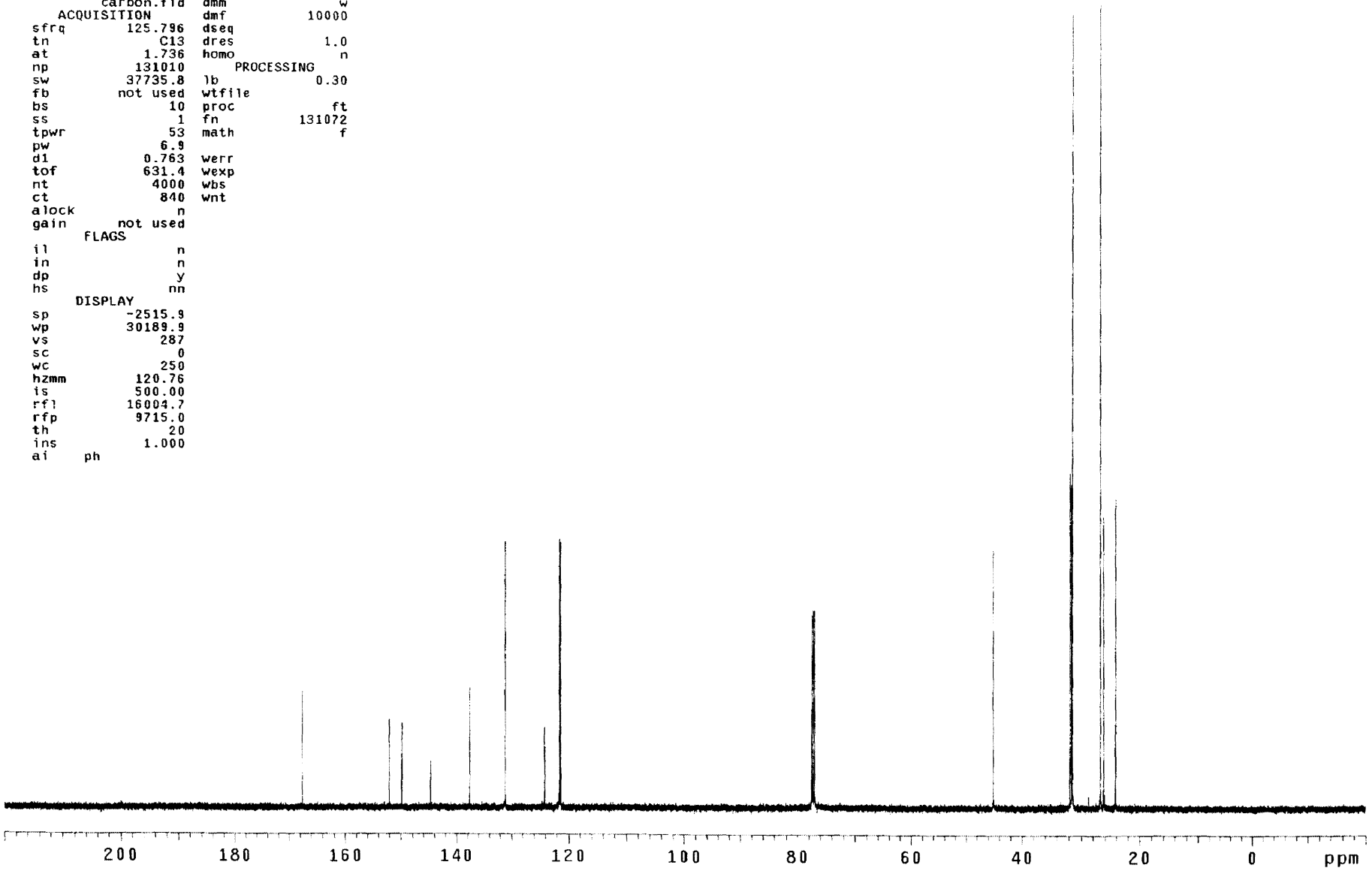
```
F2 - Acquisition Parameters
Date_           20070209
Time               9.15
INSTRUM           spect
PROBHD   5 mm QNP 1H/13
PULPROG            zg30
TD                65536
SOLVENT           CDCl3
NS                    8
DS                    2
SWH            8278.146 Hz
FIDRES        0.126314 Hz
AQ            3.9584243 sec
RG                322.5
DW               60.400 usec
DE                6.00 usec
TE                293.2 K
D1           1.00000000 sec
TD0                   1

======== CHANNEL f1 ========
NUC1                  1H
P1                13.88 usec
PL1                0.00 dB
SFO1        400.1324710 MHz

F2 - Processing parameters
SI                65536
SF          400.1300154 MHz
WDW                  EM
SSB                   0
LB                 0.30 Hz
GB                    0
PC                 1.00
```

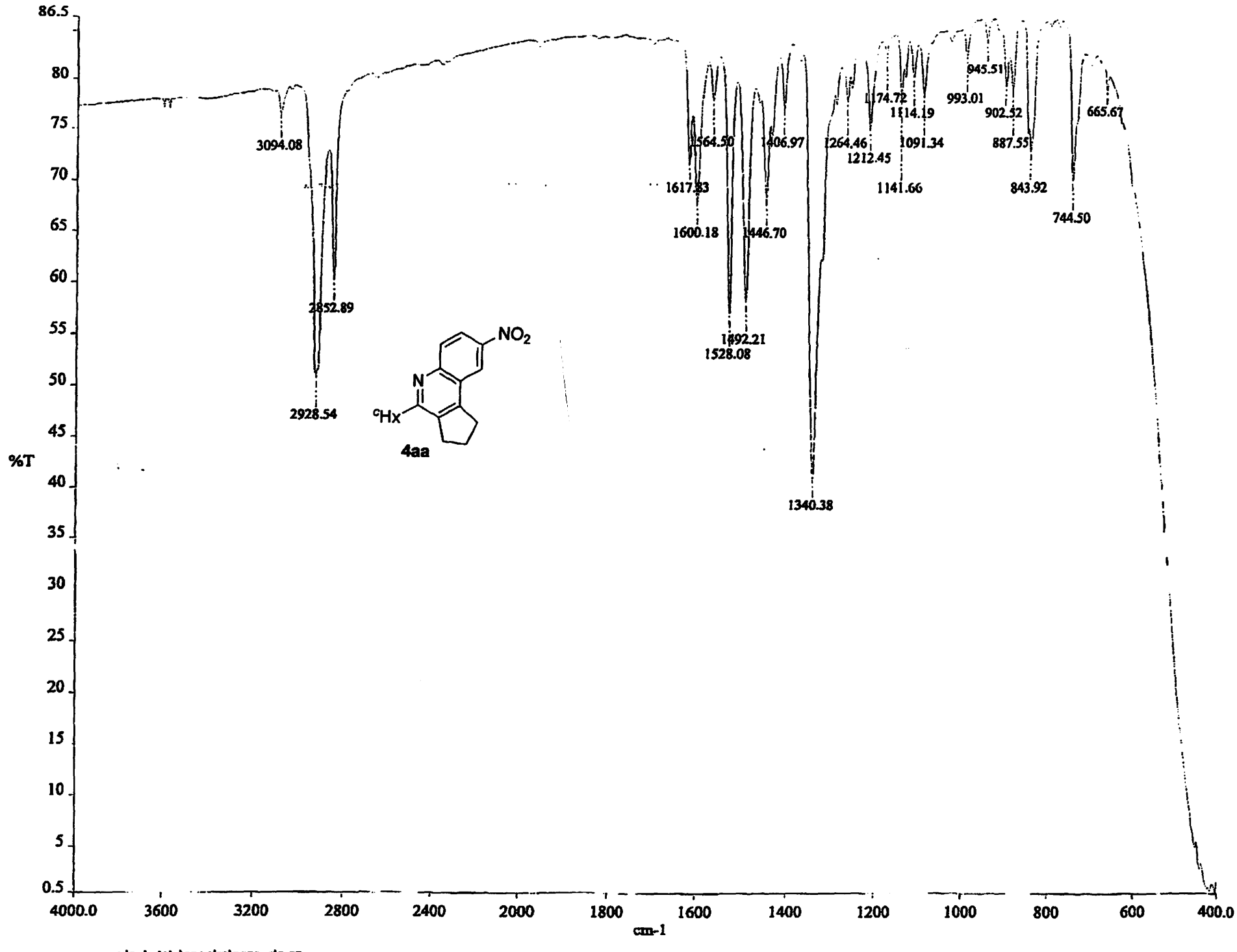




4aa

SAMPLE		DEC. & VT	
date	May 19 2007	dfrq	500.233
solvent	CDCl3	dn	H1
file	/data/export/~	dpwr	37
home/movassag/MVOa~		dof	-500.0
hm/rocky/OA-II-151~		dm	y
	carbon.fid	dmm	w
ACQUISITION		dmf	10000
sfrq	125.796	dseq	
tn	C13	dres	1.0
at	1.736	homo	n
np	131010	PROCESSING	
sw	37735.8	lb	0.30
fb	not used	wtfile	
bs	10	proc	ft
ss	1	fn	131072
tpwr	53	math	f
pw	6.9	werr	
d1	0.763	wexp	
tof	631.4	wbs	
nt	4000	wnt	
ct	840		
alock	n		
gain	not used		
FLAGS			
il	n		
in	n		
dp	y		
hs	nn		
DISPLAY			
sp	-2515.9		
wp	30189.9		
vs	287		
sc	0		
wc	250		
hzmm	120.76		
is	500.00		
rfl	16004.7		
rfp	9715.0		
th	20		
ins	1.000		
ai	ph		




86.5
80
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55
50
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30
25
20
15
10
5
0.5
%T
4000.0
3600
3200
2800
2400
2000
1800
1600
1400
1200
1000
800
600
400.0
cm-1
3094.08
2928.54
2852.89
1617.83
1600.18
1564.50
1528.08
1492.21
1446.70
1406.97
1340.38
1264.46
1212.45
1174.72
1141.66
1114.19
1091.34
993.01
945.51
902.52
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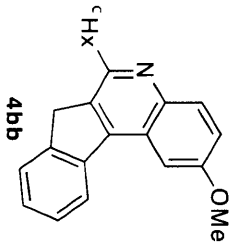
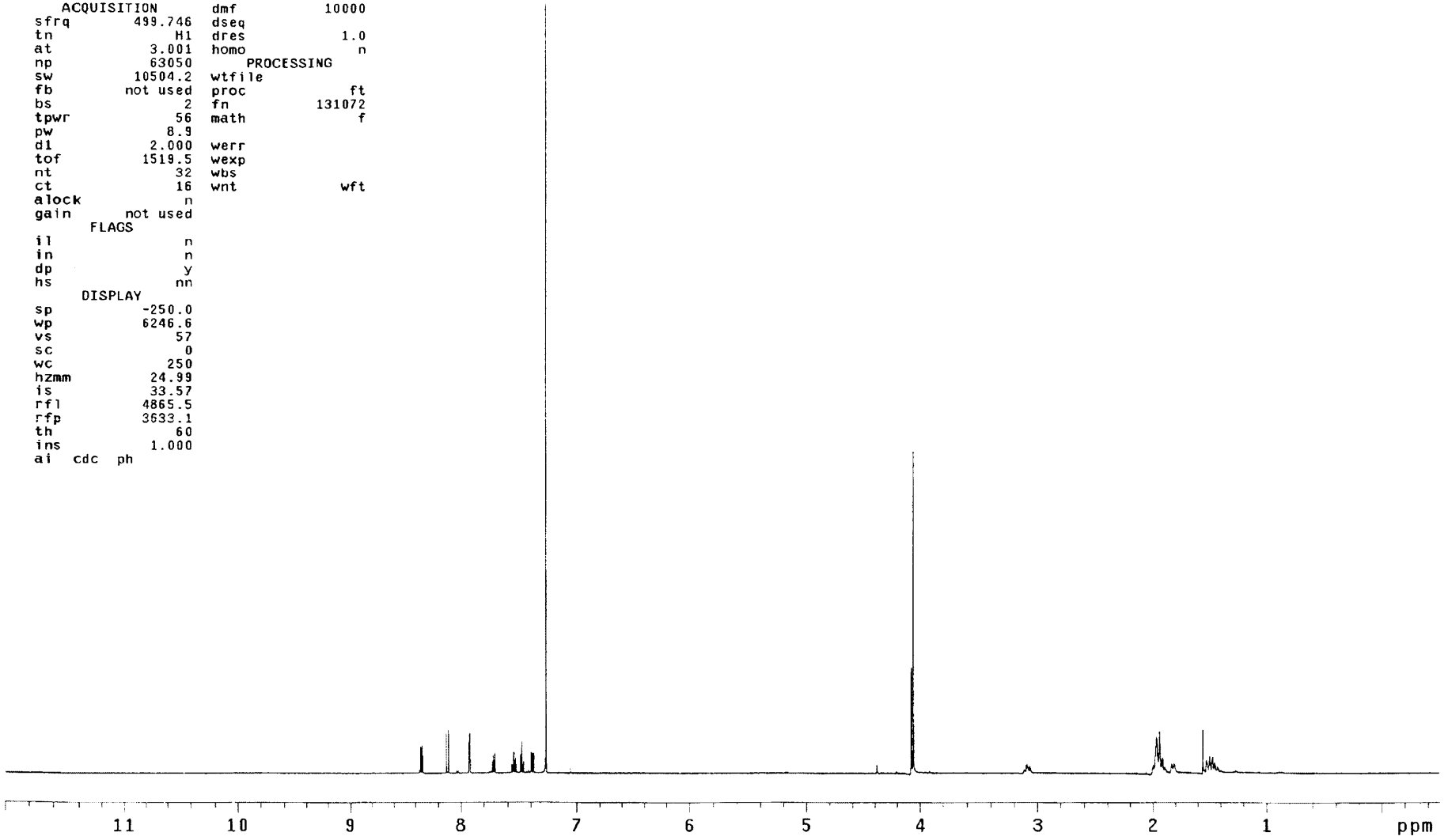
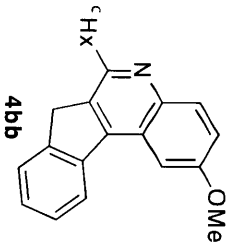
843.92
744.50
665.67
NO2
N
cHx
4aa
c:\pel_data\spectra\scan_rto.sp



4bb

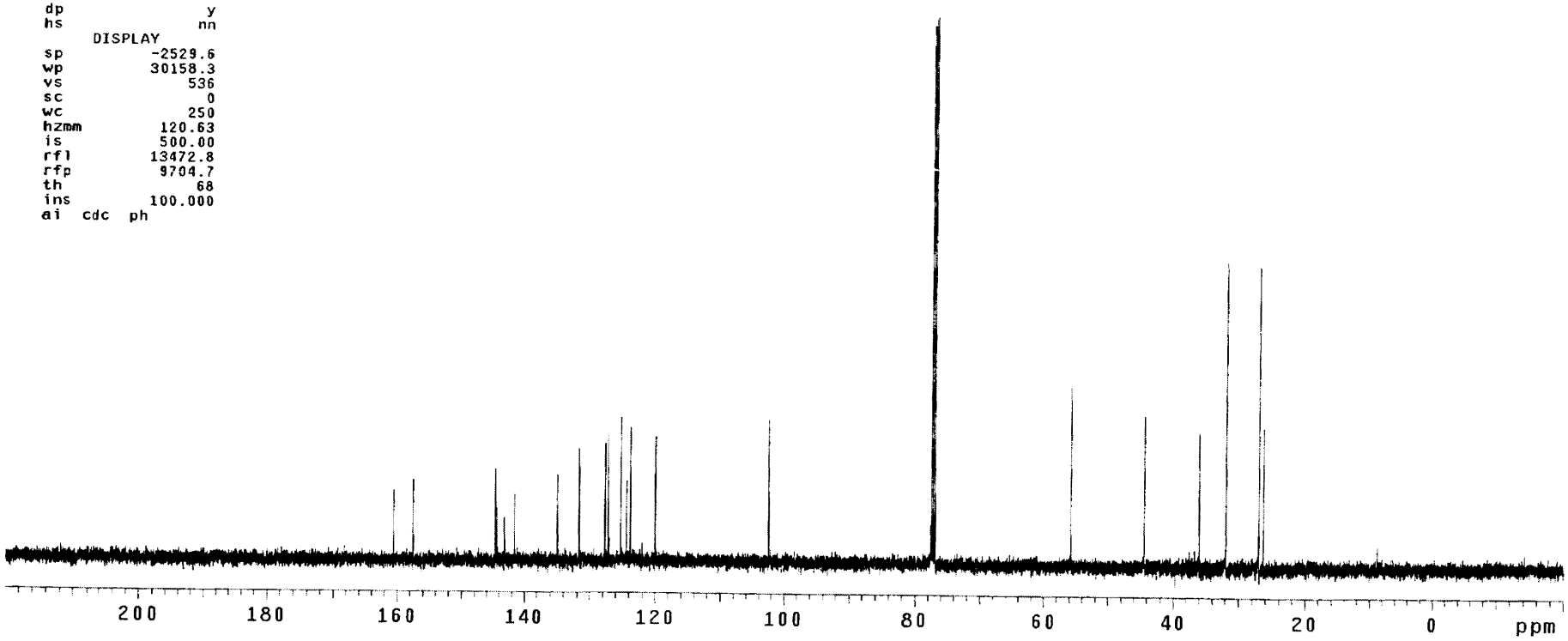
SAMPLE		DEC. & VT	
date	Jan 29 2007	dfrq	125.672
solvent	CDCl3	dn	C13
file	/data/export/~	dpwr	30
home/movassag/MVoa~		dof	0
hm/bullwinkle/OA-I~		dm	nnn
I-133fr7-12.fid		dmm	w
ACQUISITION		dmf	10000
sfrq	499.746	dseq	
tn	H1	dres	1.0
at	3.001	homo	n
np	63050	PROCESSING	
sw	10504.2	wtfile	
fb	not used	proc	ft
bs	2	fn	131072
tpwr	56	math	f
pw	8.9		
d1	2.000	werr	
tof	1519.5	wexp	
nt	32	wbs	
ct	16	wnt	wft
alock	n		
gain	not used		
FLAGS			
il	n		
in	n		
dp	y		
hs	nn		
DISPLAY			
sp	-250.0		
wp	6246.6		
vs	57		
sc	0		
wc	250		
hzmm	24.99		
is	33.57		
rfl	4865.5		
rfp	3633.1		
th	60		
ins	1.000		
ai cdc ph			

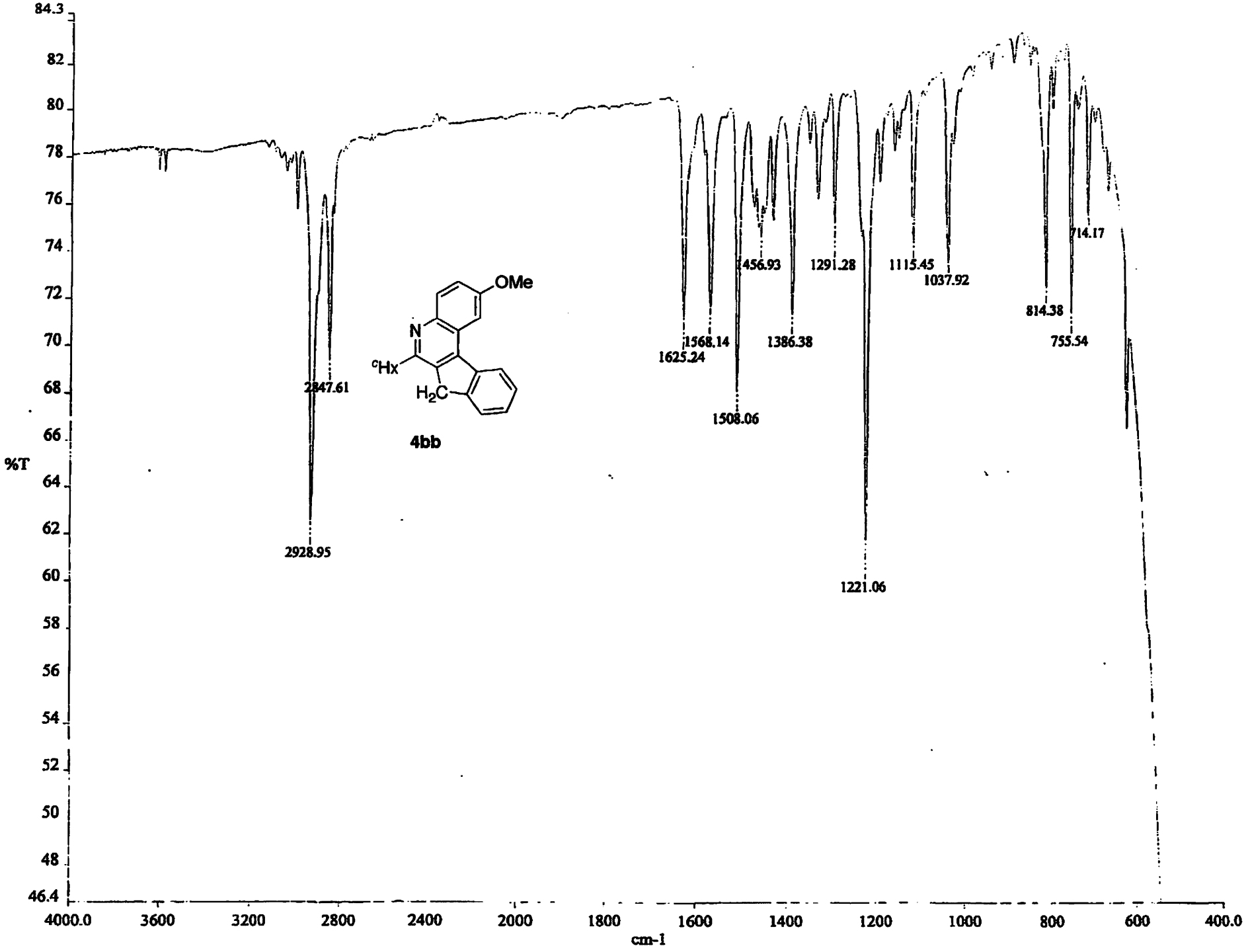




4bb

SAMPLE		DEC. & VT	
date	Feb 7 2007	dfrq	499.744
solvent	CDCl3	dn	H1
file	/data/export/~	dpwr	34
	home/movassag/MVoa~	dof	0
	hm/bullwinkle/OA-I~	dm	yyy
	I-133carbon.fid	dmm	w
ACQUISITION		dmf	10000
sfrq	125.672	dseq	
tn	C13	dres	1.0
at	2.000	homo	n
np	125588	temp	10.0
sw	31397.2	PROCESSING	
fb	not used	lb	1.00
bs	10	wtfile	
tpwr	58	proc	ft
pw	6.7	fn	131072
d1	3.000	math	f
tof	0		
nt	1000	werr	
ct	140	wexp	
alock	n	wbs	
gain	not used	wnt	
FLAGS			
il	n		
in	n		
dp	y		
hs	nn		
DISPLAY			
sp	-2529.6		
wp	30158.3		
vs	536		
sc	0		
wc	250		
hzmm	120.63		
is	500.00		
rfl	13472.8		
rfp	9704.7		
th	68		
ins	100.000		
ai cdc ph			

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76
74
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70
68
66
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62
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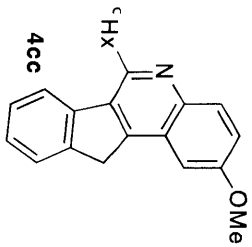
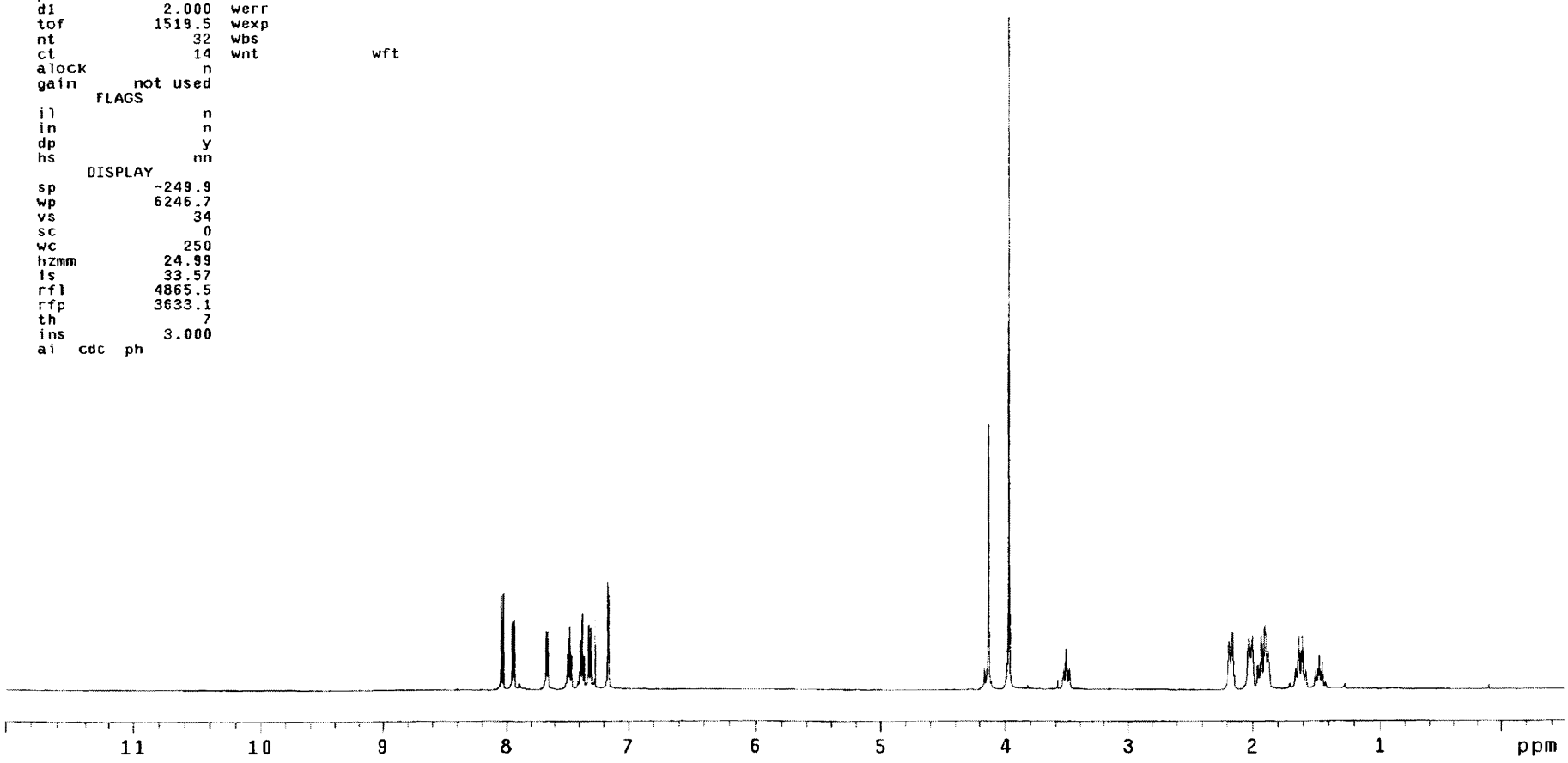
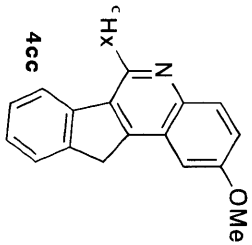
56
54
52
50
48
46.4
%T
4000.0
3600
3200
2800
2400
2000
1800
1600
1400
1200
1000
800
600
400.0
cm-1
2928.95
2847.61
1625.24
1568.14
1508.06
1456.93
1386.38
1291.28
1221.06
1115.45
1037.92
814.38
755.54
714.17
OMe
N
cHx
H2C
4bb
c:\pel_data\spectra\groups\movass~1\omar\oall105.sp

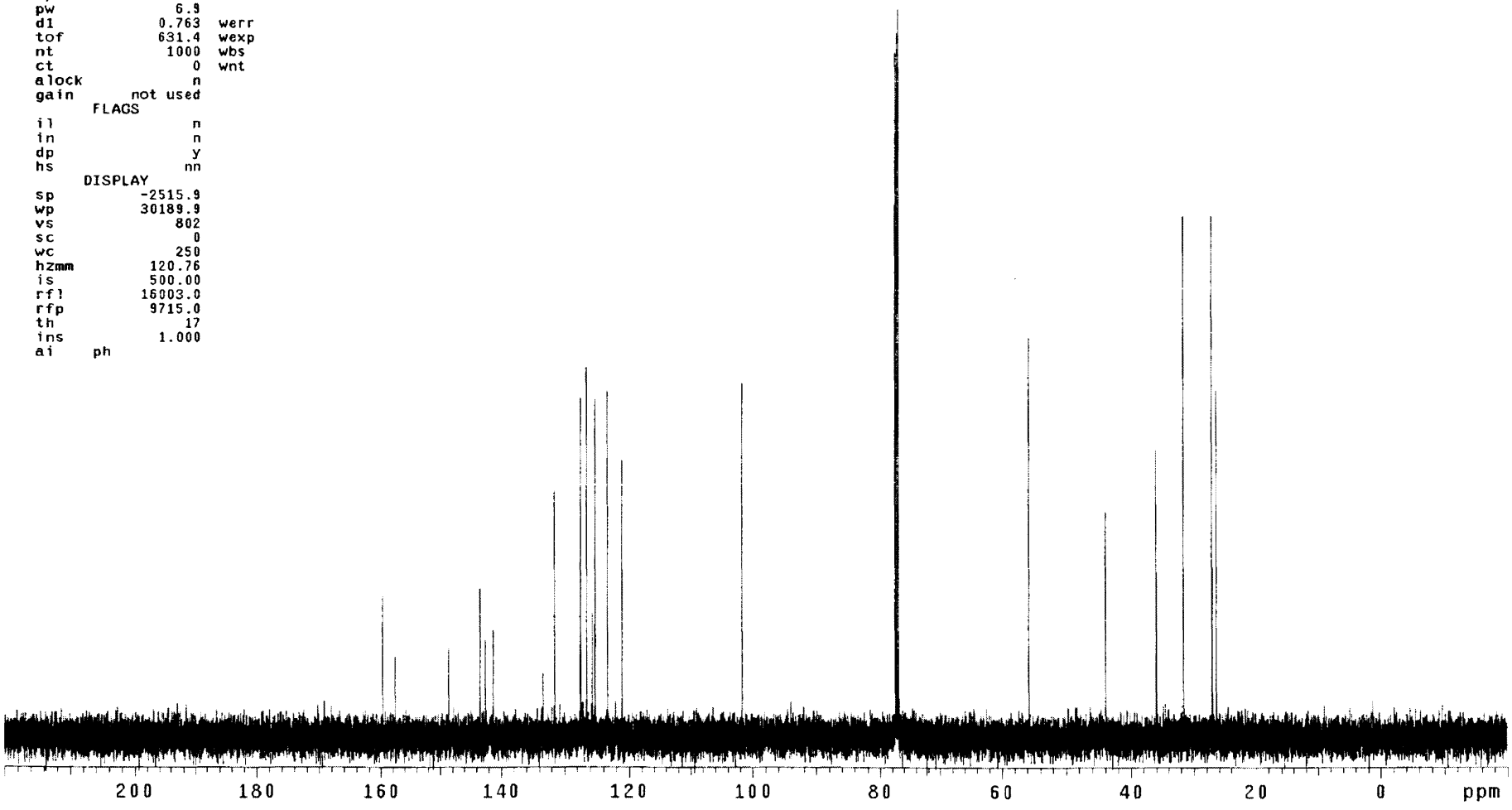


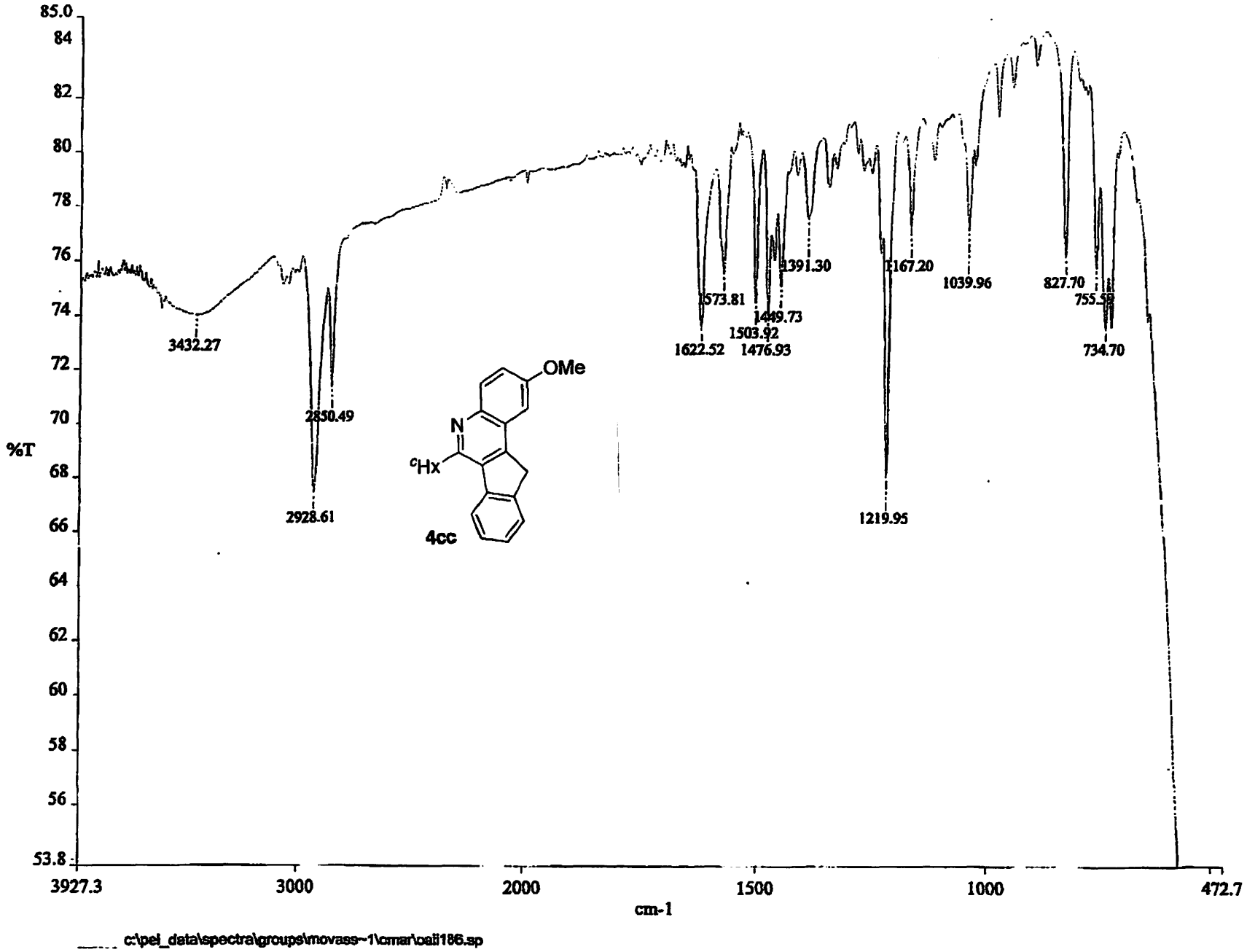
SAMPLE		DEC. & VT	
date	May 1 2007	dfrq	125.672
solvent	CDCl3	dn	C13
file	/data/export/~	dpwr	30
	home/movassag/MVoa~	dof	0
	hm/bullwinkle/OA-I~	dm	nnn
	I-99clean.fid	dmm	w
ACQUISITION		dmf	10000
sfrq	499.746	dseq	
tn	H1	dres	1.0
at	3.001	homo	n
np	63050	PROCESSING	
sw	10504.2	wtfile	
fb	not used	proc	ft
bs	2	fn	262144
tpwr	56	math	f
pw	8.6		
d1	2.000	werr	
tof	1519.5	wexp	
nt	32	wbs	
ct	14	wnt	wft
alock	n		
gain	not used		
FLAGS			
il	n		
in	n		
dp	y		
hs	nn		
DISPLAY			
sp	-249.9		
wp	6246.7		
vs	34		
sc	0		
wc	250		
hzmm	24.99		
is	33.57		
rfl	4865.5		
rfp	3633.1		
th	7		
ins	3.000		
ai cdc ph			





SAMPLE		DEC. & VT	
date	Feb 7 2007	dfrq	500.233
solvent	CDCl3	dn	H1
file	/data/export/~	dpwr	38
home/movassag/MVoa~		dof	-500.0
hm/rocky/OA-II-99g~		dm	y
	carbon.fid	dmm	w
ACQUISITION		dmf	10000
sfrq	125.796	dseq	
tn	C13	dres	1.0
at	1.736	homo	n
np	131010	PROCESSING	
sw	37735.8	lb	0.30
fb	not used	wtfile	
bs	8	proc	ft
ss	1	fn	131072
tpwr	53	math	f
pw	6.9		
d1	0.763	werr	
tof	631.4	wexp	
nt	1000	wbs	
ct	0	wnt	
alock	n		
gain	not used		
FLAGS			
il	n		
in	n		
dp	y		
hs	nn		
DISPLAY			
sp	-2515.9		
wp	30189.9		
vs	802		
sc	0		
wc	250		
hzmm	120.76		
is	500.00		
rfl	16003.0		
rfp	9715.0		
th	17		
ins	1.000		
ai	ph		

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53.8
%T
3927.3
3000
2000
1500
1000
472.7
cm-1
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2928.61
2850.49
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1573.81
1503.92
1476.93
1449.73
1391.30
1219.95
1167.20
1039.96
827.70
755.59
734.70
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cHx
4cc
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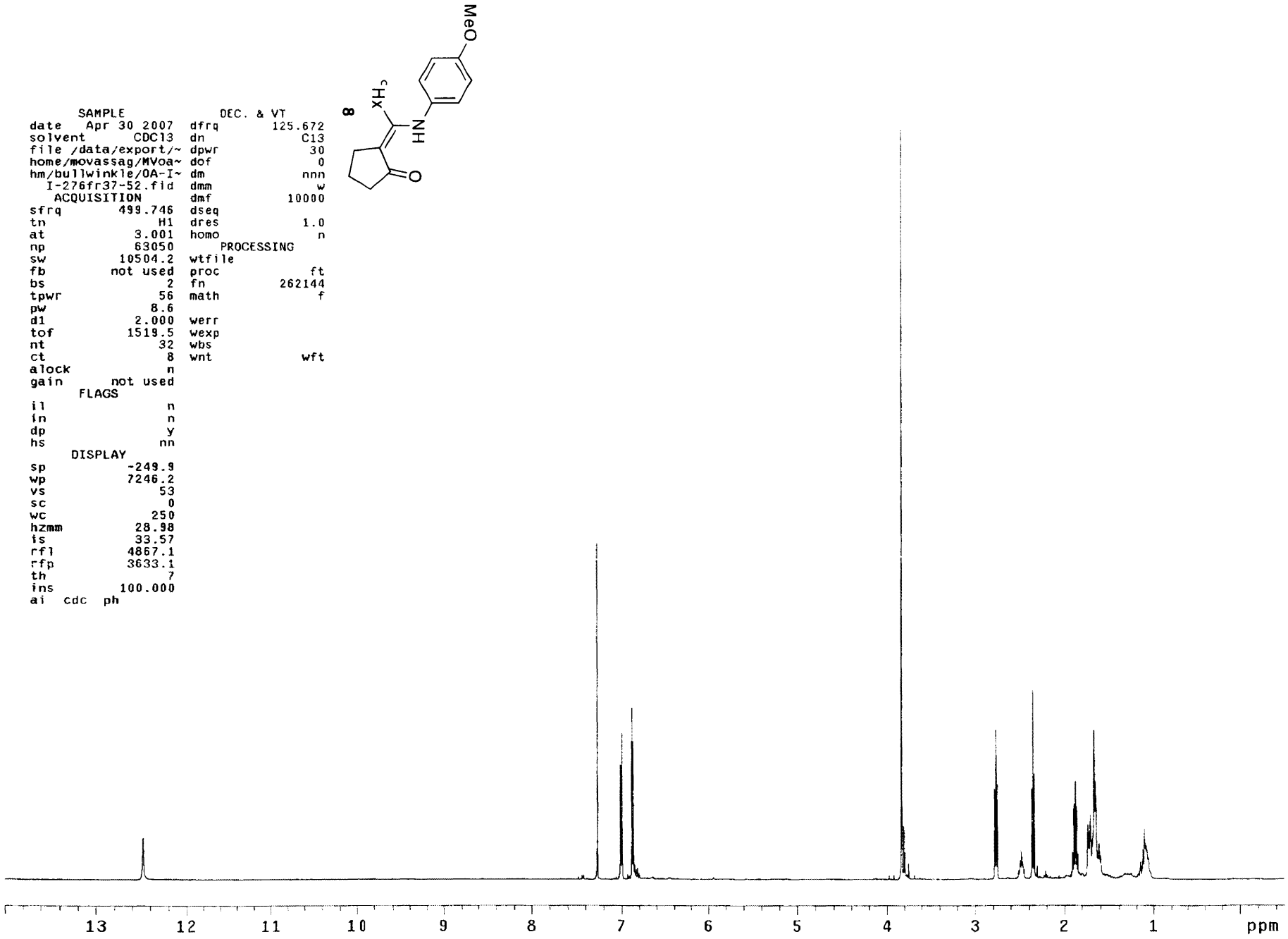
MeO
NH
O
8
SAMPLE
date Apr 30 2007
solvent CDCl3
file /data/export/~
home/movassag/MVoa~
hm/bullwinkle/OA-I~
I-276fr37-52.fid
ACQUISITION
sfrq 499.746
tn H1
at 3.001
np 63050
sw 10504.2
fb not used
bs 2
tpwr 56
pw 8.6
d1 2.000
tof 1519.5
nt 32
ct 8
alock n
gain not used
FLAGS
il n
in n
dp y
hs nn
DISPLAY
sp -249.9
wp 7246.2
vs 53
sc 0
wc 250
hzmm 28.98
is 33.57
rfl 4867.1
rfp 3633.1
th 7
ins 100.000
ai cdc ph
DEC. & VT
dfrq 125.672
dn C13
dpwr 30
dof 0
dm nnn
dmm w
dmf 10000
dseq
dres 1.0
homo n
PROCESSING
wtfile
proc ft
fn 262144
math f
werr
wexp
wbs
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11
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9
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4
3
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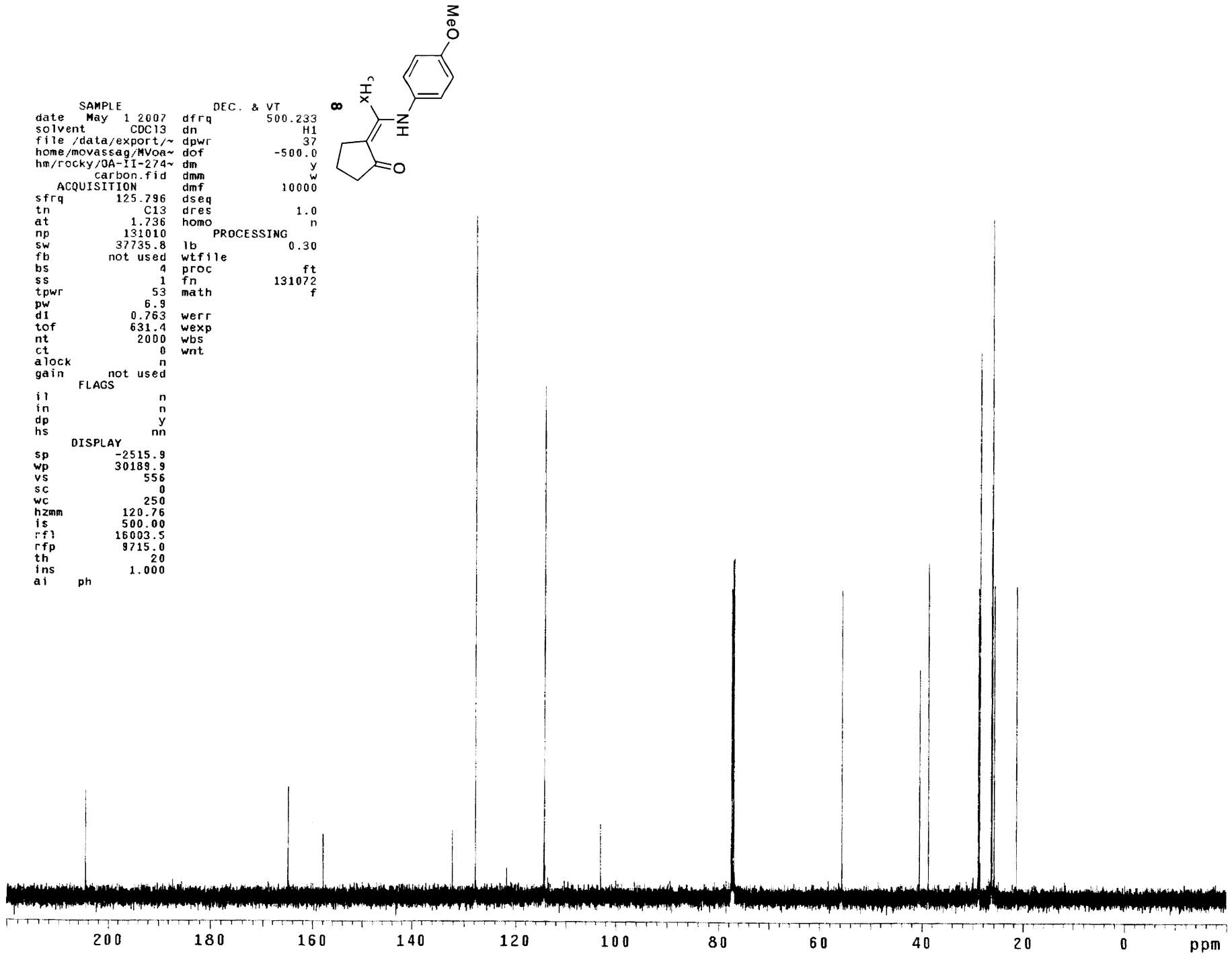
1
ppm


MeO
HN
O
8
SAMPLE
date May 1 2007
solvent CDCl3
file /data/export/~
home/movassag/MVoa~
hm/rocky/OA-II-274~
carbon.fid
ACQUISITION
sfrq 125.796
tn C13
at 1.736
np 131010
sw 37735.8
fb not used
bs 4
ss 1
tpwr 53
pw 6.9
d1 0.763
tof 631.4
nt 2000
ct 0
alock n
gain not used
FLAGS
il n
in n
dp y
hs nn
DISPLAY
sp -2515.9
wp 30189.9
vs 556
sc 0
wc 250
hzmm 120.76
is 500.00
rfl 16003.5
rfp 9715.0
th 20
ins 1.000
ai ph
DEC. & VT
dfrq 500.233
dn H1
dpwr 37
dof -500.0
dm y
dmm w
dmf 10000
dseq
dres 1.0
homo n
PROCESSING
lb 0.30
wtfile
proc ft
fn 131072
math f
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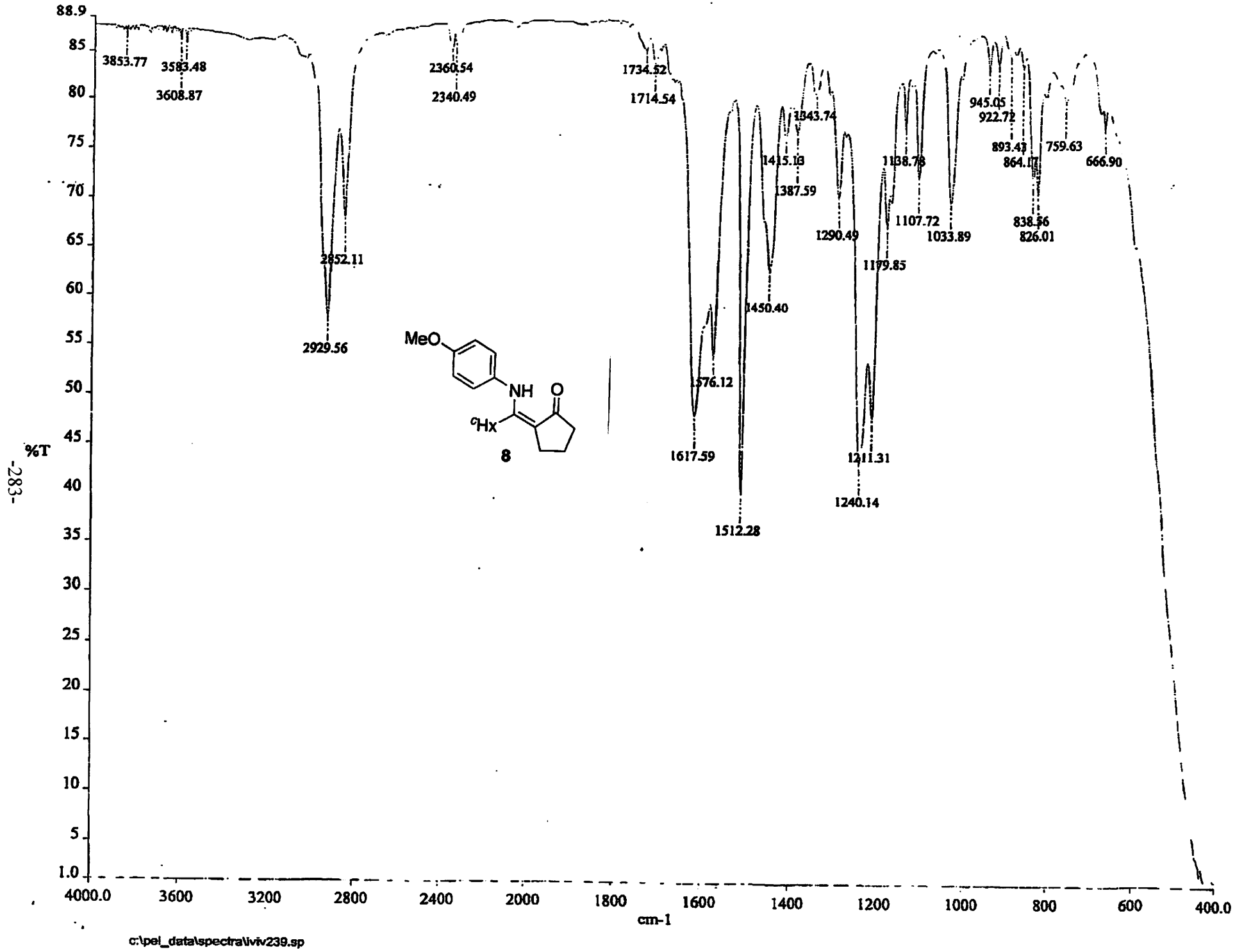
wexp
wbs
wnt
200
180
160
140
120
100
80
60
40
20
0
ppm


88.9
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80
75
70
65
60
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50
45
40
35
30
25
20
15
10
5
1.0
%T
3853.77
3583.48
3608.87
2360.54
2340.49
1734.52
1714.54
2852.11
2929.56
1343.74
1415.13
1387.59
1138.78
1107.72
1033.89
945.05
922.72
893.43
864.17
759.63
666.90
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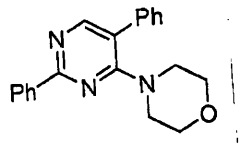
826.01
1290.49
1179.85
1450.40
1576.12
1617.59
1512.28
1211.31
1240.14
MeO
NH
O
cHx
8
4000.0
3600
3200
2800
2400
2000
1800
1600
1400
1200
1000
800
600
400.0
cm-1
c:\pel_data\spectra\iviv239.sp

Appendix D

Spectra for Chapter IV

solvent	CDCl3
file	exp
ACQUISITION	
sfrq	500.435
tn	H1
at	4.999
np	120102
sw	12012.0
fb	not used
bs	4
tpwr	56
pw	8.0
d1	0.100
tof	3003.2
nt	128
ct	20
alock	n
gain	not used
FLAGS	
il	n
in	n
dp	y
hs	nn
DISPLAY	
sp	-500.3
wp	6503.1
vs	18
sc	0
wc	250
hzmm	26.01
is	33.57
rfl	516.2
rfp	0
th	5
ins	2.000
ai cdc ph	

DEC. & VT	
dfrq	125.845
dn	C13
dpwr	30
dof	0
dm	nnn
dmm	c
dmf	200
dseq	
dres	1.0
homo	n
DEC2	
dfrq2	0
dn2	
dpwr2	1
dof2	0
dm2	n
dmm2	c
dmf2	200
dseq2	
dres2	1.0
homo2	n
DEC3	
dfrq3	0
dn3	
dpwr3	1
dof3	0
dm3	n
dmm3	c
dmf3	200
dseq3	
dres3	1.0
homo3	n
PROCESSING	
wtfile	
proc	ft
fn	262144
math	f
werr	
wexp	
wbs	
wnt	wft



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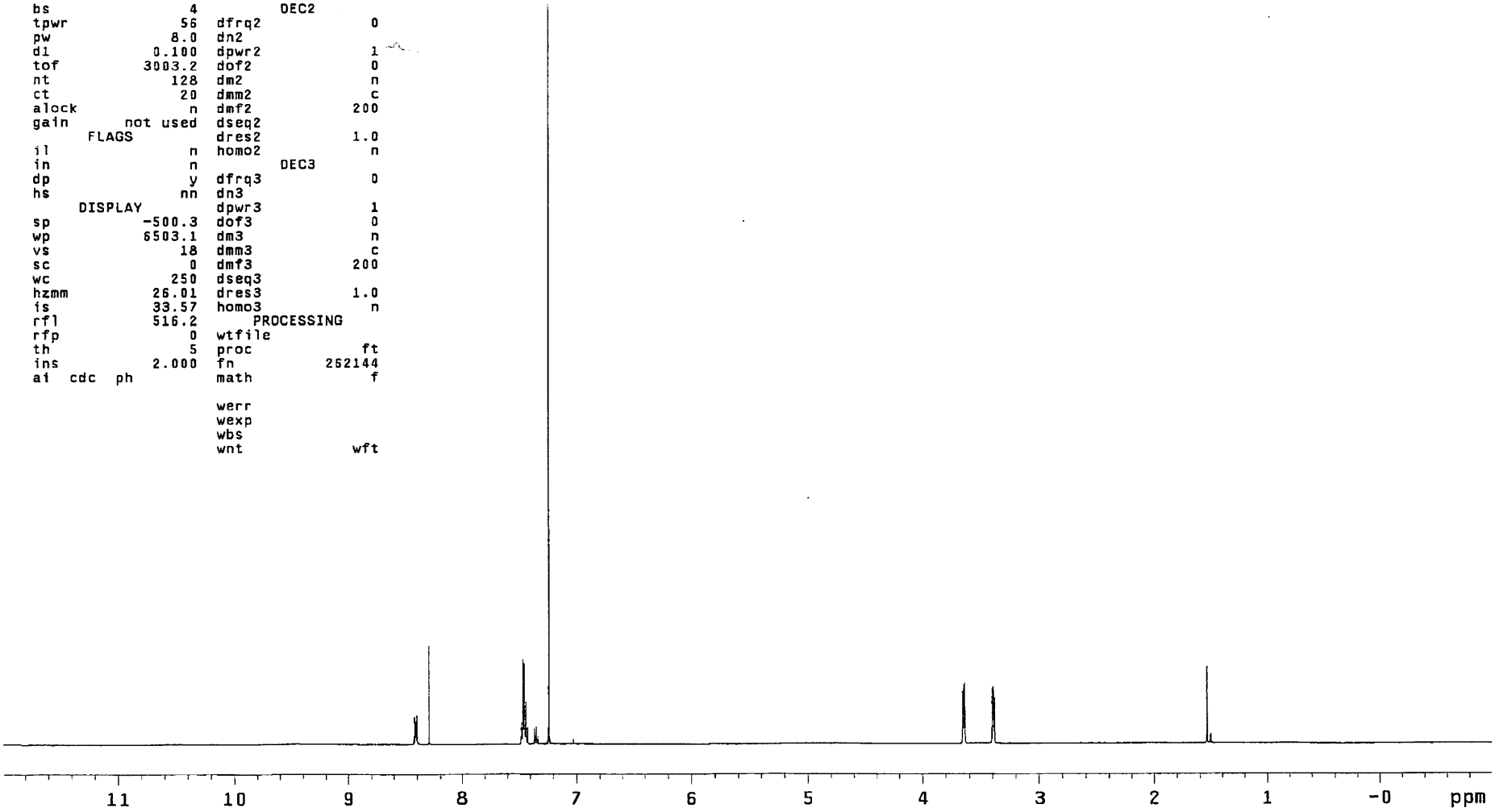
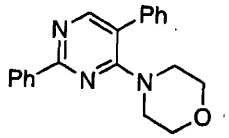


solvent	CDCl3
file	exp
ACQUISITION	
sfrq	125.795
tn	C13
at	1.736
np	131010
sw	37735.8
fb	not used
bs	8
ss	1
tpwr	53
pw	6.9
d1	0.763
tof	631.4
nt	8000
ct	344
alock	n
gain	not used
FLAGS	
il	n
in	n
dp	y
hs	nn
DISPLAY	
sp	-2522.8
wp	30198.5
vs	198
sc	0
wc	250
hzmm	120.79
is	500.00
rf1	16005.9
rfp	9714.9
th	15
ins	1.000
ai	ph

DEC. & VT	
dfrq	500.229
dn	H1
dpwr	38
dof	-500.0
dm	y
dmm	w
dmf	10000
dseq	
dres	1.0
homo	n
PROCESSING	
lb	0.30
wtfile	
proc	ft
fn	131072
math	f
werr	
wexp	
wbs	
wnt	



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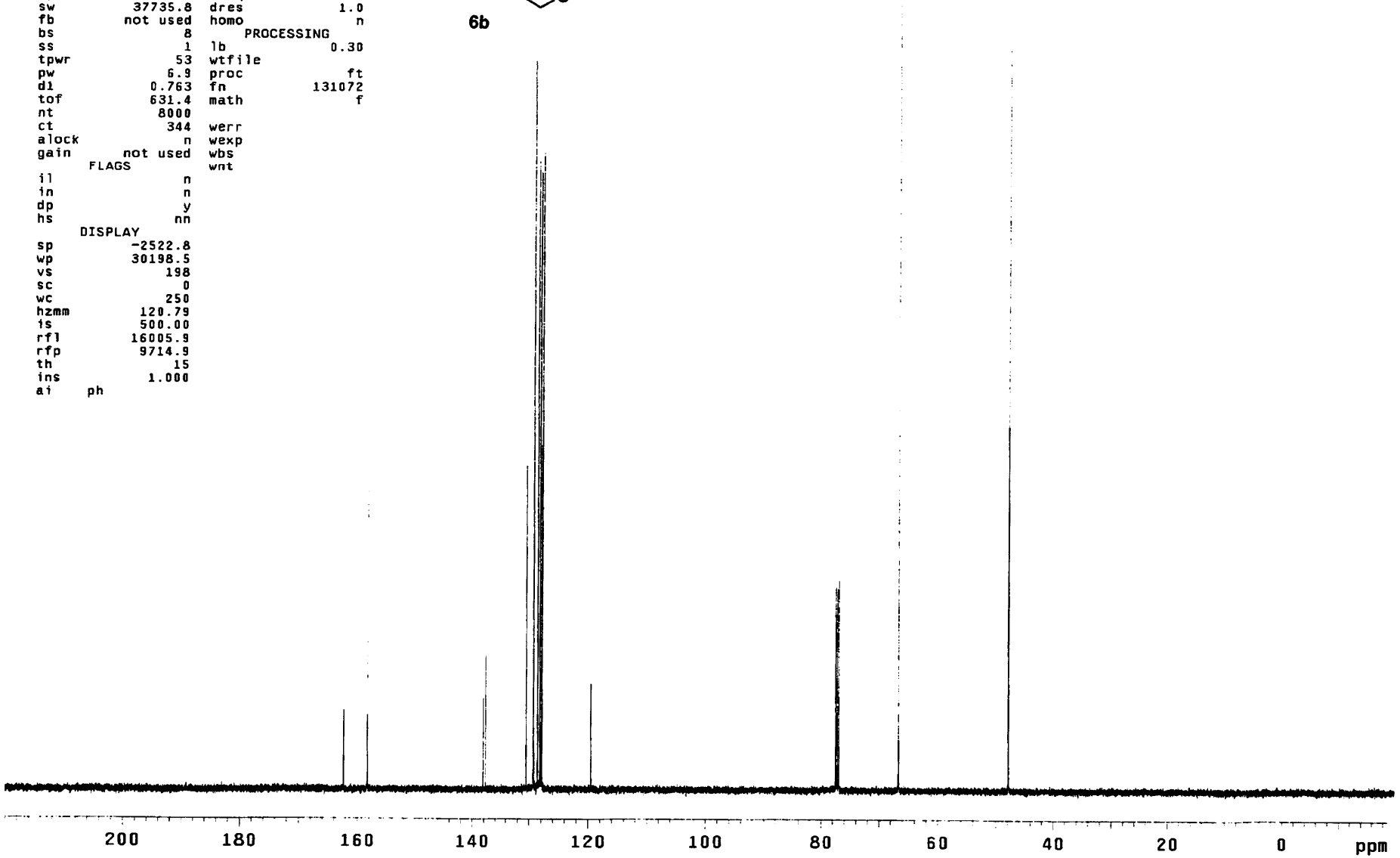
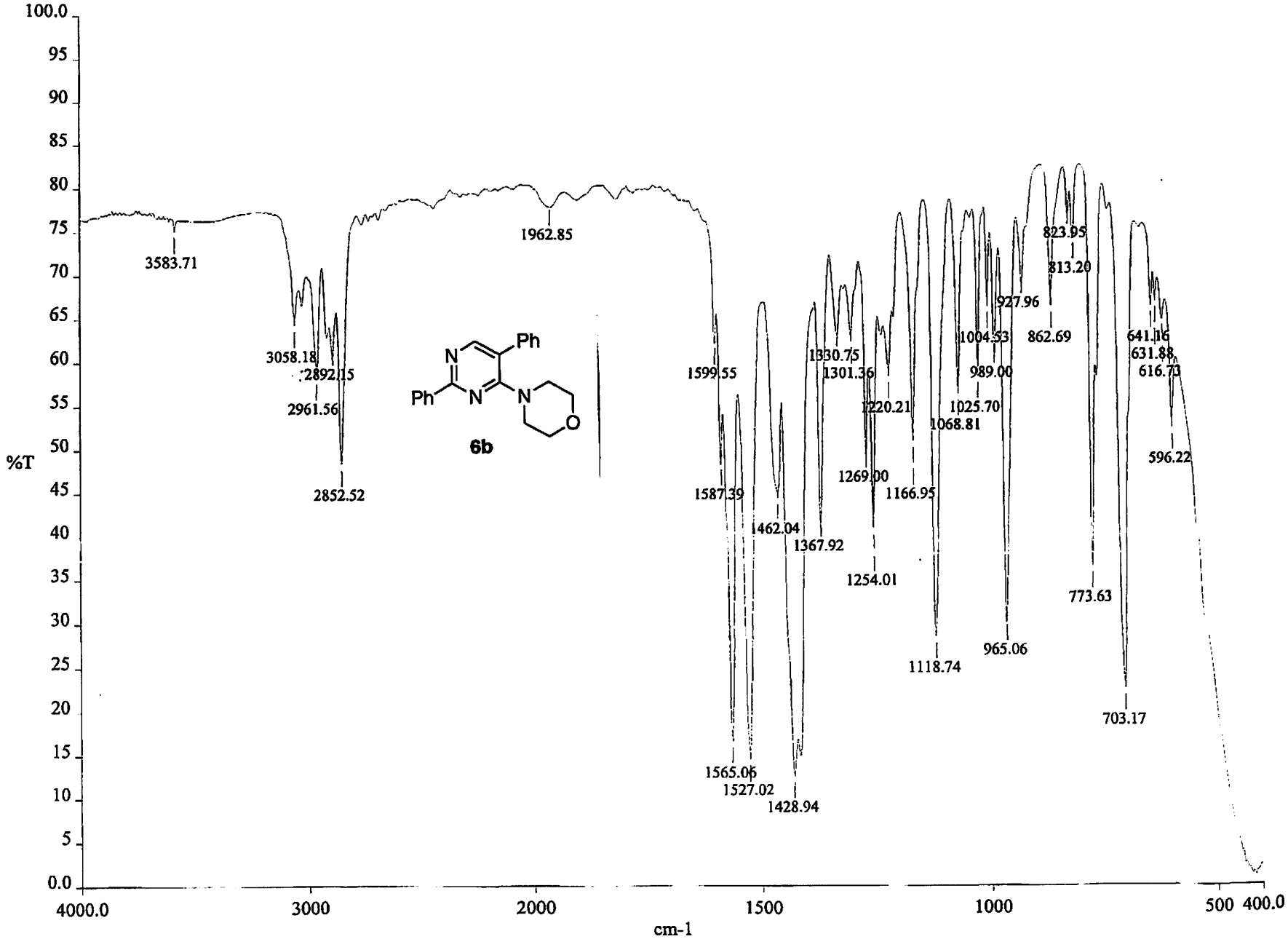
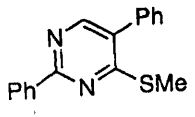



100.0
95
90
85
80
75
70
65
60
55
50
45
40
35
30
25
20
15
10
5
0.0
%T
4000.0
3000
2000
1500
1000
500
400.0
cm-1
3583.71
3058.18
2892.15
2961.56
2852.52
1962.85
1599.55
1587.39
1565.06
1527.02
1462.04
1428.94
1367.92
1330.75
1301.36
1269.00
1254.01
1220.21
1166.95
1118.74
1068.81
1025.70
1004.53
989.00
965.06
927.96
862.69
823.95
813.20
773.63
703.17
641.16
631.88
616.73
596.22
Ph
N
Ph
N
N
O
6b

exp1 s2pul

		DEC. & VT	
solvent	CDCl3	dfrq	125.845
		dn	C13
		dpwr	30
		dof	0
		dm	nnn
		dmm	c
ACQUISITION		dmf	200
sfrq	500.435	dseq	
tn	H1	dres	1.0
at	4.999	homo	n
np	120102	PROCESSING	
sw	12012.0	wtfile	
fb	not used	proc	ft
bs	4	fn	262144
tpwr	56	math	f
pw	8.0		
d1	0.100	werr	
tof	3003.2	wexp	
nt	128	wbs	
ct	24	wnt	wft
alock	n		
gain	not used		
FLAGS			
il	n		
in	n		
dp	y		
hs	nn		
DISPLAY			
sp	-250.2		
wp	6255.3		
vs	17		
sc	0		
wc	250		
hzmm	25.02		
is	33.57		
rfl	4139.1		
rfp	3623.1		
th	3		
ins	3.000		

ai cdc ph



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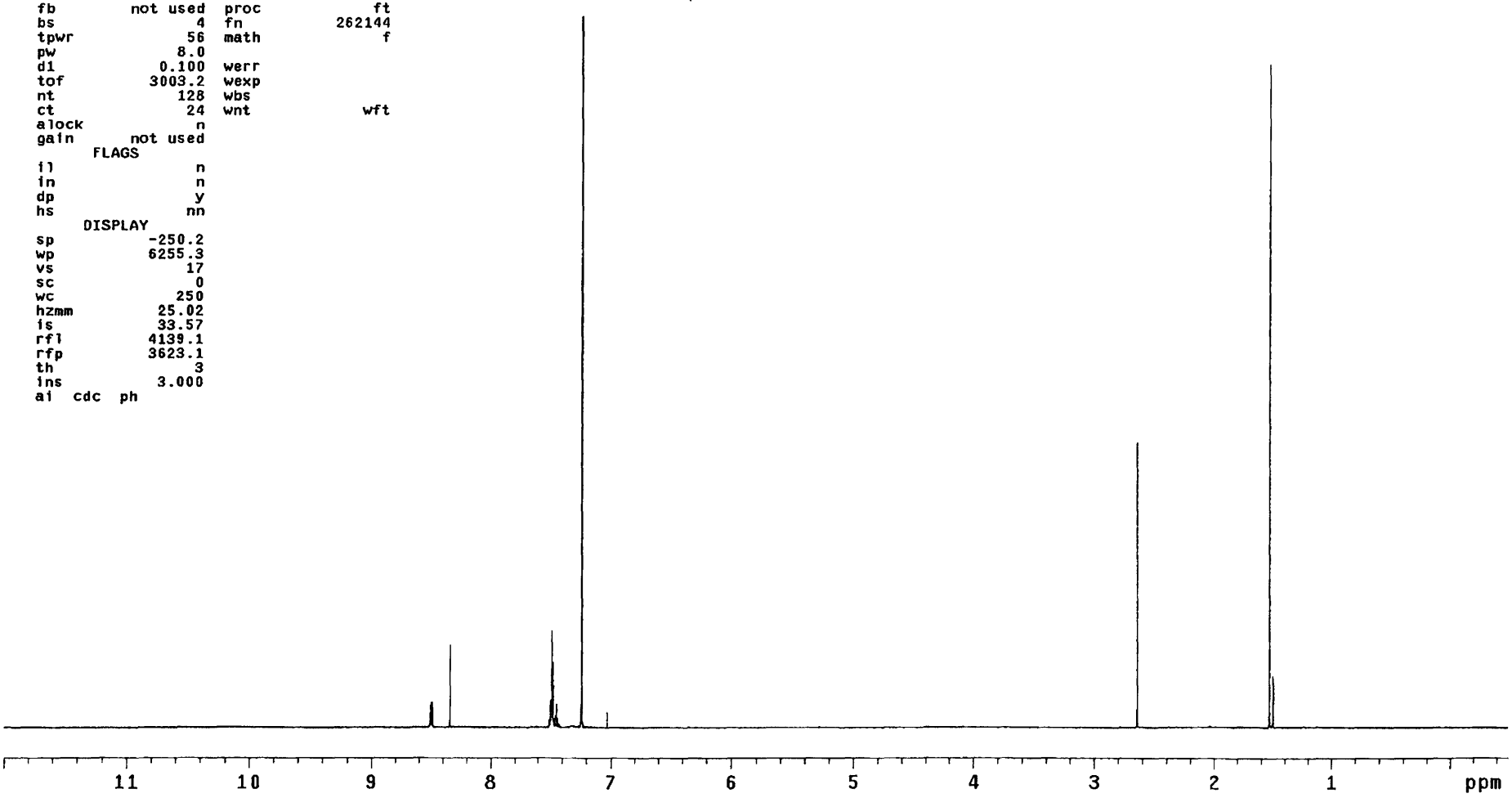
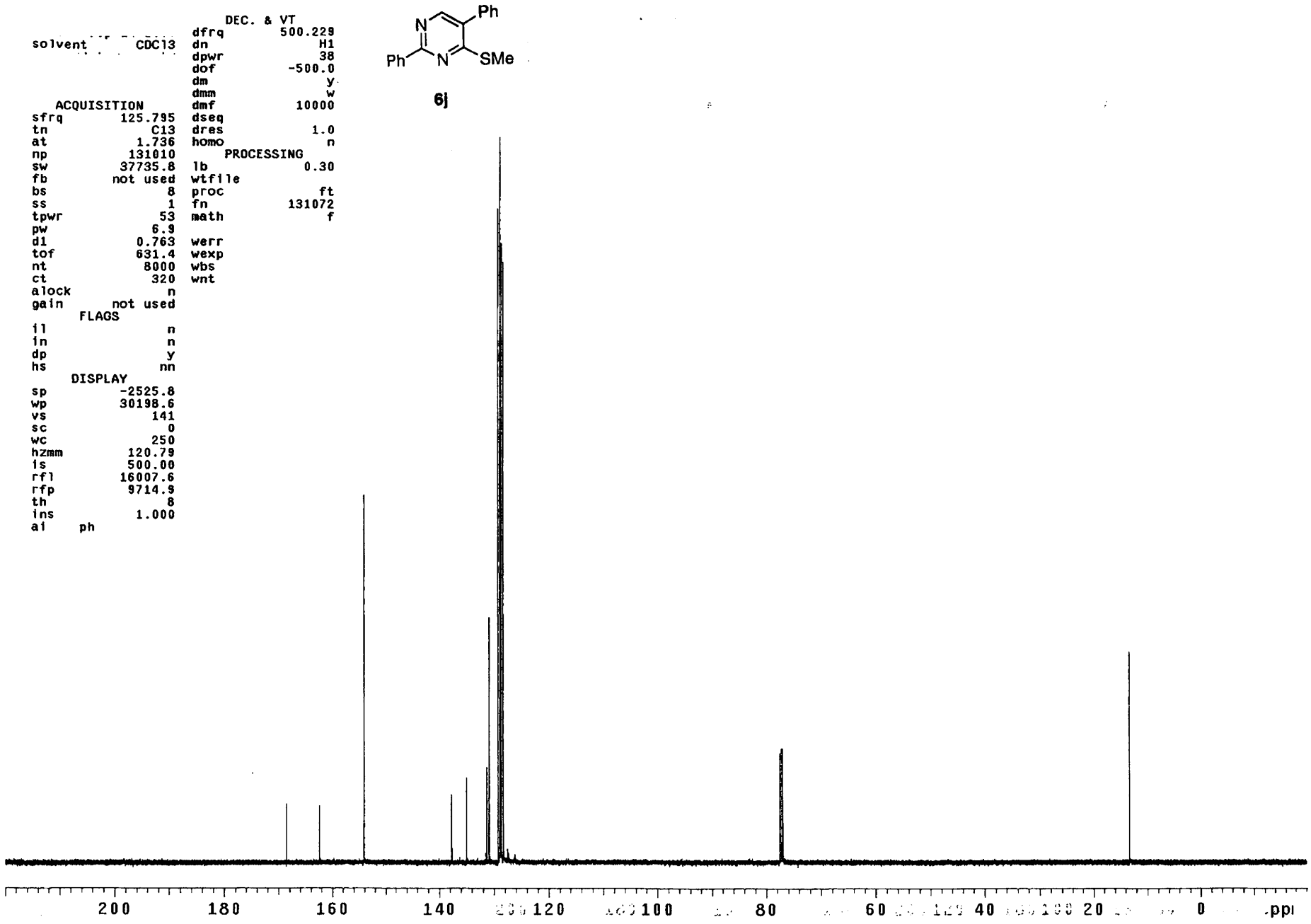
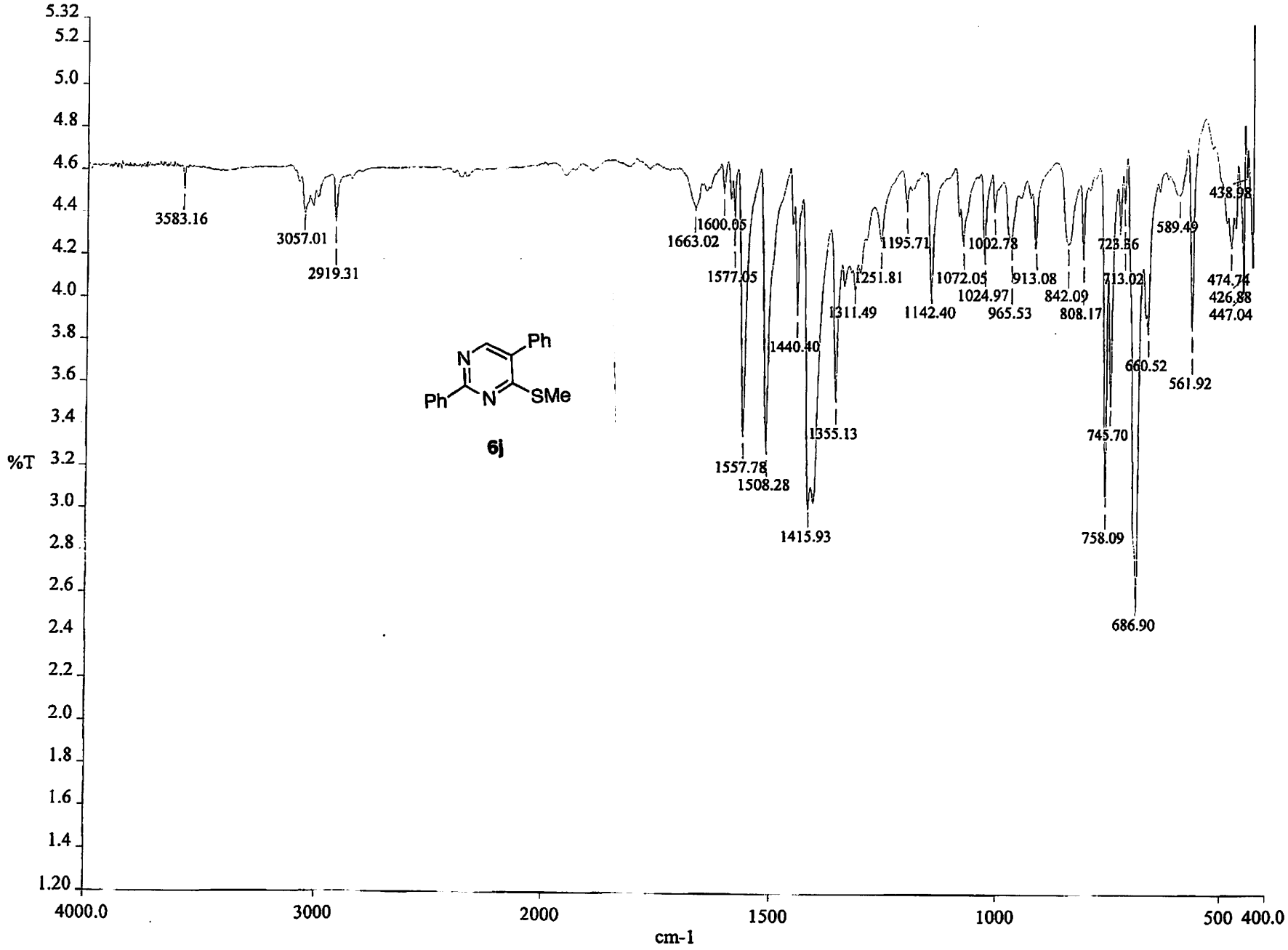
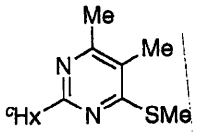


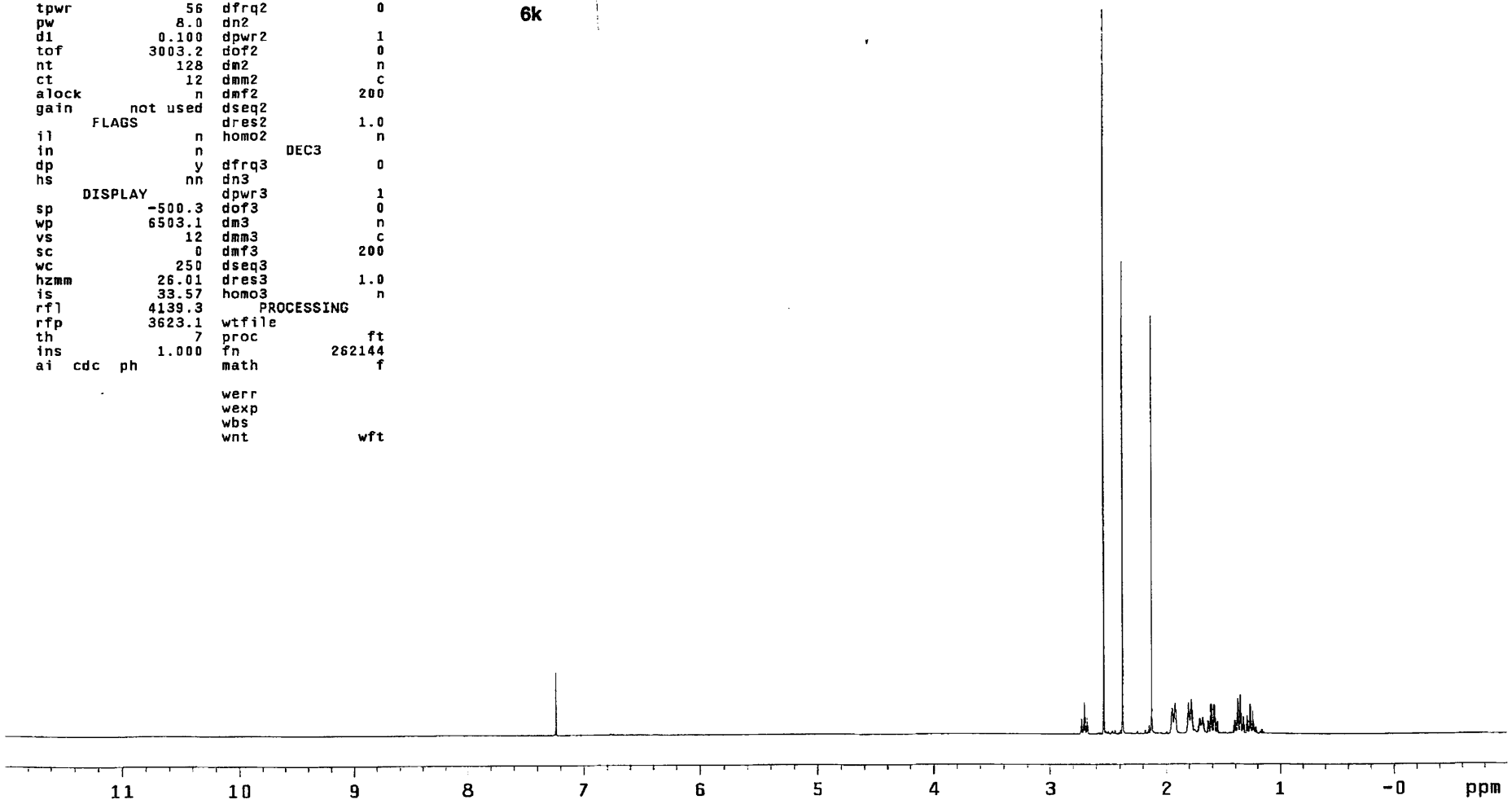

solvent CDCl3
ACQUISITION
sfrq 125.795
tn C13
at 1.736
np 131010
sw 37735.8
fb not used
bs 8
ss 1
tpwr 53
pw 6.9
d1 0.763
tof 631.4
nt 8000
ct 320
alock n
gain not used
FLAGS
il n
in n
dp y
hs nn
DISPLAY
sp -2525.8
wp 30198.6
vs 141
sc 0
wc 250
hzmm 120.79
is 500.00
rfl 16007.6
rfp 9714.9
th 8
ins 1.000
ai ph
DEC. & VT
dfrq 500.229
dn H1
dpwr 38
dof -500.0
dm y
dmm w
dmf 10000
dseq
dres 1.0
homo n
PROCESSING
lb 0.30
wtfile
proc ft
fn 131072
math f
werr
wexp
wbs
wnt
Ph
N
Ph
N
SMe
6j
200
180
160
140
120
100
80
60
40
20
0
ppm


5.32
5.2
5.0
4.8
4.6
4.4
4.2
4.0
3.8
3.6
3.4
3.2
3.0
2.8
2.6
2.4
2.2
2.0
1.8
1.6
1.4
1.20
%T
4000.0
3000
2000
1500
1000
500 400.0
cm-1
3583.16
3057.01
2919.31
1663.02
1600.05
1577.05
1557.78
1508.28
1440.40
1415.93
1355.13
1311.49
1251.81
1195.71
1142.40
1072.05
1024.97
1002.78
965.53
913.08
842.09
808.17
758.09
745.70
723.56
713.02
686.90
660.52
589.49
561.92
474.74
447.04
438.98
426.88
Ph
N
Ph
N
SMe
6j

		DEC. & VT	
		dfrq	125.845
solvent	CDCl3	dn	C13
file	exp	dpwr	30
ACQUISITION		dof	0
sfrq	500.435	dm	nnn
tn	H1	dmm	c
at	4.999	dmf	200
np	120102	dseq	
sw	12012.0	dres	1.0
fb	not used	homo	n
bs	4	DEC2	
tpwr	56	dfrq2	0
pw	8.0	dn2	
d1	0.100	dpwr2	1
tof	3003.2	dof2	0
nt	128	dm2	n
ct	12	dmm2	c
alock	n	dmf2	200
gain	not used	dseq2	
FLAGS		dres2	1.0
il	n	homo2	n
in	n	DEC3	
dp	y	dfrq3	0
hs	nn	dn3	
DISPLAY		dpwr3	1
sp	-500.3	dof3	0
wp	6503.1	dm3	n
vs	12	dmm3	c
sc	0	dmf3	200
wc	250	dseq3	
hzmm	26.01	dres3	1.0
is	33.57	homo3	n
rfl	4139.3	PROCESSING	
rfp	3623.1	wtfile	
th	7	proc	ft
ins	1.000	fn	262144
ai cdc ph		math	f
		werr	
		wexp	
		wbs	
		wnt	wft

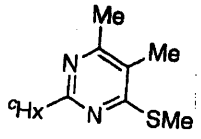


6k



solvent	CDCl3
ACQUISITION	
sfrq	125.795
tn	C13
at	1.736
np	131010
sw	37735.8
fb	not used
bs	8
ss	1
tpwr	53
pw	6.9
d1	0.763
tof	631.4
nt	8000
ct	664
alock	n
gain	not used
FLAGS	
il	n
in	n
dp	y
hs	nn
DISPLAY	
sp	-2470.5
wp	30148.5
vs	161
sc	0
wc	250
hzmm	120.59
is	500.00
rfl	16003.0
rfp	9714.9
th	4
ins	1.000
ai	ph

DEC. & VT	
dfrq	500.229
dn	H1
dpwr	38
dof	-500.0
dm	y
dmm	w
dmf	10000
dseq	
dres	1.0
homo	n
PROCESSING	
lb	0.30
wtfile	
proc	ft
fn	131072
math	f
werr	
wexp	
wbs	
wnt	



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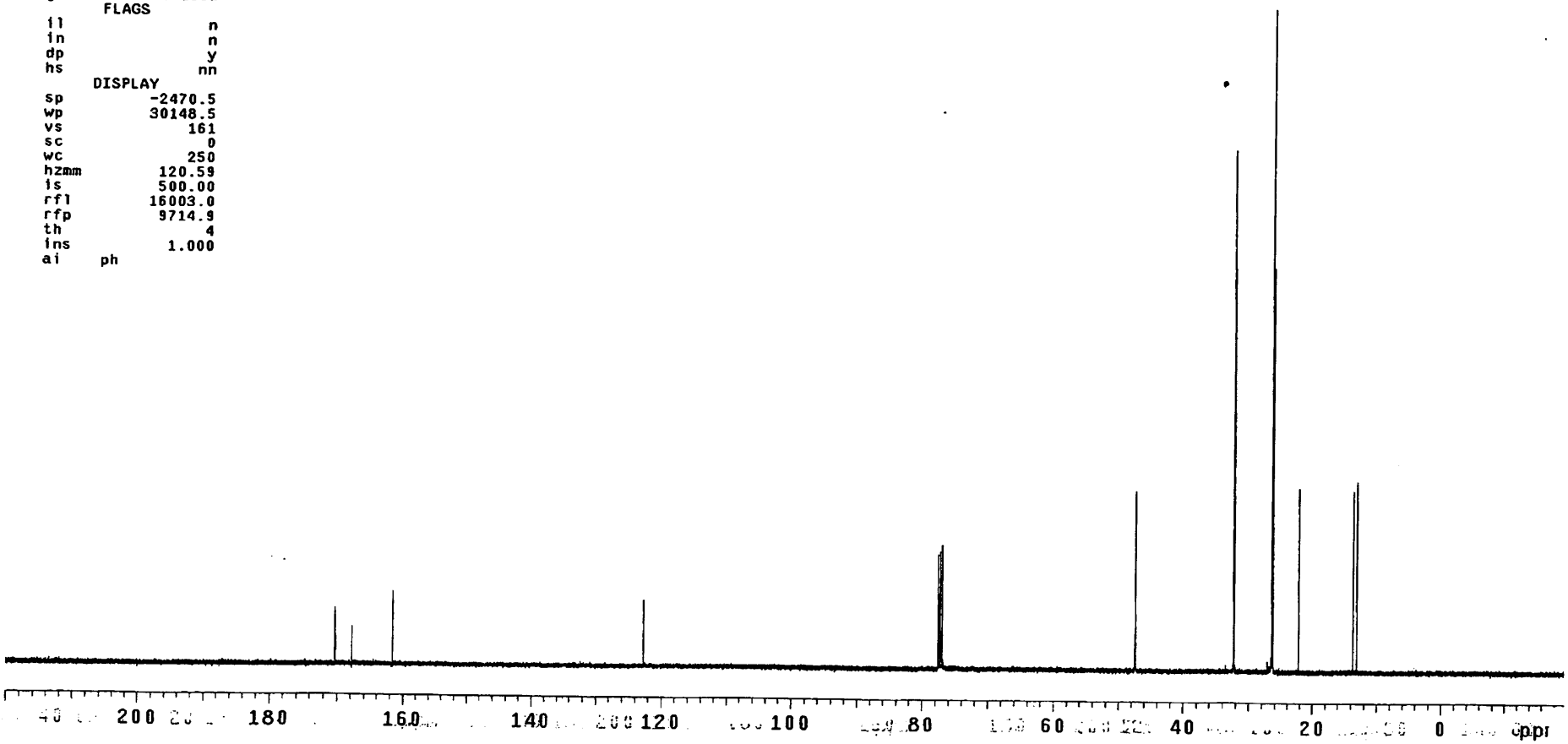

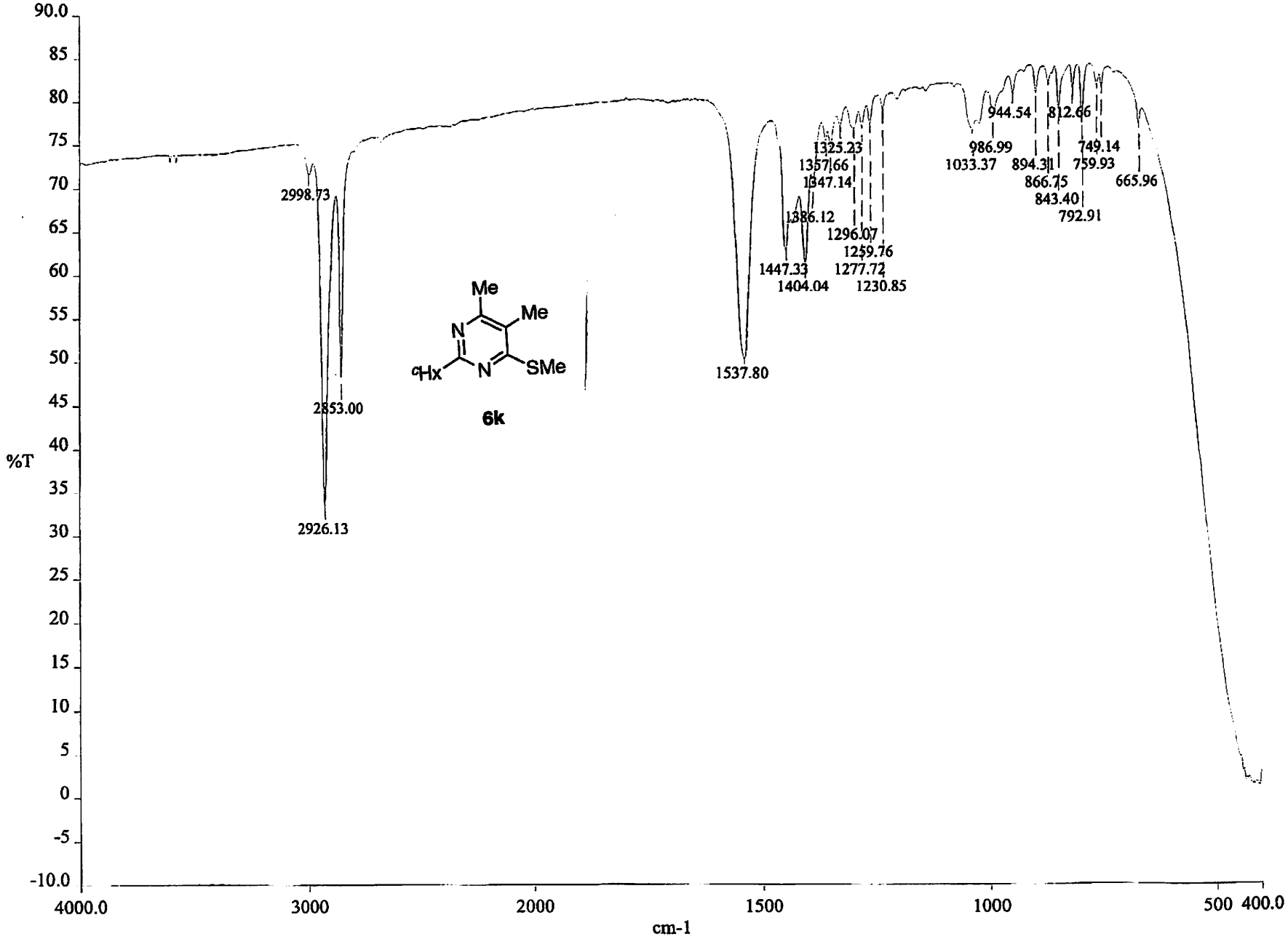
90.0
85
80
75
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65
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55
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45
40
35
30
25
20
15
10
5
0
-5
-10.0
%T
4000.0
3000
2000
1500
1000
500
400.0
cm-1
2998.73
2926.13
2853.00
1537.80
1447.33
1404.04
1386.12
1357.66
1347.14
1325.23
1296.07
1259.76
1277.72
1230.85
1033.37
986.99
944.54
894.31
866.75
843.40
812.66
792.91
759.93
749.14
665.96
Me
Me
N
N
cHx
SMe
6k

date	
solvent	CDCl3

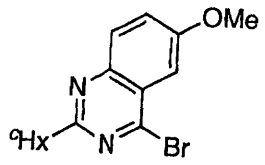
ACQUISITION	
sfrq	499.746
tn	H1
at	3.001
np	63050
sw	10504.2
fb	not used
bs	2
tpwr	56
pw	8.6
d1	2.000
tof	1519.5
nt	32
ct	10
alock	n
gain	not used

FLAGS	
il	n
in	n
dp	y
hs	nn

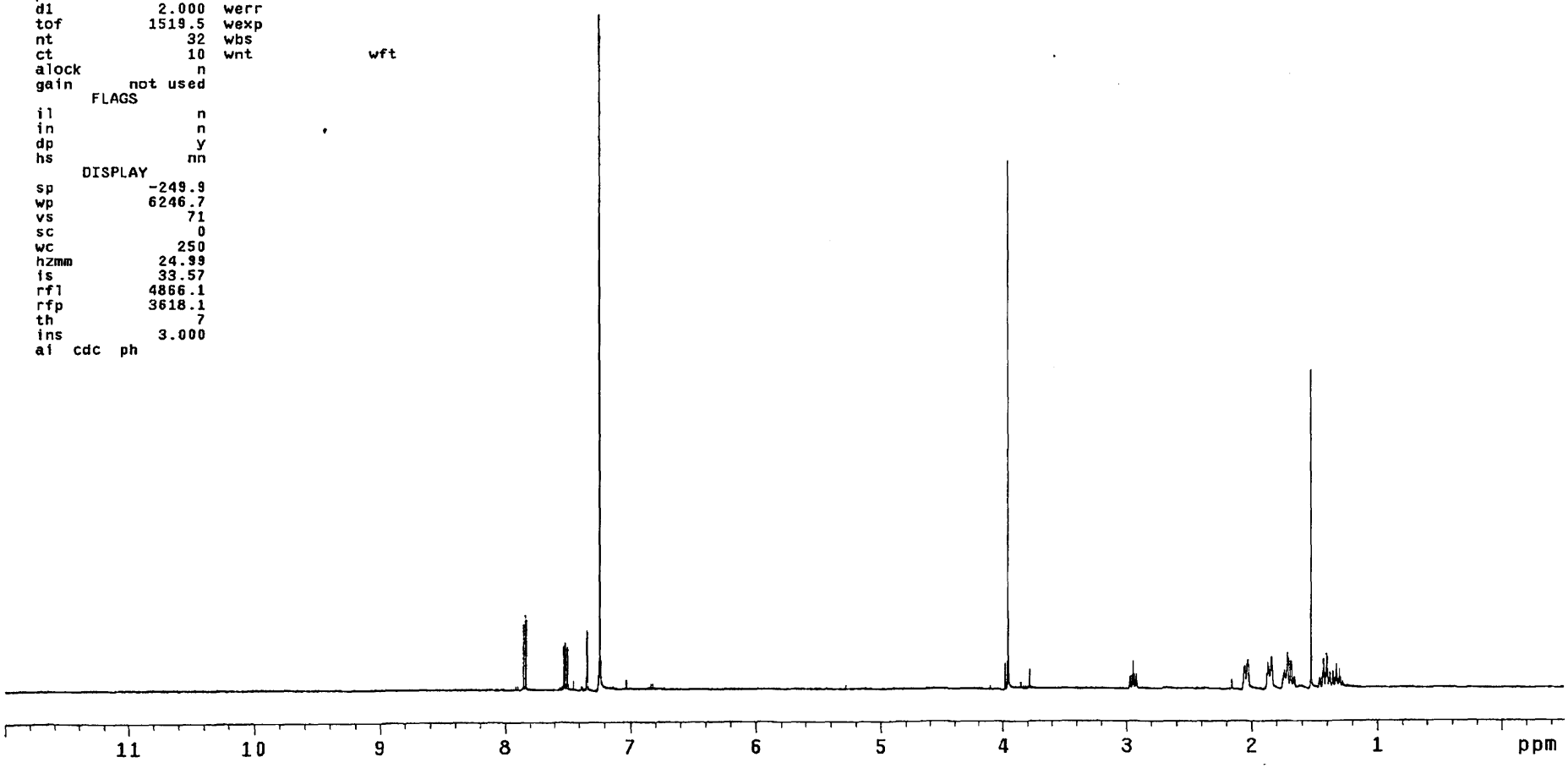
DISPLAY	
sp	-249.9
wp	6246.7
vs	71
sc	0
wc	250
hzmm	24.99
is	33.57
rfl	4866.1
rfp	3618.1
th	7
ins	3.000
ai cdc ph	

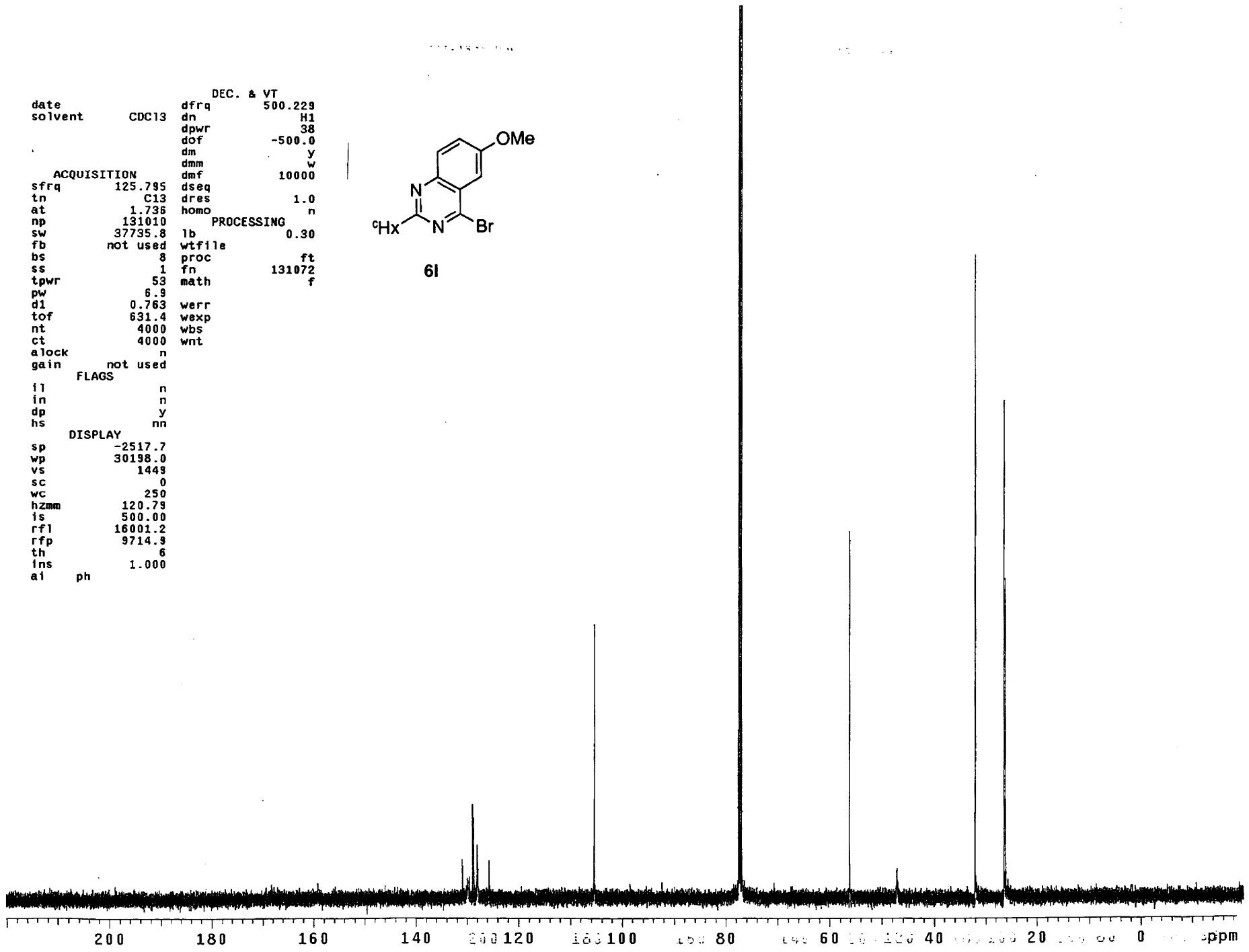
DEC. & VT	
dfrq	125.672
dn	C13
dpwr	30
dof	0
dm	nnn
dmm	w
dmf	10000
dseq	
dres	1.0
homo	n

PROCESSING	
wtfile	
proc	ft
fn	262144
math	f
werr	
wexp	
wbs	
wnt	wft



6l




date
solvent CDCl3
ACQUISITION
sfrq 125.795
tn C13
at 1.736
np 131010
sw 37735.8
fb not used
bs 8
ss 1
tpwr 53
pw 6.9
d1 0.763
tof 631.4
nt 4000
ct 4000
alock n
gain not used
FLAGS
il n
in n
dp y
hs nn
DISPLAY
sp -2517.7
wp 30198.0
vs 1449
sc 0
wc 250
hzmm 120.79
is 500.00
rfl 16001.2
rfp 9714.9
th 6
ins 1.000
ai ph
DEC. & VT
dfrq 500.229
dn H1
dpwr 38
dof -500.0
dm y
dmm w
dmf 10000
dseq
dres 1.0
homo n
PROCESSING
lb 0.30
wtfile
proc ft
fn 131072
math f
werr
wexp
wbs
wnt
OMe
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cHx
N
Br
6l
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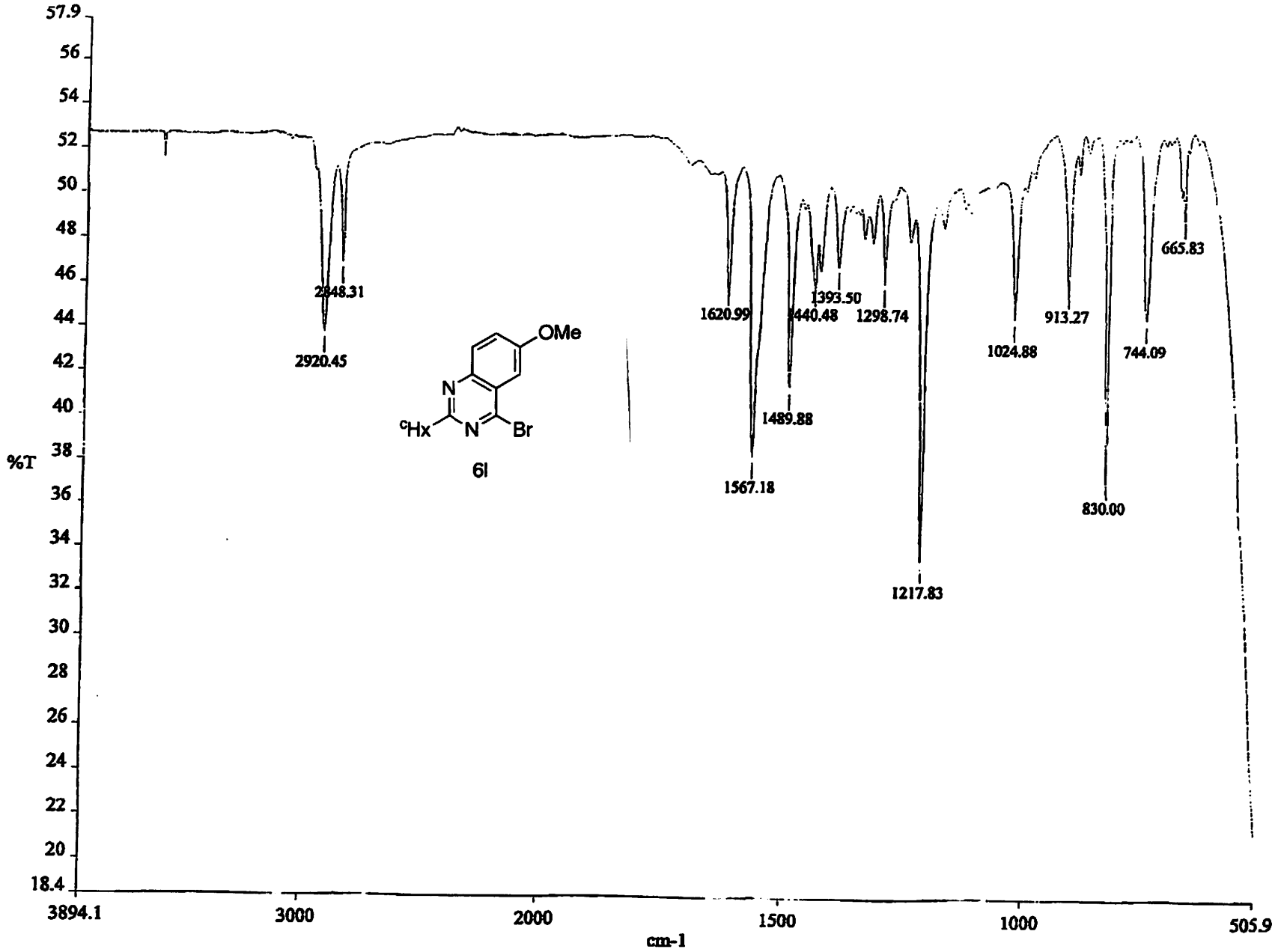
180
160
140
120
100
80
60
40
20
0
ppm


%T
cm-1
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3000
2000
1500
1000
505.9
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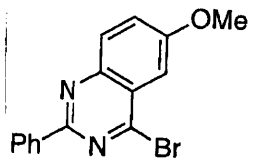
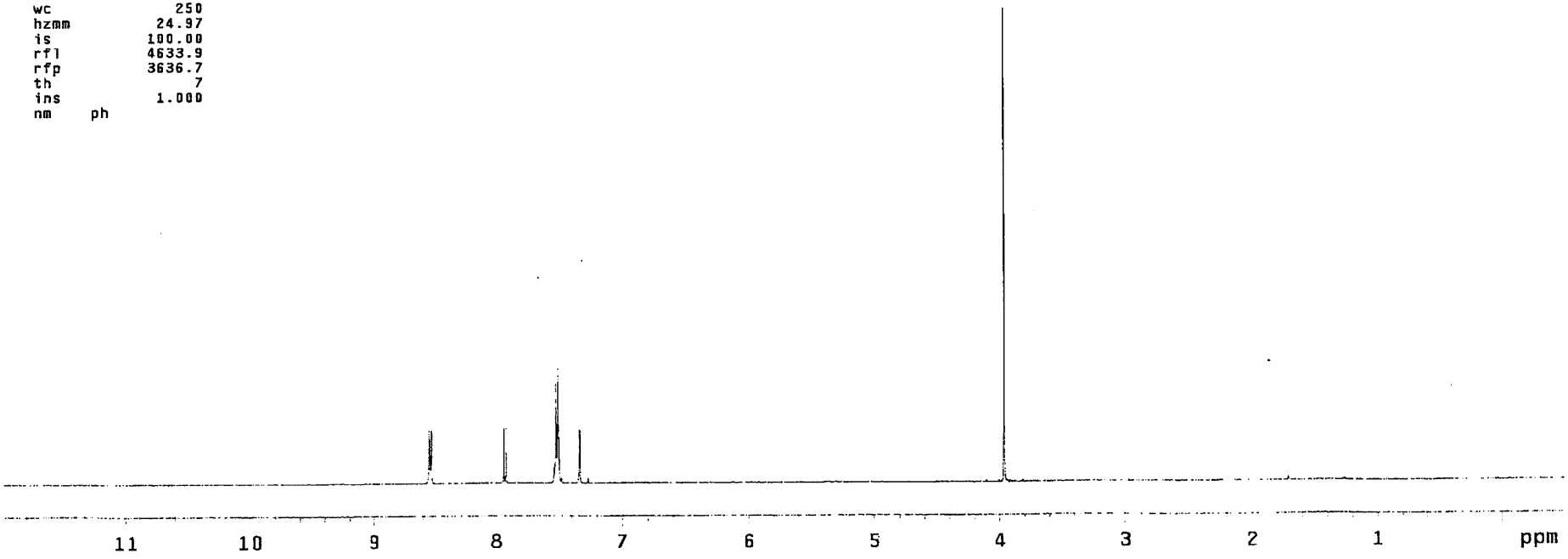
2848.31
1620.99
1567.18
1489.88
1440.48
1393.50
1298.74
1217.83
1024.88
913.27
830.00
744.09
665.83
OMe
N
N
Br
cHx

6l

		DEC. & VT	
date		dfrq	125.794
solvent	CDCl3	dn	C13
file	exp	dpwr	37
ACQUISITION		dof	0
sfrq	500.231	dm	nnn
tn	H1	dmm	c
at	3.200	dmf	10000
np	64000	dseq	
sw	10000.0	dres	1.0
fb	not used	homo	n
bs	2	PROCESSING	
ss	1	wtfile	
tpwr	58	proc	ft
pw	9.0	fn	131072
d1	0	math	f
tof	1498.2		
nt	32	werr	
ct	12	wexp	
alock	n	wbs	
gain	not used	wnt	
FLAGS			
il	n		
in	n		
dp	y		
hs	nn		
DISPLAY			
sp	-248.3		
wp	6241.7		
vs	76		
sc	0		
wc	250		
hzmm	24.97		
is	100.00		
rfl	4633.9		
rfp	3636.7		
th	7		
ins	1.000		
nm	ph		

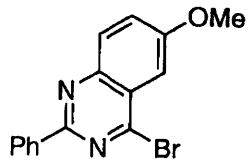


6m



exp1 s2pul

solvent	CDCl3		
		DEC. & VT	
		dfrq	500.229
		dn	H1
		dpwr	37
		dof	-500.0
		dm	y
		dmm	w
ACQUISITION		dmf	10000
sfrq	125.795	dseq	
tn	C13	dres	1.0
at	1.736	homo	n
np	131010	PROCESSING	
sw	37735.8	lb	0.30
fb	not used	wtfile	
bs	10	proc	ft
ss	1	fn	131072
tpwr	53	math	f
pw	6.9		
d1	0.763	werr	
tof	631.4	wexp	
nt	1000	wbs	
ct	40	wnt	
alock	n		
gain	not used		
FLAGS			
il	n		
in	n		
dp	y		
hs	nn		
DISPLAY			
sp	-2525.8		
wp	30198.0		
vs	39		
sc	0		
wc	250		
hzmm	120.79		
is	500.00		
rfl	16008.7		
rfp	9714.9		
th	9		
ins	1.000		
ai ph			



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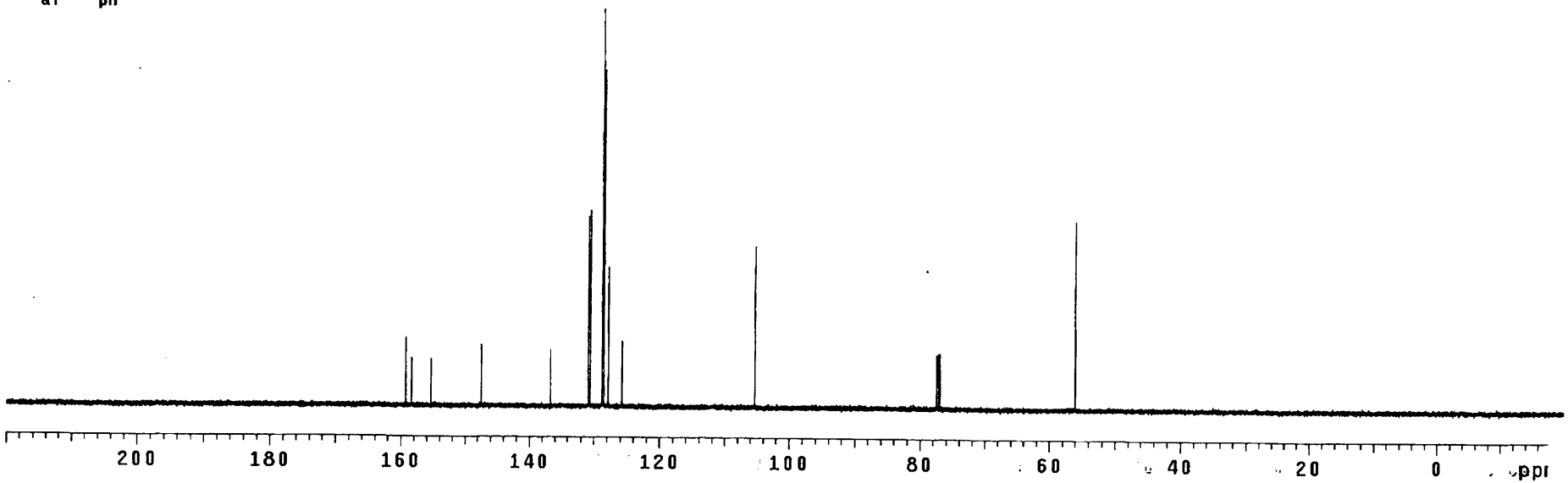
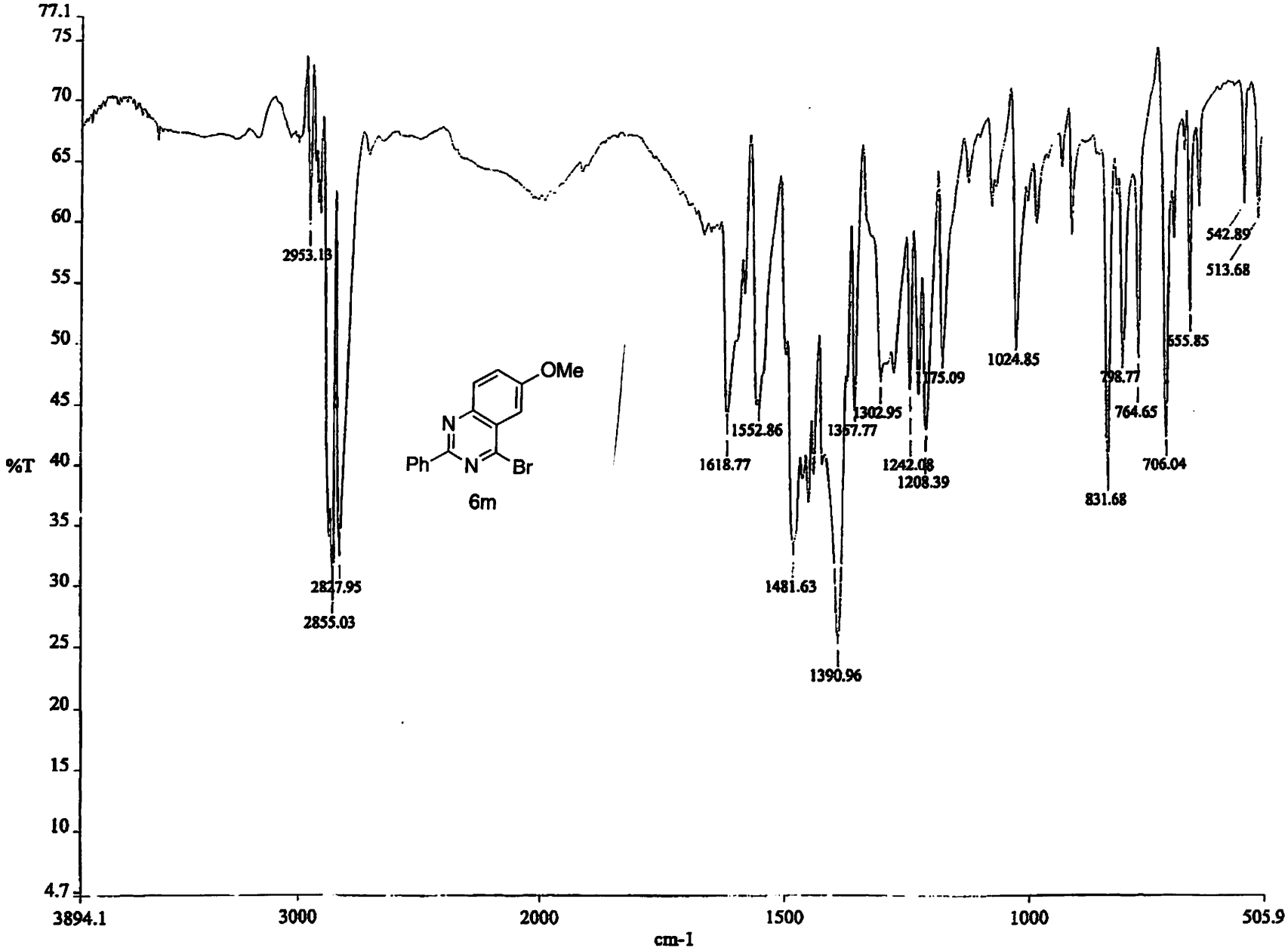



77.1
75
70
65
60
55
50
45
40
35
30
25
20
15
10
4.7
%T
3894.1
3000
2000
1500
1000
505.9
cm-1
2953.13
2827.95
2855.03
1618.77
1552.86
1481.63
1390.96
1367.77
1302.95
1242.08
1208.39
1175.09
1024.85
831.68
798.77
764.65
706.04
655.85
542.89
513.68
OMe
N
Ph
N
Br
6m

date	
solvent	CDCl3

ACQUISITION	
sfrq	499.746
tn	H1
at	3.001
np	63050
sw	10504.2
fb	not used
bs	2
tpwr	56
pw	8.6
d1	2.000
tof	1519.5
nt	32
ct	12
alock	n
gain	not used

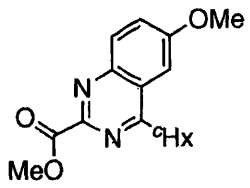
FLAGS	
il	n
in	n
dp	y
hs	nn

DISPLAY	
sp	-249.9
wp	6246.7
vs	24
sc	0
wc	250
hzmm	24.99
is	33.57
rfl	1233.8
rfp	0
th	7
ins	100.000

ai cdc ph

DEC. & VT	
dfrq	125.672
dn	C13
dpwr	30
dof	0
dm	nnn
dmm	w
dmf	10000
dseq	
dres	1.0
homo	n

PROCESSING	
wtfile	
proc	ft
fn	262144
math	f
werr	
wexp	
wbs	
wnt	wft



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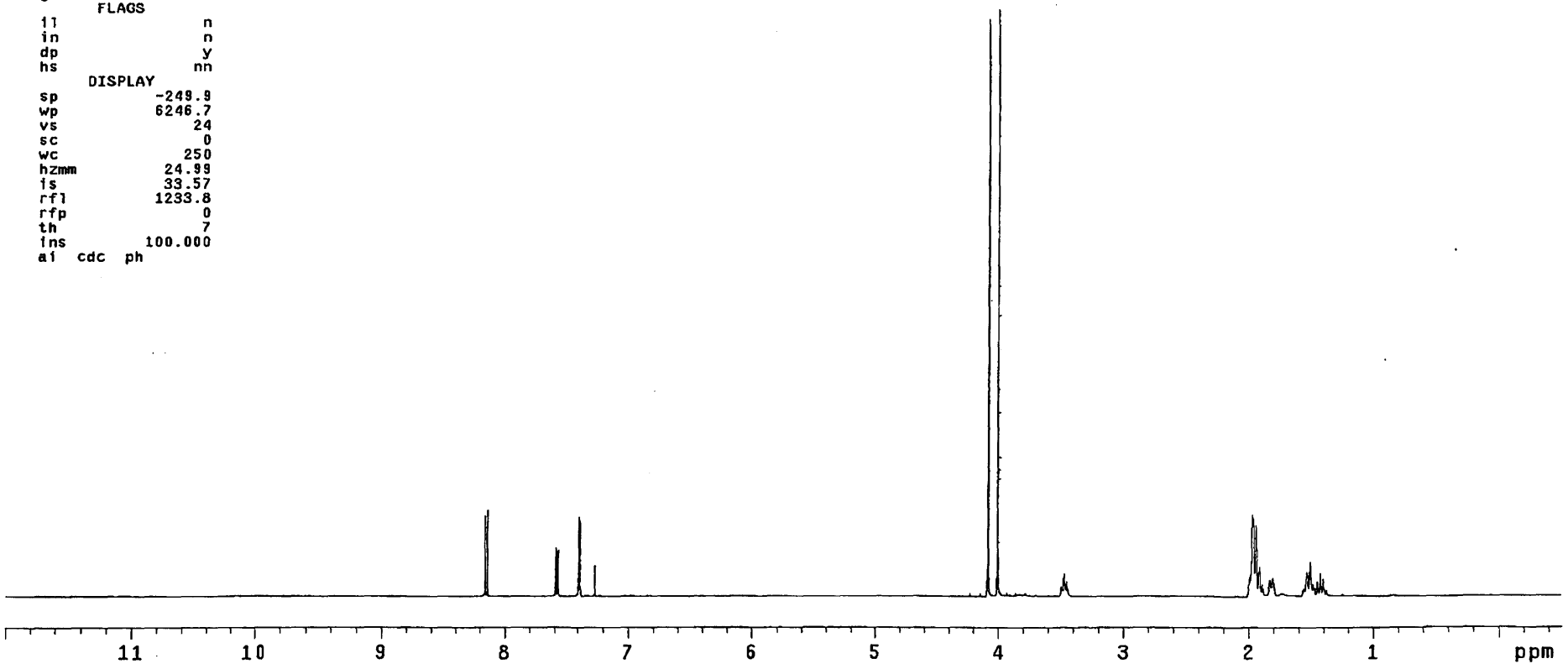
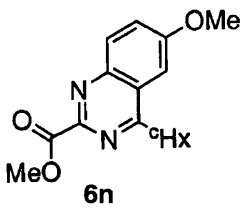


date		DEC. & VT	
solvent	CDCl3	dfrq	500.233
		dn	H1
		dpwr	44
		dof	-500.0
		dm	y
		dmm	w
ACQUISITION		dmf	10000
sfrq	125.796	dseq	
tn	C13	dres	1.0
at	1.736	homo	n
np	131010	PROCESSING	
sw	37735.8	lb	0.30
fb	not used	wtfile	
bs	10	proc	ft
ss	1	fn	131072
tpwr	54	math	f
pw	6.9		
d1	0.763	werr	
tof	631.4	wexp	
nt	4000	wbs	
ct	130	wnt	
alock	n		
gain	not used		
FLAGS			
il	n		
in	n		
dp	y		
hs	nn		
DISPLAY			
sp	-2522.2		
wp	30198.6		
vs	206		
sc	0		
wc	250		
hzmm	120.79		
is	500.00		
rfl	16005.3		
rfp	9715.0		
th	10		
ins	1.000		
ai ph			



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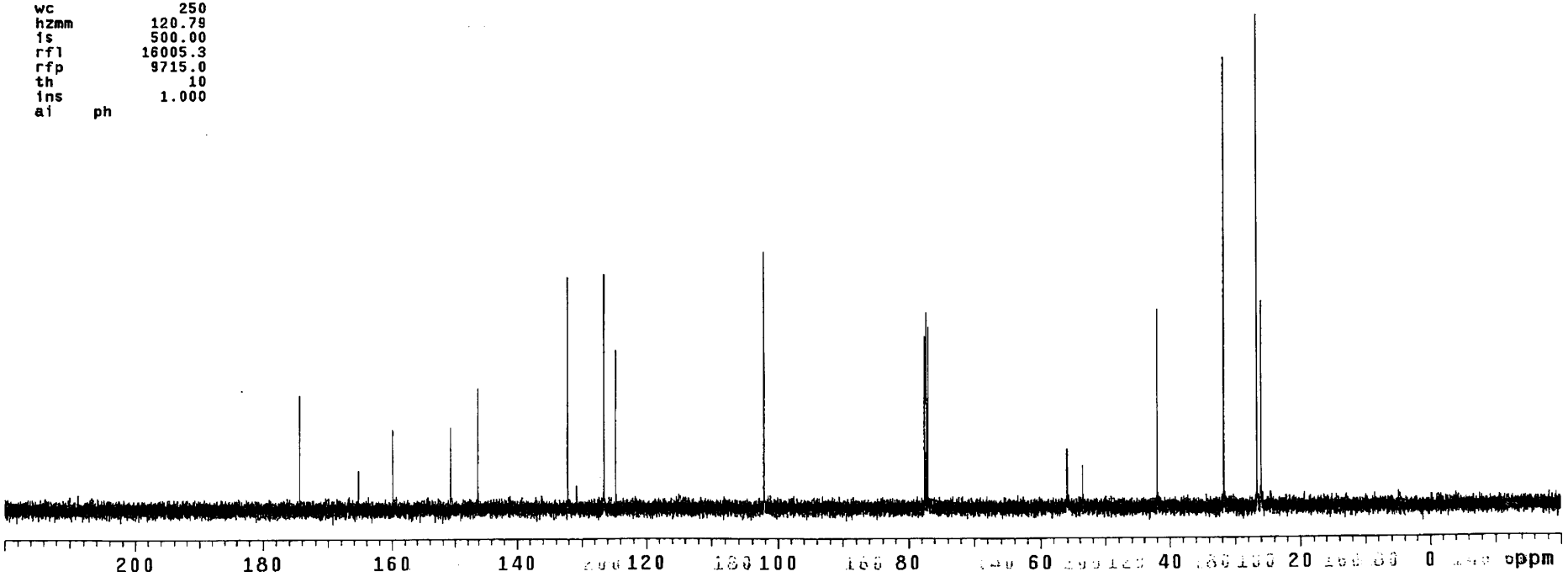
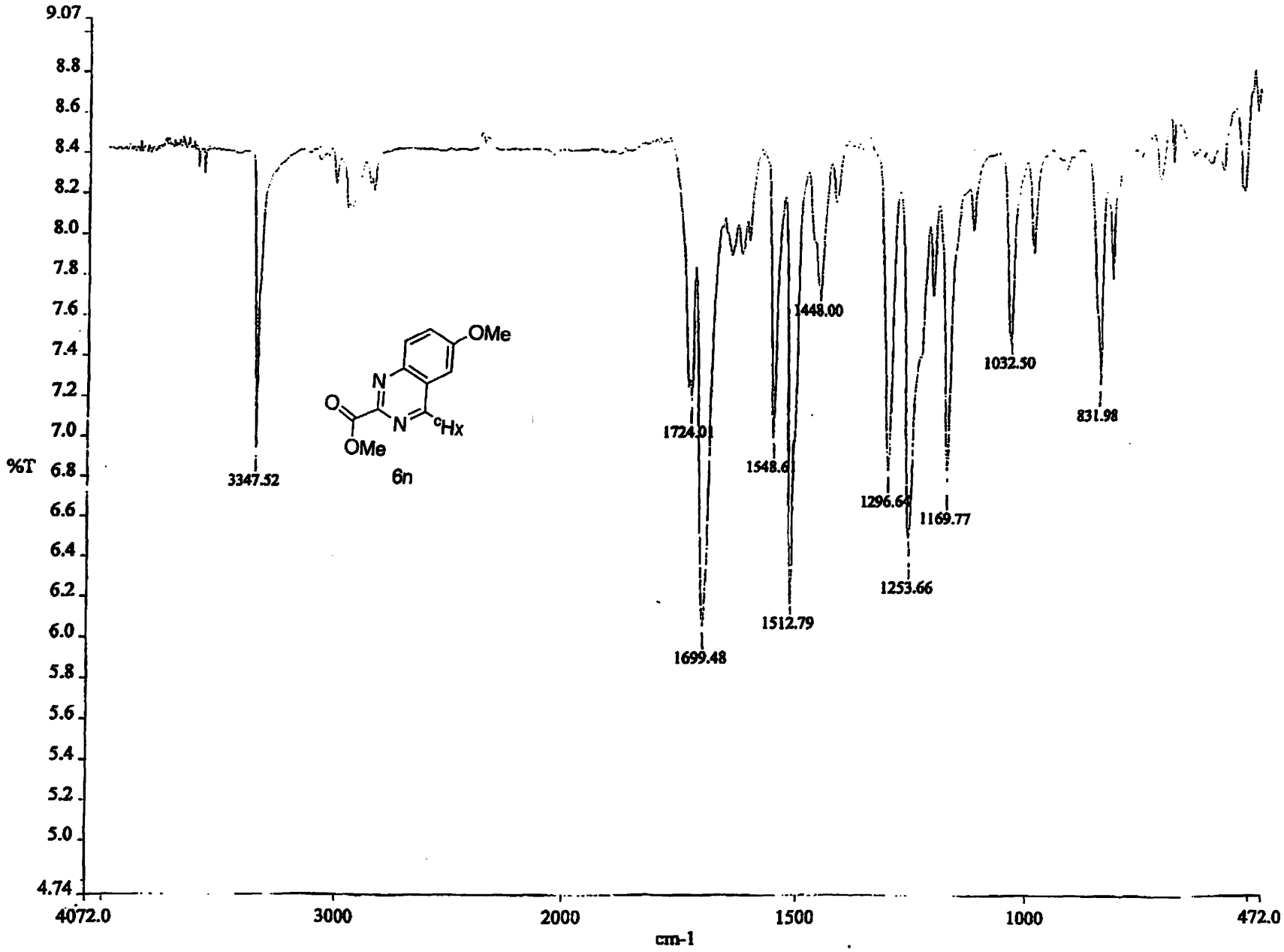
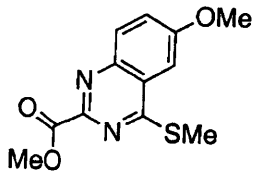



9.07
8.8
8.6
8.4
8.2
8.0
7.8
7.6
7.4
7.2
7.0
6.8
6.6
6.4
6.2
6.0
5.8
5.6
5.4
5.2
5.0
4.74
%T
4072.0
3000
2000
1500
1000
472.0
cm-1
3347.52
1724.01
1699.48
1548.61
1512.79
1448.00
1296.64
1253.66
1169.77
1032.50
831.98
OMe
N
O
N
cHx
OMe
6n

		DEC. & VT	
date		dfrq	125.845
solvent	CDCl3	dn	C13
file	exp	dpwr	30
ACQUISITION		dof	0
sfrq	500.435	dm	nnn
tn	H1	dmm	c
at	4.999	dmf	200
np	120102	dseq	
sw	12012.0	dres	1.0
fb	not used	homo	n
bs	4	DEC2	
tpwr	56	dfrq2	0
pw	8.0	dn2	
d1	0.100	dpwr2	1
tof	3003.2	dof2	0
nt	128	dm2	n
ct	16	dmm2	c
alock	n	dmf2	200
gain	not used	dseq2	
FLAGS		dres2	1.0
il	n	homo2	n
in	n	DEC3	
dp	y	dfrq3	0
hs	nn	dn3	
DISPLAY		dpwr3	1
sp	-250.2	dof3	0
wp	6255.3	dm3	n
vs	7	dmm3	c
sc	0	dmf3	200
wc	250	dseq3	
hzmm	25.02	dres3	1.0
is	33.57	homo3	n
rfl	4139.0	PROCESSING	
rfp	3623.1	wtfile	
th	5	proc	ft
ins	100.000	fn	262144
ai cdc ph		math	f
		werr	
		wexp	
		wbs	
		wnt	wft



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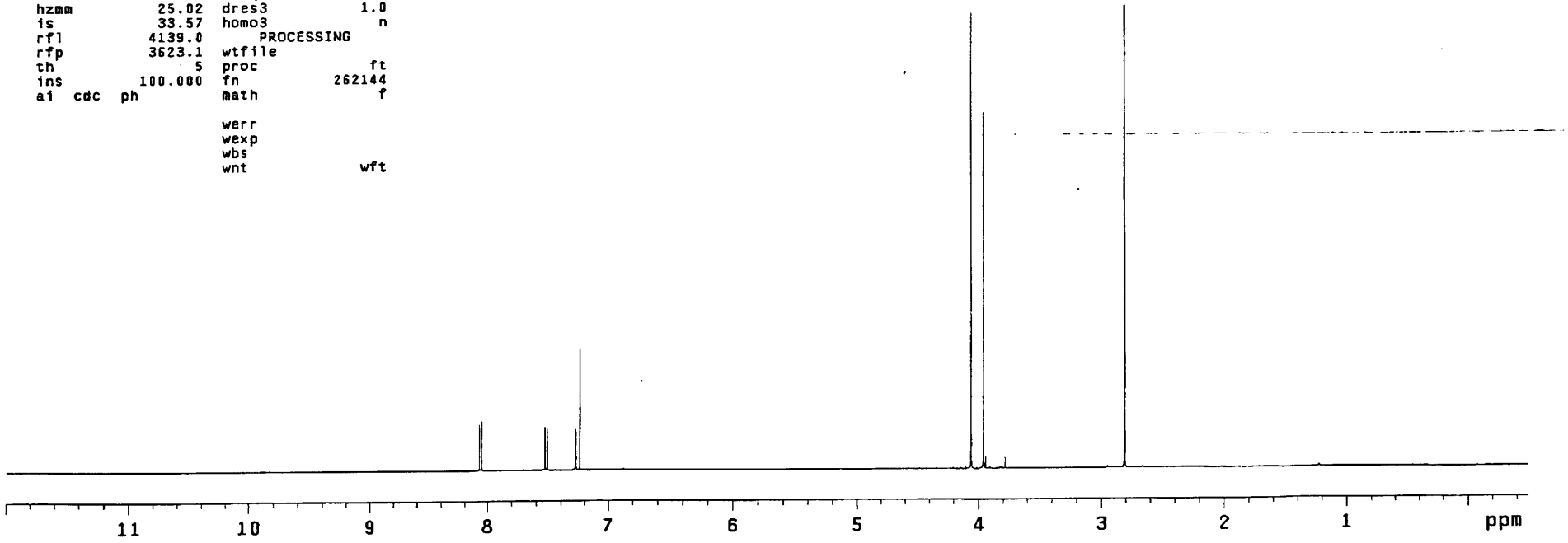
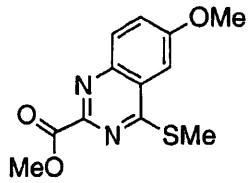


date	
solvent	CDCl3
file	exp
ACQUISITION	
sfrq	125.795
tn	C13
at	1.736
np	131010
sw	37735.8
fb	not used
bs	8
ss	1
tpwr	53
pw	6.9
dl	0.763
tof	631.4
nt	10000
ct	1088
alock	n
gain	not used
FLAGS	
il	n
in	n
dp	y
hs	nn
DISPLAY	
sp	-2519.4
wp	30198.5
vs	695
sc	0
wc	250
hzmm	120.79
is	500.00
rfl	16002.4
rfp	9714.9
th	6
ins	1.000
ai	ph

DEC. & VT	
dfrq	500.229
dn	H1
dpwr	38
dof	-500.0
dm	y
dmm	w
dmf	10000
dseq	
dres	1.0
homo	n
PROCESSING	
lb	0.30
wtfile	
proc	ft
fn	131072
math	f
werr	
wexp	
wbs	
wnt	



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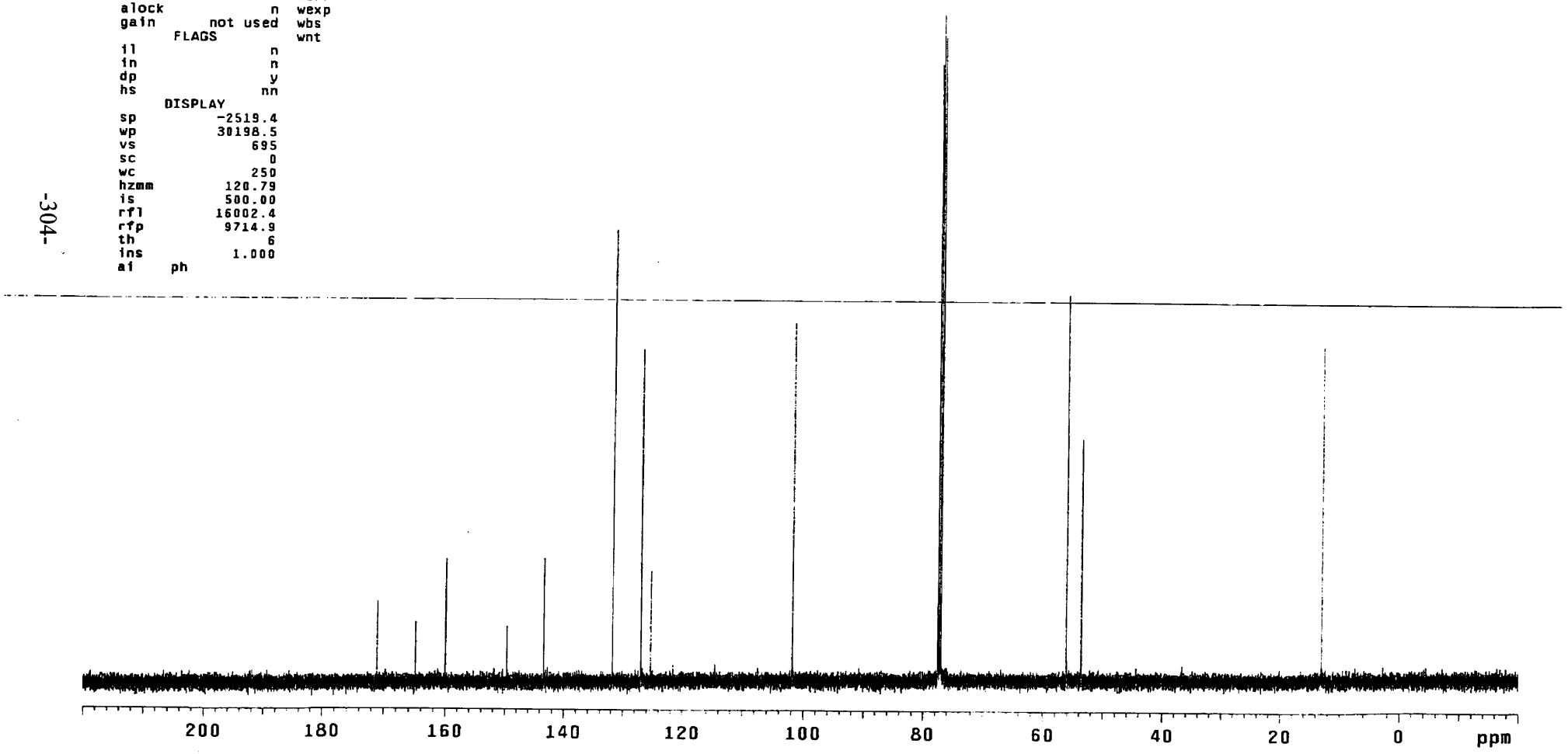
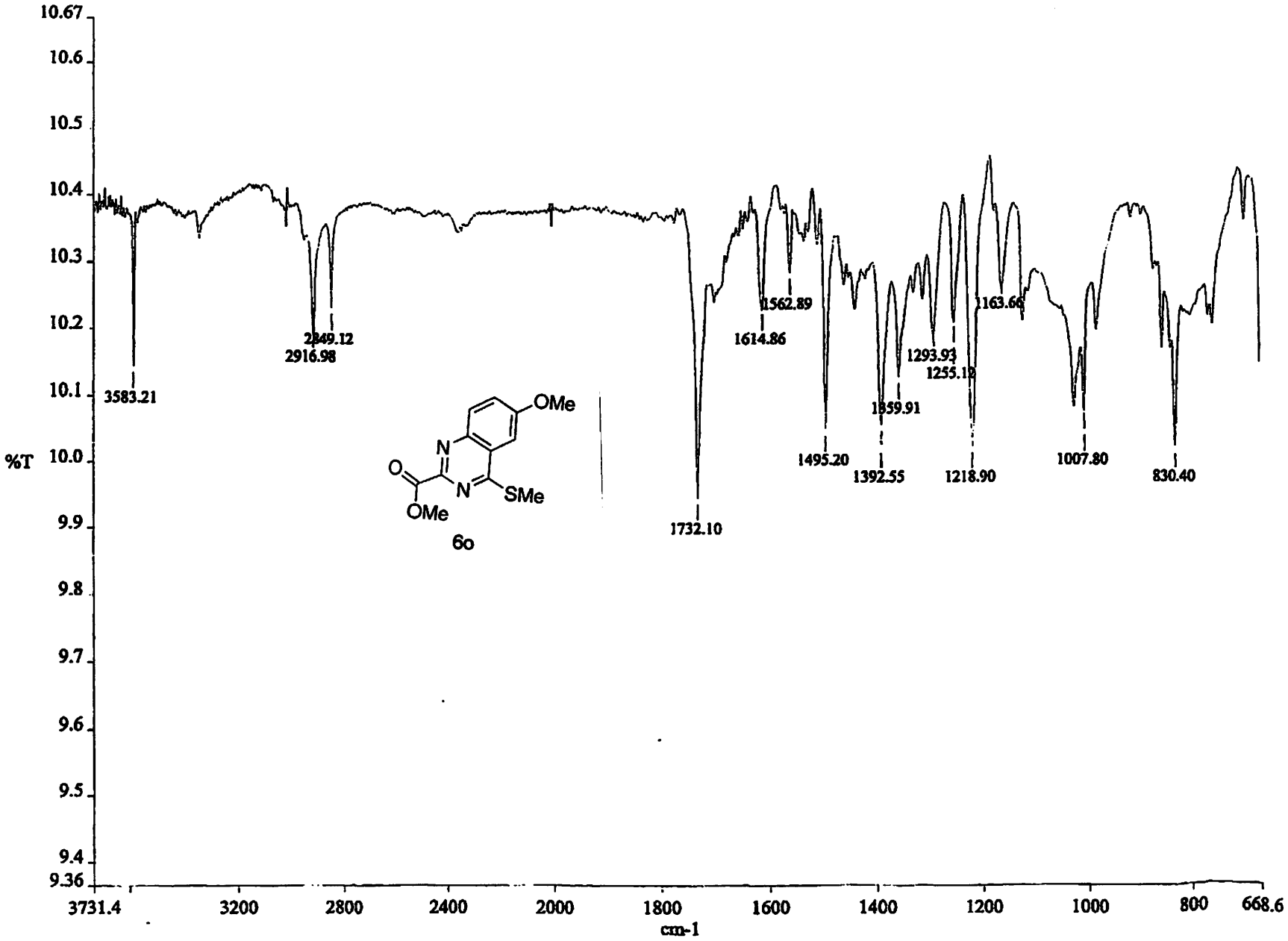
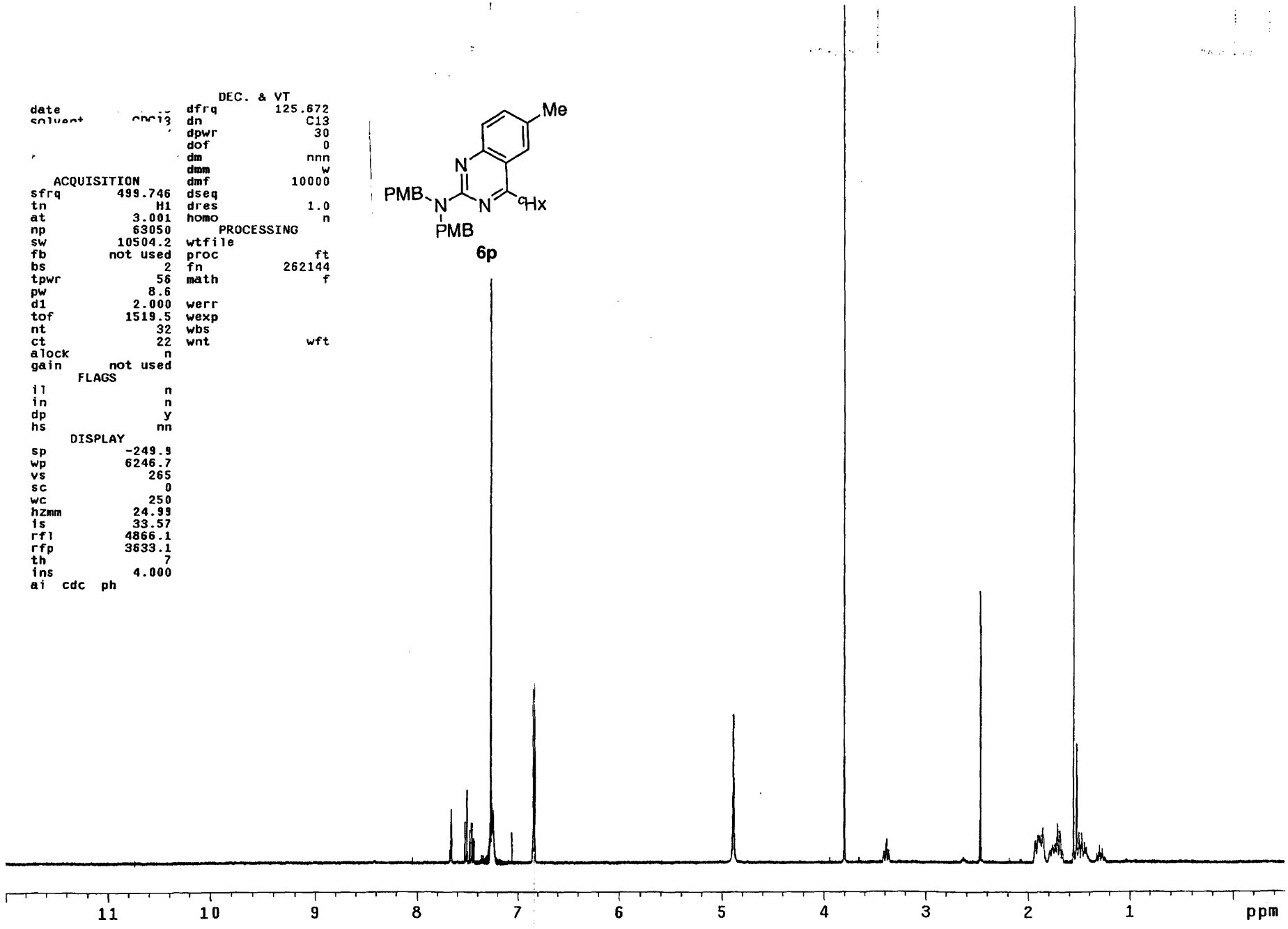



10.67
10.6
10.5
10.4
10.3
10.2
10.1
10.0
9.9
9.8
9.7
9.6
9.5
9.4
9.36
%T
3583.21
2916.98
2849.12
1732.10
1614.86
1562.89
1495.20
1392.55
1359.91
1293.93
1255.12
1218.90
1163.66
1007.80
830.40
OMe
N
O
N
SMe
OMe
6o
3731.4
3200
2800
2400
2000
1800
1600
1400
1200
1000
800
668.6
cm-1


date
solvent cdcl3
ACQUISITION
sfrq 499.746
tn H1
at 3.001
np 63050
sw 10504.2
fb not used
bs 2
tpwr 56
pw 8.6
d1 2.000
tof 1519.5
nt 32
ct 22
alock n
gain not used
FLAGS
il n
in n
dp y
hs nn
DISPLAY
sp -249.9
wp 6246.7
vs 265
sc 0
wc 250
hzmm 24.99
is 33.57
rfl 4866.1
rfp 3633.1
th 7
ins 4.000
ai cdc ph
DEC. & VT
dfrq 125.672
dn C13
dpwr 30
dof 0
dm nnn
dmm w
dmf 10000
dseq
dres 1.0
homo n
PROCESSING
wtfile
proc ft
fn 262144
math f
werr
wexp
wbs
wnt wft
Me
N
PMB
N
N
cHx
PMB
6p
11
10
9
8
7
6
5
4
3
2
1
ppm

date	
solvent	CDCl3

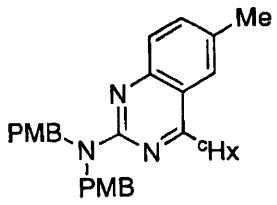
ACQUISITION	
sfrq	125.795
tn	C13
at	1.736
np	131010
sw	37735.8
fb	not used
bs	10
ss	1
tpwr	53
pw	6.9
d1	0.763
tof	631.4
nt	2000
ct	410
alock	n
gain	not used

FLAGS	
il	n
in	n
dp	y
hs	nn

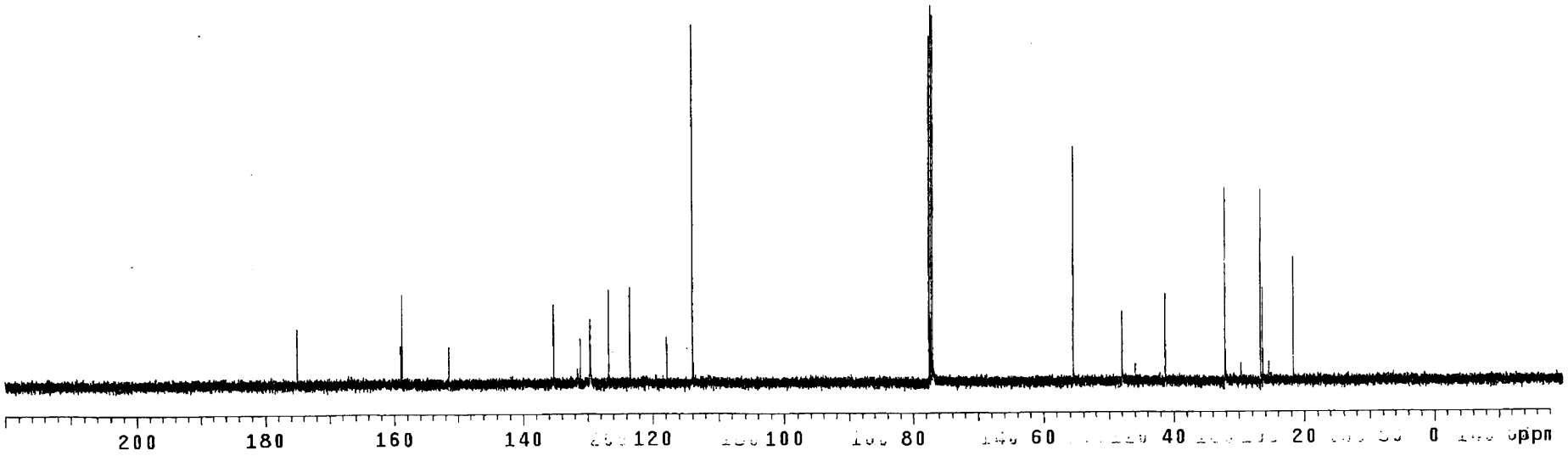
DISPLAY	
sp	-2520.0
wp	30198.0
vs	263
sc	0
wc	250
hzmm	120.79
is	500.00
rfl	16003.5
rfp	9714.9
th	6
ins	1.000
ai	ph

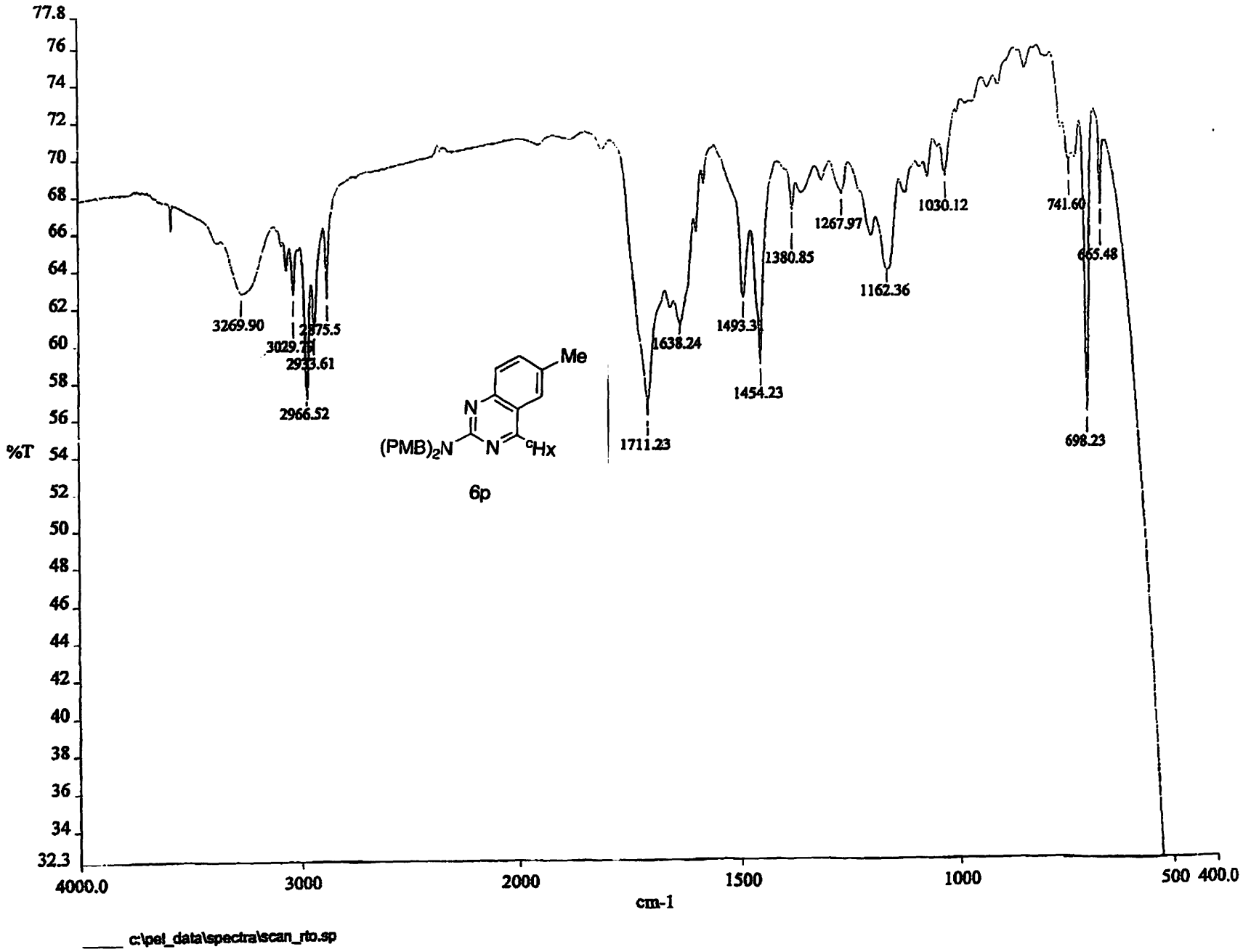
DEC. & VT	
dfrq	500.229
dn	H1
dpwr	37
dof	-500.0
dm	y
dmm	w
dmf	10000
dseq	
dres	1.0
homo	n

PROCESSING	
lb	0.30
wtfile	
proc	ft
fn	131072
math	f
werr	
wexp	
wbs	
wnt	



6p

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2933.61
2875.5
2966.52
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1638.24
1493.38
1454.23
1380.85
1267.97
1162.36
1030.12
741.60
665.48
698.23
Me
N
N
(PMB)2N
cHx
6p
%T
77.8
76
74
72
70
68
66
64
62
60
58
56
54
52
50
48
46
44
42
40
38
36
34
32.3
4000.0
3000
2000
1500
1000
500
400.0
cm-1
c:\pel_data\spectra\scan_rto.sp

SAMPLE	
date	Aug 27 2007
solvent	CDCl3

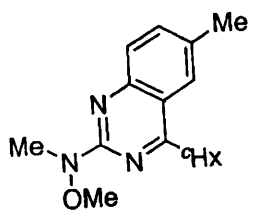
ACQUISITION	
sfrq	499.746
tn	H1
at	3.001
np	63050
sw	10504.2
fb	not used
bs	2
tpwr	56
pw	8.6
d1	2.000
tof	1519.5
nt	32
ct	20
alock	n
gain	not used

FLAGS	
il	n
in	n
dp	y
hs	nn

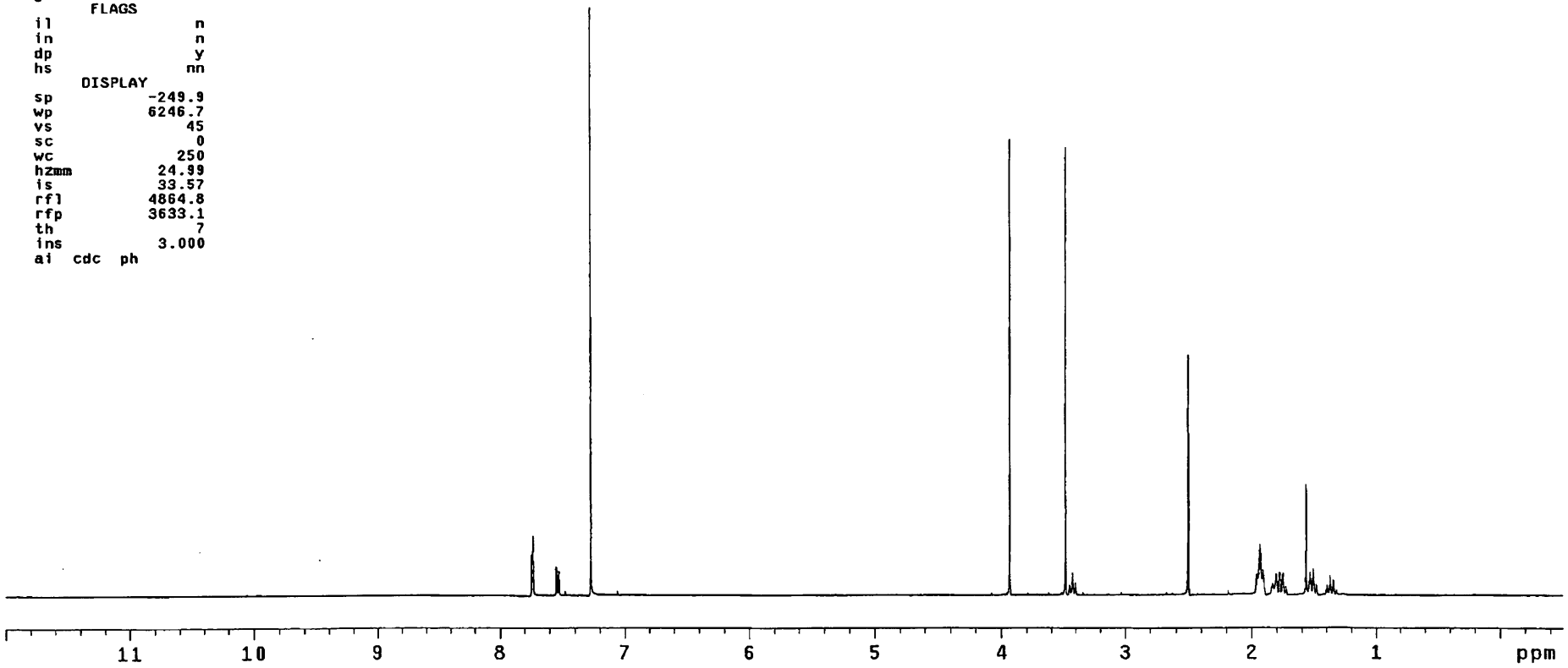
DISPLAY	
sp	-249.9
wp	6246.7
vs	45
sc	0
wc	250
hzmm	24.99
is	33.57
rfl	4864.8
rfp	3633.1
th	7
ins	3.000
ai cdc ph	

DEC. & VT	
dfrq	125.672
dn	C13
dpwr	30
dof	0
dm	nnn
dmm	w
dmf	10000
dseq	
dres	1.0
homo	n

PROCESSING	
wtfile	
proc	ft
fn	262144
math	f
werr	
wexp	
wbs	
wnt	wft



6q



date	
solven	

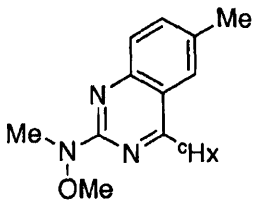
ACQUISITION	
sfrq	125.796
tn	C13
at	1.736
np	131010
sw	37735.8
fb	not used
bs	4
ss	1
tpwr	54
pw	6.9
d1	0.763
tof	631.4
nt	1000
ct	52
alock	n
gain	not used

FLAGS	
il	n
in	n
dp	y
hs	nn

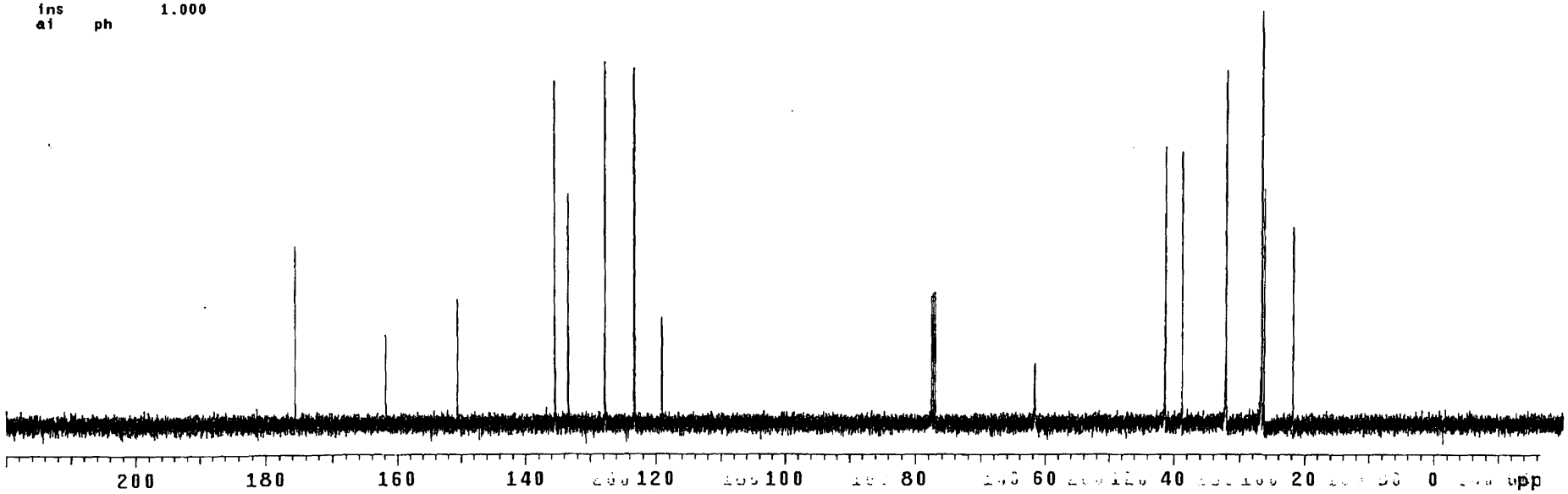
DISPLAY	
sp	-2526.3
wp	30198.0
vs	147
sc	0
wc	250
hzmm	120.79
is	500.00
rfl	16008.7
rfp	9715.0
th	17
ins	1.000
ai	ph

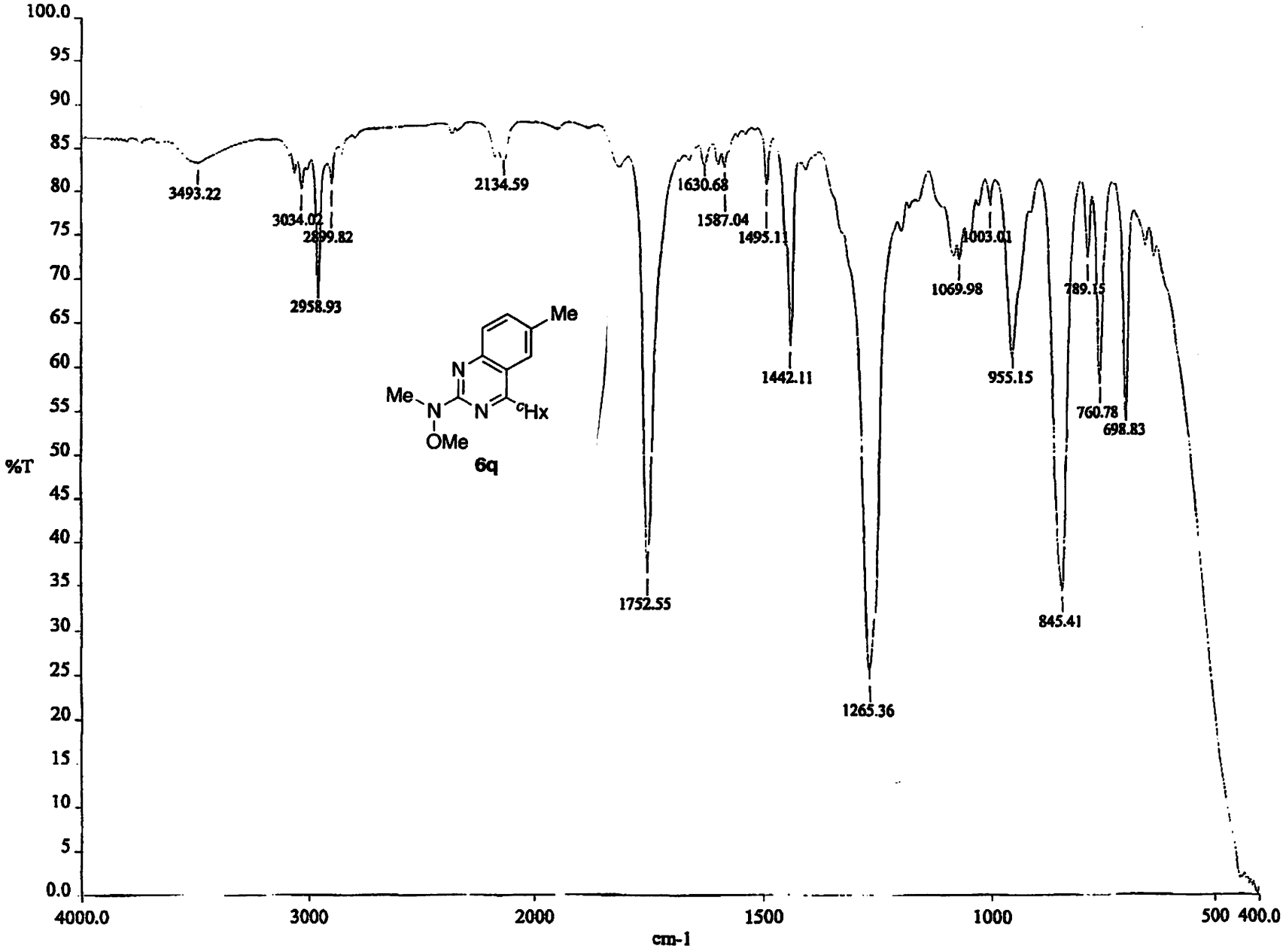
DEC. & VT	
dfrq	500.233
dn	H1
dpwr	44
dof	-500.0
dm	y
dmm	w
dmf	10000
dseq	
dres	1.0
homo	n

PROCESSING	
lb	0.30
wtfile	
proc	ft
fn	131072
math	f
werr	
wexp	
wbs	
wnt	



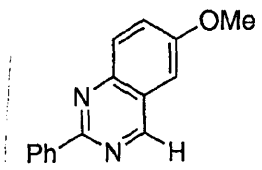
6q



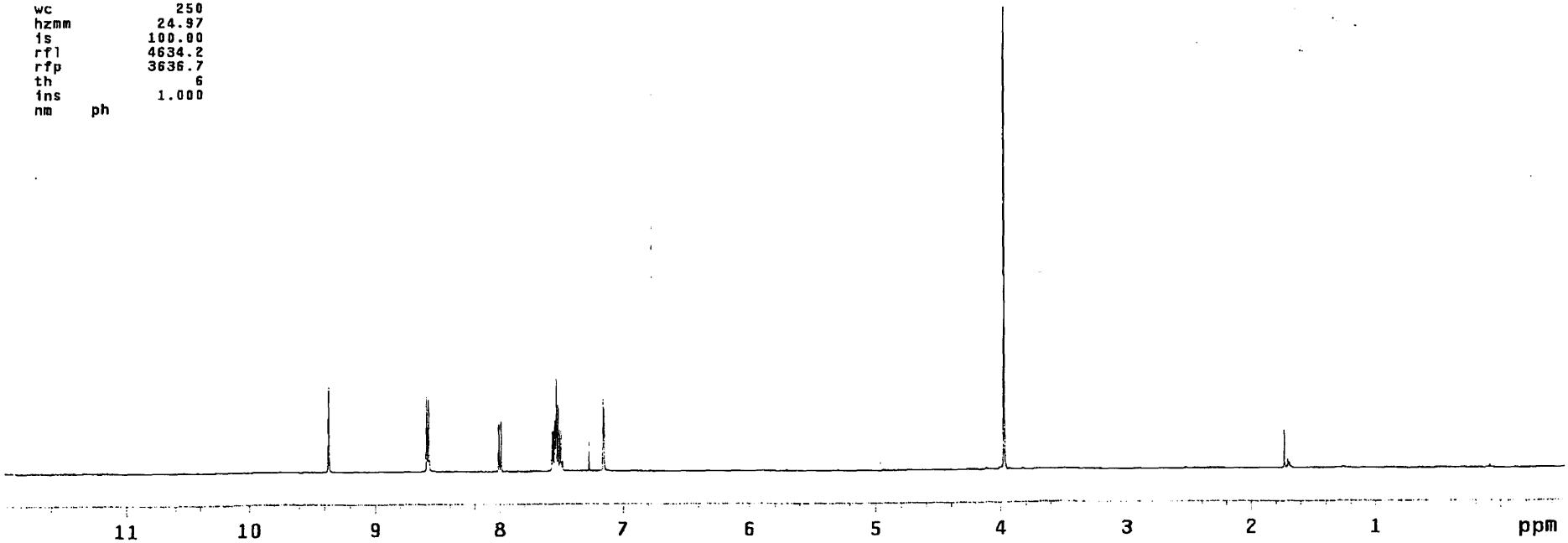

100.0
95
90
85
80
75
70
65
60
55
50
45
40
35
30
25
20
15
10
5
0.0
%T
4000.0
3000
2000
1500
1000
500
400.0
cm-1
3493.22
3034.02
2899.82
2958.93
2134.59
1630.68
1587.04
1495.11
1442.11
1752.55
1265.36
1069.98
1003.01
955.15
845.41
789.15
760.78
698.83
Me
N
Me
N
N
cHx
OMe
6q

date	
solvent	CDCl3
file	exp
ACQUISITION	
sfrq	500.231
tn	H1
at	3.200
np	64000
sw	10000.0
fb	not used
bs	2
ss	1
tpwr	58
pw	9.0
d1	0
tof	1498.2
nt	32
ct	18
alock	n
gain	not used
FLAGS	
il	n
in	n
dp	y
hs	nn
DISPLAY	
sp	-248.6
wp	6241.7
vs	76
sc	0
wc	250
hzmm	24.97
is	100.00
rfl	4634.2
rfp	3636.7
th	6
ins	1.000
nm	ph

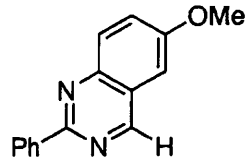
DEC. & VT	
dfrq	125.794
dn	C13
dpwr	37
dof	0
dm	nnn
dmm	c
dmf	10000
dseq	
dres	1.0
homo	n
temp	20.0
PROCESSING	
wtfile	
proc	ft
fn	131072
math	f
werr	
wexp	
wbs	
wnt	



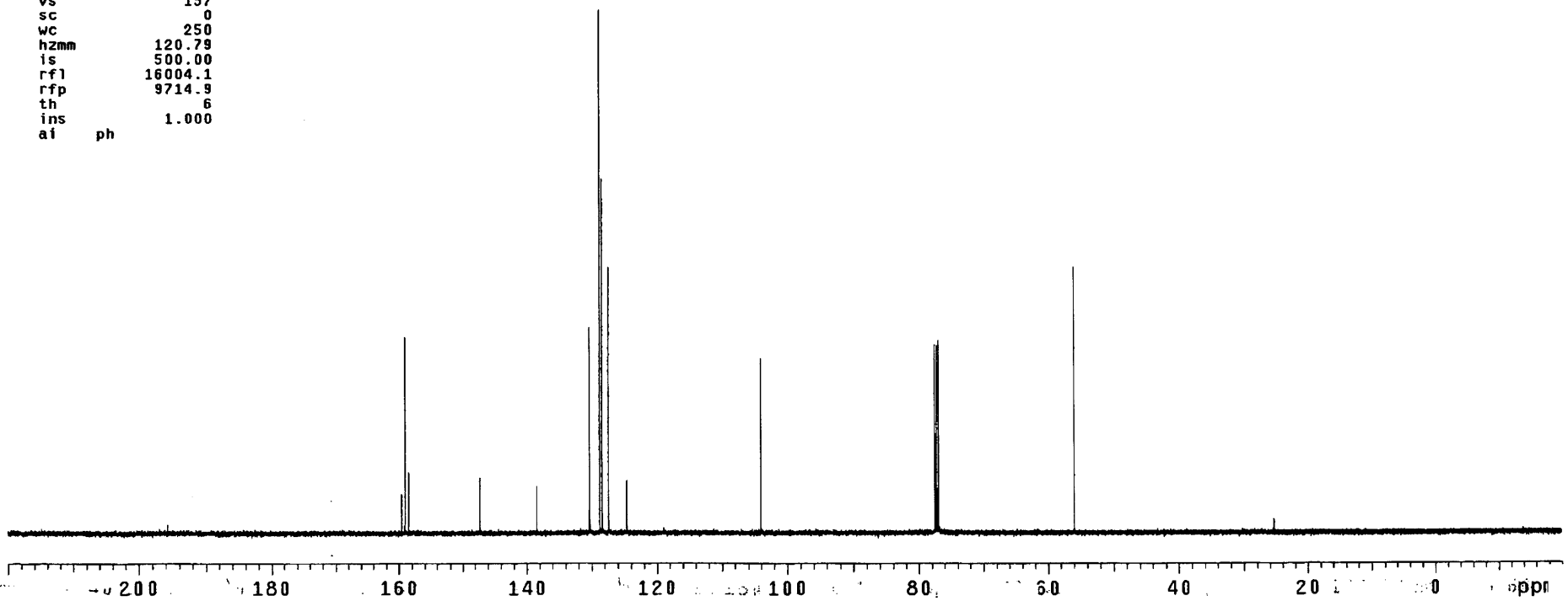
6s

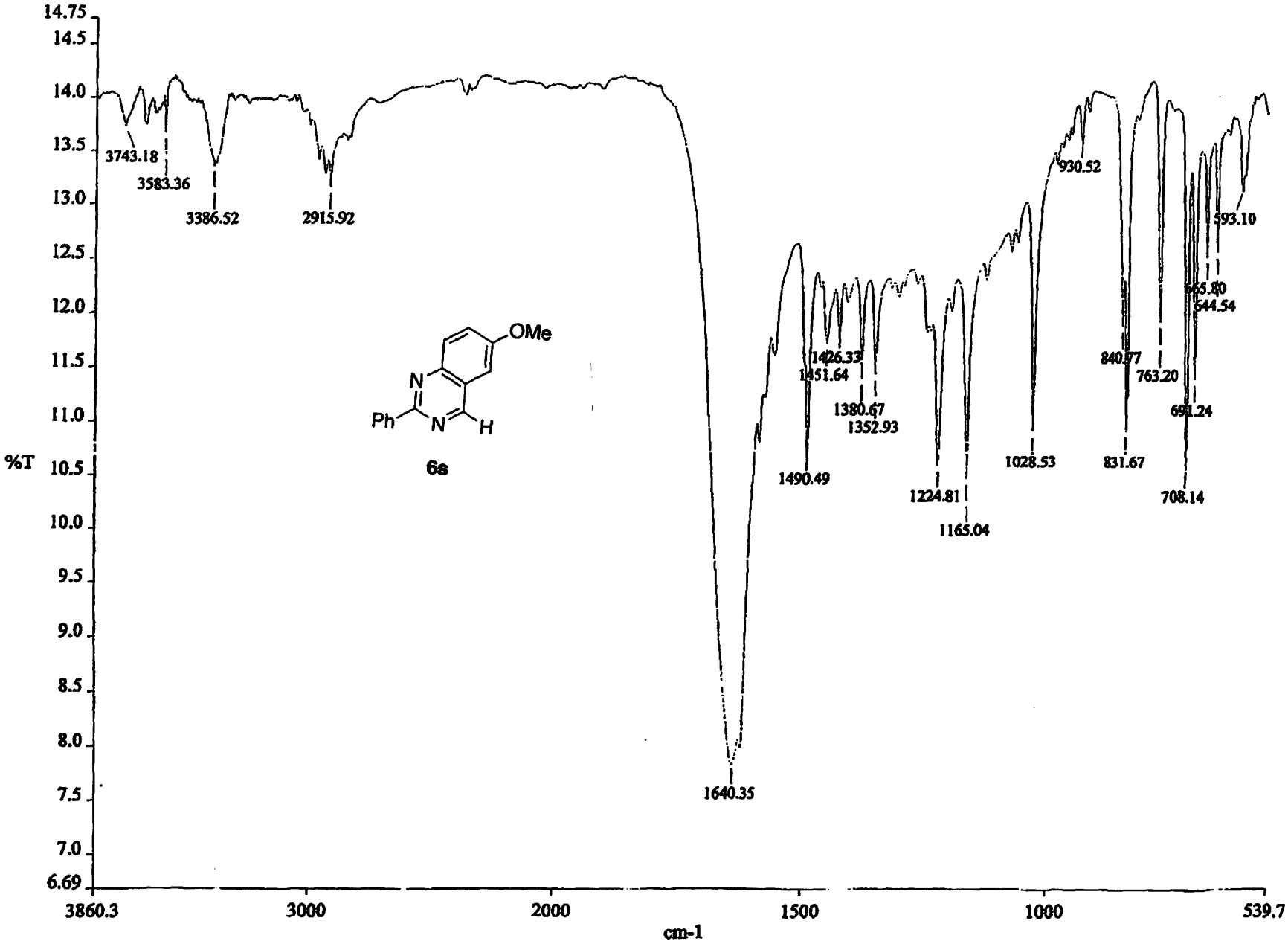


```
exp1  s2pul

solvent      CDCl3

   ACQUISITION
sfrq        125.795
tn              C13
at            1.736
np           131010
sw         37735.8
fb         not used
bs               10
ss                1
tpwr             53
pw              6.9
d1            0.763
tof           631.4
nt             2000
ct              540
alock             n
gain       not used
      FLAGS
il                n
in                n
dp                y
hs               nn
     DISPLAY
sp         -2520.6
wp         30198.0
vs             157
sc               0
wc             250
hzmm        120.79
is          500.00
rfl        16004.1
rfp         9714.9
th               6
ins          1.000
ai     ph

                DEC. & VT
dfrq        500.229
dn               H1
dpwr             37
dof          -500.0
dm                y
dmm               w
dmf           10000
dseq
dres            1.0
homo              n
temp           20.0
     PROCESSING
lb             0.30
wtfile
proc              ft
fn           131072
math               f
werr
wexp
wbs
wnt
```



6s

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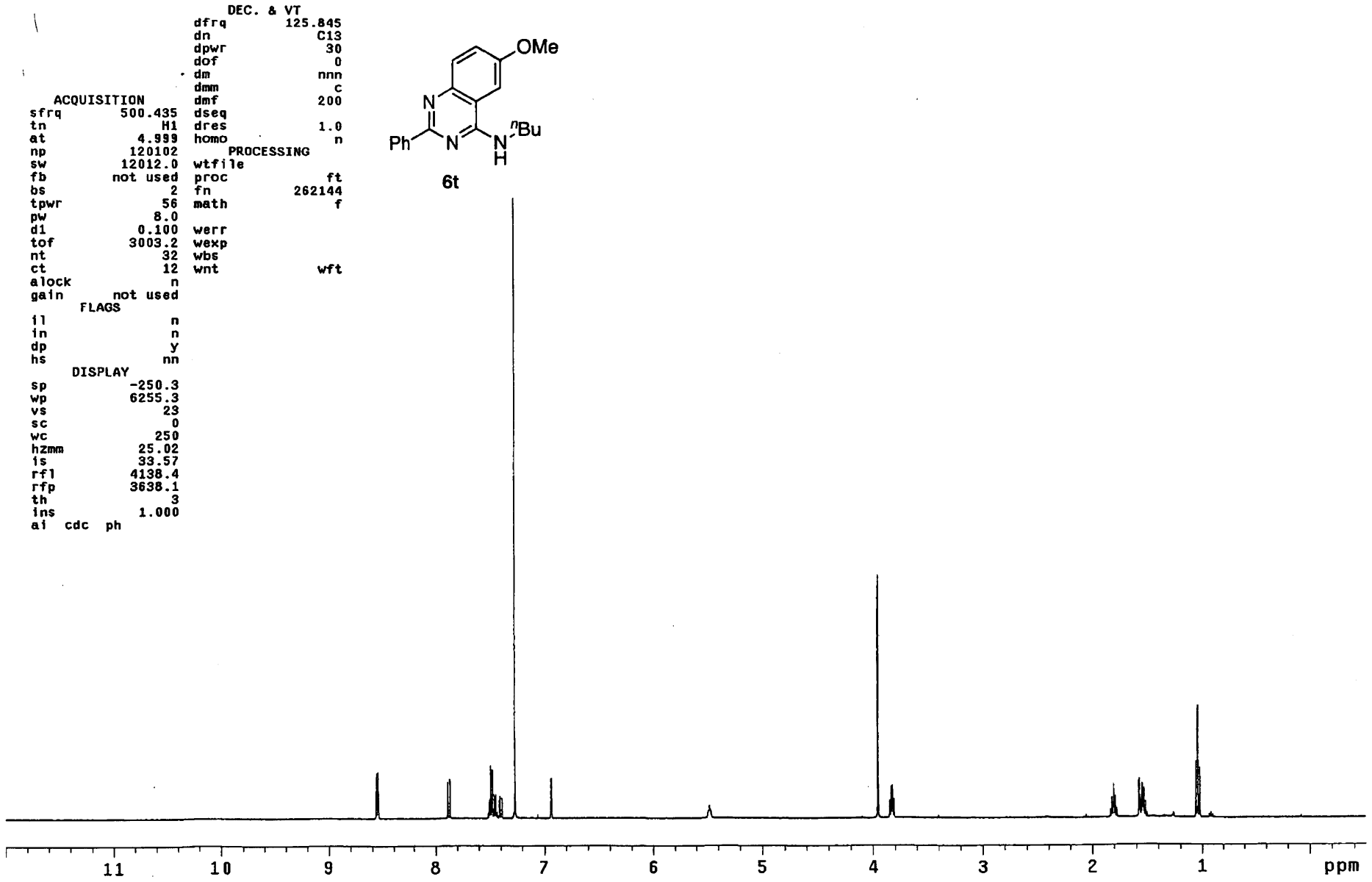
10.5
10.0
9.5
9.0
8.5
8.0
7.5
7.0
6.69
%T
3860.3
3000
2000
1500
1000
539.7
cm-1
3743.18
3583.36
3386.52
2915.92
1640.35
1490.49
1451.64
1426.33
1380.67
1352.93
1224.81
1165.04
1028.53
930.52
840.97
831.67
763.20
708.14
691.24
665.80
644.54
593.10
OMe
N
Ph
N
H
6s


ACQUISITION
sfrq 500.435
tn H1
at 4.999
np 120102
sw 12012.0
fb not used
bs 2
tpwr 56
pw 8.0
d1 0.100
tof 3003.2
nt 32
ct 12
alock n
gain not used
FLAGS
il n
in n
dp y
hs nn
DISPLAY
sp -250.3
wp 6255.3
vs 23
sc 0
wc 250
hzmm 25.02
is 33.57
rfl 4138.4
rfp 3638.1
th 3
ins 1.000
ai cdc ph
DEC. & VT
dfrq 125.845
dn C13
dpwr 30
dof 0
dm nnn
dmm c
dmf 200
dseq
dres 1.0
homo n
PROCESSING
wtfile
proc ft
fn 262144
math f
werr
wexp
wbs
wnt wft
OMe
N
Ph
N
N
H
nBu
6t
11
10
9
8
7
6
5
4
3
2
1
ppm

exp1 s2pul

solvent	CDCl3

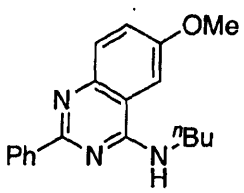
ACQUISITION	
sfrq	125.795
tn	C13
at	1.736
np	131010
sw	37735.8
fb	not used
bs	10
ss	1
tpwr	53
pw	6.9
d1	0.763
tof	631.4
nt	1000
ct	80
alock	n
gain	not used

FLAGS	
il	n
in	n
dp	y
hs	nn

DISPLAY	
sp	-2524.6
wp	30198.0
vs	134
sc	0
wc	250
hzmm	120.79
is	500.00
rfl	16007.6
rfp	9714.9
th	10
ins	1.000
ai	ph

DEC. & VT	
dfrq	500.229
dn	H1
dpwr	37
dof	-500.0
dm	y
dmm	w
dmf	10000
dseq	
dres	1.0
homo	n
temp	20.0

PROCESSING	
lb	0.30
wtfile	
proc	ft
fn	131072
math	f
werr	
wexp	
wbs	
wnt	



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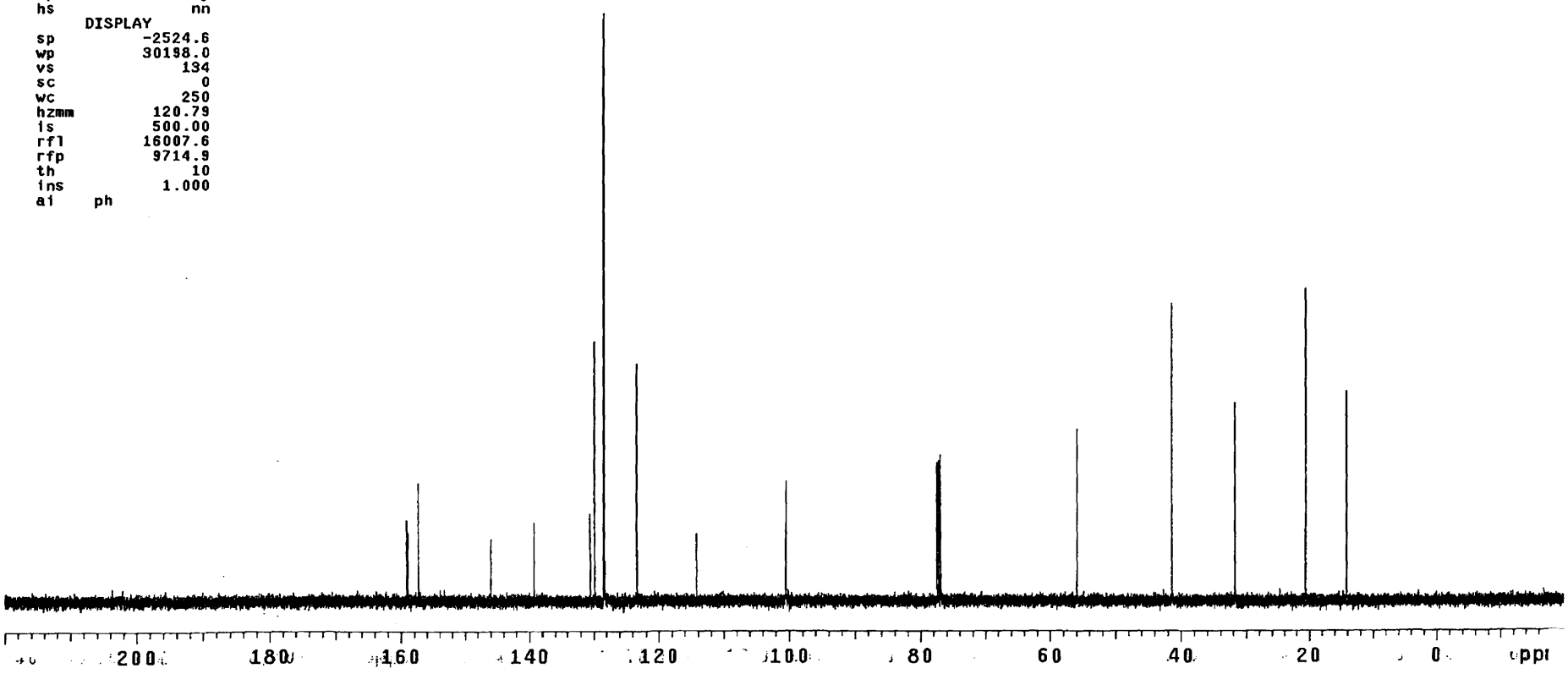
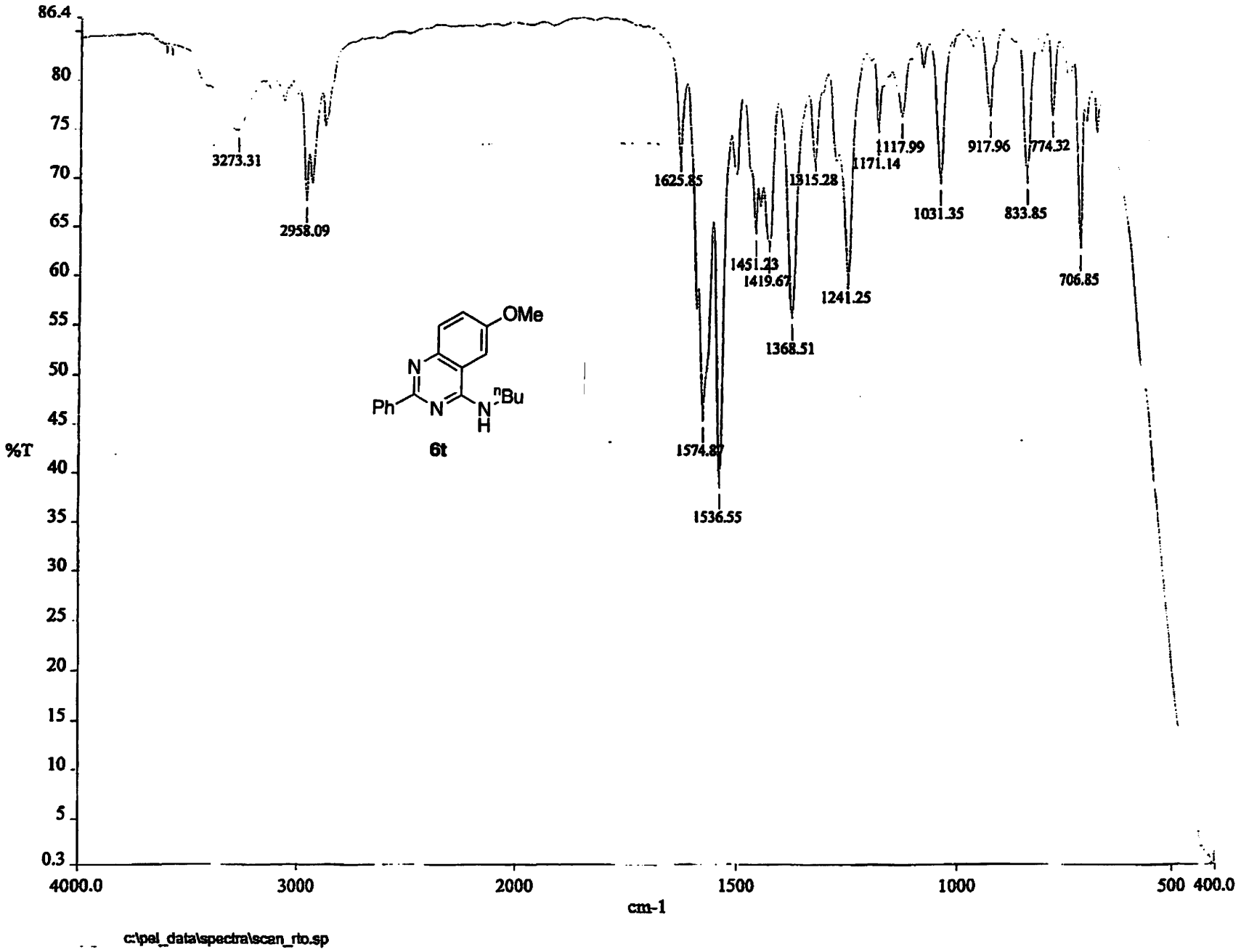
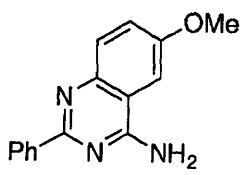



86.4
80
75
70
65
60
55
50
45
40
35
30
25
20
15
10
5
0.3
%T
3273.31
2958.09
1625.85
1574.87
1536.55
1451.23
1419.67
1368.51
1315.28
1241.25
1171.14
1117.99
1031.35
917.96
833.85
774.32
706.85
OMe
N
Ph
N
nBu
H
6t
4000.0
3000
2000
1500
1000
500
400.0
cm-1
c:\pel_data\spectra\scan_rto.sp

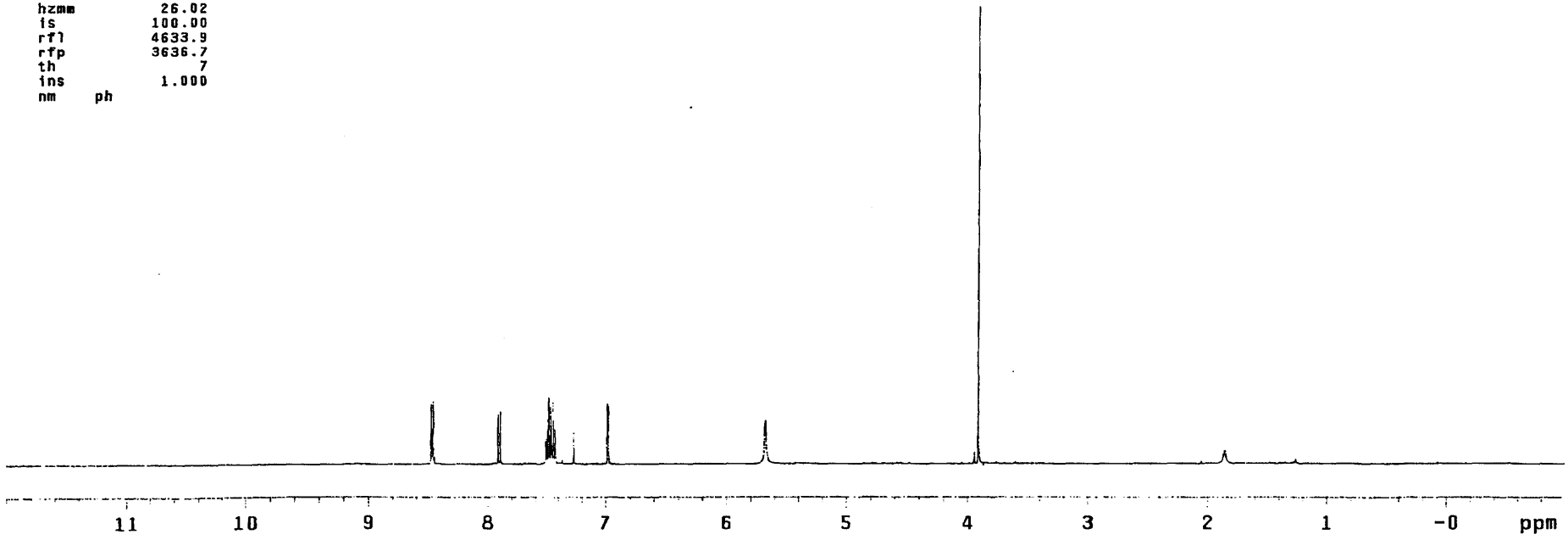
exp321 s2pul

solvent	CDCl3
file	exp
ACQUISITION	
sfrq	500.231
tn	H1
at	3.200
np	64000
sw	10000.0
fb	not used
bs	2
ss	1
tpwr	58
pw	9.0
d1	0
tof	1498.2
nt	32
ct	26
alock	n
gain	not used
FLAGS	
il	n
in	n
dp	y
hs	nn
DISPLAY	
sp	-497.9
wp	6504.5
vs	74
sc	0
wc	250
hzmm	26.02
is	100.00
rfl	4633.9
rfp	3636.7
th	7
ins	1.000
nm	ph

DEC. & VT	
dfrq	125.794
dn	C13
dpwr	37
dof	0
dm	nnn
dmm	c
dmf	10000
dseq	
dres	1.0
homo	n
temp	20.0
PROCESSING	
wtfile	
proc	ft
fn	131072
math	f
werr	
wexp	
wbs	
wnt	



6u



exp1 s2pul

solvent	CDCl3

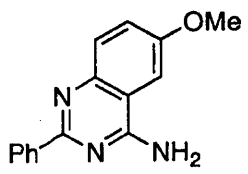
ACQUISITION	
sfrq	125.795
tn	C13
at	1.736
np	131010
sw	37735.8
fb	not used
bs	10
ss	1
tpwr	53
pw	6.9
d1	0.763
tof	631.4
nt	1000
ct	680
alock	n
gain	not used

FLAGS	
il	n
in	n
dp	y
hs	nn

DISPLAY	
sp	-2570.7
wp	30247.5
vs	237
sc	0
wc	250
hzmm	120.99
is	500.00
rfl	16004.1
rfp	9714.9
th	8
ins	1.000
ai	ph

DEC. & VT	
dfrq	500.229
dn	H1
dpwr	37
dof	-500.0
dm	y
dmm	w
dmf	10000
dseq	
dres	1.0
homo	n
temp	20.0

PROCESSING	
lb	0.30
wtfile	
proc	ft
fn	131072
math	f
werr	
wexp	
wbs	
wnt	



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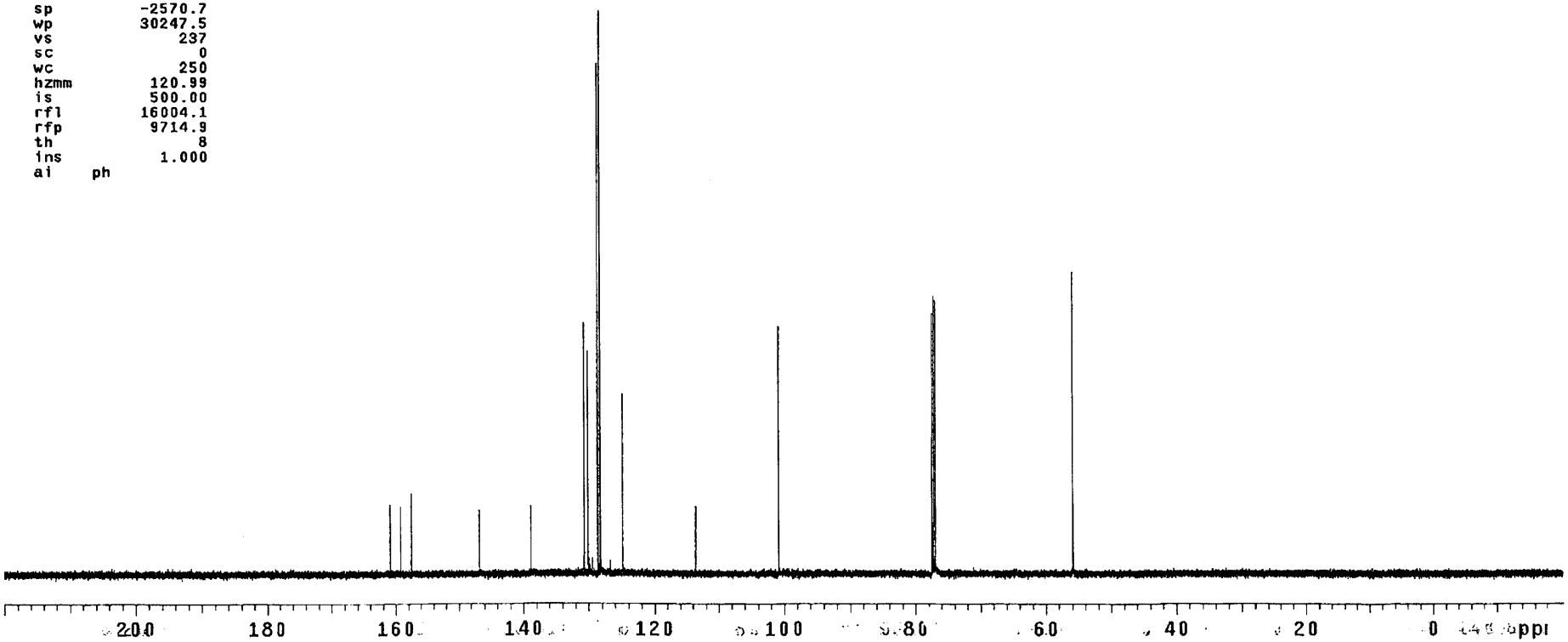

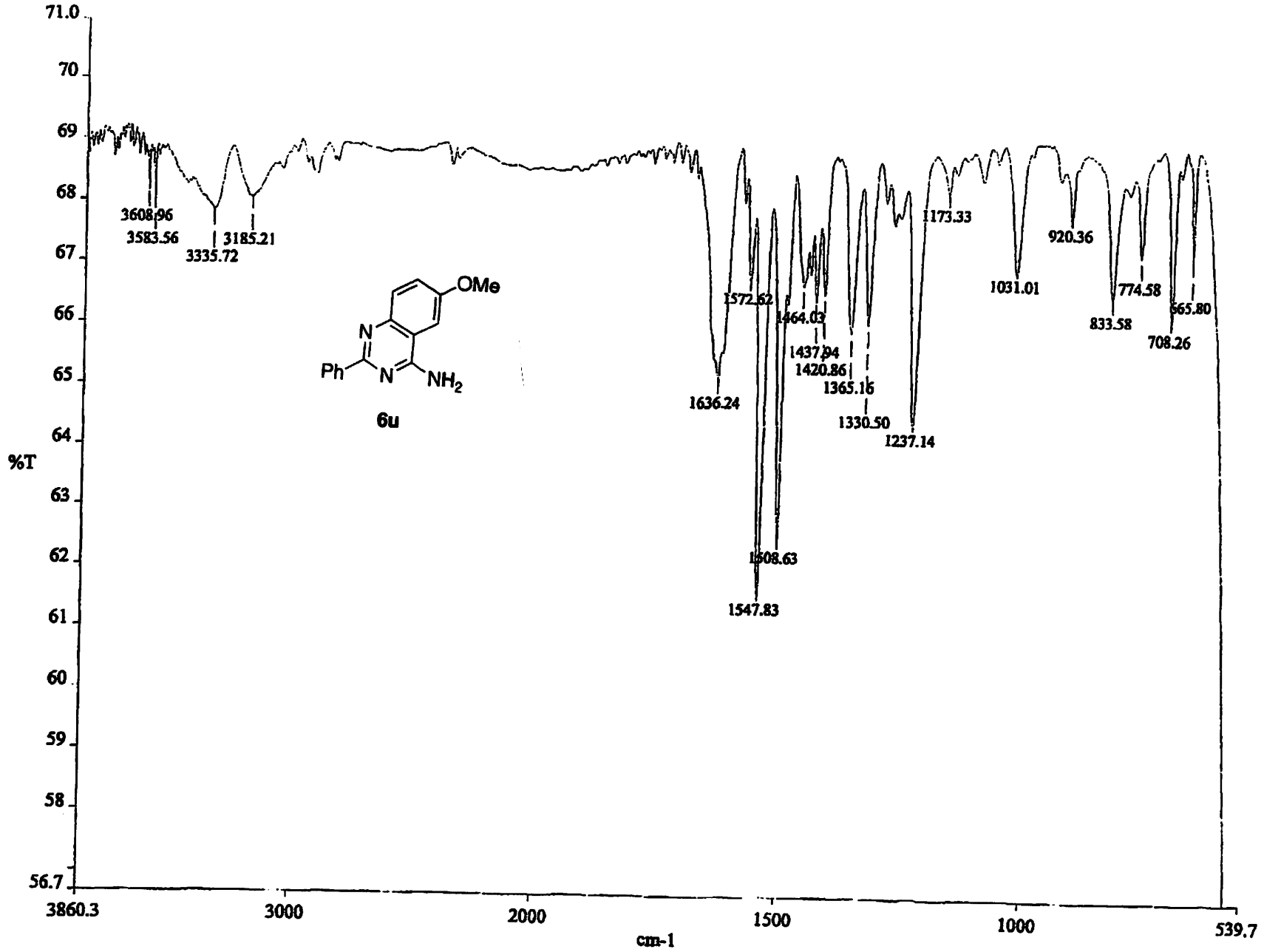
71.0
70
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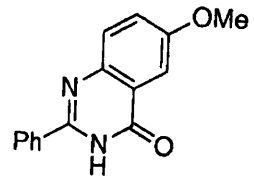
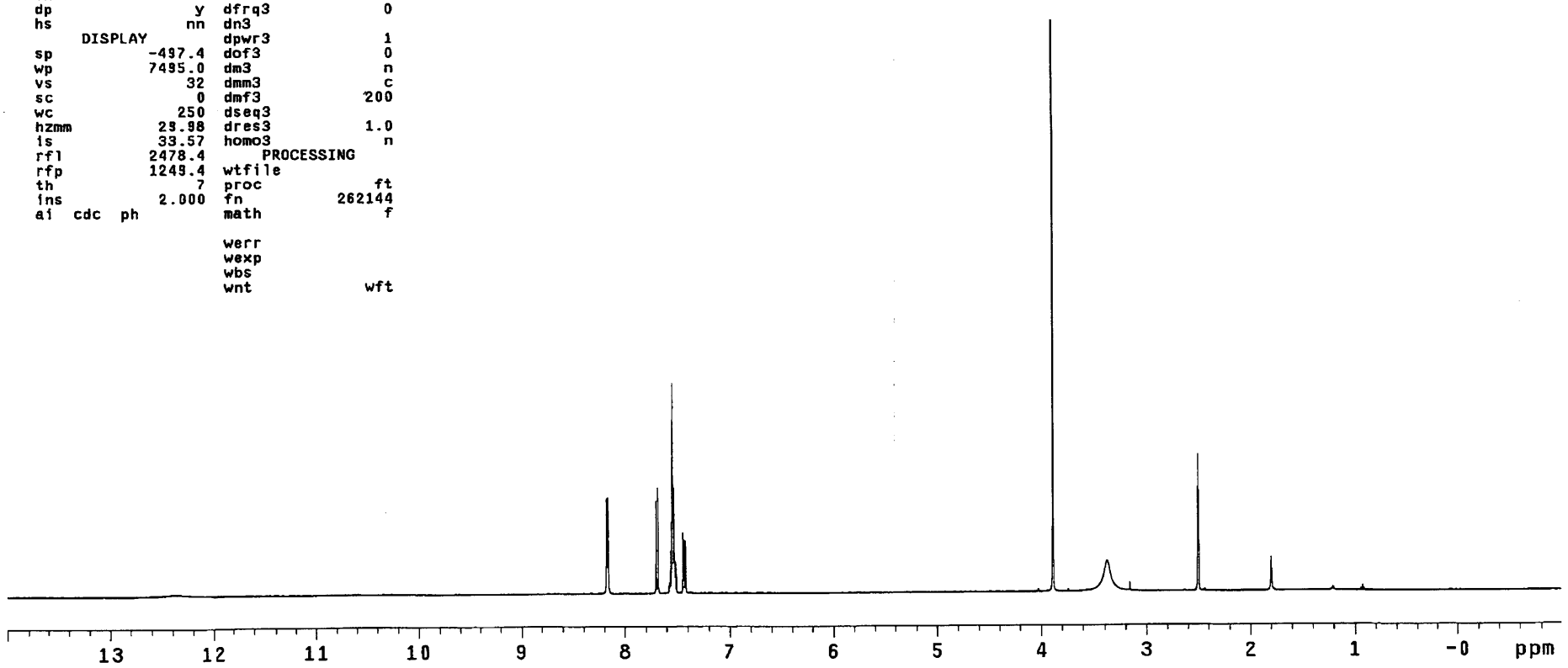
68
67
66
65
64
63
62
61
60
59
58
56.7
%T
3860.3
3000
2000
1500
1000
539.7
cm-1
3608.96
3583.56
3335.72
3185.21
1636.24
1572.62
1547.83
1508.63
1464.03
1437.94
1420.86
1365.16
1330.50
1237.14
1173.33
1031.01
920.36
833.58
774.58
708.26
665.80
OMe
N
Ph
N
NH2
6u

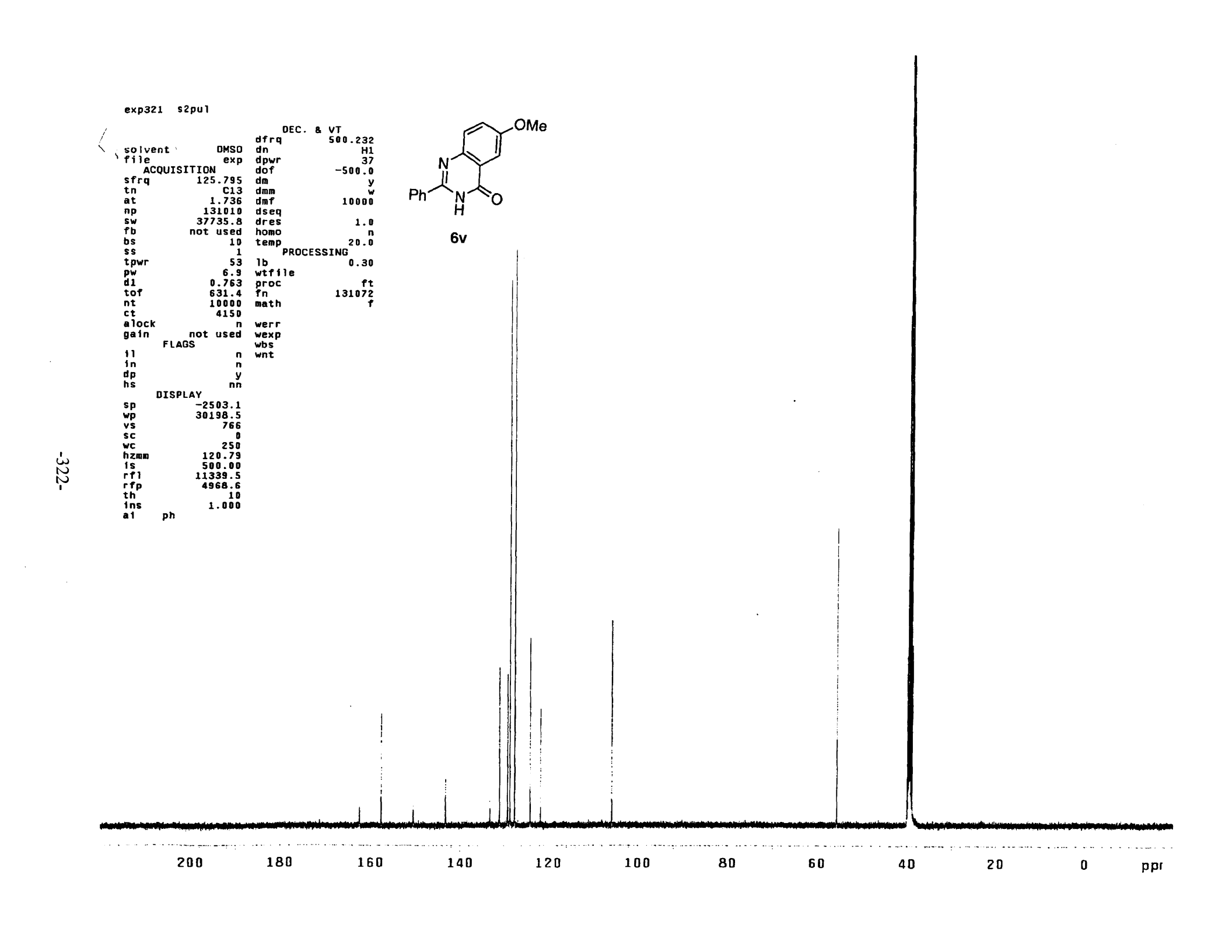
exp321 s2pul

		DEC. & VT	
		dfrq	125.673
solvent	DMSO	dn	C13
file	exp	dpwr	30
ACQUISITION		dof	0
sfrq	499.748	dm	nnn
tn	H1	dmm	w
at	3.001	dmf	10000
np	63050	dseq	
sw	10504.2	dres	1.0
fb	not used	homo	n
bs	2	DEC2	
tpwr	56	dfrq2	0
pw	8.6	dn2	
d1	2.000	dpwr2	1
tof	1519.5	dof2	0
nt	32	dm2	n
ct	18	dmm2	c
alock	n	dmf2	200
gain	not used	dseq2	
FLAGS		dres2	1.0
il	n	homo2	n
in	n	DEC3	
dp	y	dfrq3	0
hs	nn	dn3	
DISPLAY		dpwr3	1
sp	-497.4	dof3	0
wp	7495.0	dm3	n
vs	32	dmm3	c
sc	0	dmf3	200
wc	250	dseq3	
hzmm	29.98	dres3	1.0
is	33.57	homo3	n
rfl	2478.4	PROCESSING	
rfp	1249.4	wtfile	
th	7	proc	ft
ins	2.000	fn	262144
ai cdc ph		math	f
		werr	
		wexp	
		wbs	
		wnt	wft



6v




exp321 s2pul
solvent DMSO
file exp
ACQUISITION
sfrq 125.795
tn C13
at 1.736
np 131010
sw 37735.8
fb not used
bs 10
ss 1
tpwr 53
pw 6.9
d1 0.763
tof 631.4
nt 10000
ct 4150
alock n
gain not used
FLAGS
il n
in n
dp y
hs nn
DISPLAY
sp -2503.1
wp 30198.5
vs 766
sc 0
wc 250
hzmm 120.79
is 500.00
rfl 11339.5
rfp 4968.6
th 10
ins 1.000
ai ph
DEC. & VT
dfrq 500.232
dn H1
dpwr 37
dof -500.0
dm y
dmm w
dmf 10000
dseq
dres 1.0
homo n
temp 20.0
PROCESSING
lb 0.30
wtfile
proc ft
fn 131072
math f
werr
wexp
wbs
wnt
OMe
N
Ph
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H
O
6v
200
180
160
140
120
100
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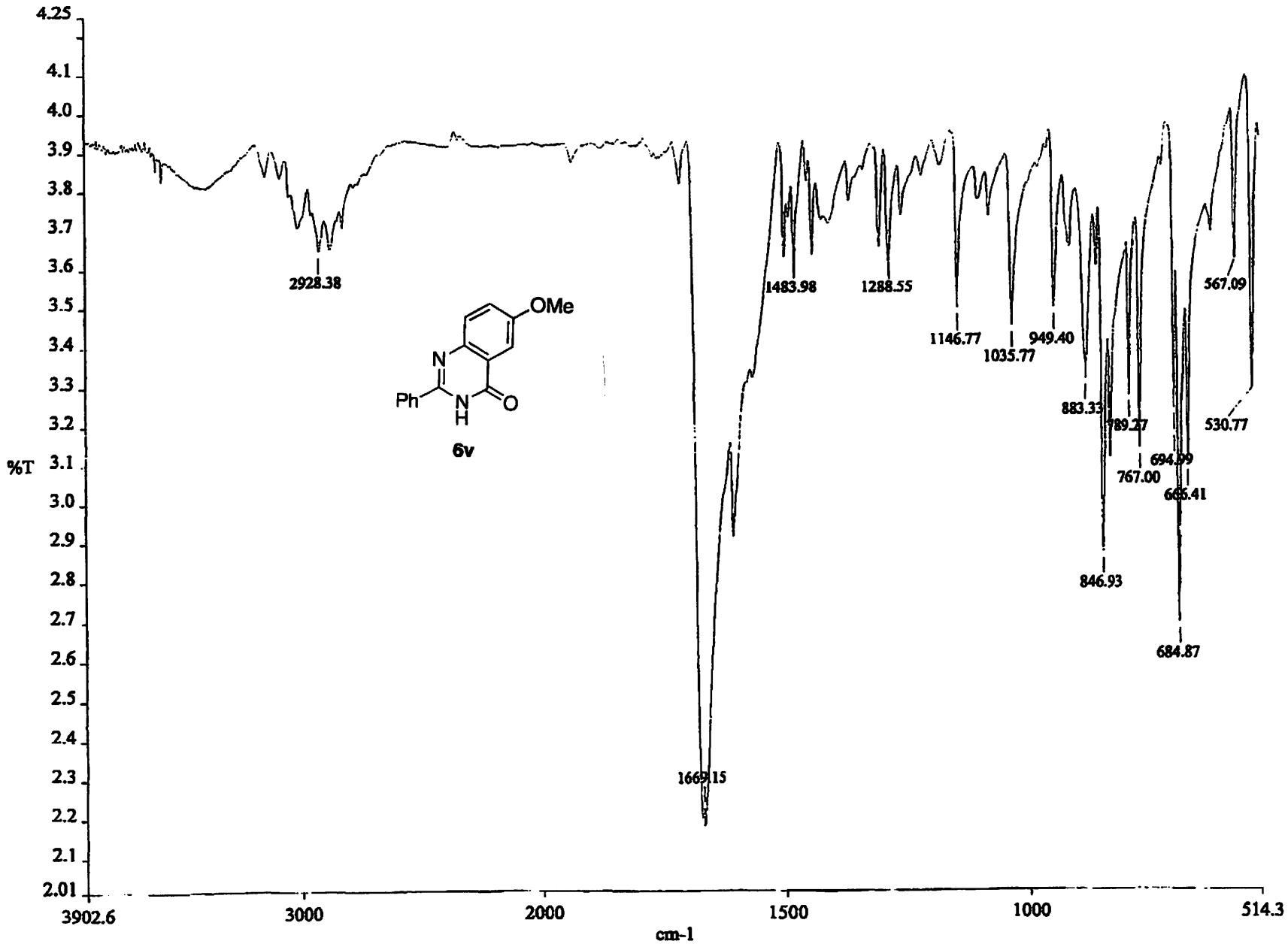
60
40
20
0
ppr


4.25
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4.0
3.9
3.8
3.7
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3.2
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3.0
2.9
2.8
2.7
2.6
2.5
2.4
2.3
2.2
2.1
2.01
%T
3902.6
3000
2000
1500
1000
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cm-1
2928.38
1669.15
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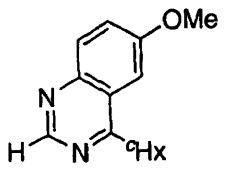
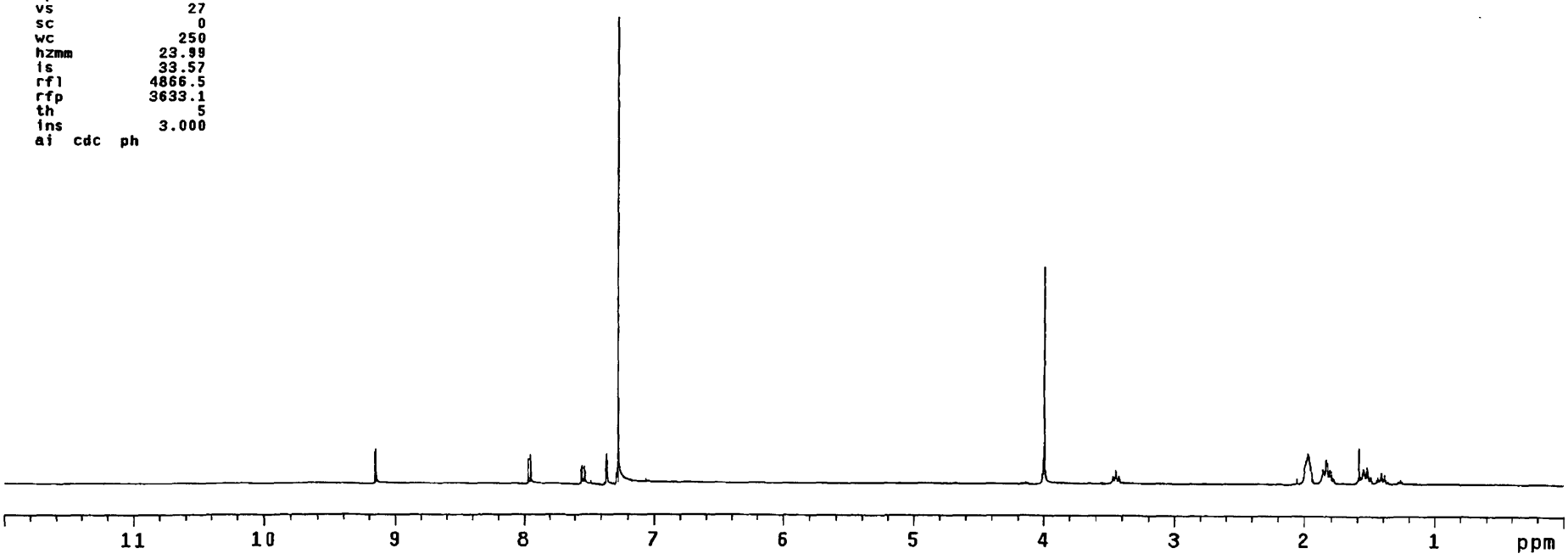
1146.77
1035.77
949.40
883.33
846.93
789.27
767.00
694.99
684.87
666.41
567.09
530.77
OMe
N
Ph
N
H
O
6v

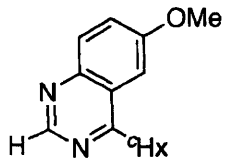
exp321 s2pul

ACQUISITION		DEC. & VT	
sfrq	499.746	dfrq	125.672
tn	H1	dn	C13
at	3.001	dpwr	30
np	63050	dof	0
sw	10504.2	dm	nnn
fb	not used	dmm	w
bs	2	dmf	10000
tpwr	56	dseq	
pw	8.6	dres	1.0
d1	2.000	homo	n
tof	1519.5	PROCESSING	
nt	32	wtfile	
ct	14	proc	ft
alock	n	fn	262144
gain	not used	math	f
FLAGS		werr	
il	n	wexp	
in	n	wbs	
dp	y	wnt	wft
hs	nn		
DISPLAY			
sp	-0.1		
wp	5996.8		
vs	27		
sc	0		
wc	250		
hzmm	23.99		
is	33.57		
rfl	4866.5		
rfp	3633.1		
th	5		
ins	3.000		
ai cdc ph			



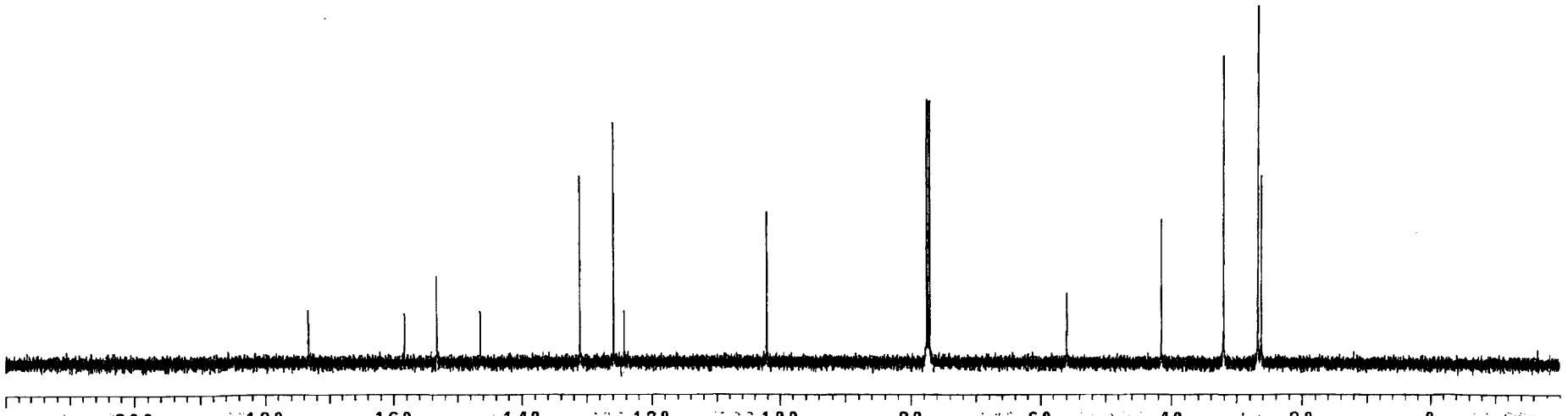
6w

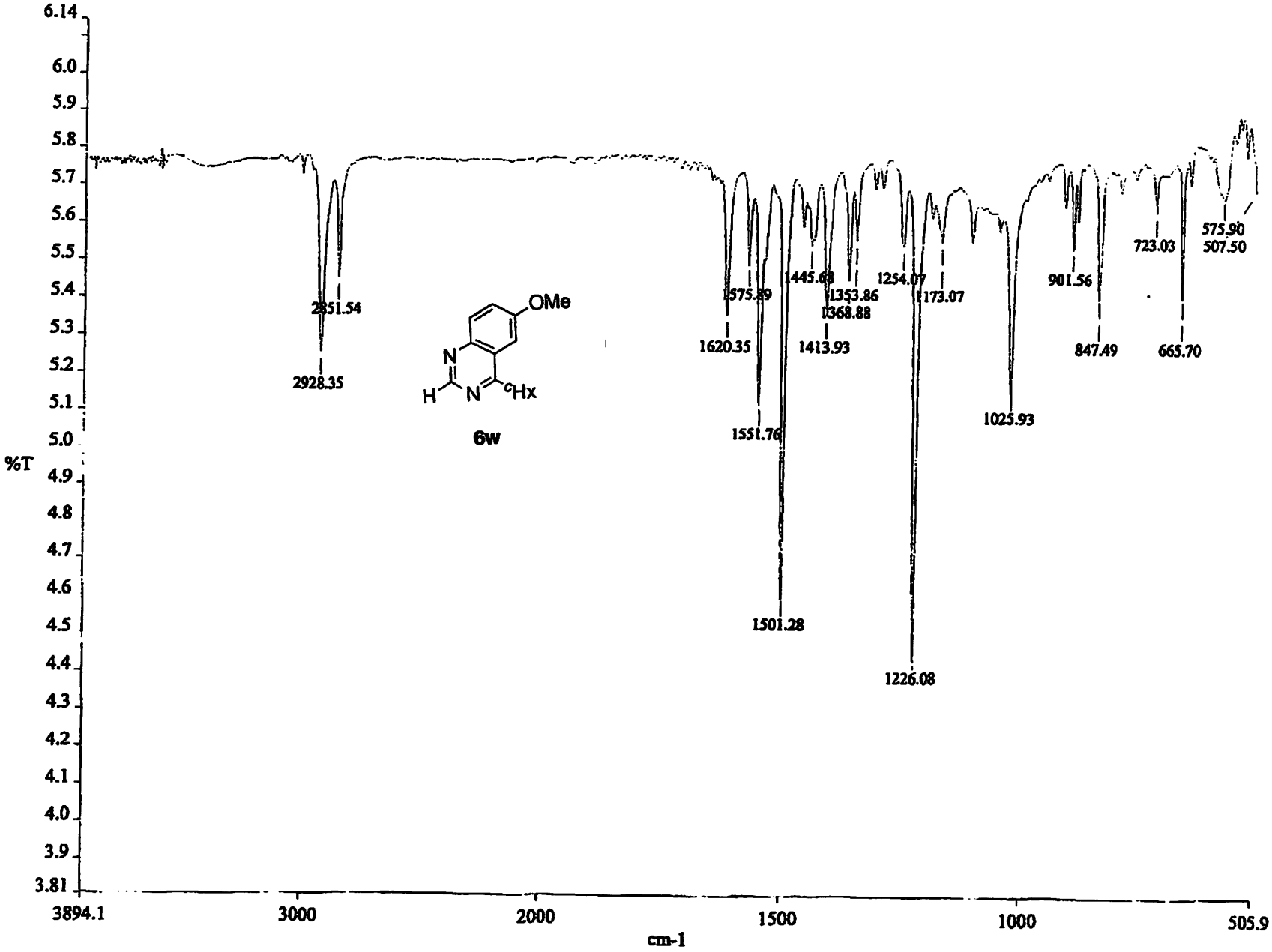




6w

ACQUISITION		DEC. & VT	
sfrq	125.796	dfrq	500.233
tn	C13	dn	H1
at	1.736	dpwr	44
np	131010	dof	-500.0
sw	37735.8	dm	y
fb	not used	dmm	w
bs	10	dmf	10000
ss	1	dseq	
tpwr	54	dres	1.0
pw	6.9	homo	n
d1	0.763	PROCESSING	
tof	631.4	lb	0.30
nt	3000	wtfile	
ct	740	proc	ft
alock	n	fn	131072
gain	not used	math	f
FLAGS		werr	
il	n	wexp	
in	n	wbs	
dp	y	wnt	
hs	nn		
DISPLAY			
sp	-2520.5		
wp	30198.0		
vs	452		
sc	0		
wc	250		
hzmm	120.79		
is	500.00		
rfl	16004.1		
rfp	9715.0		
th	19		
ins	1.000		
ai	ph		

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5.2
5.1
5.0
4.9
4.8
4.7
4.6
4.5
4.4
4.3
4.2
4.1
4.0
3.9
3.81
%T
3894.1
3000
2000
1500
1000
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cm-1
2928.35
2851.54
1620.35
1575.89
1551.76
1501.28
1445.68
1413.93
1368.88
1353.86
1254.07
1226.08
1173.07
1025.93
901.56
847.49
723.03
665.70
575.90
507.50
OMe
N
H
N
Hx
6w

solvent	CDCl3

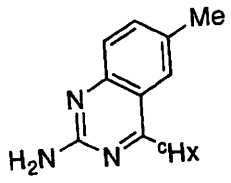
ACQUISITION	
sfrq	500.435
tn	H1
at	4.999
np	120102
sw	12012.0
fb	not used
bs	2
tpwr	56
pw	8.0
d1	0.100
tof	3003.2
nt	64
ct	54
alock	n
gain	not used

FLAGS	
il	n
in	n
dp	y
hs	nn

DISPLAY	
sp	-250.2
wp	6255.3
vs	157
sc	0
wc	250
hzmm	25.02
is	33.57
rfl	500.6
rfp	0
th	6
ins	2.000
ai cdc ph	

DEC. & VT	
dfrq	125.845
dn	C13
dpwr	30
dof	0
dm	nnn
dmm	c
dmf	200
dseq	
dres	1.0
homo	n

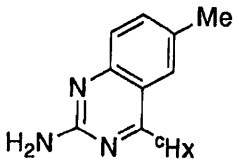
PROCESSING	
wtfile	
proc	ft
fn	262144
math	f
werr	
wexp	
wbs	
wnt	wft



6x

STANDARD CARBON PARAMETERS

		DEC. & VT	
solvent	CDCl3	lfrq	500.229
file	exp	dn	H1
ACQUISITION		dpwr	37
sfrq	125.795	dof	-500.0
tn	C13	dm	y
at	1.736	dmm	w
np	131010	dmf	10000
sw	37735.8	dseq	
fb	not used	dres	1.0
bs	8	homo	n
ss	1	PROCESSING	
tpwr	53	lb	0.30
pw	6.9	wtfile	
d1	0.763	proc	ft
tof	631.4	fn	131072
nt	4000	math	f
ct	3024		
alock	n	werr	
gain	not used	wexp	
FLAGS		wbs	
il	n	wnt	
in	n		
dp	y		
hs	nn		
DISPLAY			
sp	-2518.8		
wp	30198.5		
vs	206		
sc	0		
wc	250		
hzmm	120.79		
is	500.00		
rfl	16001.8		
rfp	9714.9		
th	12		
ins	1.000		
ai ph			



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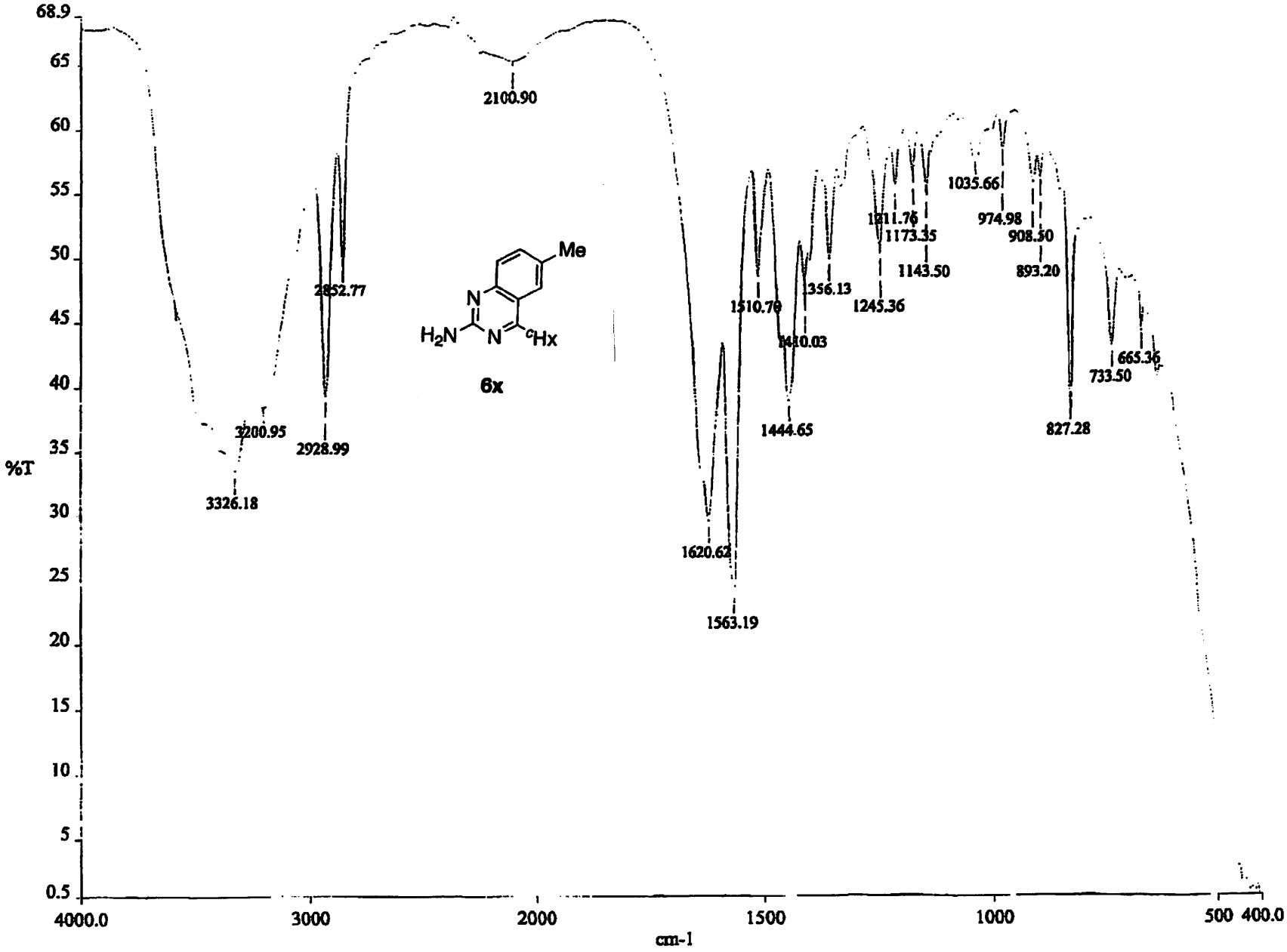
68.9
65
60
55
50
45
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3000
2000
1500
1000
500
400.0
cm-1
3326.18
3200.95
2928.99
2852.77
2100.90
1620.62
1563.19
1510.70
1444.65
1410.03
1356.13
1245.36
1211.76
1173.35
1143.50
1035.66
974.98
908.50
893.20
827.28
733.50
665.36
Me
N
H2N
N
cHx
6x

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EDUCATION

Massachusetts Institute of Technology, Cambridge, MA
Ph.D. Candidate, Organic Chemistry. GPA = 5.0/5.0
Brown University, Providence, RI
Sc.B. Chemistry with Honors, May 2005. GPA = 4.0/4.0

AWARDS

Bristol-Myers Squibb Graduate Fellowship (2009-2010)
Wyeth Scholar Award (2009)
Amgen Graduate Fellowship (2009)
Merck Graduate Fellowship (2008)
ACS Outstanding Chemistry Student Award (2005)
Graduated Magna cum Laude (2005)
Sigma Xi (2005)
Junior Prize in Chemistry (2004)
Phi Beta Kappa (2004)
Karen T. Romer Undergraduate Teaching and Research Award (2003)
CRC Freshman Chemistry Award (2002)

RESEARCH EXPERIENCE

Graduate Research, Massachusetts Institute of Technology (2005-present)
Advisor: Professor M. Movassaghi

- Explored the development of new synthetic methodology for total synthesis of dimeric hexahydropyrroloindole alkaloids.
- Developed the first catalytic and asymmetric synthesis of monoalkyl diazene intermediates for new reduction methodologies in organic synthesis.
- Explored and fully developed the chemistry of IPNBSH, a reagent that is now commercially available.
- Contributed to the development of a new synthesis of pyridine derivatives.
- Developed new syntheses of highly substituted azaheterocycles.

Undergraduate Research, Brown University (2001-2005)
Advisor: Professor A. Basu

- Explored the synthesis of crosslinked shells for encagement of gold nanoclusters.
- Developed solid-phase synthesis of stilbene derivatives.

Advisor: Professor D. Sweigart

- Investigated the synthesis of metal-organometallic networks using aryl-manganese complexes.

TEACHING EXPERIENCE

Chemistry Department, MIT
Teaching Assistant for Graduate-level Second Semester Organic Synthesis (Spring 2008)
Chemistry Department, MIT
Teaching Assistant for Undergraduate-level Organic Chemistry (Fall 2005, Spring 2006)
Chemistry Department, Brown University
Teaching Assistant for Undergraduate-level Organic Chemistry Laboratory (Fall 2003, Fall 2004)
Chemistry Department, Brown University
Teaching Assistant for General Chemistry (Fall 2002)

Curricular Resource Center, Brown University
Tutor for Introductory Calculus (Fall 2001)

LEADERSHIP EXPERIENCE

Editor-in-Chief: The Critical Review, Brown University (2004-2005)
Coordinator of International Mentoring Program: Coordinated mentoring program for first-year students at Brown University (2002-2004)
Graduate Student Mentor: Graduate student mentor for two undergraduate students in the Chemistry Department at MIT (2006-2009)

LANGUAGES

English (fluent); Urdu/Hindi (fluent); French (advanced); Modern Greek (intermediate)

PUBLICATIONS

- "Synthesis of 9-Allyl Anthracene using Palladium-Catalyzed Reduction with IPNBSH." Willwacher, J.; Ahmad, O. K.; Movassaghi, M. *Org. Synth.* manuscript in preparation.
- "Direct Synthesis of Quinazolines and Quinolines from *N*-Aryl Amides." Ahmad, O. K.; Medley, J. W.; Movassaghi, M. *Org. Synth.* manuscript in preparation.
- "Synthesis of Densely Substituted Pyrimidine Derivatives." Ahmad, O. K.; Hill, M. D.; Movassaghi, M. *J. Org. Chem.* **2009**, *74*, 8460-8463.
- "Stereospecific Palladium-Catalyzed Route to Monoalkyl Diazenes for Mild Allylic Reduction." Movassaghi, M.; Ahmad, O. K. *Angew. Chem. Int. Ed.* **2008**, *47*, 8909-8912.
- "Benzenesulfonic Acid, 2-Nitro-(1-Methylethylidene)hydrazide." Movassaghi M., Ahmad, O. K. *e-Encyclopedia of Reagents for Organic Synthesis* **2008**.
- "*N*-Isopropylidene-*N'*-2-Nitrobenzenesulfonyl Hydrazine. A Reagent for Reduction of Alcohols via the Corresponding Monoalkyl Diazenes." Movassaghi, M.; Ahmad, O. K. *J. Org. Chem.* **2007**, *72*, 1838-1841.
- "Direct Synthesis of Pyridine Derivatives." Movassaghi, M.; Hill, M. D.; Ahmad, O. K. *J. Am. Chem. Soc.* **2007**, *129*, 10096-10097.

PRESENTATIONS

- "Development of New Methodologies for Organic Synthesis." AstraZeneca Excellence in Chemistry Symposium, Waltham, MA, October 4, 2010.
- "Development of New Methodologies for Organic Synthesis." Bristol-Myers Squibb Chemistry Awards Symposium, Ewing, NJ, April 22-23, 2010.
- "Development of New Methodologies for Organic Synthesis." Graduate Research Symposium in Organic and Bioorganic Chemistry, MIT, Cambridge, MA, January 2009
- "*N*-Isopropylidene-*N'*-2-Nitrobenzenesulfonyl Hydrazine, a Reagent for Reduction of Alcohols via the Corresponding Monoalkyl Diazenes." 234th ACS National Meeting, Boston, MA, August 19, 2007.
- "Synthesis of Crosslinked Shells for the Encagement of Gold Nanoclusters." Undergraduate Awards Symposium, Rhode Island Section of the American Chemical Society, Bristol, RI, May 12, 2010.

REFERENCES

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