STUDIES ON METABOLITES OF THE SARGASSACEAE AND DICTYOTACEAE BROWN ALGAE

Midori OINUMA

1988

(1)

DISSERTATION

STUDIES ON METABOLITES OF THE SARGASSACEAE AND DICTYOTACEAE BROWN ALGAE

BY

Midori Oinuma

Department of Chemistry

University of Tsukuba

Ibaraki, Japan

Submitted in partial fulfillment of the

requirements for the degree of

Doctor of Science

1988

CONTENTS

INTRODUCTION

Plants are in very close contact with human being, and they are inevitable for our life, not only because they afford us foods, woods, and other useful materials, but also because they produce such constituents that are used as medicines, insecticides, and other biologically significant compounds. A lot of studies have been done for the constituents of terrestrial plants, but very few attention has been paid toward marine plants, seaweeds. Simple reason of this is that marine plants grow in the sea, where man cannot go without special devices, and, moreover, not much information about their physiology has been obtained in contrast to that about terrestrial plants. However, owing to recent findings that marine organisms produce a variety of compounds quite different from those of terrestrial organisms, and some of the compounds exhibit significant biological and pharmaceutical properties, increasing interests have been focused on the ingredients of seaweeds, marine mollusks, and microorganisms.

This thesis describes the structure determination of the constituents of the brown algae belonging to Sargassaceae and Dictyotaceae. The seaweeds are very commonly seen along the Japanese coasts, and I could isolate a plenty of new compounds from them. Most of them have unique structures that have never seen in terrestrial plants.

The first chapter deals with the structure determination

of the constituents of Sargassaceae seaweeds. This chapter is divided into four sections according to biogenetical types of the compounds, followed by experimental parts.

The second chapter describes the isolation and the structure determination of the diterpenoids of Dictyotaceae algae. This chapter is divided into seven sections and arranged in the same manner as in the first chapter. In the final section of them, the biogenetic pathways of the diterpenoids isolated from the Dictyotaceae brown algae are proposed.

C H A P T E R I

STUDIES ON METABOLITES OF THE SARGASSACEAE BROWN ALGAE

Brown algae belonging to the family Sargassaceae are among the most abundant seaweeds growing along Japanese coast. I investigated the constituents of ten species of this family (Table 1), collected at Awakominato, Chiba, and isolated a number of new compounds including plastoquinones, linear terpenoids, and a new type of glyceride. This chapter deals with the structures of these compounds.

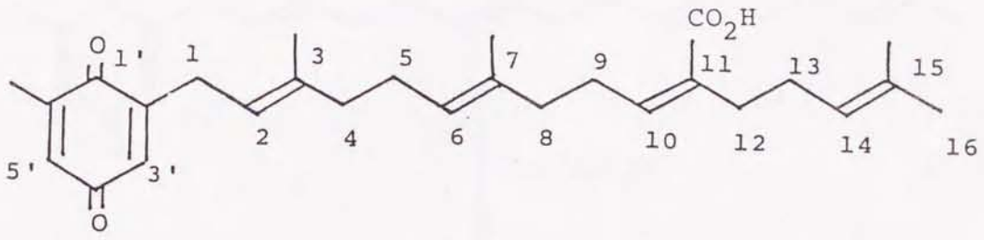
Table 1. Sargassum spp.

S. serratifolium	(nokogirimoku)
S. tortile	(yoremoku)
S. micracanthum	(togemoku)
S. fulvellum	(hondawara)
S. piluliferum	(mametawara)
S. giganteifolium	(oobanokogirimoku)
S. ringgoldianum	(oobamoku)
S. sagamianum	(nezimoku)
S. hemiphyllum	(isomoku)
S. yendoi	(endoumoku)

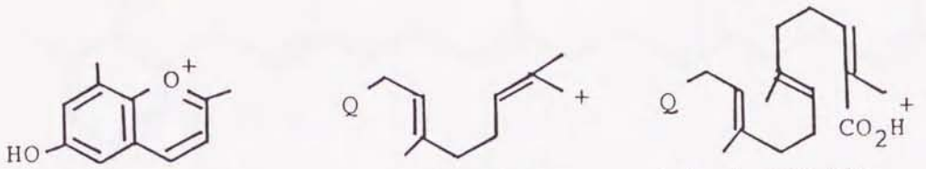
I-A Components of Sargassum serratifolium[1)]

Methanolic extraction of the fresh brown alga S. serratifolium, followed by chromatographic separation afforded three new compounds, sargaquinoic acid (1), sargaquinal (2), and sargachromenol (6).

Sargaquinoic acid (1), oil, $C_{27}H_{36}O_4$, shows the following spectral properties: λ_{max}(EtOH) 251 nm (ε14500); ^{1}H-NMR($CDCl_3$)δ 6.56 (1H, dq, J=2, 0.5 Hz), 6.46 (1H, dt, J=2, 0.5 Hz), 6.02 (1H, t, J=6 Hz, 10-H), 5.16 (3H, m, 2-, 6-, 14-H's), 3.14 (2H, brd, J=7 Hz, 1-H), 2.62 (2H, q, J=7 Hz, 9-H), 2.04 (3H, brs, quinone Me), 1.68 (3H, brs, 3-Me), 1.63, 1.61, 1.59 (each 3H, brs, 7-, 15-, 15-Me's); IR($CHCl_3$): 3400-2500, 1680, 1650, 1610 cm^{-1}. The ^{13}C-NMR ($CDCl_3$) data of sargaquinoic acid showed the presence of five methyls (δ 15.9, 16.0, 16.1, 17.7, 25.7), seven methylenes (δ 26.4, 27.6, 27.9, 28.2, 34.6, 39.1, 39.6) and six trisubstituted olefins (singlets at δ 130.7, 132.2, 134.6, 139.8, 145.9, 148.5 and doublets at δ 118.1, 123.5, 124.6, 132.3, 133.2, 145.6), together with benzoquinone carbonyls (δ 188.0) and a carboxyl carbon (δ 173.5). The coupling constant (2 Hz) of the two quinone protons in ^{1}H-NMR suggested the meta orientation of the methyl group and the C_{20}-side chain. The E-configurations of the double bonds at C_2-C_3 and C_6-C_7 were determined by the chemical shifts of the two vinyl methyls,[2)] and that at C_{10}-C_{11} by comparison of the chemical shifts of the olefinic proton at C_{10} and C_9-methylene



1



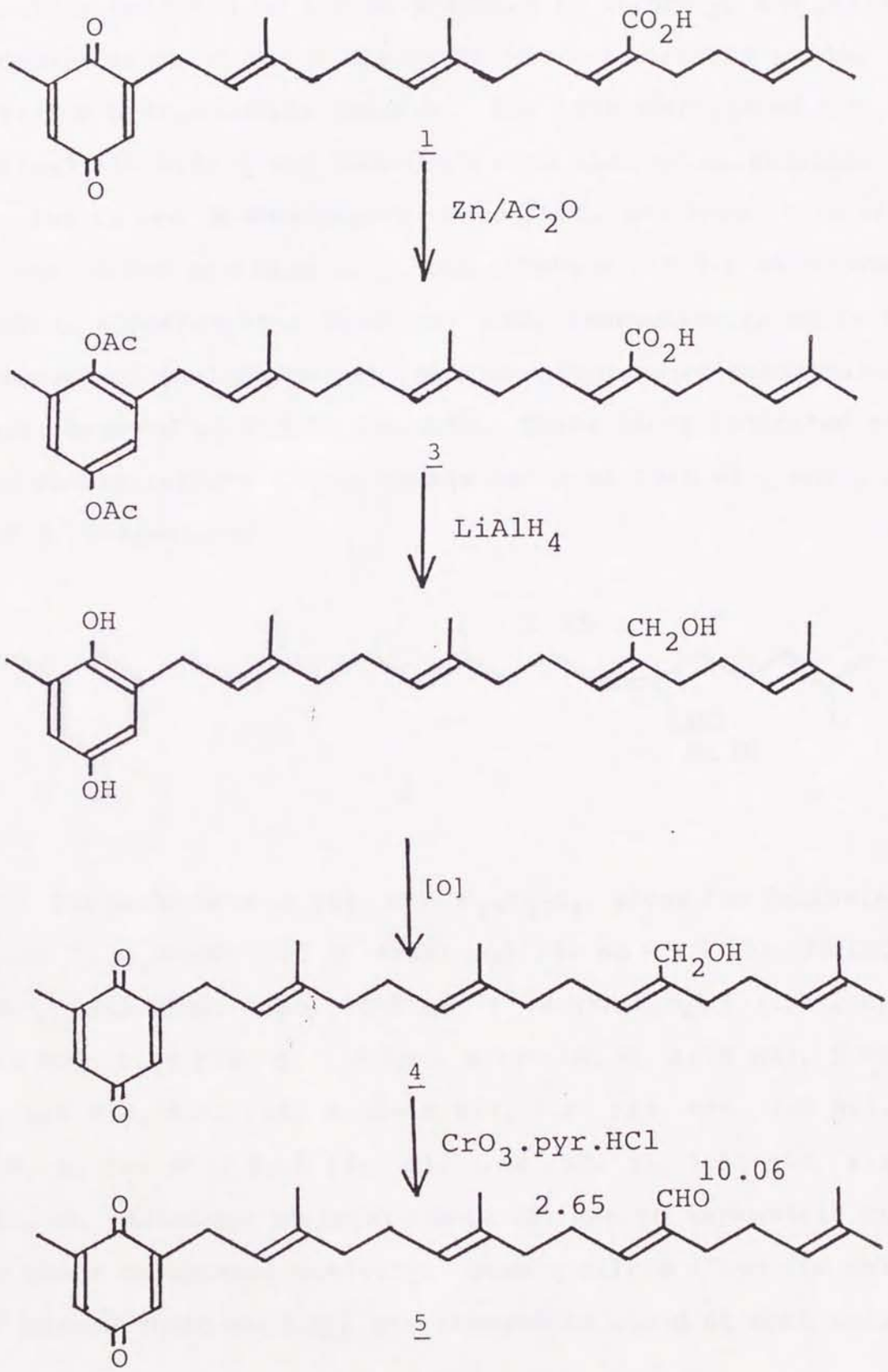
[A] m/e 175.076 [B] m/e 257.154 [C] m/e 355.186

Q = 2-methyl-2,5-cyclohexadiene-1,4-dion-6-yl

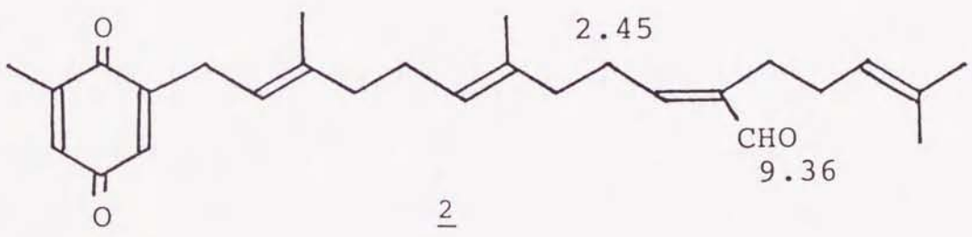
protons with those reported[3] for E- and Z-2-methyl-2-pentenoic acids. The mass spectrum of 1 showed the base peak at m/e 175 due to the fragment (A), typical of the compounds such as plastoquinones and ubiquinones. The fragments (B) and (C) settled the position of the carboxyl group at C-11.

Sargaquinal (2), oil, $C_{27}H_{36}O_3$, λ_{max}(EtOH) 250 nm (ε 15000), IR($CHCl_3$): 1675, 1650 cm^{-1} exhibited the ^{1}H-NMR spectrum similar to that of 1. From the molecular formula and a sharp singlet at δ 9.36 in the spectrum, sargaquinal was considered to have an aldehyde function instead of the carboxyl group of 1. Hence, conversion of 1 into sargaquinal was attempted (Figure 1). Treatment of 1 with zinc-acetic anhydride yielded diacetate (3), which was reduced with excess lithium aluminum hydride. The resulting hydroquinone was

Figure 1.

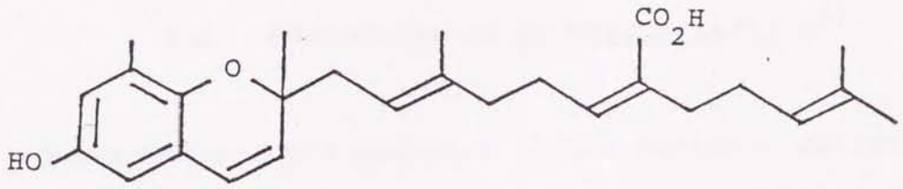

O
O
CO_2H
1
Zn/Ac_2O
OAc
OAc
CO_2H
3
$LiAlH_4$
OH
OH
CH_2OH
[O]
O
O
CH_2OH
4
$CrO_3.pyr.HCl$
O
O
10.06
2.65
CHO
5

smoothly oxidized by air on standing to afford 4, the primary hydroxyl group of which was oxidized with chromium oxide-pyridine hydrochloride complex. The mass spectrum of the derived aldehyde 5 was identical with that of sargaquinal (2), but the IR and ^{1}H-NMR spectra were different from those of 2; in the ^{1}H-NMR spectrum of 5, the aldehyde and 9-C methylene protons appeared at δ 10.06 and 2.65, respectively, while the corresponding aldehyde and methylene protons of sargaquinal (2) were observed at δ 9.36 and 2.45. These facts indicated that the configurations of the double bonds at 10-C of 5 and 2 are Z and E, respectively.



2

Sargachromenol (6), oil, $C_{27}H_{36}O_4$, gives the following data: λ_{max}(MeOH) 263 (ε 4900) and 332 nm (ε 2770); IR($CHCl_3$): 3600, 3500-2500, 1680, 1590 cm^{-1}; ^{1}H-NMR(C_6D_6) δ 6.35 (1H, d, J=2 Hz), 6.25 (1H, d, J=2 Hz), 6.11 (1H, d, J=10 Hz), 5.90 (1H, t, J=7 Hz), 5.31 (1H, d, J=10 Hz), 5.20 (2H, brt, J=6 Hz), 2.68 (2H, q, J=7 Hz), 2.15 (3H, s), 1.68 (3H, s), 1.56 (6H, s), 1.30 (3H, s). Although sargachromenol (6) has an asymmetric center, it shows no optical activity. When a dilute alcoholic solution of sargaquinoic acid (1) was allowed to stand at room tempera-



6

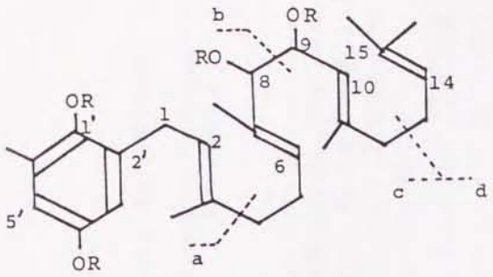
ture for one week, 1 was quantitatively converted into sargachromenol. Sargachromenol (6) must therefore be an artifact which was formed during the extraction process with methanol.

I-B Components of *Sargassum tortile*[4)]

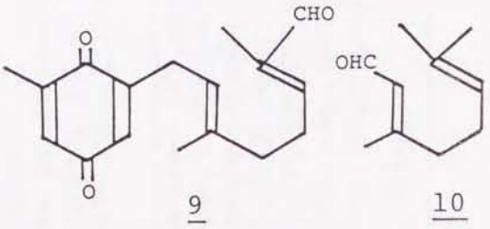
The ether-soluble material of the methanol extract of fresh *S. tortile*, collected at Awa-kominato, Chiba, was fractionated by flash chromatography using hexane-ethyl acetate (1:1). Repeated preparative TLC and HPLC of the resulting fractions afforded seven new compounds, 7, 11, 13, 15, 16, 17, and 18 (Figure 2), spectral properties of which are listed in the Table 2 and 3.

The major component, which was named as **sargatetraol (7)**, afforded tetraacetate (8). Presence of an α-glycol moiety was deduced from the ^{1}H-NMR spectra of 7 and 8. Treatment of 7 with periodic acid in dry ether yielded geranial (10) [IR(CCl_4) 1675 cm^{-1}; ^{1}H-NMR($CDCl_3$) δ 10.08 (1H, d, J=8 Hz), 5.90 (1H, d, J=8 Hz), 5.1 (1H, m), 2.15 (3H, s), 1.67 (3H, s), 1.59 (3H, s)] and the quinone (9) [IR(CCl_4) 1690, 1655, 1610 cm^{-1}; ^{1}H-NMR($CDCl_3$) δ 9.48 (1H, s), 6.62 (1H, m), 6.50 (1H, m), 6.50 (1H, t, J=7 Hz), 5.26 (1H, t, J=7 Hz), 3.17 (2H, d, J=8 Hz), 2.07 (3H, d, J=1.5 Hz), 1.76 (3H, s), 1.70 (3H, s)]. The production of these aldehydes settled the position of the two hydroxy groups at 8 and 9-C. The chemical shifts of 3-Me protons (δ 2.15) of 10 and the aldehyde proton (δ 9.48)[1,3)] of 9 were consistent with the *E,E*-configurations of 6 and 10-C double bonds of 7. The configuration of 2-C double bond was determined to be *E* from the upfield chemical shifts[5)] of the signals (δ 15.6, 16.1, 16.8, 17.6) due to 3, 7, 11 and 15 (*trans* to the olefin proton)

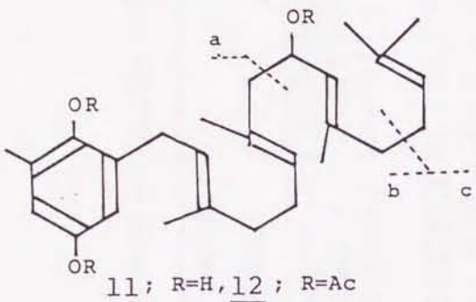
Figure 2.



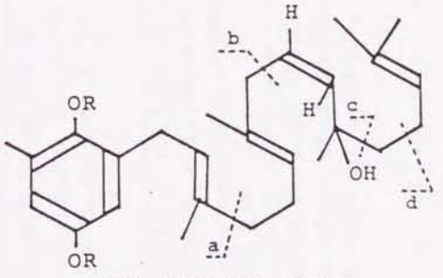
7 ; R=H, 8 ; R=Ac



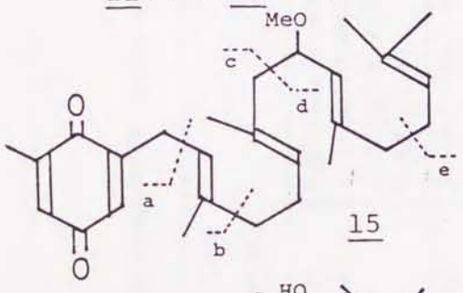
9 10



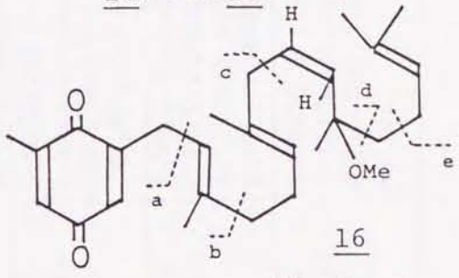
11; R=H, 12 ; R=Ac



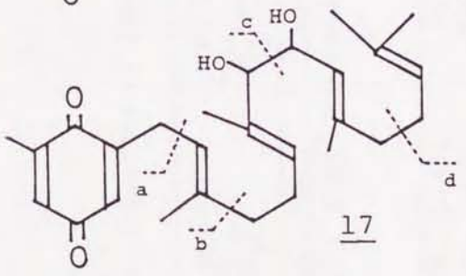
13; R=H, 14 ; R=Ac



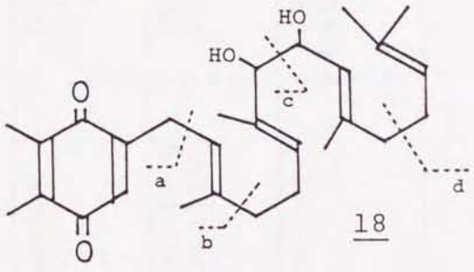
15



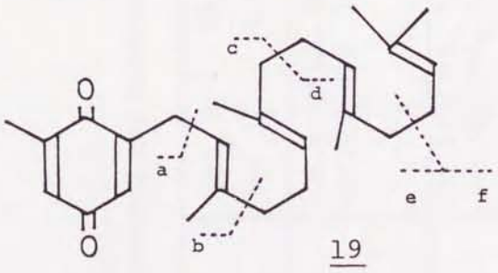
16



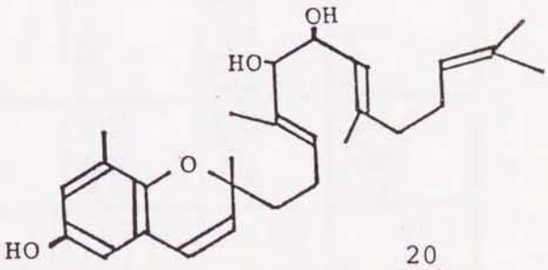
17



18



19



20

Table 2.
Spectral and physical properties of the compounds isolated from S. tortile and their derivatives.

	$[\alpha]_D$ ($CHCl_3$)	IR (cm^{-1}) (CCl_4)	UV (nm) (ε, EtOH)	NMR (δ) (CCl_4)	MS (m/e) *
7	-25.4° c=0.47	3610, 3600-3100, 1210, 1180, 1140	290 (2840)	1.57(6H,s),1.63(9H,s),2.12(3H,s), 3.12(2H,d,J=7 Hz),3.87(1H,d,J=8Hz), 4.31(1H,t,J=8 Hz),5.0-5.4(4H,m), 6.44(2H,s)	410(M-H_2O),408(M-2H-H_2O),392(M-$2H_2O$),323 (c-$2H_2O$),275(b),175 (a-2H),69(d)
8	+31.1° c=0.54	1765, 1740, 1245, 1225, 1210, 1170	260 (588)	1.56,1.60,1.65,1.73,1.94,1.97,2.11, 2.19,2.24(each 3H,s),3.16(2H,d,J=7 Hz),4.9-5.3(3H,m),5.11(1H,d,J=8Hz), 5.5(1H,m),5.66(1H,dd,J=8,10 Hz), 6.77(2H,ABq,J=3 Hz),1.65(3H,s)	536(M-AcOH),494(536-C_2H_2O),476(M-2AcOH), 434(476-C_2H_2O),401(b), 359(b-C_2H_2O),317(b-2C2H2O)
11	-12.8° c=0.89	3610, 3600-3200	290 (2470)	1.58(3H,s),1.62(3H,s),1.66(9H,s), 2.10(3H,s),3.18(2H,d,J=7 Hz),4.40 (1H,q,J=7 Hz),5.0-5.3(4H,m),6.36 (2H,ABq,J=3 Hz)	412(M),410(M-2H),394 (M-H_2O),392(410-H_2O), 325(b-H_2O),257(a-2H)
12	+7.36° c=1.10	1765, 1730, 1370, 1240, 1210, 1170	262 (605)	1.59,1.67,1.67,1.68,1.70,1.91,2.12, 2.19,2.24(each 3H,s),3.17(2H,d,J=7 Hz),5.0-5.3(4H,m),5.60(1H,q,J=8Hz), 6.78 (2H,ABq,J=2 Hz)	478(M-AcOH),436(478-C_2H_2O),409(b-AcOH), 394(436-C_2H_2O),301(a -C_2H_2O),69(c)
13	+3.51° c=0.57	3610, 3600-3200	290 (1950)	1.23(3H,s),1.57(6H,s),1.65(6H,s), 2.11(3H,s),2.66(2H,br.s),3.20(2H, d,J=7 Hz),4.8-5.6(5H,m),6.36(2H, br.s)	410(M-2H),392(410-H_2O) 327(c-2H),325(d-H_2O), 323(325-2H),257(b-2H), 175(a-2H)

Table 3.
Spectral and physical properties of the compounds isolated from S. tortile and their derivatives.

	$[\alpha]_D$ ($CHCl_3$)	IR (cm^{-1}) (CCl_4)	UV (nm) (ε, EtOH)	NMR (δ) (CCl_4)	MS (m/e) *
14	+3.17° c=0.82	3600, 1765, 1370, 1210, 1170, 975	end absorption	1.18,1.57,1.57,1.66,1.66,2.11,2.19, 2.24(each 3H,s),2.65(2H,br.s),3.16 (2H,d,J=7 Hz),4.9-5.5(5H,m),6.75 (2H,ABq,J=3 Hz)	478(M-H_2O),413(c), 371(c-C_2H_2O),329(c -2C_2H_2O),175(a-2H-2C_2H_2O)
15	+2.68 c=0.56	1655, 1615, 1295, 1100	253 (14700)	1.60(6H,s),1.65(9H,s).2.05(3H,d,J= 1.5 Hz),3.10(2H,d,J=8 Hz),3,12(3H, s),3.88(1H,q,J=8 Hz),4.9-5.2(4H,m), 6.40(1H,br.m),6.50(1H,br.m)	424(M),392(M-MeOH), 257(c),175(b),167(d), 135(a),69(e)
16	0 c=0.83	1655, 1615, 1295, 1075, 980	253 (15800)	1.16(3H,s),1.58(6H,s),1.65(6H,s), 2.04(3H,d,J=1.5 Hz),2.70(2H,d,J=5 Hz),3.07(3H,s),3.10(2H,d,J=8 Hz), 5.0-5.5(5H,m),6.39,6.50(each 1H,br. m)	424(M),392(M-MeOH), 341(d),257(c),175(b), 135(a),69(e)
17	-15.5° c=0.39	3600-3300, 1655, 1630, 1615	253 (13100)	1.58(6H,s),1.61(3H,s),1.65(6H,s), 2.04(3H,d,J=1.5 Hz),3.09(2H,d,J=8 Hz),3.71(1H,d,J=8 Hz),4.15(1H,t,J= 8 Hz),5.0-5.4(4H,m),6.45,6.53(each 1H,br.m)	426(M),410(M+2H-H_2O), 273(c),175(b),137 (a+2H),69(d)
18	-7.75° c=0.40	3600-3300, 1650, 1630, 1615	255 (13400)	1.60(9H,s),1.66(6H,s),2.01(6H,s), 3.09(2H,d,J=8 Hz),3.71(1H,d,J=8 Hz), 4.14(1H,t,J=8 Hz),5.0-5.4(4H,m), 6.44(1H,finely splitted triplet)	440(M),424(M+2H-H_2O), 422(M-H_2O),287(c), 189(b),151(a+2H),69 (d)
19		1650, 1610, 1290, 915	252 (12400)	1.59(9H,s),1.66(6H,s),2.05(3H,d, J=1.5 Hz),3.12(2H,d,J=8 Hz),5.1 (4H,m),6.42(1H,br.m),6.53(1H,br.m)	396(M+2H),394(M),325 (e),257(c),175(b), 137(d),135(a),69(f)

*Letters a,b,c,d,e,and f correspond to the fragments depicted in the Figure.

methyls, in the ^{13}C-NMR spectrum of 7. The structure was further confirmed by the following transformation. Oxidation of 7 with silver oxide in ether afforded the quinone 17, which was also isolated from this alga as a minor component (vide infra). When the synthesized quinone 17 was heated in pyridine, it changed into the chromenol (20) in a good yield. This chromenol and its triacetate (acetic anhydride-pyridine) exhibited the same spectral and chiloptical properties as those of sargatriol (20), which has been reported to be a constituent of this alga,[6] although the synthesized chromenol (20) was seemingly a mixture of epimers at 3-C.

From the fraction slightly less polar than that containing 7, two **hydroquinone** isomers, **11 and 13**, were obtained. Acetylation of 11 and 13 with acetic anhydride-pyridine afforded the triacetate (12) and the diacetate (14), respectively, suggesting the presence of a secondary hydroxyl on 11 and a tertiary hydroxyl in 13. The position of the hydroxy groups of these compounds was determined on the basis of their mass spectra (Figure 2). The trans-geometry of 9-C double bond of 13 was deduced from the IR band at 975 cm^{-1}.

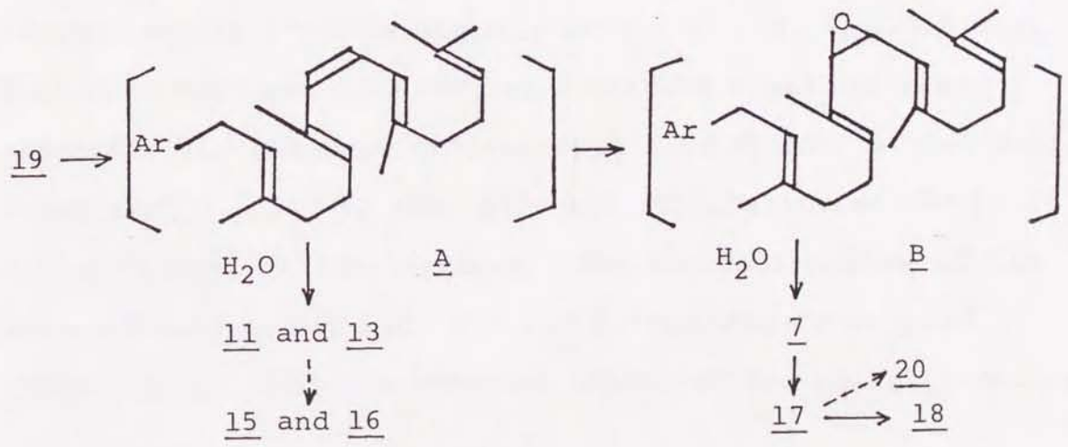
Analogous pair of **methyl ethers, 15 and 16**, were also isolated from a colored fraction. The isomer 15 exhibited a distinct optical rotation; $[\alpha]_D$ +1.8°. Although $[\alpha]_D$ value of another isomer 16 was zero, it showed plus optical rotation at shorter wave length.

Two **quinones, 17 and 18**, were obtained from less polar

fraction. The Rf values of the two quinones were quite identical under various solvent system, and the two compounds were only separable by preparative HPLC (MeOH : H_2O = 7 : 1). The mass (M^+ m/e 440) and the ^{1}H-NMR (δ 2.01, 6H, quinone Me's) spectra of 18 revealed that this compound had one additional methyl group on the quinone nucleus of 17. The position of the methyl group was determined to be 5'-C, because the broad triplet at δ 6.44 due to the quinone proton collapsed into a sharp singlet on irradiation at δ 3.09 (1-methylene protons).

From the least polar fraction, 2-geranylgeranyl-6-methylbenzoquinone (19), which was named as sargaquinone, was isolated. **Sargaquinone (19)** is possibly a precursor of geranylgeranylbenzoquinone derivatives found in some Sargassum species.

As for the biosynthesis of the present diterpenoid-substituted benzoquinone derivatives, the following Scheme, involving the pentaene (A) and epoxide (B), is proposed.

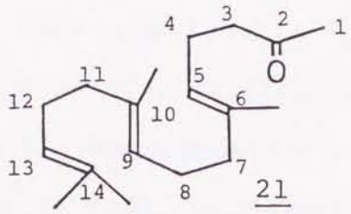


I-C Components of *Sargassum micracanthum*[7)]

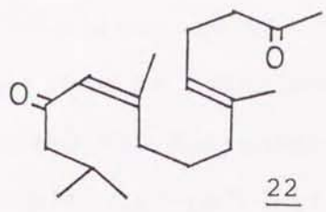
Methanol extract of fresh *S. micracanthum* was chromatographed on silica gel, affording three fractions, I-III. The fraction I consisted of almost pure farnesylacetone (21); IR(CCl_4) 1715 cm^{-1}; ^{1}H-NMR(CCl_4) δ 1.62 (9H, s), 1.68 (3H, s), 2.08 (3H, s), 5.08 (3H, brt), which was identified by converting into the semicarbazone; mp 79-80 °C (lit.[8)] mp 80.5-81.5 °C). Although the TLC of the fraction II showed only one spot, its HPLC exhibited five distinct peaks, and four new compounds (22-25) were obtained from this fraction by preparative HPLC (CH_3CN : H_2O = 3 : 1). The fraction III was a mixture of four compounds (27-30) which was separated by preparative TLC and HPLC.

The molecular formula, $C_{18}H_{30}O_2$ (M^+ m/e 278.2230, calcd 278.2245), of **compound 22** corresponded to that of dihydromonooxofarnesylacetone. The presence of $O=\underset{|}{C}-CH=\underset{|}{C}-CH_3$ moiety and an acetyl group was deduced from the IR absorption bands at 1680 and 1715 cm^{-1}, the UV absorption maximum at 239 nm (ε 10500), and the ^{1}H-NMR signals at δ 1.85 (3H, d, J=1.5 Hz), 5.95 (1H, brs) and 2.07 (3H, s). The NMR spectrum also suggested the presence of isopropyl [δ 0.92 (6H, d, J=7 Hz)], vinyl methyl [δ 1.62 (3H, s)], and trisubstituted olefin [δ 5.10 (1H, brt, J=7 Hz)] groups. The stereochemistry of the double bonds at 5-C and 10-C was determined to be *E* and *Z*, respectively, from the chemical shifts of the methyl groups at

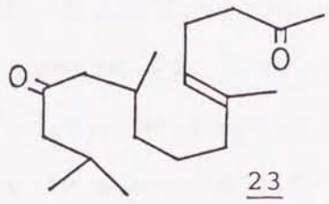
Figure 3.



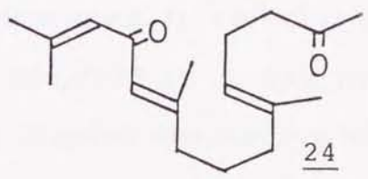
21



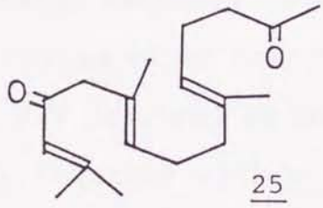
22



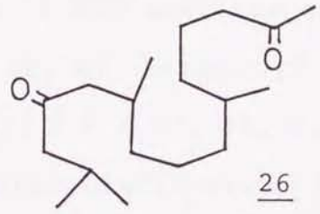
23



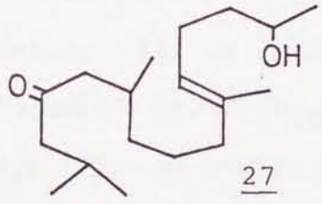
24



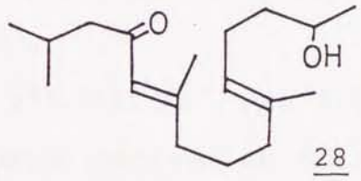
25



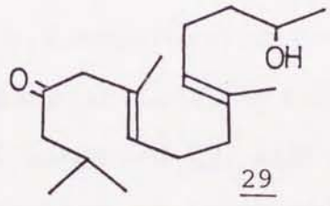
26



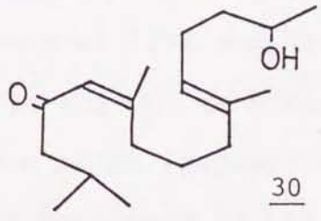
27



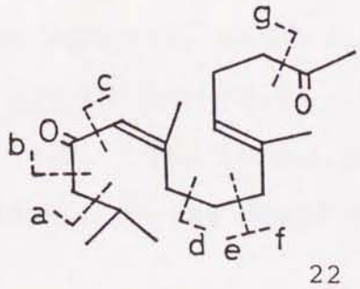
28



29



30



22

Fragment	Found	Calcd	Formula
a	235.1667	.1698	$C_{15}H_{23}O_2$
b	221.1545	.1541	$C_{14}H_{21}O_2$
c	193.1581	.1592	$C_{13}H_{21}O$
d	140.1198	.1201	$C_9H_{16}O$
e	153.1257	.1279	$C_{10}H_{17}O$
f	125.0950	.0966	$C_8H_{13}O$
g	235.2029	.2061	$C_{16}H_{27}O$

6-C (δ 1.62) and 10-C (δ 1.85).[9] The structure was further verified by high resolution mass spectrum as described in the Figure 3. Hydrogenation of 22 afforded the tetrahydro derivative (26), $C_{18}H_{34}O_2$; m/e 282 (M^+), 267 (M^+-CH_3), 225 ($M^+-C_4H_9$, $M^+-CH_2COCH_3$), 182 ($M^+-Me_2CHCH_2COCH_3$); IR(CCl_4) 1715 cm^{-1}.

Compound 23, $C_{18}H_{32}O_2$; m/e 280.2378 (M^+), 262 (M^+-H_2O), 223 ($M^+-C_4H_9$, $M^+-CH_2COCH_3$) was a dihydro derivative of compound 22. The IR spectrum (1710 cm^{-1}) showed the absence of an α,β-unsaturated carbonyl group, and the ^{1}H-NMR spectrum revealed the presence of an acetyl (δ 2.05, 3H, s), isopropyl (δ 0.90, 6H, d, J=7 Hz), and secondary methyl (δ 0.87, 3H, d, J=7 Hz) groups, together with a trisubstituted olefin group (δ 5.02, 1H, m). The structure 23 was confirmed by converting it into the diketone (26) by hydrogenation.

Compound 24, $C_{18}H_{28}O_2$; m/e 276.2141 (M^+) and 219 ($M^+-CH_2COCH_3$), showed a strong absorption maximum at 246 nm(ε 20900) in its UV spectrum, and exhibited IR absorption bands due to α,β-unsaturated carbonyl system at 1670 and 1625 cm^{-1}. The molecular formula corresponded to that of dehydro derivative of compound 22, and the presence of an isopropylidene group instead of isopropyl group was confirmed by its ^{1}H-NMR spectrum; δ 1.62 (3H, s, 6-Me), 1.86 (3H, s, 14-Me, trans to C=O), 2.05 (3H, s, $COCH_3$), 2.11 (6H, d, J=1 Hz, 10-Me and 14-Me, cis to C=O), 5.02 (1H, t, J=7 Hz, 5-H), and 5.90 (2H, m, 11, 13-H). The E-configuration of the double bond at 10-C was obvious from the downfield chemical shift (δ 2.11) of the

methyl group at 10-C.

Compound 25, $C_{18}H_{28}O_2$, was an isomer of 24, and showed the following spectral properties; m/e 276.2042 (M^+), 261 (M^+-CH_3), 233 (M^+-COCH_3), 83 ($Me_2C=CHCO$); IR(CCl_4) 1715, 1685, 1615 cm^{-1}; ^{1}H-NMR(CCl_4) δ 1.62 (6H, s), 1.87 (3H, s), 2.04 (6H, s), 2.93 (2H, s), 5.0-5.3 (2H, m), 6.01 (1H, s). The stereochemistry of the double bonds at 5-C and 9-C was determined to be E from the chemical shifts of the methyl signals.

The structures 27-30 were assigned for the remaining new compounds on the basis of the following spectral properties.

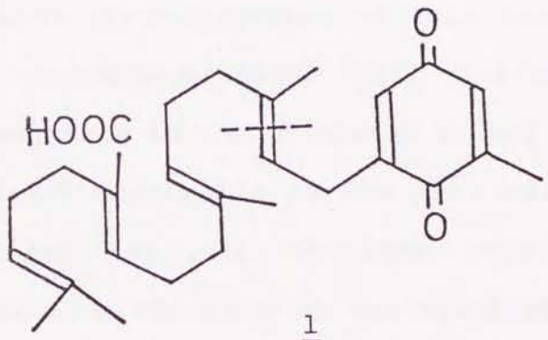
Compound 27, $C_{18}H_{34}O_2$; m/e 282.2561 (M^+), 264 (M^+-H_2O), 225 ($M^+-C_4H_9$), 85 (Me_2CHCH_2CO); IR(CCl_4) 3620, 1710, 1615 cm^{-1}; ^{1}H-NMR(CCl_4) δ 0.87 (3H, d, J=7 Hz), 0.92 (6H, d, J=7 Hz), 1.13 (3H, d, J=7 Hz), 1.62 (3H, s), 3.70 (1H, m), 5.10 (1H, m).

Compound 28, $C_{18}H_{32}O_2$; m/e 280.2393 (M^+), 265 (M^+-CH_3), 223 ($M^+-C_4H_9$), 85 (Me_2CHCH_2CO); $[\alpha]_D$ -3.75° ($CHCl_3$, c 0.53); λ_{max}(EtOH) 241 nm (ε 9500); IR(CCl_4) 3620, 1685, 1620, 1110, 1050 cm^{-1}; ^{1}H-NMR(CCl_4) δ 0.92 (6H, d, J=7 Hz), 1.13 (3H, d, J=7 Hz), 1.61 (3H, s), 2.09 (3H, s), 3.70 (1H, sextet, J=7 Hz), 5.10 (1H, t, J=7 Hz), 5.94 (1H, s).

Compound 29, $C_{18}H_{32}O_2$; m/e 280.2360 (M^+), 262 (M^+-H_2O), 247 (262-CH_3), 237 ($M^+-C_3H_7$), 223 ($M^+-C_4H_9$), 85 (base, Me_2CHCH_2CO); $[\alpha]_D$ -3.31° ($CHCl_3$, c 0.45); IR(CCl_4) 3620, 1710 cm^{-1}; ^{1}H-NMR(CCl_4) δ 0.90 (6H, d, J=7 Hz), 1.12 (3H, d, J=7 Hz), 1.61 (6H, s), 2.93 (2H, s), 3.73 (1H, sextet, J=7 Hz), 5.16 (2H, m).

Compound 30, $C_{18}H_{32}O_2$; m/e 280.2383 (M^+), 262 (M^+-H_2O), 223 ($M^+-C_4H_9$), 85 (Me_2CHCH_2CO); $[\alpha]_D$ -3.16° ($CHCl_3$, c 0.25), λ_{max}(EtOH) 239 nm (ε 10600), IR(CCl_4) 3620, 1685, 1615, 1170, 1150 cm^{-1}; ^{1}H-NMR(CCl_4) δ 0.92 (6H, d, J=7 Hz), 1.13 (3H, d, J=7 Hz), 1.64 (3H, s), 1.85 (3H, s), 3.68 (1H, sextet, J=7 Hz), 5.10 (1H, t), 5.90 (1H, s).

The farnesylacetone derivatives reported here are supposed to be norditerpenes, derived from geranylgeranylbenzoquinones such as sargaquinoic acid (1) by the oxidative cleavage of the C-C bonds pointed by the dotted lines.



1

I-D Components of *Sargassum fulvellum*[10)]

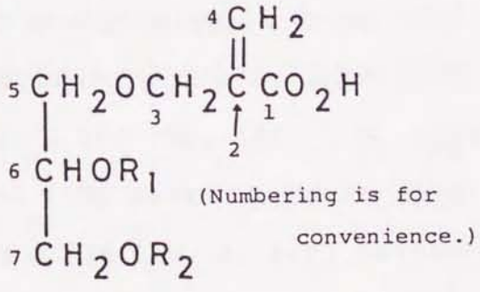
Methanol extract of *S. fulvellum* (7 Kg, collected at Awakominato, Chiba) gave a fraction, whose ^{1}H-NMR spectrum showed signals characteristic of terminal methylene protons. I was able to isolate the "terminal methylene compound", and found that the compound is a quite new glyceride bearing a methacrylic acid moiety.

The methanol extract was concentrated into an aqueous residue, which was successively extracted with hexane and ether. The ether extract was concentrated to give a brown oil (4.2 g). Column chromatography of this residue on silica gel with dichloromethane-methanol (9:1) yielded a fraction (2.8 g), the ^{1}H-NMR spectrum of which showed a couple of broad singlets at δ 6.4 and 5.9 ascribable to the terminal methylene protons. Isolation of the "terminal methylene compound" was extremely difficult, because the more it was purified, the more sensitive to air and light it became. Purification by preparative TLC was fruitless, because the compound changed to an unknown compound on the TLC plate. Isolation and purification were successfully achieved by repeated flash chromatography (hexane : ethyl acetate = 2 : 3) to give an oily substance (200 mg), showing a single spot on TLC.

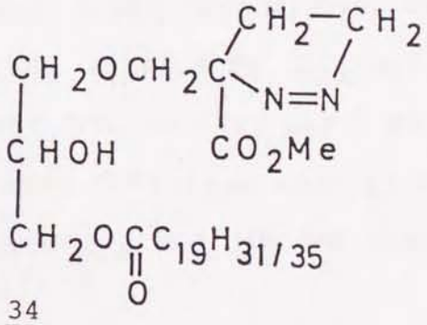
The IR spectrum of this substance, $[\alpha]_D$ +2.5° ($CHCl_3$, c 0.1), showed the bands at 3600-2200, 1690 (conjugated CO_2H), 1730 (CO_2R), and 1620 ($=CH_2$) cm^{-1}. Its ^{1}H-NMR spectrum (100

MHz, $CDCl_3$) exhibited a set of signals due to an unsaturated fatty acid moiety at δ 5.3 (brt, CH=CH), 2.80 (brs, C=C-CH_2-C=C), 2.32 (t, $CH_2\underline{CH_2}$-C=O), 2.00 (m, $CH_2\underline{CH_2}$-C=C), 1.64 (m, CH_2 β to C=O), 1.25 (brs, CH_2's), 0.90 (deformed t, CH_3). Also it showed poorly resolved multiplets in the region of 4.3-3.5 ppm, the pattern of which closely resembled that appearing in the ^{1}H-NMR spectrum of glycerine-1-stearate except a singlet at δ 4.20. The signals of the terminal methylene protons appeared at δ 6.41 (brs) and 5.95 (brs). The chemical shifts and the shapes of these two signals were reminiscent of those of the terminal methylene protons of dimethyl itaconate (δ 6.31 and 5.70).

Detailed inspection of the 360 MHz ^{1}H-NMR spectrum ($CDCl_3$) revealed that the substance had the structure 31. All the



(Numbering is for convenience.)



34

31 a ; R_1 = H, R_2 = $C_{19}H_{31}CO$

b ; R_1 = H, R_2 = $C_{19}H_{35}CO$

32 ; R_1 = H, R_2 = H
(fulvellic acid)

33 ; R_1 = Ac, R_2 = $C_{19}H_{31/35}CO$

protons belonging to the glycerine moiety formed the second-ordered coupling system [δ 4.171 (2H, 7-H, ABX, J_{AB}=9.9 Hz, J_{AX}=5.9 Hz, J_{BX}=2.9 Hz), 4.054 (1H, 6-H, ABX, pseudoquintet), 3.573 (2H, 5-H, ABX, J_{AB}=9.9 Hz, J_{AX}=6.3 Hz, J_{BX}=5.4 Hz)]. The methylene protons at 4-C appeared as a pair of doublets (J=1.2 Hz) at δ 5.970 and 6.444, both of which were sharpened by irradiating the singlet at δ 4.222 (2H, 3-H), establishing the allylic relationship of these two methylene groups.

Attempts to produce 32 by hydrolysis of 31 failed because of the fragility of the methacrylic acid moiety. Treatment of 31 with diazomethane gave a pyrazoline 34, ^{1}H-NMR($CDCl_3$) δ 3.67 (3H, s, $COOCH_3$), 4.47 (2H, t, J=8 Hz). Acetylation of 31 with acetic anhydride in pyridine gave rise to an acetate 33, IR($CHCl_3$) 1735 and 1690 cm^{-1}. Although this acetate showed a single spot on TLC after purification by column chromatography, two acetyl signals appeared in the ^{1}H-NMR (360 MHz,$CDCl_3$) spectrum; δ 2.078, 2.080 (3H, $COCH_3$), 3.652 (2H, d, 5-H, J=5.4 Hz), 4.264 (2H, ABX, 7-H, J_{AB}=11.3 Hz, J_{AX}=5.9 Hz, J_{BX}=4.1 Hz), 5.22 (1H, pseudoquintet, 6-H), 5.961 (1H, d, 4-H, J=1.4 Hz), and 6.436 (1H, d, 4-H, J=1.4 Hz). This indicated that 31 was a mixture of 31a and 31b. Separation of 31a and 31b was unsuccessful.

In order to verify the carbon skeleton of 31, the compound 38 was synthesized (Figure 4), and the ^{13}C-NMR spectra of 33 and 38 were compared (Table 4): Etheration of the acetonide 35 with the bromide 36[11] and sodium hydride in dimethylformamide

Figure 4.

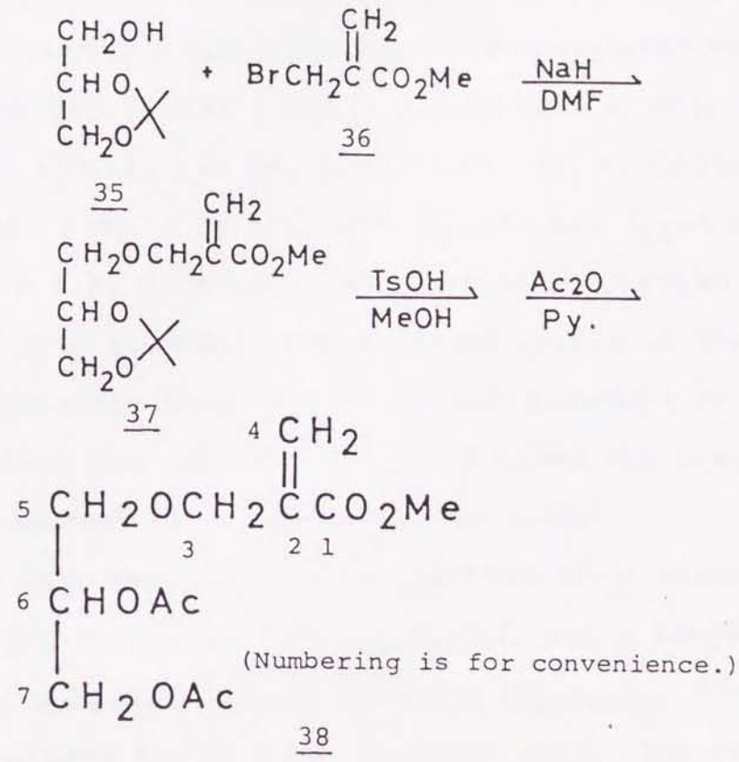


Table 4. ^{13}C-NMR chemical shifts of compounds 33 and 38.

	33	38
1-C	170.46	166.02
2-C	136.41	136.69
3-C	69.28*	68.90**
4-C	128.22	126.06
5-C	62.67	62.72
6-C	70.42	70.17
7-C	69.37*	69.54**

*,** Chemical shifts are interchangeable.

produced 37. The acetonide group of 37 was cleaved by acidic methanol, and the resulting diol was acetylated to give the diacetate 38, ^{1}H-NMR ($CDCl_3$) δ 2.02 (3H, s, Ac), 2.08 (3H, s, Ac), 3.47 (2H, d, J=6 Hz, 5-H), 3.68 (3H, s, COOMe), 4.20 (2H, d, J=1 Hz, 3-H), 4.20 (2H, ABX, J_{AB}=12 Hz, J_{AX}=4 Hz, J_{BX}=6 Hz, 7-H), 5.18 (1H, quintet, 6-H), 5.86 (1H, splitted s, 4-H), 6.30 (1H, splitted s, 4-H). The chemical shifts of the carbons 1-7 of the diacetate were reasonably correspondent to those of 33, establishing the skeleton of 31. I named the compound 32, the basic component of 31, as fulvellic acid.

The high resolution mass spectrum of 31 showed a molecular peak of 31a at m/e 504.307 ($C_{29}H_{44}O_7$), and a fragment at m/e 448.317 ($C_{27}H_{44}O_5$), formed from 31b ($C_{29}H_{48}O_7$; m/e 508 in the low resolution MS) by loss of acetic acid. The composition of the fatty acid portion of 31 was confirmed by the following experiment: Treatment of 31 in benzene with a catalytic amount of methanolic m-trifluoromethylphenyltrimethylammonium hydroxide[12] afforded a mixture of methyl esters. GC-MS analysis of this mixture revealed that it consisted of mainly two esters (90 % of the ester fraction), $C_{19}H_{31}COOCH_3$ (m/e 318) and $C_{19}H_{35}COOCH_3$ (m/e 322) (3:1), which were derived from 31a and 31b, respectively.

Among the Sargassum algae that I investigated, sagamianum, ringgoldianum, piluliferum, giganteifolium, yendoi, and hemiphyllum, were found to contain this new type of glyceride, although Hizikia fusiforme, which was taxonomically close to

Sargassum algae, did not produce the glyceride *31*. Chemotaxonomical and biological significance of this "unusual fat" is of interest.

EXPERIMENTAL

Infrared spectra were recorded on a HITACHI 215 spectrophotometer and ultraviolet spectra were recorded on a HITACHI 340 spectrophotometer. Optical rotations were recorded on a JASCO DIP-181 polarimeter, using a 10-cm microcell. ^{1}H-NMR spectra were recorded on JEOL JNM-MH-100, HITACHI R24, and HITACHI R20 NMR spectrometers; chemical shifts are reported relative to Me_4Si(δ 0), and coupling constants are given in hertz. Low-resolution mass spectra were obtained from a HITACHI RMU-6M mass spectrometer.

Algal collection, extraction, and isolation of compounds. Algae were collected at Awakominato, Chiba, in spring from 1978 to 1980. The fresh algae were soaked in MeOH immediately after the collection and allowed to stand for 1 week. The MeOH was decanted, and the residual material was again extracted with fresh MeOH for 1 week. The combined MeOH extracts were concentrated on a rotary evaporator, and the residue was successively washed with hexane, ether, and ethyl acetate. Each extract was concentrated, and the residue was fractionally separated by chromatography on silica gel (Merck, Kieselgel 60), and further purified by preparative TLC (Merck, Kieselgel 60, GF_{254}) and HPLC (LS-410K).

Acetylations. All acetylations were conducted in a

similar fashion. Acetic anhydride was added to a solution of the natural product in pyridine, and the reaction mixture was allowed to stand at room temperature overnight. The excess reagents were then removed *in vacuo* to yield the acetylated products, which were purified, when necessary, by preparative TLC.

Sargaquinal (2). MS m/e 408(M^+), 393, 390, 379, 365, 177, 175(base), 137, 69; ^{1}H-NMR(100 MHz, $CDCl_3$) δ 1.50(3H,s), 1.58(9H,s), 2.00(3H,s), 3.15(2H,d,J=7 Hz), 5.20(3H,m), 6.5(3H,m), 9.36(1H,s).

Reductive acetylation of sargaquinoic acid (1) to 3. A solution of 1 (511 mg) and zinc (500 mg) in 5 ml of acetic anhydride and triethylamine (3 drops) was stirred for 10 min. The reaction was quenched by the addition of water, and the aqueous phase was extracted with ether. The ether layer was evaporated, and the residue was chromatographed on silica-gel column to give the diacetate 3: $C_{31}H_{42}O_6$, MS m/e 510(M^+), 492, 450, 441, 423, 408, 289, 271, 217(base), 192, 69; IR($CHCl_3$) 3300-2300, 1750, 1680 cm^{-1}; ^{1}H-NMR(100 MHz,$CDCl_3$) δ 1.60(6H,bs), 1.68(6H,bs), 2.13, 2.24, 2.29(each 3H,s), 3.20(2H,d,J=8 Hz), 5.1(3H,m), 6.01(1H,t,J=7 Hz), 6.82(2H,bs).

Reduction of 3 to 4. To a solution of 3 (200 mg) in ether (20 ml) was added an excess amount of $LiAlH_4$. The

reaction mixture was refluxed for 3 hr, and quenched by careful dropwise addition of H_2O. The mixture was partitioned between ether and H_2O, and the ether layer was evaporated to give the triol (95 mg). The triol was allowed to stand at r.t. overnight to yield the quinone 4: $C_{27}H_{38}O_3$, IR($CHCl_3$) 1645, 1610 cm^{-1}; ^{1}H-NMR(60 MHz,$CDCl_3$) δ 1.60(9H,bs), 1.65(3H,bs), 2.05(3H,bs), 3.05(2H,bd,J=7 Hz), 4.07(2H,bs), 4.9-5.3(4H,m), 6.45(2H,m).

Oxidation of 4 to 5. A solution of 4 (9.7 mg) in CH_2Cl_2 (1 ml) was added to 1 equivalent of pyridinium chlorochromate. After 5 min, the reaction was quenched by the addition of EtOH, and the mixture was partitioned between ether and H_2O. The ether layer was concentrated in vacuo, and purified by preparative TLC, giving 5: $C_{27}H_{36}O_3$. The mass spectrum is almost identical with that of sargaquinal (2); IR($CHCl_3$) 1650, 1610, 910 cm^{-1}; ^{1}H-NMR(100 MHz,$CDCl_3$) δ 1.58, 1.63(each 6H,bs), 2.07(3H,bs), 3.13(2H,bd,J=7 Hz), 5.1(3H,m), 6.5(3H,m), 10.11(1H,s).

Degradation of sargatetraol (7) to aldehydes 9 and 10. A saturated solution (5 ml) of H_5IO_6 in ether was added to 7 (34.7 mg), and the solution was stirred at r.t. for 10 min. The mixture was diluted with water and extracted with ether. The ether layer was dried over $MgSO_4$ and concentrated in vacuo. Purification by preparative TLC yielded the quinone 9 (9.6 mg)

and geranial (7.0 mg).

Oxidation of sargatetraol (7) to 17. A solution of 7 (58 mg) in ether was treated with anhydrous sodium acetate (273 mg), to absorb the water formed, and the dry silver oxide was added with shaking until there was no further deeping in color. After stirring for 40 min at r.t., the reaction mixture was filtered to remove silver, and the filtrate was evaporated to give 17 (50.6 mg).

Conversion of 17 to 20. A solution of 17 (41.9 mg) in pyridine (1 ml) was heated at 50 °C for 21 hr. Then the excess pyridine was removed in vacuo, and the residue was purified by preparative TLC to give 20 (12.4 mg): $C_{27}H_{38}O_4$, ^{1}H-NMR(60 MHz,$CDCl_3$) δ 1.33(3H,s), 1.58, 1.65(each 6H,bs), 2.12(3H,bs), 3.82(1H,d,J=8 Hz), 4.32(1H,t,J=8.5 Hz), 5.2(3H,m), 5.55, 6.27(each 1H,d,J=10 Hz), 6.34, 6.50(each 1H,d,J=2.5 Hz).

Hydrogenation of 22 and 23 to 26. Compound 22 (and 23) was dissolved in EtOH, and stirred overnight with 10% Pd/C in a H_2 atmosphere. The reaction mixture was filtered and concentrated to give the perhydro compound 26.

Methylation of 31 to 34. 31 (34 mg) was treated with a solution of excess diazomethane in ether. After 5 min, the solution was concentrated to afford an oil (35 mg): ^{1}H-NMR(100

MHz,CCl_4) δ 3.47(2H,d,J=5 Hz,5-H), 3.70(3H,s,OCH_3), 3.9-4.1(4H,m,3,7-H), 4.52(2H,t,J=8 Hz,N-CH_2), 4.96(1H,m,6-H), 5.25(m,olefinic H).

Preparation of 37. To a solution of the alcohol 35 (1.292 g) in dry DMF (20 ml) was added sodium hydride (428 mg; as a 60 % dispersion in a mineral oil) during 30 min, and the mixture was stirred at r.t. for 1 hr. A solution of the bromide 36 (1.836 g) in DMF (4 ml) was added *via* syringe during 10 min (exothermic reaction), and the mixture was stirred at r.t. overnight. Water was added, and the product was extracted with ether. The ether layer was washed with water and brine, and dried over Na_2SO_4. Purification by flash chromatography afforded almost pure 37 (153 mg): $C_{11}H_{18}O_5$, ^{1}H-NMR(100 MHz,$CDCl_3$) δ 1.34, 1.39(each 3H,s), 3.54(2H,d,J=5 Hz,5-H), 3.74(3H,s,OCH_3), 3.7(1H,m,6-H), 4.1(2H,m,7-H), 4.20(2H,bs,3-H), 5.84, 6.24(each 1H,bs,4-H).

Conversion of 37 to 38. A solution of the acetonide 37 (20.3 mg) in methanol (0.15 ml) was treated with a small piece of crystals of p-TsOH. After 22 hr, the reaction mixture was diluted with MeOH, a drop of pyridine was added, and the solvent was evaporated. To the colorless residue, pyridine (0.2 ml) and acetic anhydride (0.2 ml) were added, and the resulting mixture was allowed to stand at r.t. for 5 hr. The mixture was concentrated using an oil pump at r.t., giving rise

to an oil.

Methanolysis of 31. To a solution of 31 (12 mg) in benzene (0.5 ml) was added a 5 % MeOH solution of m-trifluoromethylphenyltrimethylammonium hydroxide (0.2 ml). The solution was allowed to stand at r.t. for 1.5 hr. The reaction mixture was chromatographed on silica gel with CH_2Cl_2, affording an oil (9 mg). GC-MS of this oil was measured.

REFERENCES

1) T. Kusumi, Y. Shibata, M. Ishitsuka, T. Kinoshita, and H. Kakisawa, Chem. Lett., 277 (1979).

2) G. Cimino, S. De Stefano, and L. Minale, Tetrahedron, 28, 1315 (1972).

3) K. C. Chan, R. A. Jewell, W. H. Nutting, and H. Rapoport, J. Org. Chem., 33, 3382 (1968).

4) M. Ishitsuka, T. Kusumi, Y. Nomura, T. Konno, and H. Kakisawa, Chem. Lett., 1269 (1979).

5) M. J. Pettei, F. G. Pilkiewicz, and K. Nakanishi, Tetrahedron Lett., 2083 (1977).

6) T. Kikuchi, Y. Mori, T. Yokoi, S. Nakazawa, H. Kuroda, Y. Masuda, K. Kitamura, and I. Umezaki, Chem. Pharm. Bull., 23, 690 (1975).

7) T. Kusumi, M. Ishitsuka, Y. Nomura, T. Konno, and H. Kakisawa, Chem. Lett., 1181 (1979).

8) R. G. Buttery, R. M. Seifert, and L. C. Ling, Chem. Ind. (London), 238 (1969).

9) R. B. Bates, D. M. Gale, and B. J. Gruner, J. Org. Chem., 28, 1086 (1963).

10) T. Kusumi, M. Ishitsuka, T. Iwashita, H. Naoki, T. Konno, and H. Kakisawa, Chem. Lett., 1393 (1981).

11) A. Tanaka, T. Nakata, and K. Yamashita, Agric. Biol. Chem., 37, 2365 (1973).

12) D. K. McCreary, W. C. Kossa, S. Ramachandran, and R. R.

Kurtz, J. Chromatog. Sci., 16, 329 (1978).

C H A P T E R II

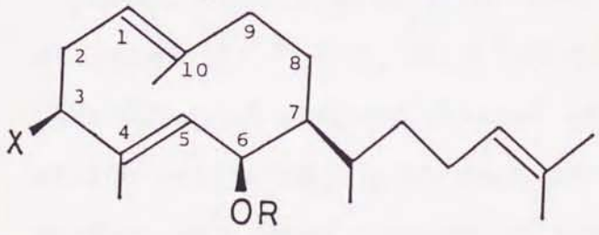
STUDIES ON METABOLITES OF THE DICTYOTACEAE BROWN ALGAE

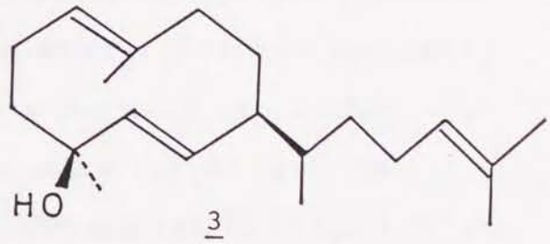
The typical metabolites of the Dictyotaceae brown algae thus far reported are cyclic diterpenes. They often have a familiar sesquiterpene ring system with an additional isoprene unit in the side-chain. For example, the carbon skeleton of pachydictyol A (12)[1] is an 'extended' guiane sesquiterpene. There are, however, some very interesting exceptions to that observation.

In this chapter the diterpenes from the Dictyotaceae are organized according to the kinds of carbocyclic rings in order of the biogenesis pathways (II-G).

II-A Diterpenes with a Cyclodecane Skeleton

Natural products possessing a cyclodecane framework are frequently found as germacrane sesquiterpenoids in terrestrial plants.[2] On the contrary, diterpenoids having a ten-membered ring are much rarer, and it is only ten years ago that the first germacrane-type diterpene, dilophol (1),[3] was isolated from an alga. Since then, several other diterpenoids having a ten-membered ring have been obtained from marine resources.[4-6] In the course of my study on the constituents of the brown alga, Pachydictyon coriaceum, I have isolated three new germacrane-type diterpenes together with known diterpenes, 3-acetoxyacetyldilophol (2)[4] and obscuronatin (3).[5] I would describe the structural elucidation of the new compounds, as well as the conformational analysis of these compounds.





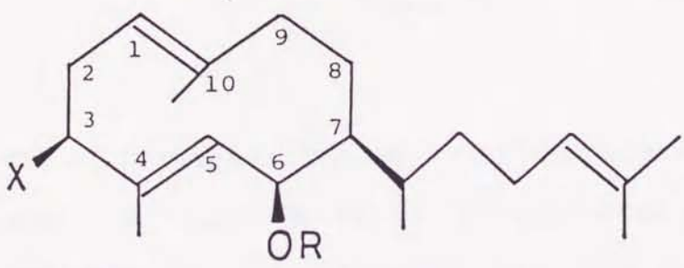
3

1 ; X = H, R = H

2 ; X = OAc, R = Ac

3-Hydroxyacetyldilophol (4),[7] $C_{22}H_{36}O_3$, $[\alpha]_D$ -7.2° (c 0.64, $CHCl_3$), IR(CCl_4) 3600, 1730, 1240 cm^{-1}, MS m/e 348(M^+), 306, 288, 270, 177, 159, 109, 69(base), exhibited the ^{1}H-NMR spectrum very similar with that of 3-acetoxyacetyldilophol

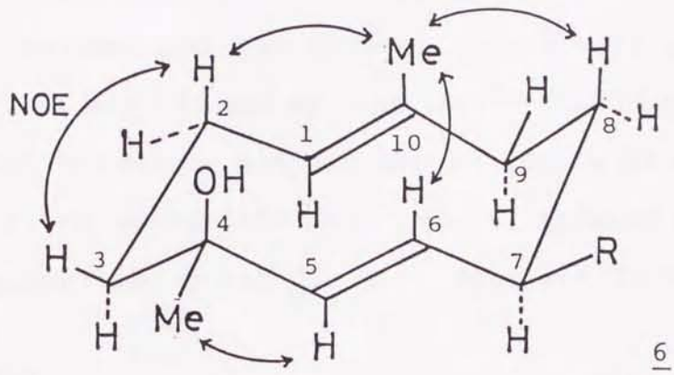
(2).[4] Noticeable differences were that (1) only one acetyl signal was found in 4 and (2) the chemical shift of 3-H in 2 (δ 5.0) moved up to δ 4.36 (t, J = 3 Hz) in 4. On the basis of these properties, the structure 4 was assigned for 3-hydroxy-acetyldilophol, and the structure was confirmed by conversion of 4 into 2 by acetylation.



4 ; X = OH , R = Ac

5 ; X = H, R = Ac

From a less polar fraction, **dilophol acetate (5)**,[7] $[\alpha]_D$ -30.9° (c 0.57, $CHCl_3$), IR($CHCl_3$) 1730, 1240 cm^{-1}, was isolated. Hydrolysis (KOH/MeOH) of dilophol acetate produced dilophol (1),[3] $[\alpha]_D$ -26.1° (c 0.44, $CHCl_3$). It is noteworthy that dilophol acetate changed into a compound on standing with silica gel in CH_2Cl_2 at room temperature for 24 hr. The product was characterized as obscuronatin (3),[5] $[\alpha]_D$ -112° (c 0.49, $CHCl_3$), by comparison of the spectral properties. The relative stereochemistry of obscuronatin has been recently confirmed by synthesis,[8] and since the absolute configuration of dilophol (1) has been established,[4] the absolute configuration of obscuronatin in the present alga was determined as in 3 by the above transformation. The 400 MHz ^{1}H-NMR spectrum (27



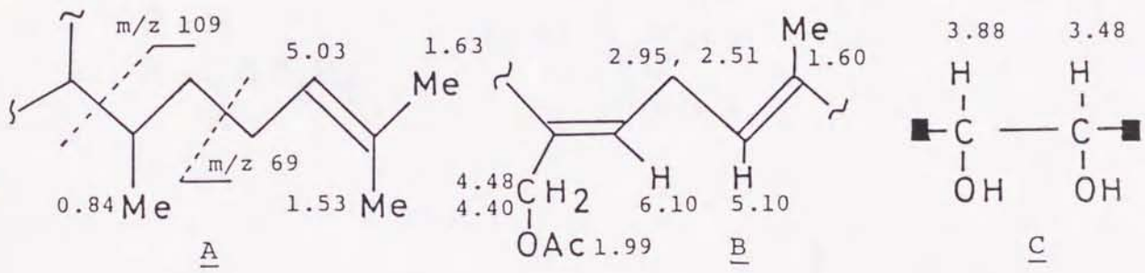
6

°C) of 3 reveals the well-defined signals. Also the ^{13}C-NMR spectrum (22.5 MHz at 27 °C) exhibited sharp signals. These indicate that obscuronatin takes one stable conformation in contrast with other germacrane-type diterpenes. The conformation of obscuronatin was determined as depicted in 6 by analysis of the spin coupling patterns of the key protons (1-H, 2-H , 5-H, 6-H) and observation of NOEs between the protons as shown in 6. Experiments using a paramagnetic shift reagent [Eu(fod)$_3$] also supported the conformation 6.

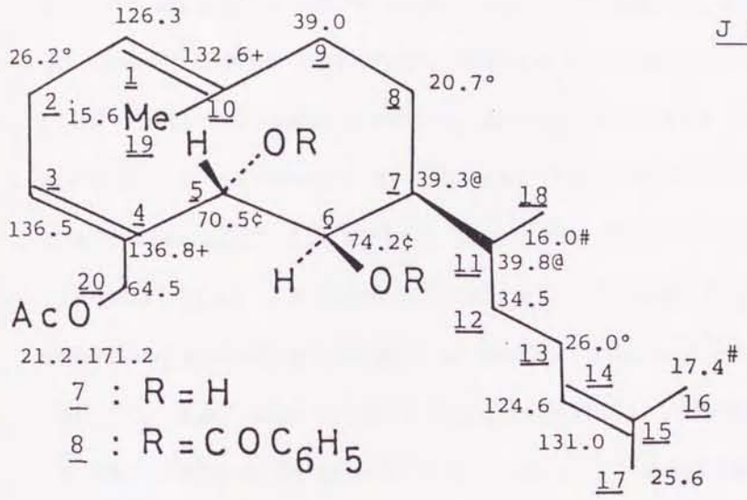
Formation of obscuronatin (3) from dilophol acetate (5) is reasonably interpreted by (i) intramolecular [1,5] shift of the acetoxy group to 4-C followed by hydrolysis, or (ii) attack of water to 4-C with concomitant removal of the acetoxy group.

Acetoxypachydiol (7),[7] $C_{22}H_{36}O_4$ (m/e for M^+, 364.248), $[\alpha]_D$ -76.4 ° (c 0.55, $CHCl_3$), was obtained as a colorless oil. The IR spectrum (CCl_4) implies the presence of acetoxy (1750 and 1240 cm^{-1}) and hydroxy (3300-3600 cm^{-1}) groups. On

acetylation (Ac_2O/py), two acetyl groups were incorporated (^{1}H-NMR), indicating that two hydroxy groups were present. Fragments at m/e 109 and 69, and the ^{1}H-NMR signals depicted in the partial structure suggest the existence of the side chain A. Decoupling works (400 MHz; -50 °C) infered additional partial structures B and C. The downfield (δ 6.10) chemical



shift of the olefin proton in moiety B indicates the cis relationship between this olefin proton and the acetoxymethyl group. Other three carbons and five protons which are not discussed above must be two CH_2's and one CH, because all of five methyl groups that exist in acetoxypachydiol (^{1}H and ^{13}C-NMR) are found in A to C. Consideration of these facts and biogenesis of diterpenes led to the gross structure 7 (without stereochemistry) or its isomer in which the glycol moiety is located on 8-C and 9-C. In the 400 MHz ^{1}H-NMR spectrum measured at 27 °C, several protons appear as broad signals, indicating that acetoxypachydiol takes two or more conformations, which invert in a moderate rate on an NMR time scale.[9] Interestingly, when the spectrum was taken at -50 °C, only one



J values (-50°C) of protons

$J_{2\alpha-2\beta}$	= 13.0 Hz
$J_{2\alpha-1}$	= 0 Hz
$J_{2\beta-1}$	= 11.4 Hz
$J_{2\alpha-3}$	= 9.2 Hz
$J_{2\beta-3}$	= 4.8 Hz
$J_{20\alpha-20\beta}$	= 12.1 Hz
J_{5-6}	= 9.9 Hz
J_{6-7}	= 0 Hz

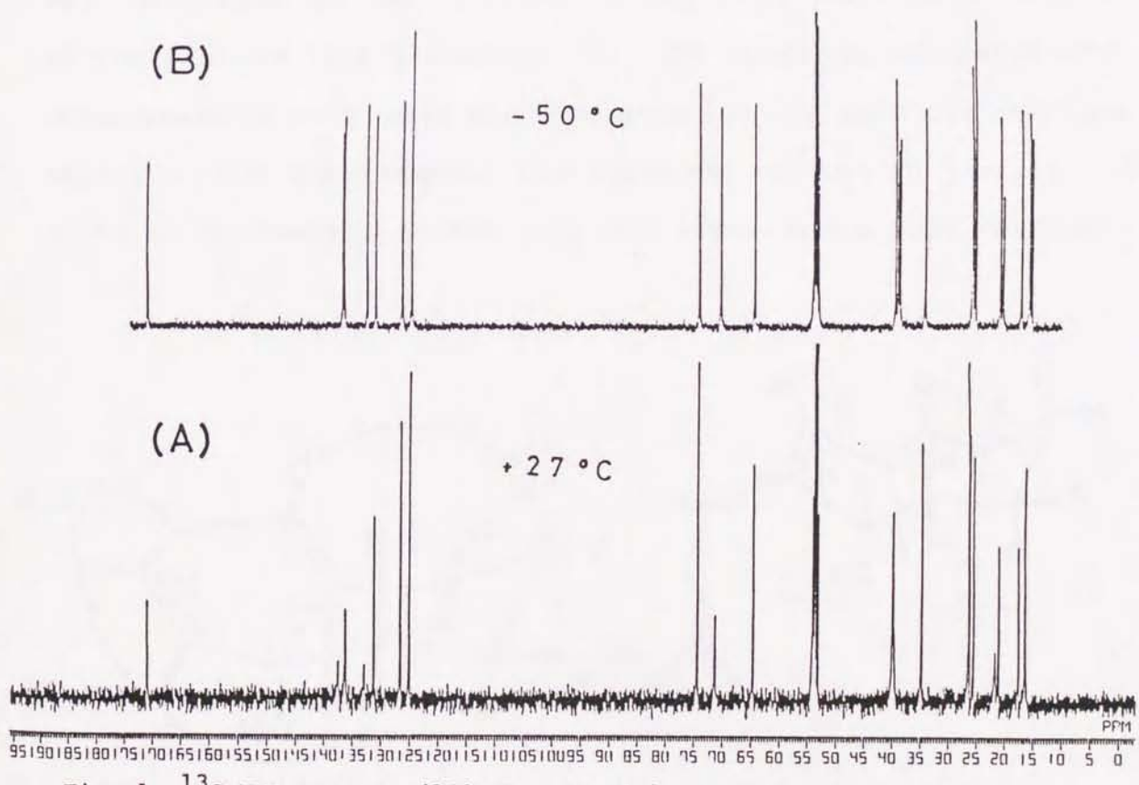
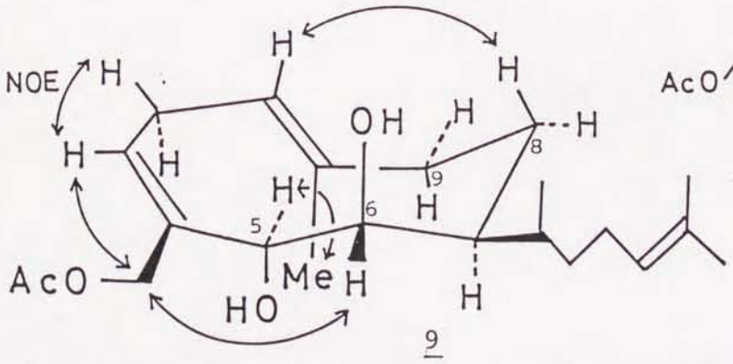
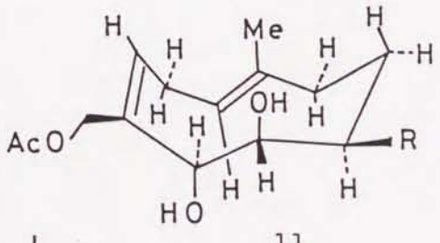


Fig. 1 ^{13}C-NMR spectra (100 MHz; CD_2Cl_2) of acetoxypachydiol (7).

set of signals were observed. Similar phenomena were observed in the ^{13}C-NMR spectra; while the spectrum measured at 27 °C (100 MHz) showed several broad signals (Figure 1) and the number of carbon signals was less than the one expected from the molecular formula, the spectrum recorded at -50 °C (Figure 1) exhibited 22 sharp signals. These facts suggest that acetoxypachydiol takes a major (possibly >98%) conformation at -50 °C, and the minor conformer(s), whose population increases as the temperature rises, is not observable in the NMR spectra at that low temperature. Double resonance experiments (400 MHz) performed at -50 °C provided the spin coupling constants of the protons (see structure 7). The coupling constants are interpretable only when the conformation and relative configurations of the substituents are supposed as seen in 9 or 10. In order to differentiate the two, NOE experiments were carried



9



11

(10; 8ß,9α-diol instead of 5,6-diol)

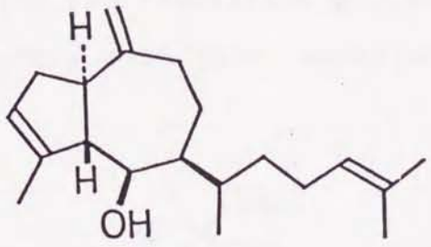
out at -50 °C using a 400 MHz spectrometer, but, unexpectedly, no NOE was observed between any pairs of protons by this high field spectrometer. On the other hand, when a 250 MHz instrument was used, small but distinct NOEs between several pairs of protons were observed. These findings (depicted in 9) confirmed the structure and stereochemistry of acetoxypachydiol to be 9. MM2 calculation revealed that free energy difference between 9 and the next favorable conformation 11 was ca. 1 Kcal. The dibenzoate 8 exhibited negative splitted Cotton effects (λ_{ext} 237 nm, $\Delta\varepsilon$ -9.8; λ_{ext} 222 nm, $\Delta\varepsilon$ +9.8), and, hence, the absolute configuration of acetoxypachydiol was determined as depicted in 9.[10)]

Acetoxypachydiol (7) is the first example of diterpene that possesses a 1,4-cyclodecadiene skeleton.

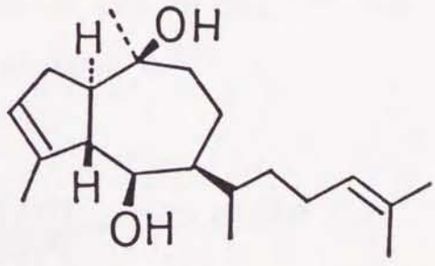
II-B Diterpenes with a Perhydroazulene Skeleton

Species of brown algae belonging to the family Dictyotaceae have been a rich source of diterpenoids containing the perhydroazulene ring system. Pachydictyol A (12),[1] which was isolated by Hirschfeld et al. from P. coriaceum at California was the first member of this family to be reported. Subsequently a number of oxygenated derivatives of pachydictyol A have been described.

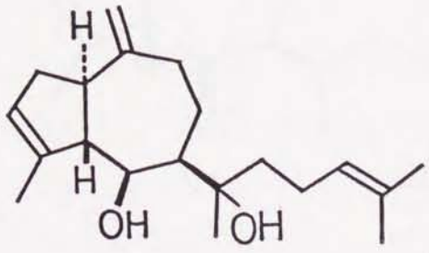
In this section, I would like to describe the diterpenoid constituents having a perhydroazulene skeleton isolated from Dictyotaceae brown algae.



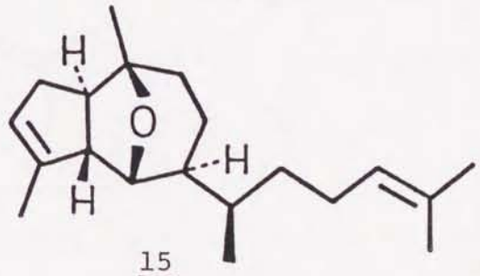
12



13



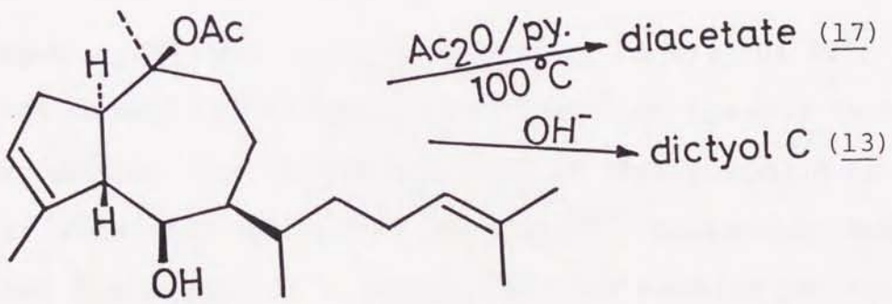
14



15

Methanol extract of P. coriaceum afforded three new diterpenes, acetyldictyol C (16),[11] isopachydictyol A (18), and hydroxydictyoxide (19), having a perhydroazulene skeleton, together with the known diterpenes, pachydictyol A (12),[1] dictyol C (13),[12] dictyol E (14),[12] and dictyoxide (15).[13]

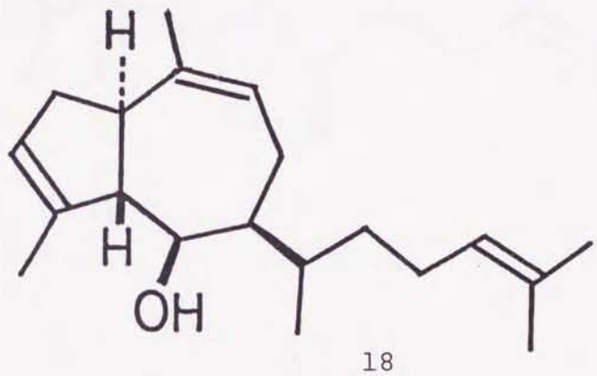
Acetyldictyol C (16; 0.1 % of the methanol extract), oil, $[\alpha]_D$ -3.6 ° (c 0.6, $CHCl_3$), unexpectedly resisted acetylation (Ac_2O/Py at room temperature), although a secondary hydroxy group was obviously present (^{1}H-NMR; δ 3.85). Acetylation at higher temperature (100 °C/48 hr) gave diacetate (17). This inertness of the hydroxy group of 16 was reminiscent of the sterically hindered C-6 hydroxy group of dictyol C (13). Indeed, hydrolysis of 16 (KOH/MeOH/3 hr) at 65 °C yielded 13, which was identified by comparison of its ^{1}H and ^{13}C-NMR spectra with those reported for dictyol C.[12]



16

Isopachydictyol A (18), oil, $[\alpha]_D$ -3.6 ° (c 0.6, $CHCl_3$), was separable by HPLC (MeOH : H_2O = 9 : 1) from the fraction

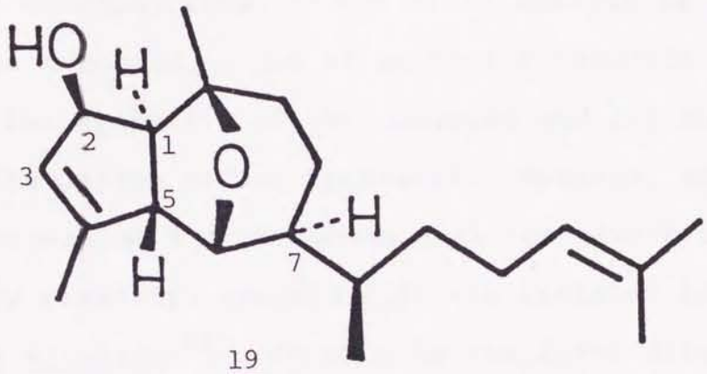
containing pachydictyol A (12), and found to be an isomer of pachydictyol A by MS. ^{1}H-NMR spectrum ($CDCl_3$) resembles that of pachydictyol A, except for the signals of an olefinic proton (δ 5.47) and an olefinic methyl (δ 1.67) instead of the exomethylene signals in 12. From these data, structure 18 was deduced for isopachydictyol A, and confirmed by comparison of its spectra with those reported for the derivative of dictyol B.[14)]



18

Hydroxydictyoxide (19), $C_{20}H_{32}O_4$, MS m/e 304 (M^+), 286, 268, 109 showed the IR band at 3610 cm^{-1} assignable to a hydroxy group. The ^{1}H-NMR spectrum of this compound is very similar with that of dictyoxide (15).[13)] Noticeable difference was that the signal of an oxygen-bearing methine proton (δ 4.48) appeared in 19. Decoupling works revealed that this proton was coupled with the olefinic proton (δ 5.67, J = 2.5 Hz) and the methine proton (δ 2.34, J = 4 Hz). This spectral property allowed me to deduce the structure 19 for hydroxy-

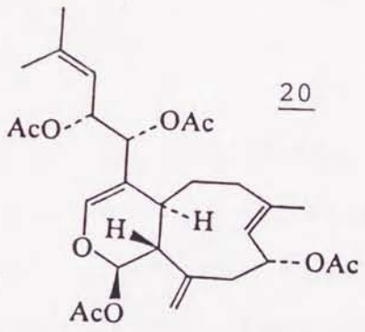
dictyoxide. The relative configuration of the hydroxy group at 2-C was determined as depicted in structure 19 by the coupling constant between 1-H and 2-H (4 Hz), and the observation of NOE between these protons.



19

II-C Diterpenes with a Xenicane Skeleton

Natural products having a cyclononane skeleton are one of the most infrequent groups of compounds, and since the structure of caryophyllene,[15] the first example of this category, was reported, a lot of synthetic chemists have been involved in the synthesis of the compound and its analogues because of its unique carbon framework. However, not so many compounds possessing a cyclononane skeleton have been reported so far. Very recently, xenicin (20) was isolated from a soft coral, Xenia elongata.[16] Xenicin is the first diterpenoid with a cyclononane skeleton and its framework has been conventionally called as a xenicane skeleton after its name.

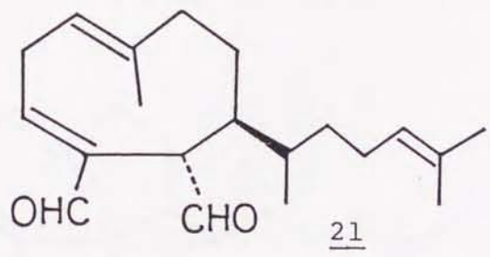


20

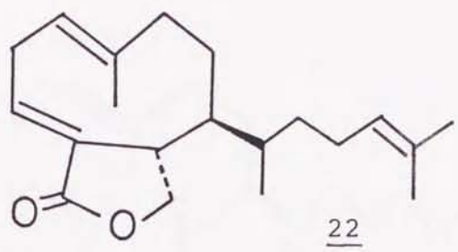
I was able to isolate a number of xenicane type compounds from the Dictyotaceae seaweeds, several of which were found to have unique structures quite different from that of xenicin (20).

Chromatographic separation of the methanol extract of P. coriaceum afforded several new compounds having a xenicane

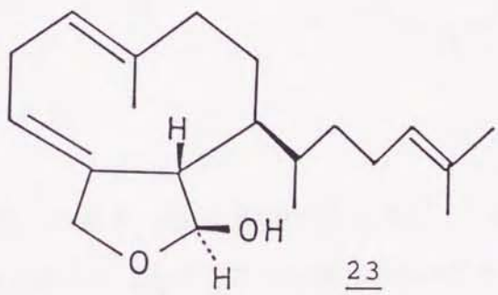
skeleton, together with the known diterpenes, dictyodial (21),[17] dictyolactone (22),[17] and isodictyohemiacetal (23).[18]



21



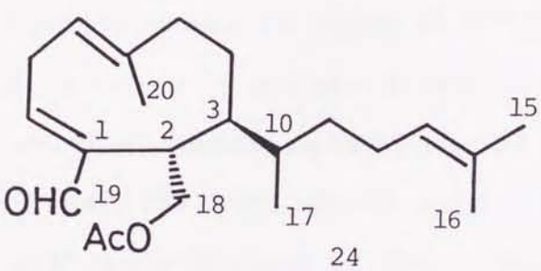
22



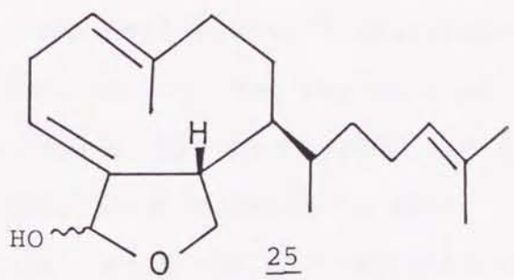
23

Acetyldictyolal (24, 0.1 % of the methanol extract)[11] exhibited IR bands due to an α,β-unsaturated aldehyde (2720 and 1685 cm^{-1}) and an ester (1735 cm^{-1}) groups. The structure 24 was deduced for acetyldictyolal from the spectral data. In the ^{1}H-NMR spectrum, the proton at 2-C appeared as a broad triplet (δ 2.76, J = 8 Hz). Decoupling works revealed that this proton was also coupled with the aldehyde proton (δ 9.40, J = 1.0 Hz), but not with the vicinal proton at 3-C. On the analogy of the corresponding protons of dictyodial (21), the configurations at 2-C and 3-C were deduced as illustrated in the structure 24.

The structure was unambiguously determined by the chemical conversion; hydrolysis (Na_2CO_3/MeOH) of 24 gave the hemiacetal (25) as an epimeric mixture, which was oxidized with manganese dioxide, affording dictyolactone (22).

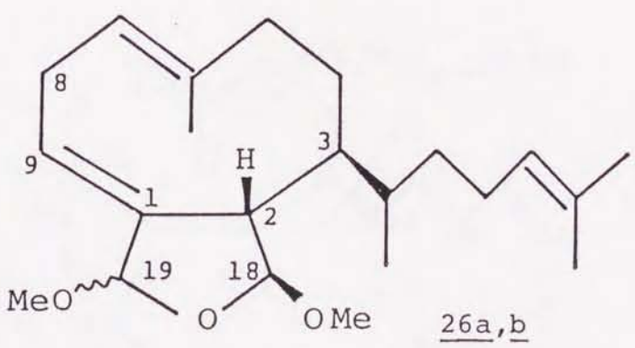


24



25

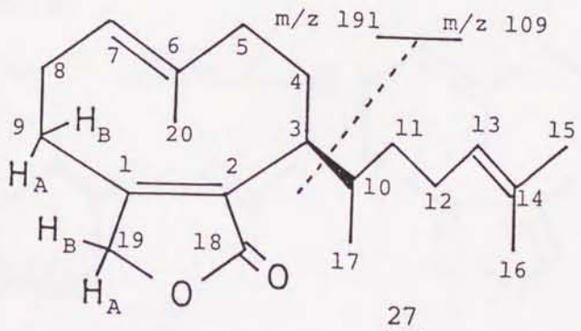
Acetals (26a, 0.2 %, and 26b; 0.2 %)[11] were separable by column chromatography. Each of them showed two methoxy signals, besides two 1H-singlets due to acetal protons (18 and 19-H) in its ^{1}H-NMR spectrum. The configuration at 18-C of each isomer was deduced by the null coupling constant between 2 and 18-H, although the configuration at 19-C was not clarified.



26a,b

When the acetals were allowed to stand with silica gel, they changed into dictyodial (21), together with sanadaol (56).[19] These acetals can be artifacts, which was formed from dictyodial (21) and methanol.

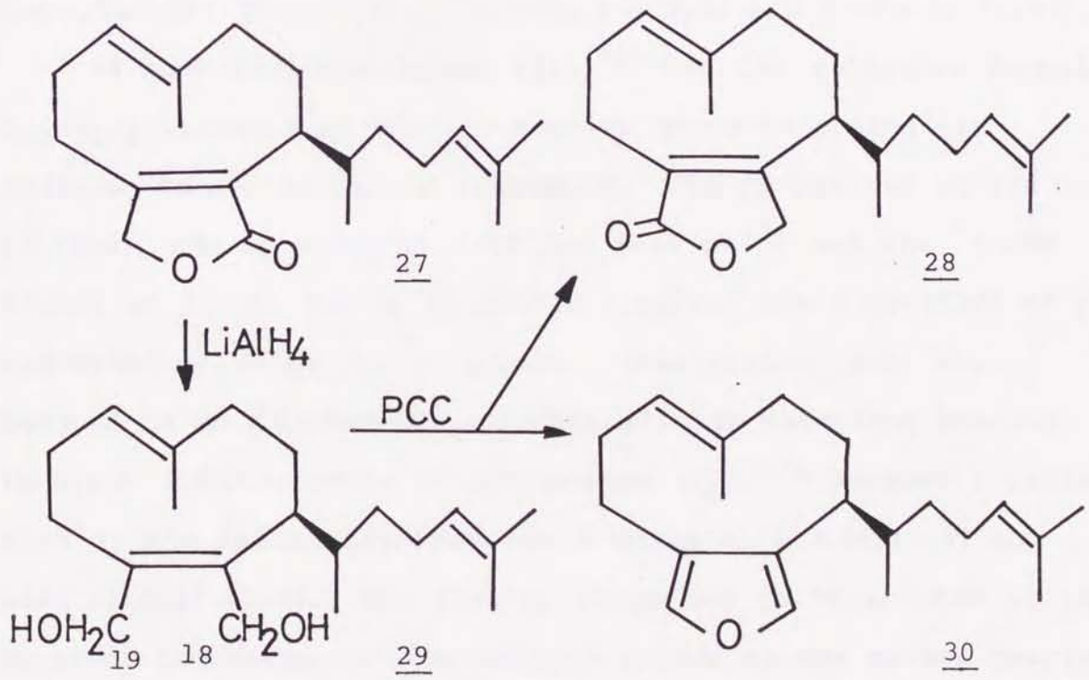
Neodictyolactone (27),[20] $C_{20}H_{30}O_2$, $[\alpha]_D$ -43.4° (c 0.29, $CHCl_3$), shows IR bands at 1750 (s) and 1645 (w) cm^{-1} attributable to an α,β-unsaturated γ-lactone moiety, the presence of which was confirmed by the UV maximum at 220 nm (ε 7800) and a ^{1}H-NMR (90 MHz) signal at δ 4.56 (2H, s) ascribable to the methylene protons at the γ-position. From the MS fragments at m/e 109 and 191 (See the structure 27.) together with the ^{13}C-NMR spectrum, it is obvious that 6-methyl-5-hepten-2-yl group, a side chain, is included in this compound. The ^{13}C-NMR spectrum reveals the presence of another trisubstituted olefin bearing a methyl group [δ 15.8 (q; 20-C), 123.5 (d; 7-C), 140.0 (s; 6-C)], and also four methylene and one methine groups in addition to the aforementioned moieties, which indicates that one more ring other than the lactone ring is included in



27

neodictyolactone. The configuration of the trisubstituted olefin is deduced to be E from the chemical shift (δ 15.8) of the olefinic methyl. In the ^{1}H-NMR spectrum, this methyl group appears as a broad singlet at δ 1.26. This highly shielded olefinic methyl is reminiscent of acetylcoriacenone (45),[21] in which the olefinic methyl is shielded by a transannular effect of the cyclobutene group. These facts together with biogenetic considerations allowed me to propose two possible structures 27 and 28 for neodictyolactone. The position of the lactonic carbonyl, 18-C (27) or 19-C (28), was determined by the following chemical transformations (Figure 2). Neodictyo-

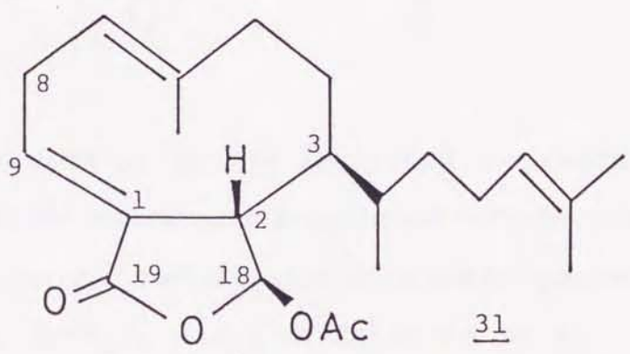
Figure 2.



lactone was reduced with lithium aluminum hydride to afford the diol 29 [δ 4.11 (2H, ABq, J = 11 Hz), 4.12 (2H, s)]. The diol was treated with PCC in dichloromethane, giving rise to a lactone together with dictyofuran T (30),[22] the formation of which supported the carbon framework of neodictyolactone. In this oxidation process, it is likely that the less hindered hydroxy group (19-C) of the diol 29 would have been oxidized in preference to the more hindered one (18-C),[23] so that the resulting lactone would have the 19-keto structure (28). This lactone was different from neodictyolactone in TLC, GC, and MS, therefore, the structure 27 is assignable to neodictyolactone. NOEDS experiments (400 MHz) are consistent with the structure 27; on irradiation at δ 4.60 (19-H_b), significant NOEs were detected for the signals of 9-H_b (δ 2.3) and 20-Me (δ 1.26).

18-Acetoxydictyolactone (31),[20] has the molecular formula $C_{22}H_{32}O_4$, suggesting that an acetoxy group is present in addition to a diterpenoid framework. The UV maximum at 224 nm (ε 8200), the IR bands at 1785 and 1640 cm^{-1}, and the ^{1}H-NMR signal at δ 7.06 due to an olefinic proton are suggestive of an α-alkylidene-γ-lactone structure. This proton (9-H) was deduced to be adjacent to a doubly allylic methylene protons (8-H_2; δ 2.8-3.4) as in dictyolactone (22),[17] because irradiation of the latter affected the signals at δ 7.06 (9-H) and also at 5.37 (7-H). The acetoxy group has to be located at 18-C, since the signal of the methine proton on the carbon bearing the acetoxy group shifts down to δ 6.68. These findings

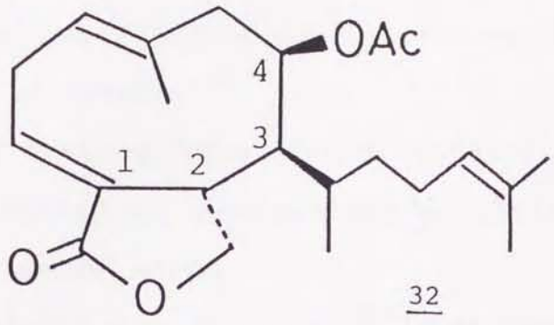
allowed me to deduce the structure of this compound to be 31, and the other spectral properties are compatible with the structure. The relative configurations at 2, 3, and 18-C of 31 were assigned as illustrated in the structure from the consideration of the null coupling constants between 18-H and 2-H, as well as 2-H and 3-H. Molecular models reveal that the dihedral angles formed by each of these protons are 90° in 31.



31

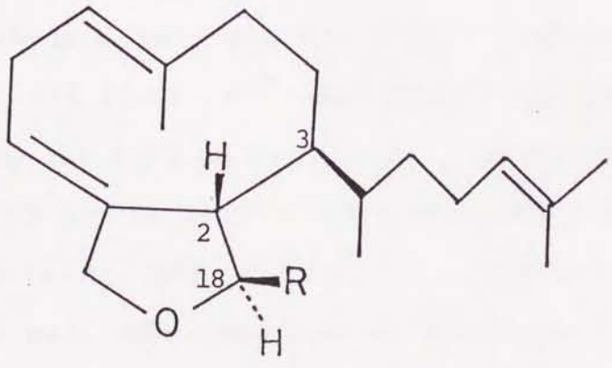
4-Acetoxydictyolactone (32), $C_{22}H_{32}O_4$, $[\alpha]_D$ -224° (c 0.86, $CHCl_3$), UV(EtOH) 220 nm (ε 8500), IR(CCl_4) 1760, 1740, 1640 cm^{-1}, is an isomer of acetoxydictyolactone (31). The ^{1}H-NMR spectrum of this compound is very similar with that of dictyolactone (22)[17] except for the signals of an acetoxy (δ 2.03) and oxygen-bearing methine proton (δ 5.27). On the basis of the COSY spectrum, the acetoxy group was deduced to be located at 4-C, and the relative configuration of this carbon was assigned as illustrated in the structure 32 from the coupling constants (J = 4.5, 2.3 Hz) of this methine proton. The relative configurations of other carbons in this compound were

determined to be identical with those of dictyolactone (22) by comparison of the coupling pattern.



32

In the similar way as described for neodictyolactone, 18-acetoxydictyolactone and 4-acetoxydictyolactone, the structure of another new diterpene, **isodictyoacetal**,[20] $[\alpha]_D$ -7.7 ° (c 0.75, $CHCl_3$), was elucidated to be 33. On hydrolysis of 33 (TsOH in dioxane-water) there was obtained a hemiacetal, which exhibits an acetalic methine proton signal at δ 5.65 in the ^{1}H-NMR spectrum. This chemical shift and also other spectral features of this product are identical with those



33 : R = OMe
23 : R = OH

reported for isodictyohemiacetal (23).[18] As observed in 18-acetoxydictyolactone (31), the coupling constants, J_{2-3} and J_{2-18}, in the ^{1}H-NMR spectrum of 33 are zero, which led to the assignment of the relative configurations at 2, 3, and 18-C as seen in the structure.

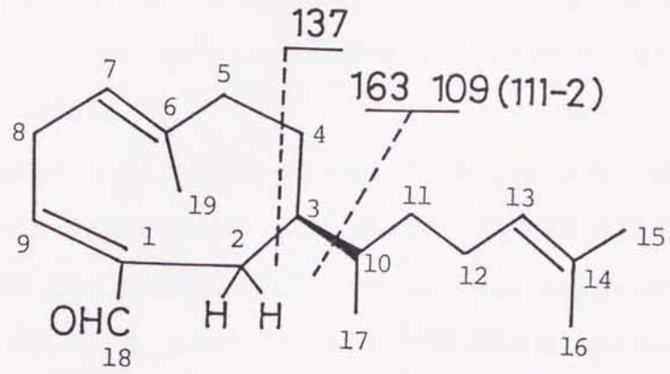
Further fractionation of the methanol extract afforded another new diterpene, **pachyaldehyde [(34); 3 mg],**[24] composed of nineteen carbon atoms.

The proton-noise decoupled ^{13}C-NMR spectrum of pachyaldehyde (34), $[\alpha]_D$ -40° (c 0.21, $CHCl_3$), contains nineteen signals. The multiplicities of the carbon signals (off-resonance spectrum), which indicate the number of the protons, and the molecular ion at m/e 274 in the mass spectrum suggest the molecular formula $C_{19}H_{30}O$ for pachyaldehyde. The high resolution mass spectrum supports this formula (M^+, m/e 274.229, $C_{19}H_{30}O$ requires 274.230). The ^{13}C-NMR spectrum contains signals due to six olefinic carbon atoms (three C=C's) and an aldehydic carbon atom (δ 195.9), which show that pachyaldehyde is monocyclic. The presence of an α,β-unsaturated aldehyde moiety was shown by the IR bands at 2720, 1685 (CHO), and 1610 (C=C) cm^{-1}, and the ^{1}H-NMR (90 MHz) signals at δ 9.32 (CHO) and 6.69 (H-C=C-CHO). The proton at δ 6.69 (9-H, dd, J = 8, 3 Hz) is coupled with the methylene protons appearing at δ 3.23 (8-H_b, ddd, J = 16, 12, 3 Hz) and 2.96 (8-H_a, ddd, J = 16, 8, 4 Hz). The methylene protons are further coupled with the olefinic proton at δ 5.39 (7-H, dd, J= 12, 4 Hz), irradiation

Table 1. The ^{13}C n.m.r. data[a] for pachyaldehyde (34), acetyldictyolal(24), dictyodial(21), and dictyolactone (22).

C atom	Pachyaldehyde(34)	Acetyldictyolal(24)	Dictyodial(21)	Dictyolactone(22)
1	149.4	150.1	148.5	135.4
2	29.5	42.3	56.5[c]	43.8
3	45.8	46.9	48.5	47.1
4	28.0	28.5	29.1	28.6
5	40.4	41.4	40.7	40.1
6	137.1	138.3	137.9	136.4
7	122.3	122.1	122.3	122.8
8	29.1	29.1	28.7[c]	30.3
9	155.3	156.9	157.4	139.5
10	36.7	32.1	32.7	32.5
11	35.7	38.0	37.6	37.2
12	26.4	26.2	25.7	25.6
13	125.2	124.9	124.4	124.1
14	130.8	130.9	130.9	131.1
15	25.7	25.7	25.4	25.4
16	17.7[b]	17.7	17.4	17.5
17	14.8	16.8	17.0	17.1
18	195.9	195.9	194.2	172.5
19	17.6[b]	17.3	17.1	17.5
20	-	63.1	203.5	67.8

[a]Chemical shifts are relative to the center line of $CDCl_3$. [b]Assignment may be reversed. [c]Assignment of these signals appearing in the reference 17 should be corrected as in this Table.



34

Table 2. ^{1}H N.m.r (400 MHz) data for pachyaldehyde (34).

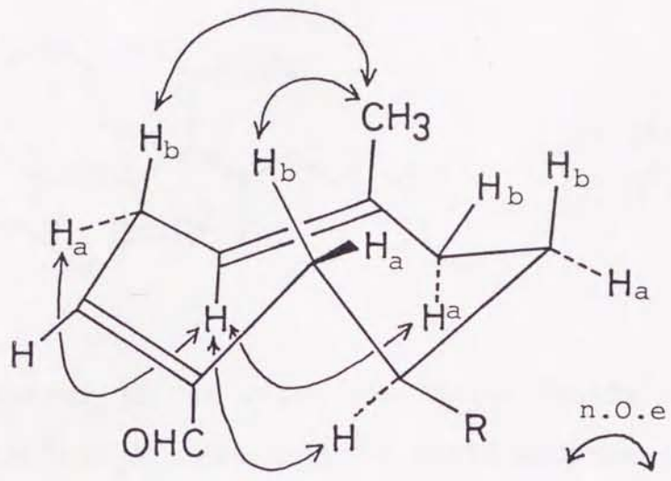
proton	δ^{a}	proton	δ^{a}
2	2.43 (dd)	9	6.69 (br. dd)
	1.51 (d)	10	1.66 (m)
3	1.28 (ddd)	11	1.20 (m)
4	1.55 (dddd)	12	1.90 (m)
	1.39 (dq)	13	5.05 (br. t)
5	1.98 (dt)	15	1.66 (br. s)
	2.21 (ddd)	16	1.57 (br. s)
7	5.39 (br. dd)	17	0.85 (d)
8	2.96 (ddd)	18	9.32 (s)
	3.23 (ddd)	19	1.75 (br. s)

[a] In $CDCl_3$ at 28° and from TMS as an internal standard. J(H-H) values in Hz: (2a-2b) 14, (2a-3) 7, (2b-3) 0, (4a-4b) 12, (4b-3) 12, (4a-5a) 5, (4a-5b) 3, (4b-5a) 12, (4b-5b) 4, (5a-5b) 12, (7-8a) 4, (7-8b) 12, (8a-8b) 16, (8a-9) 8, (8b-9) 3, (13-12) 7, (17-10) 7; others not resolved.

of which resulted in sharpening of the methyl signal at δ 1.75 (19-Me, bs). These data indicated the partial structure (OHC-C=CH-CH_2-CH=C-Me).

The presence of the 6-methyl-5-hepten-2-yl group, the side chain which is frequently encountered in the diterpenes isolated from the Dictyotaceae algae, was evident from the mass fragment at m/e 109, and also the ^{13}C-NMR signals which correspond well with the side chain carbon atoms (see structure 34 and Table 1). The ^{13}C-NMR spectrum shows the presence of three additional methylene and one methine groups. Biogenetic considerations led to the structure 34 (or its alternative having the side chain at 4-C) for pachyaldehyde. The configuration of the double bond at 1(9)-C was deduced as E from the upfield chemical shift of the aldehyde proton (δ 9.32) in the ^{1}H-NMR spectrum.[25] Also, the E-configuration of C_6=C_7 was determined from the ^{13}C-NMR chemical shift of the 19-methyl group (δ 17.6).[25]

As to the position of the side chain, 3-C was considered to be more appropriate than 4-C, because the ^{13}C-NMR spectrum of pachyaldehyde (34) corresponds well with those of acetyldictyolal (24),[11] dictyodial (21),[17] and dictyolactone (22),[17] as shown in Table 1. Furthermore, the 400 MHz ^{1}H-NMR spectrum (Table 2) of pachyaldehyde established the coupling constants between the protons on the ring carbon atoms, providing the conformation of the cyclononadiene ring illustrated in 35, and also further suggesting the position of



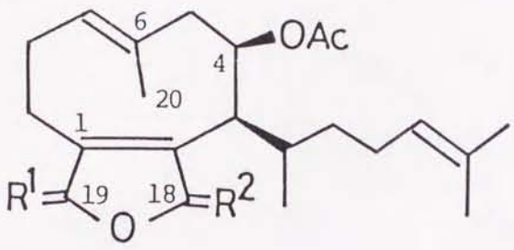
35

the side chain at 3-C. The NOE found for 34 (depicted in 35 by arrows) are consistent with the proposed conformation.

Pachyaldehyde is the first example of a norditerpene possessing a cyclononadiene skeleton.

Fractionation of the methanol extract of Dictyota dichotoma afforded a novel new diterpenoid, dictyotalide B, which has a bridged γ-lactone ring having a double bond at bridgehead.

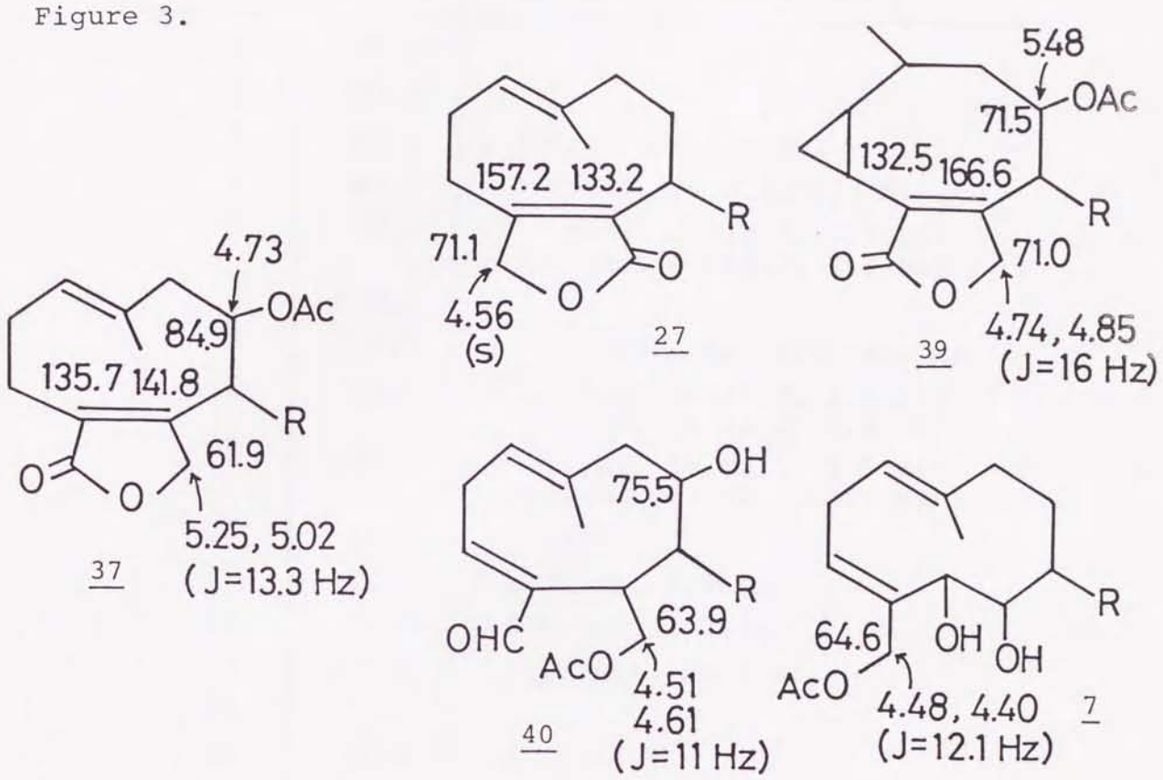
Dictyotalide B (36), $C_{22}H_{32}O_4$ (m/e 360.2338), $[\alpha]_D$ +50.3° (c 0.59, $CHCl_3$), is an isomer of 4-acetoxydictyolactone (32). The presence of a γ-lactone, 6-methyl-5-hepten-2-yl group, and a trisubstituted olefin moiety bearing a methyl group is apparent from the spectral properties (Table 3). The absence of the downfield olefinic proton observed for 9-H of 32 strongly suggested that dictyotalide B had the structure 37 or its 18-C



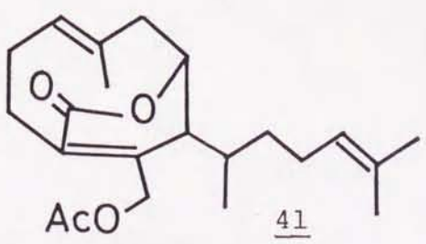
37: $R^1=H_2$, $R^2=O$
38: $R^1=O$, $R^2=H_2$

carbonyl isomer 38, in which the $C_9(C_1)$ double bond of 32 migrated to $C_1(C_2)$. Actually we could propose reasonable conformation for dictyotalide B that completely satisfied all the observed coupling patterns and NOEs of the protons, and the structure 37 (or 38) had been believed to be that of dictyotalide B, until I noticed some conflicts in the NMR chemical shifts of several protons and carbons when I compared them with those of other diterpenes from the Dictyotaceae algae (Figure 3): (i) The chemical shift of 4-C (δ 84.9) of 37 (tentative structure) is too low for acetoxy methine carbons (cf. 39[23]). (ii) The shift of 18-C is too high for ordinary γ-methylene carbons of α,β-unsaturated γ-lactone (cf. 27,[20] 39), and also the geminal coupling constant (J = 13 Hz) between the 18-methylene protons of 37 is too small (cf. 27, 39), rather resembling those of the acetoxymethylene (cf. 40,[18,26] 7[7]). (iii) The β-carbon (2-C) of 37 shows the carbon signal at about 20 ppm higher field than those of 27, and 39. On the basis of these considerations, we proposed two other structures 36 and 41 instead of 37 (or 38) for dictyotalide B. At first sight

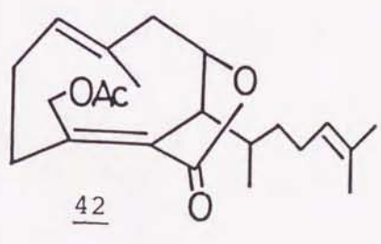
Figure 3.



the structures seemed to be implausible since they apparently violate Breds' rule. The structure 41 is the case; it was impossible to construct the molecular models for 41. However, the models for 36 (or stereoisomer 42) were quite easily built,



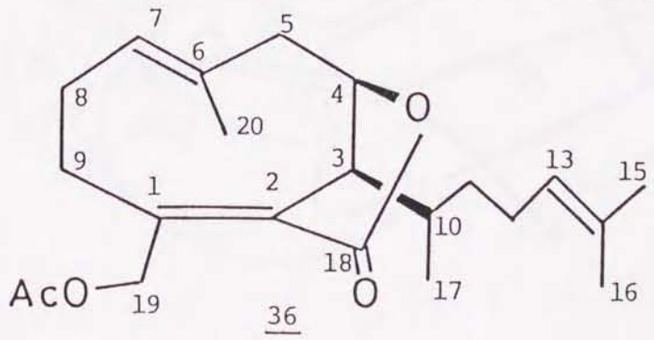
41



42

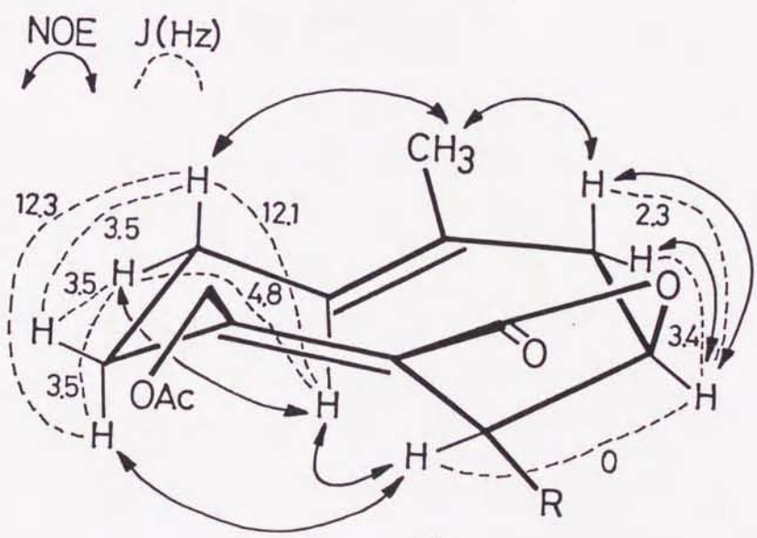
Table 3. ^{1}H and ^{13}C-NMR spectra of dictyotalide B (36)

Carbon	^{13}C-NMR	^{1}H-NMR (500 MHz, $CDCl_3$)
1	141.8	-
2	133.3	-
3	50.7	2.52(d, J= 8.5 Hz)
4	84.9	4.73(dd, J= 3.4, 2.3 Hz)
5	44.2	a)2.18(dd, J= 13.7, 3.4 Hz) b)2.60(dd, J= 13.7, 2.3 Hz)
6	135.7	-
7	125.9	5.07(brdd, J= 12.1, 4.8 Hz)
8	29.7	a)2.46(dq, J= 12.3, 3.5 Hz) b)2.11(qd, J= 12.3, 3.5 Hz)
9	33.5	a)1.87(td, J= 12.3, 3.5 Hz) b)2.54(dt, J= 12.3, 3.5 Hz)
10	34.5	1.49(m)
11	33.5	1.38(m), 0.96(m)
12	25.7	2.00(m), 1.85(m)
13	124.0	5.00(brt, J= 7 Hz)
14	132.0	-
15	25.8	1.66(brs)
16	17.8	1.57(brs)
17	17.3	0.92(d, J= 6.6 Hz)
18	169.3	-
19	61.9	5.25(d, J= 13.3 Hz) 5.02(d, J= 13.3 Hz)
20	19.2	1.38(brs)
AcO	170.8	-
	21.0	2.10(s)



36

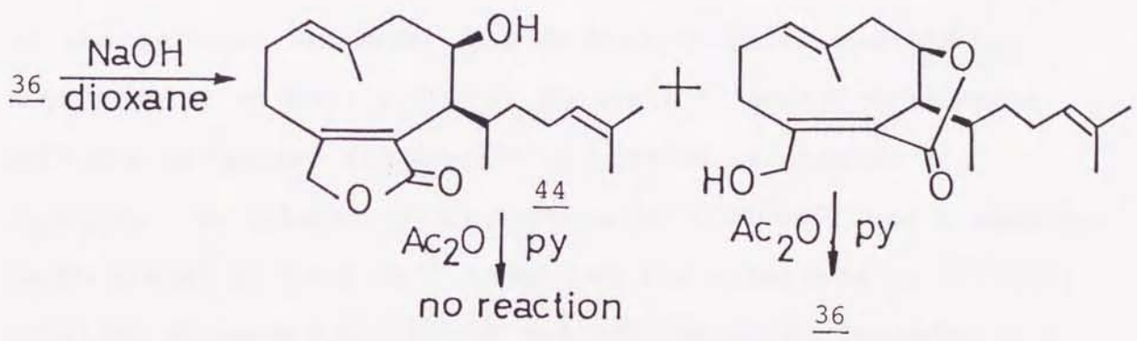
and the attention was focused on the structure 36 (or 42). This structure was compatible with all the chemical shifts of the protons and carbons that were argued above [(i)-(iii)] as well as the coupling patterns of other protons. Thus, the unusual upfield chemical shift (δ 141.8) of 1-C is interpretable by the finding that, in the molecular models, the carbonyl group is out of the plane formed by the double bond (C_1=C_2). The end absorption of the UV spectrum is also suggestive that the lactonic carbonyl is not fully conjugated with the double bond (cf. 27; λ_{max}(EtOH) 220 nm, 22; λ_{max}(MeOH) 226 nm). Eventually, dictyotalide B was proved to have the structure 36 (or 42) by observing the long-range couplings between protons and carbons: In the COLOC experiments the correlation peaks showing the coupling between the carbonyl carbon (18-C) and the methine proton at 4-C were clearly observed. Also, the



43

couplings from the methylene protons at 19-C to the carbonyl carbon of the acetoxy group were present. These observations could eliminate the possibility of the structure 36 (or 42). The conformation 43 is the most probable one that fits the coupling patterns and NOEs found for dictyotalide B.

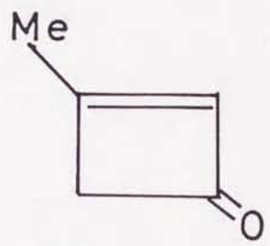
The Z-configuration of $C_1=C_2$ was confirmed by the following chemical transformations. Dictyotalide B was saponified (NaOH/dioxane), and the product was acetylated to give a 1 : 2 mixture of 36 and 44. Formation of the lactone 44 is in agreement with the Z-configuration of the 1-olefin group.



II-D Diterpenes with a Bicyclo[7.2.0]undecane Skeleton

Further biogenetic cyclization of the xenicane skeleton has produced several very unusual diterpenes, the most striking of which are **acetylcoriacenone (45)**[21] and **isoacetylcoriacenone (46)**.[21]

The methanol extract of P. coriaceum afforded a pair of isomers as very minor components after separation by column chromatography. These isomers could be separated by preparative TLC (hexane : ethyl acetate = 95 : 5, 11 developments) as viscous oils, which were designated as acetylcoriacenone (0.09% of the methanol extract) and isoacetylcoriacenone (0.07%). High resolution mass spectral analysis of acetylcoriacenone showed a molecular ion at m/e 344.233 corresponding to $C_{22}H_{32}O_3$. An intense IR absorption at 1770 cm^{-1} and a weak but sharp signal at 1610 cm^{-1} suggested the existence of a highly strained enone system, which was assumed to be included in a cyclobutane ring because these IR absorptions were reasonably close to those reported for 3-methylcyclobutenone (47).[27] A short wavelength absorption maximum (229 nm) with a small molar

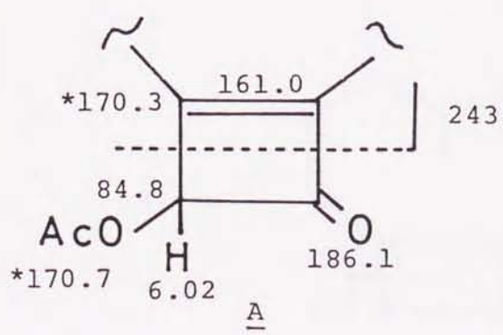


47

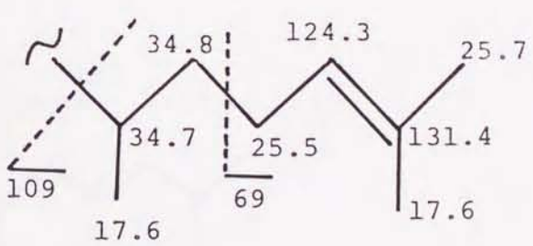
absorptivity (ε 6500) in the UV spectrum was also compatible with the reported value (219 nm, ε 6300) of 47. The unusual downfield chemical shifts of the olefinic carbons, δ 170.3 (or 170.7) and δ 161.0, together with the upfield chemical shift of the carbonyl carbon (δ 186.1) in the ^{13}C-NMR spectrum (Table 4) were characteristic of a cyclobutenone moiety.

The presence of an acetoxy group in acetylcoriacenone was easily recognized from the IR bands at 1740 and 1220 cm^{-1} and also the sharp singlet at δ 2.10 in the ^{1}H-NMR spectrum (Table 4). The position of the acetoxy group was assumed to be adjacent to the carbonyl group of the cyclobutenone system on the basis of a downfield singlet at δ 6.02 (1H) in the ^{1}H-NMR spectrum and a doublet at δ 84.8 in the ^{13}C-NMR spectrum. These properties allowed me to deduce partial structure A. A fragment at m/e 243 (base peak) in the mass spectrum supported this partial structure.

Further analysis of the spectra of acetylcoriacenone revealed the presence of a side chain B (^{13}C-NMR and mass

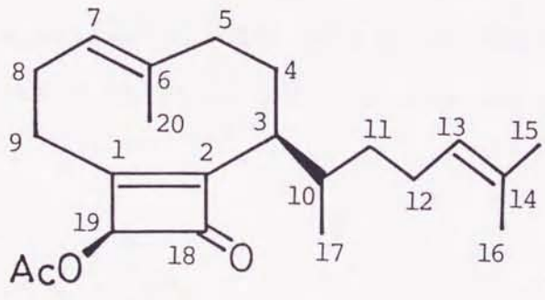


A

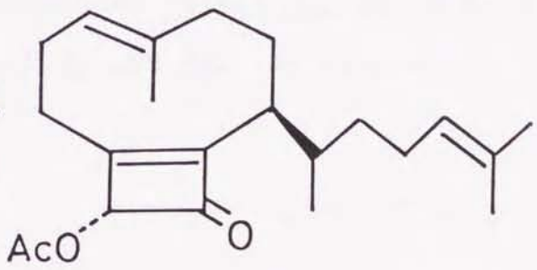


B

spectra) and a trisubstituted olefin having a methyl group. The configuration of the olefin was deduced to be E from the ^{13}C chemical shift (δ 16.3) of the methyl group. In the ^{1}H-NMR spectrum, the signal due to this methyl appeared relatively upfield (δ 1.41). Such shielded olefinic methyls are frequently encountered in the ^{1}H-NMR spectra of sesqui- and diterpenes that consist of medium-sized rings.[28)]

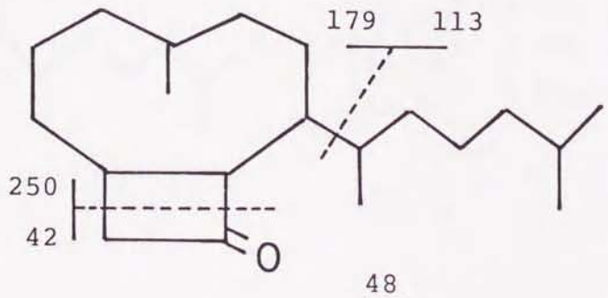


45



46

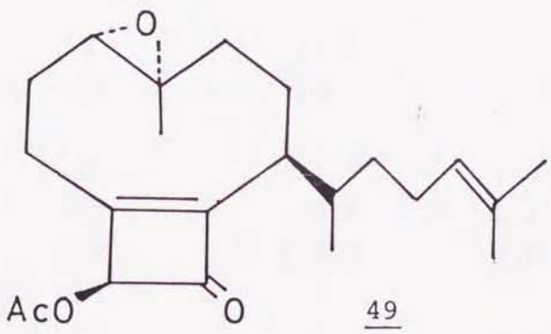
Catalytic hydrogenation of acetylcoriacenone brought about removal of the allylic acetoxyl, yielding the hexahydro derivative 48. An attempted Baeyer-Villiger reaction (MCPBA, $CDCl_3$, room temperature, 72 hr) resulted in recovery of 48. This



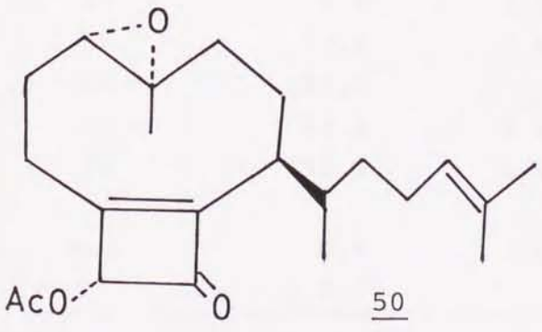
48

inertness is reasonable only if the carbonyl group of 48 is located close to a bulky group, the side chain. From these facts as well as biogenetic considerations, structure 45 (except the configurations of the substituents) was assumed for acetylcoriacenone. Since hydrogenation of isoacetylcoriacenone under the same conditions also afforded 48, the structure of this isomer was assumed to be 46.

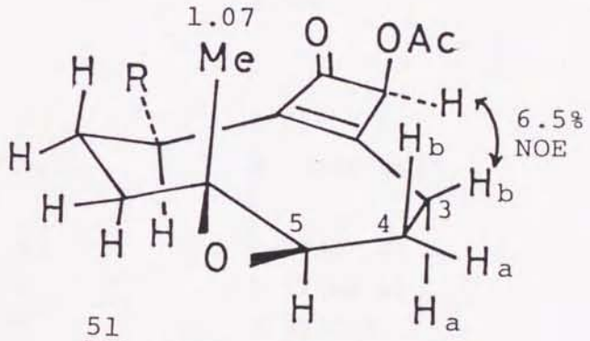
Structures 45 and 46 were confirmed by the following experiments, carried out on the epoxides 49 and 50, which were easily obtained by autoxidation of 45 and 46. By triple



49



50



51

$J_{3a,3b}$ = 14 Hz, $J_{3a,4a}$ = 4 Hz,
$J_{3a,4b}$ = 13 Hz, $J_{3b,4a}$ = 3 Hz,
$J_{3b,4b}$ = 3 Hz, $J_{4a,4b}$ = 15 Hz,
$J_{4a,5}$ = 0 Hz, $J_{4b,5}$ = 10 Hz

Table 4. Nuclear Magnetic Resonance Data for Acetylcoriacenone (45) and the Epoxide(49)

position number	carbon-13 chemical shift[a] 45	proton chemical shift[b] 45	proton chemical shift[b] 49
1	161.0	-	-
2	170.3[c]	-	-
3	28.5	2.79(dt,12,3)	2.67(ddd,14,13,4)
		2.3[d]	2.88(br d,14)
4	25.2	1.98[d]	1.18(ddd,15,13,10)
		2.28[d]	2.28(br dd,15,4)
5	122.8	5.13(dd,11,3)	2.88(br d,10)
6	140.4	-	-
7	40.2	1.9[d]	2.22[d]
		2.25[d]	
			[e]
8	31.6	[e]	1.85[d]
		[e]	[e]
9	43.4	[e]	[e]
10	34.7	1.7[d]	1.7[d]
11	34.8	1.3[d]	
			[e]
12	25.5	1.85[d]	1.85[d]
13	124.3	5.01(br t,7)	5.01(br t,7)
14	131.4	-	-
15	25.7	1.67(br s)	1.67(br s)
16	17.6	1.57(br s)	1.57(br s)
17	17.6	0.91(d,7)	0.93(d,7)
18	186.1	-	-
19	84.8	6.02(s)	6.07(s)
20	16.3	1.41(br s)	1.07(s)
AcO	20.8	2.11(s)	2.08(s)
	170.7[c]		

resonance experiments, the protons on 3-C, 4-C, and 5-C of 49 could be assigned in perspective structure 51. Observation of a 6.5% NOE on 19-H (δ 6.07) upon irradiation of 3-H_b (δ 2.88) lead to confirmation of the location of the acetoxyl at 19-C. Although no NOE between 19-H and 20-methyl (δ 1.07) was found for 49, a 10% NOE was detected between the corresponding proton (δ 5.93) and methyl (δ 1.00) for the isomer 50. On the basis of these findings, the configurations of the acetoxy groups relative to 20-methyls of 49 and 50 were assigned as depicted in the respective structures. The chiroptical properties of 45 and 46 supported these assignments; the CD curves (Figure 4) of 45 [226 nm (Δε -7.8), 316 nm (Δε 1.2)] and 46 [234 nm (Δε 11.6), 317 nm (Δε -2.2)] are almost antisymmetric, showing that the Cotton effect is primarily affected by the acetoxy adjacent to the carbonyl group and that the acetoxycyclobutenone

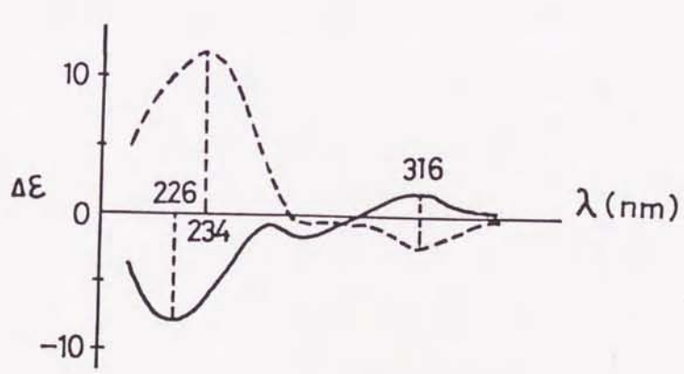


Figure 4. CD spectra of acetylcoriacenone (45, ——) and isoacetylcoriacenone (46, ----).

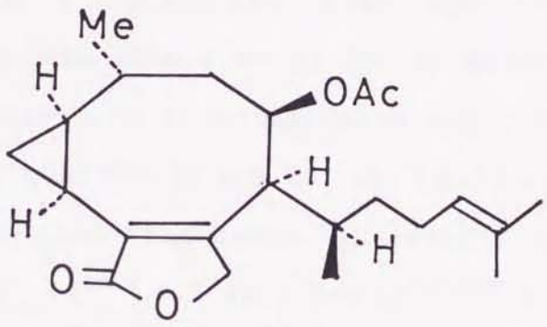
moieties of these two isomers are in an enantiomeric relationship.

Of the possible conformations of epoxide 49, the conformer 51 (or its enantiomer) is the only one that fulfills the ^{1}H-NMR properties, that is, coupling patterns, shielding of the methyl at 6-C, and NOE.

Acetylcoriacenone and isoacetylcoriacenone are the first representatives of a novel class of diterpenes that incorporate a cyclobutenone fused to a nine-membered ring system.

II-E Diterpenes with a Crenulide Skeleton

Among the diterpenes found from the Dictyotaceae seaweeds, crenulides are one of the most unique groups, because they have a novel skeleton composed of a cyclooctane ring fused with a cyclopropane ring, as exemplified by acetoxycrenulide (52).[23]



52

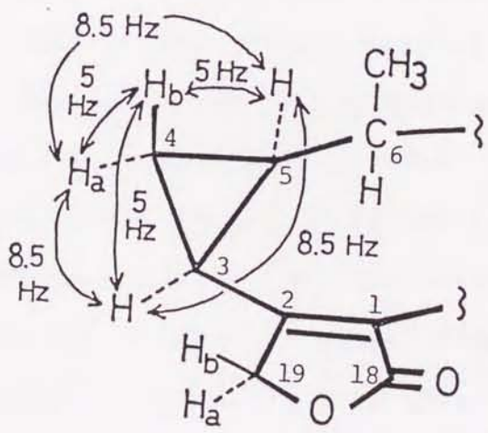
A new compound having a crenulide skeleton was isolated from P. coriaceum, and its structure together with the stereochemical features was elucidated by spectral analyses.

By repeated column chromatography on silica gel of the methanol extract of the alga, followed by HPLC separation, a new compound, which was designated as pachylactone,[29] was obtained as an oil (4 mg from 30 g of the methanol extract).

Pachylactone (53), $C_{20}H_{30}O_2$ (M^+, m/e 302), $[\alpha]_D$ -23.3° (c 0.18, $CHCl_3$), exhibits IR bands at 1755 (s) and 1660 (w) cm^{-1}, and ^{1}H-NMR signals (90 MHz) centered at δ 4.60 (2H, ABq, J = 16 Hz), which, coupled with the UV maximum at 228 nm (ε 11700), indicate the presence of an α,β-unsaturated γ-lactone. The

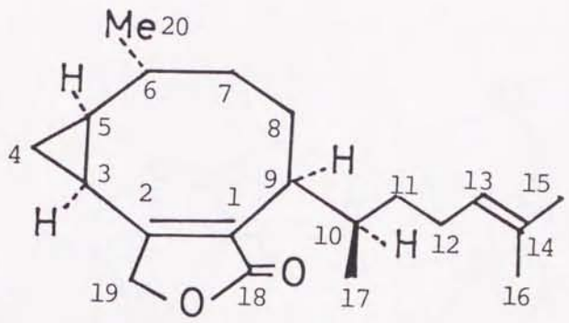
fragments at m/e 191 (100%) and 109 (44%) suggest that 6-methyl-5-hepten-2-yl group is included in pachylactone. Its ^{13}C-NMR spectrum (Table 6) shows a series of signals, the chemical shifts of which correspond well to those reported for the side chain carbons. The presence of a cyclopropane ring in pachylactone is recognized by the multiplet at δ 0.11 (1H) appearing in the ^{1}H-NMR spectrum (90 MHz).

Analysis of the 400 MHz ^{1}H-NMR spectrum (Table 5) allowed me to propose the structure 53 for pachylactone. The upfield signal ascribable to a cyclopropane methylene proton (4-H_b) appears as a quartet (J = 5 Hz) at δ 0.11. The coupling pattern shows that this proton is equally coupled with three protons, 4-H_a (J^{gem} = 5 Hz), 3-H (J^{trans} = 5 Hz), and 5-H (J^{trans} = 5 Hz). The other methylene proton signal (4-H_a) appears at δ 0.91 as a double triplet (J^{gem} = 5 Hz; J^{cis}_{4a-3} = J^{cis}_{4a-5} = 8.5 Hz). From these properties, it is obvious that the cyclopropane ring is cis-disubstituted.[30] Decoupling



experiments showed that two other cyclopropane protons exhibit signals at δ 1.0 and 1.7. The downfield chemical shift of the latter suggests that the cyclopropane ring is connected with an unsaturated moiety, the α,β-unsaturated γ-lactone. By means of 2D-correlation spectroscopy (COSY), together with decoupling works, a tertiary carbon (6-C) possessing a methyl group is revealed to be adjacent to the other side of the cyclopropane ring. Surprisingly, the proton (6-H) on this tertiary carbon is highly shielded up to δ 0.85, indicating that this proton orients above the plane formed by a carbon-carbon double bond (C_1=C_2). Detection of a 5% NOE between 4-H_b (δ 0.11) and 19-H_b (δ 4.46) settled the position of the lactonic carbonyl at 18-C (not at 19-C).

The downfield triplet (J = 9 Hz) at δ 2.54 is ascribable to an allylic methine (9-H). Irradiation at this signal simplified the multiplets at δ 1.45 (8-H_b) and 2.33. Inversely, irradiation at the latter multiplet (δ 2.33) simultaneously changed the triplet at δ 2.54 into a doublet, and a doublet due to a methyl (17-Me; δ 0.95) into a singlet. These facts show that the multiplet at δ 2.33 is assignable to 10-H. This unusual downfield chemical shift of 10-H, and also the relatively large coupling constant (9 Hz) between 10-H and 9-H are best interpreted by assuming that the rotation about C_9-C_{10} axis of the side chain would be restricted, and the side chain would take the conformation, in which 10-H has to be located close to the carbonyl group (18-C), and, at the same time, the



53

Table 5. ^{1}H-NMR chemical shifts of pachylactone (53).

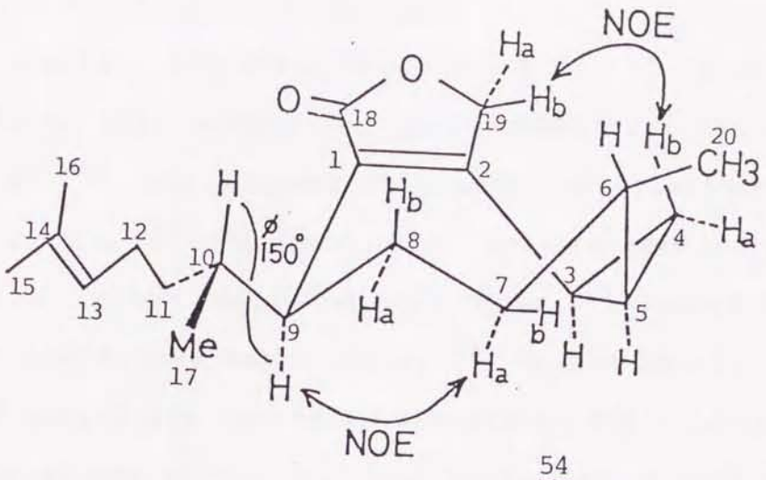
position No.	
3	δ 1.7 (m)
4a	0.91 (dt,J=5,8.5 Hz)
4b	0.11 (q,J=5 Hz)
5	1.0 (dtd,J=10,8.5,5 Hz)*
6	0.85 (m)
7a	1.54 (m)
7b	1.7 (ddd,J=12,7,2 Hz)*
8a	2.0 (m)
8b	1.45 (m)
9	2.54 (t,J=9 Hz)
10	2.33 (m)
11	1.32 (m)
11	1.05 (m)
12	1.95 (2H,m)
13	5.08 (bt,J=7 Hz)
15	1.66 (3H,s)
16	1.58 (3H,s)
17	0.95 (3H,d,J=7 Hz)
19a	4.68 (d,J=17 Hz)
19b	4.46 (d,J=17 Hz)
20	1.00 (3H,d,J=7 Hz)

*Coupling pattern was determined by J-resolved 2D-spectroscopy.

Table 6. ^{13}C-NMR chemical shifts of 53 and isoacetoxycrenulatin (55).

carbon No.	53	55
1	δ 131.1	δ 131.3
2	160.3	162.4
3	13.6*	13.2
4	8.7	7.9
5	25.5*	25.7
6	35.7	29.8
7	39.0	44.8
8	30.1	70.9**
9	43.0	46.8
10	32.0	30.1
11	35.4	35.6
12	25.5	26.4
13	124.9	124.7
14	135.0	131.5
15	25.7	24.7
16	17.8	17.5
17	17.7	18.0
18	174.0	173.8
19	71.7	71.3
20	23.3	23.7

*Assignment was confirmed by heterospin selective decoupling works. **Carbon bearing an acetoxyl group.

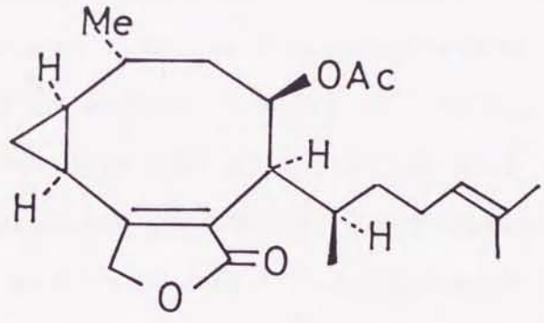


54

dihedral angle formed by 9-H and 10-H has to be around 150°. A significant NOE was detected for 9-H by irradiating at 7-H_a (δ 1.54) (NOE difference spectrum). From the considerations of all these properties, the conformation of pachylactone, as well as the relative configurations at 6-C and 9-C, was deduced as in 54. The unusual upfield chemical shift of 6-H (δ 0.85) is well interpreted by this conformation; the proton situates not only above the plane of C_1=C_2, but also above the cyclopropane ring.[31] Molecular models show that the dihedral angles formed by 9-H and each of 10-H, 8-H_b, and 8-H_a are 150°, 170°, and 75°, respectively, thus, verifying the triplet nature of 9-H. The coupling constant between 5-H and 6-H was determined to be 10 Hz by J-resolved 2D-NMR spectrum. This magnitude is quite reasonable, since these protons are in the anti-coplanar relationship in 54. Detection of NOEs between 19-H_b and 4-H_b

(2.2 Å) and also between 7-H_a and 9-H (2.3 Å) is a good evidence for this conformation.

Recently, the structure elucidation of isoacetoxycrenulatin (55) (except for stereochemistry) has been reported.[32] The present diterpene, pachylactone (53), exhibits the ^{13}C-NMR spectrum closely resembling that of 55 (Table 6), which indicated that these diterpenes have the same carbon framework, crenulatane.[33] On the basis of the ^{1}H-NMR data reported for isoacetoxycrenulatin (55), coupled with the considerations of the proposed conformation (54) of pachylactone, the stereochemistry of isoacetoxycrenulatin was deduced to be as illustrated in 55.



55

II-F Diterpenes with a Bicyclo[4.3.1]decane Skeleton

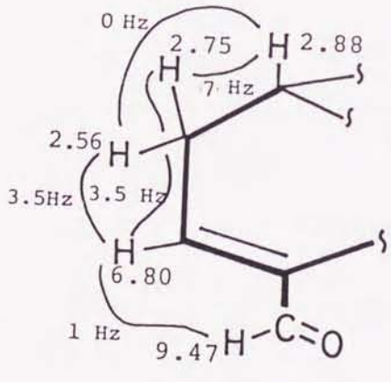
Cyclization of the xenicane skeleton with formation of a bond between carbons 7 and 18 provides the bridged bicyclic diterpenes, which have never been found thus far.

Chromatographic separation of the methanol extract of P. coriaceum afforded two new diterpenoids having the bicyclo[4.3.1]decane skeleton, sanadaol[34] and acetyl-sanadaol.[34]

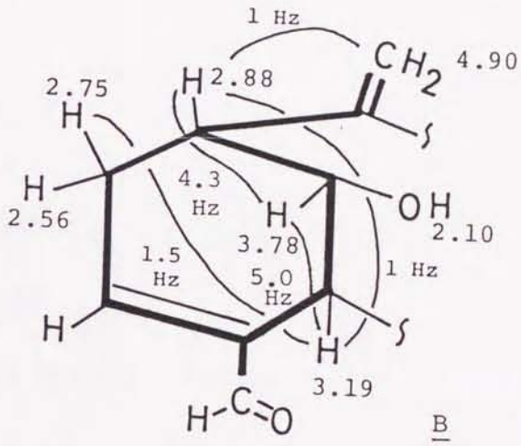
Sanadaol (56) showed the highest ion peak at m/e 302 corresponding to the molecular formula $C_{20}H_{30}O_2$ in the mass spectrum. The ^{13}C-NMR spectrum also supported this molecular formula. Sanadaol exhibited IR absorption bands due to a hydroxy (3560 cm^{-1}) and an α,β-unsaturated aldehyde (2710, 1685, 1630 cm^{-1}) groups. In the ^{1}H-NMR spectrum (100 MHz), the aldehyde proton appeared as a singlet at δ 9.47. The chemical shift of an olefinic proton (δ 6.80) showed that this proton was on the β-carbon of the α,β-unsaturated aldehyde, and had the cis-relationship with the aldehyde group. The olefin signal was splitted into a triplet (J = 3 Hz) by coupling with methylene protons which appeared at δ 2.6 as a multiplet. More detailed experiments by means of a 270 MHz NMR instrument (Table 7) revealed that the aldehyde and the olefinic protons were weakly coupled (J = 1 Hz) with each other. The signals due to the methylene protons now appeared as well-separated peaks at δ 2.75 and 2.56 (each 1H). Double resonance experi-

ments showed that each of them was equally coupled with the olefinic proton (δ 6.80) with the coupling constant of 3.5 Hz. Furthermore, the signal at δ 2.75 was found to be coupled with a methine proton at δ 2.88, suggesting part structure A.

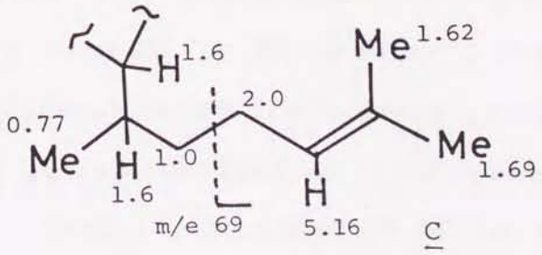
The methine proton resonating at δ 2.88 should be adjacent to an exomethylene group, the signal of which was sharpened on irradiation at the methine signal. Moreover, since this methine proton was coupled with a proton at δ 3.78 (J = 4.3 Hz), the methine group should be bonded to another tertiary carbon bearing a hydroxy group. This carbinyl proton was coupled with two other protons, a hydroxy (δ 2.10, J = 9.0 Hz) and another down-field methine (δ 3.19, J = 5.0 Hz) protons.



A



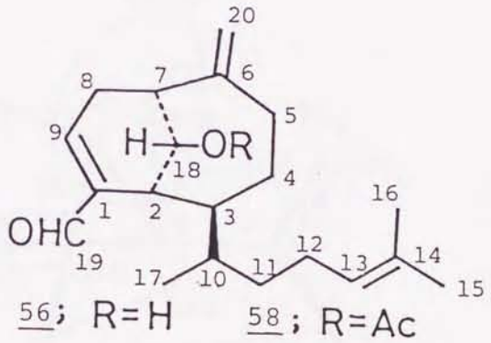
B



C

Observation of a long range coupling between this methine proton (δ 3.19) and the aforementioned proton at δ 2.75 (J = 1.5 Hz) allowed the part structure A to be expanded to B.

Presence of fragment C in sanadaol was evident from its ^{1}H-NMR and mass spectra, although a signal ascribable to a secondary methyl group appeared at considerably upfield (δ 0.77) in contrast to those of dictyodial (21)[17] (δ 0.89) and dictyolactone (22)[17] (δ 0.95), indicating that the environment of the side chain of sanadaol was different from those of the two diterpenes. Combination of the part structures B, C, and remaining two methylene units on the basis of the consideration of the ^{13}C-NMR spectrum and the coupling constants lead to the structure 56 for sanadaol including relative stereochemistry.

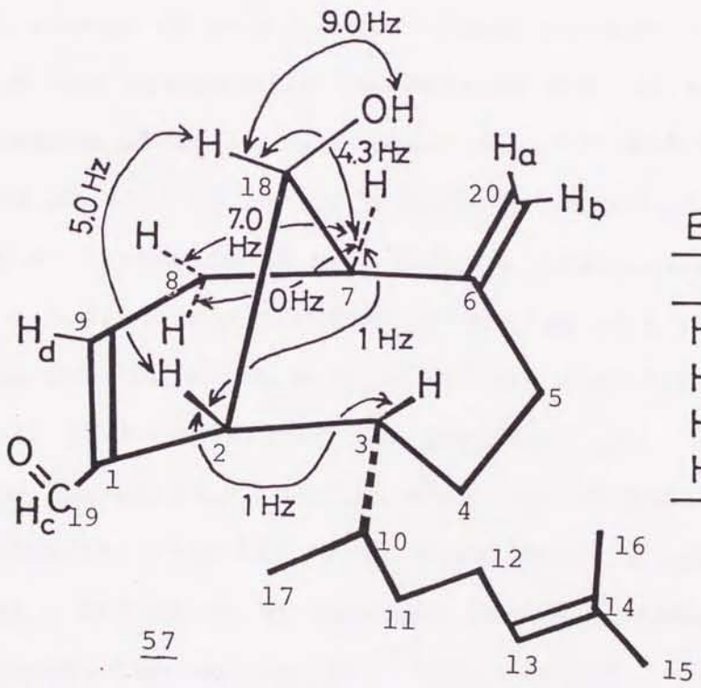


56; R=H 58; R=Ac

Orientation of the side chain on 3-C was verified from a small coupling constant (1 Hz) between 2-H (δ 3.19) and 3-H (δ 1.6). The configuration of the hydroxy group at 18-C was determined to be as described in 57 by means of a lanthanide shift reagent. That is, on addition of 2.6 molar equivalents

Table 7. ^{1}H-NMR spectrum (270 MHz, $CDCl_3$) of sanadaol (56).

proton	chemical shift (δ)
H- 2	3.19 (dddd,J=5.0,1.5,1,1 Hz)
3	1.6 (obscured by Me signals)
4	1.3 (2H,m)
5	2.25 (2H,m)
7	2.88 (dddt,J=7.0,4.3,1,1 Hz)
8a	2.75 (dddd,J=21.0,7.0,3.5,1.5 Hz)
8b	2.56 (dd,J=21.0,3.5 Hz)
9	6.80 (td,J=3.5,1 Hz)
10	1.6 (obscured by Me signals)
11	1.0 (2H,m)
12	2.0 (2H,m)
13	5.16 (t,J=7.0 Hz)
15	1.69 (s)
16	1.62 (s)
17	0.77 (d,J=6.2 Hz)
18	3.78 (ddd,J=9.0,5.0,4.3 Hz)
19	9.47 (d,J=1 Hz)
20	4.90 (2H,td,J=1,1 Hz)
OH	2.10 (d,J=9.0 Hz)



57

Eu(fod)$_3$shift	
	Δδ
Ha	1.58
Hb	1.10
Hc	0.85
Hd	0.73

of $Eu(fod)_3$, the signal due to the exomethylene protons (20-H) shifted to downfield much more significantly (δ 1.58 for 20-H_a and 1.10 for 20-H_b) than those of 8-H (δ 0.73) and 19-H (δ 0.85).

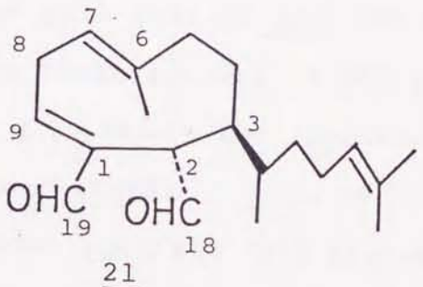
The structure 56 of sanadaol was unambiguously confirmed by the following chemical conversion. A solution of dictyodial (21) in dichloromethane was allowed to stand with silica gel at room temperature for 12 hr, affording sanadaol. An acid-catalyzed ene reaction might be involved in this transformation.[19]

Acetylsanadaol (58) exhibited a molecular ion perk at m/e 344 corresponding to an acetate of sanadaol (56) in the mass spectrum. The IR spectrum (1730, 1690, 1630 cm^{-1}) suggested the occurrence of an α,β-unsaturated aldehyde. The ^{1}H-NMR spectrum was essentially the same as that of sanadaol except the presence of an acetyl signal (δ 2.03) and downfield chemical shift (δ 4.75) of a methine proton on the carbon bearing an oxygen function. Indeed, acetylation of 56 with acetic anhydride and pyridine gave rise to a product, the spectral data of which were identical with those of acetylsanadaol, thus confirming the structure 58.

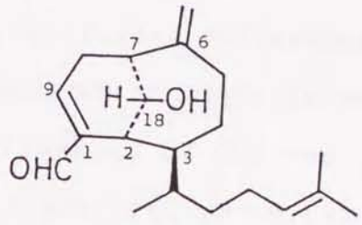
The bicyclo[4.3.1]decane skeleton of sanadaol (56) and acetylsanadaol (58) has never been found in natural products thus far. Formation of sanadaol from dictyodial (21) on silica gel suggests the possibility that sanadaol could be an artifact which was produced during chromatographic separation. However,

existence of acetylsanadaol, which is without doubt a natural product, in the methanol extract of the alga, shows that sanadaol is, at least in part, of a natural origin.

The conversion of dictyodial (21) was carried out under extremely mild reaction conditions.[19] Thus, when 21 (230 mg) was allowed to stand with silica gel (10 g; Merck, Kieselgel 60 F_{254}, Art. 7734) in dichloromethane (10 ml) at room temperature for 12 hr, there was obtained two unknown products, A (30 mg, 13%) and B (28 mg, 12%), together with sanadaol (56; 74 mg, 33%).



21

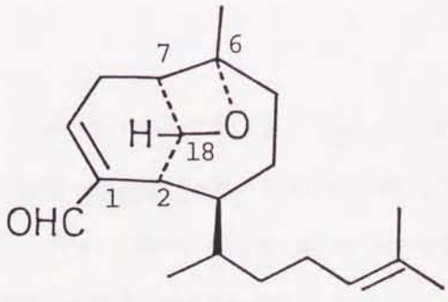


56

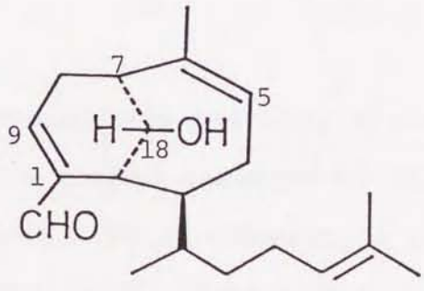
Compound A has the same molecular composition ($C_{20}H_{30}O_2$) as that of sanadaol (56). Of the two aldehydic proton signals at δ 10.13 (d, J = 3Hz) and 9.28 (s) in the ^{1}H-NMR spectrum of dictyodial (21), the signal corresponding to the former doublet is absent in the ^{1}H-NMR spectrum of compound A. The unconjugated aldehyde group at 18-C and the olefin group at 6-C must be involved in the reaction, because the signals due to the olefinic proton at 7-C and the olefinic methyl at 6-C are not present in the ^{1}H-NMR spectrum of compound A. The ^{1}H-NMR

spectrum considerably resembles that of sanadaol (56), except for a sharp singlet at δ 1.36 due to a tertiary methyl group instead of the exo-methylene signals in 56. On the basis of these data, the structure 59 was deduced for compound A. The downfield chemical shifts of the signals assignable to 18-H (δ 4.40) and 6-C (δ 90.9) in the NMR spectra of the compound A are compatible with the oxetane structure in 59. It should be emphasized that an oxetane was formed under very mild conditions, that is, in the absence of light or strong acids.

Compound B ($C_{20}H_{30}O_2$) is also an isomer of sanadaol (56). In fact, the ^{1}H-NMR spectrum of this compound is extremely similar with that of 56. The only significant difference between their spectra is the appearance of an olefinic methyl signal (δ 1.76) in the spectrum of B instead of the exo-methylene signal in that of 56. This spectral property, and also other spectral data allowed me to deduce the structure 60 for compound B, which was designated as isosanadaol.



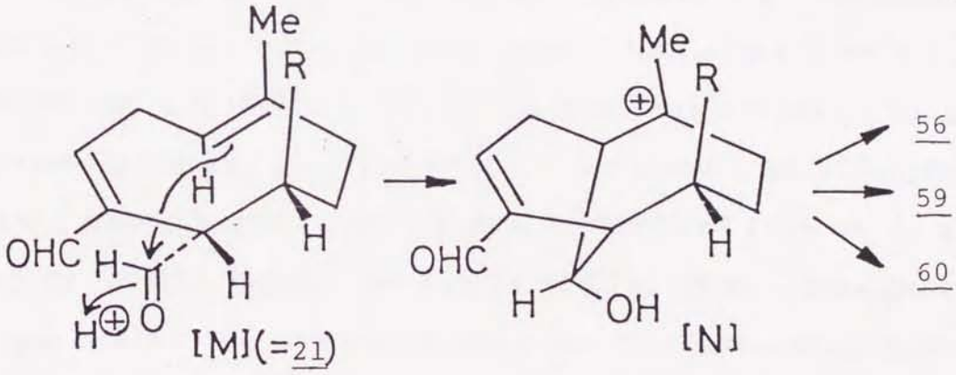
59



60

The relative configuration of the hydroxy group at 18-C was determined as depicted in structure 60 by use of a lanthanide shift reagent in ^{1}H-NMR works; on addition of 0.13 molar equivalent of Eu(fod)$_3$ the signal due to 5-H shifts to downfield more significantly than the signal due to 9-H (δ 0.39).

The reaction may proceed via the conformer M to the cation N, which is the common intermediate leading to 56, 59, and 60. Noteworthy is the fact that all the products have R* (relative) configuration at 18-C. No epimer at 18-C has been isolated so far.

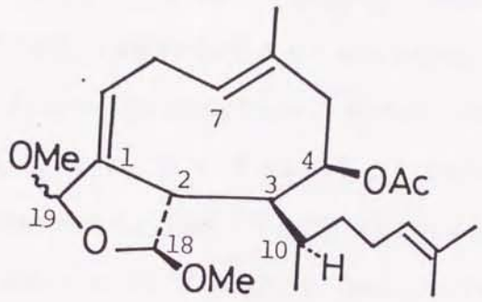


Fukurinal (61),[26] a diterpene, was recently isolated from Dilophus okamurai, with the same carbon skeleton as sanadaol (56). The structure was proposed from spectroscopic analyses, but the configuration at 10-C remained undetermined. In my studies on acid-catalyzed cyclization of dictyodial derivatives,[19] I have now synthesized fukurinal (61) from dictyodi-

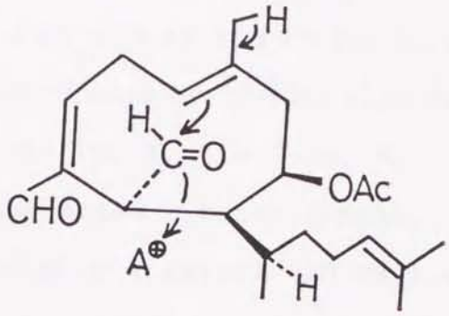
acetal (62),[18] the stereochemistry of which was firmly established. This transformation chemically confirmed the complete stereochemistry of fukurinal (61).[35]

On mild acid treatment, dictyodial (21) was converted into sanadaol (56) by transannular cyclization. Under the same conditions, dictyodiacetal (62) was not converted into a bicyclic compound, but, instead, was hydrolyzed to a dialdehyde (63). On the other hand, treatment of dictyodiactal with boron trifluoride etherate,[36] for 30 min at room temperature, afforded three cyclization products, A (25%), B (8%), and C (5%).

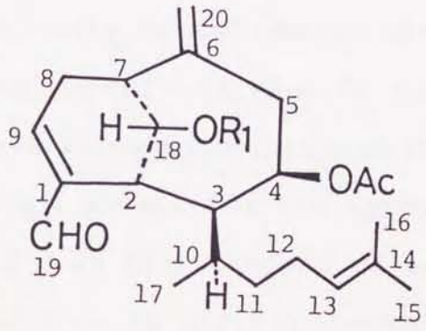
Compound A, $C_{22}H_{32}O_4$, was a colorless oil. IR bands at 1735 and 1235 cm^{-1}, as well as the ^{1}H-NMR signals at δ 1.92 (3H, s) and 5.0 (1H, m), indicated that the acetoxy group remained intact. Presence of an α,β-unsaturated aldehyde moiety was deduced from IR bands at 1695 and 1635 cm^{-1}, and also by ^{1}H-NMR signals at δ 9.50 (1H, s, CHO). Disappearance of one acetal (or aldehyde) group in dictyodiacetal (62) and the appearance of new signals at δ 4.96 (2H, s, $=CH_2$) and 3.88 (1H, m, CH-O) suggested that an intramolecular ene-type reaction occurred between the aldehyde and methyl vinyl groups affording a bicyclic compound 64. Acetylation of compound 64 afforded an acetate 61 with ^{1}H and ^{13}C-NMR properties identical in all respects to those reported for fukurinal.[26] Thus, the configuration of fukurinal at 2, 3, 4-C, and especially at 10-C, have been established to be identical with those of dictyo-



62

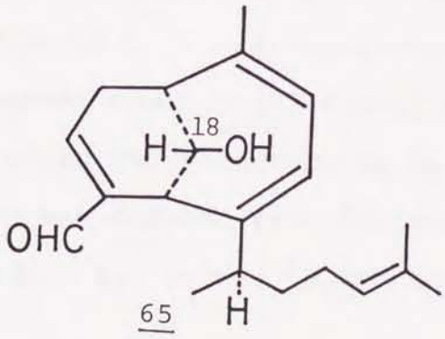


63

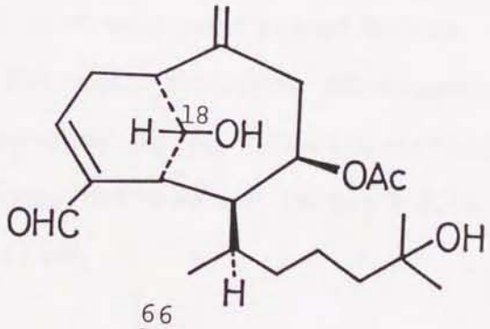


61 ; R_1= Ac

64 ; R_1= H



65



66

diacetal (62).

Compound B, $C_{20}H_{28}O_2$, lacked an acetoxy group and, instead, revealed a UV absorption maximum at 258 nm due to a homodiene chromophore, which was confirmed by ^{1}H-NMR signals at δ 5.72 (1H, d, J = 8 Hz; 4-H) and 5.79 (1H, d, J = 8 Hz; 5-H). Furthermore, the ^{1}H-NMR spectrum exhibited a broad singlet ascribable to a highly deshielded olefinic methyl (20-CH_3) at 1.89, as well as signals due to an α,β-unsaturated aldehyde moiety at δ 9.40 (1H, s) and 6.72 (1H, bs). These data provide structure 65 for compound B. Configuration of the hydroxy group at the newly formed chiral center 18-C was deduced from the coupling pattern of 18-H (δ 4.01, dd, J = 6, 3.5 Hz).

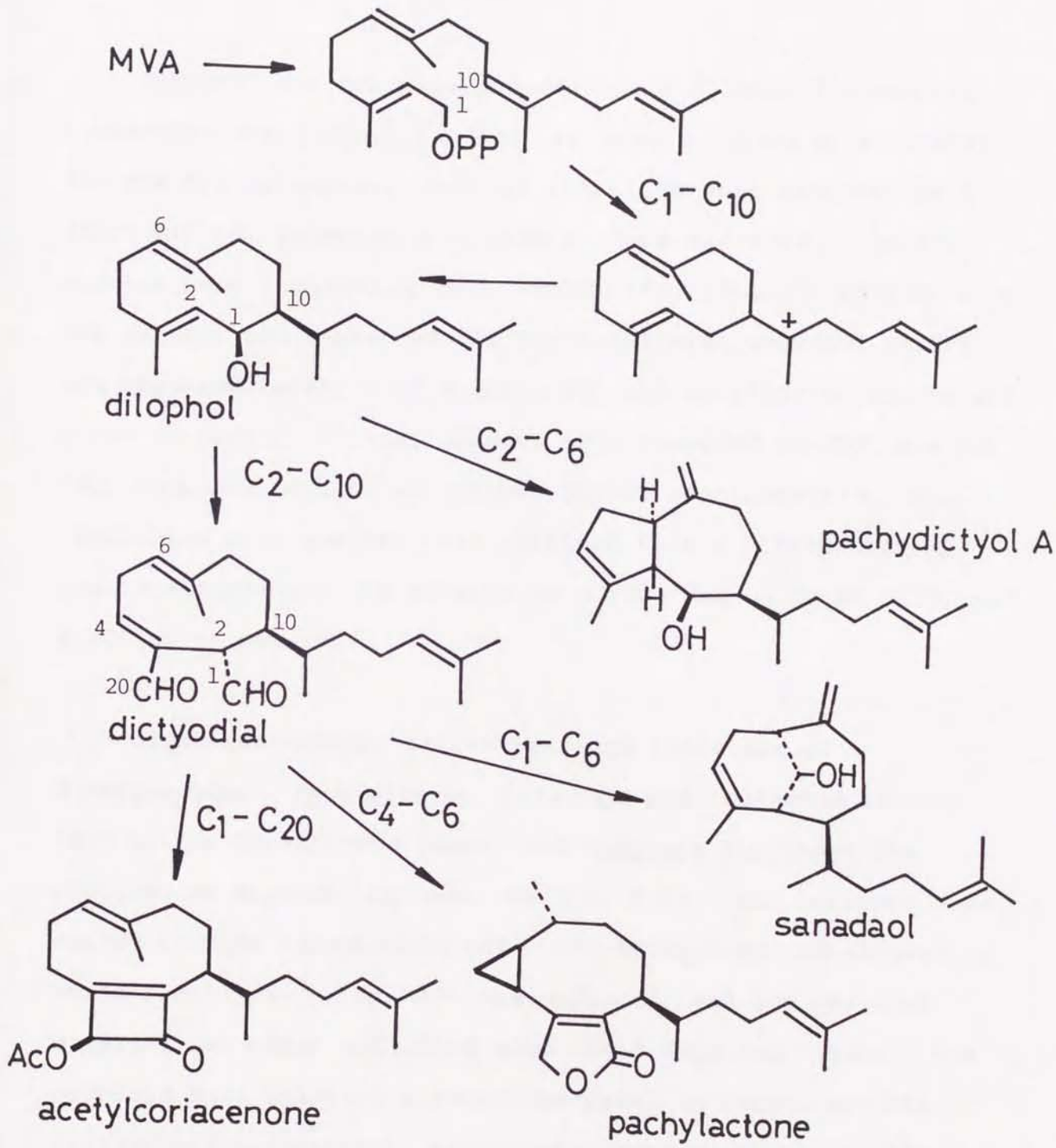
Compound C, $C_{22}H_{34}O_5$, showed the ^{1}H-NMR spectrum similar to compound 64, except for the appearance of sharp singlets at δ 1.22 (3H) and 1.24 (3H) instead of olefinic methyl signals (1.64 and 1.70) as in bicyclic compound 64. These properties suggested that the side chain olefinic bond was hydroxylated in compound C. A hydroxy group at 14-C was confirmed by the fragment m/e 319 (M^+-C_3H_7O) in the mass spectrum of compound C, allowing the structure to be assigned as 66. Configuration of 18-C was deduced from the coupling pattern of 18-H (δ 3.88, dd, J = 5, 3 Hz) in the ^{1}H-NMR spectrum.

II-G Biogenesis

The biogenesis pathways of the diterpenoids reported in this chapter are illustrated in Figure 5.

Geranylgeraniol can produce the "germacrane-like" diterpenoids (described in II-A) by 1-C to 10-C bond formation. Further ring closure at 2-C to 6-C would yield the perhydroazulene skeleton found in pachydictyol A (II-B). Rearrangement of 10-C to 2-C in the cyclodecane ring can produce the xenicane skeleton found in dictyodial (II-C). Furthermore, ring closure of the xenicane ring at 1-C to 2-C, 4-C to 6-C, and 1-C to 6-C gives the bicyclo[7.2.0]undecane (II-D), the crenulide (II-E), and the bicyclo[4.3.1]decane (II-F) skeletons, respectively.

Figure 5.


MVA
10
1
OPP
C1-C10
6
2
1
10
OH
dilophol
C2-C6
C2-C10
H
H
OH
pachydictyol A
6
4
2
10
20CHO
1CHO
dictyodial
C1-C6
C1-C20
C4-C6
OH
sanadaol
AcO
O
acetylcoriacenone
O
O
pachylactone

EXPERIMENTAL

Infrared spectra were recorded on a HITACHI 215 spectrophotometer and ultraviolet spectra were recorded on a HITACHI 340 spectrophotometer. Optical rotations were recorded on a JASCO DIP-181 polarimeter, using a 10-cm microcell. ^{1}H-NMR spectra were recorded on JEOL JNM-MH-100, JEOL JNM-FX-90Q, JEOL JNM-GX-400, and Bruker AM-500 spectrometers; chemical shifts are reported relative to Me_4Si(δ 0), and coupling constants are given in hertz. ^{13}C-NMR spectra were recorded on JEOL JNM-FX-90Q, JEOL JNM-GX-400, and Bruker AM-500 spectrometers. Low-resolution mass spectra were obtained from a HITACHI RMU-6M mass spectrometer. CD spectra were recorded on JASCO J-20, and J-20C polarimeters.

Algal collection, extraction, and isolation of diterpenoids. Pachydictyon coriaceum was collected in June 1981 at the Izu-Shimoda beach, and Dictyota dichotoma was obtained at Yagachi, Okinawa, in June 1983. The seaweeds were soaked in MeOH immediately after the collection and allowed to stand for 1 week. The MeOH was decanted, and the residual material was again extracted with fresh MeOH for 1 week. The combined MeOH extracts were concentrated in vacuo, and the residue was successively washed with hexane, dichloromethane, and ethyl acetate. The hexane extract was concentrated, and the residue was fractionally separated by chromatography on

silica gel (Merck, Kieselgel 60, Wakogel C-300), and further purified by preparative TLC (Merck, Kieselgel 60, GF_{254}) and HPLC (LS-410K, LIChrosorb SI-60).

Acetylations. All acetylations were conducted in a similar fashion. Acetic anhydride was added to a solution of the natural product in pyridine, and the reaction mixture was allowed to stand at room temperature overnight. The excess reagents were then removed in vacuo to yield the acetylated products, which were purified, when necessary, by preparative TLC.

3-Hydroxyacetyldilophol (4). ^{1}H-NMR(90 MHz,$CDCl_3$) δ 0.96(3H,d,J=7 Hz), 1.50(3H,bs), 1.60(3H,bs), 1.68(6H,bs), 2.10(3H,s), 4.36(1H,t,J=3 Hz), 5.1-5.5(3H,m), 5.68(1H,dd,J=7, 2 Hz).

Dilophol acetate (5). MS m/e 332(M^+), 290, 272, 161(base), 159, 81, 69; ^{1}H-NMR(90 MHz,$CDCl_3$) δ 0.93(3H,d,J=6 Hz), 1.50(3H,bs), 1.56(6H,bs), 1.65(3H,bs), 1.96(3H,s), 4.95(2H,m), 5.05(1H,bt,J=7 Hz), 5.56(1H,bd,J=8 Hz); ^{13}C-NMR(22.5 MHz,$CDCl_3$) δ 16.6, 17.2, 17.7, 21.3, 24.5, 25.8, 34.3, 72.8, 124.8, 131.3, 134.1, 170.7. Other signals were broad.

[Eu(fod)$_3$] shift of obscuronatin (3). Δδ values (ppm,$CDCl_3$) on addition of 1.4 molar equivalent of Eu(fod)$_3$:

2.82(4-Me), 2.55(3-H), 2.46(6-H), 1.85(2-H), 1.55(5-H), 1.11(1-H). Other signals did not show significant shifts.

Acetyldictyol C (16). MS m/e 288(M^+-60), 270, 255, 159(base); ^{1}H-NMR(100 MHz,$CDCl_3$) δ 0.96(3H,d,J=6 Hz), 1.49(3H,s), 1.58, 1.66, 1.82(each 3H,bs), 1.97(3H,s), 3.85(1H,bd,J=8 Hz), 5.07(1H,bt,J=7 Hz), 5.23(1H,bs); ^{13}C-NMR(22.5 MHz,$CDCl_3$) δ 16.3(q), 17.5(q), 17.7(q), 19.7(t), 22.5(q), 25.6(t), 25.7(q), 26.2(q), 33.0(t), 34.5(d), 34.9(t), 40.5(t), 49.7(d), 51.7(d), 52.2(d), 74.6(d), 84.4(s), 123.1(d), 124.7(d), 131.5(s), 142.4(s), 170.4(s).

Isopachydictyol A (18). MS m/e 288(M^+), 270, 159(base), 157; ^{1}H-NMR(90 MHz,$CDCl_3$) δ 0.95(3H,d,J=6 Hz), 1.58(3H,bs), 1.67(6H,bs), 1.83(3H,bs), 3.90(1H,m), 5.10(1H,bt,J=7 Hz), 5.33(1H,bs), 5.47(1H,bd,J=8 Hz); ^{13}C-NMR(22.5 MHz,$CDCl_3$) δ 142.9(s), 138.7(s), 131.5(s), 126.1(d), 124.9(d), 124.3(d), 74.7(d), 57.6(d), 47.0(d), 46.2(d), 35.5(t), 34.9(t), 33.9(d), 25.7(q), 25.6(t), 24.6(t), 23.1(q), 17.7(q), 17.6(q), 16.3(q).

Hydroxydictyoxide (19). ^{1}H-NMR(90 MHz,$CDCl_3$) δ 0.88(3H,d,J=6 Hz), 1.38(3H,s), 1.57, 1.65, 1.81(each 3H,bs), 2.34(1H,dd,J=11, 4 Hz), 3.30(1H,bd,J=11 Hz), 4.05(1H,d,J=3.5 Hz), 4.48(1H,dd,J=4, 2.5 Hz), 5.06(1H,bt,J=7 Hz), 5.67(1H,m); ^{13}C-NMR(22.5 MHz,$CDCl_3$) δ 147.0(s), 134.1(d), 131.5(s), 124.7(d), 77.1(d), 75.0(s), 70.6(d), 62.9(d), 57.2(d), 39.3(t),

38.1(d), 37.2(d), 34.5(t), 26.2(t), 25.7(q), 21.5(q), 20.3(t), 17.8(q), 16.5(q), 16.3(q).

Acetyldictyolal (24). UV(EtOH) 230 nm; MS m/e 346(M^+), 328, 286, 243, 175, 149, 109, 82(base), 69; ^{1}H-NMR(100 MHz,$CDCl_3$) δ 0.86(3H,d,J=7 Hz), 1.57, 1.66, 1.77(each 3H,bs), 1.97(3H,s), 2.76(1H,bt,J=8 Hz), 4.5(2H,m), 5.1(1H,bt,J=7 Hz), 5.36(1H,bd,J=10 Hz), 6.80(1H,dd,J=8, 4 Hz), 9.40(1H,bs); ^{13}C-NMR(25 MHz,$CDCl_3$) δ 16.8(q), 17.3(q), 17.7(q), 21.1(q), 25.7(q), 26.2(t), 28.5(t), 29.1(t), 32.1(d), 38.0(t), 41.4(t), 42.3(d), 46.9(d), 63.1(t), 122.1(d), 124.9(d), 130.9(s), 138.3(s), 150.1(s), 156.9(d), 170.8(s), 195.9(d).

Acetal (26a). MS m/e 348(M^+), 316, 284, 173, 159, 145, 109(base), 97, 69; ^{1}H-NMR(100 MHz,$CDCl_3$) δ 0.88(3H,d,J=6 Hz), 1.58, 1.68, 1.73(each 3H,bs), 3.26, 3.33(each 3H,s), 5.01(1H,s), 5.10(1H,s), 5.15(1H,bt,J=7 Hz), 5.5(1H,bdd,J=10, 4 Hz), 5.80(1H,bd,J=7 Hz); ^{13}C-NMR(22.5 MHz,$CDCl_3$) δ 17.1(2xq), 17.6(q), 25.7(q), 25.9(t), 28.2(t), 30.4(t), 31.5(d), 38.4(t), 40.6(t), 46.9(d), 51.6(d), 54.5(q), 54.7(q), 107.3(2xd), 125.0(d), 125.4(d), 126.2(d), 130.8(s), 135.0(s), 146.2(s).

Acetal (26b). ^{1}H-NMR(100 MHz,$CDCl_3$) δ 0.93(3H,d,J=6 Hz), 1.61, 1.69, 1.72(each 3H,bs), 3.32, 3.47(each 3H,s), 5.10(1H,s), 5.1(1H,bt,J=7 Hz), 5.27(1H,bs), 5.40(1H,dd,J=10, 4 Hz), 5.88(1H,bd,J=7 Hz); ^{13}C-NMR(25 MHz,$CDCl_3$) δ 17.2(q),

17.7(q), 18.1(q), 25.6(q), 26.1(t), 28.4(t), 29.7(t), 31.4(d), 37.8(t), 40.5(t), 46.0(d), 53.4(d), 54.3(q), 55.4(q), 106.4(2xd), 124.6(d), 124.9(d), 125.8(d), 131.1(s), 135.0(s), 145.9(s).

Neodictyolactone (27). MS m/e 302(M^+), 287, 257(base), 201, 191, 187, 147, 145, 109, 82, 69; ^{1}H-NMR(400 MHz,$CDCl_3$) δ 0.98(3H,d,J=6.5 Hz,17-H), 1.26, 1.54, 1.64(each 3H,bs,20,16,15-H), 4.56, 4.60(each 1H,d,J=17 Hz,19-H), 4.98(1H,bt,J=7 Hz,13-H), 5.22(1H,dd,J=12, 4 Hz,7-H); ^{13}C-NMR(100 MHz,$CDCl_3$) δ 15.8(q,20-C), 17.6(q,16-C), 18.0(q,17-C), 25.0*(t,12-C), 25.6(q,15-C), 25.8*(t,8-C), 28.4(t,9-C), 32.1(t,4-C), 33.1(d,10-C), 35.2(t,11-C), 40.5(t,5-C), 43.1(d,3-C), 71.1(t,19-C), 123.5(d,7-C), 124.7(d,13-C), 131.1(s,14-C), 133.2(s,2-C), 140.0(s,6-C), 157.4(s,1-C), 173.8(s,18-C).

18-Acetoxydictyolactone (31). MS m/e 360(M^+), 343, 300, 257, 229, 137, 109, 82, 81, 69; ^{1}H-NMR(90 MHz,$CDCl_3$) δ 1.03(3H,d,J=6 Hz,17-H), 1.57, 1.67, 1.69(each 3H,bs,16,15,20-H), 2.55(1H,bs,2-H), 2.8-3.4(2H,m,8-H), 5.03(1H,bt,J=7 Hz,13-H), 5.37(1H,bdd,J=11, 5 Hz,7-H), 6.68(1H,s,18-H), 7.06(1H,bdd,J=7, 3 Hz,9-H); ^{13}C-NMR(22.5 MHz,$CDCl_3$) δ 17.3*(17-C), 17.6*(20-C), 17.7(16-C), 21.0(AcO), 25.7(15-C), 26.0(12-C), 29.1(4-C), 30.0(8-C), 32.9(10-C), 37.7(11-C), 40.1(5-C), 47.0(2-C), 50.9(3-C), 96.0(18-C), 122.8(7-C), 124.0(13-C), 131.9(14-C), 132.4(1-C), 136.9(6-C), 143.1(9-C).

4-Acetoxydictyolactone (32). MS m/e 360(M^+), 318, 300, 165, 136, 109, 82, 69; ^{1}H-NMR(500 MHz,$CDCl_3$) δ 0.90(3H,d,J=6.7 Hz,17-H), 1.54, 1.64, 1.78(each 3H,d,J=1.5 Hz,16,15,20-H), 1.88(2H,m,12-H), 2.03(3H,s,Ac), 2.10(1H,dd,J=2.3, 1.5 Hz,3-H), 2.17(1H,ddd,J=13.8, 4.5, 1.0 Hz,5-H_a), 2.47(1H,dd,J=13.8, 2.3 Hz,5-H_b), 2.99(1H,dddd,J=17.6, 7.5, 4.0, 1.0 Hz,8-H_a), 3.19(1H,ddt,J=17.6, 11.6, 2.2 Hz,8-H_b), 3.36(1H,bdtd,J=7.7, 2.2, 1.6 Hz,2-H), 4.10(1H,dd,J=9.6, 7.7 Hz,18-H_b), 4.44(1H,dd,J=9.6, 1.6 Hz,18-H_a), 4.99(1H,tseptet,J=7.1, 1.5 Hz,13-H), 5.27(1H,dd,J=4.5, 2.3 Hz,4-H), 5.36(1H,bdd,J=11.6, 4.0 Hz,7-H), 6.95(1H,dt,J=7.5, 2.2 Hz,9-H); ^{13}C-NMR(125 MHz,$CDCl_3$) δ 172.9*(19-C), 169.8*(AcO), 139.8(9-C), 134.9(1-C), 134.9(6-C), 132.1(14-C), 126.5(7-C), 123.8(13-C), 75.6(4-C), 68.1(18-C), 49.8(3-C), 45.1(5-C), 37.6(11-C), 36.7(2-C), 32.3(10-C), 29.5(8-C), 25.8(12-C), 25.7(15-C), 21.5(AcO), 19.7(20-C), 17.8(16-C), 17.4(17-C).

Isodictyoacetal (33). IR(CCl_4) 1090, 1045, 925 cm^{-1}; MS m/e 318(M^+), 286, 243, 215, 205, 203, 147, 133, 109, 107, 69; ^{1}H-NMR(90 MHz,$CDCl_3$) δ 0.91(3H,d,J=6 Hz,17-H), 1.58, 1.66, 1.71(each 3H,bs,16,15,20-H), 2.26(1H,bs,2-H), 3.24(3H,s,OMe), 4.29(2H,bs,19-H), 5.07(1H,s,18-H), 5.07(1H,bt,J=7 Hz,13-H), 5.40(1H,bdd,J=11, 4 Hz,7-H), 5.50(1H,m,9-H); ^{13}C-NMR(22.5 MHz,$CDCl_3$) δ 17.2(17-C), 17.7(16-C), 17.7(20-C), 25.7(15-C), 26.3(12-C), 28.4(4-C), 29.8(8-C), 31.6(10-C), 38.1(11-C), 40.7(5-C), 45.9(2-C), 53.0(3-C), 54.3(MeO), 71.1(19-C),

107.4(18-C), 119.0(9-C), 124.8(13-C), 125.8(7-C), 131.2(14-C), 134.6(6-C), 146.1(1-C).

Isoacetylcoriacenone (46). UV(EtOH) 229 nm(ε 6100); IR(CCl_4) 1765, 1740, 1610, 1220, 1020 cm^{-1}; MS m/e 344(M^+), 302, 274, 243(base), 163, 147, 109, 69; ^{1}H-NMR(400 MHz,$CDCl_3$) δ 0.96(3H,d,J=6.5 Hz,17-H), 1.35, 1.58, 1.68(each 3H,bs,20,16,15-H), 2.10(3H,s,Ac), 2.67(1H,dd,J=12, 3 Hz,3-H), 5.07(1H,bt,J=7 Hz,13-H), 5.19(1H,dd,J=10, 4 Hz,5-H), 5.92(1H,s,19-H); ^{13}C-NMR(22.5 MHz,$CDCl_3$) δ 16.2(q), 17.8(2xq), 20.9(q), 23.8(t), 25.4(t), 25.7(q), 28.1(t), 32.7(t), 34.5(d), 34.9(t), 40.4(t), 43.6(d), 84.5(d), 123.6(d), 124.7(d), 131.4(s), 140.3(s), 163.7(s), 170.6(s), 172.9(s), 187.0(s).

Sanadaol (56). MS m/e 302(M^+), 284, 273, 269, 173, 145, 109, 82, 69(base); ^{13}C-NMR(25 MHz,$CDCl_3$) δ 193.1(d), 150.5(d), 146.4(s), 143.9(s), 130.8(s), 125.3(d), 116.5(t), 68.9(d), 46.0(d), 39.2(d), 37.7(d), 36.2(d), 35.9(t), 31.9(t), 29.9(t), 25.7(q), 25.4(t), 24.2(t), 17.7(2xq).

Acetylsanadaol (58). MS m/e 344(M^+), 326, 284, 266, 173, 145, 109, 82, 69; ^{1}H-NMR(100 MHz,$CDCl_3$) δ 0.72(3H,d,J=6 Hz), 1.58, 1.66(each 3H,bs), 2.03(3H,s), 4.73(2H,bs), 4.75(1H,m), 5.1(1H,bt,J=7 Hz), 6.76(1H,t,J=3.5 Hz), 9.42(1H,s); ^{13}C-NMR(22.5 MHz,$CDCl_3$) δ 192.6(d), 170.3(s), 150.3(d), 146.9(s), 143.2(s), 131.0(s), 125.1(d), 115.4(t), 72.4(d), 42.4(d),

39.5(d), 37.2(d), 36.0(d), 35.9(t), 32.7(t), 30.5(t), 25.7(q), 25.3(t), 24.6(t), 21.3(q), 17.7(q), 17.4(q).

Compound A (59). MS m/e 302(M^+), 284, 173, 145, 109, 82, 69(base); UV(MeOH) 232 nm(ε 16200); IR(CCl_4) 2720, 1685, 1630, 1150, 960 cm^{-1}; ^{1}H-NMR(100 MHz,$CDCl_3$) δ 0.61(3H,d,J=6 Hz,17-H), 1.36(3H,s,20-H), 1.59, 1.66(each 3H,bs,16,15-H), 2.47(2H,dd,J=7, 4 Hz,8-H), 2.6(1H,m,3-H), 3.22(1H,dt,J=8, 7 Hz,7-H), 3.58(1H,dd,J=7, 3.5 Hz,2-H), 4.40(1H,dd,J=8, 7 Hz,18-H), 5.07(1H,bt,J=7 Hz,13-H), 6.90(1H,t,J=4 Hz,9-H), 9.47(1H,s,19-H); ^{13}C-NMR(22.5 MHz,$CDCl_3$) δ 193.1(d), 151.9(d), 142.4(s), 130.9(s), 125.0(d), 90.9(s), 75.1(d), 40.6(d), 40.3(d), 37.7(d), 36.8(t), 35.7(t), 35.1(d), 30.7(q), 26.0(t), 25.7(q), 24.5(t), 21.3(t), 17.7(q), 16.1(q).

Compound B (60). MS m/e 302(M^+), 284, 202, 173, 145, 109, 82, 69(base); UV(MeOH) 229 nm(ε 19800); IR(CCl_4) 3600-3100(br), 2720, 1690, 1635, 1155, 1065, 1045 cm^{-1}; ^{1}H-NMR(100 MHz,$CDCl_3$) δ 0.64(3H,d,J=6 Hz,17-H), 1.60, 1.66, 1.76(each 3H,bs,16,15,20-H), 2.65(2H,bs,8-H), 3.32(1H,bd,J=5 Hz,2-H), 3.80(1H,bt,J=5 Hz,18-H), 5.10(1H,bt,J=7 Hz,13-H), 5.57(1H,m,5-H), 6.88(1H,t,J=3 Hz,9-H), 9.43(1H,s,19-H); ^{13}C-NMR(22.5 MHz,$CDCl_3$) δ 193.0(d), 152.6(d), 142.3(s), 139.1(s), 131.0(s), 125.9(d), 125.0(d), 69.5(d), 42.5(d), 40.9(d), 36.9(d), 36.6(t), 35.8(d), 33.3(t), 28.3(q), 25.7(q), 25.6(t), 24.9(t), 17.7(q), 17.2(q).

Compound A (64). MS m/e 360(M^+), 342, 300, 218, 171, 143, 109, 82(base), 69; IR(CCl_4) 1735, 1695, 1635, 1235 cm^{-1}; ^{1}H-NMR(90 MHz,$CDCl_3$) δ 0.80(3H,d,J=7 Hz,17-H), 1.64, 1.70(each 3H,bs,16,15-H), 1.92(3H,s,Ac), 3.88(1H,m,18-H), 4.96(2H,s,20-H), 5.0-5.4(2H,m,4,13-H), 6.70(1H,m,9-H), 9.50(1H,s,19-H).

Compound B (65). MS m/e 300(M^+,base), 143, 82, 69; UV(EtOH) 229, 258 nm; ^{1}H-NMR(400 MHz,$CDCl_3$) δ 1.02(3H,d,J=6.5 Hz,17-H), 1.62, 1.67, 1.89(each 3H,bs,16,15,20-H), 2.72(3H,m,7,8-H), 3.70(1H,bd,J=6 Hz,2-H), 4.01(1H,dd,J=6.0, 3.5 Hz,18-H), 5.15(1H,bt,J=7 Hz,13-H), 5.72(1H,d,J=8 Hz,4-H*), 5.79(1H,d,J=8 Hz,5-H*), 6.72(1H,bs,9-H), 9.40(1H,s,19-H).

Compound C (66). MS m/e 360(M^+), 343, 300, 218, 189, 176, 109, 82(base), 69; ^{1}H-NMR(400 MHz,$CDCl_3$) δ 0.79(3H,d,J=7 Hz,17-H), 1.22, 1.24, 1.91(each 3H,s,15,16-H,Ac), 2.44(1H,dd,J=20, 4 Hz,8-H), 2.79(1H,dm,J=20 Hz,8-H), 2.85(1H,m,7-H), 3.08(1H,dd,J=13, 10 Hz,5-H), 3.17(1H,bd,J=5 Hz,2-H), 3.88(1H,dd,J=5, 3 Hz,18-H), 4.96(2H,s,20-H), 5.06(1H,m,4-H), 6.71(1H,bs,9-H), 9.50(1H,s,19-H).

Hydrolysis of dilophol acetate (5) to dilophol (1). A 20 % methanolic KOH solution was added to a solution of 5 (16 mg) in MeOH. The reaction mixture was allowed to stand at r.t. for 4 hr. The solution was diluted with water and extracted with ether. The ether layer was washed with brine and evaporated,

and the residue was purified by preparative TLC to obtain 1 (7.3 mg).

Benzoylation of acetoxypachydiol (7) to 8. Excess benzoyl chloride was added to a solution of 7 (3.6 mg) in pyridine, and the reaction mixture was stirred at r.t. for 4.5 hr. The reaction was quenched by the addition of water, and the solution was extracted with ether. The ether layer was washed with brine, dried over $MgSO_4$, and concentrated. The residue was purified by column chromatography and preparative TLC to give 8 (2.5 mg): $C_{36}H_{44}O_6$, ^{1}H-NMR(90 MHz,$CDCl_3$) δ 0.85(3H,d,J=7 Hz,18-H), 1.56, 1.63(each 3H,bs,17,16-H), 1.97(6H,s,Ac), 2.7, 3.4(each 1H,m,2-H), 4.60, 4.72(each 1H,d,J=12 Hz,20-H), 5.03(1H,bt,J=7 Hz,14-H), 5.33(1H,bd,J=10 Hz,1-H), 5.78(2H,bs,5,6-H), 6.33(1H,dd,J=9, 4 Hz,3-H), 7.3(6H,m,Ar), 7.8(4H,m,Ar).

Acetylation of acetyldictyol C (16) to 17. A solution of 16 in pyridine and acetic anhydride was refluxed at 100 C in a sealed tube for 24 hr. The excess reagents were removed in vacuo to give the diacetate 17: $C_{24}H_{38}O_4$, MS m/e 330(M^+-AcOH), 270, 255, 199, 185, 159(base), 145, 131, 69; IR(CCl_4) 1730, 1240 cm^{-1}; ^{1}H-NMR(60 MHz,$CDCl_3$) δ 0.83(3H,d,J=6 Hz), 1.53(3H,s), 1.56, 1.60, 1.68(each 3H,bs), 2.03, 2.06(each 3H,s), 5.0-5.3(3H,m).

Hydrolysis of acetyldictyol C (16) to dictyol C (13). An excess KOH-MeOH solution was added to a solution of 16 (12.2 mg) in MeOH. The reaction mixture was refluxed for 3 hr. The solution was diluted with water and extracted with ethyl acetate. The organic layer was washed with brine and evaporated to give an oily material (10 mg), which was identified with dictyol C (13).

Conversion of acetyldictyolal (24) to dictyolactone (22). To a solution of 24 (3.3 mg) in MeOH (0.4 ml) was added 4.9 mg of Na_2CO_3, and the reaction mixture was stirred for 48 hr at r.t.. The solution was evaporated, extracted with CH_2Cl_2, and again evaporated to give oily materials. There were two new spots besides that of the starting material on TLC.

The mixture was dissolved in CH_2Cl_2 (0.5 ml), and a small amount of active MnO_2 was added. The reaction mixture was stirred for 24 hr at r.t.. After the solid residue was filtered off, the solvent was removed in vacuo, and the mixture was purified by HPLC to obtain a product identical with dictyolactone (22).

Reduction of neodictyolactone (27) to the diol 29. To a solution of 27 (10 mg) in ether (5 ml) was added 10 mg of $LiAlH_4$, and the reaction mixture was refluxed for 2 hr. The reaction was quenched by careful dropwise addition of water. The mixture was partitioned between ether and H_2O, and the

ether layer was washed with brine, dried over $MgSO_4$, and concentrated. Purification by chromatography on silica gel yielded the diol 29 (3.8 mg): $C_{20}H_{34}O_2$, MS m/e 306(M^+), 288, 275, 270, 257, 149, 109, 69(base); ^{1}H-NMR(90 MHz,$CDCl_3$) δ 0.96(3H,d,J=6 Hz), 1.36, 1.56, 1.66(each 3H,bs), 4.00, 4.22(each 1H,d,J=11 Hz), 4.12(2H,s), 5.1(2H,m).

Oxidation of the diol 29. A solution of 29 (3.8 mg) in CH_2Cl_2 (0.5 ml) was added to a solution of sodium acetate (0.5 mg) and 2 equivalents of pyridinium chlorochromate (5.7 mg) in CH_2Cl_2 (0.2 ml). The resultant brown solution was stirred at r.t. for 2 hr. The reaction was quenched by the addition of EtOH and the mixture was partitioned between ether and H_2O. The ether layer was washed with brine, dried over $MgSO_4$, and evaporated to give a mixture. Purification by preparative TLC gave dictyofuran T (30) as a major product and the lactone 28: $C_{20}H_{30}O_2$, MS m/e 302(M^+), 221, 191, 149, 109, 82(base), 69; ^{1}H-NMR spectrum is essentially the same as that of neodictyolactone (27).

Hydrolysis of isodictyoacetal (33) to isodictyohemiacetal (23). To a solution of 33 in dioxane-H_2O was added a small amount of p-TsOH. The reaction mixture was allowed to stand at r.t. for 3 days. The aqueous solution was extracted with ethyl acetate, and the organic layer was evaporated to give the hemiacetal, identical with isodictyohemiacetal (23).

Reaction of dictyotalide B (36). To a solution of 36 (0.9 mg) in dioxane (0.25 ml) was added one drop of 1N NaOH, and the mixture was allowed to stand at r.t. for 4 hr. The solution was neutralized with HCl, and extracted with ether. The ether layer was dried over $MgSO_4$ and evaporated to give a crude products. Separation by preparative TLC yielded the compound a (44) as a major product, and the compound b. a (44): $C_{20}H_{30}O_3$, MS m/e 318(M^+), 300, 250, 232, 217, 140, 109, 82, 69(base); ^{1}H-NMR(500 MHz,$CDCl_3$) δ 0.99(3H,d,J=6 Hz), 1.42, 1.62(each 3H,bs), 1.5(3H,bs,overlapped with H_2O signal), 3.98(1H,bs), 4.68, 4.73(each 1H,d,J=17 Hz), 4.94(1H,bt,J=7 Hz), 5.12(1H,bdd,J=12, 4 Hz). b: Mass spectrum is almost identical with that of a.

Acetylation of a (44) with Ac_2O-pyridine at r.t. did not occur. b was acetylated to give the acetate, the TLC and GC-MS of which were identical with those of 36.

Hydrogenation of acetylcoriacenone (45) and isoacetylcoriacenone (46) to 48. A 2.3 mg portion of 45 (46; 2.0 mg) was dissolved in EtOH, and the solution was stirred with a catalytic amount of Pd-C in a H_2 atmosphere for 8 hr. The reaction mixture was filtered and concentrated. This product is a mixture of stereoisomers, because it shows two intense spots, the Rf values of which are very close, on TLC. 48: $C_{20}H_{36}O$, MS m/e 292(M^+), 250, 179, 137, 109, 95(base), 81, 69; IR(CCl_4) 1770 cm^{-1}.

Autoxidation of acetylcoriacenone (45) and isoacetylcoriacenone (46). A solution of 33 (17 mg) in $CDCl_3$ (0.3 ml) was allowed to stand in a refrigerator for 48 hr. Separation of the product by flash chromatography yielded unchanged 45 (14 mg) and the epoxide 49 (2 mg): $C_{22}H_{32}O_4$, MS m/e 360(M^+), 332, 318, 300, 243, 161, 109(base), 69, 43; IR(CCl_4) 1765, 1740, 1620, 1220 cm^{-1}. Isoacetylcoriacenone was autoxidized in a similar way to give 50: $C_{22}H_{32}O_4$, mass and IR spectra are almost identical with those of 49; ^{1}H-NMR(400 MHz,$CDCl_3$) δ 0.96(3H,d,J=6 Hz,17-H), 1.00(3H,s,20-H), 1.58, 1.68(each 3H,bs,16,15-H), 2.11(3H,s,Ac), 2.62(1H,td,J=13, 4 Hz,3-H_a), 2.75(1H,dt,J=13, 4 Hz,3-H_b), 2.88(1H,bd,J=11 Hz,5-H), 5.07(1H,bt,J=7 Hz,13-H), 5.93(1H,s,19-H).

Cyclization of dictyodiacetal (62). To a solution of 62 (8.7 mg) in CH_2Cl_2 was added a 1% BF_3OEt_2 solution (0.3 ml) in CH_2Cl_2, and the reaction mixture was stirred for 30 min at r.t.. The reaction was quenched with H_2O, and the aqueous solution was extracted with CH_2Cl_2. The organic layer was washed with brine, dried over $MgSO_4$, and concentrated. Separation by preparative TLC gave 64 (1.9 mg), 65 (0.5 mg), and 66 (0.3 mg).

REFERENCES

1) D. R. Hirschfeld, W. H. Fenical, G. H. Y. Lin, R. M. Wing, P. Radlick, and J. J. Sims, J. Am. Chem. Soc., 95, 4049 (1973).

2) N. H. Fischer, E. J. Oliver, and H. D. Fischer, "Progress in the Chemistry of Natural Products", vol.38, p.47, Springer-Verlag, Wien, New York, 1979.

3) V. Amico, G. Oriente, M. Piattelli, C. Tringali, E. Fattorusso, S. Magno, and L. Mayol, J. C. S. Chem. Comm., 1024 (1976).

4) N. Enoki, H. Shirahama, A. Furusaki, K. Suehiro, E. Osawa, R. Ishida, and T. Matsumoto, Chem. Lett., 459 (1984).

5) Y. Kashman, and A. Groweiss, J. Org. Chem., 45, 3814 (1980).

6) H. H. Sun, and W. Fenical, J. Org. Chem., 44, 1354 (1979).

7) M. Ishitsuka, T. Kusumi, H. Kakisawa, Y. Kawakami, Y. Nagai, and T. Sato, Tetrahedron Lett., 27, 2639 (1986).

8) M. Kodama, K. Okumura, Y. Kobayashi, T. Tsunoda, and S. Ito, Tetrahedron Lett., 25, 5781 (1984).

9) K. Tori, I. Horibe, H. Minato, and K. Takeda, Tetrahedron Lett., 12, 4355 (1971).

10) T. Yoshida, J. Nobuhara, M. Uchida, and T. Okuda, Tetrahedron Lett., 17, 3717 (1976).

11) M. Ishitsuka, T. Kusumi, J. Tanaka, and H. Kakisawa, Chem. Lett., 1517 (1982).

12) B. Danise, L. Minale, R. Riccio, V. Amico, G. Oriente, M. Piattelli, C. Tringali, E. Fattorusso, S. Magno, and L. Mayol, Experientia, 33, 413 (1977).

13) N. Enoki, K. Tsuzuki, S. Omura, R. Ishida, and T. Matsumoto, Chem. Lett., 1627 (1983).

14) E. Fattorusso, S. Magno, L. Mayol, C. Santacroce, D. Sica, V. Amico, G. Oriente, M. Piattelli, and C. Tringali, J. C. S. Chem. Comm., 575 (1976).

15) D. H. R. Baton, Rodd's Chemistry of Carbon Compounds, 1st ed., vol.2B, p.652, Elsevier Publishing, Amsterdam, 1953.

16) D. J. Vanderah, P. A. Steudler, L. S. Ciereszko, F. J. Schmitz, J. D. Extrand, and D. VanderHelm, J. Am. Chem. Soc., 99, 5780 (1977).

17) J. Finer, J. Clardy, W. Fenical, L. Minale, R. Riccio, J. Battaile, M. Kirkup, and R. E. Moore, J. Org. Chem., 44, 2044 (1979).

18) N. Enoki, R. Ishida, and T. Matsumoto, Chem. Lett., 1749 (1983).

19) M. Ishitsuka, T. Kusumi, and H. Kakisawa, Chem. Lett., 999 (1983).

20) M. Ishitsuka, T. Kusumi, J. Tanaka, M. Chihara, and H. Kakisawa, Chem. Lett., 151 (1984).

21) M. Ishitsuka, T. Kusumi, H. Kakisawa, Y. Kawakami, Y. Nagai, and T. Sato, J. Org. Chem., 48, 1937 (1983).

22) N. Enoki, H. Shirahama, E. Osawa, S. Urano, R. Ishida, and T. Matsumoto, Chem. Lett., 1399 (1983).

23) H. H. Sun, F. J. McEnroe, and W. Fenical, J. Org. Chem., 48, 1903 (1983).

24) M. Ishitsuka, T. Kusumi, H. Kakisawa, Y. Nagai, Y. Kawakami, and T. Sato, J. C. S. Chem. Comm., 906 (1984).

25) T. Kusumi, Y. Shibata, M. Ishitsuka, T. Kinoshita, and H. Kakisawa, Chem. Lett., 277 (1979).

26) M. Ochi, N. Masui, H. Kotsuki, I. Miura, and T. Tokoroyama, Chem. Lett., 1927 (1982).

27) P. Dowd, and K. Sachdev, J. Am. Chem. Soc., 89, 715 (1967).

28) N. H. Fischer, E. J. Olivier, and H. D. Fischer, In "Progress in the Chemistry of Organic Natural Products 38", W. Herz, H. Grisepach, G. W. Kirby, Eds., Springer-Verlag, Wien, West Germany, p.47-388, 1979.

29) M. Ishitsuka, T. Kusumi, H. Kakisawa, Y. Kawakami, Y. Nagai, and T. Sato, Tetrahedron Lett., 24, 5117 (1983).

30) W. Brungel, "Handbook of NMR Spectral Parameters", 251, Heyden and Son Ltd., 1979.

31) L. M. Jackman, and S. Sternhell, "Applications of Nuclear Magnetic Resonance Spectroscopy in Organic Chemistry", 2nd eds., 98, Pergamon Press, 1969.

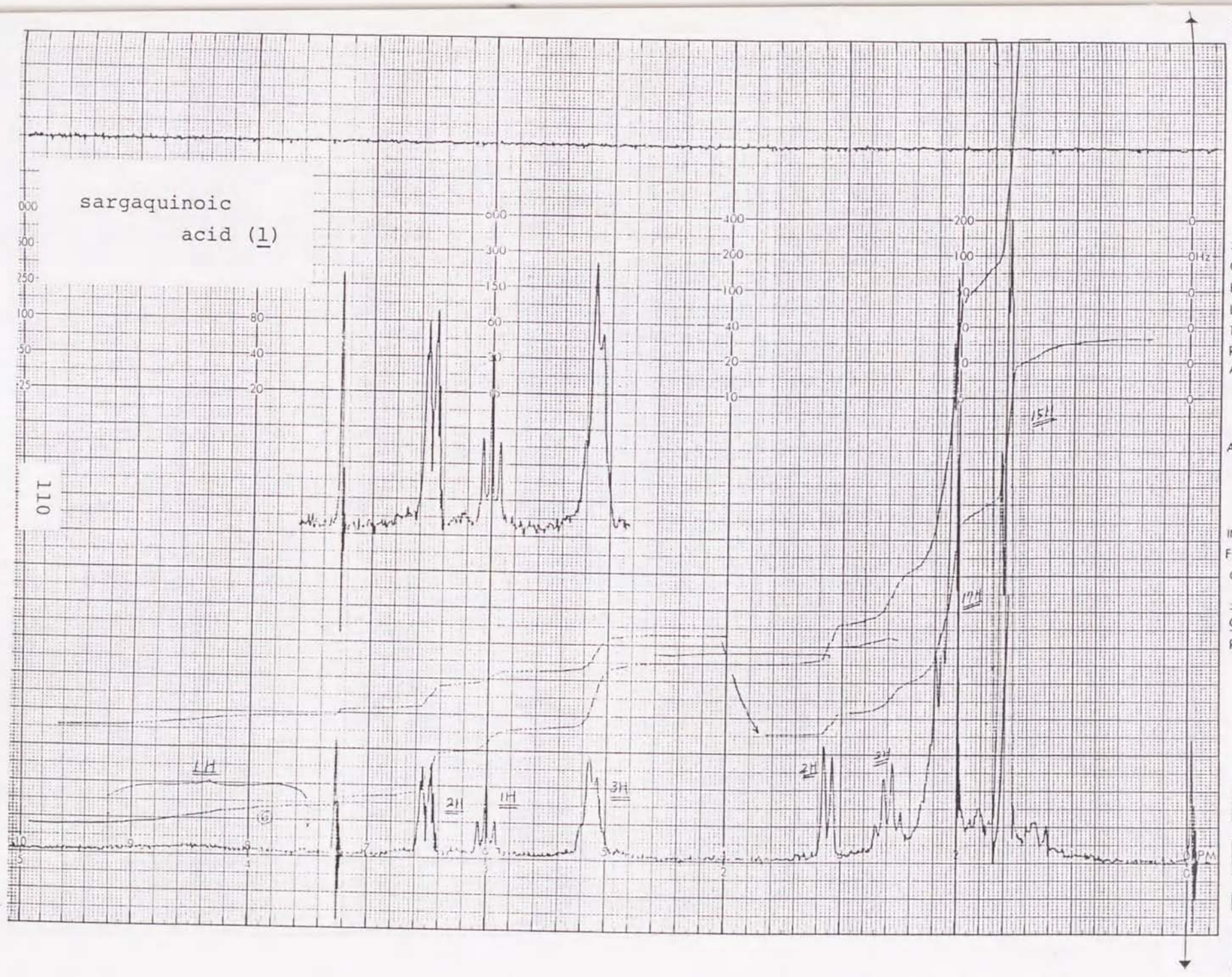
32) N. Enoki, T. Matsumoto, R. Ishida, and S. Urano, The 23rd Symposium on the Chemistry of Natural Products, 474, Nagoya, 1980.

33) D. J. Faulkner, Tetrahedron, 33, 1421 (1977).

34) M. Ishitsuka, T. Kusumi, and H. Kakisawa, Tetrahedron Lett., 23, 3179 (1982).

35) M. Ishitsuka, T. Kusumi, H. Kakisawa, N. Enoki, and T. Matsumoto, Jour. Nat. Prod., 48, 477 (1985).

36) M. P. Kirkup and R. E. Moore, Phytochemistry, 22, 2527 (1983).



SPECTRUM No. 2
DATE 22/11/7
FREQ.
NUCLEUS
SAMPLE

K

SOLVENT CDCl
CONC.
REFERENCE
LOCK
TEMP.
R. F. LEVEL
A. F. LEVEL
OBSERVE
LOCK
SD
AMPLITUDE
OBSERVE R.F.
A.F.
LOCK
INTEGRATOR
FILTER
OFFSET
FREQ. FIELD/FREQ. FI
OPERATOR T.K.
REMARKS;

1037

SWEEP TIME (SEC)

25	50	100	250
1000	2500	5000	10000

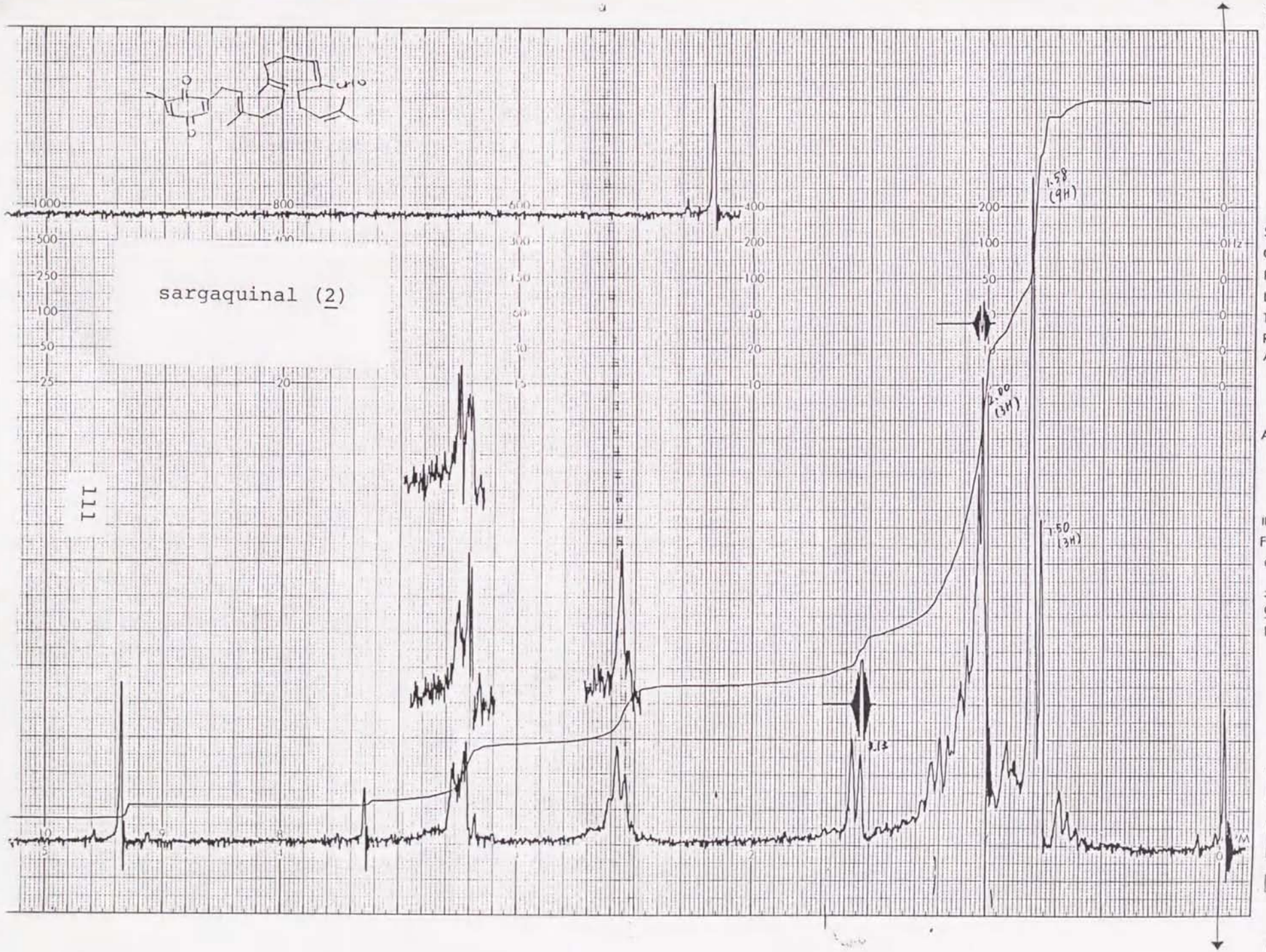
SWEEP WIDTH (Hz X)

27	54	108	270
1080	2700	5400	10800

WIDE SWEEP (GAUSS)

10.8	27	54	108

JEOL



SPECTRUM No. 5
DATE 780406
FREQ.
NUCLEUS
SAMPLE
G

SOLVENT CDCl3
CONC. 35mg/0.7ml
REFERENCE
LOCK
TEMP. °C
R.F. LEVEL
A.F. LEVEL
OBSERVE
LOCK
SD
AMPLITUDE
OBSERVE R.F.
A.F.
LOCK
INTEGRATOR
FILTER Hz
OFFSET PPM
FREQ. FIELD/FREQ. FIELD

OPERATOR 沢井
REMARKS;

1253

SWEEP TIME (SEC.)

25	50	100	250	500
1000	2500	5000	10000	

SWEEP WIDTH (Hz)(X0.01PPM)

27	54	108	270	540
1080	2700	5400	10800	

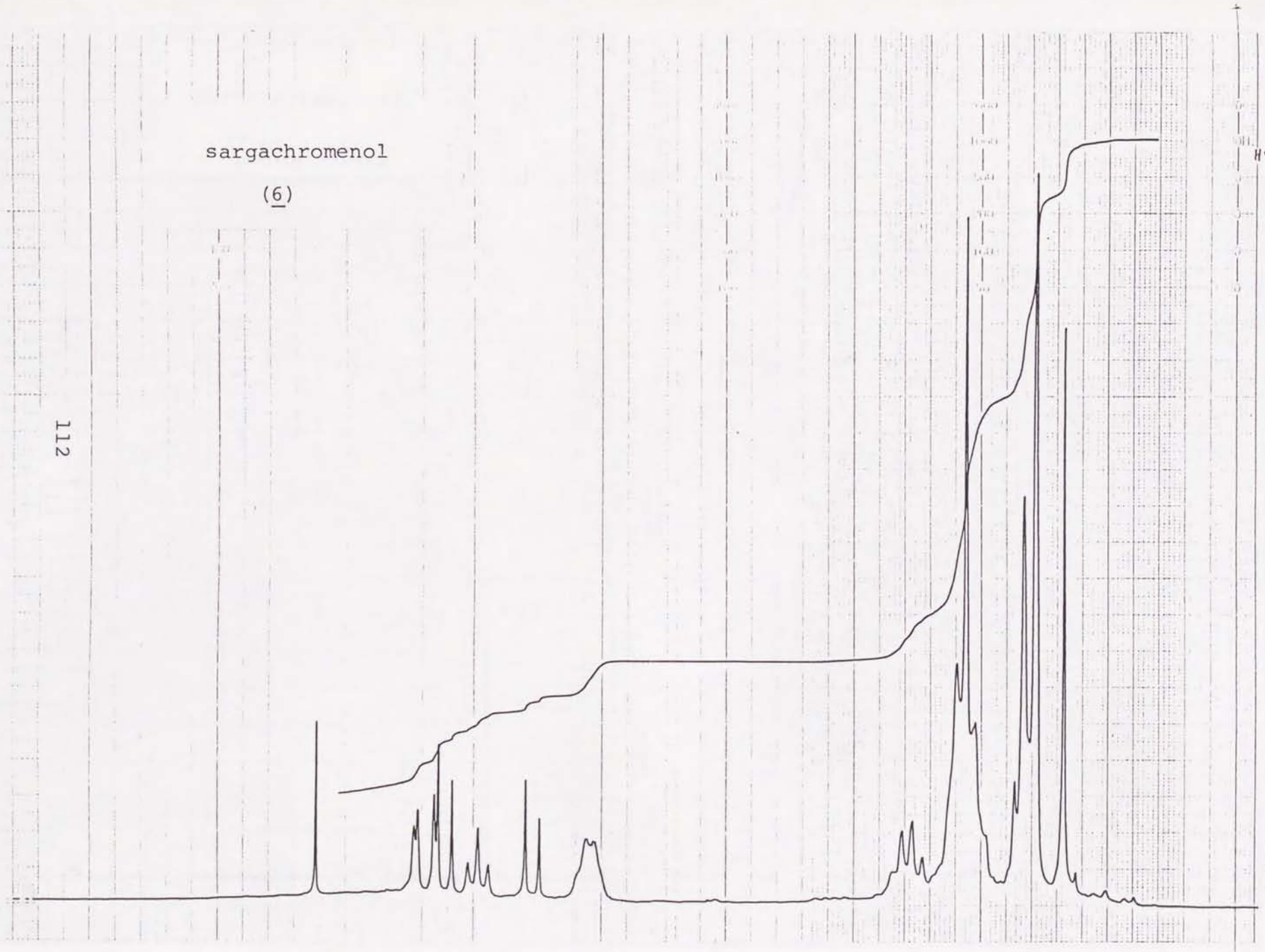
WIDE SWEEP (GAUSS)

10.8	27	54	108	540

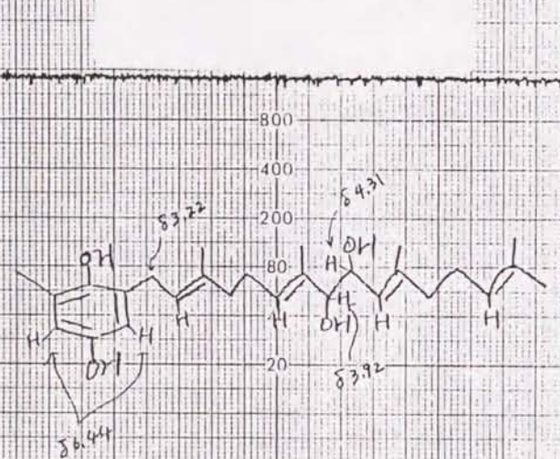
JEOL LTD

sargachromenol

(6)



sargatetraol (7)



113

SPECTRUM No. 15
DATE 880525
FREQ. 400M
NUCLEUS 1H
SAMPLE
テトラオール

SOLVENT	CDCl
CONC.	60mg
REFERENCE	TMS
LOCK	ZL
TEMP.	
R. F. LEVEL	0.1
A.F. LEVEL	6
OBSERVE	
LOCK	
SD	
AMPLITUDE	4X1
OBSERVE R.F.	
A.F.	
LOCK	
INTEGRATOR	
FILTER	2H
OFFSET	

FREQ. FIELD/FREQ.
OPERATOR T. K.
REMARKS;

22:15

SWEEP TIME (SEC.)

25	50	100	250
1000	2500	5000	10000

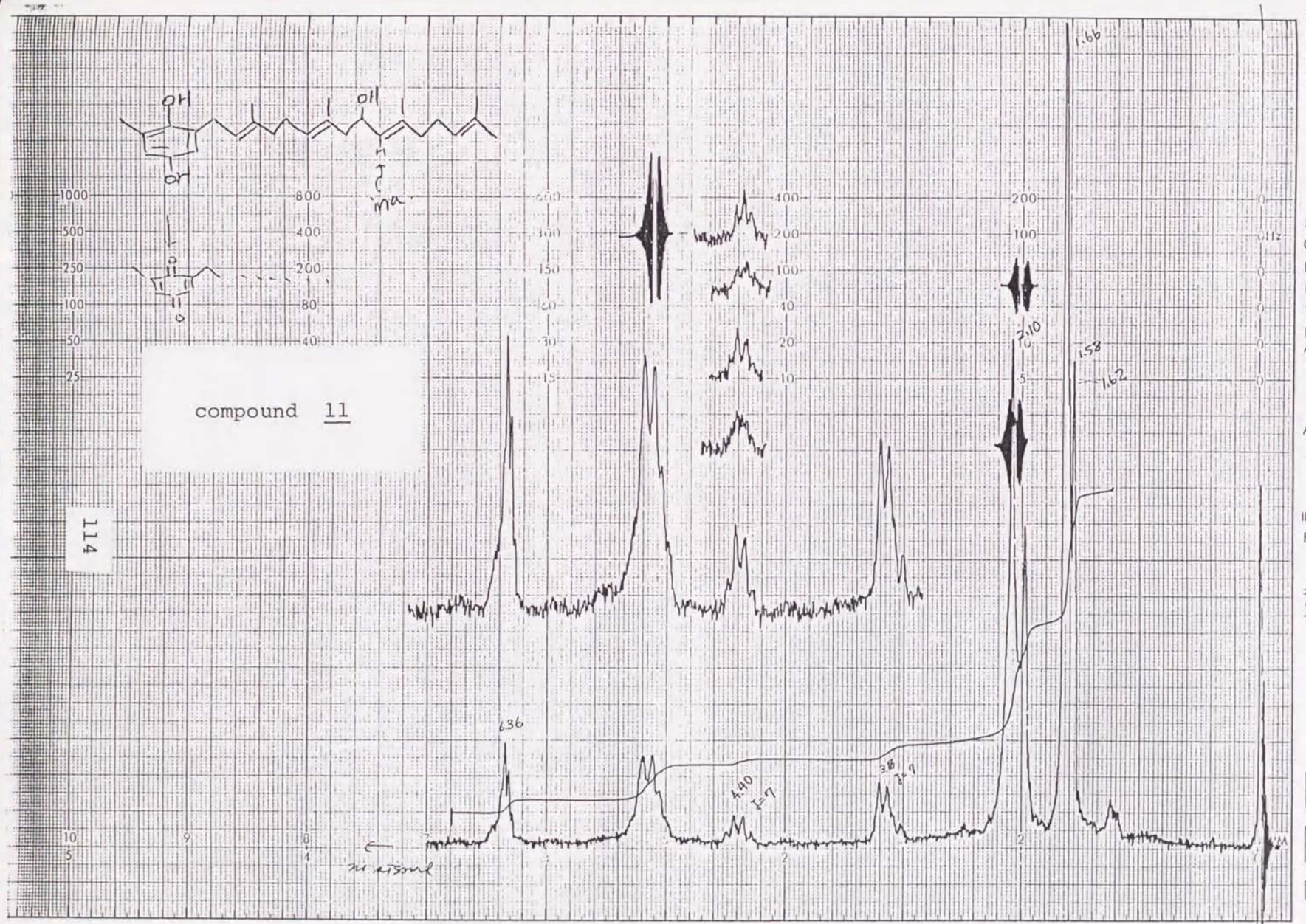
SWEEP WIDTH (Hz)(KHz)

27	54	108	270
KHz 2.7	5.4	10.8	27

WIDE SWEEP (GAUSS)

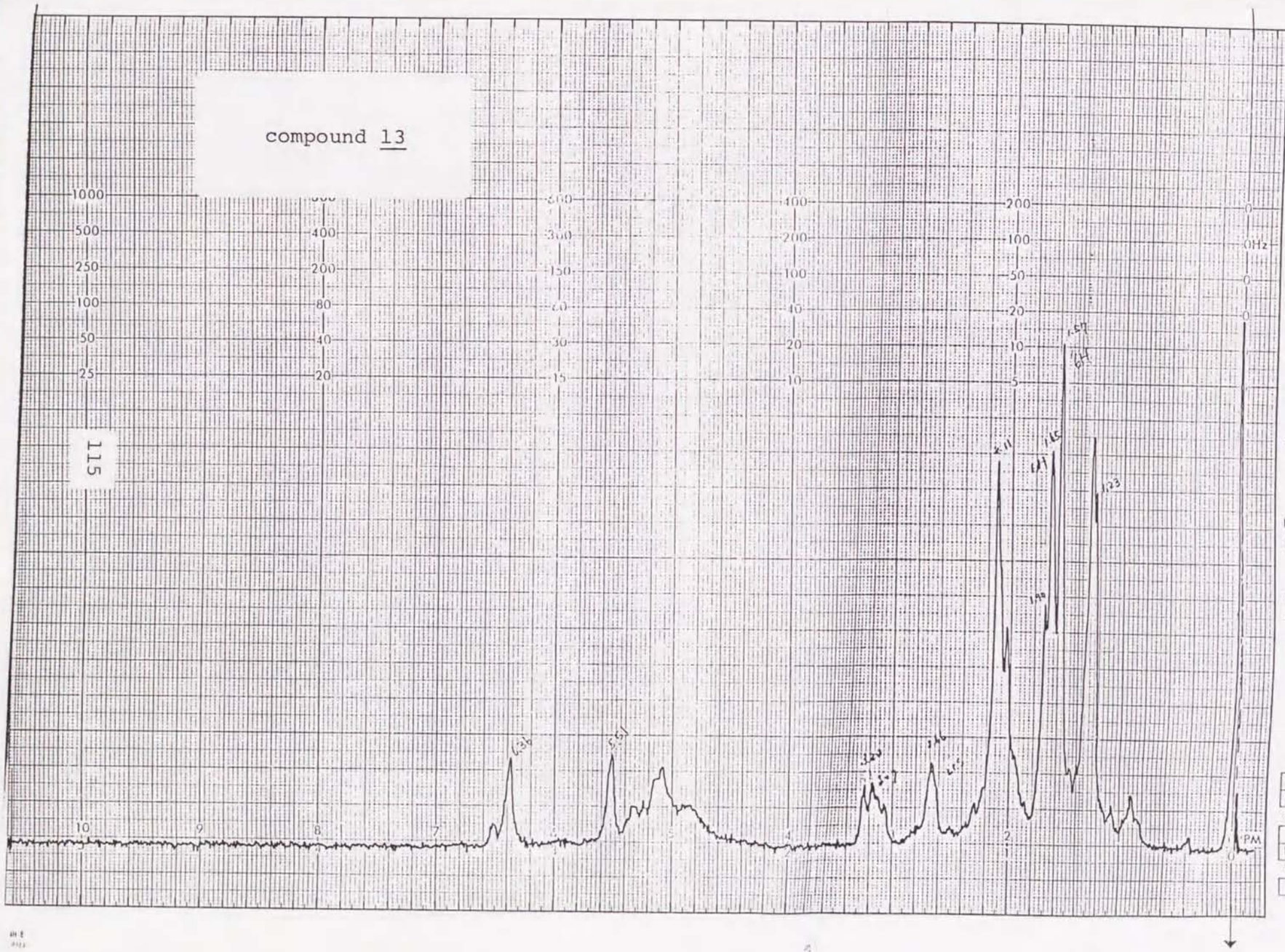
10.8	27	54	108

11-15


compound 11
114
1.66
7.10
1.58
1.62
6.36
4.40
3.85
3.29
DATE
FREQ.
NUCLEUS
SAMPLE
#1
SOLVENT CCl4
CONC. ~ 35%
REFERENCE TMS
LOCK
TEMP.
R. F. LEVEL
A.F. LEVEL
OBSERVE
LOCK
SD
AMPLITUDE 5X10
OBSERVE R.F.
A.F.
LOCK
INTEGRATOR
FILTER 20
OFFSET
OPERATOR
REMARKS;
SWEEP TIME (SEC.)
25 | 50 | 100 | 250
1000 | 2500 | 5000 | 10000
SWEEP WIDTH (Hz)
27 | 54 | 108 | 270
1080 | 2700 | 5400 | 10800
WIDE SWEEP (GAUSS)
10.8 | 27 | 54 | 108
2307
75116
H-15

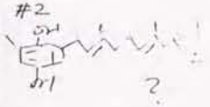
compound 13

115



DATE
FREQ.
NUCLEUS
SAMPLE

#2



SOLVENT	DMS
CONC.	ca. 15%
REFERENCE	TMS
LOCK	
TEMP.	
R. F. LEVEL / A.F. LEVEL	8-0-1
OBSERVE	
LOCK	
SD	
AMPLITUDE	6X10
OBSERVE	R.F.
	A.F.
LOCK	
INTEGRATOR	
FILTER	10
OFFSET	

FREQ. FIELD/FREQ. 1:

OPERATOR Kuc

REMARKS;

SWEEP TIME (SEC.)

25	50	100	250
1000	2500	5000	10000

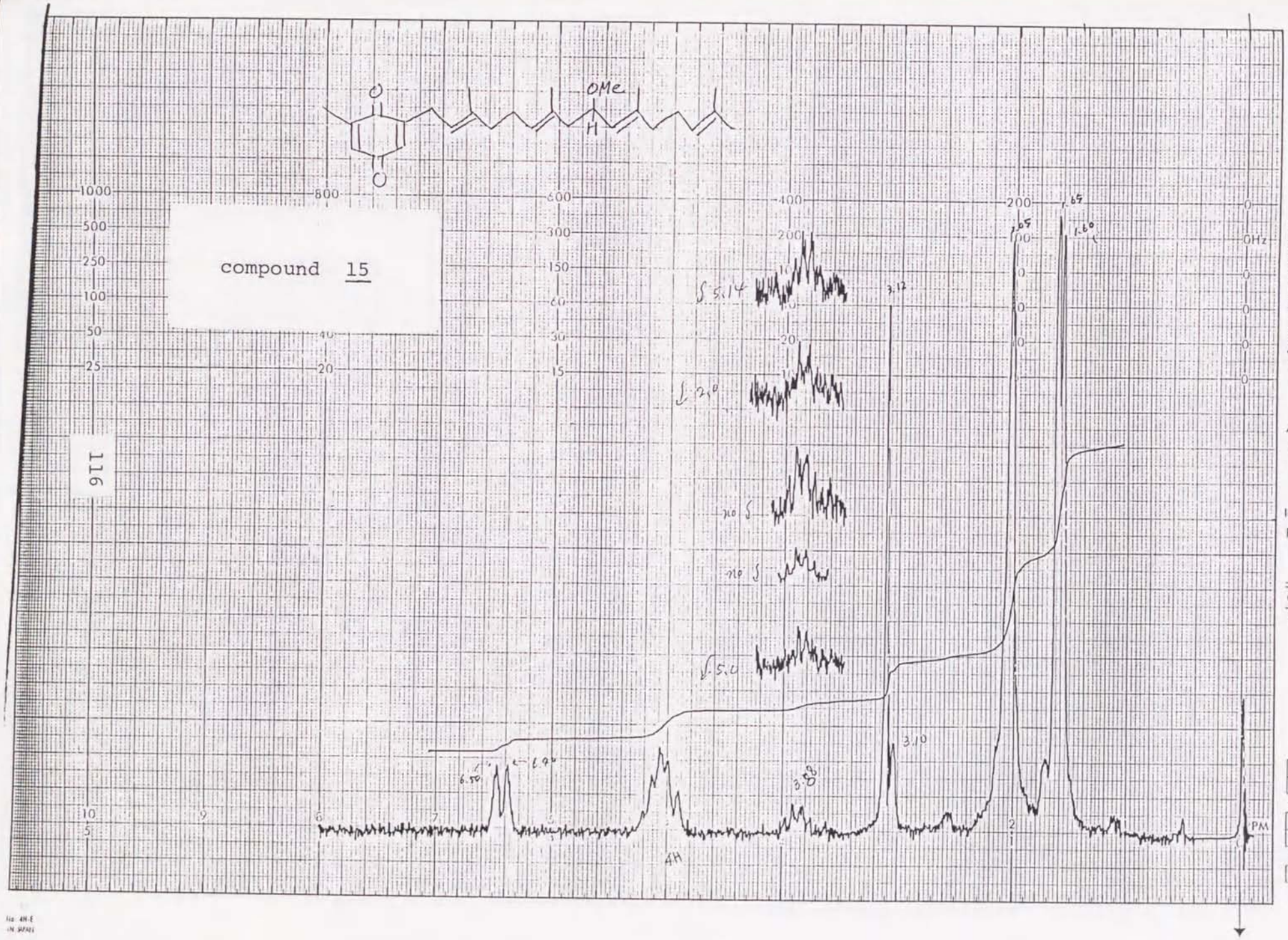
SWEEP WIDTH (Hz)X0.01

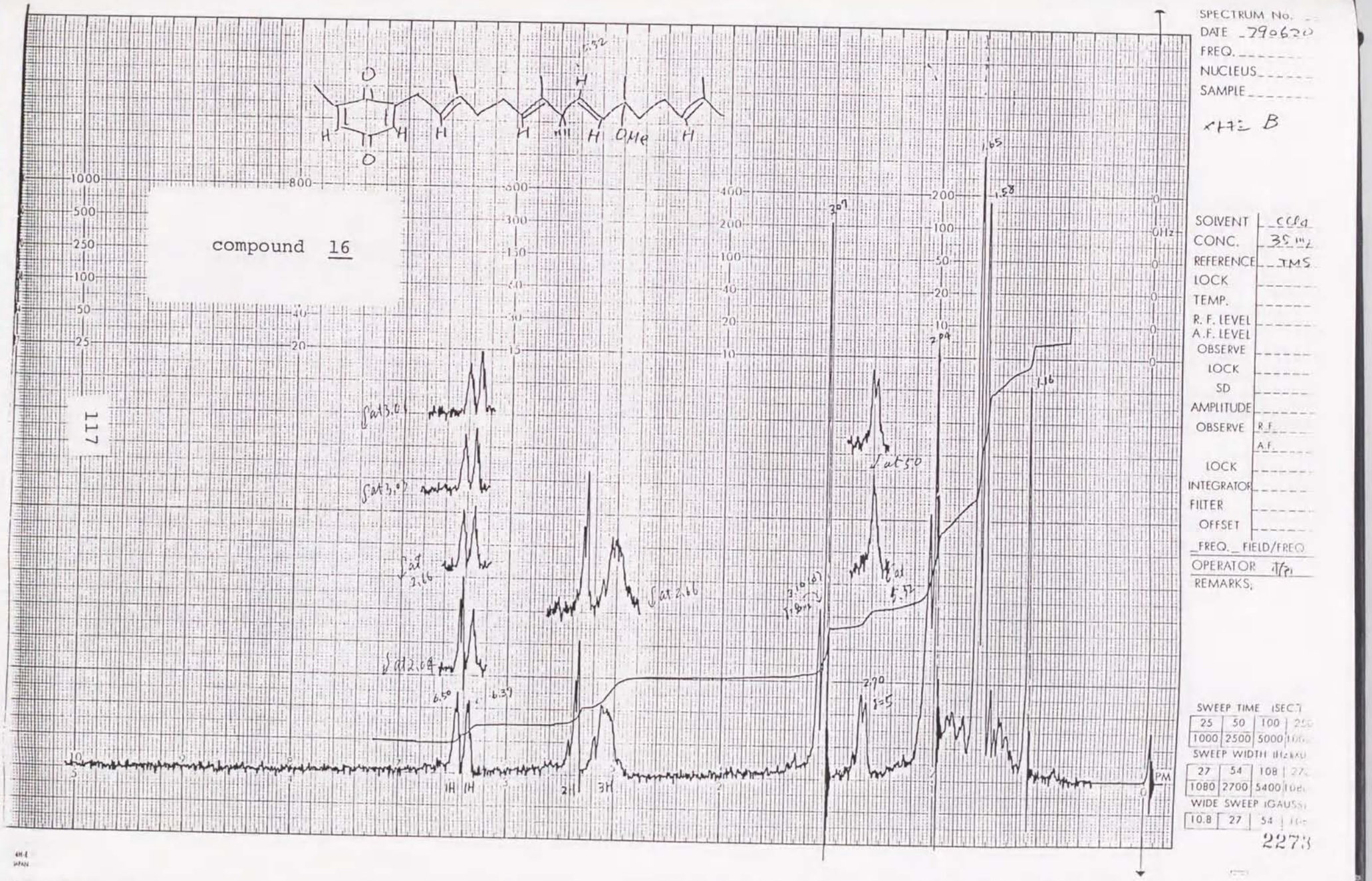
27	54	108	270
1080	2700	5400	10800

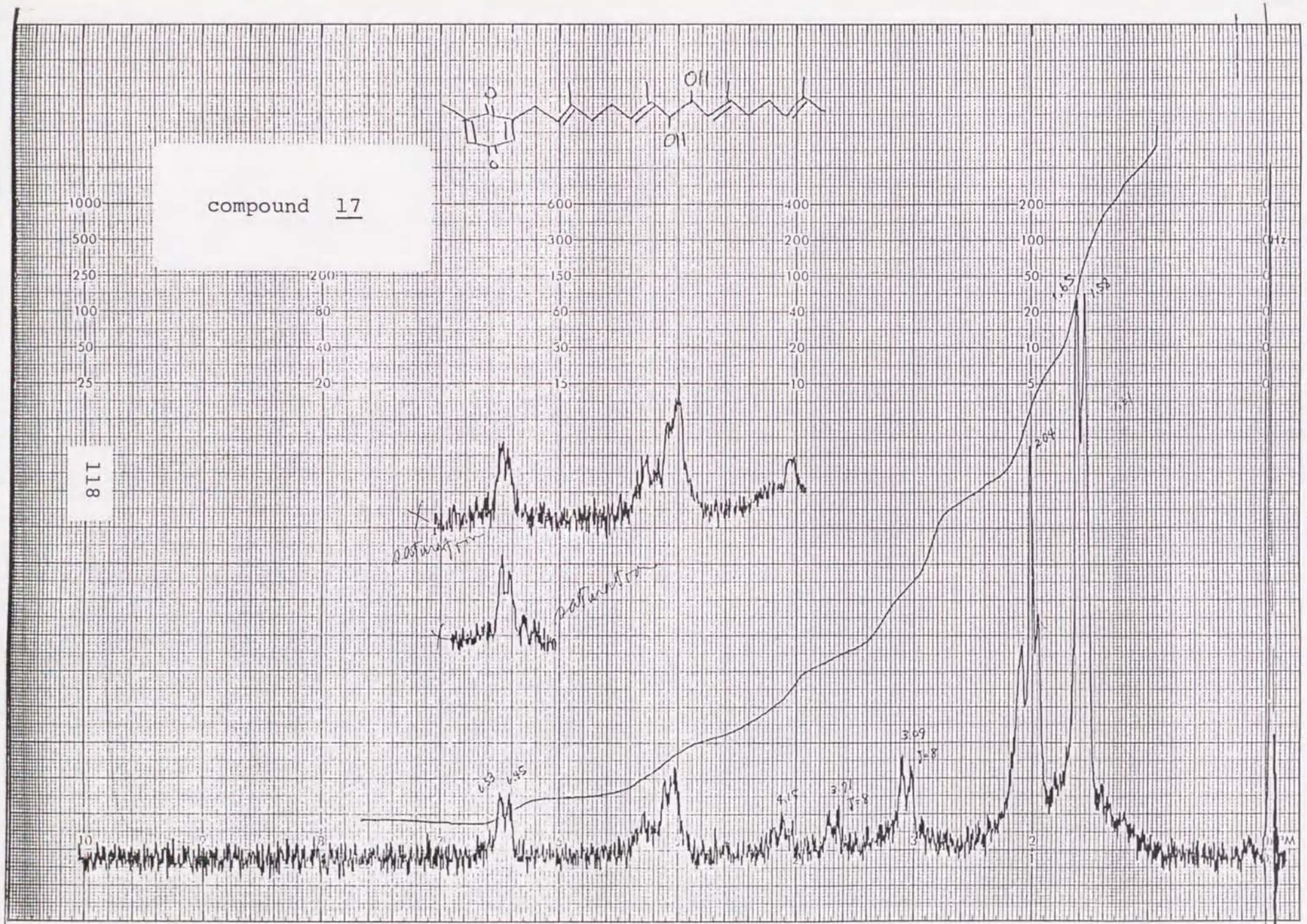
WIDE SWEEP (GAUSS)

10.8	27	54	108

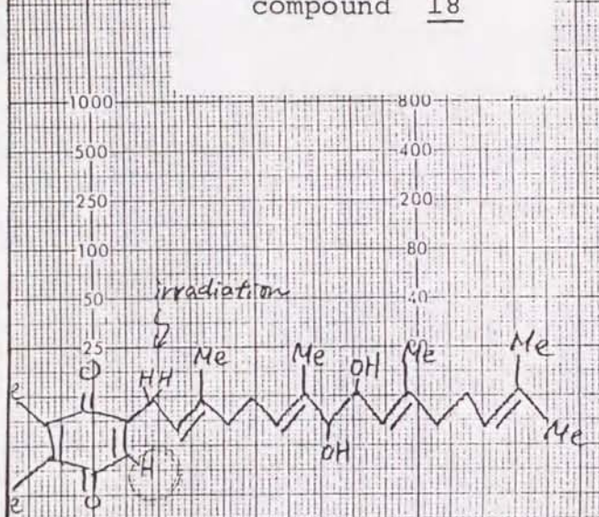
2308


compound 15
OMe
H
O
O
116
δ 5.14
δ 2.10
δ 1.0
δ 1.0
δ 5.0
6.50
6.48
3.88
3.12
3.10
4H
1.65
1.60
1.05
PM
DATE 790627
FREQ.
NUCLEUS
SAMPLE
メトキシ A.
SOLVENT CCl4
CONC. 15%
REFERENCE TMS
LOCK
TEMP.
R. F. LEVEL
A.F. LEVEL
OBSERVE
LOCK
SD
AMPLITUDE
OBSERVE R.F.
A.F.
LOCK
INTEGRATOR
FILTER
OFFSET
FREQ. FIELD/FREQ
OPERATOR
REMARKS;
SWEEP TIME (SEC)
25 50 100
1000 2500 5000
SWEEP WIDTH (Hz)
27 54 108
1080 2700 5400
WIDE SWEEP (GAU)
10.8 27 54


compound 16
117
SPECTRUM No.
DATE 790620
FREQ.
NUCLEUS
SAMPLE
THE B
SOLVENT CCl4
CONC. 35 mg
REFERENCE TMS
LOCK
TEMP.
R. F. LEVEL
A.F. LEVEL
OBSERVE
LOCK
SD
AMPLITUDE
OBSERVE R.F.
A.F.
LOCK
INTEGRATOR
FILTER
OFFSET
FREQ. FIELD/FREQ.
OPERATOR
REMARKS:
SWEEP TIME (SEC)
25 50 100
1000 2500 5000
SWEEP WIDTH (Hz/cm)
27 54 108
1080 2700 5400
WIDE SWEEP (GAUSS)
10.8 27 54
2273


compound 17
118
DATE 7907
FREQ.
NUCLEUS
SAMPLE
2
SOLVENT CCl4
CONC.
REFERENCE TMS
LOCK
TEMP.
R. F. LEVEL
A.F. LEVEL
OBSERVE
LOCK
SD
AMPLITUDE
OBSERVE R.F.
A.F.
LOCK
INTEGRATOR
FILTER
OFFSET
FREQ. FIELD/FREQ
OPERATOR
REMARKS;
SWEEP TIME (SEC)
25 50 100
1000 2500 5000
SWEEP WIDTH (Hz)
27 54 108
1080 2700 5400
WIDE SWEEP (GAU
10.8 27 54
2331
H-1

compound 18



119

original

x2

DATE 790605
FREQ.
NUCLEUS
SAMPLE
quinone minor

SOLVENT CCl4
CONC. 12mg/0.7
REFERENCE TMS
LOCK
TEMP.
R. F. LEVEL 8
A.F. LEVEL 0.1
OBSERVE
LOCK
SD
AMPLITUDE 6x2x1
OBSERVE R.F.
A.F.
LOCK
INTEGRATOR
FILTER 2s
OFFSET
FREQ. FIELD/FREQ.
OPERATOR CJ
REMARKS;

22:30

SWEEP TIME (SEC.)

25	50	100	250
1000	2500	5000	1000

SWEEP WIDTH (Hz)

27	54	108	270
1080	2700	5400	1080

WIDE SWEEP (GAUSS)

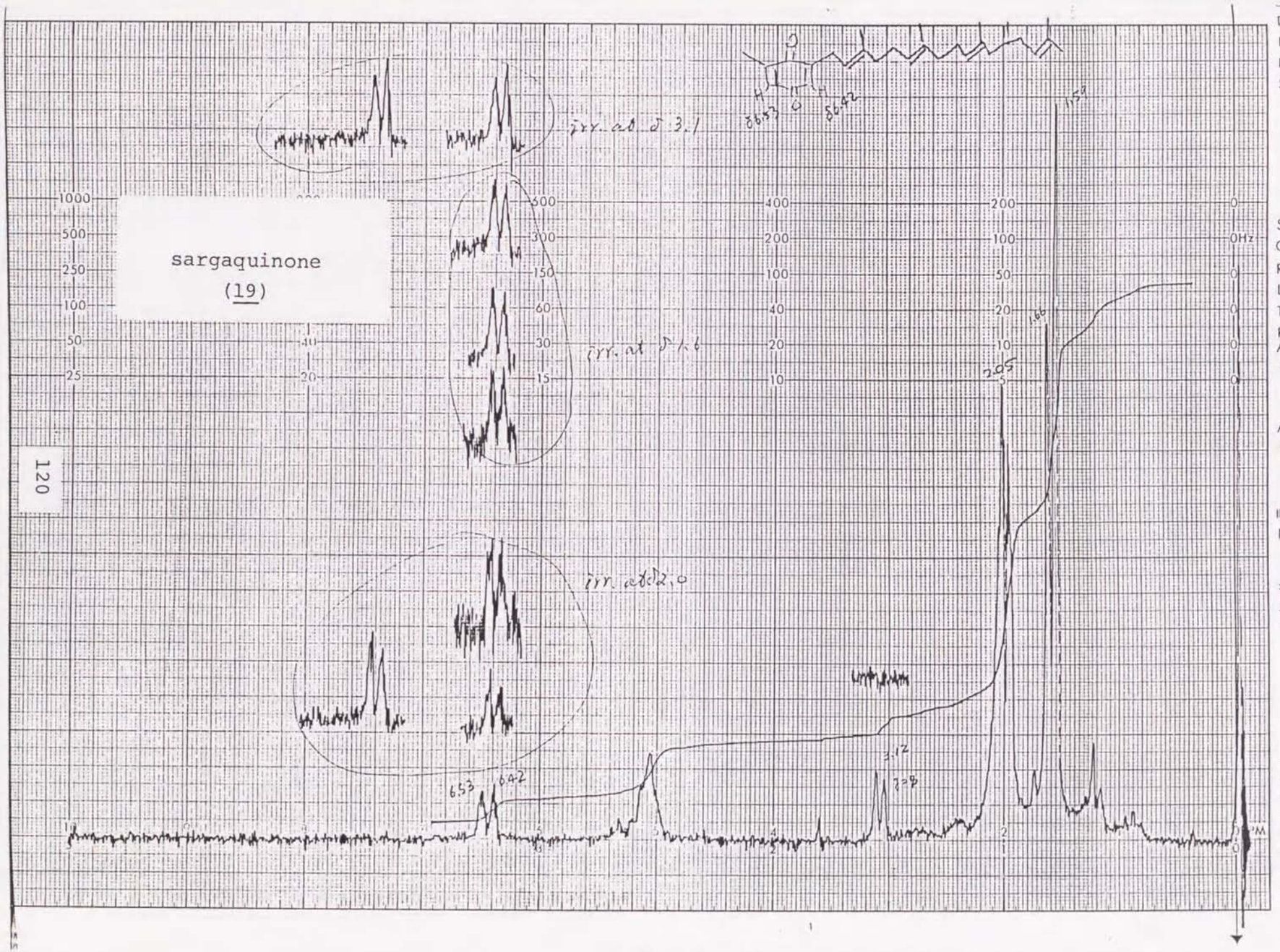
10.8	27	54	108

H-15

75116

sargaquinone

(19)



120

DATE
FREQ.
NUCLEUS
SAMPLE
(1)

SOLVENT
CONC.
REFERENCE
LOCK
TEMP.
R. F. LEVEL
A.F. LEVEL
OBSERVE
LOCK
SD
AMPLITUDE
OBSERVE
LOCK
INTEGRATOR
FILTER
OFFSET
FREQ.
OPERATOR
REMARKS,

SWEEP TIME	
25	50
1000	2500

SWEEP WIDTH	
27	54
1080	2700

WIDE SWEEP	
10.8	27

farnesylacetone

(21)

121

SPECTRUM No. 6

DATE 780107

FREQ.

NUCLEUS

SAMPLE X

fr.7 20(1) crude

SOLVENT CCl4

CONC. 200mg/1

REFERENCE TMS

LOCK

TEMP.

R. F. LEVEL

A.F. LEVEL

OBSERVE

LOCK

SD

AMPLITUDE

OBSERVE R.F.

A.F.

LOCK

INTEGRATOR

FILTER

OFFSET

FREQ. FIELD/FREQ.

OPERATOR TFH

REMARKS;

SWEEP TIME (SEC.)

25	50	100	250
1000	2500	5000	10000

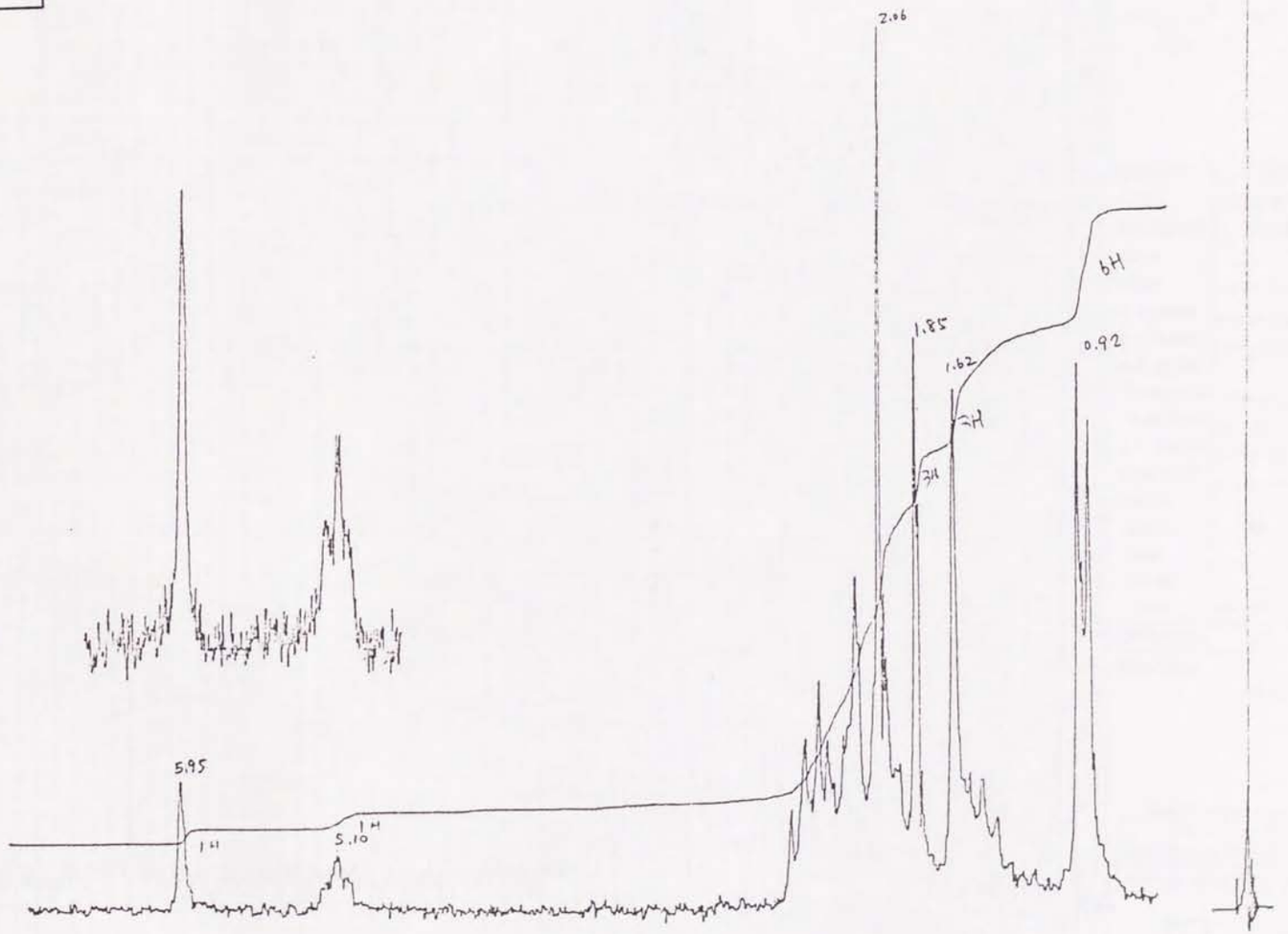
SWEEP WIDTH (Hz)X0.01

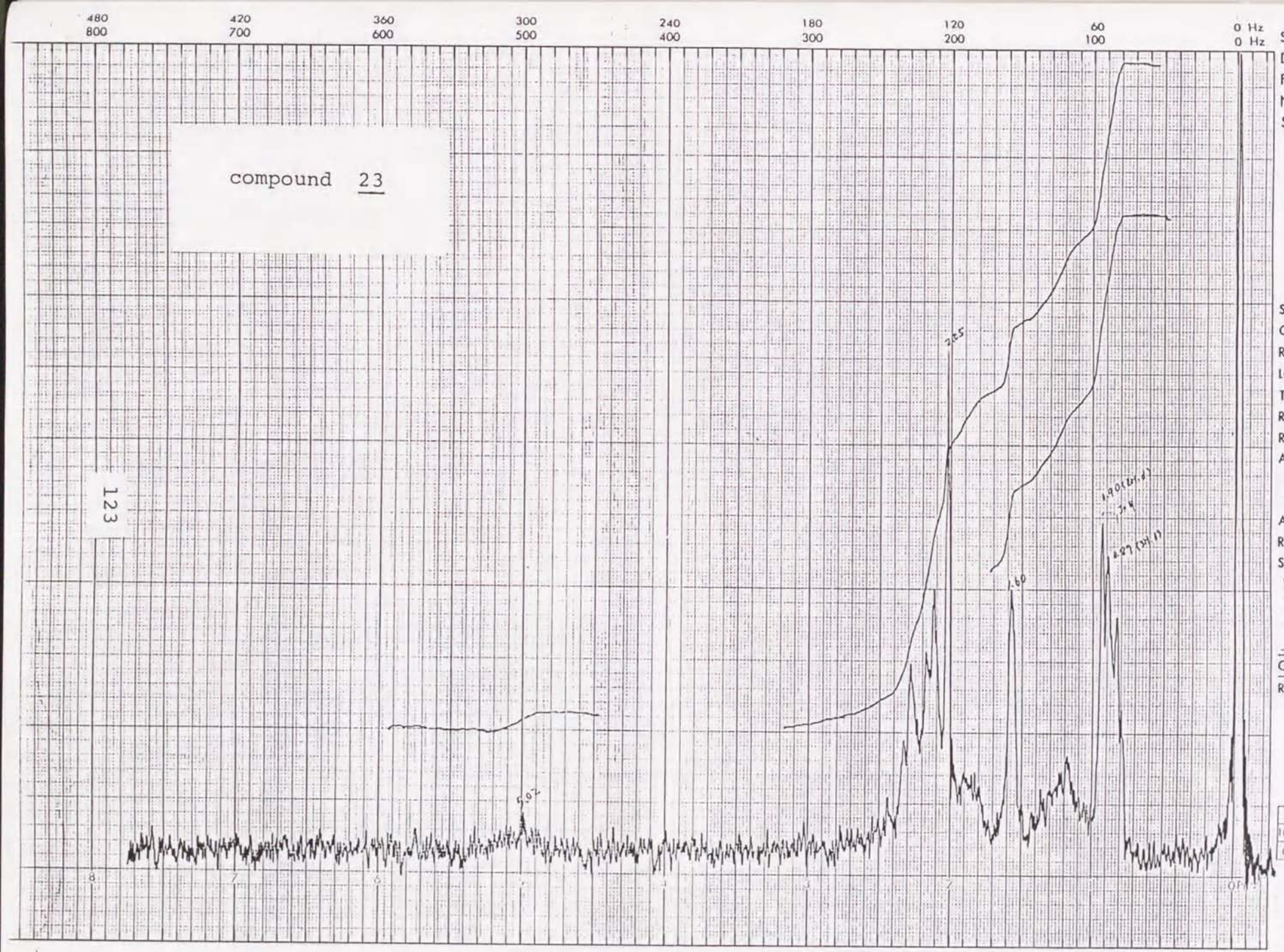
27	54	108	270
1080	2700	5400	10800

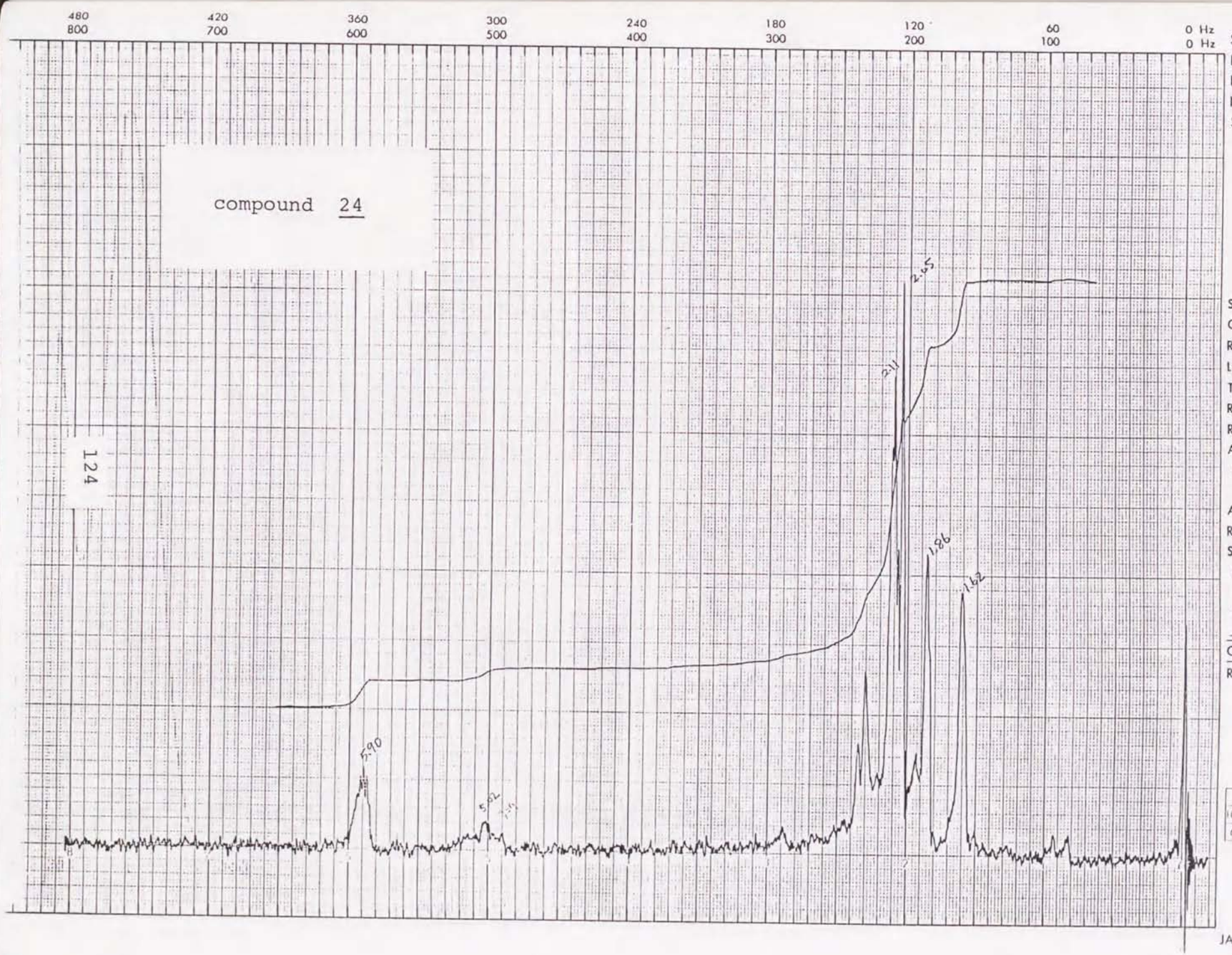
WIDE SWEEP (GAUSS)

10.8	27	54	108

compound 22




480
800
420
700
360
600
300
500
240
400
180
300
120
200
60
100
0 Hz
0 Hz
compound 23
123
2.25
1.60
5.07
SPECTRUM No. 25
DATE
FREQ.
NUCLEUS
SAMPLE B1
SOLVENT CCl4
CONC. 4mg/0.2ml
REFERENCE TMS
LOCK
TEMP. °C
R. F. LEVEL
R. F. GAIN
A.F. LEVEL
FIXED FREQ
VARI. FREQ
A.F. GAIN
RESPONSE
SWEEP
WIDTH 9X PPM
TIME MIN
OFFSET PPM
FREQ. FIELD/FREQ. FIELD
OPERATOR JI
REMARKS;
SWEEP WIDTH (Hz/DIV)
1/10 1/5 1/2 1 2
100MHz 0.25 0.5 1.25 2.5 5
60MHz 0.15 0.3 0.75 1.5 3
JEOL
JAPAN ELECTRON OPTICS LAB.
TOKYO JAPAN



SPECTRUM No. 24
DATE 790314
FREQ.
NUCLEUS
SAMPLE βy

SOLVENT	CCl4
CONC.	10mg/0.7ml
REFERENCE	TMS
LOCK	
TEMP.	°C
R. F. LEVEL	
R. F. GAIN	
A.F. LEVEL	
FIXED FREQ.	
VARI. FREQ.	
A.F. GAIN	
RESPONSE	
SWEEP	
WIDTH	9X PPM
TIME	MIN.
OFFSET	PPM

FREQ. FIELD/FREQ. FIELD,

OPERATOR JH

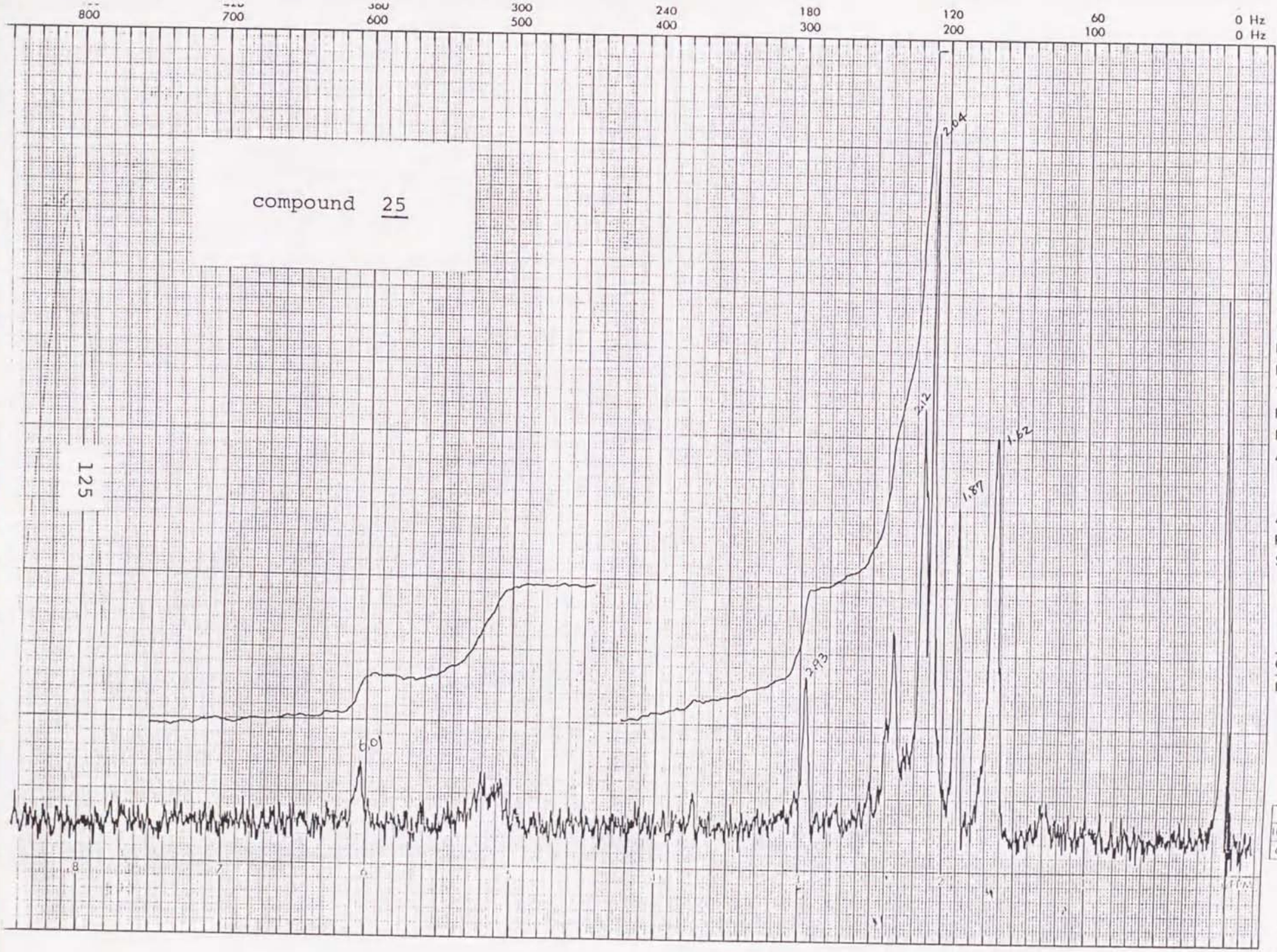
REMARKS;
1.25 x 100

SWEEP WIDTH (Hz/DIV.)

	1/10	1/5	1/2	1	2	1
100MHz	0.25	0.5	1.25	2.5	5	2
60MHz	0.15	0.3	0.75	1.5	3	1

JEOL

JAPAN ELECTRON OPTICS LAB.
TOKYO, JAPAN

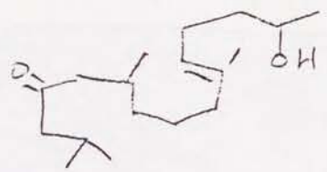


SPECTRUM No. 29
DATE 790314
FREQ.
NUCLEUS
SAMPLE B5

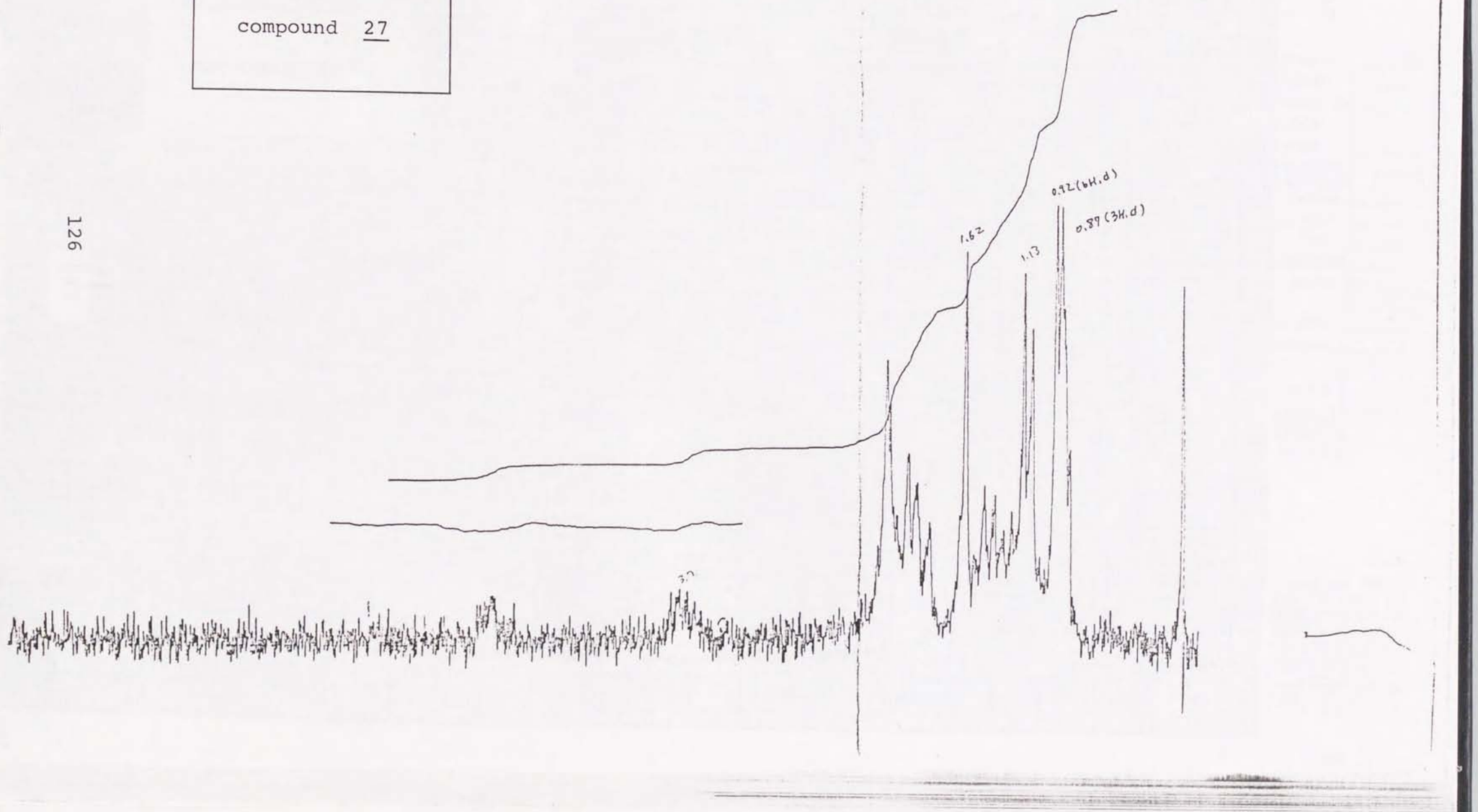
SOLVENT CCl4
CONC. 4mg/0.2 ml
REFERENCE TMS
LOCK
TEMP. °C
R. F. LEVEL
R. F. GAIN
A.F. LEVEL
FIXED FREQ.
VARI. FREQ.
A.F. GAIN
RESPONSE
SWEEP
WIDTH 9X PPM
TIME MIN
OFFSET PPM
FREQ. FIELD/FREQ. FIELD,
OPERATOR 白井
REMARKS;

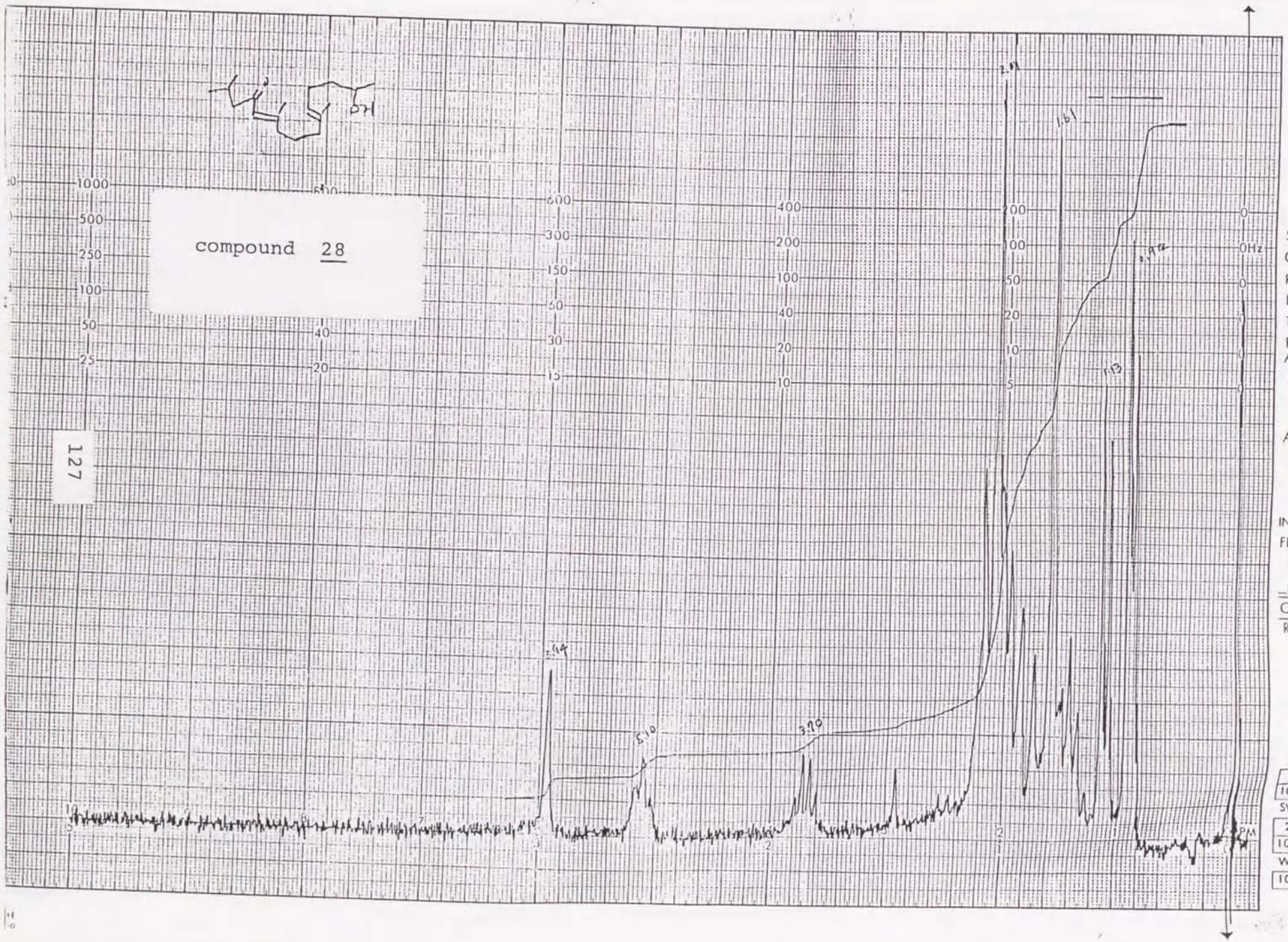
SWEEP WIDTH (Hz/DIV.)	1/10	1/5	1/2	1	2	5
100MHz	0.25	0.5	1.25	2.5	5	
60MHz	0.15	0.3	0.75	1.5	3	

JEOL
JAPAN ELECTRON OPTICS LTD.

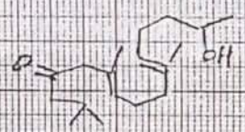


compound 27




compound 28
127
SPECTRUM No.
DATE 29-7-70
FREQ.
NUCLEUS
SAMPLE
SOLVENT CCl4
CONC.
REFERENCE
LOCK
TEMP.
R. F. LEVEL
A.F. LEVEL
OBSERVE
LOCK
SD
AMPLITUDE
OBSERVE R.F.
A.F.
LOCK
INTEGRATOR
FILTER
OFFSET
FREQ. FIELD/FREQ.
OPERATOR
REMARKS;
SWEEP TIME (SEC.)
25 50 100 250
1000 2500 5000 10000
SWEEP WIDTH (Hz)
27 54 108 270
1080 2700 5400 10800
WIDE SWEEP (GAUSS)
10.8 27 54 108
2.94
5.10
3.90
1.61
1.13
0.98
0Hz
PM

compound 29



128

SPECTRUM No. 22
DATE 790216
FREQ.
NUCLEUS
SAMPLE

γ-2 ACETATE
γ4

SOLVENT	CCl4
CONC.	10MG/0.3ML
REFERENCE	
LOCK	
TEMP.	°C
R. F. LEVEL	
A.F. LEVEL	
OBSERVE	
LOCK	
SD	
AMPLITUDE	
OBSERVE	R.F.
	A.F.
LOCK	
INTEGRATOR	
FILTER	
OFFSET	H FI

FREQ. FIELD/FREQ. FIELD

OPERATOR

REMARKS;

2098

SWEEP TIME (SEC.)

25	50	100	250	50
1000	2500	5000	10000	

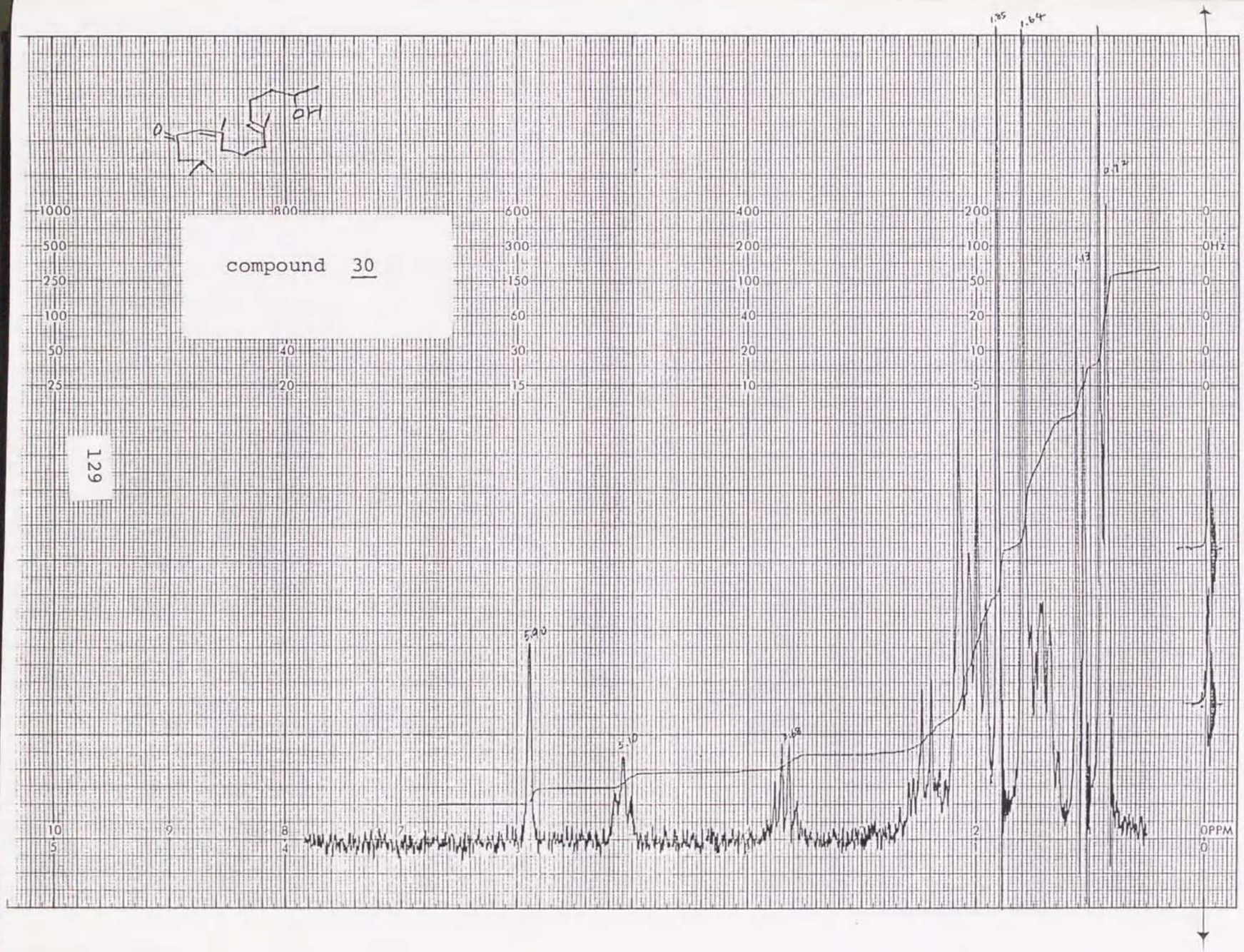
SWEEP WIDTH (Hz)X0.01 PPM

27	54	108	270	54
1080	2700	5400	10800	

WIDE SWEEP (GAUSS)

10.8	27	54	108	54

H-153



SPECTRUM No. 21
DATE 790205
FREQ.
NUCLEUS
SAMPLE
γ pure
γ-1 ヨウコウブツ

γ_2

SOLVENT	CCl4
CONC.	8 mg/0.3 ml
REFERENCE	TMS
LOCK	
TEMP.	℃
R. F. LEVEL	
A.F. LEVEL	
OBSERVE	
LOCK	
SD	
AMPLITUDE	
OBSERVE	R.F.
	A.F.
LOCK	
INTEGRATOR	
FILTER	
OFFSET	

FREQ. FIELD/FREQ. FIELD

OPERATOR 才原

REMARKS;

2073

SWEEP TIME (SEC.)

25	50	100	250	500
1000	2500	5000	10000	

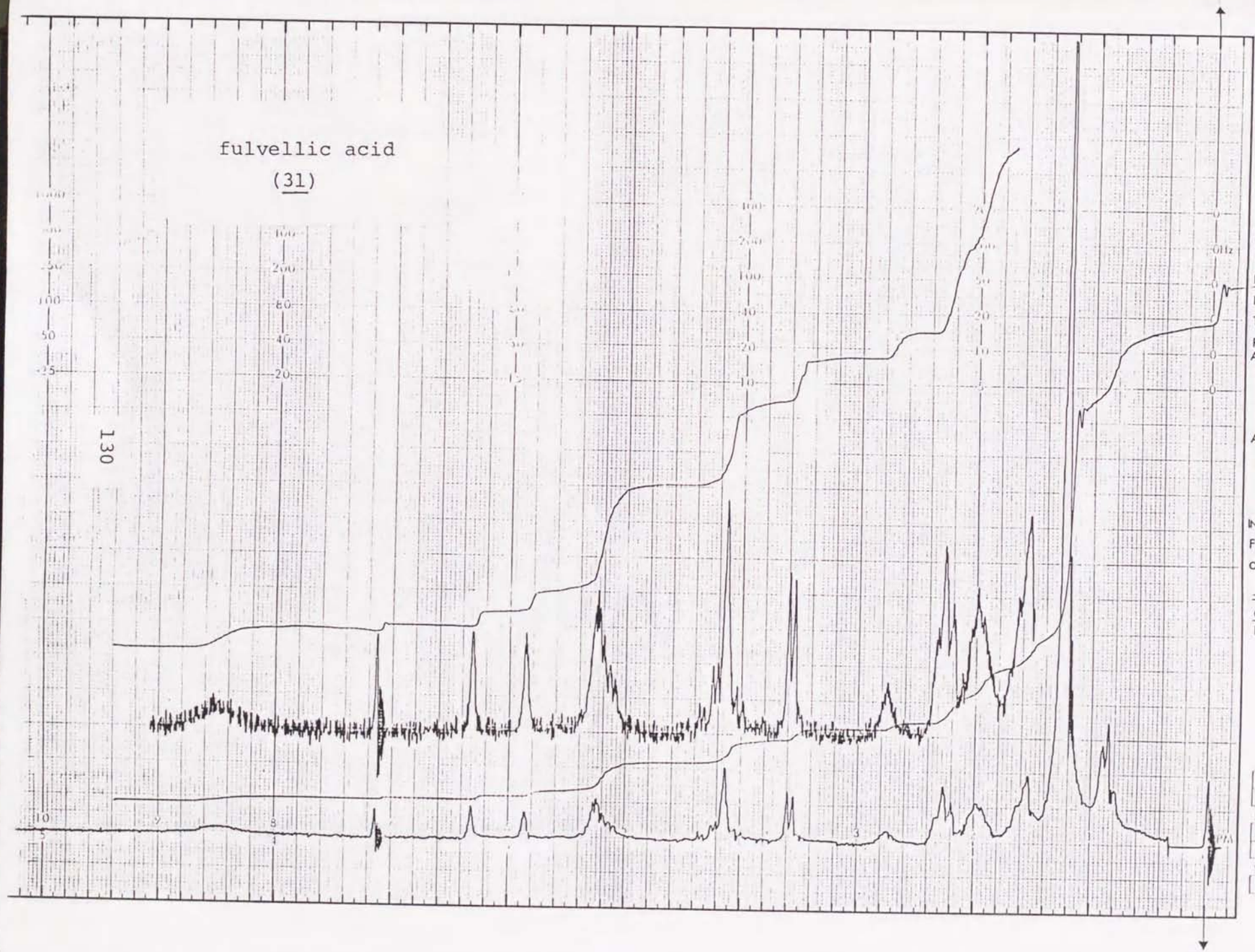
SWEEP WIDTH (Hz)(X0.01PPM)

27	54	108	270	540
1080	2700	5400	10800	

WIDE SWEEP (GAUSS)

10.8	27	54	108	540

H-153



SPECTRUM No. .....
DATE .....
FREQ. .....
NUCLEUS .....
SAMPLE .....

ON-1 & Chromatofilm

ON-110

SOLVENT	$CDCl_3$
CONC.	
REFERENCE	
LOCK	
TEMP.	°C
R.F.LEVEL	
A.F.LEVEL	
OBSERVE	
LOCK	
SD	
AMPLITUDE	
OBSERVE	R.F.
	A.F.
LOCK	
INTEGRATOR	
FILTER	
OFFSET	Hz / PPM

__FREQ.__ FIELD/FREQ.__ FIELD.

OPERATOR

REMARKS;

SWEEP TIME (SEC.)

25	50	100	250	500
1000	2500	5000	10000	

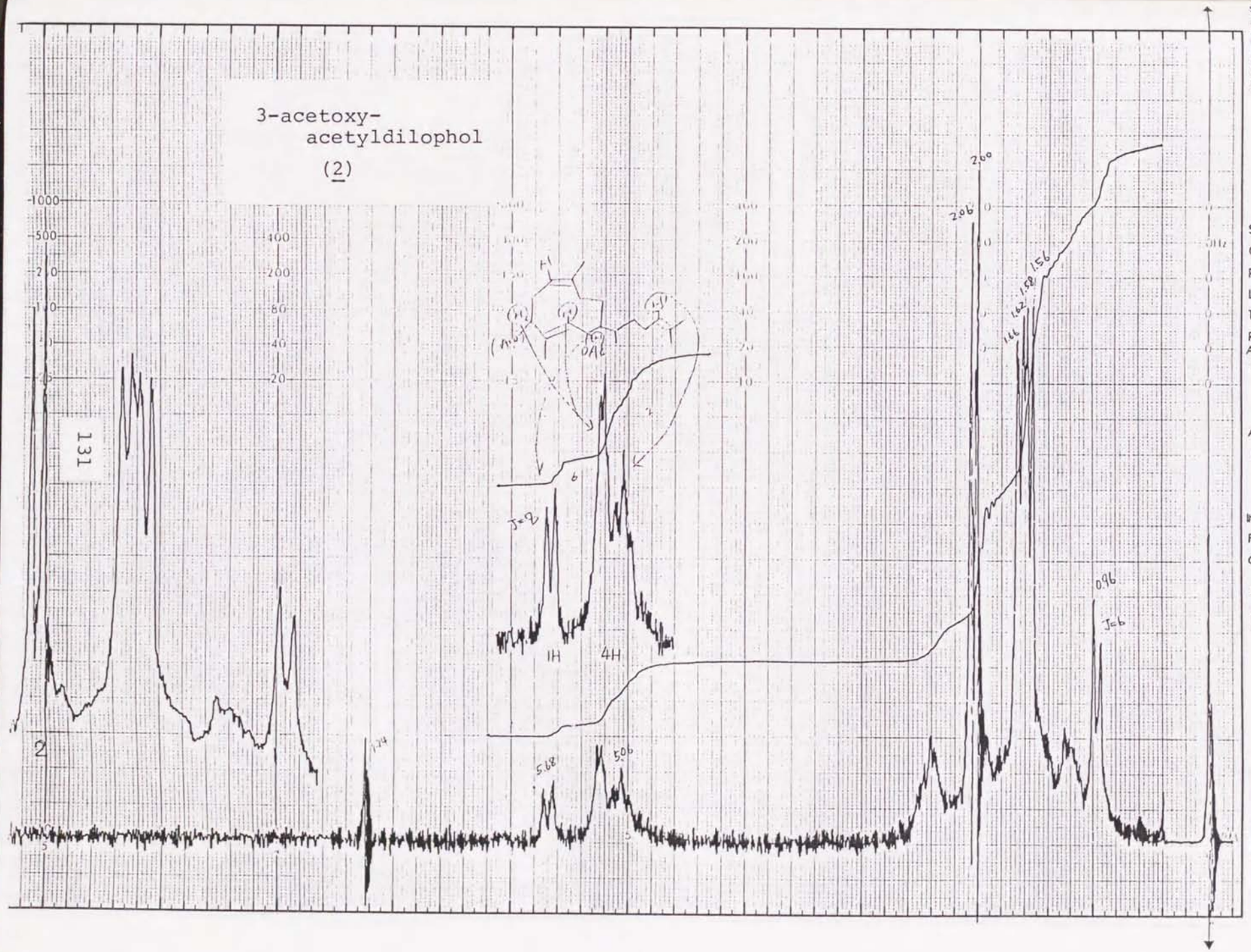
SWEEP WIDTH (Hz)(X 0.01PPM)

27	54	108	270	540
1080	2700	5400	10800	

WIDE SWEEP (GAUSS)

10.8	27	54	108	540

3321



SPECTRUM No. 190
DATE 820617
FREQ.
NUCLEUS
SAMPLE
P
fr.4-7(31)

SOLVENT	CDCl3
CONC.	17mg
REFERENCE	TMS
LOCK	
TEMP.	°C
R.F.LEVEL	
A.F.LEVEL	
OBSERVE	
LOCK	
SD	
AMPLITUDE	
OBSERVE	R.F.
	A.F.
LOCK	
INTEGRATOR	
FILTER	
OFFSET	Hz / PPM

FREQ. FIELD/FREQ._ FIELD.

OPERATOR 21
REMARKS;

SWEEP TIME (SEC.)

25	50	100	250	500
1000	2500	5000	10000	

SWEEP WIDTH (Hz)(X 0.01PPM)

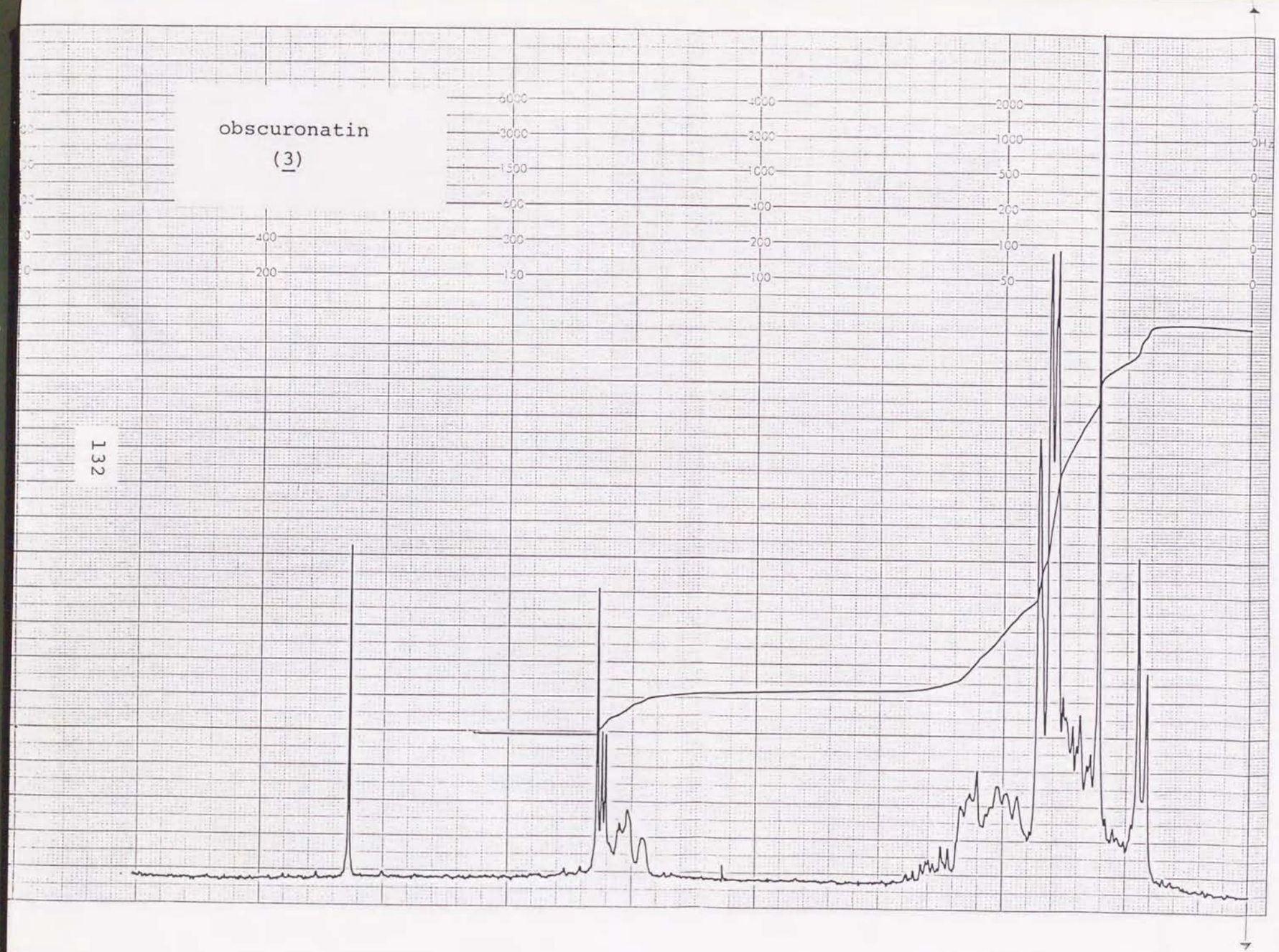
27	54	108	270	540
1080	2700	5400	10800	

WIDE SWEEP (GAUSS)

10.8	27	54	108	540

4207

obscuronatin
(3)



132

FX
CHART NO. 344
SAMPLE

TLC(37) ①

SOLVENT(CDCl3) TUBE mm
CONCENTRATION
REFERENCE
TEMPERATURE

NUCLEUS
OBS.
LOCK D F H
IRR.
OFFSET
OBS. KH
IRR. KH
PULSE SINGLE MULT
WIDTH μSEC
INTERVAL SEC
REPETITION SEC

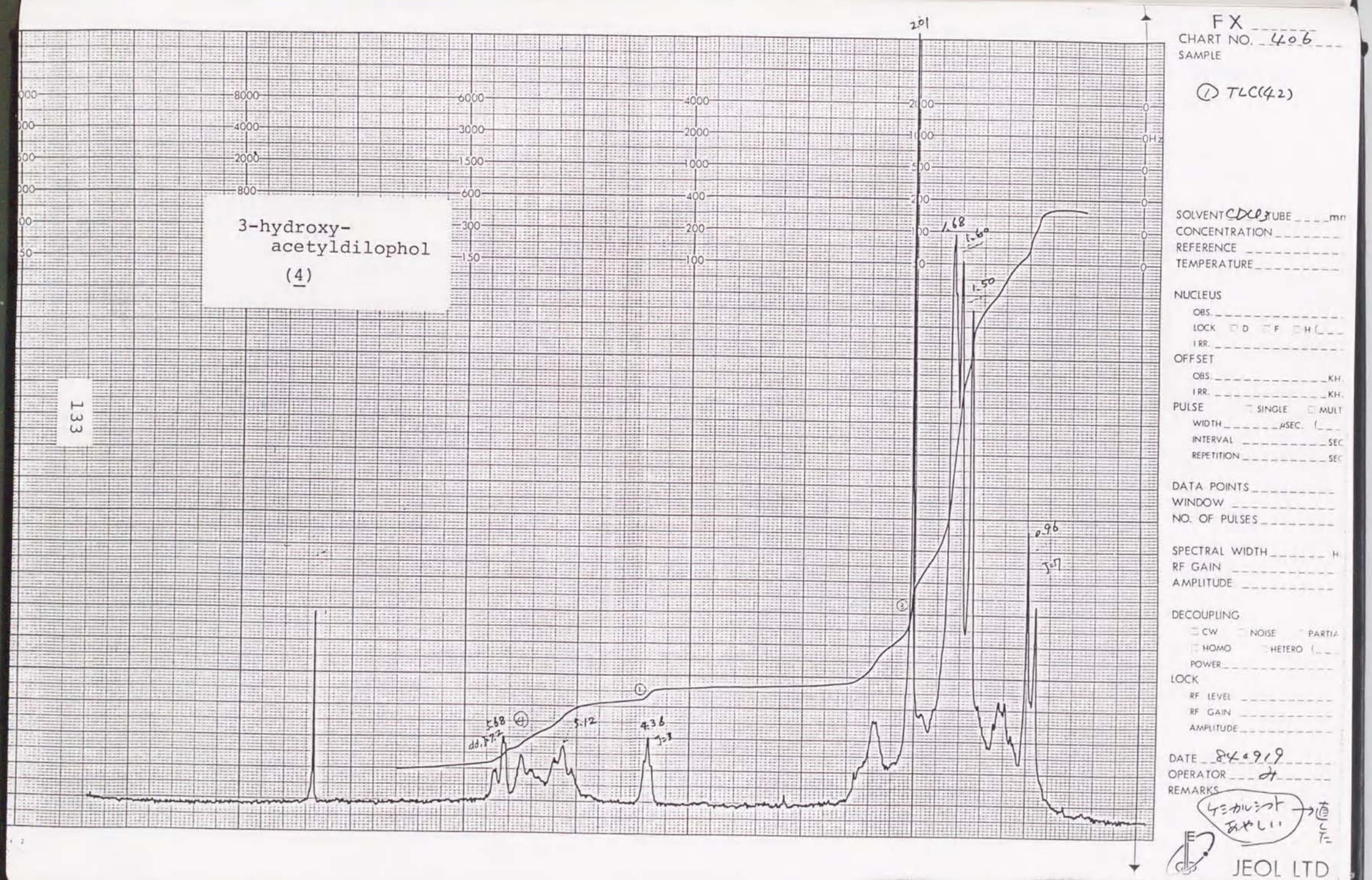
DATA POINTS
WINDOW
NO. OF PULSES

SPECTRAL WIDTH H
RF GAIN
AMPLITUDE

DECOUPLING
CW NOISE PARTIAL
HOMO HETERO
POWER
LOCK
RF LEVEL
RF GAIN
AMPLITUDE

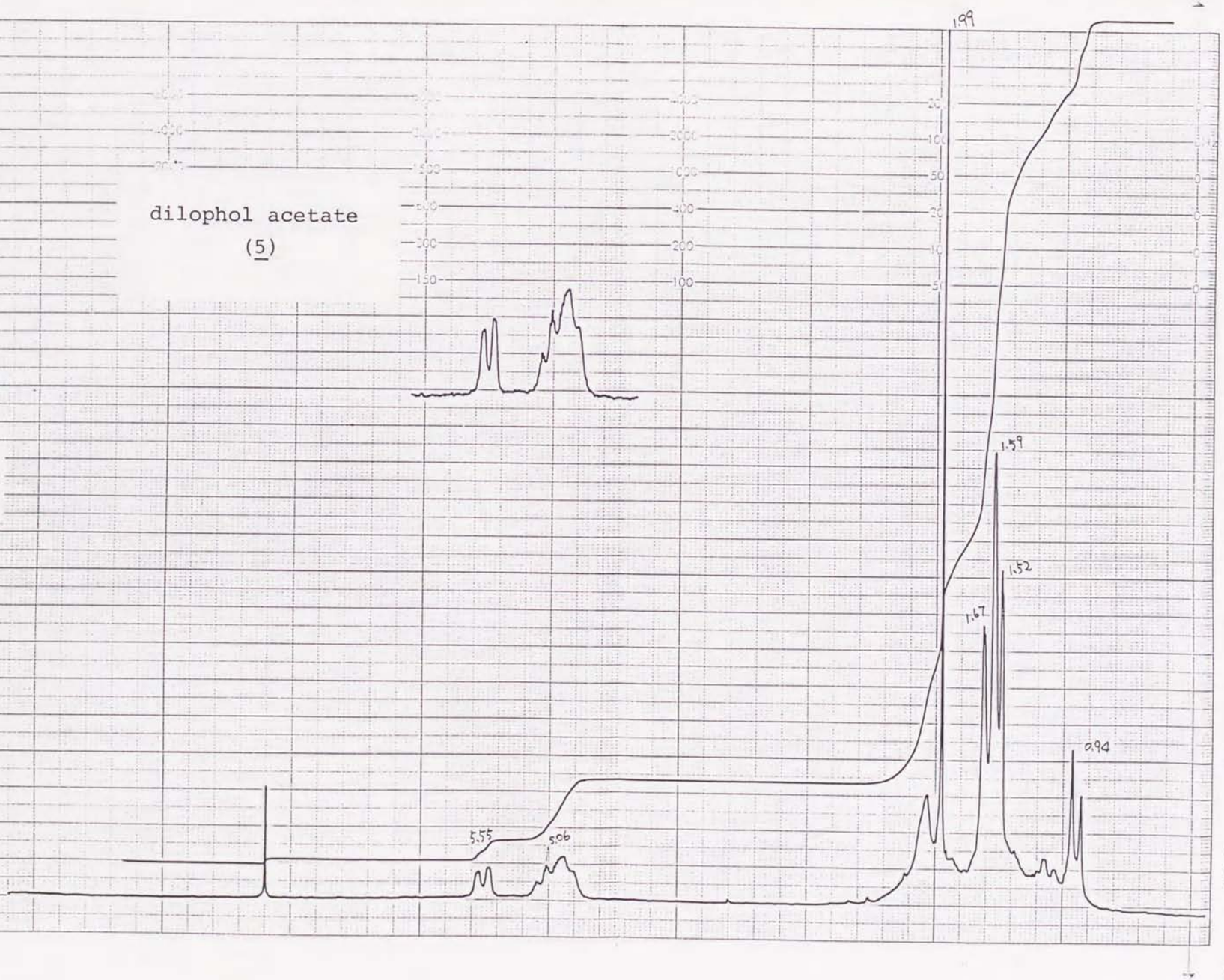
DATE 840622
OPERATOR
REMARKS

JEOL LTD


3-hydroxy-
acetyldilophol
(4)
133
201
1.68
1.60
1.50
0.96
J=7
5.68
dd.J=7.2
5.12
4.36
J=3
FX
CHART NO. 406
SAMPLE
① TLC(42)
SOLVENT CDCl3 TUBE mm
CONCENTRATION
REFERENCE
TEMPERATURE
NUCLEUS
OBS.
LOCK D F H
IRR.
OFFSET
OBS. KH
IRR. KH
PULSE SINGLE MULT
WIDTH μSEC.
INTERVAL SEC
REPETITION SEC
DATA POINTS
WINDOW
NO. OF PULSES
SPECTRAL WIDTH H
RF GAIN
AMPLITUDE
DECOUPLING
CW NOISE PARTIA
HOMO HETERO
POWER
LOCK
RF LEVEL
RF GAIN
AMPLITUDE
DATE 84.9.19
OPERATOR M
REMARKS
ケミカルシフト おかしい
JEOL LTD

dilophol acetate

(5)

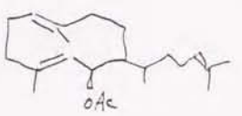


FX

CHART NO 507

SAMPLE

TLC (59) pure.



SOLVENT $CDCl_3$ TUBE mm

CONCENTRATION 8 mg

REFERENCE

TEMPERATURE

NUCLEUS

OBS

LOCK D F H

IRR

OFFSET

OBS

IRR

PULSE SINGLE

WIDTH μSEC

INTERVAL

REPETITION

DATA POINTS

WINDOW

NO. OF PULSES

SPECTRAL WIDTH

RF GAIN

AMPLITUDE

DECOUPLING

CW NOISE

HOMO HETERO

POWER

LOCK

RF LEVEL

RF GAIN

AMPLITUDE

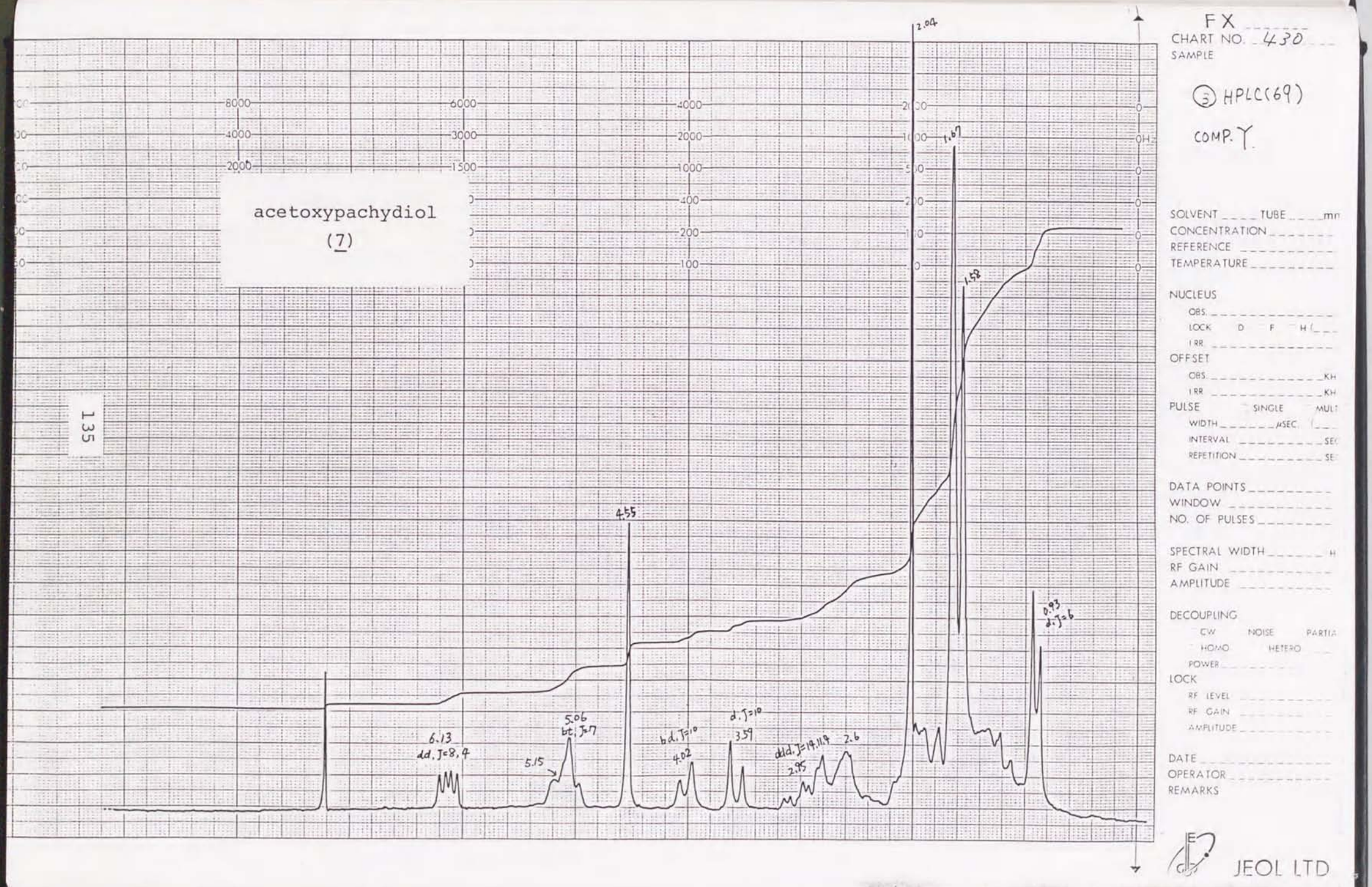
DATE 851030

OPERATOR M.

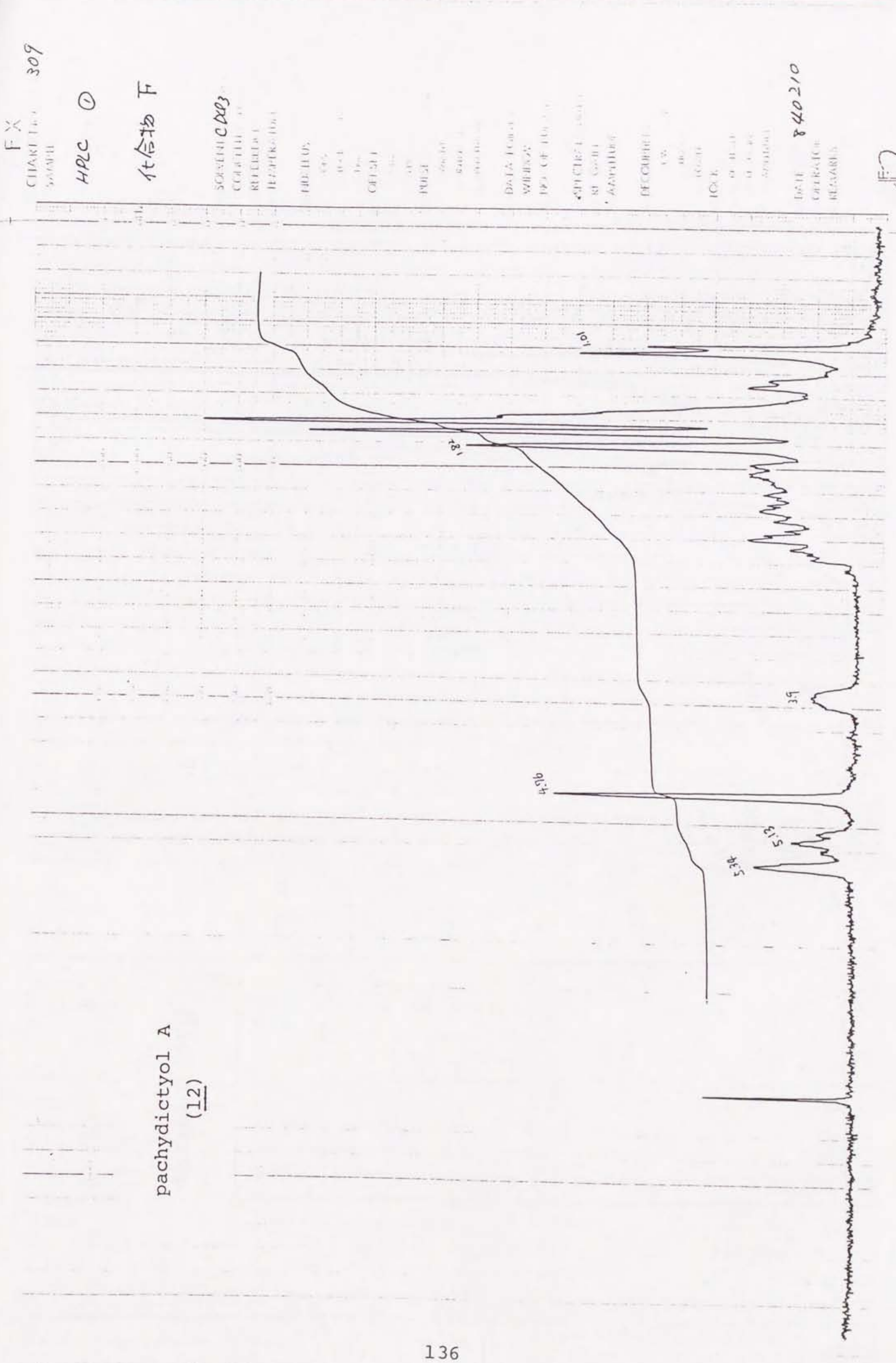
REMARKS

JEOL LTD

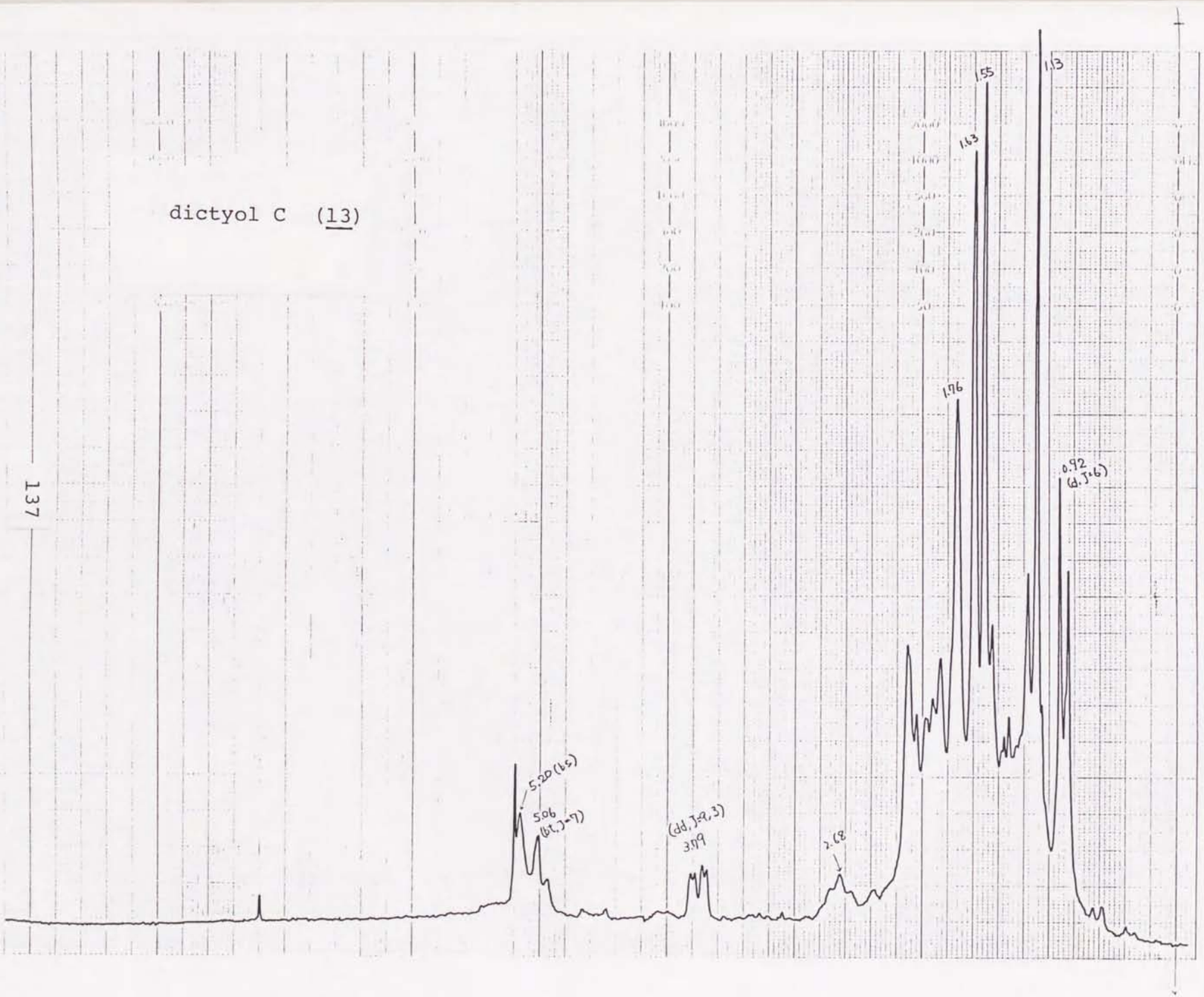
134


acetoxypachydiol
(7)
135
8000
6000
4000
3000
2000
1500
4000
2000
1000
400
200
100
2.04
1.67
1.58
4.55
6.13
dd, J=8, 4
5.15
5.06
bt, J=7
bd, J=10
4.02
d, J=10
3.59
ddd, J=14, 11.9
2.95
2.6
0.93
d, J=6
FX
CHART NO. 430
SAMPLE
③ HPLC(69)
COMP. Y
SOLVENT TUBE mm
CONCENTRATION
REFERENCE
TEMPERATURE
NUCLEUS
OBS.
LOCK D F H
IRR
OFFSET
OBS. KH
IRR KH
PULSE SINGLE MULT
WIDTH μSEC
INTERVAL SEC
REPETITION SEC
DATA POINTS
WINDOW
NO. OF PULSES
SPECTRAL WIDTH H
RF GAIN
AMPLITUDE
DECOUPLING
CW NOISE PARTIA
HOMO HETERO
POWER
LOCK
RF LEVEL
RF GAIN
AMPLITUDE
DATE
OPERATOR
REMARKS
JEOL LTD

pachydictyol A
(12)



dictyol C (13)



137

FX
CHART NO. 440
SAMPLE
3(76)

SOLVENT CDCl3
CONCENTRATION
REFERENCE
TEMPERATURE

NUCLEUS
OBS
LOCK
DEC
OFFSET
OBS
DEC
PULSE
WIDTH
INTERVAL
REPETITION

DATA POINTS
WINDOW
NO. OF PULSES

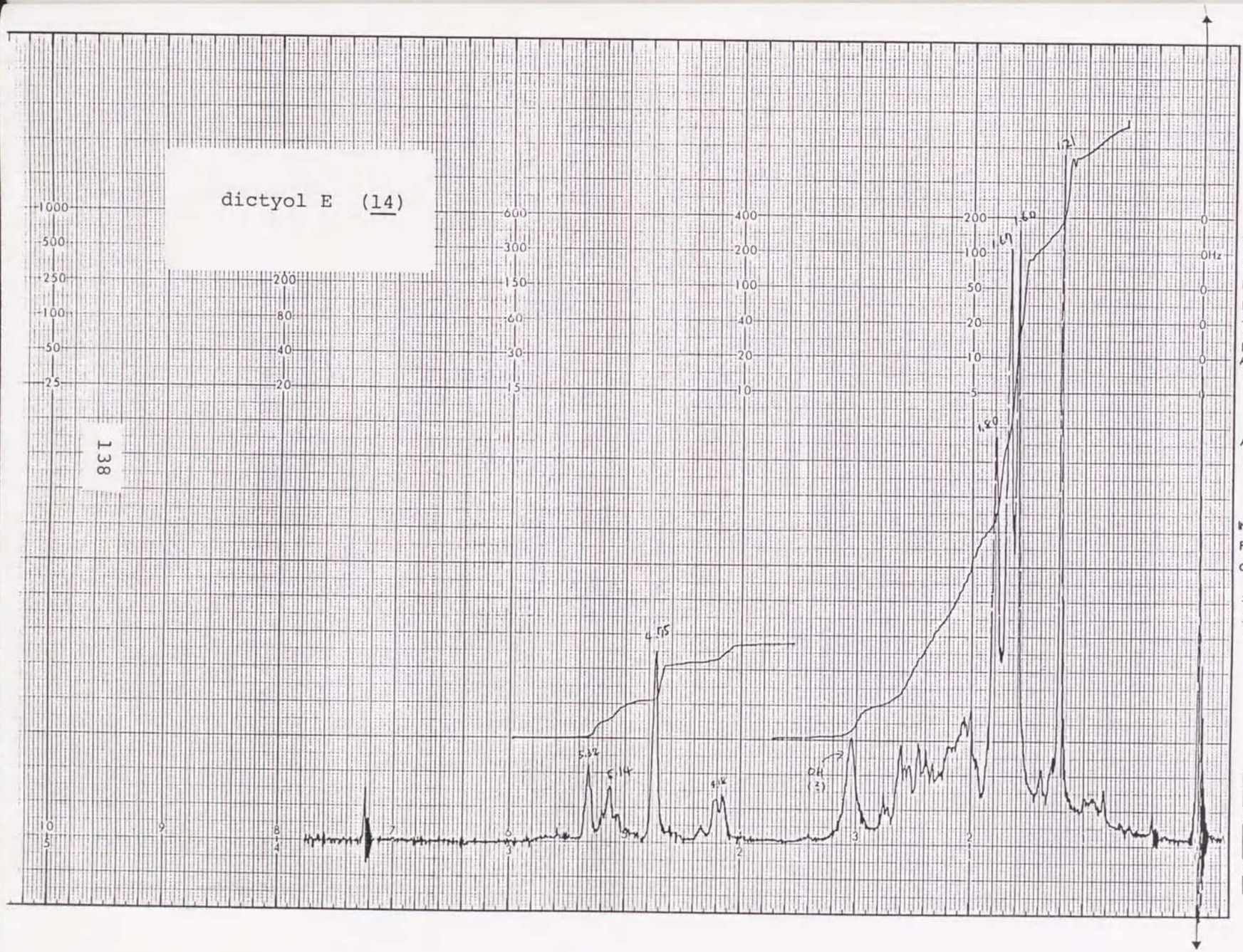
SPECTRAL WIDTH
RF GAIN
AMPLITUDE

DECOUPLING
CW
HOMO
POWER
LOCK
RF LEVEL
RF GAIN
SWEEPING

DATE 85 01 11
OPERATOR
REMARKS

dictyol E (14)

138



SPECTRUM No. 55
DATE 811027
FREQ.
NUCLEUS
SAMPLE
hb2f(11) fr3-4
comp. M

SOLVENT	CDCl3
CONC.	90 mg
REFERENCE	TMS
LOCK	
TEMP.	°C
R.F.LEVEL A.F.LEVEL	
OBSERVE	
LOCK	
SD	
AMPLITUDE	
OBSERVE	R.F.
	A.F.
LOCK	
INTEGRATOR	
FILTER	
OFFSET	H PP

FREQ, FIELD/FREQ,_ FIELD.

OPERATOR JH
REMARKS;

SWEEP TIME (SEC.)

25	50	100	250	500
1000	2500	5000	10000	

SWEEP WIDTH (Hz)(X 0.01PPM

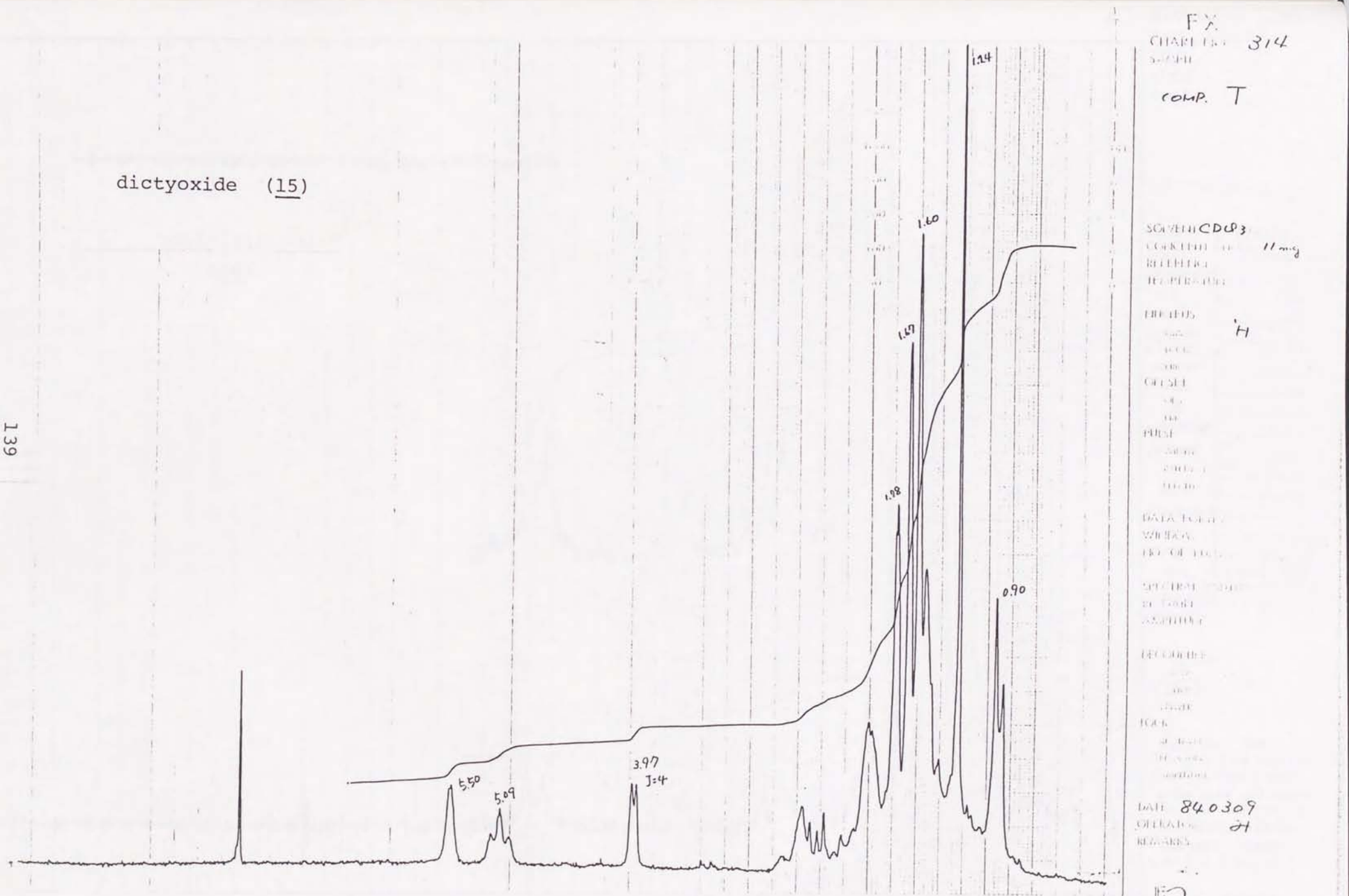
27	54	108	270	540
1080	2700	5400	10600	

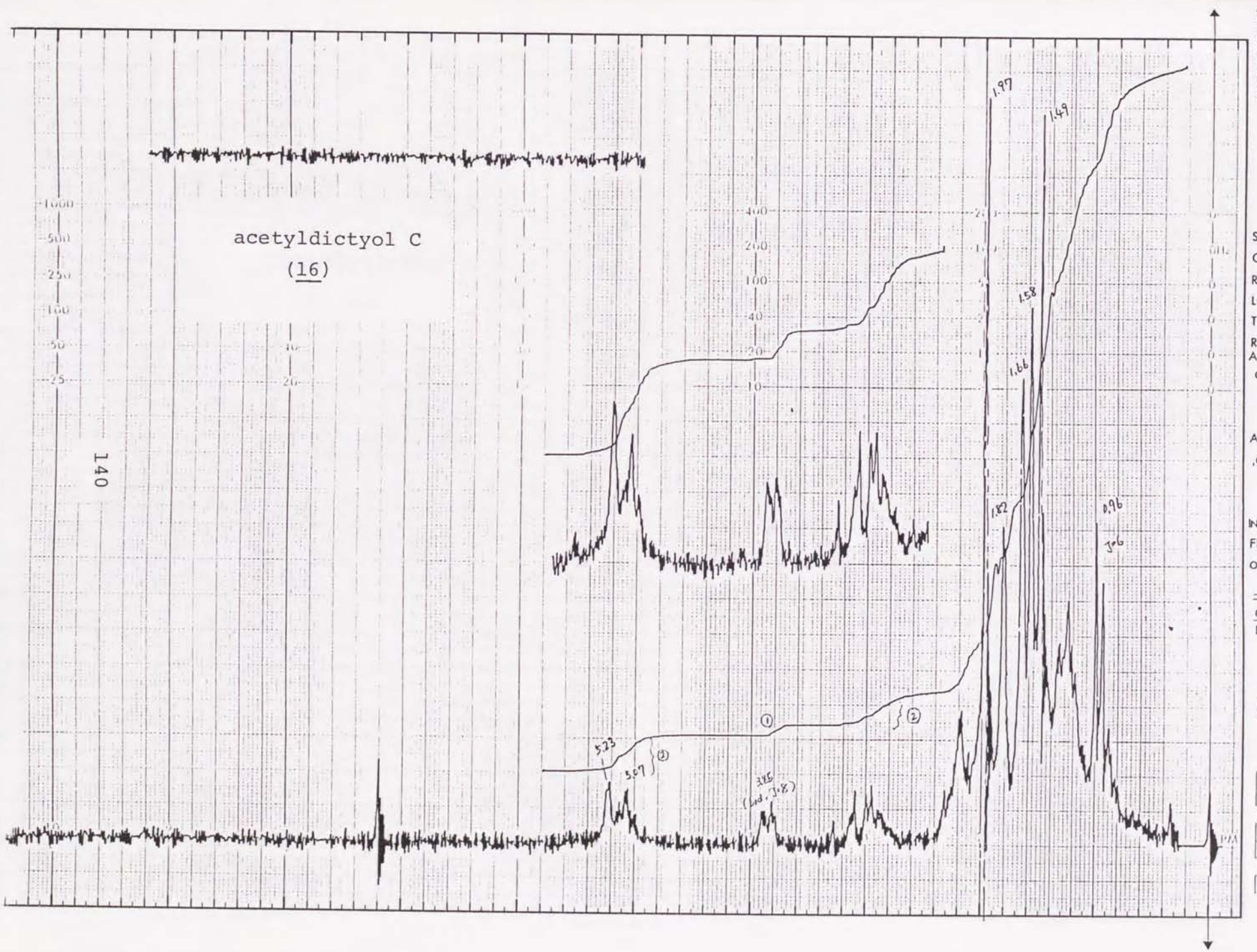
WIDE SWEEP (GAUSS)

10.8	27	54	108	540

3847

dictyoxide (15)





SPECTRUM No. 138
DATE 820520
FREQ.
NUCLEUS
SAMPLE

Q

TLC(in) Q

SOLVENT	CDCl3
CONC.	27 mg
REFERENCE	
LOCK	
TEMP.	C
R.F.LEVEL	
A.F.LEVEL	
OBSERVE	
LOCK	
SD	
AMPLITUDE	
OBSERVE	R.F.
	A.F.
LOCK	
INTEGRATOR	
FILTER	
OFFSET	H F

__FREQ,__ FIELD/FREQ,__ FIELD.

OPERATOR
REMARKS;

論文データ

SWEEP TIME (SEC.)

25	50	100	250	500
1000	2500	5000	10000	

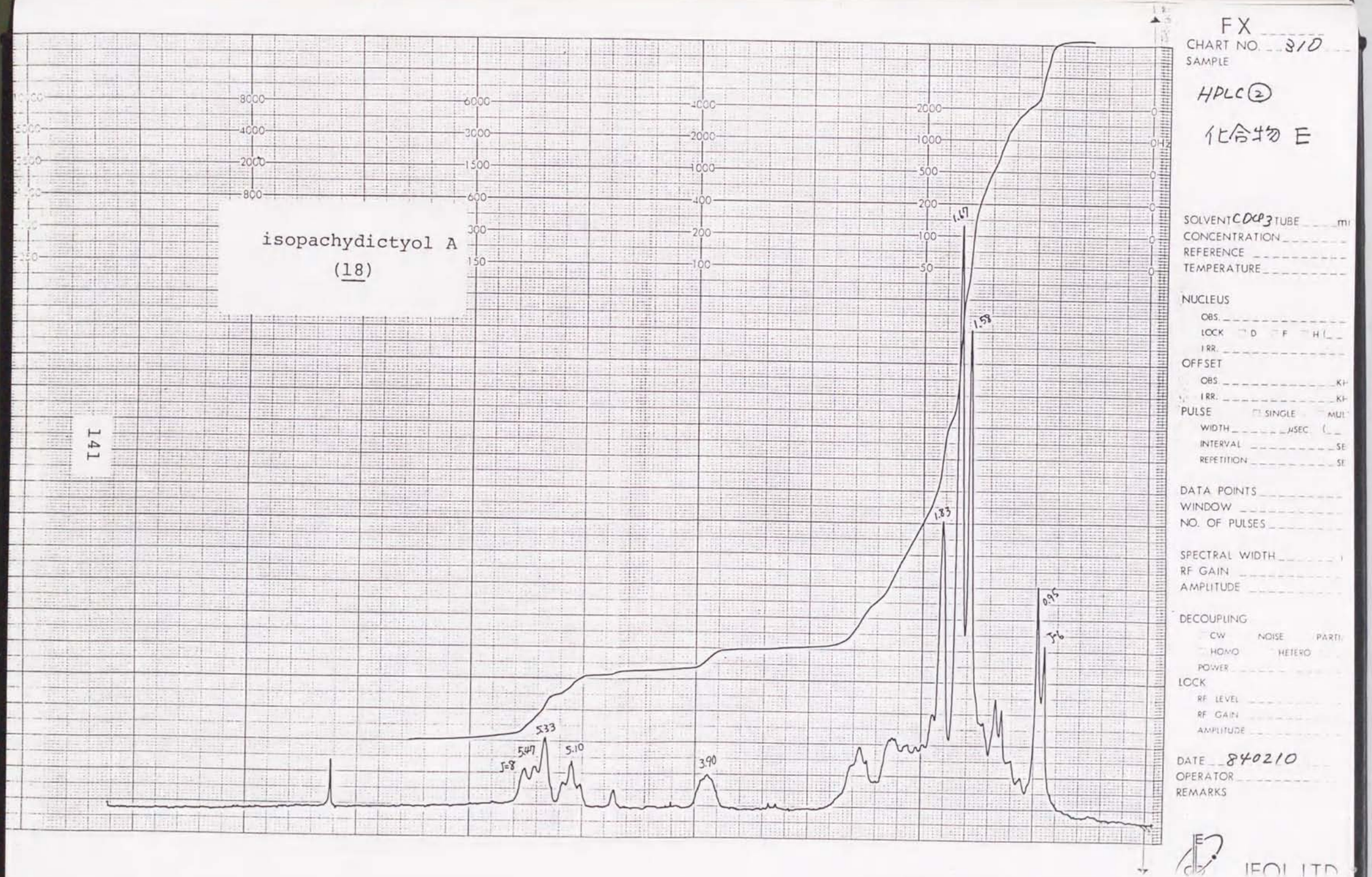
SWEEP WIDTH (Hz)(X0.01PPM)

27	54	108	270	540
1080	2700	5400	10800	

WIDE SWEEP (GAUSS)

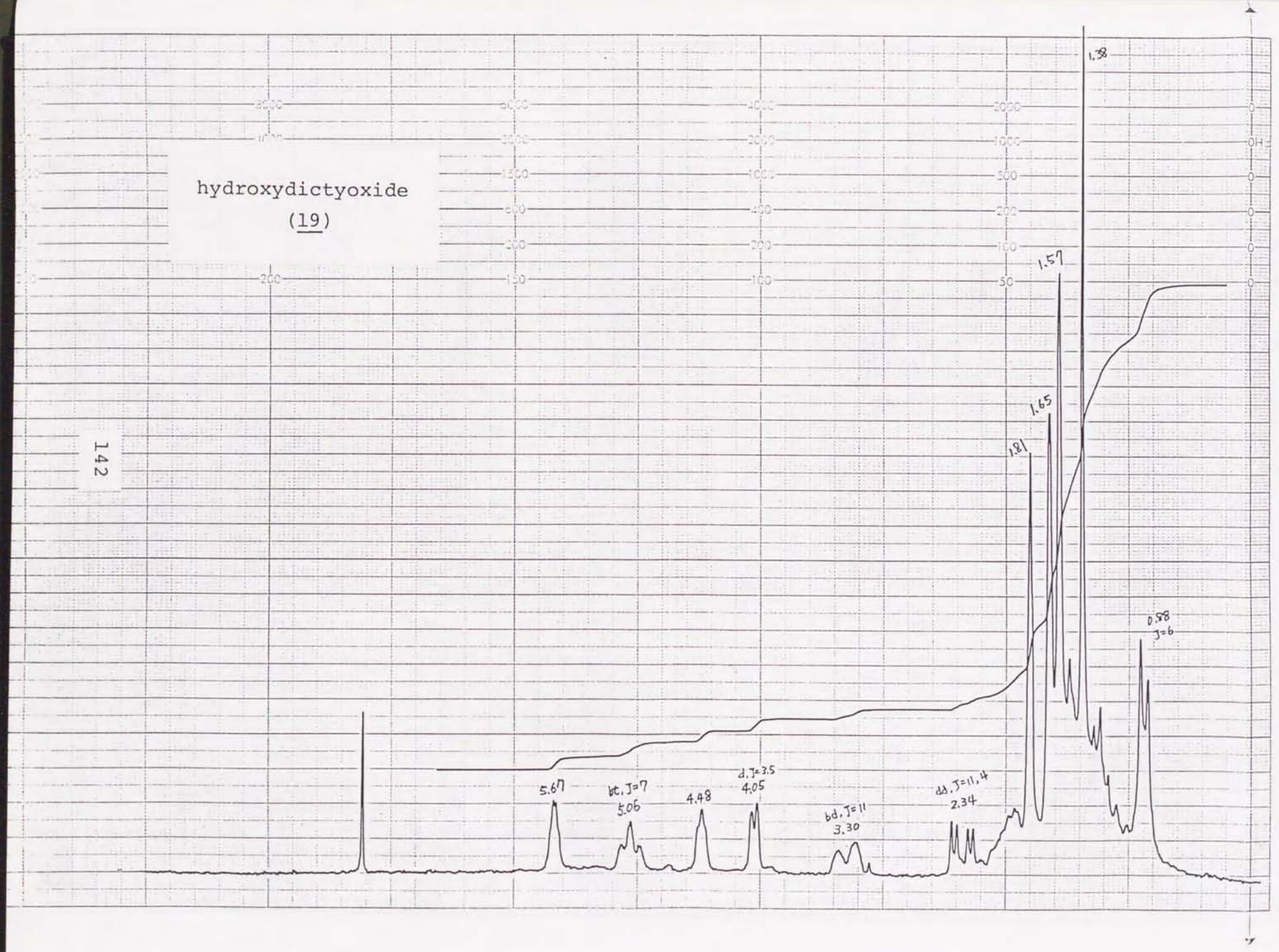
10.8	27	54	108	54

4179


isopachydictyol A
(18)
141
8000
6000
4000
3000
2000
1500
800
600
300
150
4000
2000
1000
400
200
100
2000
1000
500
200
100
50
1.67
1.58
1.83
0.95
5.33
5.47
5.10
3.90
J=8
FX
CHART NO. 310
SAMPLE
HPLC ②
化合物 E
SOLVENT CDCl3 TUBE mm
CONCENTRATION
REFERENCE
TEMPERATURE
NUCLEUS
OBS.
LOCK D F H
IRR.
OFFSET
OBS. KH
IRR. KH
PULSE SINGLE MULT
WIDTH μSEC
INTERVAL SE
REPETITION SE
DATA POINTS
WINDOW
NO. OF PULSES
SPECTRAL WIDTH
RF GAIN
AMPLITUDE
DECOUPLING
CW NOISE PARTI
HOMO HETERO
POWER
LOCK
RF LEVEL
RF GAIN
AMPLITUDE
DATE 840210
OPERATOR
REMARKS
JEOL LTD

hydroxydictyoxide
(19)

142



FX
CHART NO. 454
SAMPLE

TLC (49)

comp. C

SOLVENT CDCl3 UBE
CONCENTRATION 4.5 mg
REFERENCE
TEMPERATURE

NUCLEUS
OBS
LOCK D F H
FRR
OFFSET
OBS
FRR
PULSE SINGLE MU
WIDTH μSEC
INTERVAL S
REPETITION

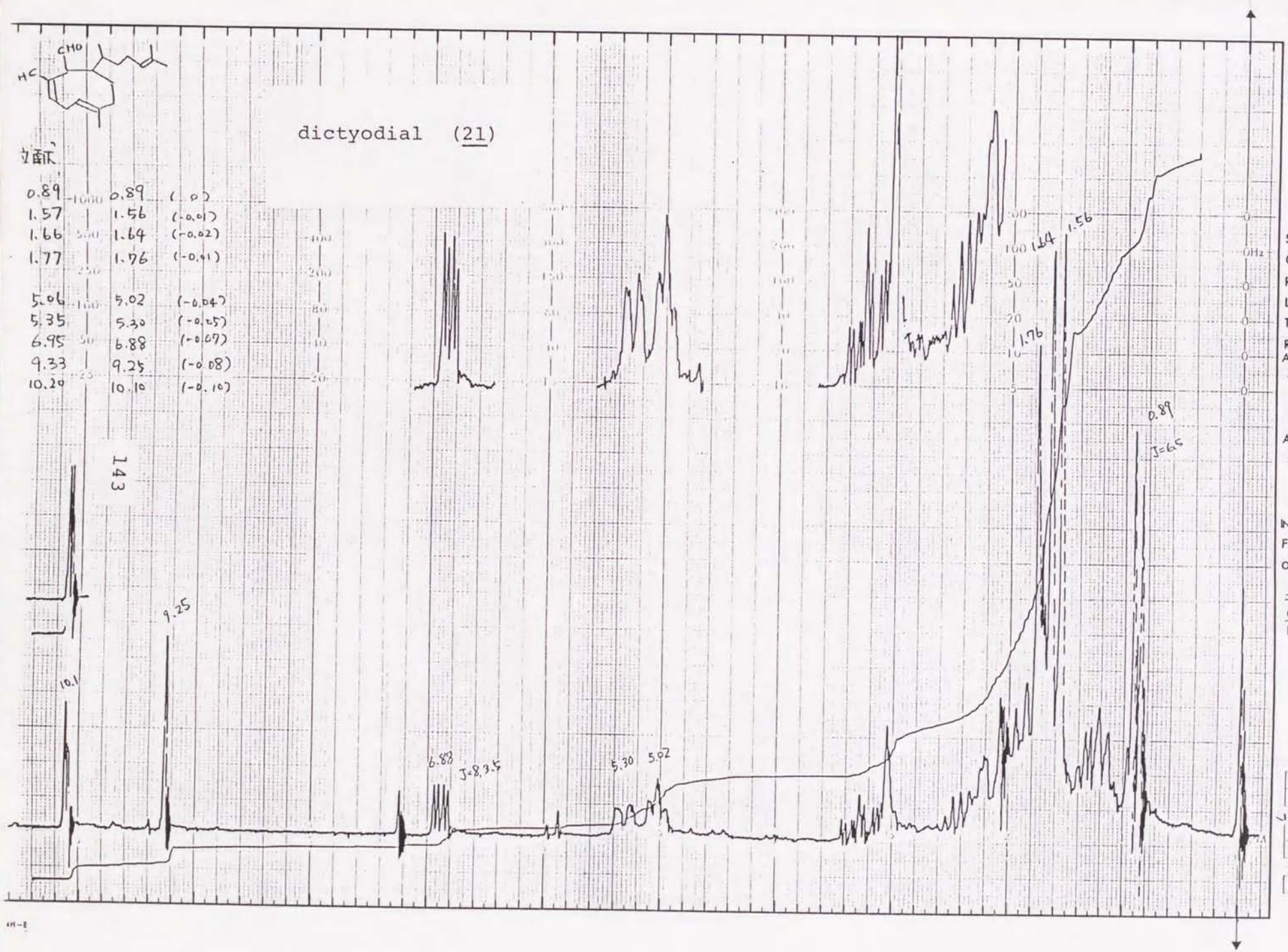
DATA POINTS
WINDOW
NO. OF PULSES 47

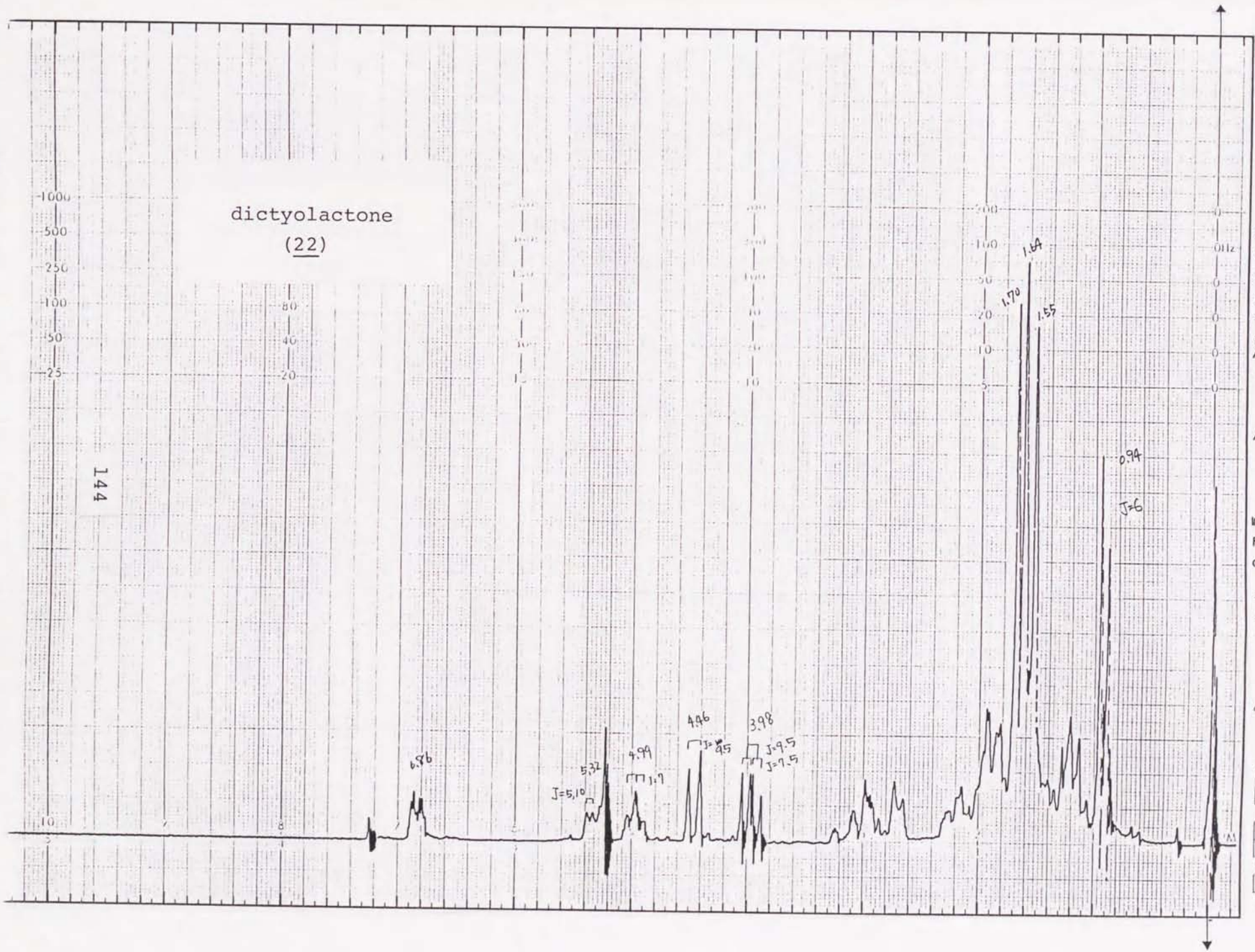
SPECTRAL WIDTH
RF GAIN
AMPLITUDE 15

DECOUPLING
CW NOISE FREE
HOMO HETERO
POWER
LOCK
RF LEVEL
RF GAIN
AMPLITUDE

DATE 850131
OPERATOR H.
REMARKS

JEOL LTD


dictyodial (21)
立体
0.89 0.89 (0)
1.57 1.56 (-0.01)
1.66 1.64 (-0.02)
1.77 1.76 (-0.01)
5.06 5.02 (-0.04)
5.35 5.30 (-0.05)
6.95 6.88 (-0.07)
9.33 9.25 (-0.08)
10.20 10.10 (-0.10)
143
10.1
9.25
6.88
J=8,3.5
5.30
5.02
1.64
1.56
1.76
0.89
J=6.5
SPECTRUM No.
DATE 820201
FREQ.
NUCLEUS
SAMPLE
fv. 31-47
dictyodial
SOLVENT CDCl
CONC.
REFERENCE TMS
LOCK
TEMP.
R.F.LEVEL
A.F.LEVEL
OBSERVE
LOCK
SD
AMPLITUDE
OBSERVE R.F.
A.F.
LOCK
INTEGRATOR
FILTER
OFFSET
FREQ. FIELD/FREQ.
OPERATOR
REMARKS;
SWEEP TIME (SEC.)
25 50 100 250
1000 2500 5000 10000
SWEEP WIDTH (Hz)(X0.
27 54 108 270
1080 2700 5400 10800
WIDE SWEEP (GAUSS)
10.8 27 54 108
4049



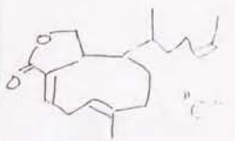
SPECTRUM No. 95
DATE 820209
FREQ.
NUCLEUS
SAMPLE
fr. 16-28 (25)

SOLVENT	CDCl3
CONC.	
REFERENCE	TMS
LOCK	
TEMP.	C
R.F.LEVEL	
A.F.LEVEL	
OBSERVE	
LOCK	
SD	
AMPLITUDE	
OBSERVE	R.F.
	A.F.
LOCK	
INTEGRATOR	
FILTER	
OFFSET	H / PP

FREQ. FIELD/FREQ. FIELD.

OPERATOR

REMARKS;



SWEEP TIME (SEC.)

25	50	100	250	500
1000	2500	5000	10000	

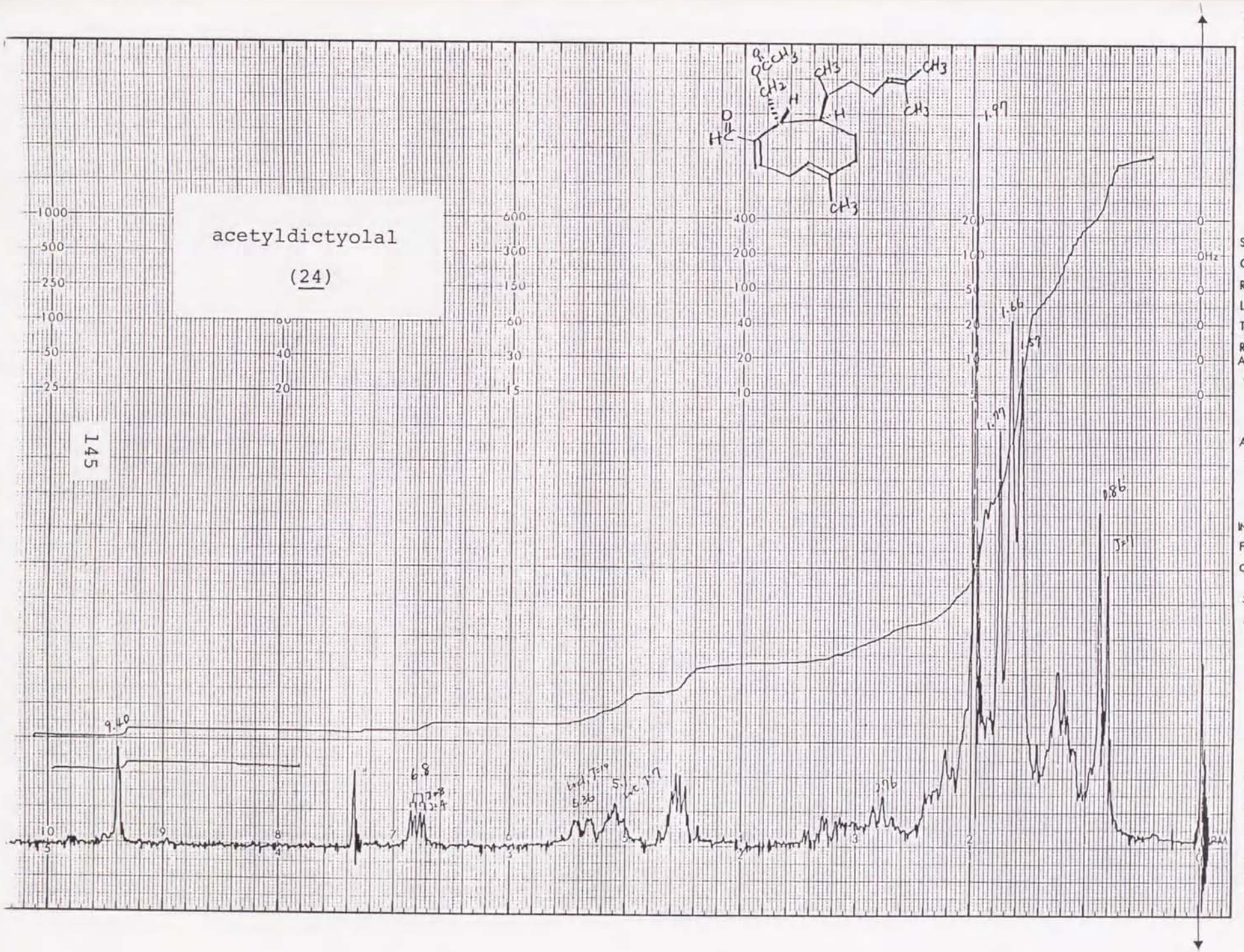
SWEEP WIDTH (Hz) (X 0.01PPM)

27	54	108	270	540
1080	2700	5400	10800	

WIDE SWEEP (GAUSS)

10.8	27	54	108	540

405S



SPECTRUM No. 42
DATE 81.10.02
FREQ.
NUCLEUS
SAMPLE

comp. I

SOLVENT	CDCl3
CONC.	30 mg
REFERENCE	TMS
LOCK	
TEMP.	°C
R.F.LEVEL	
A.F.LEVEL	
OBSERVE	
LOCK	
SD	
AMPLITUDE	
OBSERVE R.F.	
A.F.	
LOCK	
INTEGRATOR	
FILTER	
OFFSET	H. PP

_ FREQ, _ FIELD/FREQ, _ FIELD,

OPERATOR

REMARKS;

論文data

SWEEP TIME (SEC.)

25	50	100	250	500
1000	2500	5000	10000	

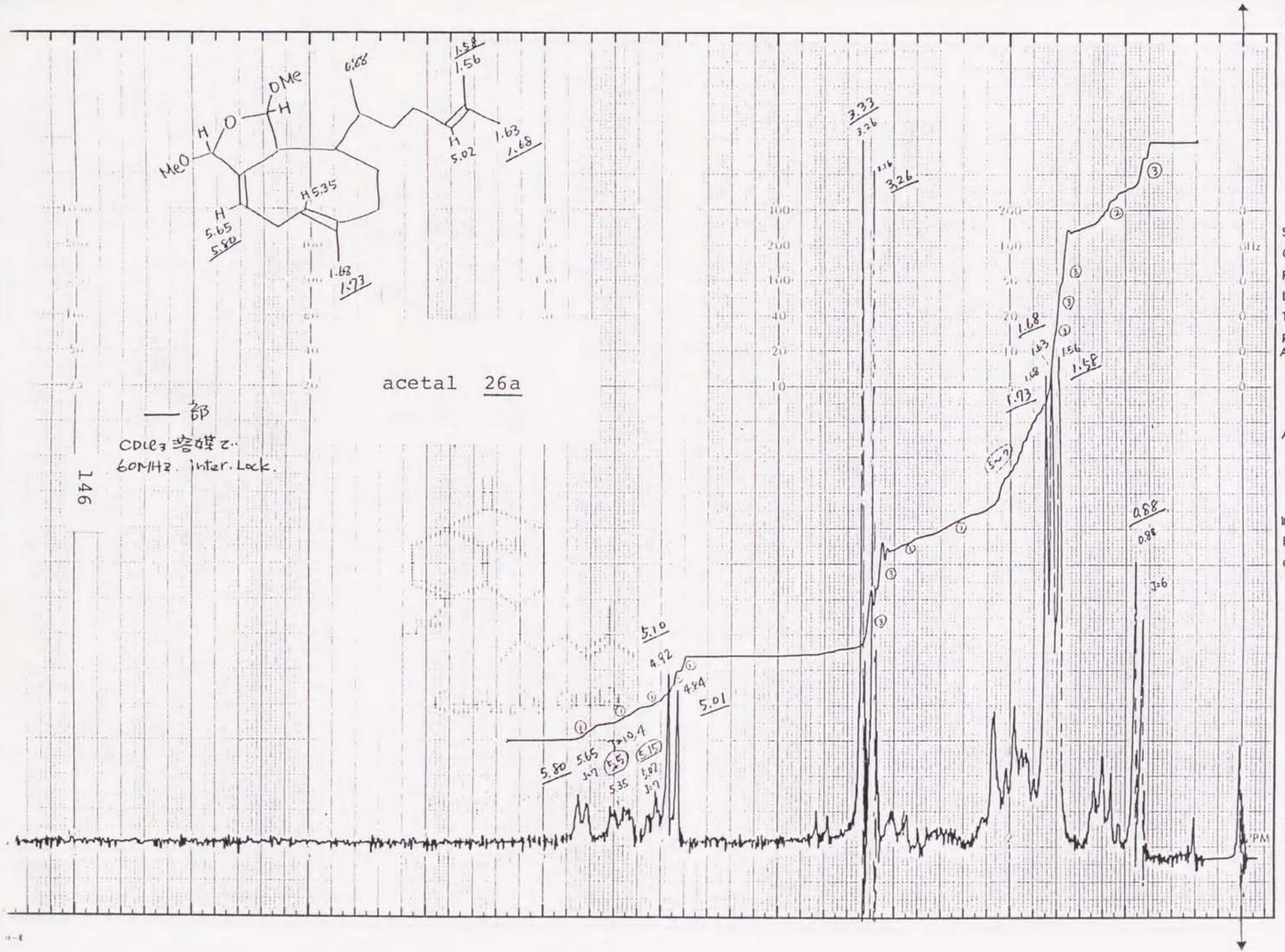
SWEEP WIDTH (Hz)(X 0.01PPM

27	54	108	270	540
1080	2700	5400	10800	

WIDE SWEEP (GAUSS)

10.8	27	54	108	540

3793



SPECTRUM No. [illegible]
DATE 82.01.18
FREQ.
NUCLEUS
SAMPLE
TLC分取(+)
精製物
comp. N

SOLVENT	CCl4
CONC.	22mg
REFERENCE	TMS
LOCK	
TEMP.	
R.F.LEVEL	
A.F.LEVEL	
OBSERVE	
LOCK	
SD	
AMPLITUDE	
OBSERVE	R.F.
	A.F.
LOCK	
INTEGRATOR	
FILTER	
OFFSET	

FREQ. FIELD/FREQ. FI

OPERATOR 21
REMARKS;

一価 計(H)

SWEEP TIME (SEC.)

25	50	100	250
1000	2500	5000	10000

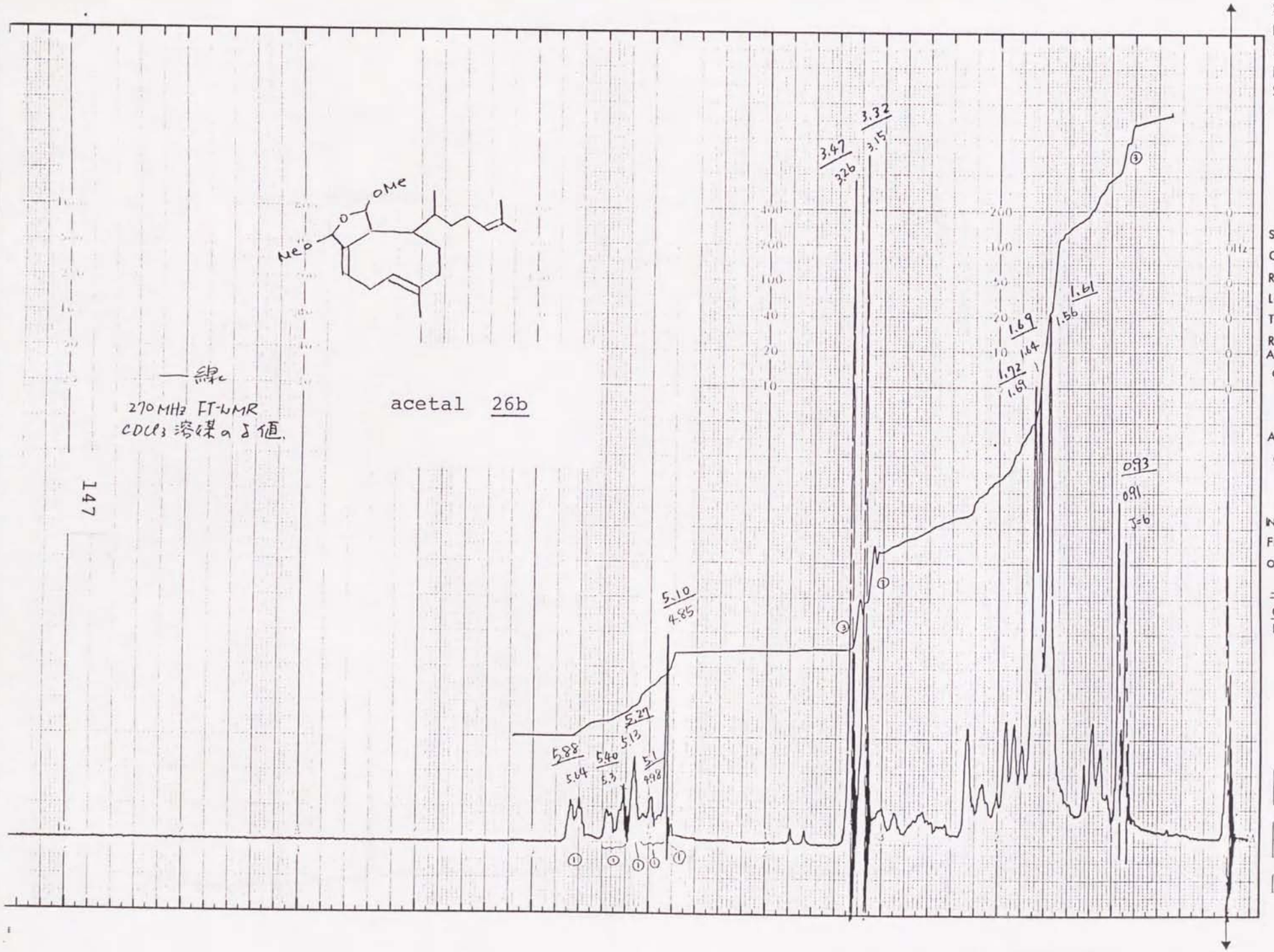
SWEEP WIDTH (Hz) (X0.0)

27	54	108	270
1080	2700	5400	10800

WIDE SWEEP (GAUSS)

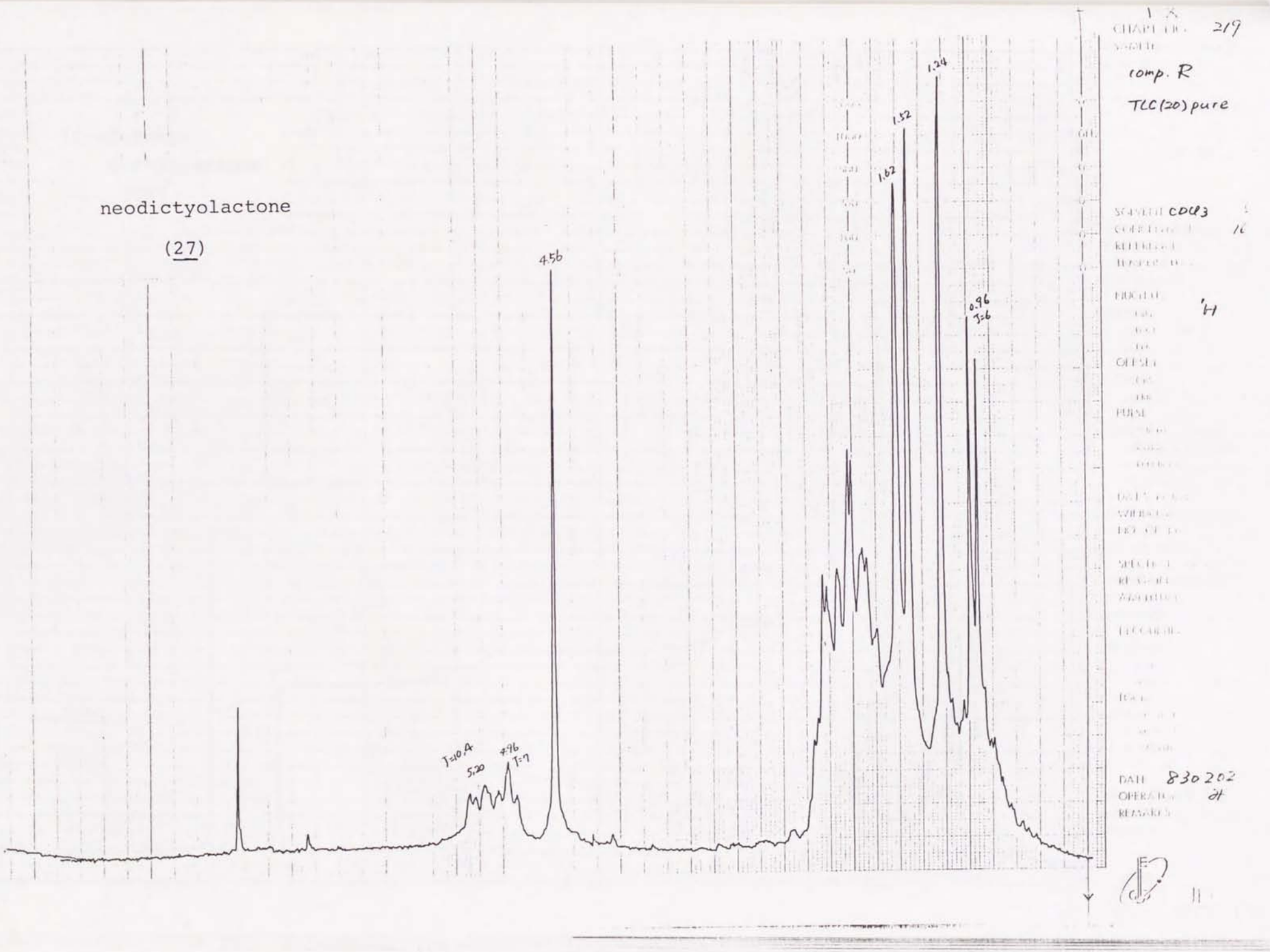
10.8	27	54	108

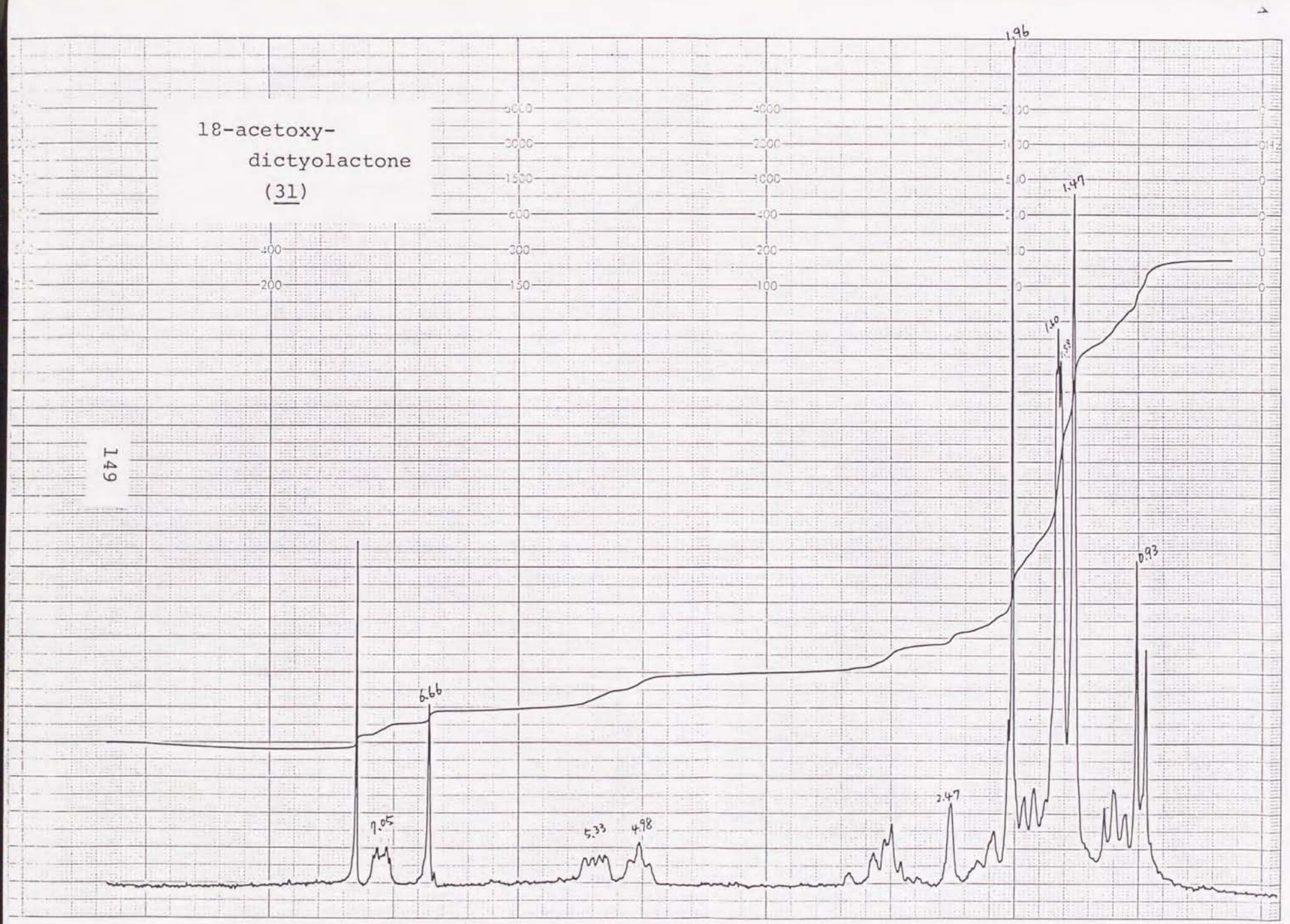
4025


OMe
MeO
acetal 26b
—線
270MHz FT-NMR
CDCl3 溶媒のδ値.
147
5.88
5.64
5.40
5.3
5.27
5.13
5.1
4.98
5.10
4.85
3.47
3.26
3.32
3.15
1.69
1.64
1.72
1.69
1.61
1.56
0.93
0.91
J=6
SPECTRUM No. 91
DATE 820126
FREQ.
NUCLEUS
SAMPLE
fr. 6-9 (23)
comp. O
SOLVENT CCl4
CONC.
REFERENCE TMS
LOCK
TEMP. C
R.F.LEVEL
A.F.LEVEL
OBSERVE
LOCK
SD
AMPLITUDE
OBSERVE R.F.
A.F.
LOCK
INTEGRATOR
FILTER
OFFSET
FREQ. FIELD/FREQ. FIEL
OPERATOR
REMARKS;
—値. 溶媒
SWEEP TIME (SEC.)
25 50 100 250
1000 2500 5000 10000
SWEEP WIDTH (Hz) (X 0.01)
27 54 108 270
1080 2700 5400 10800
WIDE SWEEP (GAUSS)
10.8 27 54 108
4041

neodictyolactone

(27)





149

FX

CHART NO. 409

SAMPLE

COMP. W-Acetate
||
COMP. U

SOLVENT $CDCl_3$ TUBE 5 m/m

CONCENTRATION 3 mg

REFERENCE

TEMPERATURE

NUCLEUS ^1H

OBS

LOCK D F H

IRR

OFFSET

OBS. K

IRR. K

PULSE SINGLE MU

WIDTH μSEC

INTERVAL S

REPETITION S

DATA POINTS

WINDOW

NO. OF PULSES

SPECTRAL WIDTH

RF GAIN

AMPLITUDE

DECOUPLING

CW NOISE PART

HOMO HETERO

POWER

LOCK

RF LEVEL

RF GAIN

AMPLITUDE

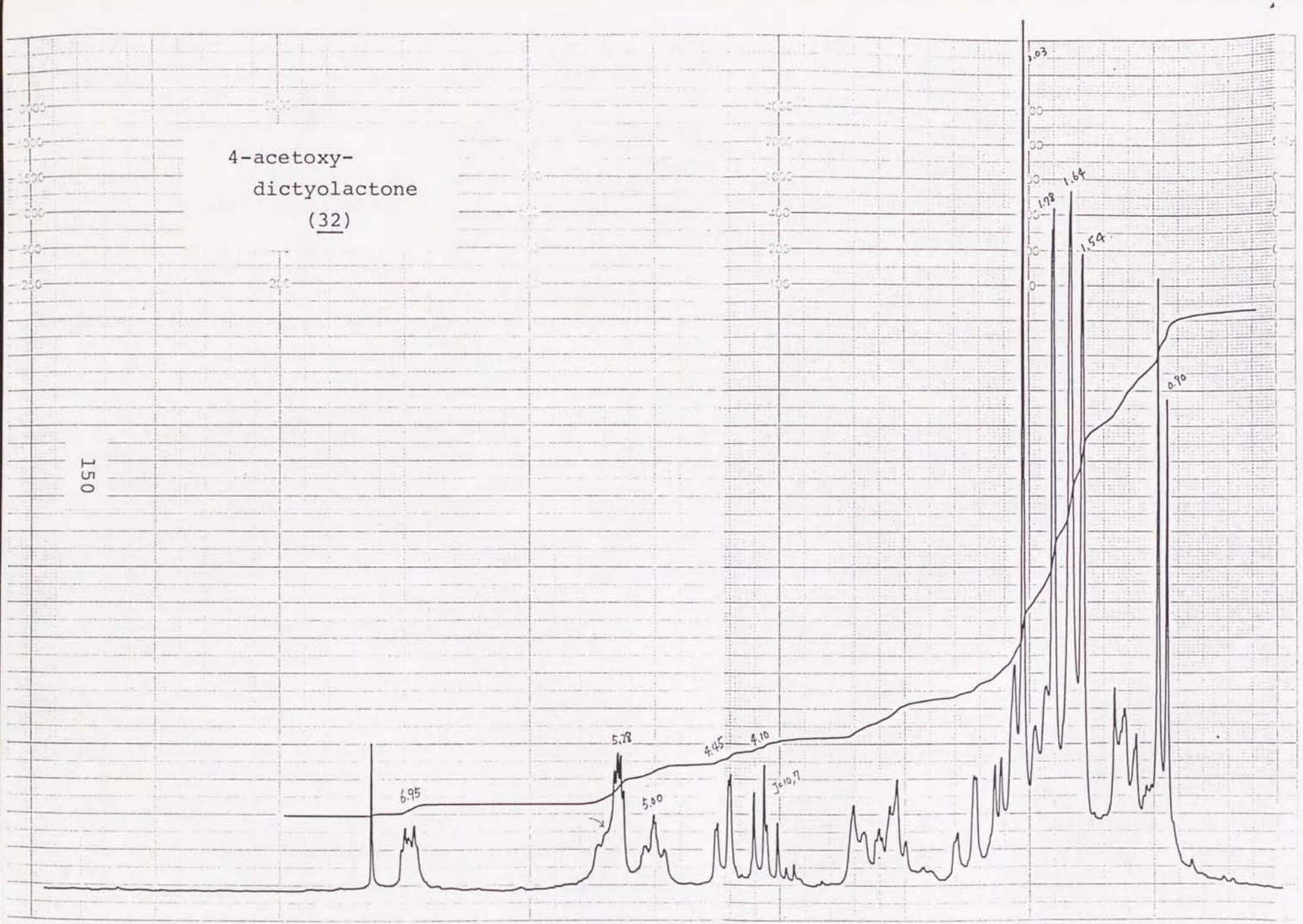
DATE 84 09 25

OPERATOR

REMARKS

JEOL LTD

4-acetoxy-
dictyolactone
(32)



FX
CHART NO. 129
SAMPLE
BAH (45)-9-2
compound VII

SOLVENT CDCl3 TUBE
CONCENTRATION 13 mg
REFERENCE
TEMPERATURE

NUCLEUS
OBS
LOCK D F
RR
OFFSET
SW
AF
PULSE SINGLE
WIDTH μSEC
INTERVAL
REPETITION

DATA POINTS
WINDOW
NO. OF PULSES

SPECTRAL WIDTH
RF GAIN
AMPLITUDE

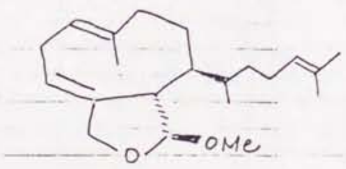
DECOUPLING
ON NOISE
POWER METHOD

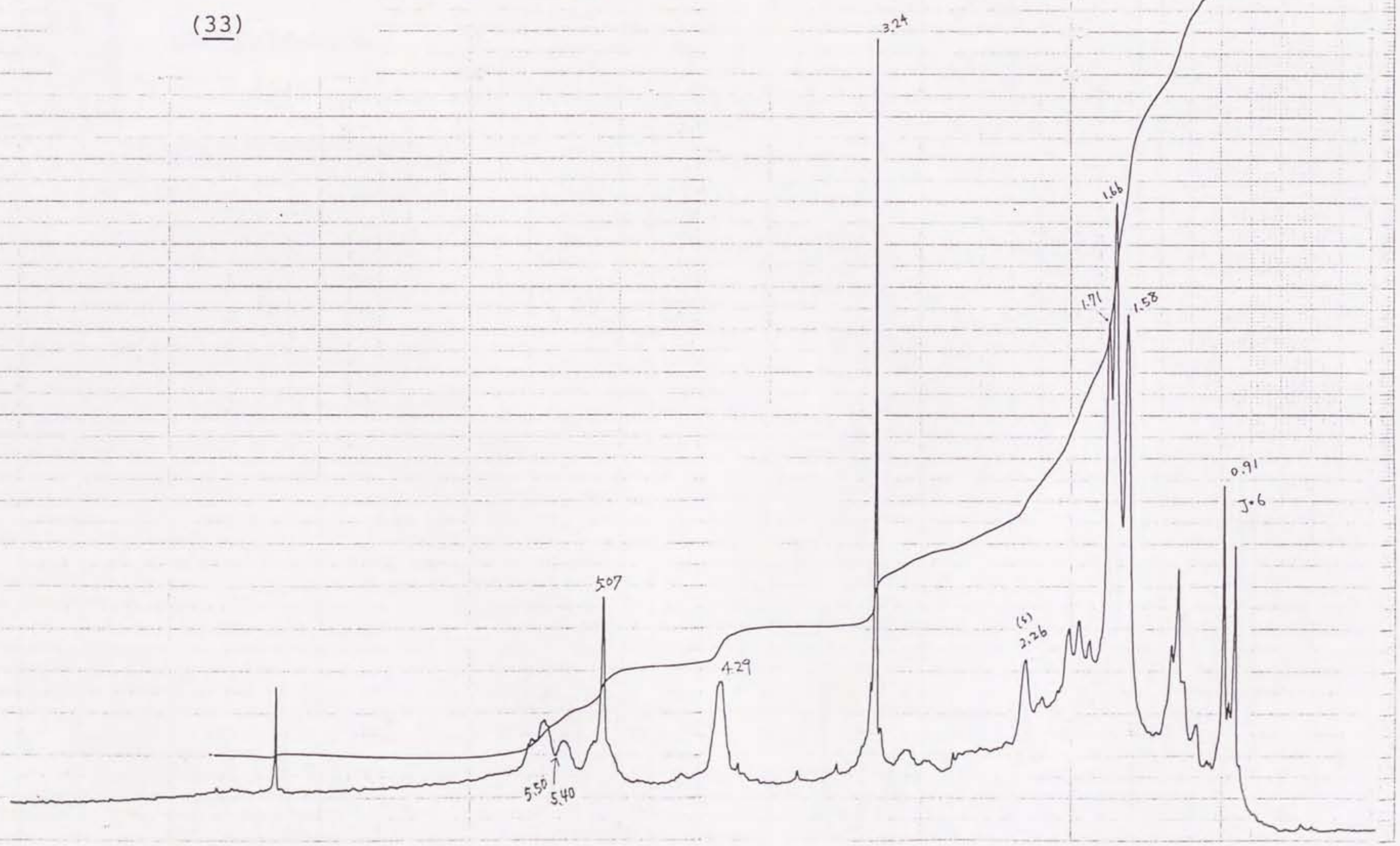
LOCK

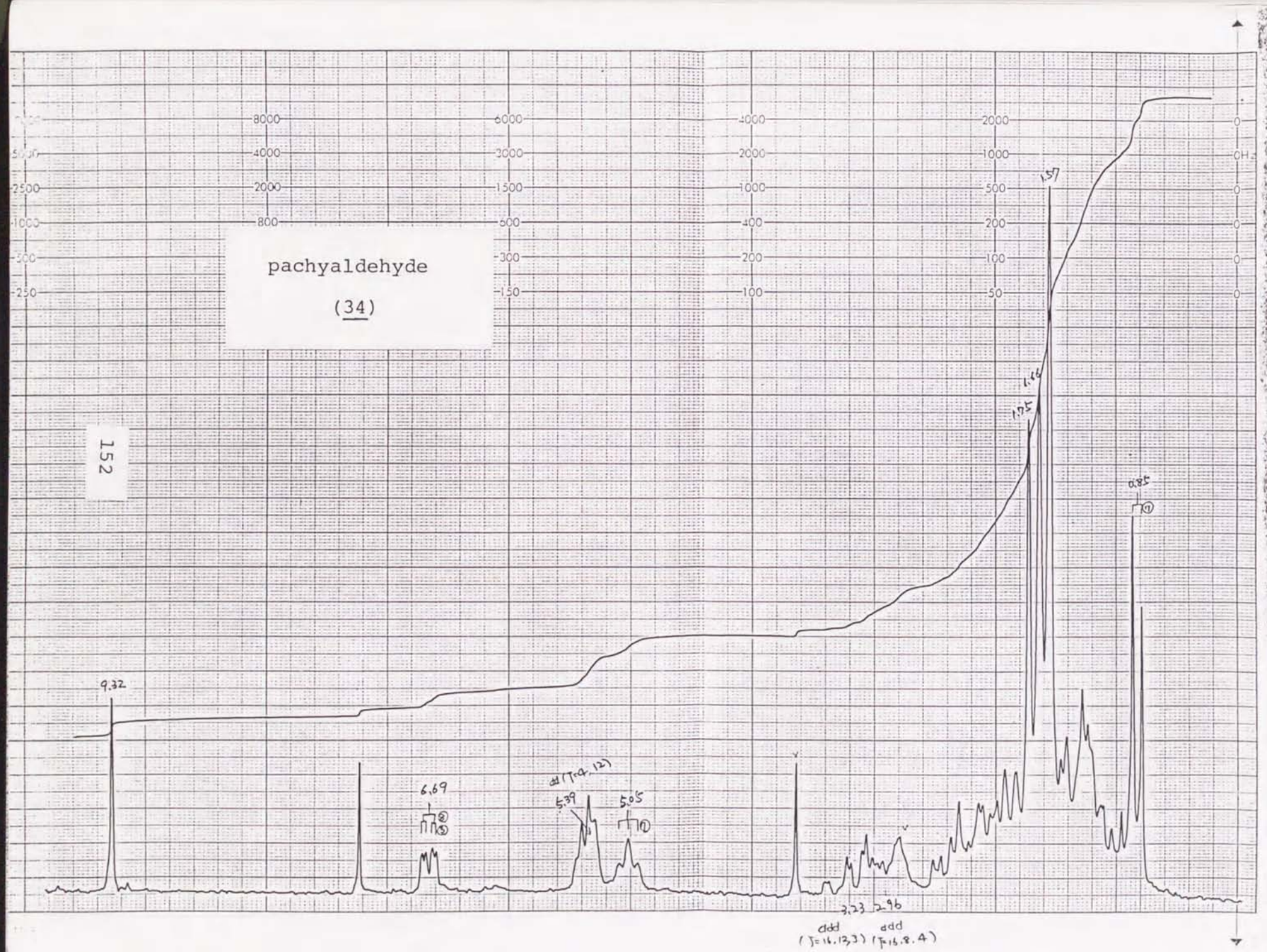
DATE 861201
H.

isodictyoacetal

(33)







FX

CHART NO. 292

SAMPLE

comp. A

SOLVENT CDCl3 TUBE mm

CONCENTRATION

REFERENCE

TEMPERATURE

NUCLEUS

OBS.

LOCK D F H

IRR.

OFFSET

OBS. KH

IRR. KH

PULSE SINGLE MULT

WIDTH μSEC

INTERVAL SE

REPETITION SE

DATA POINTS

WINDOW

NO. OF PULSES 36

SPECTRAL WIDTH 1800

RF GAIN

AMPLITUDE

DECOUPLING

CW NOISE PARTI

HOMO HETERO

POWER

LOCK

RF LEVEL

RF GAIN

AMPLITUDE

DATE

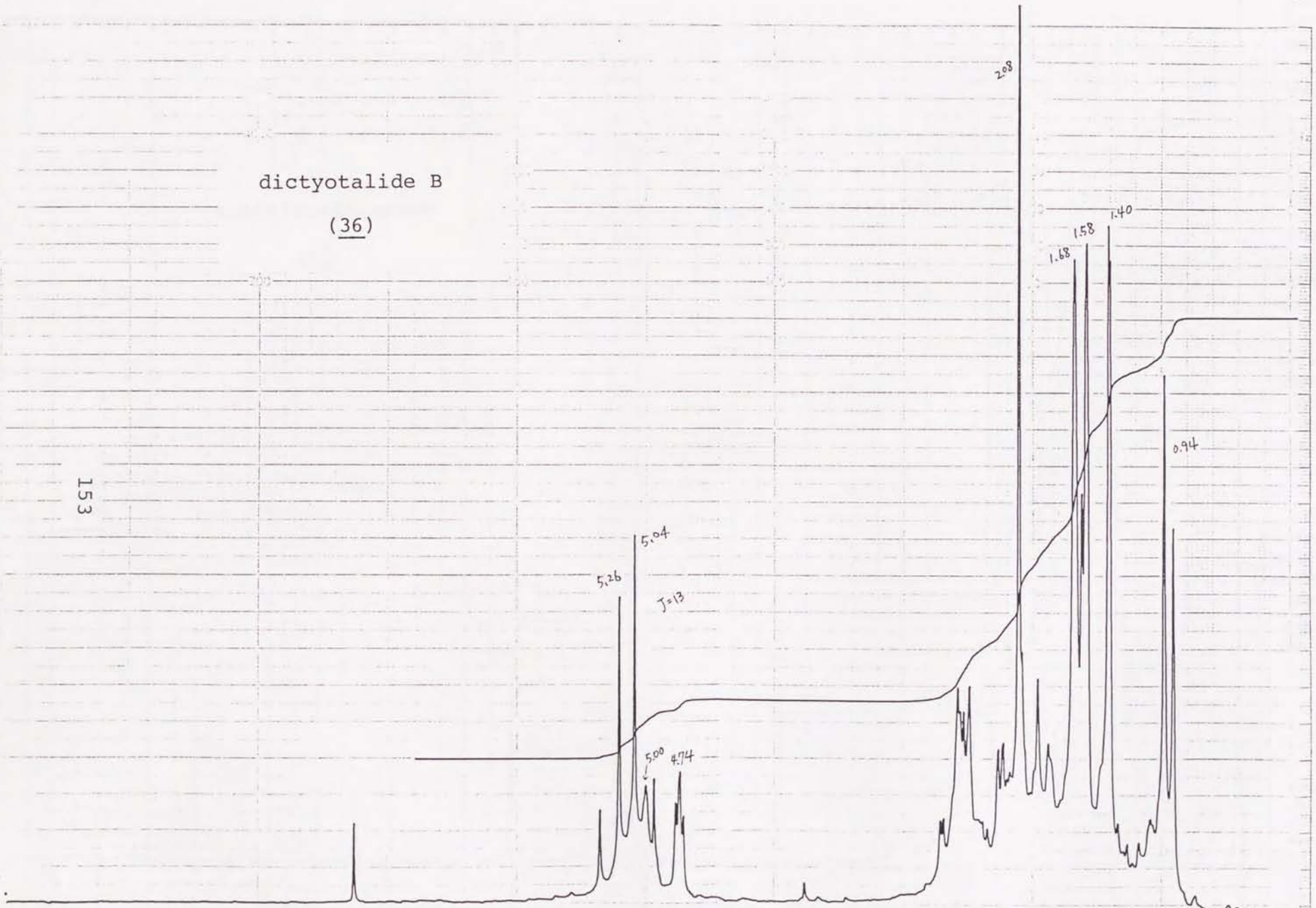
OPERATOR

REMARKS

JEOL LTD

dictyotalide B

(36)



FX

CHART NO. 125

SAMPLE

BAH(45)-7-4-3-3-②-①

SOLVENT CDCl3 TUBE

CONCENTRATION 8.9mg

REFERENCE

TEMPERATURE

NUCLEUS

OFFSET

PULSE

DATA POINTS

WINDOW

NO. OF PULSES

SPECTRAL WIDTH 1800

RF CHAN.

AMPLITUDE

DECOUPLER

ION

DATE 86 10 31

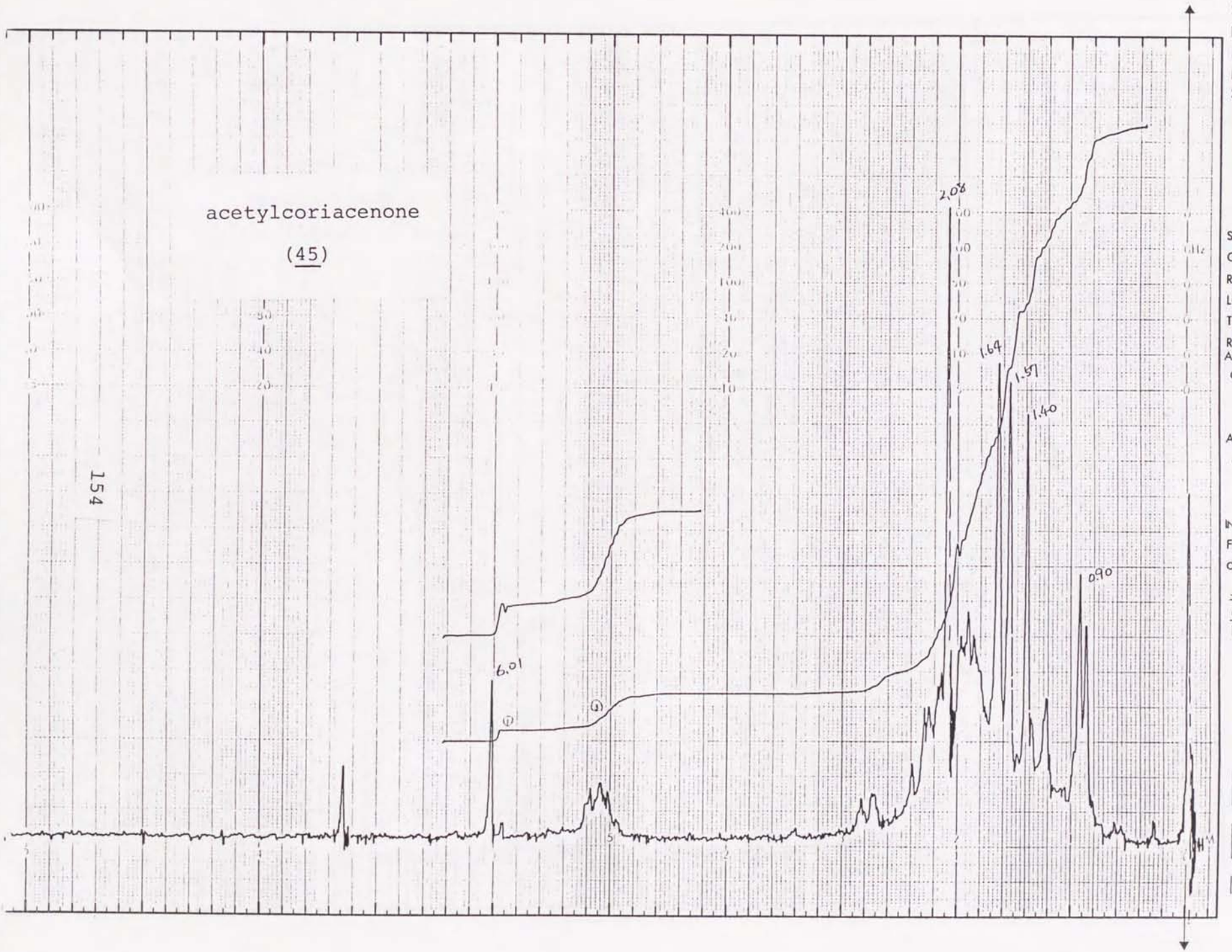
REMARKS

MHD No.4

153

acetylcoriacenone

(45)



154

SPECTRUM No. 188
DATE 820928
FREQ.
NUCLEUS
SAMPLE
H,°
1(40) + 1(43)

SOLVENT	CDCl3
CONC.	16 mg
REFERENCE	TMS
LOCK	
TEMP.	°C
R.F.LEVEL A.F.LEVEL	
OBSERVE	
LOCK	
SD	
AMPLITUDE	
OBSERVE R.F.	
A.F.	
LOCK	
INTEGRATOR	
FILTER	
OFFSET	Hz PPM

FREQ. FIELD/FREQ._ FIELD.

OPERATOR JT
REMARKS;

SWEEP TIME (SEC.)

25	50	100	250	500
1000	2500	5000	10000	

SWEEP WIDTH (Hz)(X 0.01PPM)

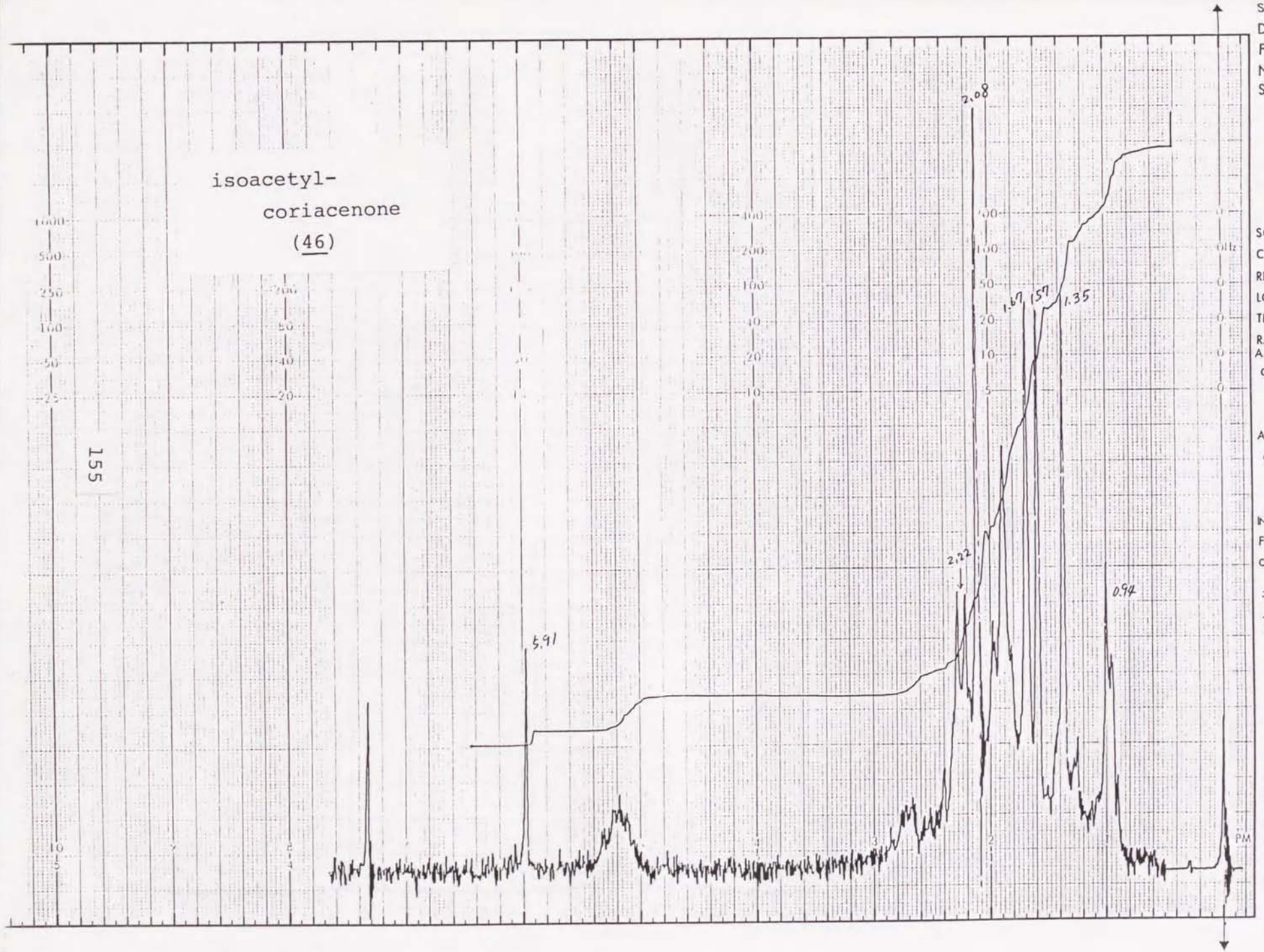
27	54	108	270	540
1080	2700	5400	10800	

WIDE SWEEP (GAUSS)

10.8	27	54	108	540

4265

isoacetyl-
coriacenone
(46)



155

SPECTRUM No. 119
DATE 821028
FREQ.
NUCLEUS
SAMPLE
H_2O

SOLVENT	$CDCl_3$
CONC.	9.5 mg
REFERENCE	TMS
LOCK	
TEMP.	C
R.F.LEVEL / A.F.LEVEL	
OBSERVE	
LOCK	
SD	
AMPLITUDE	
OBSERVE R.F.	
OBSERVE A.F.	
LOCK	
INTEGRATOR	
FILTER	
OFFSET	

_FREQ, _FIELD/FREQ, _FIELD.

OPERATOR
REMARKS;

δ値… FX-90Q on D_2O

SWEEP TIME (SEC.)
25	50	100	250	5
1000	2500	5000	10000	

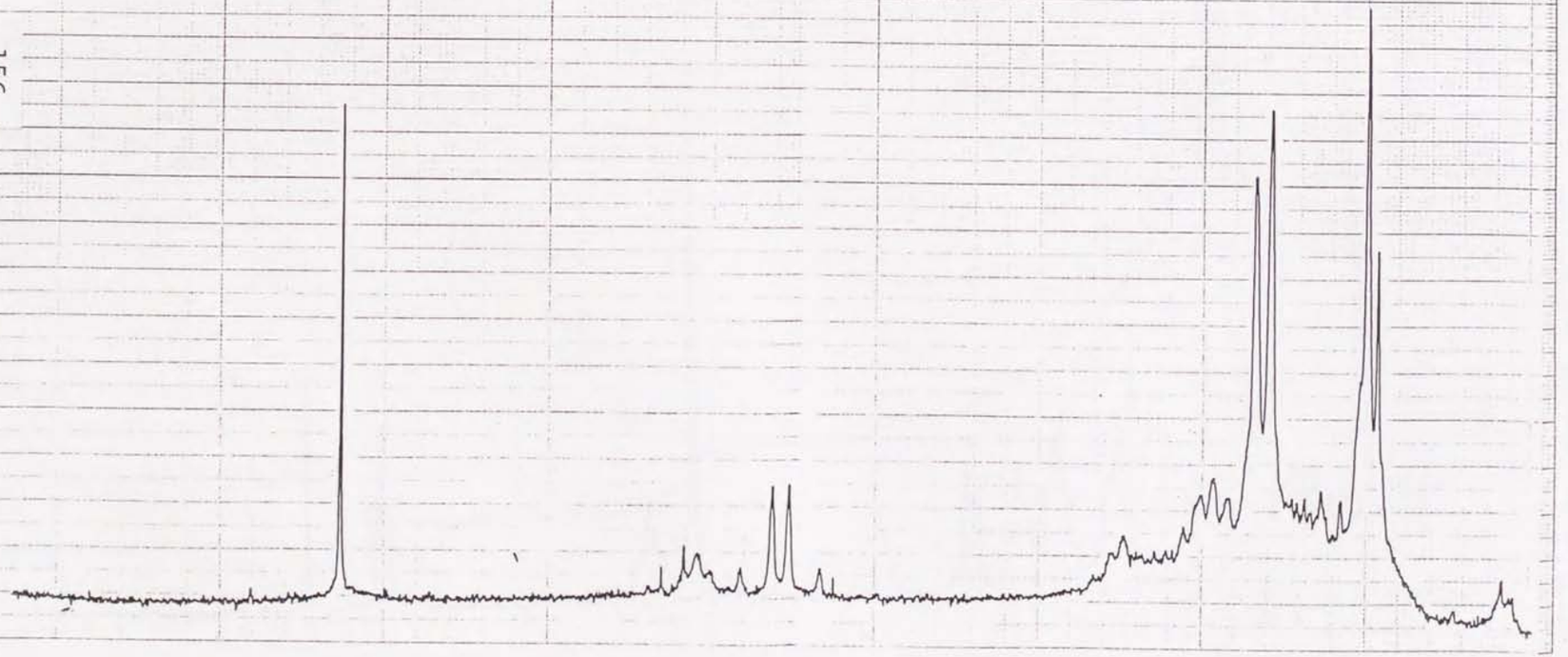
SWEEP WIDTH (Hz) (X 0.01PP
27	54	108	270	5
1080	2700	5400	10800	

WIDE SWEEP (GAUSS)
10.8	27	54	108	5

4299

pachylactone

(53)



156

FX

CHART NO. 264

SAMPLE

1t合物S

LC pure

SOLVENT CDCl3 TUBE

CONCENTRATION 2.6 mg

REFERENCE

TEMPERATURE

NUCLEUS

OBS

ICON

FRR

OFFSET

CHS

FRR

PULSE WIDTH INTERVAL REPETITION

DATA POINTS

WINDOW

NO. OF PULSES 20

SPECTRAL WIDTH

RF GAIN

AMPLITUDE

DECOUPLING

ICON

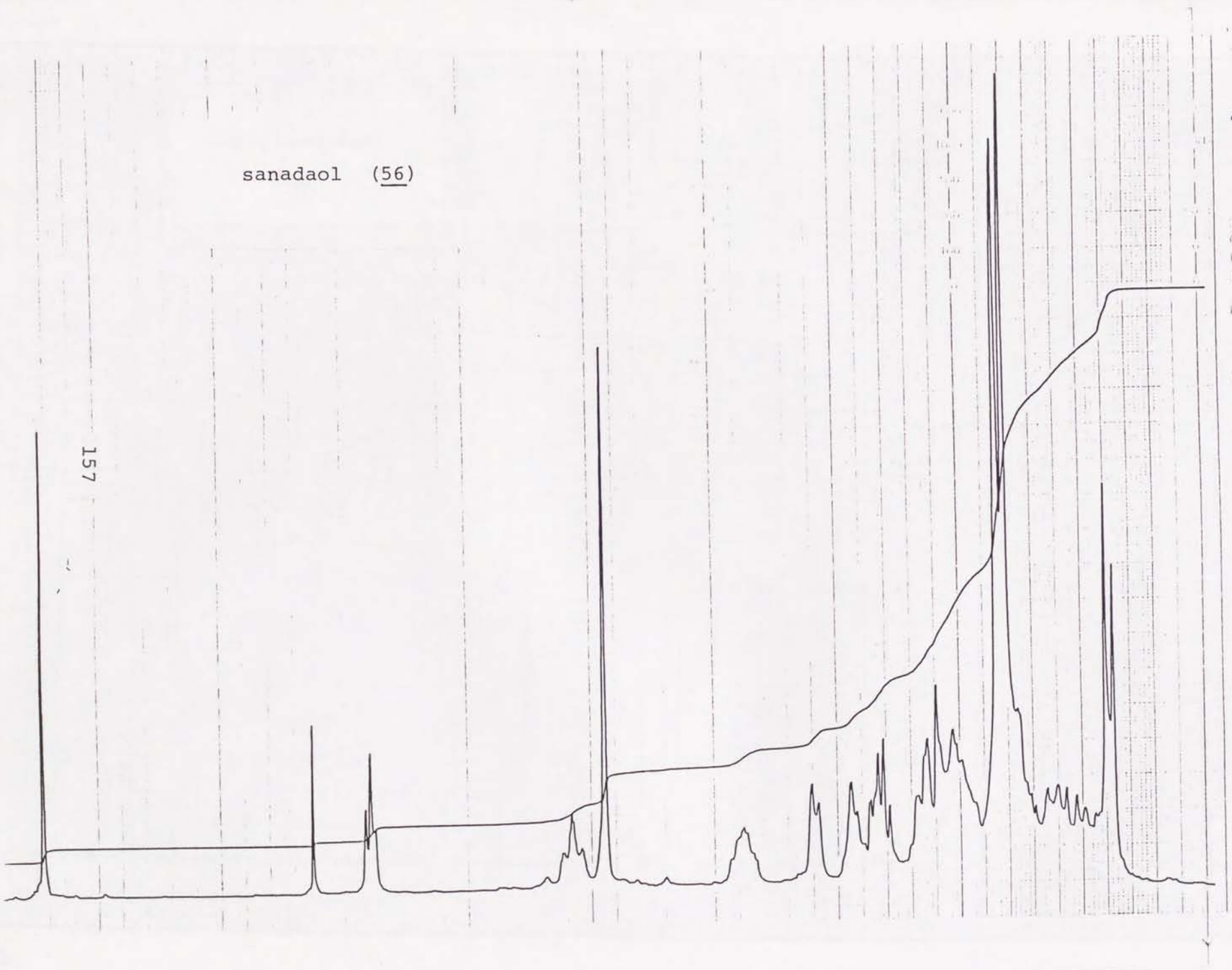
ICOFF

NOE

DATE 830627

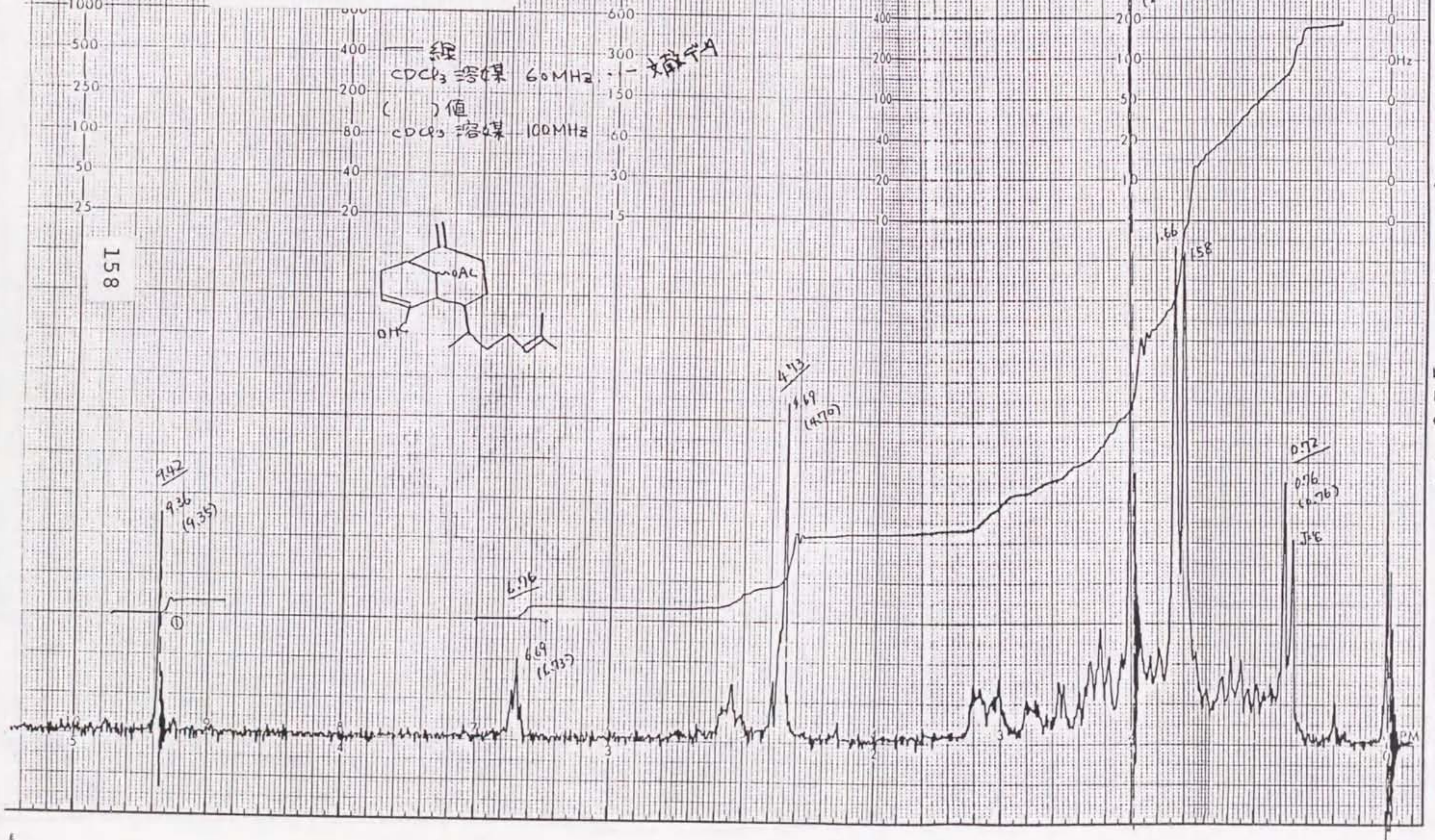
CHECKED 27

REMARKS


sanadaol (56)
157
CHART NO. 138
SOLVENT CDCl3
DATE 870112
OPERATOR A
REMARKS
JEOL

acetylsanadaol

(58)



SPECTRUM No. 45
DATE 81.10.14
FREQ.
NUCLEUS
SAMPLE

TLC分取(7) ②

comp. K

SOLVENT	CCl_4
CONC.	11 mg
REFERENCE	
LOCK	
TEMP.	C
R.F. LEVEL / A.F. LEVEL	
OBSERVE	
LOCK	
SD	
AMPLITUDE	
OBSERVE	R.F. / A.F.
LOCK	
INTEGRATOR	
FILTER	
OFFSET	H / PPM

FREQ., FIELD/FREQ., FIELD.

OPERATOR 河

REMARKS;

Dacetate と一致

SWEEP TIME (SEC.)

25	50	100	250	500
1000	2500	5000	10000	

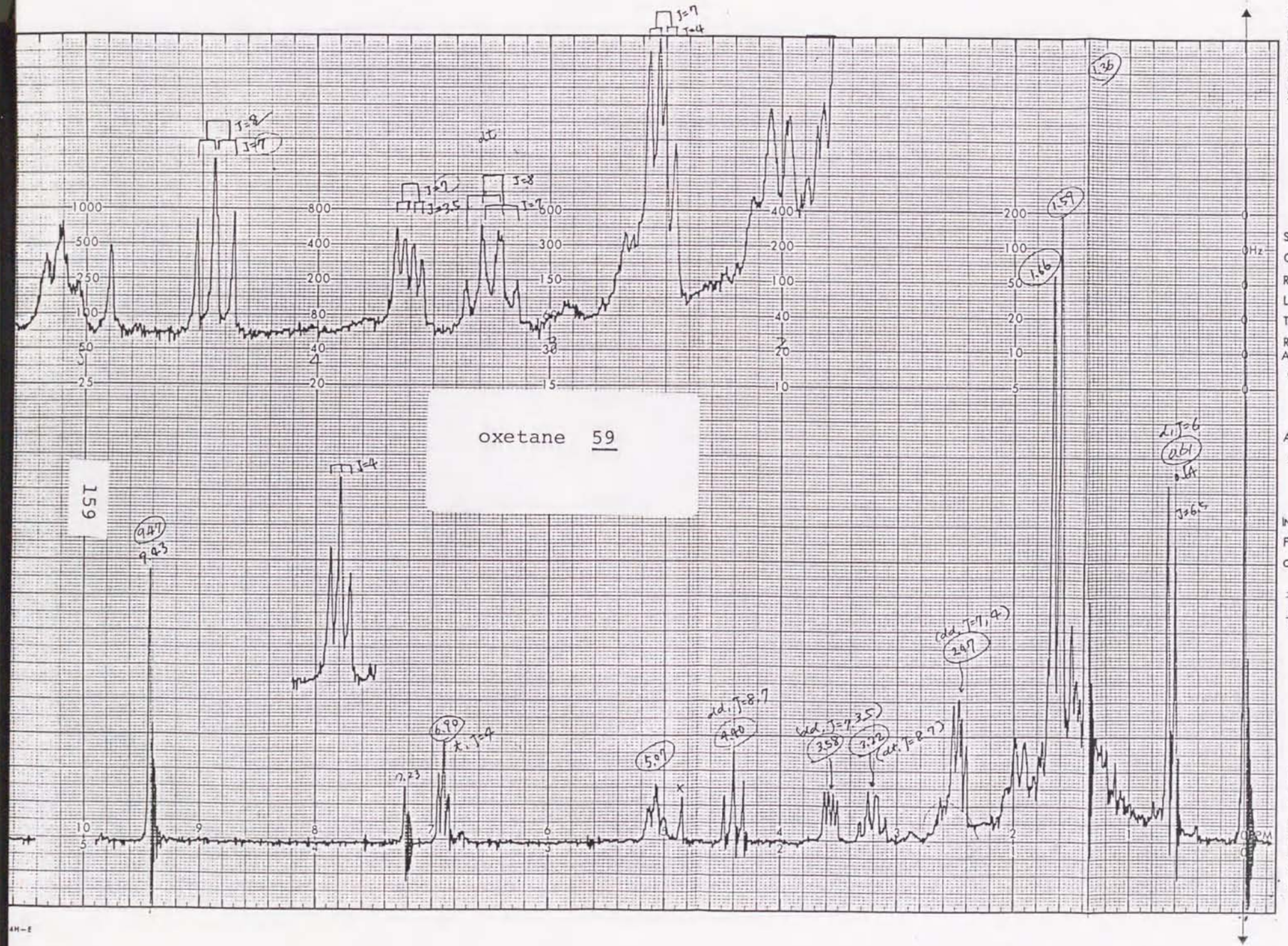
SWEEP WIDTH (Hz) (X 0.01 PPM)

27	54	108	270	540
1080	2700	5400	10800	

WIDE SWEEP (GAUSS)

10.8	27	54	108	540

3808



SPECTRUM No. 109
DATE 820302
FREQ.
NUCLEUS
SAMPLE
NZ-2

SOLVENT $CDCl_3$
CONC.
REFERENCE TMS
LOCK
TEMP. °C
R.F.LEVEL
A.F.LEVEL
OBSERVE
LOCK
SD
AMPLITUDE
OBSERVE R.F.
A.F.
LOCK
INTEGRATOR
FILTER
OFFSET Hz PPM
FREQ. FIELD/FREQ. FIELD.

OPERATOR 井
REMARKS;

文献データ

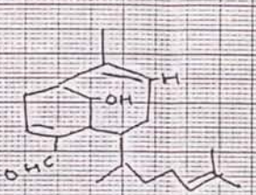
SWEEP TIME (SEC.)				
25	50	100	250	500
1000	2500	5000	10000	

SWEEP WIDTH (Hz)(X0.01PPM)				
27	54	108	270	540
1080	2700	5400	10800	

WIDE SWEEP (GAUSS)				
10.8	27	54	108	540

4103

isosanadaol (60)



160

SPECTRUM No. 110
DATE 820226
FREQ.
NUCLEUS
SAMPLE
N'3

SOLVENT	CDCl3
CONC.	27mg
REFERENCE	TMS
LOCK	
TEMP.	°C
R.F.LEVEL / A.F.LEVEL	
OBSERVE	
LOCK	
SD	
AMPLITUDE	
OBSERVE	R.F.
	A.F.
LOCK	
INTEGRATOR	
FILTER	
OFFSET	Hz / PPM

_ FREQ, _ FIELD/FREQ, _ FIELD,

OPERATOR
REMARKS;

SWEEP TIME (SEC.)				
·25	50	100	250	500
1000	2500	5000	10000	
SWEEP WIDTH (Hz) (X 0.01PPM)				
27	54	108	270	540
1080	2700	5400	10800	
WIDE SWEEP (GAUSS)				
10.8	27	54	108	540

4101

4H-E

ACKNOWLEDGMENT

The author wishes to express her deepest appreciation to Professor Hiroshi Kakisawa for his continuing interest, valuable suggestions, and encouragement throughout this study.

The author is much indebted to Associate Professor Yoshinobu Inouye and Dr. Takenori Kusumi for their helpful discussions and suggestions.

The author wishes to express her sincere gratitude to Dr. Toshinori Konno, Tokyo University of Fisheries, for collection of the Sargaceae algae, and Professor Mitsuo Chihara, Institute of Biological Sciences, University of Tsukuba, for identification of the Dictyotaceae algae.

The author is sincerely grateful to Dr. Takashi Iwashita, Suntory Institute for Bioorganic Research, for measurements of NMR spectra.

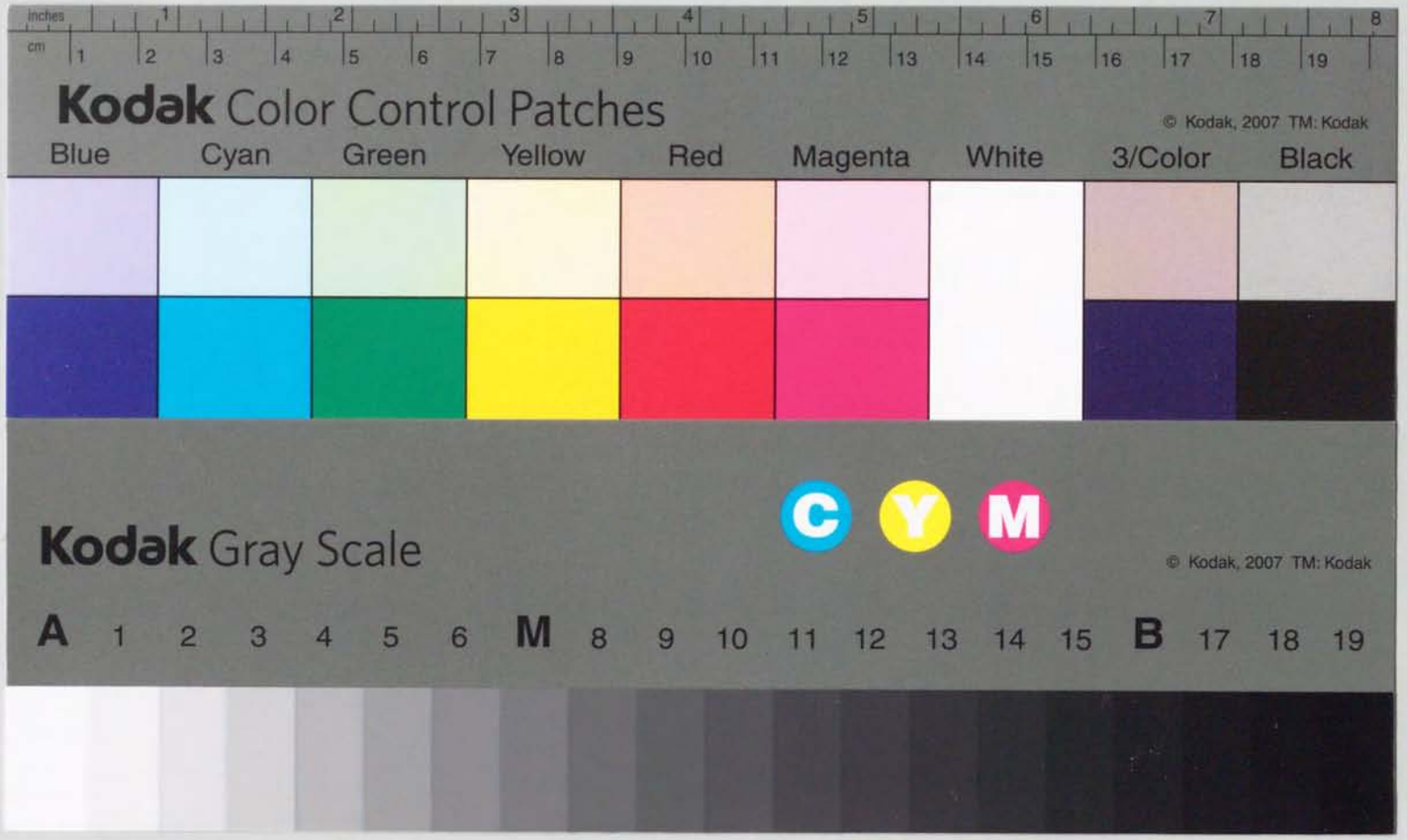
Thanks are also made to Dr. Yoshiyuki Kawakami, Mr. Yasushi Nagai, and Dr. Tadashi Sato, Tsukuba Research Laboratory, Eisai Company Co. Ltd., for measurements of NMR spectra and their helpful discussions.

The author is sincerely grateful to my parents for their continuing support.

Finally, the author would like to thank her husband, Hitoshi Oinuma, for his constant support and hearty encouragement during this work.

February, 1988

Midori Oinuma


inches
cm
Kodak Color Control Patches
© Kodak, 2007 TM: Kodak
Blue
Cyan
Green
Yellow
Red
Magenta
White
3/Color
Black
Kodak Gray Scale
C
Y
M
© Kodak, 2007 TM: Kodak
A 1 2 3 4 5 6 M 8 9 10 11 12 13 14 15 B 17 18 19