Photoisomerization of 9-Substituted Verbenones

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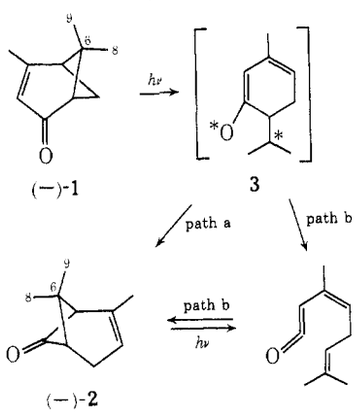
Irradiation of 9-trideuterioverbenone (**4**) in cyclohexane or acetic acid gave a 1:1 mixture of 8- and 9-trideuteriochrysanthenon e (**6** and **7**). Irradiation of 9-acetoxyverbenone (**5**) gave 9- and 8-acetoxychrysanthenone (**9** and **10**). The ratio **9**:**10** was solvent dependent. The results are best explained by a nonconcerted diradical or dipolar mechanism.

The photoisomerization of verbenone (**1**) to chrysanthenone (**2**)[1] was shown by Erman[2] to proceed by two pathways, one (path a) with optical retention and the other (path b) with racemization (Chart I).

Chart I

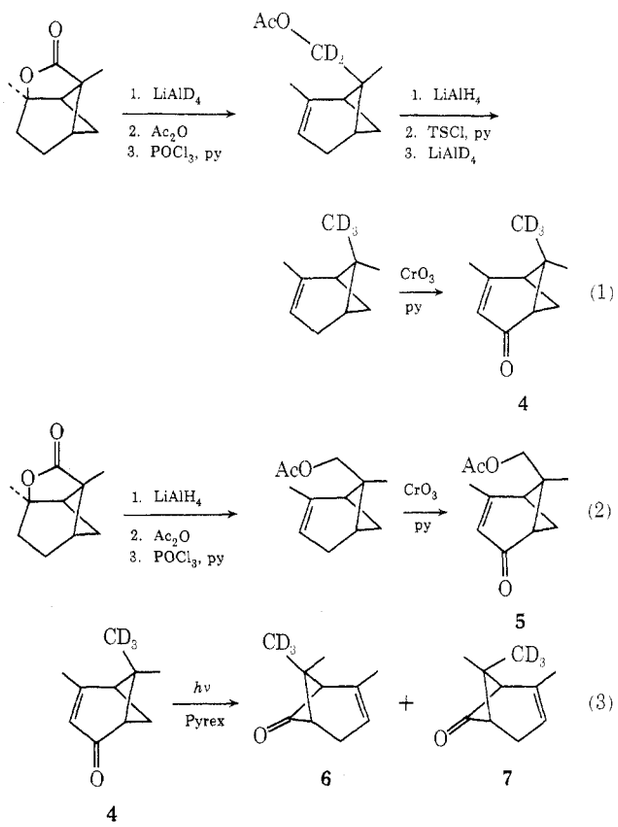


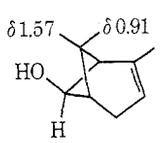
Until now, the nature of species **3** and the stereochemical fate of the migrating carbon atom (C-6) have not been determined. The present research has been directed toward elucidation of these mechanistic aspects of the rearrangement.

The irradiation of two 9-substituted verbenones, 9-trideuterioverbenone (**4**) and 9-acetoxyverbenone (**5**), has been studied. These substituted verbenones were prepared by allylic oxidation with chromium trioxide–pyridine[3] of the corresponding α-pinene derivatives, which in turn were prepared according to the procedures of Gibson and Erman[4] (eq 1 and 2). Phosphorus oxychloride dehydration of the tertiary alcohols to the α-pinenes occurred with formation of minor amounts of the β-pinene derivatives.[4] In both cases, the pinene mixture was oxidized and purification of the substituted verbenones was accomplished by silica gel chromatography. The nmr spectrum of **4** was identical with that of verbenone[2] except for the absence of the C-9 methyl singlet at δ 1.01.

Irradiation of **4** in either cyclohexane or acetic acid gave 8- and 9-trideuteriochrysanthenone (**6** and **7**) in a ratio of approximately 1:1 (eq 3). The nmr spectrum of chrysanthenone has absorption for the *gem*-dimethyl group as two singlets (6 hydrogens) at δ 1.19 and 1.22. The nmr spectrum of the trideuteriochrysanthenone mixture obtained from irradiation of **4** has these same two singlets (3 hydrogens) in equal intensity, thus showing the presence of both C-8 and C-9 methyl groups.

Further evidence of a 1:1 mixture was obtained by reduction of the photoproduct to trideuteriochrysanthenol, whose nmr spectrum has two methyl singlets of nearly equal intensity at δ 0.91 and 1.57 coincident with the methyl absorptions of chrysanthenol (**8**).[1] The chrysanthenol nmr singlet at δ 1.57 was assigned to the methyl group in close proximity to the hydroxyl group.





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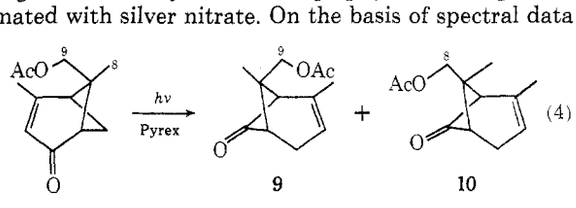
Trideuterioverbenone, recovered after irradiation, gave an nmr spectrum identical with that obtained before irradiation. Therefore, species **3** does not reclose to verbenone with scrambling of the methyl groups.

Irradiation of **5** gave two major photoproducts (eq 4) which were isolated in 50–60% yield by chromatography on silica gel followed by rechromatography on silica gel impregnated with silver nitrate. On the basis of spectral data



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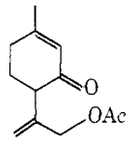
(see Experimental Section), the structures were assigned as 9- and 8-acetoxychrysanthenone (**9** and **10**). The stereochemistry at C-6 was established by reduction of **9** and **10** with lithium aluminum hydride. One of the diols obtained had an nmr methyl singlet at δ 0.95 and the other had a singlet at δ 1.64. The δ 0.95 methyl singlet can be assigned to the C-9 methyl group in analogy with α-pinene (δ 0.84), α-*trans*-bergamotene (δ 0.85),[5] and chrysanthenol (δ 0.91). Consequently, the chrysanthenone precursor of this diol was assigned structure **10.**

The ratio **9:10** was quite dependent on the solvent system and either isomer could be preferentially obtained with the proper choice of conditions (see Table I).

The acetoxychrysanthenones **9** and **10** did not photochemically interconvert under the conditions of irradiation and there was no evidence for the formation of 8-acetoxyverbenone during the irradiation of **5.** The major volatile by-product (7% yield) from irradiation of **5** in cyclohexane was identified on the basis of spectral data as 9-acetoxyisopiperitenone (**11**).



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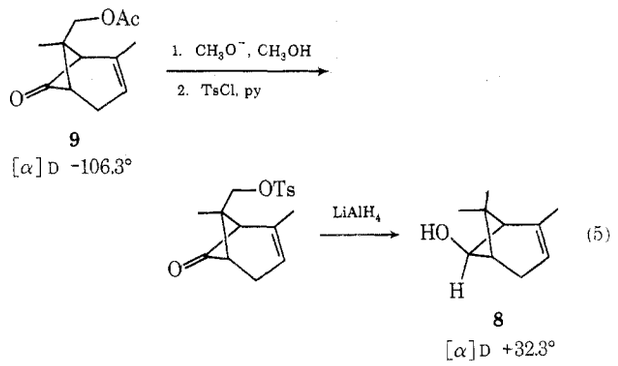
The optical activity of **9** and **10** was essentially independent of solvent (Table II). At first, this result appeared in conflict with that of chrysanthenone (**2**), where the optical purity was dramatically lowered when the irradiation solvent was changed from acetic acid to cyclohexane (−76 and −36°, respectively).[2] However, when the irradiation of verbenone (**1**) was repeated in both acetic acid and cyclohexane, **2** of comparable optical rotation could be isolated from either solvent (Table II) provided that irradiation was terminated prior to complete disappearance of **1.** The rearrangement of **1** to **2** is more rapid in cyclohexane than in acetic acid; so, if the irradiation time is extended in cyclohexane, **2** is readily racemized (Table II) through photoisomerization to the ketene followed by reclosure (Chart I).

Acetoxychrysanthenone **9** also rapidly racemizes under the conditions of irradiation. After 1 hr of irradiation in cyclohexane, a sample of **9** with a rotation of −107° was recovered with a rotation of −26.3°. The racemization of **10** was not tested.

An estimate of the amount of 9-acetoxyverbenone (**5**) that photoisomerizes *via* each pathway is possible if **9** and/or **10** of known rotation are correlated with **2,** since the absolute rotation of **2** is known[2] (−108°).

9-Acetoxychrysanthenone (**9**) was converted to chrysanthenol (**8**) (eq 5), which was identical with an authentic



9 $[\alpha]_D$ −106.3°

(5)

8 $[\alpha]_D$ +32.3°

sample. The nmr spectrum of **8** derived from **9** was devoid of any singlet at δ 1.19 corresponding to 7-epichrysanthenol.[6] A corresponding conversion of **10** to **8** was unsuccessful.[7]

Table I
Ratio of 9:10 Obtained from Irradiation of 5

Solvent	Ratio 9:10	Solvent	Ratio 9:10
Cyclohexane	1.9	Cyclohexane–silica gel	0.9
Neat (30°)	1.2	Methanol	0.9
Acetic acid	1.0	Neat (−65°)	0.3

Table II
Optical Rotations of Chrysanthenones Obtained from Pyrex-Filtered Irradiation of Verbenones

Photoproduct	Irradiation solvent	$[\alpha]^{25}D$, deg
9	Acetic acid	−106.3
9	Methanol	−107.0
9	Cyclohexane	−102.8
10	Acetic acid	−82.8
10	Cyclohexane	−78.5
2	Acetic acid (0.11 *M*, 1.5 hr)	−91.5
2	Cyclohexane (0.11 *M*, 0.4 hr)	−81.2
2	Cyclohexane (0.11 *M*, 1.5 hr)	−62.2

Lithium aluminum hydride reduction of **2** with a rotation of −91.5° (85% optically pure) gave **8** with a rotation of +38.7°. Since this reduction of **2** is known[6] to give **8** stereospecifically, the absolute rotation of **8** can be estimated to be +45.5°. Therefore, the optical purity of **9** is approximately 71%.

The 9-acetoxypinene used for the synthesis of **5** was optically pure as determined by conversion[4] to optically pure α-pinene (−55.4°). Since allylic oxidation of 9-acetoxypinene should not affect the optical purity, the racemization of **9** must have occurred during the irradiation of **5.** Therefore, at least 71% of the **9** from **5** is formed *via* path a. However, since the chrysanthenones rapidly racemize under the conditions of irradiation, there is a possibility that verbenones photoisomerize >90% *via* path a. The highest amount of path a isomerization that we were able to demonstrate was 85% in the case of **2.**

Regarding the nature of species **3,** scrambling of the methyl groups during formation of trideuteriochrysanthenone (**6** and **7**) from irradiation of **4** indicates that **3** is best represented as a discrete intermediate of diradical or dipolar nature. A photochemical concerted 1,3-sigmatropic rearrangement, controlled by local symmetry, should have occurred with retention of stereochemistry at C-6, and 8-trideuteriochrysanthenon e (**6**) should have been the only product.

In polar solvents, near room temperature, rearrangement of **5** also occurs with nearly complete scrambling of the acetoxy group. In cyclohexane, the electronic repulsion of the acetoxy and keto groups in the absence of polar solvation probably disfavors the formation of **10.** The rearrangement of **5** to **10** involves the least movement of atoms and this could explain the preferential formation of **10** in the low-temperature rigid matrix.

Experimental Section

Preparative irradiations were carried out with a 450-W medium-pressure Hanovia mercury lamp in a quartz, water-cooled, immersion probe. The filter was a glass cylinder of Pyrex (>290 nm) insertable between the lamp and the probe. Solutions were outgassed with argon before and during the irradiations.

Infrared spectra were taken as neat samples and absorptions are reported as inverse centimeters, nmr spectra were taken on a Varian A-60A as chloroform-d_1 solutions and are reported as δ units relative to TMS, and optical rotations were taken as chloroform solutions. Gas–liquid chromatography (glc) was done on a 3% OV-1 column (8 ft × 0.125 in.).

9-Acetoxyverbenone (5). To a slightly cooled solution of 143 g (1.81 mol) of anhydrous pyridine in 2400 ml of methylene chloride was added 90.0 g (0.90 mol) of chromium trioxide, and the mixture was allowed to stir at room temperature for 45 min. A solution of 13.9 g (0.072 mol) of 9-acetoxy-α-pinene[4] (90% pure, major impurity 9-acetoxy-β-pinene) in a small amount of methylene chloride was added and the mixture was allowed to stir for 24 hr at room temperature. The solution was decanted, the residue was rinsed with ether, and the combined organic phase was washed in succession with saturated sodium bicarbonate solution, 2 *N* hydrochloric acid, saturated sodium bicarbonate solution, and saturated salt solution. The organic phase was dried, filtered, and concentrated under reduced pressure, and the residual oil (16.9 g) was chromatographed on 500 g of silica gel (6 cm i.d.). Hexane–ether (3:1) eluted 1.72 g of recovered starting material. Hexane–ether (1:1) first eluted 1.94 g of several minor by-products and then 98% pure **5**: 7.86 g (59% yield); ir 1740 (s), 1680 (s), 1620 (w), 1240 (s), 1035 cm^{-1} (s); λ_{max} (EtOH) 251 nm (ϵ 5800), 315 (67); nmr δ 5.75 (1 H, q, J = 1.5 Hz, vinylic H), 3.87 and 4.16 (2 H, AB q, J = 11 Hz, H α to acetoxy), 2.39–3.12 (4 H, m, cyclobutyl H), 2.05 (3 H, d, J = 1.5 Hz, vinylic methyl H), 2.03 (3 H, s, acetoxy methyl H), 1.55 (3 H, s, methyl H); $[\alpha]^{25}D$ −119.3° (*c* 19.9).

Anal. Calcd for $C_{12}H_{16}O_3$: C, 69.21; H, 7.74. Found: C, 69.36; H, 7.96.

The 9-acetoxy-α-pinene that was oxidized to **5** was converted[4] to optically pure α-pinene, $[\alpha]^{25}D$ −55.4° (*c* 4.05) (reported rotation[8] of optically pure α-pinene in solution 54°).

9-Trideuterioverbenone (4). A mixture of 9-trideuterio-α- and -β-pinene was prepared, following the procedure of Gibson and Erman,[4] from 6,9-dimethyl-8-oxo-7-oxatricyclo[4.3.0.0^{3,9}]nonane using lithium aluminum deuteride for the appropriate reduction steps. The nmr spectrum was identical with that of a mixture of α- and β-pinene except for the absence of methyl singlets at δ 0.84 (α) and 0.72 (β). The molecular weight of each isomer was 139 (mass spectrum).

The trideuteriopinenes (1.46 g, 0.01 mol, 75% α, 25% β) were oxidized as described above with chromium trioxide–pyridine. The reaction product (1.04 g) was chromatographed on 150 g of silica gel (2.5 cm i.d., 3:1 hexane–ether) to give 9-trideuterioverbenone (**4**): 0.328 g (27% yield); ir 2100–2300 (w), 1680 (s), 1620 cm^{-1} (m); nmr identical with that of verbenone[2] except for the absence of the C-9 methyl singlet at δ 1.01; mol wt 153 (mass spectrum); identical with verbenone on glc.

Irradiation of 9-Trideuterioverbenone (4). Dilute solutions (0.03–0.06 *M*) of 9-trideuterioverbenone (**4**) in either cyclohexane or glacial acetic acid were irradiated (0.5–1.0 hr) as described above. After irradiation, when the solvent was acetic acid, the solution was partitioned between ether and water, and the ethereal solution was neutralized with sodium carbonate, dried, filtered, and concentrated. When the solvent was cyclohexane, the solution was concentrated under reduced pressure without any prior work-up. The crude reaction mixtures were chromatographed on silica gel (9:1 hexane–ether) to give trideuteriochrysanthenone (**6** and **7**): 20–25% yield; ir 2100–2300 (w), 1785 cm^{-1} (s); nmr identical with that of chrysanthenone[2] except that the *gem*-dimethyl singlets at δ 1.19 and 1.22 integrated for three rather than six hydrogens; mol wt 153 (mass spectrum); identical with chrysanthenone on glc. The nmr *gem*-dimethyl singlets at δ 1.22 and 1.19 for trideuteriochrysanthenone (**6** and **7**) from irradiation in cyclohexane were in the ratio of 54:46, respectively. For trideuteriochrysanthenone (**6** and **7**) from irradiation in acetic acid, these methyl singlets were in the ratio of 50:50.

Lithium aluminum hydride reduction of trideuteriochrysanthenone from irradiation in cyclohexane gave trideuteriochrysanthenol with *gem*-dimethyl nmr singlets at δ 0.91 (56%) and 1.57 (44%). Chrysanthenol has equal intensity nmr singlets at δ 0.91 (C-9 methyl) and 1.57 (C-8 methyl).

9-Trideuterioverbenone (**4**) recovered after irradiation in acetic acid gave an nmr spectrum identical with that obtained before irradiation.

Irradiation of 9-Acetoxyverbenone (5). Dilute solutions (0.03–0.06 *M*) of 9-acetoxyverbenone (**5**) in cyclohexane, methanol, or glacial acetic acid were irradiated (0.5–1.0 hr) as described above. Glc showed two major photoproducts, 9-acetoxychrysanthenone (**9**, 0.7 retention time relative to **5**) and 8-acetoxychrysanthenone (**10**, 0.8 retention time relative to **5**). The chrysanthenones were isolated from the irradiation mixture (58% yield in cyclohexane, 46% yield in acetic acid) by chromatography on silica gel (3:1 hexane–ether) and separated by rechromatography on silica gel impregnated with silver nitrate (20% silver nitrate, 4:1 hexane–ether). 9-Acetoxychrysanthenone (**9**) had ir 1780 (s), 1740 cm^{-1} (s); nmr δ 5.42 (1 H, m, vinylic H), 4.47 and 4.25 (2 H, AB q, J = 11 Hz, H α to acetoxy), 2.58–2.87 (4 H, m, allylic and cyclobutyl H), 2.08 (3 H, s, acetoxy methyl H), 1.75 (3 H, q, J = 1.5 Hz, vinylic methyl H), 1.27 (3 H, s, methyl H); $[\alpha]^{25}D$ −102.8° (*c* 1.25) (from irradiation in cyclohexane), −106.3° (*c* 1.20) (from irradiation in acetic acid), −107.0° (*c* 0.71) (from irradiation in methanol). 8-Acetoxychrysanthenone (**10**) had ir 1780 (s), 1740 cm^{-1} (s); nmr δ 5.42 (1 H, vinylic H), 4.10 (2 H, s, H α to acetoxy), 2.60–2.89 (4 H, m, allylic and cyclobutyl H), 2.07 (3 H, s, acetoxy methyl H), 1.75 (3 H, q, J = 1.5 Hz, vinylic methyl H), 1.22 (3 H, s, methyl H); $[\alpha]^{25}D$ −78.5° (*c* 1.30) (from irradiation in cyclohexane), −82.8° (*c* 1.16) (from irradiation in acetic acid). The high-resolution mass spectrum showed *m/e* 208.1087; the elemental composition was $C_{12}H_{16}O_3$.

The ratio of **9**:**10** changed with solvent: cyclohexane, 1.9; neat (30°), 1.2; acetic acid, 1.0; cyclohexane–silica gel, 0.9; methanol, 0.9; neat (−65°), 0.3.

A mixture of the two acetoxychrysanthenones (62% of the isomer first eluted from glc) was reduced in the normal manner with lithium aluminum hydride to a mixture of diols. The nmr spectrum of the diols had two methyl singlets at δ 0.95 (35%) and 1.64 (65%). 9-Acetoxychrysanthenone (**9**) was assigned as the isomer whose corresponding diol gave a methyl group nmr signal at δ 1.64. The nmr spectrum of the diol obtained by lithium aluminum hydride reduction of pure **9** (first eluted isomer on glc) had a methyl singlet at δ 1.64 and no absorption at δ 0.95.

Irradiation (cyclohexane, 0.06 *M*, Pyrex filter, 1 hr) of either **9** or **10** (each >90% pure) did not interconvert the isomers.

9-Acetoxychrysanthenone (**9**) rapidly racemized when irradiated. The optical rotation of **9** decreased from −107 to −26.3° (*c* 0.17) after 1 hr of irradiation as a very dilute solution (0.001 *M*) in cyclohexane.

The major volatile by-product from irradiation of **5** in cyclohexane was isolated in 7% yield by chromatography on silica gel (1:1 hexane–ether) and identified by spectral data as 9-acetoxyisopiperitenone (**11**): ir 1740 (s), 1670 (s), 1230 cm^{-1} (s); nmr δ 5.91 (1 H, q, J = 1.5 Hz, vinylic H), 5.29 and 5.02 (2 H, 2 broad s, terminal vinylic H), 4.67 (2 H, s, H α to acetoxy), 3.08 (1 H, t, J = 8 Hz, H α to ketone), 2.07 (3 H, s, acetoxy methyl H), 1.98 (3 H, broad s, vinylic methyl H).

9-Acetoxyverbenone (**5**), recovered after irradiation in acetic acid, gave an nmr spectrum identical with that obtained before irradiation.

Conversion of 9-Acetoxychrysanthenone (9) to Chrysanthenol (8). A solution of 0.102 g of **9** ($[\alpha]^{25}D$ −106.3°), 0.02 g of sodium methoxide, and 20 ml of methanol was heated under reflux in a nitrogen atmosphere for 1.5 hr. After work-up, an ir spectrum of the crude oil (0.072 g) showed OH absorption (3480 cm^{-1}), cyclobutyl carbonyl absorption (1775 cm^{-1}), and no acetate absorption (1740 cm^{-1}).

The crude hydroxy ketone was dissolved in 3 ml of anhydrous pyridine, the solution was cooled in an ice bath, and 0.3 g of recrystallized tosyl chloride was added. After stirring in the ice bath for 1 hr, the mixture was placed in a refrigerator (6°) for 2 days. The mixture was poured into cold water and extracted with ether, and the ethereal extract was washed successively with 2 *N* hydrochloric acid, half-saturated sodium bicarbonate solution, and saturated sodium chloride solution, dried, filtered, and concentrated under reduced pressure. The crude tosylate (0.115 g) was chromatographed on silica gel (1:1 hexane–ether) to give crystalline 9-tosyloxychrysanthenone: 0.080 g, 80–90% pure; ir 1777 cm^{-1} (s), no OH absorption; nmr δ 7.40 and 7.84 (4 H, AB q, J = 8.5 Hz, aromatic H), 5.36 (1 H, broad, vinylic H), 4.21 and 4.41 (2 H, AB q, J = 10 Hz, H α to tosyloxy), 2.2–2.8 (7 H, m, tosylate methyl s at 2.45), 1.66 (3 H, d, J = 1.5 Hz, vinylic methyl), 1.19 (3 H, s, methyl).

A solution of the tosylate in ether was added dropwise to a mixture of 0.3 g of lithium aluminum hydride in ether. After addition, the mixture was heated under reflux for 3 hr and cooled, and saturated ammonium chloride solution was added dropwise until a clear ether layer was obtained. The ethereal solution was decanted and the precipitate was rinsed several times with ether. The combined etherial solution was washed with water, dried, filtered, concentrated under reduced pressure, and vacuum distilled on a Kugelrohr apparatus to give chrysanthenol (**8**): 0.032 g, 90–95% pure; $[\alpha]^{25}D$ +32.3° (*c* 0.5); nmr spectrum was identical with that of **8** derived from lithium aluminum hydride reduction of **2**, and there was no detectable singlet at δ 1.19 corresponding to 7-epichrysanthenol.[5]

Attempted conversion of 8-acetoxychrysanthenone (**10**) to **8** was

unsuccessful. During reaction with sodium methoxide in methanol, rearrangement occurred to a compound tentatively identified as 2,4-dimethyl-2-hydroxymethylcyclohex-3- and -4-enecarboxylic acid lactone: ir 1775 (s), 1136 (s), 1018 cm^{-1} (s); nmr δ 5.43 (broad) and 5.20 (broad s, 1 H, vinylic H), 3.95 and 3.98 (2 H, two absorptions of AB q, H α to oxygen), 1.66 (3 H, broad s, vinylic methyl), 1.15 and 1.17 (3 H, two s, methyl); mol wt 166 (mass spectrum).

Chrysanthenone (2) from Irradiation of Verbenone (1) and Reduction to Chrysanthenol (8). Dilute solutions of 1 (2.5 g of 1 in 150 ml of solvent, 0.11 *M*) in either cyclohexane or glacial acetic acid were irradiated as described above. Chrysanthenone (2) was isolated from the irradiation mixture by chromatography on silica gel (2 was eluted with 3:1 hexane–ether and then the purest fractions of 2 were rechromatographed with 9:1 hexane–ether) and distilled under vacuum on a Kugelrohr apparatus.

After 1.5 hr of irradiation in acetic acid, glc showed 26% remaining 1; 2 isolated from this irradiation had optical rotation $[\alpha]^{25}D$ −91.5° (*c* 1.0). After 25 min of irradiation in cyclohexane, glc showed 26% remaining 1; 2 isolated from this irradiation had optical rotation $[\alpha]^{25}D$ −81.2° (*c* 0.42). After 1.5 hr of irradiation in cyclohexane, glc showed essentially no remaining 1; 2 isolated from this irradiation had optical rotation $[\alpha]^{25}D$ −62.2° (*c* 0.43).

Chrysanthenone (2) with rotation −91.5° was reduced with lithium aluminum hydride to chrysanthenol (8) with $[\alpha]^{25}D$ +38.7° (*c* 0.91).

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Registry No.—**4,** 51897-93-9; **5,** 51849-16-2; **6,** 51897-95-1; **7,** 51897-96-2; **9,** 51849-17-3; **10,** 51897-97-3; **11,** 51849-18-4; 9-trideuterio-α-pinene, 51897-94-0; 9-acetoxy-α-pinene, 23971-93-9; 9-trideuterio-β-pinene, 51849-19-5.

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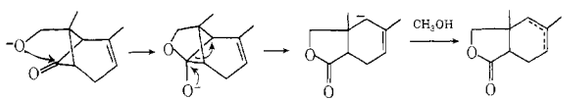

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Configuration of 9-Imino Derivatives of Erythromycin

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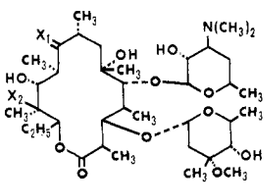
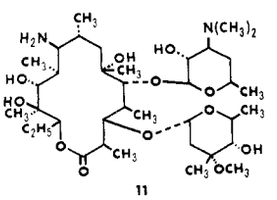
Both isomers of erythromycin B oxime have been isolated and configurationally identified. The major stable isomer has been shown to be (*E*)-erythromycin B oxime by ^1H nmr and ir. The *E* isomer has been suggested to predominate in the oxime, hydrazone, and isopropylidene hydrazone of both erythromycin A and B.

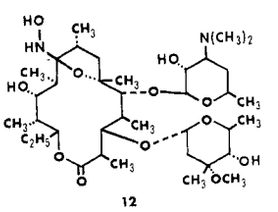
Several imino derivatives of the ketone of erythromycin A (1) have been prepared, including the oxime (**2**),[1,2] hydrazone (**3**),[1,3] isopropylidene hydrazone (**4**),[1] and the imine (**5**).[4,5] Interest in these derivatives centers on their utility as antibiotics and as substrates for further modification such as reduction to erythromycyclamine.[1,2,4,5]We wish now to report our results in this area which concerns the preparation, isolation, and configurational assignments of the two erythromycin B oxime isomers (**7a** and **7b**) and the configurational analysis of **2, 3, 4, 8,** and **9.**



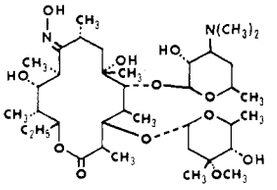
X_1	X_2 = OH	X_2 = H
O	1	6
N–OH	2	7
$N–NH_2$	3	8
$N–N=C(CH_3)_2$	4	9
NH	5	10



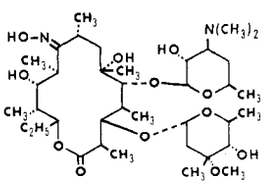
11



12



7a (E) - oxime



7b (Z) - oxime

Discussion

Preparation, Isolation, and Characterization of Oxime Isomers. Two new compounds analyzing for the oxime structure were obtained on reaction of erythromycin B with hydroxylamine. The major product was readily identified as an oxime in the infrared.[6] However, the minor product, which could be obtained only 80% pure, failed to show a significant band in the 1600-cm^{-1} region in both the infrared and the Raman.[7]

Positive evidence for an oxime was considered necessary, as an alternate hemiacetal type structure **12** was possible for the minor isomer. The latter structure was suggested by a band in the hydroxyl region at 3240 cm^{-1} ($\Delta\nu_{1/2}$ 100 cm^{-1}) in CCl_4 which could be interpreted as a hydrogen-bonded NH absorption of a hydroxylamine.[8] Such a structure is also consistent with the known chemistry of the erythromycins.[9]

Conclusive evidence for the oxime structure of the minor product was derived from both ^1H nmr spectra in dimethyl sulfoxide-d_6 solution and ^{13}C nmr spectra. In DMSO-d_6,