Extractives of *Angelica genuflexa* Nutt.

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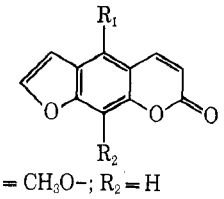
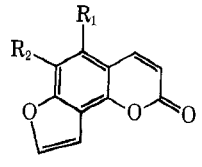
Imperatorin, bergapten, isobergapten, pimpinellin, and 6-isopentenyloxyisobergapten have been isolated from the extracts of *Angelica genuflexa* Nutt. (Umbelliferae). Mild acid hydrolysis of 6-isopentenyloxyisobergapten gave 6-hydroxyisobergapten, which was in turn converted by methylation into pimpinellin. 6-Hydroxyisobergapten was correlated with isopimpinellin through the quinone (**14**), hydroquinone (**15**), and 5,8-dibenzyloxypsoralen (**16**) followed by methylation and rearrangement. These correlations and spectroscopic considerations establish the structure as 6-isopentenyloxyisobergapten. Fruit of *A. genuflexa* collected the following season gave only (+)-oxypeucedanin. Oxypeucedanin (**17**) was converted into the episulfide (**20**) and trithiocarbonate (**21**). ORD and CD studies on **21** establish the absolute configuration of **17** as *R*.

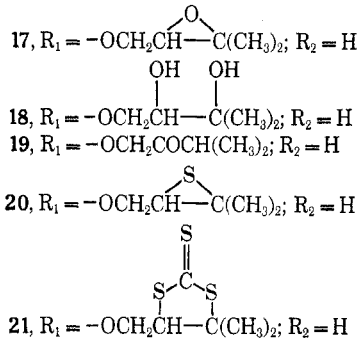
The extractives of *Angelica genuflexa* Nutt. (Umbelliferae) have been the subject of a previous study by Nikonov and coworkers.[1] They reported the isolation of imperatorin and two other new furocoumarins, genufline, $C_{16}H_{14}O_4$, mp 70–72°, and genuflinine, $C_{16}H_{16}O_6$, mp 132°. The present study has resulted in the isolation of a new angular furocoumarin, as well as imperatorin (**2**), bergapten (**1**), isobergapten (**3**), pimpinellin (**4**), and (+)-oxypeucedanin (**17**), from *A. genuflexa*.



1, $R_1 = CH_3O-$; $R_2 = H$
2, $R_1 = H$; $R_2 = -OCH_2CH{=}C(CH_3)_2$

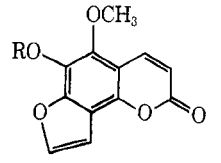


3, $R_1 = CH_3O-$; $R_2 = H$
4, $R_1 = R_2 = CH_3O-$
5, $R_1 = R_2 = H$
6, $R_1 = H$; $R_2 = CH_3O-$

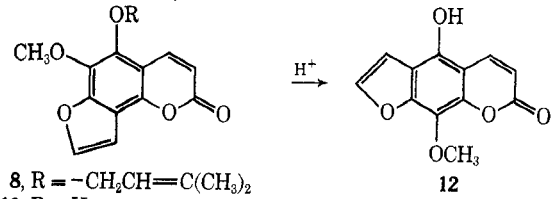


17, $R_1 = -OCH_2CH(O)C(CH_3)_2$; $R_2 = H$
18, $R_1 = -OCH_2CH(OH)C(CH_3)_2$; $R_2 = H$
19, $R_1 = -OCH_2COCH(CH_3)_2$; $R_2 = H$
20, $R_1 = -OCH_2CH(S)C(CH_3)_2$; $R_2 = H$
21, $R_1 = -OCH_2CH(SC(=S)S)C(CH_3)_2$; $R_2 = H$

The new coumarin, mp 95–96°, analyzed for $C_{17}H_{16}O_5$. Its uv spectrum was similar to that of isobergapten (**3**) and pimpinellin (**4**),[2] indicating that the compound was an isopsoralen (**5**) derivative. The nmr spectrum showed resonances for H-3 and H-4 of a coumarin lactone ring, one methoxy group, a fused furan ring, and an isopentenyl group. The chemical shift of the methylene doublet of the isopentenyl group indicated that it was attached to an ether oxygen atom rather than directly to a benzene ring.[3] The presence of an isopentenyl ether group was shown chemically by mild acid hydrolysis. A phenolic product was obtained, which corresponded to loss of the isopentenyl group. These results are consistent with two possible structures, **7** or **8**, for the natural coumarin and **9** or **10** for the dealkylated phenol respectively.



7, $R = -CH_2CH{=}C(CH_3)_2$
9, $R = H$
11, $R = Ac$



8, $R = -CH_2CH{=}C(CH_3)_2$
10, $R = H$
12

The presence of an isopsoralen system was shown chemically by methylation of the phenol to give pimpinellin (**4**). The phenol formed a monoacetate, whose uv spectrum was similar to that of isobergapten and unlike that of sphodin (**6**).[4] An acetoxy group is generally considered to cause the uv spectrum of the acetate derivative to be similar to that of the derived unsubstituted hydrocarbon.[5] This strongly supports structure **9** for the dealkylated phenol and thus **7** for the natural coumarin.

The dealkylated coumarin was recovered unchanged after treatment with base and acidification, indicating that a change from an angular furocoumarin to the linear analog, **12**, allowed by structure **10** had not taken place.[6] This provides further permissive evidence for structure **9**.

Distinction between structures **9** and **10** was finally shown chemically by correlation with isopimpinellin (**13**). Isopimpinellin (**13**) or imperatorin (**2**) was oxidized to the quinone (**14**) which was in turn reduced to the hydroquinone (**15**) by published procedures.[7] To block the free phenolic groups, the hydroquinone

(1) G. K. Nikonov, N. I. Rodian, and M. G. Pimenov, *Aptechn. Delo*, **13**, 23 (1965); *Chem. Abstr.*, **62**, 815 (1965).

(2) P. D. Desai, T. R. Govindachari, K. Nagarajan, and N. Viswanathan, *Ind. J. Chem.*, **5**, 41 (1967).

(3) Compare with nmr data on other isopentenyl substituted furocoumarin: D. L. Dreyer, *J. Org. Chem.*, **33**, 3574 (1968); *Tetrahedron*, **22**, 2923 (1966); *Phytochemistry*, **5**, 367 (1966).

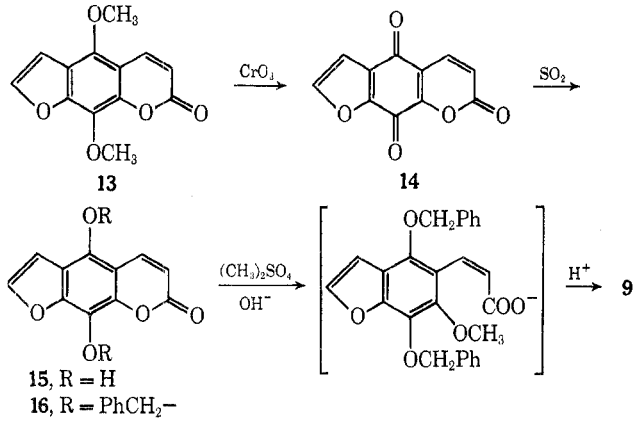
(4) T. R. Seshadri and M.S. Sood, *J. Ind. Chem. Soc.*, **39**, 539 (1962); A. Mustafa, "Furopyrans and Furopyrones," Interscience Publishers, Inc., New York, N. Y., 1967, p 24.

(5) H. Brockmann, E. H. F. Falkenhausen, R. Neeff, A. Dorlars, and G. Budde, *Chem. Ber.*, **84**, 865 (1951); H. Brockmann, *Fort. Chem. Org. Naturstoffe*, **14**, 141 (1957); A. I. Scott, "Interpretation of the Ultraviolet Spectra of Natural Products," The Macmillian Co., New York, N. Y., 1964, p 294.

(6) *Cf.* E. Spaeth and L. Socias, *Ber. Deut. Chem. Ges.*, **67**, 59 (1934).

(7) M. E. Brokke and B. E. Christensen, *J. Org. Chem.*, **24**, 523 (1959); see also E. A. Abu-Mustafa, B. A. H. El-Tawil, and M. B. E. Fayez, *Ind. J. Chem.*, **5**, 283 (1967).

(**15**) was converted into its dibenzyl ether (**16**). This allowed selective methylation of the lactone hydroxy group under basic conditions with dimethyl sulfate and aqueous base. Acid-catalyzed removal of the benzyl groups and concurrent lactonization gave the desired isobergapten derivative (**9**) in low yield, identical by spectroscopic criteria and tlc with that obtained from the natural material.



Extracts of fruit from the following season gave quite different results. The major product, mp 101–102°, $[\alpha]D$ +11.1° was obtained in good yield. Its uv spectrum was superimposable on that of bergapten. The nmr spectrum showed a one-proton aromatic singlet as well as two sets of AB doublets assignable to H-3 and H-4, and a fused furan ring in a psoralen system. The remaining resonances were consistent with a 2′, 3′-epoxyisopentyloxy system. These data are consistent with structure **17**, (+)-oxypeucedanin, for the coumarin.[8,9]

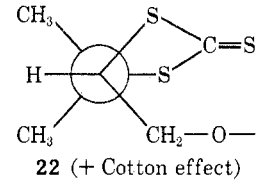
Chemical evidence for the presence of the epoxy group was obtained by acid catalyzed hydrolysis. Two products were obtained, after chromatography on alumina. One was the expected 1,2-diol (**18**), oxypeucedanin hydrate, and the other was the known 2′-oxo derivative (**19**), isooxypeucedanin.[8,9] The new coumarin found in this study differs both in analytical and physical properties from those reported for genufline and genuflinine. On the other hand, no evidence for the presence of genufline and genuflinine in *A. genuflexa* was found in this study.

Extractives with isopentenyl side chains are widely distributed in the Umbelliferae and Rutaceae. Many of these isopentenyl extractives occur epoxidized, as 1,2-diols or ring closed to isopropyldihydrobenzofurans. These extractives are, with a few exceptions, optically active. The absolute configuration of the isopentyl derivatives is known in only a few cases.[10] The stereochemical relationships between the different types of extractives in the plant are not known; *e.g.*, does oxide ring opening to the diol occur with retention or inversion of configuration in the plant? The absolute configuration of such extractives might also be of interest from a chemotaxonomic standpoint. Can the concept of absolute configuration in this class of extractives be used as a chemotaxonomic indicator?

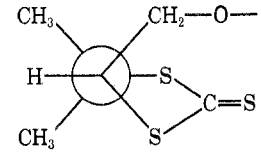
The availability of substantial amounts of **17** from this work permitted studies to be undertaken designed to determine its absolute configuration. Trithiocarbonates are optically active chromophores which have low intensity adsorptions near 430 mμ.[11] The preparation of trithiocarbonates from epoxides with potassium methyl xanthanate proceeds through the episulfide and involves two inversions so that the stereochemistry of the trithiocarbonate product is the same as the starting epoxide.[12]

It is generally accepted that the chirality, or sense of twist, of the heterocycle ring is the major factor in determining the sign of the Cotton effect in trithiocarbonates[13,14] and the magnitude of the Cotton effect depends on the amount of twist of the ring. The position of substitutents on the ring has relatively little effect on the sign of the Cotton effect. If the chirality is positive, a positive Cotton effect would be predicted and correspondingly a negative chirality leads to a negative Cotton effect. In bicyclic systems the chirality, or sense of twist of the trithiocarbonate ring, is determined by the stereochemistry of the ring juncture and preferred conformations of the system in those cases where flexibility exists.[14]

Trithiocarbonates of open-chain systems might be expected to be nearly planar. However, twisting of the heterocycle ring would result in relief of the eclipsing interactions of the groups on the ring. Relief of these eclipsed interactions by rotation about the C–C bond will cause twisting of the trithiocarbonate ring. The sense of twist will depend on the absolute stereochemistry of the starting system. Newman projections of the two possibilities are shown in **22** and **23**. For case **22** a positive Cotton effect would be predicted and a negative Cotton effect for **23**.



22 (+ Cotton effect)



23 (− Cotton effect)

After treatment of oxypeucedanin (**17**) with potassium methyl xanthanate it was possible to isolate, after chromatography, both the episulfide (**20**) and trithiocarbonate (**21**). The ORD and CD curves of the trithiocarbonate (**21**) showed the usual pattern for such compounds[11,13] with a positive Cotton effect at 443 mμ followed by a negative Cotton effect at 322 mμ. These data would indicate that (+)-oxypeucedanin has the *R* configuration. Chemical studies recently reported by Nielsen and Lemmich[15] on oxypeucedanin hydrate also lead to the *R* configuration.

(8) E. Spaeth and K. Klayer, *Ber. Deut. Chem. Ges.*, **66**, 914 (1933).

(9) A. Butenandt and A. Marten, *Ann.*, **495**, 187 (1932).

(10) B. Eichstedt, Nielsen and J. Lemmich, *Acta Chem. Scand.*, **18**, 2111 (1964); W. A. Bonner, N. I. Burk, W. E. Fleck, R. K. Hill, J. A. Joule, B. Sjoberg, and L. H. Zalkow, *Tetrahedron*, **20**, 1419 (1964); M. Nakazaki, Y. Hirose, and K. Ikematsu, *Tetrahedron Lett.*, 4735 (1966); I. Harada, Y. Hirose, and M. Nakazaki, *ibid.*, 5463 (1968).

(11) C. Djerassi, H. Wolff, D. A. Lightner, E. Bunnenberg, K. Takeda, T. Komeno, and K. Kuriyama, *Tetrahedron*, **19**, 1547 (1963).

(12) C. G. Overberger and A. Drucker, *J. Org. Chem.*, **29**, 360 (1964); see also, A. M. Creighton and L. N. Owen, *J. Chem. Soc.*, 1024 (1960); S. M. Iqbal and L. N. Owen, *ibid.*, 1030 (1960).

(13) D. A. Lightner, C. Djerassi, K. Takeda, K. Kuriyama, and T. Komeno, *Tetrahedron*, **21**, 1581 (1965); K. Kuriyama and T. Komeno, "Optical Rotatory Dispersion and Circular Dichroism in Organic Chemistry," G. Snatzke, Ed., Heyden and Son, London, 1967, Chapter 21.

(14) A. H. Haines and C. S. P. Jenkins, *Chem. Comm.*, 350 (1969).

(15) B. E. Nielsen and J. Lemmich, *Acta Chem. Scand.*, **23**, 962 (1969).

Experimental Section[16]

Isolation.—Plant material was collected July 1967 at Neptune State Park on the Oregon Coast. Dried and ground seed heads were extracted with acetone. Solvent was removed from the extracts and the residue chromatographed on alumina. Solvent was removed from the first fractions showing fluorescence on tlc and the residue crystallized from hexane or ethyl acetate–hexane, to give the new coumarin (**7**): mp 95–96° after further crystallization from ethyl acetate–hexane; λ_{max}^{EtOH} 221 mμ (ε 27,700), 252 (26,000), 304 (12,300); nmr δ 8.09 (d, J = 10 Hz, H-4), 7.68 (d, J = 2 Hz, H-7), 7.06 (d, J = 2 Hz, H-8), 6.35 (d, J = 10 Hz, H-3), 5.60 (t, J = 7 Hz, vinyl), 4.82 (d, J = 7 Hz, α-methylene), 4.07 (s, methoxyl), 1.78, 1.72 (C-methyls) (in $CDCl_3$).

Anal. Calcd for $C_{17}H_{16}O_5$: C, 67.99; H, 5.37. Found: C, 68.1; H, 5,44.

The fractions following from the column eluted with benzene and chloroform gave upon work-up imperatorin (**2**), after crystallization from ethyl acetate–hexane, identical with an authentic sample.[17] The mother liquors from work-up of the imperatorin give further amounts of **7**. Large amounts of bergapten (**1**), mp 183–186° (from ethyl acetate–hexane) were recovered from the benzene eluents.

The mother liquors from these operations were combined, the solvent was removed, and the residue was heated with a trace of hydrochloric acid in acetic acid on a steam bath for 30 min. After work-up, the product was chromatographed on alumina to give isobergapten (**3**) and pimpinellin (**4**), both crystallized from ethyl acetate–hexane. The pimpinellin was identical in all respects with a sample provided by Dr. T. R. Govindachari.

Acid Hydrolysis of 6-Isopentenyloxyisobergapten (7).—A solution of the coumarin (**7**) in glacial acetic acid and a trace of hydrochloric acid was heated for 30 min on a steam bath. The solution was cooled, diluted with water, and extracted with ethyl acetate. After drying and removal of solvent, the residue was crystallized from ethyl acetate–methanol–hexane and sublimed for analysis to give **9**: mp 223–224°; λ_{max}^{EtOH} 221 mμ (ε 21,000), 254 (18,700), 308 (9,000); $\lambda_{max}^{EtOH-NaOH}$ 275, 323 mμ; nmr δ 8.14 (d, J = 10 Hz, H-4), 7.86 (d, J = 2 Hz, H-7), 7.07 (d, J = 2 Hz, H-8), 6.37 (d, J = 10 Hz, H-3), 3.97 (methoxyl) (in deuteriodimethyl sulfoxide–$CDCl_3$).

Anal. Calcd for $C_{12}H_8O_5$: C, 62.07; H, 3.47. Found: C, 62.1; H, 3.90.

Acetylation of **9** with acetic anhydride–pyridine gave the monoacetate (**11**): mp 171–173° from ethyl acetate–hexane; λ_{max}^{EtOH} 219, 249, 301 mμ; nmr δ 8.09 (d, J = 10 Hz, H-4), 7.64 (d, J = 2 Hz, H-7), 7.11 (d, J = 2 Hz, H-8), 6.40 (d, J = 10 Hz, H-3), 4.00 (methoxy), 2.47 (acetoxy) (in $CDCl_3$).

Anal. Calcd for $C_{14}H_{10}O_6$: C, 61.32; H, 3.68. Found: C, 61.6; H, 3.77.

Methylation of **9** with diazomethane gave pimpinellin (**4**), identical in all respects with an authentic sample: nmr δ 8.07 (d, J = 10 Hz, H-4), 7.67 (d, J = 2 Hz, H-7), 7.06 (d, J = 2 Hz, H-8), 6.34 (d, J = 10 Hz, H-3), 4.15, 4.06 (methoxyls) (in $CDCl_3$).

5,8-Dibenzyloxypsoralen (16).—A solution of 1.5 g of 15[7] and 2 g of benzyl chloride in dry acetone was refluxed over anhydrous potassium carbonate for 8 hr. The cooled solution was filtered and solvent was removed from the filtrates. The residue was taken up in chloroform and filtered through a short column of alumina with chloroform. Solvent was removed from the filtrates and the residue was recrystallized from methanol: mp 157.5–158°; nmr δ 8.12 (d, J = 10 Hz, H-4), 7.70 (d, J = 2 Hz, H-7), 7.47 (m, phenyl), 6.95 (d, J = 2 Hz, H-6), 6.23 (d, J = 10 Hz, H-3), 5.43, 5.33 (s, benzyl methylenes) (in $CDCl_3$); λ_{max}^{EtOH} 241, 249, 268, 312 mμ.

Anal. Calcd for $C_{25}H_{18}O_5$: C, 75.37; H, 4.55. Found: C, 75.60; H, 4.82.

6-Hydroxyisobergapten (9).—One gram of dibenzyl ether **16** was dissolved in ethanol–10% aqueous sodium hydroxide by means of heating. The solution was then diluted with more water. Dimethyl sulfate was added with stirring. Alternate additions of dimethyl sulfate and aqueous sodium hydroxide were made so that the solution was kept basic. After six times the calculated amount of dimethyl sulfate was consumed, the basic solution was warmed on a steam bath a further 20 min. The mixture was cooled and extracted with chloroform. The aqueous phase was acidified and re-extracted with chloroform. Solvent was removed from the latter chloroform extracts and the residue warmed with acetic acid–hydrochloric acid for 20 min on a steam bath. The cooled mixture was poured into water and extracted with chloroform. The chloroform extracts were dried and solvent was removed. The residue was sublimed. The sublimate was identical with natural **9** by ir, uv, and tlc criteria.

Isolation.—Fruit of *A. genuflexa* was collected at the end of Aug 1968 on the Oregon Coast along Highway 101 just south of the Drift Creek bridge, south of Lincoln City, Ore. Solvent was removed from the acetone extracts and the residue was chromatographed on alumina. Those fractions eluted with hexane which did not show fluorescence on tlc were discarded. Elution with hexane–benzene mixtures and benzene gave fractions which after work-up gave (+)-oxypeucedanin (**17**): mp 101–102° from ethyl acetate–hexane [lit.[18] mp 104° for (+) isomer]; $[\alpha]_D$ −11.1° ($CHCl_3$); nmr δ 9.23 (d, J = 10 Hz, H-4), 7.71 (d, J = 2 Hz, H-7), 7.13 (s, H-8), 7.06 (d, J = 2 Hz, H-6), 6.25 (d, J = 10 Hz), 4.50 (m, α-methylene), 3.15 (q, epoxy), 1.34, 1.39 (C-methyls) (in $CDCl_3$).

Anal. Calcd for $C_{16}H_{14}O_5$: C, 67.12; H, 4.93. Found: C, 67.3; H, 4.96.

Further work-up of the mother liquors gave mixtures of oxypeucedanin and isoimperatorin.

Acid Hydrolysis of Oxypeucedanin (17).—A solution of 1 g of crude **17** in aqueous ethanol containing 5% oxalic acid was refluxed for 1 hr. The solution was cooled and extracted with ethyl acetate. The ethyl acetate extracts were dried, the solvent was removed, and the residue was chromatographed over a short column of alumina. Isooxypeucedanin was eluted with benzene and the diol **18** was eluted with chloroform. Solvent was removed from the chloroform eluents and the residue was crystallized from benzene–acetone to give oxypeucedanin hydrate (**18**), identical in all respects with that of a sample isolated from expressed lemon oil: nmr δ 8.41 (d, J = 10 Hz, H-4), 7.79 (d, J = 2 Hz, H-7), 7.20 (s, H-8), 7.19 (d, J = 2 Hz, H-6), 6.35 (d, J = 10 Hz, H-3), 4.62 (m, α-methylene), 4.00 (q, methine), 1.40, 1.38 (C-methyls) (in $CDCl_3$).

Anal. Calcd for $C_{16}H_{16}O_6$: C, 63.15; H, 5.30. Found: C, 63.2; H, 5.22.

Workup of the benzene elutents gave isooxypeucedanin (**19**):[8,9] mp 148–149.5° from ethyl acetate–hexane; nmr δ 8.65 (d, J = 10 Hz, H-4), 7.89 (d, J = 2 Hz, H-6), 7.39 (s, H-8), 7.09 (d, J = 2 Hz, H-5), 6.50 (d, J = 10 Hz, H-3), 6.26 (s, α-methylene), 2.97 (sept, J = 7 Hz, methine), 1.30, 1.18 (C-methyls) (in $CDCl_3$).

Anal. Calcd for $C_{16}H_{14}O_5$: C, 67.12; H, 4.93. Found: C, 67.3; H, 4.96.

Reaction of Oxypeucedanin (17) with Potassium Methyl Xanthanate.—Three milliliters of CS_2 was added to a solution of 1 g of KOH in 8 ml of methanol. One gram of oxypeucedanin (**17**) was added and the mixture was warmed briefly on a steam bath to affect solution. The mixture was then allowed to stand 48 hr at room temperature. The solution was then poured into water and the aqueous mixture was extracted with ethyl acetate. Solvent was removed from the dried ethyl acetate extracts and the residue was chromatographed over a short column of alumina. Benzene eluted the episulfide (**20**), mp 125–127°, after recrystallization from ethyl acetate–hexane: nmr δ 8.16 (d, J = 10 Hz, H-4), 7.64 (d, J = 2 Hz, H-7), 7.14 (s, H-8), 6.97 (d, J = 2 Hz, H-6), 6.29 (d, J = 10 Hz, H-3), 4.58 (m, α-methylene), 3.20 (q, methine), 1.68, 1.62 (C-methyls) (in $CDCl_3$).

Anal. Calcd for $C_{16}H_{14}O_4S$: C, 63.5; H, 4.66. Found: 64.8; H, 4.76.

Further elution of the column with chloroform gave the yellow trithiocarbonate (**21**): mp 184–186° from benzene; nmr δ 8.29 (d, J = 10 Hz, H-4), 7.84 (d, J = 2 Hz, H-7), 7.34 (s, H-8), 7.02 (d, J = 2 Hz, H-6), 6.38 (d, J = 10 Hz, H-3), 4.92–4.34 (m, α-methylene and methine), 1.92, 1.78 (C-methyls) (in $CDCl_3$); ORD in dioxane (c 0.03) $[\alpha]_{473}$ +3200°, $[\alpha]_{425}$ +330°, $[\alpha]_{380}$ +2000° (last reading); CD in dioxane (c 0.0008) 500 (0), 446 (+2.5), 380 (0). A qualitative CD curve in ethanol showed

(16) Nmr spectra were taken at 60 MHz. The relative areas of the peaks were consistent with their assignments. J values are in hertz.

(17) D. L. Dreyer, *J. Org. Chem.*, **30**, 749 (1965).

(18) B. E. Nielsen and J. Lemmich, *Acta Chem. Scand.*, **18**, 1379 (1964).

positive Cotton effects at 442 and 293 mμ and a negative Cotton effect at 323 mμ.

Anal. Calcd for $C_{17}H_{14}O_4S_3$: C, 53.94; H, 3.72. Found: C, 54.0; H, 3.81.

Registry No.—**7**, 24099-29-4; **9**, 24099-3-7; **11**, 24099-31-8; **16**, 24099-32-9; **17**, 3173-02-2; **18**, 2643-85-5; **20**, 24099-34-1; **21**, 24099-35-2.

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Solvolyses of A-Norcholesteryl *p*-Toluenesulfonate Derivatives. III[1,2]

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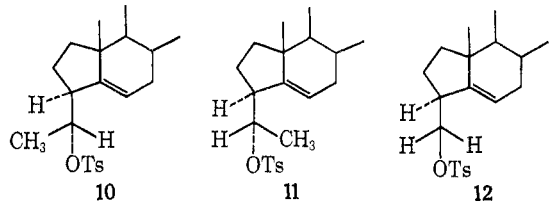
The syntheses and solvolyses of 3β-(1β-hydroxyethyl)-Δ⁵-A-norcholestenyl (**10**) and 3β-(1α-hydroxyethyl)-Δ⁵-A-norcholestenyl (**11**) *p*-toluenesulfonates are reported. The products of solvolysis in each case were similar to those formed in the solvolyses of the related ring-expanded cholesteryl derivatives, namely, 4β-methylcholesteryl (**7**) and 4α-methylcholesteryl (**4**) *p*-toluenesulfonates, respectively. The interrelationships among the various cationic intermediates in these solvolyses are discussed.

Experiments directed toward defining the structures of intermediary ions in the solvolyses of cholesteryl systems with methyl substituents in the A ring has led to a number of interesting results. The examples[4-8] shown in Scheme I summarize some of these findings.

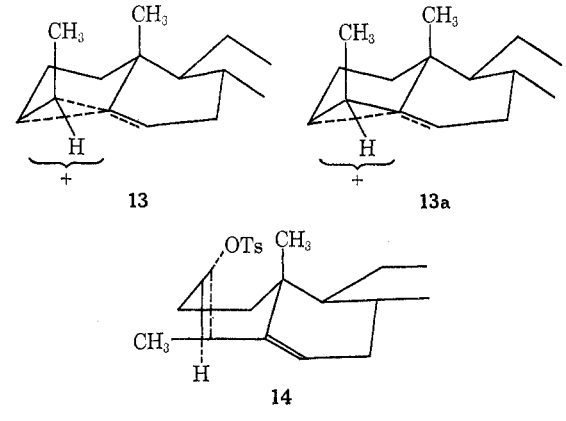
As can be seen, the configuration of the C_4 methyl group in **4** and **7** is extremely important with respect to the products of solvolysis. In the case of the 4α and equatorial orientation present in **4**, the outcome of the reaction is similar to tht observed in the unsubstituted cholesteryl system. The 4β and axial orientation of the methyl group in **7** caused the reaction to take a significantly different course, yielding the conjugated diene Δ³,⁵-4-methylcholestadiene (**8**) as the predominant product. A difference in the geometry of the A ring of **4** and **7** has been offered as an explanation for this divergent behavior.[5,6,8] Thus, the A ring of **4** is considered to exist in a chair form, while the A ring of **7**, in order to relieve the 1,3-diaxial methyl interaction, adopts either a flattened chair conformation[5,6] or a boat form.[8] These shapes should persist in the transition state. In the latter, the favorable geometry for elimination of *p*-TsOH is present, and this is obviously a very favored process. This process does not involve a homoallylic ion. The rate acceleration in solvolysis (*ca.* 200:1) for **7** compared with its saturated analog, 4β-methylcholestanyl *p*-toluenesulfonate,[6] could be due to both steric driving force and the stability of the transition state leading to the conjugated diene. On the other hand, some evidence was found to indicate that diene **8** was not a primary reaction product but rather resulted from a secondary reaction involving a highly reactive precursor.[6]

It was felt that a potential clarification of this point might be achieved from the solvolytic behavior of the A-ring-contracted compounds **10** and **11**. Whitham[9]



showed that **12** yielded the same products upon solvolysis as cholesteryl *p*-toluenesulfonate except that no hydrocarbon was formed, in contrast to the 1–2% obtained with cholesteryl toluenesulfonate. This result indicated the intermediacy of a common homoallylic ion resulting from each precursor *i.e.*, cholesteryl or A-nor-Δ⁵-cholestenyl.

The key point in the solvolyses of **10** and **11** would be whether **10** yields diene **8** upon solvolysis in amounts similar to that obtained starting from **7**. This would indicate a common intermediate. Furthermore, it is very unlikely that diene can come directly from either the symmetrical homoallylic ion **13**, or the unsym-



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