Anal. Calcd. for $C_9H_8N_2O_2.H_2O$: C, 55.66; H, 5.19; N, 14.43. Found: C, 56.21; H, 4.74; N, 14.82.

2. **From Dibenzalazine.**—5-Phenylhydantoin has been prepared in 54% yield by treating dibenzalazine under the above conditions. The compound melted at 180–182° and did not depress appreciably the melting point of an authentic sample of 5-phenylhydantoin.

3. **From N-Benzylidine Aniline.**—A mixture of N-benzylidine aniline (12.7 g., 0.070 mole), ammonium carbonate (11.0 g., 0.110 mole), sodium bisulfite (1.0 g., 0.010 mole), hydrogen cyanide (3.0 g., 0.110 mole), 40 ml. of methanol, and 40 ml. of water was heated at 100° for 4 hr. under autogenous pressure. 5-Phenylhydantoin was isolated in 81% (10.0 g., 0.057 mole). After one recrystallization from ethanol, the compound melted at 181–183° and did not depress the melting point of an authentic sample of 5-phenylhydantoin.

4. **From N-Benzylidinemethylamine.**—A mixture of N-benzylidinemethylamine (8.4 g., 0.017 mole), sodium bisulfite (1.0 g., 0.010 mole), hydrogen cyanide (3.0 g., 0.110 mole), 40 ml. of methanol, and 40 ml. of water reacted as above. The product (7.0 g., 0.040 mole; 56%) after recrystallization from ethanol melted at 182–184°. It did not depress the melting point of an authentic sample of 5-phenylhydantoin.

1,3-Diazaspiro[4.4]nonane-2,4-dione. 1. From Cyclopentanone Thiosemicarbazone.—A mixture of cyclopentanone thiosemicarbazone (10.0 g., 0.063 mole), ammonium carbonate (11.0 g., 0.110 mole), hydrogen cyanide (1.5 g., 0.056 mole), sodium bisulfite (3.0 g., 0.030 mole), 50 ml. of water, and 50 ml. of ethanol was heated 4 hr. at 120° under autogenous pressure. Cooling the resulting product mixture yielded thiosemicarbazide (2.6 g., 0.028 mole; m.p. 181–182°) which was regenerated in the reaction. The filtrate was taken to dryness *in vacuo* and the crystalline mass obtained extracted with 100 ml. of chloroform. The residue was then extracted with 30 ml. of ethanol. The latter extract was concentrated to about 10 ml. and cooled to yield the product (4.1 g., 0.027 mole, 43%) as a crystalline mass. It melted at 208–210°.

Anal. Calcd. for $C_7H_{10}O_2N_2$: C, 54.53; H, 6.54; N, 18.17. Found: C, 54.37; H, 6.42; N, 18.16.

2. **From Cyclopentanone Oxime.**—The above procedure was used to convert cyclopentanone oxime to 1,3-diazaspiro-[4.4]nonane-2,4-dione. The product melted at 208–210°.

Anal. Calcd. for $C_7H_{10}O_2N_2$: C, 54.53; H, 6.54; N, 18.17. Found: C, 54.37; H, 6.48; N, 18.19.

5-Methyl-5-*i*-butylhydantoin from Methyl *i*-Butyl Ketone Azine.—Reaction of methyl *i*-butyl ketone azine (6.8 g., 0.035 mole), ammonium carbonate (11.0 g., 0.110 mole), sodium bisulfite (1.0 g., 0.010 mole), and hydrogen cyanide (3.0 g., 0.110 mole) in 40 ml. of methanol and 40 ml. of water yielded 5-methyl-5-*i*-butylhydantoin (7.3 g., 0.043 mole, 61%). The product melted at 146–147°.

Anal. Calcd. for $C_8H_{14}O_2N_2$: C, 56.47; H, 8.24; N, 16.47. Found: C, 56.62; H, 8.57; N, 16.63.

In the absence of sodium bisulfite, 5-methyl-5-*i*-butylhydantoin was obtained in only 28% yield.

Arnidiol and Faradiol

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Evidence is presented that the hydroxyl functions of arnidiol and faradiol are located at positions 3 and 12 of the taraxastane skeleton.

Arnidiol and faradiol are pentacyclic triterpenoid diols which frequently occur together and are separable only with considerable difficulty. They were first isolated from the blossoms of *Arnica montana L.* and *Tussilago Farfara* and characterized by Klobb[1]; more extensive work by Dieterle and co-workers[2] indicated that they were isomers of empirical formula, $C_{30}H_{50}O_2$, containing two hydroxyl groups and an ethylenic bond. An extensive survey of the occurrence of these diols was made by Zimmermann,[3] who confirmed the assigned empirical formulas and succeeded in isolating pure arnidiol and faradiol.

Chromic acid oxidation[4] of the unsaturated diols yielded the diketones, arnidione and faradione which differ; the saturated diols, dihydroarnidiol and dihydrofaradiol, obtained by catalytic hydrogenation, also differ. Dihydroarnidione and dihydrofaradione, however, have been shown to be identical by Jeger and Lardelli,[5] thus establishing that arnidiol and faradiol differ in the location of the ethylenic bond and the configuration of at least one hydroxyl group. Since arnidione, on Wolff-Kishner reduction, gave taraxastene (I) and faradione gave ψ-taraxastene (II),[4] the constitutions of which were later elucidated,[6] the parent pentacyclic taraxastane skeleton of the naturally occurring diols was established. The reported acid isomerization of arnidione (*x*,*y*-diketotaraxast-20(30)-ene) to faradione (*x*,*y*-diketotaraxast-20-ene) clearly paralleled the conversion of I to II. The mixture of arnidiol and faradiol used in this investigation was obtained either from marigold flowers (*Calendula officinalis*) as previously described[7] or from arnica flowers (see Experi-

(1) (a) T. Klobb, *Compt. rend.*, **138**, 763 (1904); (b) *Compt. rend.*, **140**, 1700 (1905); (c) *Bull. soc. chim. France*, **33**, iii, (1905); (d) *Bull. soc. chim. France*, **35**, iii, 741 (1906); (e) *Compt. rend.*, **149**, 999 (1909); (f) *Ann. Chim.* (France), **22**, viii, 5 (1911).

(2) (a) H. Dieterle and K. Engelhard, *Arch. Pharm.*, **279**, 312 (1941). (b) H. Dieterle and I. Schreiber, *Arch. Pharm.*, **278**, 225 (1940).

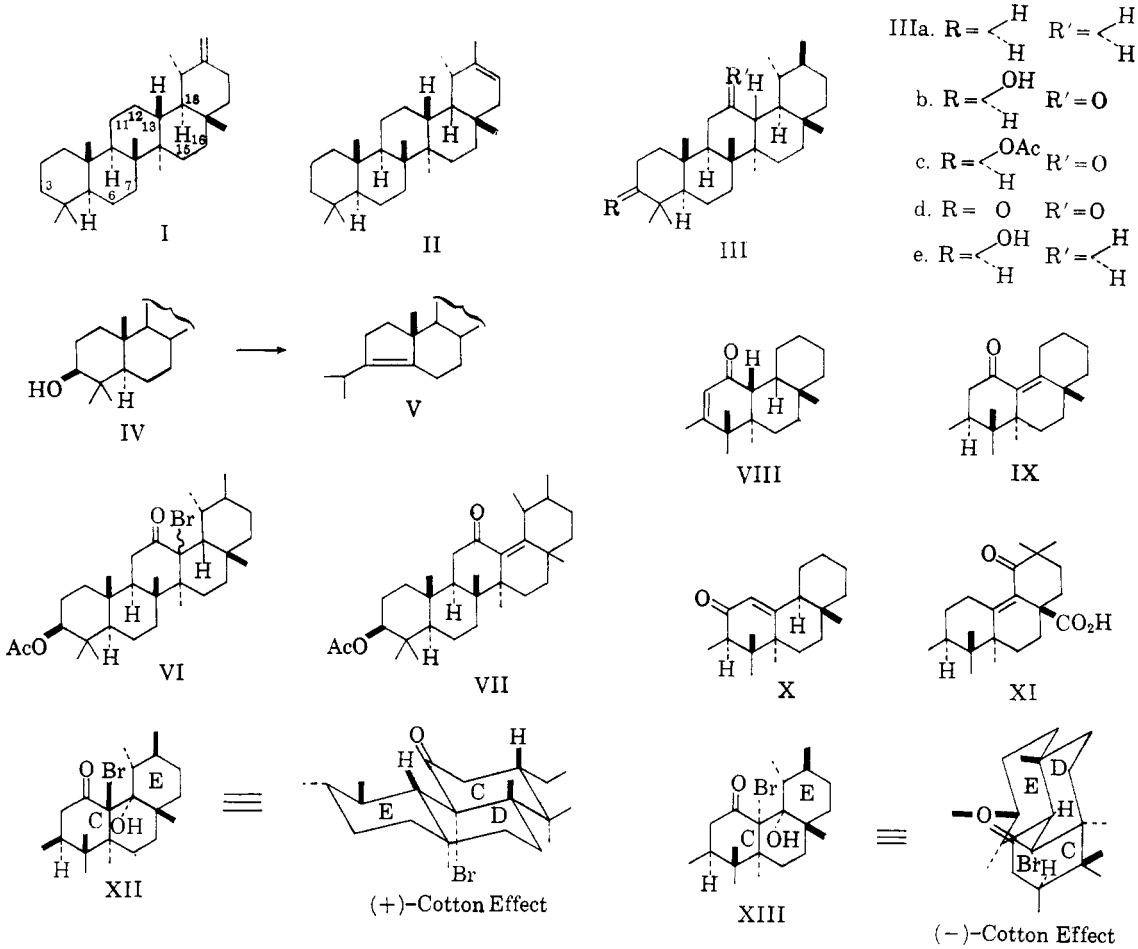
(3) (a) J. Zimmermann, *Helv. Chim. Acta*, **26**, 642 (1943); (b) *Helv. Chim. Acta*, **27**, 332 (1944); (c) *Helv. Chim. Acta*, **29**, 1455 (1946).

(4) G. Lardelli, H. K. Krüsi, O. Jeger, and L. Ruzicka, *Helv. Chim. Acta*, **31**, 1815 (1948).

(5) (a) O. Jeger and G. Lardelli, *Helv. Chim. Acta*, **30**, 1020 (1947). (b) G. Lardelli and O. Jeger, *Helv. Chim. Acta*, **31**, 813 (1948).

(6) T. R. Ames, J. L. Beton, A. Bowers, T. G. Halsall, and E. R. H. Jones, *J. Chem. Soc.*, 1905 (1954).

(7) R. Stevenson, *J. Org. Chem.*, **26**, 5228 (1961).



mental). From the latter source, the specific rotation of the mixture indicated the presence of two parts of faradiol to one part of arnidiol. The identity of the arnidiol–faradiol mixture was established by conversion to the common derivative, faradione, by oxidation with chromium trioxide in acetone,[8] followed by mineral acid isomerization of the arnidione–faradione mixture.

Catalytic hydrogenation of the arnidiol–faradiol mixture proceeded smoothly to yield the corresponding dihydrodiol mixture which gave dihydrofaradione on chromic acid oxidation as previously described.[5] The specific rotation of dihydrofaradione, so obtained from arnica flowers, differed from that previously reported, but agreed with the product similarly isolated from calendula flowers.[7] In confirmation of previous conclusions, it was established that dihydrofaradione was a diketotaraxastane by Huang-Minlon reduction to the parent hydrocarbon, taraxastane (IIIa). We may anticipate the subsequent discussion by assigning the constitution, 3,12-diketotaraxastane (IIId) to dihydrofaradione.

Partial reduction of dihydrofaradione (IIId) was effected by catalytic hydrogenation in acetic acid solution with termination of the reaction after one mole of hydrogen had been absorbed. Chromatographic purification of the reaction mixture yielded a hydroxytaraxastanone (IIIb), characterized by preparation of the derived acetate (IIIc). The reduction of IIIb by the Huang-Minlon method yielded taraxastan-3β-ol (IIIe), identified by mixed melting point comparisons with authentic alcohol and acetate derivative. The x-oxygen function of arnidiol, faradiol and derivatives is consequently located at the C-3 position of taraxastane.

Since faradione is not an α- or β- diketone and does not possess an α,β-unsaturated carbonyl system, the y-ketone group must be restricted to one of six positions, C-6 or 7 (ring B), C-11 or 12 (ring C), or C-15 or 16 (ring D). The ready reduction of the y-ketone function to a methylene group indicated that it was unlikely to be located at either C-6 (*cf.* the 6-ketone derived from sumaresinolic acid[9a]) or at C-11 (*cf.* methyl 11-ketooleananolate acetate[9b]), both sites of considerable steric hindrance. Further evidence excluding C-6 (and probably C-7) as the location of the y-ketone came from dehydration of IIIb to effect the standard retropinacolic rearrangement (IV → V).

(8) K. Bowden, I. M. Heilbron, E. R. H. Jones, and B. C. L. Weedon, *J. Chem. Soc.*, 39 (1946).

(9) (a) C. Djerassi, G. H. Thomas, and O. Jeger, *Helv. Chim. Acta*, **38**, 1304 (1955). (b) D. H. R. Barton and N. J. Holness, *J. Chem. Soc.*, 78 (1952).

The oily product gave a positive tetranitromethane test, indicating that dehydration had occurred but gave no indication, before or after treatment with base, of the presence of a conjugated ketone as determined by the infrared spectrum.

The exclusion of ring D as the site of the γ-ketone was effected in the following way. Treatment of the acetoxytaraxastanone (IIIc) with bromine in acetic acid yielded a bromo ketone (VI) whose ultraviolet absorption maximum, compared to the parent ketone, showed an enhanced extinction coefficient and bathochromic shift (29 mμ), thus establishing its axial conformation.[10]

Dehydrobromination of the bromo ketone proved troublesome but was finally accomplished by the action of silver nitrate in pyridine solution. Fractional crystallization of the reaction mixture gave a dehydrobrominated product with characteristic ultraviolet and infrared spectra of an α,β-unsaturated ketone. Since such a grouping cannot be incorporated in ring D, the γ-ketone cannot be located at C-15 or 16.

Of the three possible α,β-unsaturated ketones (VIII–X) which can be derived from a ketone in ring C, the high ultraviolet absorption maximum wave length (255 mμ) exhibited by the dehydrobrominated ketone suggests that it has the chromophore of IX. By comparison, in the 18α-oleanane series, the chromophore of VIII has maximum absorption at 242 mμ and X at 244–245 mμ.[11] Although the chromophore of IX has not apparently been recorded in the triterpenoid field, the ketone (XI) from siaresinolic acid, possessing the Δ13(18)-ethylenic bond shows maximum absorption at 253 mμ.[12] Confirmation that the unsaturated ketone possessed chromophore (IX) was obtained from the n.m.r. spectrum[13] which did not have a signal characteristic of an olefinic proton. This excludes C-11 and C-7 as the site of the γ-ketone and by elimination locates it at C-12. The dehydrobrominated ketone is therefore formulated as VII.[14]

The structure of the bromo ketone (VI) derived from 3β-acetoxy-12-ketotaraxastane (IIIc) is of some interest. The dehydrobromination to VII suggests, although does not prove, that the halogen is located at C-13 rather than at C-11. The axial conformation of the halogen atom established from the ultraviolet spectrum was confirmed by comparison of the optical rotatory dispersion spectra of ketone (IIIc) and bromo ketone in which a bathochromic shift of 26 mμ in the first extremum was observed. In an all-chair arrangement of the taraxastane system, a 13-(axial) substituent must have a β-configuration (drawn inverted in XII to emphasize Axial Halo ketone rule[15] relationship) and should exhibit a positive Cotton effect. The bromo ketone, however, exhibits a negative Cotton effect and does not show the usual greatly increased amplitude. If bromination of the enol has proceeded from the rear side—a strong likelihood in view of the 1:3-diaxial hindering effect of the 8β- and 17β-methyl groups to frontal attack at C-13—to yield a 13α-bromo ketone, a boat conformation of one of the rings is a necessary consequence. A ring C boat arrangement (XIII) should show a negative Cotton effect as is observed and the principal nonbonded interactions introduced (13α-bromine with 19α-methyl and 9α-hydrogen) probably compare favorably, with regard to destabilization, with those introduced in XII (13β-bromine with 8β- and 17β-methyl groups and 12-ketone with 19α-methyl group). The observed comparative stability of the bromo ketone toward dehydrobromination is also difficult to rationalize on the basis of the diaxial arrangement of substituents, desirable for elimination, at C-13 and C-18 in XII.

The presence of an oxygen function at C-12 in natural triterpenoids is a rare occurrence, the tetracyclic polyporenic acid A[16] being the best authenticated example.

Experimental[17]

Isolation of Arnidiol–Faradiol Mixture.—Extraction of ground arnica flowers (780 g.) for 24 hr. in a Soxhlet apparatus with benzene yielded a gum (52 g.) which was heated under reflux for 4 hr. with methanolic potassium hydroxide solution (10%, 1 l.). Concentration, dilution with water, and extraction with ether gave an extract which, after drying over sodium sulfate, was evaporated to yield a yellow gum (20.6 g.). Crystallization from ether–petroleum ether (b.p. 30–60°) gave a yellow solid (4.60 g.) which was chromatographed on alumina (140 g., Merck, basic). Elution with benzene (600 cc.) and benzene–chloroform (3:1, 900 cc.) gave no residues. After elution with benzene–chloroform (1:1, 900 cc.) gave no residue, the same eluant (1200 cc.) gave solids (3.30 g.) which crystallized from petroleum ether (b.p. 60–80°) to give the diol mixture (3.02 g.), λ^{KBr} 2.81, 2.94, 11.31 μ. $[\alpha]_D$ +57° (*c*, 2.1) corresponding to 33% arnidiol and 67% faradiol. Reported,[3a] arnidiol $[\alpha]_D$ +83°, faradiol $[\alpha]_D$ +46.5°.

Hydrogenation of Arnidiol–Faradiol Mixture.—A solution of the mixed diols (2.49 g.) in glacial acetic acid was hydrogenated, using prereduced platinum oxide as catalyst. When uptake was complete, the filtered solution was poured into water and extracted with ether, and the extract washed successively with water, dilute sodium hydroxide solution, and water and dried. Evaporation of the solvent gave the mixed dihydrodiols as a white solid (2.39 g.), $[\alpha]_D$ +7°

(10) (a) R. C. Cookson, *J. Chem. Soc.*, 282 (1954). (b) R. C. Cookson and S. H. Dangegaonker, *ibid.*, 352 (1955).

(11) G. G. Allan and F. S. Spring, *ibid.*, 2125 (1955).

(12) (a) P. L. Bilham, G. A. R. Kon, and W. C. J. Ross, *ibid.*, 535 (1942). (b) L. Ruzicka, A. Grob, R. Egli, and O. Jeger, *Helv. Chim. Acta*, **26**, 1218 (1943).

(13) Kindly determined by Dr. N. S. Bhacca, Varian Associates, California.

(14) The possibility of epimerisation at C-19 has not been excluded.

(15) C. Djerassi, "Optical Rotatory Dispersion," McGraw-Hill, New York, 1960, pp. 120–128.

(16) T. G. Halsall, R. Hodges, and E. R. H. Jones, *J. Chem. Soc.*, 3019 (1953).

(17) Melting points were determined on Fisher-Johns melting point apparatus. Specific rotations were measured in chloroform solution and rotatory dispersion spectra in dioxan solution. Merck acid washed alumina was used for chromatography, unless otherwise stated.

(*c*, 2.1), which gave no color with tetranitromethane in chloroform solution.

Dihydrofaradione (IIId) from Dihydroarnidiol–Dihydrofaradiol Mixture.—A solution of chromium trioxide (112 mg.) in aqueous acetic acid (1.0 ml.) was added dropwise to a stirred solution of the dihydrodiol mixture (362 mg.) in acetic acid (25 ml.) at room temperature. The mixture turned green immediately, was allowed to stand overnight and worked up in the usual way by dilution and ether extraction. Crystallization of the product from methanol, gave dihydrofaradione as plates (248 mg.), m.p. 187–189°, $[\alpha]_D$ −22° (*c*, 1.3), λ^{KBr} 5.88 μ. Reported m.p. 183°, $[\alpha]_D$ −61°[5a]; m.p. 184–187°, $[\alpha]_D$ −18°.[7]

Anal. Calcd. for $C_{30}H_{48}O_2$: C, 81.80; H, 10.91. Found: C, 82.03; H, 11.33.

Rotatory dispersion (R.D.) in dioxane (*c*, 0.116), $[\alpha]_{700}$ −17°, $[\alpha]_{589}$ −26°, $[\alpha]_{316.5}$ −790°, $[\alpha]_{309.5}$ −495°, $[\alpha]_{306}$ −528°, $[\alpha]_{298}$ −49°, inflex, $[\alpha]_{275}$ +543°, $[\alpha]_{265}$ +420°.

Taraxastane (IIIa) from Dihydrofaradione.—Potassium hydroxide (1.0 g.) and hydrazine hydrate (99–100%, 3.0 ml.) was added to a suspension of dihydrofaradione (100 mg.) in diethylene glycol (17 ml.) and the mixture he ted under reflux for 20 min. The condenser was then removed, the mixture boiled until the temperature reached 220°, and the resultant solution refluxed for 5 hr. The crude product, isolated by dilution with water and extraction with chloroform, was purified by filtration through alumina to give taraxastane (57 mg.), m.p. and mixed m.p. 196–197°, $[\alpha]_D$ +7° (*c*, 3.2). Reported[5b] m.p. 196–196.5°, $[\alpha]_D$ +10°.

Faradione from Arnidiol–Faradiol Mixture.—A solution of the arnidiol–faradiol mixture (1.0 g.) in acetone (150 ml.) was cooled to 10° and treated with a solution (1.2 ml.) of chromium trioxide in dilute sulfuric acid (prepared by dissolving 2.672 g. of chromium trioxide in 2.3 ml. sulfuric acid and diluting to 10 ml. with water). After 5 min., the mixture was poured into water (300 ml.) and the precipitate of mixed diketones collected by filtration. A portion of the dried mixed diketones (50 mg.) was dissolved in a mixture (15 cc.) of ethanol–benzene–sulfuric acid (volume ratio 10:5:1), heated under reflux for 4 hr., diluted with water, the product isolated in the usual way by ether extraction, and purified by filtration through alumina. Crystallization from ether–petroleum ether gave faradione (24 mg.), m.p. 247–249°, λ^{CS_2} 5.86 μ.

R.D. in dioxane (*c*, 0.074), $[\alpha]_{700}$ +11°, $[\alpha]_{589}$ +3°, $[\alpha]_{314}$ −1031°, $[\alpha]_{307}$ −616°, $[\alpha]_{305}$ −636°, $[\alpha]_{270}$ +1422°, $[\alpha]_{255}$ +1132°.

Partial Reduction of Dihydrofaradione (IIId).—A solution of dihydrofaradione (1.0 g.) in glacial acetic acid (*ca.* 150 ml.) was shaken in an atmosphere of hydrogen with platinum catalyst (from pre-reduction of 100 mg. of platinum oxide) until the measured uptake was 61 cc. (*ca.* 1.1 moles). The catalyst was removed by filtration, the filtrate diluted with water, extracted with ether, and worked up in the usual way to yield a product which was dissolved in benzene and chromatographed on acid-washed alumina (Merck: 45 g.), and eluates collected in 50-ml. fractions. Fractions 1–4, eluted by benzene, gave no material. Fractions 5–7 gave crystals (197 mg.) shown to be unchanged diketone by infrared spectrum comparison. Fractions 8–36, eluted by benzene, and 37–45, eluted by benzene–chloroform (4:1), were solids with melting points between 196 and 225° and showed hydroxyl and carbonyl absorption bands in the infrared spectra. No crystalline material was obtained from fractions 46–48, eluted by benzene–chloroform (4:1), fractions 49–52, eluted by benzene–chloroform (1:1), and fractions 53–55, eluted with chloroform.

Fractions 8–45 were combined and recrystallized several times from ether–petroleum ether to give 3β-hydroxy-12-ketotaraxastane (IIIb, 462 mg.) as felted needles, m.p. 224–227°, $[\alpha]_D$ +9° (*c*, 1.34), λ^{KBr} 2.99, 5.89 μ.

Anal. Calcd. for $C_{30}H_{50}O_2$: C, 81.39; H, 11.38. Found: C, 81.97; H, 11.66.

3β-Acetoxy-12-ketotaraxastane (IIIc).—Acetylation of the hydroxyketone with pyridine and acetic anhydride at room temperature for 12 hr., gave 3β-acetoxy-12-ketotaraxastane, crystallized from chloroform–methanol as plates, m.p. 236–238°, $[\alpha]_D$ −40° (*c*, 0.5), λ^{CHCl_3} 292 mμ (ε 48). λ^{KBr} 5.75, 5.87 μ. R.D. in dioxane (*c*, 0.075): $[\alpha]_{600}$ −75°, $[\alpha]_{589}$ −75°, $[\alpha]_{317}$ −740°, $[\alpha]_{310}$ −515°, $[\alpha]_{307}$ −600°, $[\alpha]_{300}$ −160°, inflex $[\alpha]_{278}$ +416°, $[\alpha]_{260}$ +256°.

Anal. Calcd. for $C_{32}H_{52}O_3$: C, 79.39; H, 10.82. Found: C, 79.67; H, 10.87.

Reduction of 3β-Hydroxy-12-ketotaraxastane (IIIb) to Taraxastanol (IIIc).—The hydroxy ketone (79 mg.) was dissolved in diethylene glycol (15 ml.) containing hydrazine hydrate (3.0 ml.) and potassium hydroxide (1.0 g.), the mixture refluxed for 30 min., concentrated until the solution temperature reached 220°, then refluxed for a further 5 hr. Working up in the usual way gave a solid which was dissolved in benzene and filtered through acid-washed alumina (Merck, 17 g.). Elution with the same solvent (130 ml.) yielded a trace of oil, followed by a solid eluted by the next 400 ml. of benzene. Crystallization from ether–petroleum ether gave taraxastanol (40 mg.), m.p. and mixed m.p. 224–226°, $[\alpha]_D$ +4° (*c*, 2.5), further characterized by preparation of taraxastanyl acetate, m.p. and mixed m.p. 271–272°.

Dehydration of 3β-Hydroxy-12-ketotaraxastane.—Phosphorus pentoxide (200 mg.) was added to a solution of the hydroxy ketone (89 mg.) in dry benzene (10 cc.), and the mixture stirred for 17 hr. The product was isolated in the usual way by careful addition of water and ether extraction to give a yellow oil (80 mg.) which gave a positive tetranitromethane color and whose infrared absorption spectrum (λ^{KBr} 5.87 μ) did not show the presence of hydroxyl or conjugated ketone groups. The oil was recovered unchanged (identical infrared spectrum) after being heated under reflux with 5% methanolic potassium hydroxide solution for 1 hr.

Bromination of 3β-Acetoxy-12-ketotaraxastane.—Two drops of a saturated solution of hydrogen bromide in chloroform was added to a solution of the acetoxy ketone (200 mg.) in acetic acid, followed by dropwise addition of a solution (1.5 ml.) of bromine (0.55 *M*) in acetic acid. The mixture was heated for 2 min. on the steam bath, allowed to stand at room temp. for 4 hr. (in another experiment for 48 hr.), and crystalline material which had separated was collected. Dilution of the filtrate with water gave a second crop of the same product. Two crystallizations from chloroform–methanol gave 3β-acetoxy-13α-bromo-12-ketotaraxastane (XIII) as small prisms, m.p. 232–234°, $[\alpha]_D$ −14° (*c*, 2.1), λ 321 mμ (ε 124), λ^{KBr} 5.75, 5.85 μ. R.D. in dioxane (*c*, 0.063): $[\alpha]_{600}$ ±0°, $[\alpha]_{539}$ ±0° $[\alpha]_{343}$ −192°, $[\alpha]_{270}$ +384°, $[\alpha]_{260}$ +320°.

Anal. Calcd. for $C_{32}H_{51}O_3Br$: C, 68.18; H 9.12; Br, 14.18. Found: C, 68.34; H, 8.98; Br, 14.68.

The bromo ketone was recovered unchanged after standing at room temperature for 3 days in chloroform solution containing hydrogen bromide.

3β-Acetoxy-12-ketotaraxast-13(18)-ene (VII).—A solution of silver nitrate (500 mg.) and 3β-acetoxy-13α-bromo-12-ketotaraxastane (260 mg.) in pyridine (10 ml.) was heated under reflux for 20 hr., cooled, diluted with water, and extracted several times with ether. The combined ether extracts were washed with 2 *N* hydrochloric acid and water and dried ($MgSO_4$). Removal of the solvent gave a gummy yellow solid which was crystallized from methanol–chloroform. The first crop (51 mg.) showed only low intensity ultraviolet absorption at 320 mμ indicating absence of conjugated ketone. The second crop, after several recrystallizations, gave 3β-acetoxy-12-ketotaraxast-13(18)-ene as needles (68 mg.), m.p. 235–239°, $[\alpha]_D$ +1° (*c*, 1.5),[18]

(18) The absence of the pronounced laevorotation usually observed with $\Delta^{13(18)}$-unsaturated triterpenes is an abnormality possibly caused by the proximity of the 19-methyl and 12-ketone groups.

λ^{EtOH} 255 mμ (ε 8700), λ^{KBr} 5.76, 5.93, 6.20 μ. The nuclear magnetic resonance spectrum determined in deuteriochloroform solution did not have a signal characteristic of an olefinic proton.

Anal. Calcd. for $C_{32}H_{50}O_3$: C, 79.62; H, 10.44. Found: C, 79.73; H, 10.79.

Attempted dehydrobromination with lithium bromide and lithium carbonate in dimethylformamide gave a mixture of debrominated and dehydrobrominated product.[19]

(19) M. E. Kuehne, *J. Am. Chem. Soc.*, **83**, 1492 (1961), has noted debromination accompanying dehydrobromination with this reagent.

Acknowledgment.—We wish to thank Professor Carl Djerassi, Stanford University, for the optical rotatory dispersion spectra reported. The support of the National Institute of Arthritic and Metabolic Diseases, Public Health Service (Grant A-3439), is gratefully acknowledged.

The Pinacol Rearrangement of 1-Phenyl-2-methylpropane-1,2-diol

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The classical example of the aldehyde–ketone rearrangement, that of 2-phenyl-2-methylpropanal and the related glycol, 1-phenyl-2-methylpropane-1,2-diol, in formic acid has been studied kinetically. The phenyl–methyl migratory ratio has been found to be 24.8 to 1. The rearrangement of the glycol in concentrated sulfuric acid has also been studied, and the results compared with those in formic acid. The results of both reactions are interpreted in the light of the complex equilibria of carbonium ions proposed for reactions of this type.

The pinacol rearrangements of trisubstituted 1,2-glycols, and the closely related aldehyde–ketone rearrangement have long been considered to be an anomalous case of the pinacol rearrangement, where migratory aptitudes are apparently reversed.[1]

Although the apparent anomaly of this reaction has been satisfactorily explained recently by Collins,[2] the classical example of the aldehyde–ketone rearrangement, that of 2-phenyl-2-methylpropanal (I) to 3-phenyl-2-butanone[1,3] (II), has not been reinvestigated since the advent of modern theoretical concepts or experimental methods. Our attention was drawn to this reaction several years ago, when it was found that 2-phenyl-2-methylpropanal prepared from the reaction of 1-phenyl-2-methylpropane-1,2-diol (III) and formic acid[4] showed infrared absorption at 5.94 μ in addition to the expected aldehyde band at 5.78 μ. This band could only be consistent with the formation of isobutyrophenone (IV) in this reaction, whereas it would be expected that any subsequent rearrangement of the aldehyde should give 3-phenyl-2-butanone.[2,3]

It was found early in our work that by increasing the reaction time in the dehydration of 1-phenyl-2-methylpropane-1,2-diol with formic acid, that the percentage of aldehyde produced decreased. It is thus apparent that, since the over-all yield of rearranged product is good even after a relative short reaction time,[4] the pinacol rearranges rapidly, followed by a considerably slower rearrangement of the aldehyde to 3-phenyl-2-butanone, and/or isobutyrophenone.

We have carried out a series of rearrangements at various times and analyzed the products by a combination of gas chromatography and chemical techniques. The results of these rearrangements are summarized in Table I. We have also found that both ketones (II and IV), are recovered unchanged on boiling with formic acid for forty hours, and that at the end of thirty minutes all the glycol is consumed.[5]

TABLE I

SUMMARY OF THE RESULTS OF THE REACTION OF III WITH 97% FORMIC ACID

Time	% I	% II	% IV
15 min.	77	6	17
30 min.	76	7	17
1 hr.	77	6	17
4 hr.	74	6	20
13.5 hr.	56	13	31
20.5 hr.	51	15	34
26 hr.	38	19	43
36 hr.	35	19	46
48.7 hr.	25	19	56
60 hr.	22	21	57
68 hr.	21	19	60
80 hr.	23	19	58
95.5 hr.	21	19	60
209.5 hr.	12	23	65

(1) (a) G. W. Wheland, "Advanced Organic Chemistry," 2nd ed., John Wiley and Sons, Inc., New York, 1953, pp. 494–534; (b) C. K. Ingold, "Structure and Mechanism in Organic Chemistry," Cornell University Press, Ithaca, New York, 1953, p. 479.

(2) (a) C. J. Collins, *Quart. Rev.*, **14**, 357 (1960); (b) B. M. Benjamin and C. J. Collins, *J. Am. Chem. Soc.*, **78**, 4329 (1956).

(3) A. Orekhov and M. Tiffeneau, *Compt. rend.*, **182**, 67 (1926).

(4) N. H. Cromwell and H. H. Eby, *J. Am. Chem. Soc.*, **74**, 4201 (1952).

(5) This was done by carefully weighing the products from a thirty-minute run, diluting with a known weight of acetophenone, and checking the relative percentages of acetophenone and total reaction products by gas chromatography. The diol is not removed from the column under the conditions of temperature and flow rate used in this determination.