[CONTRIBUTION FROM THE DEPARTMENT OF CHEMISTRY OF WAYNE STATE UNIVERSITY]

Optical Rotatory Dispersion Studies. XXV.[1] Effect of Carbonyl Groups in Pentacyclic Triterpenes[2]

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A systematic study of the rotatory dispersion curves of pentacyclic triterpenoid ketones and aldehydes has been carried out. In many cases, the characteristic anomalous dispersion curves can be used for locating a carbonyl group (and hence the corresponding alcoholic function) or for determining certain stereochemical features. The latter is particularly noticeable in α,β-unsaturated ketones. The use of plain dispersion curves is illustrated with certain double bond isomers in the oleanene series. Attention is called to the fact that Barton's kinetic data concerning "conformational transmission" in 3-keto triterpenoids bear a certain relationship to their rotatory dispersions.

Our original aim in examining the rotatory dispersion curves of a variety of steroidal ketones[3] was to develop a new method for locating carbonyl groups (and hence hydroxyl functions from which they were derived) in such a polycyclic system by relating the characteristic shape of the anomalous[4] dispersion curve to the skeletal and stereochemical environment of the particular carbonyl function. This approach has met with conspicuous success[5] and subsequently it was possible to extend the results from the steroid studies to the determination of absolute configuration[6] and the examination[7] of conformational factors in a variety of cyclic ketones.

We have anticipated already in the first paper[8] of this series that if rotatory dispersion should prove to be useful in the steroid series, the same general approach should also be applicable to triterpenoids and we should now like to present experimental results in support of this prediction. A new tool for the structural organic chemist is particularly welcome in this field where much work on the constitution of new triterpenes is still in progress. Since there are only a few major groups of triterpenoids[9] (*e.g.*, oleanane, ursane, lupane and friedelane types), which can usually be recognized quite readily by their different response to various reagents[9] (*e.g.*, selenium dioxide, N-bromosuccinimide, ozone, etc.), the structure of a novel triterpenoid is generally established by first determining membership in one of these broad classes followed by interconversion with a known representative of that particular group. It is this aspect of structure elucidation which presents the greatest difficulties since this involves the characterization of the various oxygen functions followed by judicial removal or transformation of one or more of them. The use of physico-chemical methods for this purpose is not yet as refined as in the steroid series: ultraviolet absorption is helpful only in recognizing α,β-unsaturated ketones, which are quite rare among naturally occurring triterpenoids; infrared spectroscopy[10] has been studied in some detail, while calculations of molecular rotation differences[11] at a single wave length (589 $m\mu$) have not found as extensive an application as among steroids.

Rotatory Dispersion of Triterpenes Lacking Carbonyl Groups.—As pointed out in earlier studies in the steroidal sapogenin,[12] bile acid[13] and cardiac aglycone[5d] series, proper evaluation of the rotatory dispersion curves of a closely related group of compounds requires a knowledge of the "background"[4] dispersion of the particular system. This represents the rotatory dispersion of the corresponding hydrocarbon and/or alcohol and while such curves will be plain[4] over the currently accessible spectral range and will exhibit no peaks or troughs,[4] the sign and slope of this plain dispersion curve may lower or raise the Cotton effect curve[4] of the corresponding ketone to a very marked extent. This was very noticeable among steroidal sapogenins[12] and etianic acids[13] and attention will be drawn to this factor in the sequel.

Saturated triterpenoids—especially among the ursane and oleanane groups—lacking carbonyl groups are very rare and we have, therefore, concerned ourselves almost exclusively with unsaturated representatives. These included double bond

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(1) Paper XXIV, C. Djerassi and L. E. Geller, THIS JOURNAL, **81**, 2789 (1959).

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(3) C. Djerassi, *Bull. soc. chim. France*, 741 (1957), and earlier references cited therein.

(4) See Djerassi and W. Klyne, *Proc. Chem. Soc.*, 55 (1957), for nomenclature as well as method of recording experimental data.

(5) For pertinent examples see: (a) C. Djerassi, G. W. Krakower, A. J. Lemin, L. H. Liu, J. S. Mills and R. Villotti, THIS JOURNAL, **81**, 6284 (1958); (b) H. Schröter, C. Tamm and T. Reichstein, *Helv. Chim. Acta*, **41**, 720 (1958); (c) H. Aebli, C. A. Grob and E. Schumacher, *ibid.*, **41**, 774 (1958); (d) C. Djerassi, O. Halpern, V. Halpern, O. Schindler and C. Tamm, *ibid.*, **41**, 250 (1958); (e) R. Neher, P. Desaulles, E. Vischer, P. Wieland and A. Wettstein, *ibid.*, **41**, 1667 (1958); (f) J. Castells, E. R. H. Jones, R. W. J. Williams and G. D. Meakins, *Proc. Chem. Soc.*, 7 (1958); (g) A. Bowers, H. J. Ringold and R. I. Dorfman, THIS JOURNAL, **79**, 4556 (1957); (h) S. W. Pelletier and D. M. Locke, *ibid.*, **79**, 4531 (1957). Additional references will be found in C. Djerassi, *Rec. Chem. Progress*, **20**, No. 3 (1959).

(6) *Inter al.:* (a) C. Djerassi, R. Riniker and B. Riniker, *ibid.*, **78**, 6362 (1956); (b) C. Djerassi and W. Klyne, *ibid.*, **79**, 1506 (1957); (c) C. Djerassi, J. Osiecki and W. Herz, *J. Org. Chem.*, **22**, 1361 (1957).

(7) *Inter al.:* (a) C. Djerassi, O. Halpern, V. Halpern and B. Riniker, THIS JOURNAL, **80**, 4001 (1958); (b) C. Djerassi and L. E. Geller, *Tetrahedron*, **3**, 319 (1958); (c) C. Djerassi, L. A. Mitscher and B. J. Mitscher, THIS JOURNAL, **81**, 947 (1959).

(8) C. Djerassi, E. W. Foltz and A. E. Lippman, *ibid.*, **77**, 4354 (1955).

(9) For pertinent references see J. Simonsen and W. C. J. Ross, "The Terpenes," Cambridge University Press, 1957, Vol. IV and V.

(10) (a) A. R. H. Cole and D. W. Thornton, *J. Chem. Soc.*, 1007 (1956); (b) I. L. Allsop, A. R. H. Cole, D. E. White and R. L. S. Willix, *ibid.*, 4868 (1956); (c) A. R. H. Cole and D. W. Thornton, *ibid.*, 1332 (1957); (d) A. R. H. Cole, G. T. A. Müller, D. W. Thornton and R. L. S. Willix, *ibid.*, 1218 (1959).

(11) (a) D. H. R. Barton and E. R. H. Jones, *ibid.*, 659 (1944); (b) W. Klyne, *ibid.*, 2916 (1952); (c) W. Klyne and W. M. Stokes, *ibid.* 1979 (1954).

(12) C. Djerassi and R. Ehrlich, THIS JOURNAL, **78**, 440 (1956).

(13) C. Djerassi and W. Closson, *ibid.*, **78**, 3761 (1956).

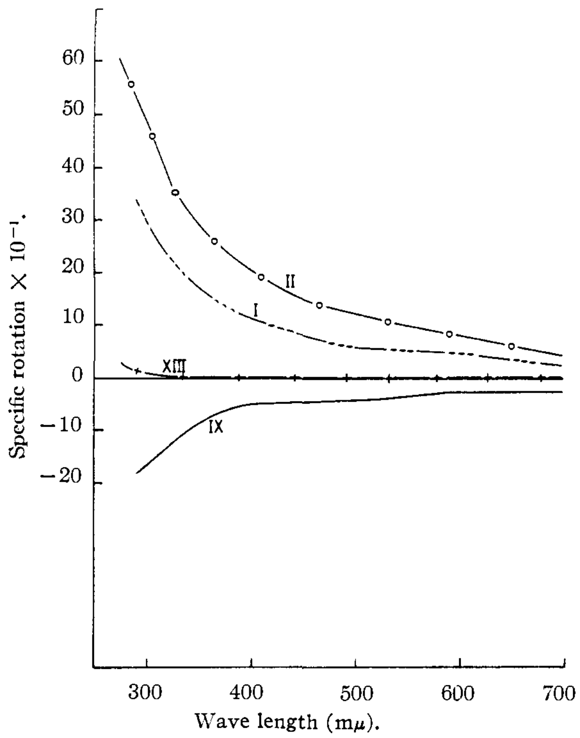

Fig. 1.–Optical rotatory dispersion curves (dioxane solution) of Δ^{12}-oleanene (I), methyl 3-deoxyoleanolate (II), $\Delta^{13(18)}$-oleanene (IX) and Δ^{18}-oleanene (XIII).

isomers as well as an examination of the effect of hydroxyl and ester functions upon the "background" dispersion. In the cholestane series,[14] placement of an isolated double bond into various positions in rings A or B was accompanied in several instances by marked changes in slope and even sign of the plain dispersion curve and since double bond isomers in rings C, D and E are available among the oleanene triterpenes, it was of interest to see whether such an effect was also noticeable here.

The parent compound of the series is Δ^{12}-oleanene (I), since it possesses the two features typical of virtually all members of the β-amyrin (oleanene) class—a D/E *cis* juncture (18β-hydrogen) and a double bond at 12–13. Its rotatory dispersion curve (Fig. 1) is characterized by a positive plain dispersion curve. Replacement of the angular methyl group at C-17 by a carbomethoxy substituent (II) increases the slope (Fig. 1) while addition of the ubiquitous 3β-hydroxyl group as in methyl oleanolate (III) produces no further change as compared to the curve of its 3-desoxy analog II, and this applies also to the type of substitution found in erythrodiol diacetate (IV). Another interesting comparison is that between methyl oleanolate (III) and methyl 11-deoxoglycyrrhetate (V), the only structural difference being the site of the carbomethoxyl function. As indicated in the Experimental section, the dispersion curve of the latter shows a somewhat steeper increase toward lower wave length. This is not the case with methyl myritillogeneate 3-monoacetate (VI),[15] whose curve again resembles closely that of methyl oleanolate (III), and this may be either a reflection of the additional substituents of VI or else it indicates that the carbomethoxyl group attached to C-20 possesses the α-orientation[16] in contrast to the β-orientation[17] of V.

The ursane and oleanane groups differ only in the nature of the methyl substitution in ring E[18] and the rotatory dispersion curves of two typical members of the former class, α-amyrin acetate (VII) and methyl ursolate (VIII), do not show any marked alterations, both of them exhibiting positive plain dispersion curves.

The paucity of saturated oleanane and ursane derivatives is due to their non-occurrence in nature and the difficulty[9] in reducing the 12,13-double bond, since this is completely resistant to catalytic hydrogenation. On the other hand, in the Δ^{12}-oleanene (I) series, exposure to mineral acid causes partial migration to the 13,18-position (IX). The resulting equilibrium mixture is extremely difficult to separate, but Spring and associates[19] have succeeded in preparing pure $\Delta^{13(18)}$-oleanene (IX). Its rotatory dispersion curve (Fig. 1) exhibits a *negative* sign, in contrast to the plain *positive* curve of its Δ^{12}-isomer I. This negative curve is not altered upon further substitution by a hydroxyl group at C-3 (X) or by acetoxyl functions at C-3 and C-24 (XI). The negative drift caused by the 13,18-double bond is so pronounced that it is already felt to an appreciable extent at the sodium D line (589 mμ), but this difference is greatly magnified in the ultraviolet region as can be seen from an inspection of Fig. 1. For purposes of determining the composition of a mixture of I and IX or one of their derivatives, determination of the rotation at a wave length below 300 mμ would be much more suitable than at 589 mμ.

A negative plain dispersion curve *per se* does not necessarily imply the presence of a 13,18-double bond, since such a negative one was also observed (see Experimental) with 22-deoxydumortierigenin acetate (XIIa),[20] where the location of the double bond between C-12 and C-13 was established chemically by conversion to erythrodiol diacetate (IV). Rather this appears to be the result of a conformational deformation, produced by the lactone ring, which manifests itself not only in the chemical behavior[20] of this double bond but also in the rotatory dispersion curves of some of its carbonyl-containing derivatives (*vide infra*).

Further movement of the double bond as in Δ^{18}-oleanene (XIII)[21] or its corresponding alcohol,

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[14] C. Djerassi, W. Closson and A. E. Lippman, THIS JOURNAL, **78**, 3163 (1956).

[15] C. Djerassi and H. G. Monsimer, *ibid.*, **79**, 2901 (1957).

[16] The α-orientation (equatorial) was originally assigned (ref. 15) to myrtillogenic acid since the rate of saponification of its methyl ester was considerably more rapid than that of the axially (β)-oriented (ref. 17) V. Some doubt, however, was thrown on the validity of this conclusion by the observation (private communication from Dr. J. W. W. Morgan) that the methyl ester of katonic acid, which has been shown to be Δ^{12}-3α-hydroxyoleanene-29-oic acid (see F. E. King and J. W. W. Morgan, *Proc. Chem. Soc.*, 228 (1957)), is saponified even more readily.

[17] J. M. Beaton and F. S. Spring, *J. Chem. Soc.*, 3126 (1955).

[18] See A. Melera, D. Arigoni, A. Eschenmoser, O. Jeger and L. Ruzicka, *Helv. Chim. Acta*, **39**, 441 (1956), and E. J. Corey and E. W. Cantrall, THIS JOURNAL, **81**, 1745 (1959).

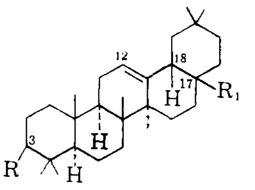
[19] G. Brownlie, M. B. F. Fayez, F. S. Spring, R. Stevenson and W. S. Strachan, *J. Chem. Soc.*, 1377 (1956).

[20] C. Djerassi, C. H. Robinson and D. B. Thomas, THIS JOURNAL, **78**, 5685 (1956).

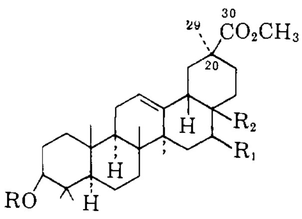
[21] S. David, *Bull. Soc. Chim. France*, 427 (1949).

germanicol (XIV),[21] again restored a plain positive curve (Fig. 1), the steepness of its slope, however, being reduced very considerably as compared to that of Δ^{12}-oleanene (I). Replacement of the C-17 angular methyl group of germanicol (XIV) by a carbomethoxy substituent as in methyl morolate (XV)[22] increased the slope of the curve to an even more marked extent than had been observed (Fig. 1) in the analogous transformation (I → II) in the Δ^{12}-oleanene series.

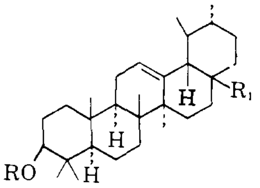
A final illustration of the information which can be gained from plain dispersion curves can be offered in the third important group of triterpenes, namely lupeol (XVI)[23] and its relatives. This series is characterized by a saturated nuclear skeleton, the double bond being present in an isopropenyl function attached to a five-membered ring E. Lupeol (XVI) and its acetate XVII exhibit a plain, positive dispersion curve, but the latter's hydrogenation product, lupanol acetate (XVIII) now shows a weakly negative one. From the two dispersion curves, a suitable wave length can be selected where the divergence in rotations of XVII and XVIII is most pronounced, and as can be seen from the Experimental section, at 290 mμ their respective rotations differ by 304°.



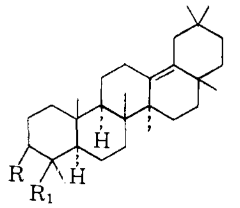
I, R = H; $R_1 = CH_3$
II, R = H; $R_1 = CO_2CH_3$
III, R = OH; $R_1 = CO_2CH_3$
IV, R = OAc; $R_1 = CH_2OAc$



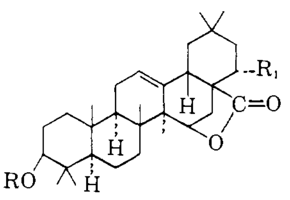
V, R = R_1 = H;
$R_2 = CH_3$
VI, R = Ac;
R_1 = OH;
$R_2 = CH_2OH$



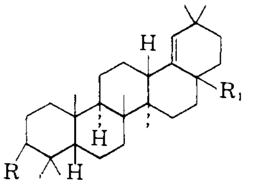
VII, R = Ac;
$R_1 = CH_3$
VIII, R = H;
$R_1 = CO_2CH_3$



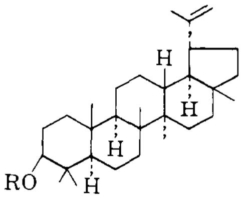
IX, R = H; $R_1 = CH_3$
X, R = OH; $R_1 = CH_3$
XI, R = OAc; $R_1 = CH_2OAc$



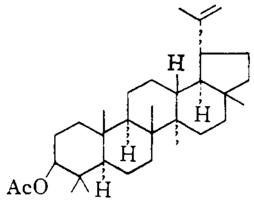
XIIa, R = Ac;
R_1 = H
b, R = H;
R_1 = OH



XIII, R = H; $R_1 = CH_3$
XIV, R = OH; $R_1 = CH_3$
XV, R = OH; $R_1 = CO_2CH_3$



XVI, R=H
XVII, R=Ac



XVIII

Rotatory Dispersion of Triterpenes with Unconjugated Carbonyl Groups.—Since virtually all naturally occurring triterpenoids possess an oxygen function at C-3, special attention has been paid to the effect of remote substituents upon the rotatory dispersion of 3-keto triterpenoids. This was particularly pertinent since Barton and collaborators[24] have attempted to relate in a quantitative manner the rate of benzylidene formation of these ketones with structural alterations in distant rings, thus demonstrating the existence of conformational transmission over a considerable distance. As pointed out in one of our earlier papers[7a] which also included rotatory dispersion curves of a variety of tetracyclic triterpenes, the conformational environment of a given ketone plays a crucial role in determining the character of the rotatory dispersion curve and there appeared to exist some relationship between Barton's kinetic data[24] and our rotatory dispersion results. Additional comment on this point will be made below.

β-Amyrone (XIX) represents the parent substance in the oleanane series and its rotatory dispersion curve (Fig. 2) is characterized by a positive

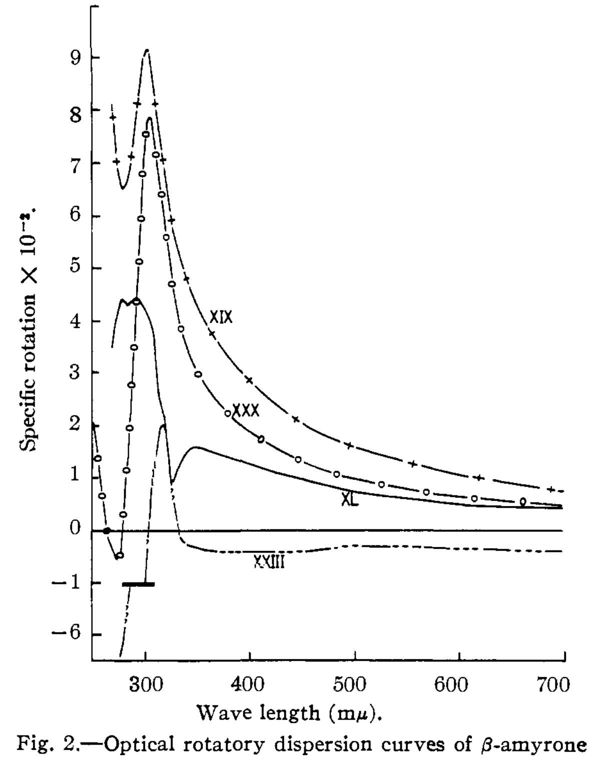


Fig. 2.—Optical rotatory dispersion curves of β-amyrone (XIX) (methanol), $\Delta^{13(18)}$-oleanen-3-one (XXIII) (dioxane), hydroxydammarenone-II (XXX) (methanol) and methyl sumaresinonate 3-acetate (XL) (dioxane).

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[22] D. H. R. Barton and C. J. W. Brooks, *J. Chem. Soc.*, 257 (1951).

[23] T. G. Halsall, E. R. H. Jones and G. D. Meakins, *ibid.*, 2862 (1952) and references cited.

[24] D. H. R. Barton, A. J. Head and P. J. May, *ibid.*, 935 (1957).

Cotton effect curve. In dioxane solution the trough is usually not discernible in 3-ketones of the oleanene series (see Experimental), but when measurements are conducted in methanol solution (see Fig. 2) it will be seen that the dispersion curve is quite unsymmetrical, the trough appearing usually on the positive side. This applies also to substituted derivatives (XX, XXI) or even to the 18α-isomer XXII,[19] where rings D and E are *trans* fused. When a strong "background" rotation of opposite sign is present—*e.g.*, the negative plain dispersion of $\Delta^{13(18)}$-oleanene (IX)—then the positive Cotton effect of the corresponding ketone XXIII ($\Delta^{13(18)}$-oleanen-3-one)[19] is shifted accordingly (see Fig. 2) with the trough now occurring on the negative side. The unsymmetrical character of the Cotton effect curve of β-amyrone (XIX) and its relatives is largely due to the rather strong positive background rotation of the Δ^{12}-oleanene system and this can be established graphically by subtracting the curve of I from that of β-amyrone (XIX). All the other 3-ketones of this group (XXIV–XXVII) possess positive Cotton effect curves (see Experimental section) with some differences in amplitude[4] which may be a reflection of the various substituents or stereochemical arrangements in rings D and E. The general shape of the dispersion curve is, however, of the β-amyrone (XIX) type and it is interesting to note that all of these ketones condense with benzaldehyde at a similar rate.[24] We consider this significant, since the shape of the dispersion curve (Fig. 2) of β-amyrone (XIX) is very similar to that[25] of Δ^8-lanosten-3-one (XXXVIII), but completely different from that of Δ^7-lanosten-3-one (XXXIX), which is characterized by a negative Cotton effect.[25] Similarly, Barton, Head and May[24] have found that the rate of benzaldehyde condensation with β-amyrone (XIX) and Δ^8-lanosten-3-one (XXXVIII) is virtually identical, while that of Δ^7-lanosten-3-one (XXXIX) is greatly reduced. We have already indicated[7a] that these conformational effects cannot be attributed to any great extent to a 1,3-diaxial interaction between the C-4 and C-10 methyl groups[24] and this can be seen further from an inspection of the dispersion curves (see Experimental) of the methyl hedragonate derivatives[26] XXVIII and XXIX. The conformational factors responsible for the great divergence in chemical behavior[24] or shape of rotatory dispersion curve in closely related compounds (XXXVIII *vs.* XXXIX) on the one hand and the similarity by these two criteria of structurally dissimilar ketones (*e.g.*, XIX *vs.* XXXVIII) are not clearly understood and may be due to two or more factors.[7a] The interaction of the axial angular methyl groups at C-8 and C-10 must also be taken into consideration, especially since we have now observed that the rotatory dispersion curve (Fig. 2) of hydroxydammarenone-II (XXX)[27] bears considerable resemblance[28] to that of β-amyrone (XIX), while related tetracyclic triterpenes[7a] lacking the C-8 methyl group show an inverted (negative Cotton effect) curve associated with the "4,4-dimethyl effect."[7a]

The situation in the α-amyrin series is substantially the same, the rotatory dispersion curve of α-amyrone (XXXII) closely resembling that (Fig. 2) of β-amyrone (XIX). Even the relationship between the dispersion curves (see Experimental) of methyl β-boswellonate (XXXIII)[29] and nor-β-boswellenone (XXXIV) is very similar to that existing between the hedragonate derivatives XXVIII and XXIX and methyl oleanonate (XX).

The rotatory dispersion curves (see Experimental) of lupenone (XXXV) and lupanone (XXXVI) offer another example of the influence of the "background" rotation since the positive Cotton effect of lupanone (XXXVI) occurs at considerably lower rotation values than that of lupenone (XXXV) due to the negative plain curve associated (*vide supra*) with the saturated lupane system (*e.g.*, XVIII). This marked effect of the isolated double bond in the side chain is not reflected in the chemical behavior of the two ketones, since their rates of condensation with benzaldehyde[24] are virtually identical, and the rotatory dispersion curves of XXXV and XXXVI in fact become very similar if account is taken in each instance of the background rotation (XVII and XVIII). The constitution of melaleucic acid[30] is not yet completely settled,[31] although it is almost certainly a derivative of betulinic acid with another carboxyl group. Support for this structural assignment can now be offered by rotatory dispersion means, since the curve of the 3-ketone of methyl dihydromelaleucate (XXXVII with one additional carbomethoxyl group) is very similar (see Experimental) to that of lupanone (XXXVI).

Turning now to carbonyl groups in other positions of the pentacyclic triterpene skeleton, the most readily available triterpene with a hydroxyl group at C-6 is sumaresinolic acid.[32] The derived 6-ketone, methyl sumaresinonate 3-acetate (XL), has a negative Cotton effect curve (Fig. 2) on a positive background.[32a] Apparently, the Cotton effect is of such weak amplitude that the positive "background" rotation of the Δ^{12}-oleanene system (*e.g.*, III) governs the sign. This is in contrast to the fairly strong negative Cotton effect shown[13,14] by 6-keto steroids and this difference may reflect a conformational distortion of ring B imposed by the

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(25) See Fig. 11 in ref. 7a.

(26) D. H. R. Barton and P. de Mayo, *J. Chem. Soc.*, 887 (1954).

(27) J. S. Mills, *ibid.*, 2196 (1956). For stereochemistry at C-13 and C-17 see J. F. Biellmann, P. Crabbé and G. Ourisson, *Tetrahedron*, **3**, 303 (1958).

(28) The trough occurs at a more negative value but this may actually be due to the "background" rotation of the system since the plain, positive dispersion curve of the corresponding alcohol, dammarenediol-II (XXXI), does not have as steep a slope (see Experimental) as that of I.

(29) See J. L. Beton, T. G. Halsall and E. R. H. Jones, *J. Chem. Soc.*, 2904 (1956).

(30) H. R. Arthur, A. R. H. Cole, K. J. L. Thieberg and D. E. White, *Chemistry & Industry*, 926 (1956).

(31) D. E. White, *Nature*, **182**, 300 (1958).

(32) See C. Djerassi, G. H. Thomas and O. Jeger, *Helv. Chim. Acta*, **38**, 1304 (1955), and earlier references.

(32a) *Note added in proof.*—An illustration of the use to which this characteristic dispersion curve (Fig. 2) can be put in structure work is the novel triterpene zeorin (D. H. R. Barton, P. de Mayo and J. C. Orr, *J. Chem. Soc.*, 2239 (1958). Its secondary hydroxyl group is almost certainly located at C-6, but independent evidence is desirable. The rotatory dispersion curve of the derived ketone, zeorinone (kindly supplied by Prof. D. H. R. Barton), is sufficiently similar (see Experimental) to that of the authentic 6-ketone XL as to afford strong support for the location of this oxygen atom at C-6 as well as for the stereochemical identity at C-5 of zeorin and sumaresinolic acid.

serious diaxial interactions between the methyl groups at positions 4, 8 and 10.

Saturated 11-ketones in the triterpene series were not available to us, but measurements could be conducted with a number of 12-ketones. Of particular interest is the α-amyrin (ursane) series, since considerable confusion exists in the literature[33] on the formation and stereochemistry of the products. Originally, it was believed that the initial product formed by oxidation of α-amyrin acetate (VII) with ozone or hydrogen peroxide was an oxide (XLI) which was rearranged with acid to a ketone. Spring and associates[33] assumed that a ketone (XLII) was formed directly, which then underwent isomerization to the more stable form XLIII. Finally, Fieser's group[34] showed that all three products could be isolated provided proper experimental precautions are taken and we have been able to confirm these structural conclusions fully by means of rotatory dispersion as illustrated in Fig. 3. Thus, the initial product, α-amyrin oxide (XLI), exhibits only a plain, positive dispersion curve, as would be expected of a substance lacking a carbonyl group. The primary product of mild acid treatment, in spite of the doubts expressed,[34] can safely be assigned[33] the 13α-orientation (XLII) for reasons discussed below. Its acetate XLIIa (see Fig. 3) or benzoate XLIIb (see experimental) now show Cotton effect curves with a peak of over 1000°, while the product of more drastic acid treatment should be represented as the 13β-isomer XLIII. Its rotatory dispersion curve (Fig. 3) is also characterized by a positive Cotton effect, but this is now moved to considerably lower rotation values as compared to XLII and this affords now a very ready means of recognizing the stereochemistry at C-13 of a 12-ketoursane. The reason for the considerable differences in the rotatory dispersion curves of the two isomers XLII and XLIII is most likely due to a major conformational alteration in the unstable 13α-isomer, since the steric interaction between the 8β-methyl and 17β-methyl groups is so severe as to make quite impossible the existence of an all-chair stereochemistry. This is undoubtedly the driving force in the isomerization of the 13α- (XLII) to the 13β- (XLIII) isomer, since in the latter the interference between the methyl groups attached to C-8 and C-17 is now eliminated completely.

The sensitivity of rotatory dispersion to conformational distortion—especially if it occurs in close proximity to the carbonyl chromophore—is further illustrated in Fig. 3 by considering the curve of 13β-oleanan-3β-ol-12-one acetate (XLIV), which possesses exactly the same stereochemistry as the 13β-ursane derivative XLIII, the only difference being the shift of the C-19 methyl group in the latter to C-20. Nevertheless the rotatory dispersion curves of these two ketones are actually of mirror image type and we believe that this grossly distinct dispersion picture can again be ascribed to conformational distortion. In the oleanan-12-one (XLIV), an all-chair conformation can be constructed with models without difficulty. In the corresponding ursane derivative XLIII, the steric situation—though greatly improved over its 13α-isomer XLII—is still not very favorable, the equatorial C-19 methyl group causing serious crowding with the C-12 carbonyl function and to a lesser extent also with the angular methyl group attached to C-14. This steric interference probably accommodates itself by some departure from the all-chair arrangement found in the 12-keto-oleanane series (XLIV) and this in turn produces a steric environment around the carbonyl group (which is responsible for the Cotton effect) of XLIII sufficiently different so as to modify greatly the shape of the rotatory dispersion curve. It is pertinent to mention that most of our considerations about conformations proceed in terms of perfect chairs and boats, because at the present time there is not available a satisfactory way of dealing with distorted ones. As is pointed out several times in this paper, the latter situation must arise rather frequently in polycyclic systems exhibiting many 1,3-diaxial interactions.

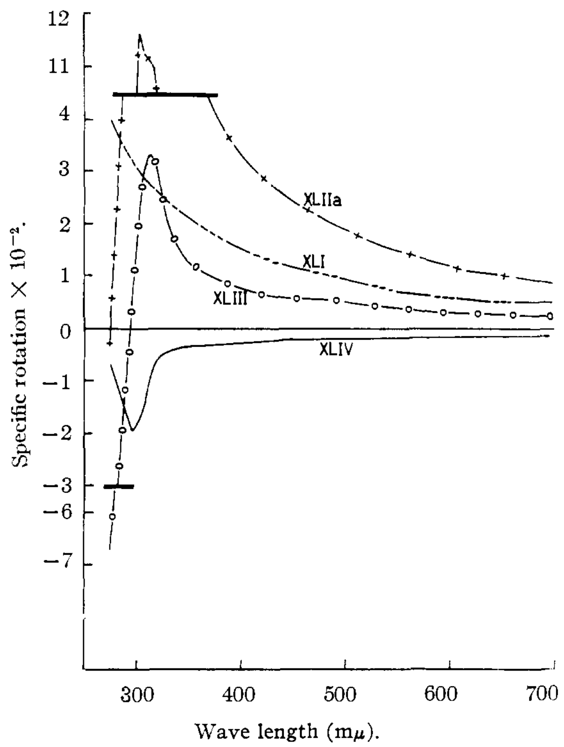

Fig. 3.—Optical rotatory dispersion curves (dioxane solution) of α-amyrin 12,13-oxide (XLI), 13α-ursan-3β-ol-12-one (XLIIa), 13β-ursan-3β-ol-12-one acetate (XLIII) and 13β-oleanan-3β-ol-12-one acetate (XLIV).

The only naturally occurring triterpene for which the presence of an oxygen function at C-15 has been demonstrated[20] rigorously is dumortierigenin (XIIb)[35] and this has been transformed[20] into 15-ketoerythrodiol diacetate (XLV). Its rotatory dispersion curve (Fig. 4) with its negative Cotton effect can now be safely considered as a standard for other 15-keto-β-amyrin derivatives, especially since its curve is roughly antipodal to that (see Experimental) of 9α-methyl-Δ^7-ergosten-3β-ol-11-one ace-

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(33) For leading references see G. G. Allan, F. S. Spring and R. Stevenson, *J. Chem. Soc.*, 3072 (1955).

(34) I. A. Kaye, M. Fieser and L. F. Fieser, THIS JOURNAL, **77**, 5936 (1955).

(35) C. Djerassi, E. Farkas, A. J. Lemin, J. C. Collins and F. Walls, *ibid.*, **76**, 2969 (1954).

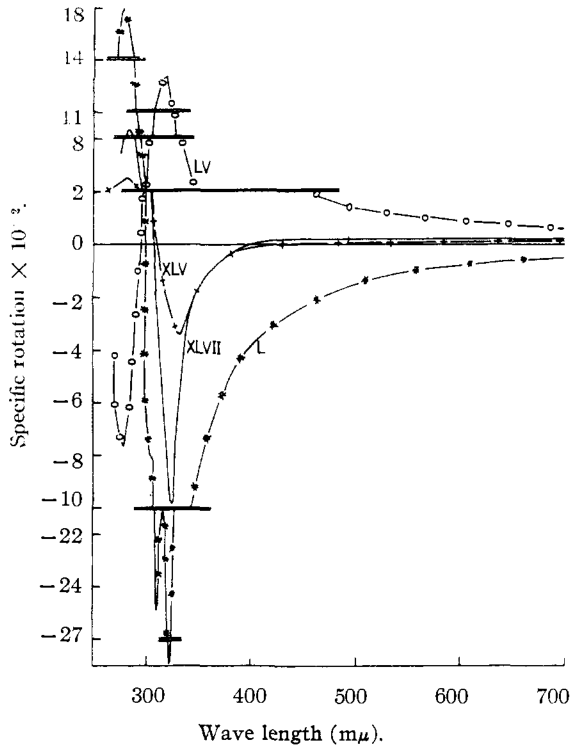

Fig. 4.—Optical rotatory dispersion curves of 15-ketoerythrodiol diacetate (XLV) (methanol), Δ^{12}-oleanen-3β-ol-16-one (XLVII) (dioxane), norechinocystenolone acetate (L) (dioxane) and methyl 19-keto-oleanolate 3-acetate (LV) (methanol).

tate (XLVI).[36] This is to be expected since the relevant stereochemical environment around the carbonyl group is virtually identical in both substances—readily discernible by rewriting XLVI as expression XLVIa—except for bearing a mirror image relationship.

Introduction of a keto group in position 16 of the β-amyrin system imposes a rather strong negative Cotton effect upon the rotatory dispersion curve. This is apparent from Fig. 4, where the curve of Δ^{12}-oleanen-3β-ol-16-one (manilaolone) (XLVII)[37] is reproduced, and from the Experimental section where the rotatory dispersion data are listed for methyl 16-keto-oleanolate (XLVIII)[38] and methyl Δ^{12}-oleanen-3β,28-diol-16-one-29-oate 3-acetate (IL).[15] In the latter case, rotatory dispersion played an important role in its structure elucidation.[15] The rotatory dispersion curve (Fig. 4) of norechinocystenolone acetate (L)[38,39] also shows a strong negative Cotton effect with marked resolution (in dioxane solution) of the trough. Such separation has been observed in this work with a number of saturated ketones, but the resolution is particularly effective in this example. The negative Cotton effect supports the assignment of a β-orientation (D/E *cis* juncture) to the hydrogen atom at the invertible position as would be expected for a product prepared[38,39] under conditions favoring the thermodynamically preferred isomer. Rings C, D and E of L represent essentially a *trans-syn-cis*-perhydrophenanthrene system which is known[40] to be more stable than the *trans-syn-trans* isomer where a boat form is required for the central ring. Noller and collaborators[39,41] working in the corresponding diketone series have isolated both possible isomers of the 28-nor-3,16-dione LI. The stable isomer corresponds in terms of rotation as well as method of preparation to the above discussed norechinocystenololone acetate (L) and therefore should be assigned the 17β-orientation (LI). The unstable isomer, produced by *in situ* decarboxylation[41] of diketoechinocystic acid (LIII) must possess the 17α-orientation (D/E juncture *trans*)—thus reversing the stereochemical assignments made earlier by Alves and Noller[42]—and it is interesting to speculate that decarboxylation of such β-keto acids may be a general route to the inaccessible *trans-syn-trans*-perhydrophenanthrene system.[43]

The negative Cotton effect associated with the 16-keto group is so strong as to overcome the positive one of a 3-keto function. Both 3,16-diketones LII[39] and LIV[15] exhibited a strong negative Cotton effect curve, which did *not* represent the summation of dispersion curves of the individual 3- and 16-monoketones.

Finally, there have been examined a series of Δ^{12}-oleanene derivatives with keto groups in ring E. Methyl 19-keto-oleanolate 3-acetate (LV), readily obtainable[44] from siaresinolic acid, showed a positive Cotton effect (Fig. 4) while the corresponding 21-ketone LVI (methyl machaerate[45]) possessed a negative one (Fig. 5), resolution of the trough being again quite noticeable. A negative Cotton effect is also associated with a carbonyl group at C-22 as was observed in measurements with certain derivatives of chichipegenin.[46] Both 22-ketones[46] LVII and LVIII exhibited the same type of negative Cotton effect curve (see Fig. 5 and Experimental) and it is pertinent to note that the bulky trityl ether grouping of LVII did not interfere with the experimental measurements. The 22-ketone LIX derived from dumortierigenin (XIIb)[20,35] still retained a negative Cotton effect (Fig. 5), but the peak now appeared on the negative side. This is only in part due to the negative "background" rotation observed above in this series—as can be seen by subtracting the curve of XIIa from that of LIX—and another factor operating is the conforma-

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(36) E. R. H. Jones, G. D. Meakins and J. S. Stephenson, *J. Chem. Soc.*, 2156 (1958).

(37) O. Jeger, M. Montavon and L. Ruzicka, *Helv. Chim. Acta*, **29**, 1124 (1946).

(38) C. Djerassi, G. H. Thomas and H. Monsimer, THIS JOURNAL, **77**, 3579 (1955).

(39) W. R. White and C. R. Noller, *ibid.*, **61**, 983 (1939).

(40) W. S. Johnson, *Experientia*, **7**, 8 (1951).

(41) R. N. Jones, D. Todd and C. R. Noller, THIS JOURNAL, **61**, 2421 (1939).

(42) F. A. Alves and C. R. Noller, *ibid.*, **74**, 4043 (1952).

(43) A similar pair of isomers, using the same method as employed by Noller (ref. 39, 41), has been obtained by Barton and de Mayo (ref. 26) in the icterogenin series, the second keto group being at C-22 rather than C-16. Using the same reasoning as applied above to Noller's pair of norechinocystene-3,16-diones, stereochemical assignments can now be made to Barton and de Mayo's two isomeric 3,22-diketones; the unstable isomer (m.p. 212–217°) should have the 17α-, and the stable isomer (m.p. 220–226°) the 17β-orientation.

(44) P. L. Bilham, G. A. R. Kon and W. C. J. Ross, *J. Chem. Soc.*, 540 (1942).

(45) C. Djerassi and A. E. Lippman, THIS JOURNAL, **77**, 1825 (1955).

(46) A. Sandoval, A. Manjarrez, P. R. Leeming, G. H. Thomas and C. Djerassi, *ibid.*, **79**, 4468 (1957).

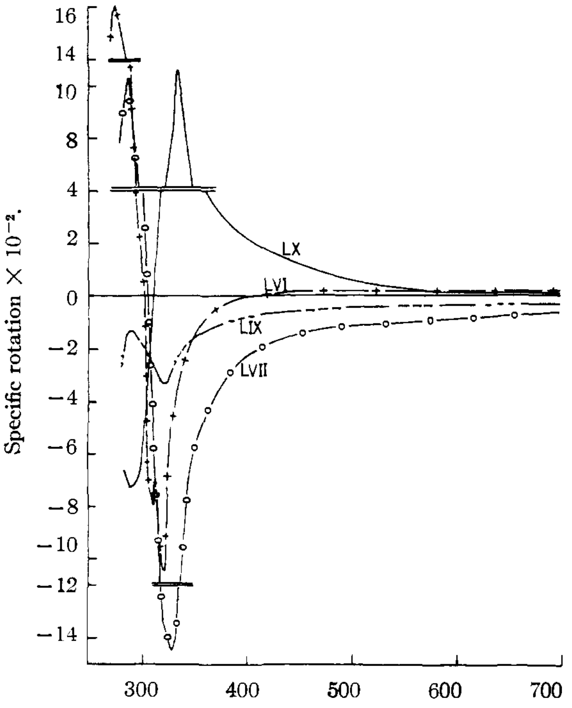

Fig. 5.—Optical rotatory dispersion curves of methyl machaerate (LVI) (dioxane), Δ^{12}-oleanen-3β,16β,28-triol-22-one 3,16-diacetate 28-trityl ether (LVII) (dioxane), 22-dehydrodumortierigenin 3-acetate (LIX) (methanol) and trisnorlupanonyl acetate (LX) (dioxane).

tional alteration involved in construction of the five-membered lactone ring.

The use of rotatory dispersion studies for stereochemical assignments can be documented further by considering certain ketones of triterpenes possessing a five-membered E ring. While the stereochemistry of the D/E ring juncture (*trans*) has been established conclusively for lupeol (XVI)[23] and its relatives,[47] this does not apply to the corresponding trisnor-19-ketones, especially since the stability of fused hydrindanones[48] cannot be predicted safely. However, just as with the C-14 epimeric 15-keto steroids,[6a] a stereochemically decisive answer can be obtained from rotatory dispersion considerations, using the strongly positive Cotton effect[6a] of the steroidal ketone LXV as a reference standard. As can be seen from Fig. 5, trisnorlupanonyl acetate (LX)[49] shows a positive Cotton effect and this also applies (see Experimental) to the trisnor-19-ketones of the betulin (LXI)[50] and melaleucic acid (LXII with additional carbomethoxyl group)[30,31] series. Consequently, all of these ketones possess a D/E *cis* junction (the corresponding *trans* isomer would have shown[6a] a negative Cotton effect), isomerization having occurred at C-18 during their preparation.

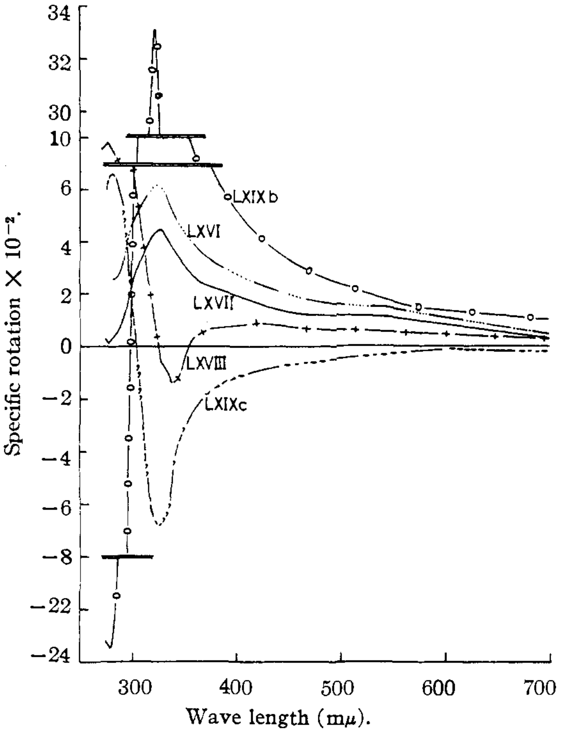

Fig. 6.—Optical rotatory dispersion curves (dioxane solution) of gypsogenin methyl ester (LXVI), methyl quillaiate (LXVII), gummosogenin (LXVIII), friedelan-x-one (LXIXb) and friedelan-y-one (LXIXc).

Another case which is amenable to this type of analysis is 21-ketotrisnorhopane (LXIII), which has been obtained[51] by systematic degradation of hydroxyhopanone (LXIV),[52] a new type of triterpenoid arising by an alternate biosynthetic cyclization of squalene. The rotatory dispersion curve (see Experimental) of the ketone LXIII is characterized by a positive Cotton effect, whose peak occurs almost at the identical rotation value as does that of the positive Cotton effect curve[6a] of the reference steroid LXV. It follows, therefore, that the ketone LXIII must have the $17\alpha,18\alpha$ (D/E *cis*)-orientation as depictured in stereoformula LXIII.

The discussion so far has centered on ketones, largely because of their wide occurrence and ready availability. The only naturally occurring aldehydes with an oleanene skeleton are gypsogenin, quillaic acid and gummosogenin and we have been able to examine the rotatory dispersion curves (Fig. 6) of derivatives of all three. A particularly instructive example is shown in Fig. 6, where it can be seen that the rotatory dispersion curves of gypsogenin methyl ester (LXVI) and methyl quillaiate (LXVII) are so similar as to establish their stereochemical identity in ring A. This particular feature of the chemistry of gypsogenin and quillaic acid was the last one to be elucidated and this was accomplished by a laborious interconversion[53] of quillaic

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[47] J. M. Guider, T. G. Halsall and E. R. H. Jones, *J. Chem. Soc.*, 3024 (1953).

[48] For pertinent discussion see C. Djerassi, T. T. Grossnickle and L. B. High, THIS JOURNAL, **78**, 3166 (1956).

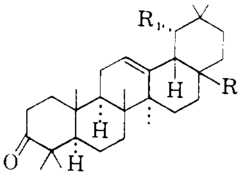
[49] L. Ruzicka, W. Huber and O. Jeger, *Helv. Chim. Acta*, **28**, 195 (1945); G. S. Davy, E. R. H. Jones and T. G. Halsall, *Rec. trav. chim.*, **69**, 368 (1950).

[50] C. Djerassi and R. Hodges, THIS JOURNAL, **78**, 3534 (1956).

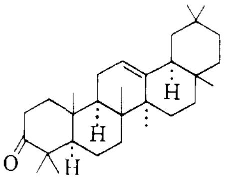
[51] W. J. Dunstan, H. Fazakerley, T. G. Halsall and E. R. H. Jones, *Croat. Chem. Acta*, **29**, 173 (1957).

[52] K. Schaffner, L. Caglioti, D. Arigoni, O. Jeger, H. Fazakerley, T. G. Halsall and E. R. H. Jones, *Proc. Chem. Soc.*, 353 (1957); K. Schaffner, L. Caglioti, D. Arigoni and O. Jeger, *Helv. Chim. Acta*, **41**, 152 (1958).

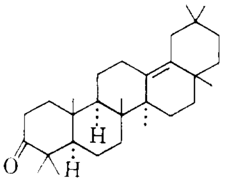
[53] L. Ruzicka, B. Bischof, E. C. Taylor, A. Meyer and O. Jeger, *Coll. Czech. Chem. Comm.*, **15**, 893 (1950).



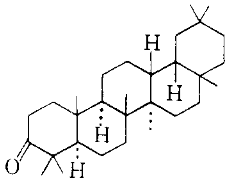
XIX, R = CH_3; R_1 = H
XX, R = CO_2CH_3; R_1 = H
XXI, R = CO_2CH_3; R_1 = OAc



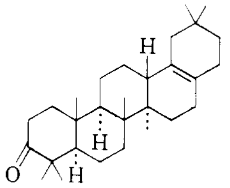
XXII



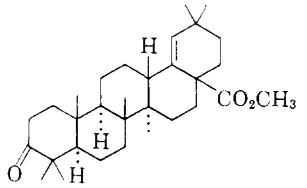
XXIII



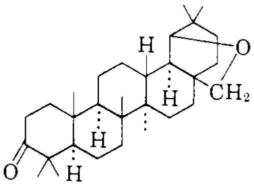
XXIV



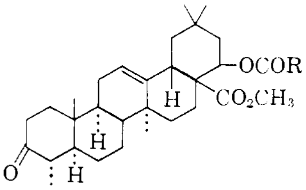
XXV



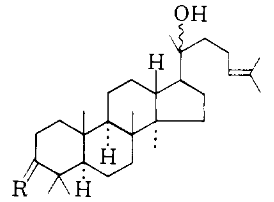
XXVI



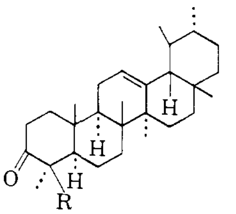
XXVII



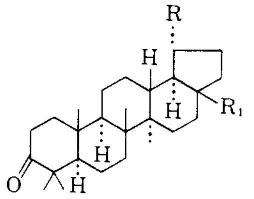
XXVIII, R = C_4H_9
XXIX, R = C_4H_7



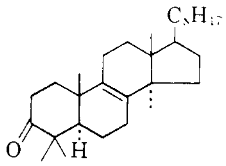
XXX, = O
XXXI, R = $<^{OH}_{H}$



XXXII, R = CH_3
XXXIII, R = CO_2CH_3
XXXIV, R = H



XXXV, R = $\overset{\overset{CH_3}{|}}{C}{=}CH_2$; R_1 = CH_3
XXXVI, R = $CH(CH_3)_2$; R_1 = CH_3
XXXVII, R = $CH(CH_3)_2$; R_1 = CO_2CH_3



XXXVIII

acid (LXVII) with hederagenin[9] which in turn has been related with gypsogenin (LXVI). The stereochemistry of the latter was established in a separate investigation[54] which took advantage of monochromatic molecular rotation evidence accumulated with pertinent diterpenoids. It should be noted that utilization of the rotatory dispersion method would have required chemical evidence for the stereochemistry in ring A of only one aldehyde (LXVI or LXVII), which could then be used as the reference compound in comparing rotatory dispersion curves. Figure 6 also contains the dispersion data of gummosogenin (LXVIII)[55] and it will be noted that the curve is quite different from that of the two triterpenes (LXVI, LXVII) possessing an aldehyde function in ring A, which should facilitate the detection of such groups in new aldehydes of the oleanane series if any additional ones should be discovered in nature. It is noteworthy that the trough of the gummosogenin curve occurs at 340 mμ as compared to 325 mμ for the corresponding peak of the other aldehydes (LXVI, LXVII) and this is completely consistent with the 15 mμ difference found by us in their ultraviolet absorption maxima (LXVI, λ_{max}^{diox} 290 mμ; LXVIII, λ_{max}^{diox}; 305 mμ). This wave length difference may prove to be useful in locating aldehyde groups in unknown triterpenes.

The above discussion of rotatory dispersion data of unconjugated triterpenoid ketones can be summarized by stating that the rotatory dispersion method should prove to be a very desirable adjunct to triterpene methodology, especially as it pertains to the location of carbonyl groups and the determination of certain stereochemical factors in the oleanane group. While the number of relevant examples in the ursane and lupane series is smaller, many of the conclusions from the oleanane group can also be applied to the other two.

A very attractive application of these conclusions would be to locate the ketone group in friedelane-x-one (LXIXb) and friedelane-y-one (LXIXc), two monofunctional degradation products of novel substituted friedelin (LXIXa) derivatives.[56] Unfortunately, except for friedelin (LXIXa)[6a] and some of its brominated derivatives,[57] no rotatory dispersion data are available for other positions of the molecule and the empirical comparison approach cannot be used. Similarly, comparison with bicyclic or steroidal model ketones is fraught with danger in this series because of the unknown conformational distortions[7a] produced by the many axial methyl groups, but it does seem possible to apply the "octant rule"[58] to predict the sign of the rotatory dispersion curve of carbonyl groups in various positions of rings A, B, C and probably also D. Since the presence of an 18β-hydrogen atom, and hence a D/E *cis* juncture in friedelin

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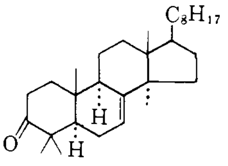
(54) A. Vogel, O. Jeger and L. Ruzicka, *Helv. Chim. Acta*, **34**, 2321 (1951).

(55) C. Djerassi, L. E. Geller and A. J. Lemin, THIS JOURNAL, **76**, 4089 (1954).

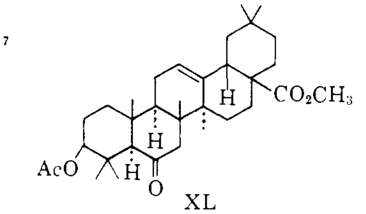
(56) J. L. Courtney and R. M. Gascoigne, *J. Chem. Soc.*, 2115 (1956).

(57) C. Djerassi, J. Osiecki, R. Riniker and B. Riniker, THIS JOURNAL, **80**, 1216 (1958).

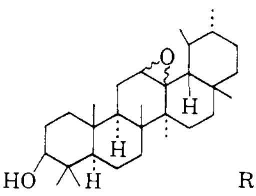
(58) W. Moffitt, A. Moscowitz, R. B. Woodward, W. Klyne and C. Djerassi, in preparation.



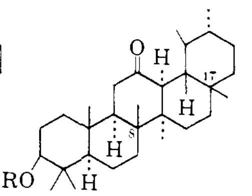
XXXIX



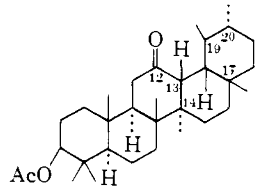
XL



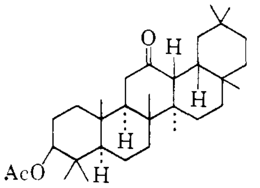
XLI



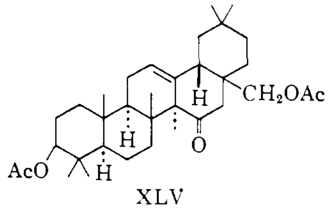
XLIIa, R = H
b, R = Bz



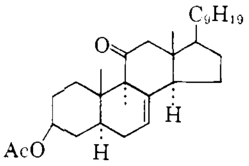
XLIII



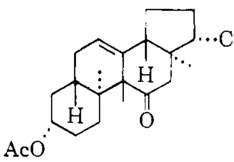
XLIV



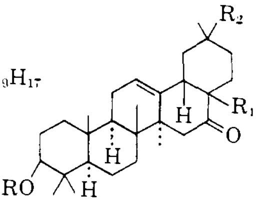
XLV



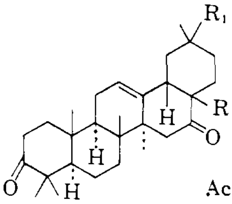
XLVI



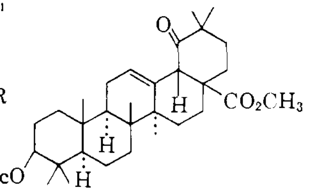
XLVIa



XLVII, R = H; $R_1 = R_2 = CH_3$
XLVIII, R = H; $R_1 = CO_2CH_3$; $R_2 = CH_3$
IL, R = Ac; $R_1 = CH_2OH$; $R_2 = CO_2CH_3$
L, R = Ac; R_1 = H; $R_2 = CH_3$



LI, R = H; $R_1 = CH_3$
LII, R = CO_2CH_3; $R_1 = CH_3$
LIII, R = CO_2H; $R_1 = CH_3$
LIV, R = CH_2OH; $R_1 = CO_2CH_3$



LV

(LXIXa) has been established,[59] the enormous steric interference between the 13α- and 20α-methyl groups precludes a chair form of ring E and may even involve a conformational change of ring D.

The rotatory dispersion curves of friedelan-x-one (LXIXb) and friedelan-y-one (LXIXc) are reproduced in Fig. 6 and they were found to possess Cotton effect curves of opposite sign. With the above reservations in mind concerning conformational distortion, the octant rule[58] would predict[60] positive Cotton effect curves for positions 6, 7 and probably also 15 and 16. Ring A is eliminated on chemical grounds[56] and no predictions can be made about ring E. Of these three possibilities for friedelan-x-one (LXIXb), C-15 can probably be eliminated since it has been reported[56] that this x-keto group can be removed under conditions which failed[20] with 15-ketoerythrodiol diacetate (XLV) and a ketone in position 15 of the friedelane skeleton (LXIX) would be expected to show about the same degree of hindrance. The same statement can also be made about C-7. Both positions 6 and 16 would be compatible with the recorded[56] chemical information.

Friedelan-y-one (LXIXc) shows a negative Cotton effect curve (Fig. 6) and its carbonyl group is even more hindered[56] than that of friedelan-x-one (LXIXb). Ignoring again ring E (for conformational reasons) and eliminating ring A for chemical reasons,[56] only positions 11 and (probably) 12 would be expected[58,60] to cause a negative Cotton effect. Of these, C-12 will be somewhat more hindered than C-11, but no firm distinction can be made between them with the chemical information now available.

While rotatory dispersion has not offered a definite answer concerning the structures of either friedelan-x-one or -y-one and has not been able to offer any information concerning ring E, a consideration of the dispersion curves has nevertheless reduced considerably the number of structural possibilities and to that extent has simplified further chemical work.

Rotatory Dispersion of Triterpenes with α,β-Unsaturated Carbonyl Groups.—The presence of the various angular and *gem*-methyl functions in an intact oleanane system permits only seven different locations for an α,β-unsaturated carbonyl moiety. Since pentacyclic triterpenoids with oxygen functions at C-1 and C-7 are unknown, this reduces further the various possibilities. In fact, virtually all of the chemical work in the triterpene area with α,β-unsaturated ketones has been limited to rings C and E and we have been able to examine typical representatives of most of them.

Glycyrrhetic acid[17,61] is the only naturally occurring triterpene[62] of the oleanane series which possesses an α,β-unsaturated keto moiety in the form of a Δ^{12}-11-keto grouping. The latter is, however, easily introduced chemically by allylic oxida-

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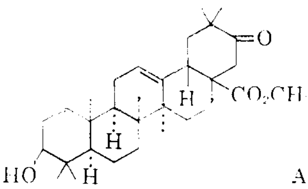
[59] J. L. Courtney, R. M. Gascoigne and A. Z. Szumer, *J. Chem. Soc.*, 881 (1958).

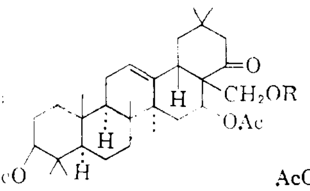
[60] A detailed discussion as to how these predictions are determined will be given in ref. 58.

[61] For structure see: (a) L. Ruzicka and A. Marxer, *Helv. Chim. Acta*, **22**, 195 (1939); (b) L. Ruzicka, O. Jeger and M. Winter, *ibid.*, **26**, 265 (1943); (c) C. Djerassi and C. M. Foltz, THIS JOURNAL, **76**, 4085 (1954).

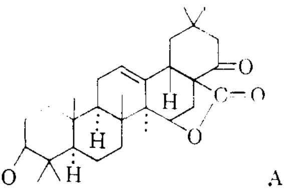
[62] Glabric acid, whose constitution has not yet been established, is probably a hydroxylated derivative of 18α-glycyrrhetic acid; J. M. Beaton and F. S. Spring, *J. Chem. Soc.*, 2417 (1954).



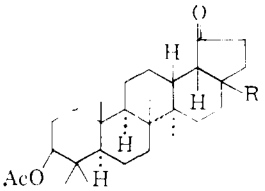
LVI



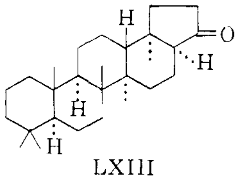
LVII, R = $C(C_6H_5)_3$
LVIII, R = Ac



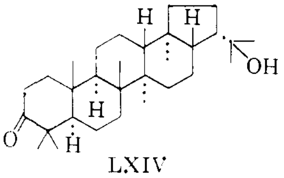
LIX



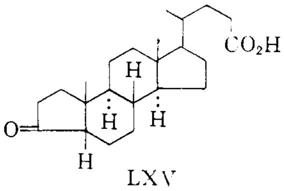
LX, R = CH_3
LXI, R = CH_2OAc
LXII, R = CO_2CH_3



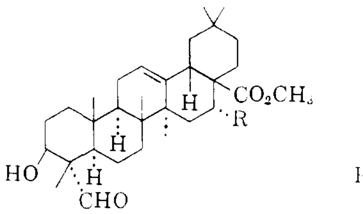
LXIII



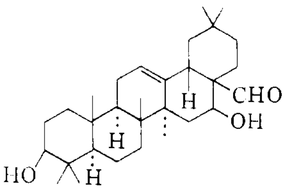
LXIV



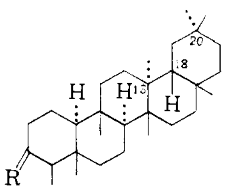
LXV



LXVI, R = H
LXVII, R = OH



LXVIII



LXIXa, R = O
LXIXb, (with x-one); R = H_2
LXIXc, (with y-one); R = H_2

tion[9] and the chemistry of these unsaturated ketones has been studied thoroughly.[9] The rotatory dispersion curve of the methyl ester acetate LXX of glycyrrhetic acid, depicted in Fig. 7, is quite similar to that of a Δ^4-3-keto steroid[63]—a result which is not too surprising since the stereochemistry of the respective octalone systems (rings C and D in LXX) is identical. The dispersion curve of the corresponding ursane representative, 11-keto-α-amyrin acetate (LXXI),[64] is of the same type (Fig. 7) including the identical fine structure in the 390-350 mμ region. Spring's group[65] has demonstrated that in the 11-keto-Δ^{12}-oleanene series, the 18β-hydrogen is invertible by treatment with strong base. The rotatory dispersion curve of such an isomerization product, Δ^{12}-18α-oleanen-3β-ol-11-one acetate (LXXII),[65] is reproduced in Fig. 7 and while it still shows the typical fine structure between 390-350 mμ, this is now shifted very considerably to negative rotation values. This change toward negative rotation attending isomerization of the D/E *cis* to the D/E *trans* juncture appears to be typical and is also found (see Experimental) in methyl 18α-glycyrrhetate (LXXIII).[17] It already has been pointed out[62] that 18α-isomers and 18β-isomers of Δ^{12}-11-keto-oleanene derivatives are not readily distinguishable by spectroscopic means and the above rotatory dispersion results appear to satisfy this need to a considerable extent.

The ultraviolet absorption of 11-ketodumortierigenin (LXXIV)[20] is anomalous in that the maximum[20] occurs at a considerably lower wave length

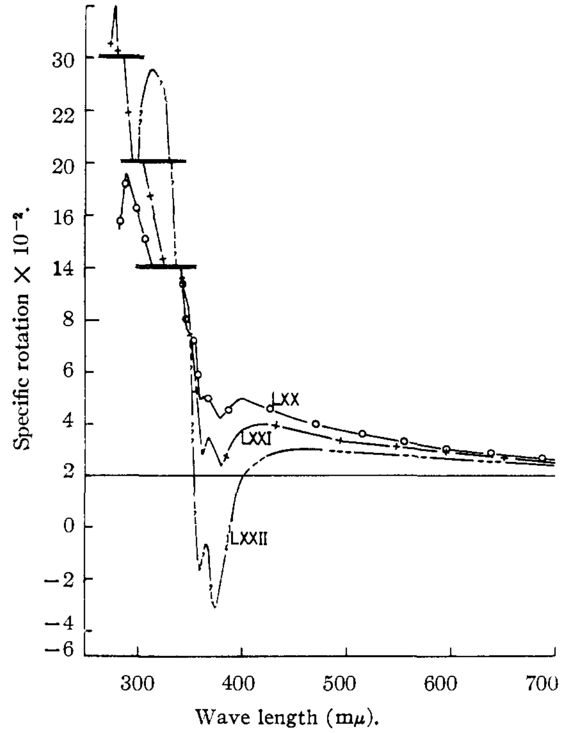


Fig. 7.—Optical rotatory dispersion curves (dioxane solution) of methyl glycyrrhetate 3-acetate (LXX), 11-keto-α-amyrin acetate (LXXI) and Δ^{12}-18α-oleanen-3β-ol-11-one acetate (LXXII).

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[63] (a) E. W. Foltz, A. E. Lippman and C. Djerassi, THIS JOURNAL, **77**, 4359 (1955); (b) C. Djerassi, R. Riniker and B. Riniker, *ibid.*, **78**, 6377 (1956).

[64] F. S. Spring and T. Vickerstaff, *J. Chem. Soc.*, 1859 (1934); 249 (1937).

[65] R. Budziarek, W. Manson and F. S. Spring, *ibid.*, 3336 (1951).

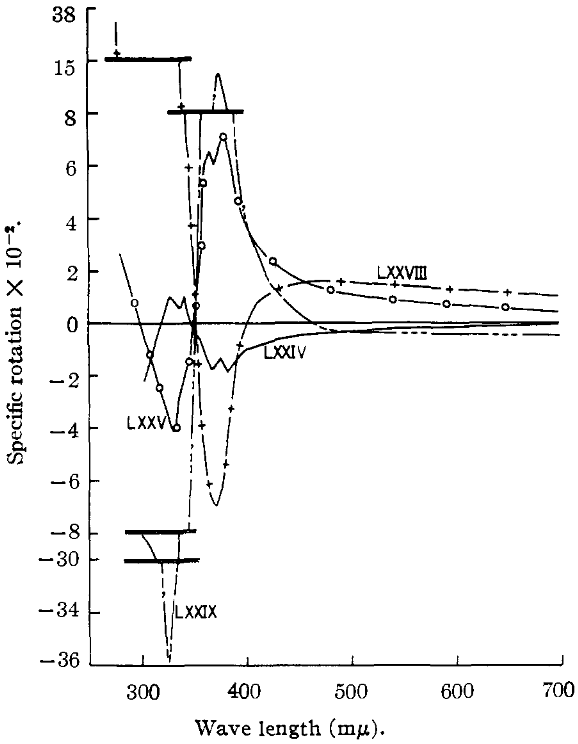

Fig. 8.—Optical rotatory dispersion curves (dioxane solution) of 11-ketodumortierigenin (LXXIV), $\Delta^{9(11)}$-oleanen-3β-ol-12-one acetate (LXXV), $\Delta^{9(11)}$-18α-oleanen-3β-ol-12-one acetate (LXXVIII) and $\Delta^{9(11),14}$-taraxeradien-3β-ol-12-one acetate (LXXIX).

than is usually observed[66] with triterpenoid Δ^{12}-11-ketones and this divergence has been attributed to the additional lactone ring fusion. Consequently, it was of interest to examine the rotatory dispersion of the unsaturated ketone LXXIV and as shown in Fig. 8, its dispersion curve was also rather different from that of the other 18β-Δ^{12}-11-ketones (LXX, LXXI).

Another important group of triterpenoid unsaturated ketones are the $\Delta^{9(11)}$-12-ketones. The reference curve (Fig. 8) is that of $\Delta^{9(11)}$-oleanen-3β-ol-12-one acetate (LXXV)[67] and its multiple Cotton effect is similar in shape to that of 6β-methyltestosterone[7a] and 7-ketocholesteryl acetate,[63b] two steroids whose bicyclic stereochemical environment (in rings A and B) simulates rings B and C of LXXV. The same type of curve was also observed (see Experimental) for the related LXXVI and for $\Delta^{9(11)}$-ursen-3β-ol-12-one acetate (LXXVII),[68] thus demonstrating in a striking manner the complete stereochemical coincidence of the B/C/D/E ring junctures in these α,β-unsaturated ketones of the oleanane and ursane series. The validity of this conclusion is fortified by the observation that when the stereochemistry of the D/E ring fusion is altered as in $\Delta^{9(11)}$-18α-oleanen-3β-ol-12-one acetate (LXXVIII),[69] the character of its rotatory dispersion curve (Fig. 8) suffers a fundamental change.

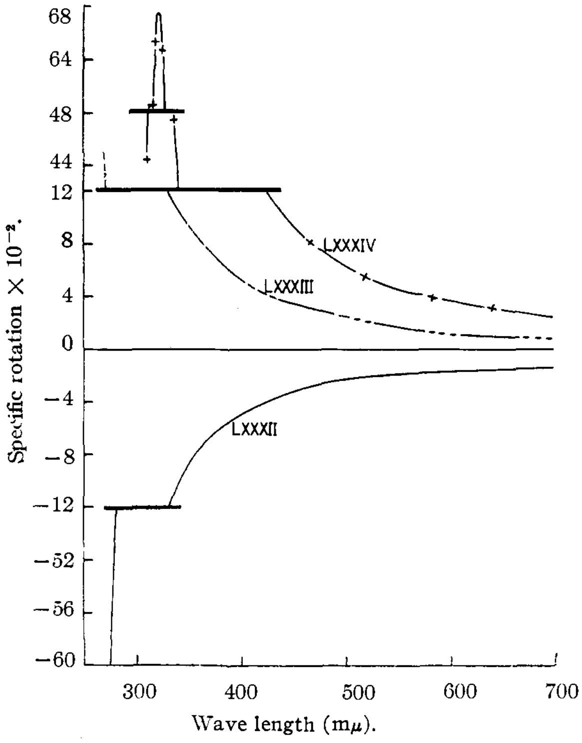

Fig. 9.—Optical rotatory dispersion curves (dioxane solution) of methyl dehydro-oleanonate (LXXXII), methyl isodehydrooleanonate (LXXXIII) and $\Delta^{9(11),12}$-ursadien-3-one (LXXXIV).

Still another instance where rotatory dispersion can offer useful confirmatory evidence for stereochemical questions is in those triterpenes, where the C-27 methyl group has migrated from position 14 to 13. The rotatory dispersion curve of $\Delta^{9(11),14}$-taraxeradien-3β-ol-12-one acetate (LXXIX) is reproduced in Fig. 8 and can be used as a standard since all of its stereochemical features have been established.[70] A similar rearrangement product has been reported[71] in the α-amyrin series ("iso-α-amyradienolone" (LXXX)), but some doubt as to its assigned[68] constitution has been expressed.[72] The similarity of their rotatory dispersion curves (see Fig. 8 and Experimental section) leaves little doubt as to the stereochemical identity of LXXIX and LXXX with respect to their B/C/D/E ring fusions.

An attempt was also made to measure the rotatory dispersion curves of certain 3-keto triterpenes with a diene chromophore in another portion of the molecule. Barton and collaborators[24] included such ketones in their kinetic study and found definite evidence of conformational transmission in LXXXI–LXXXIV. As can be seen from Fig. 9 and the Experimental section, the Cotton effect of the 3-ketone was completely overshadowed by the powerful background dispersion of the heteroannu-

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[66] See C. R. Noller, THIS JOURNAL, **66**, 1269 (1944).

[67] C. W. Picard, K. S. Sharples and F. S. Spring, *J. Chem. Soc.*, 1045 (1939).

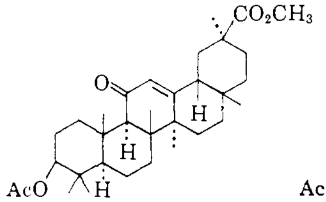
[68] See A. Meisels, O. Jeger and L. Ruzicka, *Helv. Chim. Acta*, **33**, 700 (1950), and earlier references.

[69] G. G. Allan and F. S. Spring, *J. Chem. Soc.*, 2125 (1955).

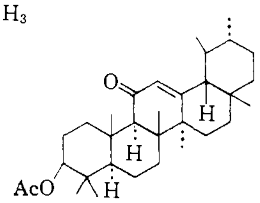
[70] J. M. Beaton, F. S. Spring, R. Stevenson and J. L. Steward, *ibid.*, 2131 (1957).

[71] L. Ruzicka, R. Ruegg, E. Volli and O. Jeger, *Helv. Chim. Acta*, **30**, 140 (1947).

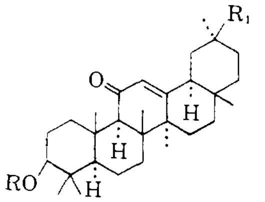
[72] J. McLean, S. U. Ruff and F. S. Spring, *J. Chem. Soc.*, 1093 (1951). See, however, J. M. Beaton, J. D. Easton, M. M. Macarthur, F. S. Spring and R. Stevenson, *ibid.*, 3992 (1955).



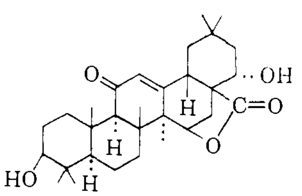
LXX



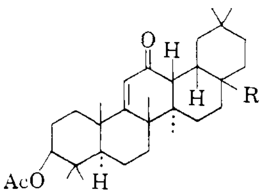
LXXI



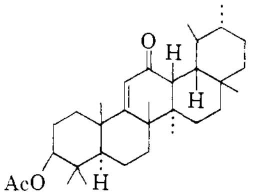
LXXII, $R = Ac; R_1 = CH_3$
LXXIII, $R = H; R_1 = CO_2CH_3$



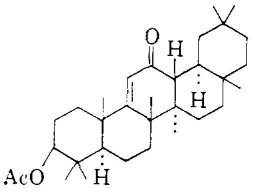
LXXIV



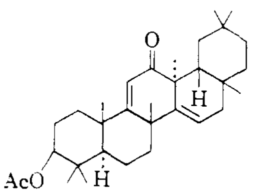
LXXV, $R = CH_3$
LXXVI, $R = CH_2OAc$



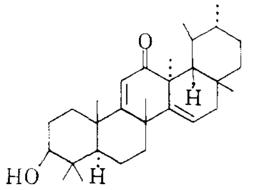
LXXVII



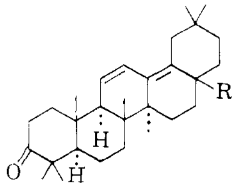
LXXVIII



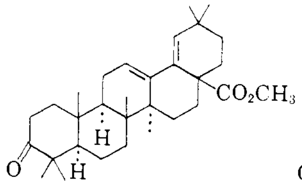
LXXIX



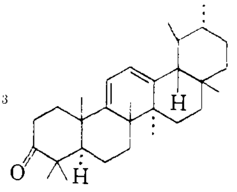
LXXX



LXXXI, $R = CH_3$
LXXXII, $R = CO_2CH_3$



LXXXIII



LXXXIV

lar diene system (LXXXI–LXXXIII) and even in the homoannular $\Delta^{9(11),12}$-ursadien-3-one (LXXXIV), the powerful positive drift ascribable to the diene chromophore makes impossible any deductions concerning the dispersion of the 3-ketone function. The relevant "background" curves on which these conclusions are based can be found at the end of the Experimental section.

Acknowledgment.—We are greatly indebted to the investigators listed in the Experimental section for supplying us with samples, and to Dr. W. Klyne (Postgraduate Medical School, London) for interesting correspondence. In particular, we should like to express our indebtedness to Prof. D. H. R. Barton (Imperial College of Science and Technology, London) and Prof. F. S. Spring (Royal Technical College, Glasgow) who have generously and patiently fulfilled our numerous requests for specimens.

Experimental[73]

Δ^{12}-Oleanene (I) (F. S. Spring), R. D. (Fig. 1) in dioxane (c 0.18): $[\alpha]_{700}$ +23°, $[\alpha]_{589}$ +52°, $[\alpha]_{400}$ +113°, $[\alpha]_{350}$ +173°, $[\alpha]_{325}$ + 224°, $[\alpha]_{300}$ +301°, $[\alpha]_{290}$ +338°.

Methyl 3-deoxy-oleanolate (II),[74] R. D. (Fig. 1) in dioxane (c 0.08): $[\alpha]_{700}$ +46°, $[\alpha]_{589}$ +83°, $[\alpha]_{400}$ +204°, $[\alpha]_{350}$ +286°, $[\alpha]_{325}$ +356°, $[\alpha]_{300}$ +474°, $[\alpha]_{290}$ +535°, $[\alpha]_{280}$ +579°, $[\alpha]_{272.5}$ +612°.

Methyl oleanolate (III), R. D. in dioxane (c 0.1): $[\alpha]_{700}$ +67°, $[\alpha]_{589}$ +76°, $[\alpha]_{400}$ +197°, $[\alpha]_{350}$ +285°, $[\alpha]_{300}$ +476°, $[\alpha]_{290}$ +487°, $[\alpha]_{270}$ +594°.

Erythrodiol diacetate (IV), R. D. in methanol (c 0.09): $[\alpha]_{700}$ +47°, $[\alpha]_{589}$ +73°, $[\alpha]_{400}$ +168°, $[\alpha]_{350}$ +259°, $[\alpha]_{320}$ +336°, $[\alpha]_{300}$ +415°, $[\alpha]_{290}$ +457°, $[\alpha]_{280}$ +513°, $[\alpha]_{270}$ +574°, $[\alpha]_{260}$ +651°, $[\alpha]_{250}$ +746°.

Methyl 11-deoxoglycyrrhetate (V),[75] R. D. in dioxane (c 0.12): $[\alpha]_{700}$ +85°, $[\alpha]_{589}$ +122°, $[\alpha]_{400}$ +312°, $[\alpha]_{355}$ +471°, $[\alpha]_{320}$ +634°, $[\alpha]_{300}$ +800°, $[\alpha]_{285}$ +889°, $[\alpha]_{270}$ +836°.

Methyl myrtillogenate 3-acetate (VI), R. D. in dioxane (c 0.15): $[\alpha]_{700}$ +51°, $[\alpha]_{589}$ +74°, $[\alpha]_{400}$ +192°, $[\alpha]_{350}$ +285°, $[\alpha]_{320}$ +369°, $[\alpha]_{312.5}$ +452°.

α-Amyrin acetate (VII) (E. J. Corey), R. D. in dioxane (c 0.51): $[\alpha]_{700}$ +53°, $[\alpha]_{589}$ +81°, $[\alpha]_{400}$ +200°, $[\alpha]_{350}$ +298°, $[\alpha]_{320}$ +395°, $[\alpha]_{300}$ +503°, $[\alpha]_{290}$ +557°.

Methyl ursolate (VIII), R. D. in dioxane (c 0.12): $[\alpha]_{700}$ +47°, $[\alpha]_{589}$ +81°, $[\alpha]_{400}$ +155°, $[\alpha]_{325}$ +336°, $[\alpha]_{315}$ +379°, $[\alpha]_{300}$ +452°, $[\alpha]_{280}$ +546°.

$\Delta^{13(18)}$-Oleanene (IX) (F. S. Spring), R.D. (Fig. 1) in dioxane (c 0.18): $[\alpha]_{700}$ −23°, $[\alpha]_{589}$ −24°, $[\alpha]_{400}$ −43°, $[\alpha]_{350}$ −86°, $[\alpha]_{325}$ −125°, $[\alpha]_{300}$ −164°, $[\alpha]_{290}$ −177°.

$\Delta^{13(18)}$-Oleanen-3β-ol (X) (F. S. Spring), R. D. in dioxane (c 0.19): $[\alpha]_{700}$ −14°, $[\alpha]_{589}$ −20°, $[\alpha]_{400}$ −63°, $[\alpha]_{350}$ −90°, $[\alpha]_{325}$ −110°, $[\alpha]_{300}$ −133°, $[\alpha]_{290}$ −153°, $[\alpha]_{285}$ −166°.

$\Delta^{13(18)}$-Oleanene-3β,24-diol diacetate (XI)[76] (O. Jeger). R. D. in dioxane (c 0.08): $[\alpha]_{700}$ −46°, $[\alpha]_{589}$ −53°, $[\alpha]_{400}$ −117°, $[\alpha]_{350}$ −167°, $[\alpha]_{320}$ −232°, $[\alpha]_{300}$ −303°, $[\alpha]_{290}$ −356°, $[\alpha]_{280}$ −428°, $[\alpha]_{275}$ −487°.

22-Deoxydumortierigenin acetate (XIIa), R. D. in dioxane (c 0.11): $[\alpha]_{700}$ −18°, $[\alpha]_{589}$ −18°, $[\alpha]_{400}$ −67°, $[\alpha]_{350}$ −108°, $[\alpha]_{320}$ −155°, $[\alpha]_{300}$ −221°, $[\alpha]_{290}$ −282°, $[\alpha]_{280}$ −354°, $[\alpha]_{275}$ −361°.

Δ^{18}-Oleanene (XIII) (F. S. Spring), R. D. (Fig. 1) in dioxane (c 0.17): $[\alpha]_{700}$ +1°, $[\alpha]_{589}$ +3°, $[\alpha]_{400}$ +5°, $[\alpha]_{350}$ +9°, $[\alpha]_{325}$ +12°, $[\alpha]_{300}$ +21°, $[\alpha]_{290}$ +21°, $[\alpha]_{280}$ +26°, $[\alpha]_{275}$ +34°.

Germanicol (XIV) (D. H. R. Barton), R. D. in dioxane (c 0.07): $[\alpha]_{700}$ +3°, $[\alpha]_{589}$ +5°, $[\alpha]_{330}$ +100°, $[\alpha]_{280}$ +114°.

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[73] The majority of the measurements were conducted in dioxane solution since most triterpenes are not sufficiently soluble in methanol even though this solvent would have been preferable, because hemiketal formation (see ref. 7c) could have been measured at the same time. A few of the determinations were performed by Mrs. A. James and Mrs. T. Nakano to whom we are indebted. Samples for which no source is given come from the collection of the senior author. The data are reported in the manner outlined in ref. 4 except that for plain curves, several additional points are listed to facilitate determination of the slope of the curve.

[74] C. Djerassi, J. A. Henry, A. J. Lemin, T. Rios and G. H. Thomas, THIS JOURNAL, **78**, 3783 (1956).

[75] L. Ruzicka, H. Leuenberger and H. Schellenberg, *Helv. Chim. Acta*, **20**, 1271 (1937).

[76] G. Cainelli, J. J. Britt, D. Arigoni and O. Jeger, *ibid.*, **41**, 2053 (1958).

Methyl morolate (XV) (D. H. R. Barton), R. D. in dioxane (*c* 0.1): $[\alpha]_{700}$ +4°, $[\alpha]_{589}$ +14°, $[\alpha]_{400}$ +95°, $[\alpha]_{350}$ +163°, $[\alpha]_{320}$ +245°, $[\alpha]_{300}$ +358°, $[\alpha]_{290}$ +422°, $[\alpha]_{280}$ +535°.

Lupeol (XVI), R. D. in dioxane (*c* 0.09): $[\alpha]_{700}$ +22°, $[\alpha]_{589}$ +48°, $[\alpha]_{400}$ +109°, $[\alpha]_{350}$ +157°, $[\alpha]_{320}$ +179°, $[\alpha]_{300}$ +220°, $[\alpha]_{290}$ +258°, $[\alpha]_{280}$ +328°.

Lupeol acetate (XVII), R. D. in dioxane (*c* 0.18): $[\alpha]_{700}$ +37°, $[\alpha]_{589}$ +37°, $[\alpha]_{400}$ +87°, $[\alpha]_{350}$ +141°, $[\alpha]_{320}$ +197°, $[\alpha]_{300}$ +240°, $[\alpha]_{290}$ +268°, $[\alpha]_{280}$ +298°, $[\alpha]_{270}$ +354°.

Lupanol acetate (XVIII), R. D. in dioxane (*c* 0.35): $[\alpha]_{700}$ −11°, $[\alpha]_{589}$ −11°, $[\alpha]_{400}$ −13°, $[\alpha]_{350}$ −26°, $[\alpha]_{325}$ −29°, $[\alpha]_{300}$ −34°, $[\alpha]_{290}$ −36°.

β-Amyrone (XIX) (D. H. R. Barton), R. D. (Fig. 2) in methanol (*c* 0.1): $[\alpha]_{700}$ +73°, $[\alpha]_{589}$ +113°, $[\alpha]_{305}$ +921°, $[\alpha]_{277.5}$ +650°, $[\alpha]_{265}$ +795°; R. D. in dioxane (*c* 0.1): $[\alpha]_{700}$ +69°, $[\alpha]_{589}$ +95°, $[\alpha]_{305}$ +775°, $[\alpha]_{290}$ +685°.

Methyl oleanonate (XX), R. D. in dioxane (*c* 0.09): $[\alpha]_{700}$ +44°, $[\alpha]$ +80°, $[\alpha]_{312.5-310}$ +578° (sh.), $[\alpha]_{305}$ +618°, $[\alpha]_{280}$ +476°; R. D. in methanol (*c* 0.14): $[\alpha]_{700}$ +74°, $[\alpha]_{589}$ +101°, $[\alpha]_{305}$ +848°, $[\alpha]_{275}$ +465°, $[\alpha]_{250}$ +703°.

Methyl siaresinonate 19-acetate (XXI) (O. Jeger), R. D. in dioxane (*c* 0.08): $[\alpha]_{700}$ +39°, $[\alpha]_{589}$ +58°, $[\alpha]_{302.5}$ +390°, $[\alpha]_{295}$ +337°.

Δ^{12}-18α-Oleanen-3-one (XXII) (F. S. Spring), R. D. in dioxane (*c* 0.1): $[\alpha]_{700}$ +56°, $[\alpha]_{589}$ +65°, $[\alpha]_{315}$ +812°, $[\alpha]_{310}$ +807° (sh.), $[\alpha]_{275}$ +513°.

$\Delta^{13(18)}$-Oleanen-3-one (XXIII) (F. S. Spring), R. D. (Fig. 2) in dioxane (*c* 0.1): $[\alpha]_{700}$ −21°, $[\alpha]_{589}$ −27°, $[\alpha]_{450}$ −47° (infl.), $[\alpha]_{317.5}$ +203°, $[\alpha]_{275}$ −633°.

Oleanan-3-one (XXIV) (D. H. R. Barton), R. D. in dioxane (*c* 0.18): $[\alpha]_{700}$ +26°, $[\alpha]_{589}$ +35°, $[\alpha]_{310}$ +456°, $[\alpha]_{282.5}$ +154°.

Δ^{17}-28-Noroleanen-3-one (XXV) (D. H. R. Barton), R. D. in methanol (*c* 0.1): $[\alpha]_{700}$ +74°, $[\alpha]_{589}$ +108°, $[\alpha]_{307.5}$ +1130°, $[\alpha]_{275}$ +137°, $[\alpha]_{260}$ +304°.

Methyl moronate (XXVI) (D. H. R. Barton), R. D. in dioxane (*c* 0.11): $[\alpha]_{700}$ +29°, $[\alpha]_{589}$ +45°, $[\alpha]_{315}$ +676°, $[\alpha]_{311}$ +654°, $[\alpha]_{307.5}$ +670°, $[\alpha]_{285}$ +264°, $[\alpha]_{282.5}$ +267°, $[\alpha]_{280}$ +258°, $[\alpha]_{270}$ +350°.

Allobetulone (XXVII) (D. H. R. Barton), R. D. in dioxane (*c* 0.1): $[\alpha]_{700}$ +12°, $[\alpha]_{589}$ +35°, $[\alpha]_{310}$ +669°, $[\alpha]_{275}$ +83°.

Methyl 22β-(α-methyl-*n*-butyroyloxy)-hedragonate (XXVIII) (D. H. R. Barton), R. D. in dioxane (*c* 0.04): $[\alpha]_{700}$ +46°, $[\alpha]_{589}$ +81°, $[\alpha]_{312.5-310}$ +1000°, $[\alpha]_{275}$ +97°, $[\alpha]_{272.5}$ +130°.

Methyl 22β-angeloyloxy-hedragonate (XXIX), (D. H. R. Barton) R. D. in methanol (*c* 0.01): $[\alpha]_{700}$ +80°, $[\alpha]_{589}$ +107°, $[\alpha]_{310-307.5}$ +1175°, $[\alpha]_{280}$ −625°.

Hydroxydammarenone-II (XXX) (J. S. Mills), R. D. (Fig. 2) in methanol (*c* 0.1): $[\alpha]_{700}$ +54°, $[\alpha]_{589}$ +66°, $[\alpha]_{307}$ +782°, $[\alpha]_{273}$ −69°, $[\alpha]_{252}$ +196°.

Dammarenediol-II (XXXI) (J. S. Mills), R. D. in methanol (*c* 0.1): $[\alpha]_{700}$ +1°, $[\alpha]_{589}$ +18°, $[\alpha]_{400}$ +83°, $[\alpha]_{350}$ +126°, $[\alpha]_{320}$ +171°, $[\alpha]_{300}$ +211°, $[\alpha]_{290}$ +235°, $[\alpha]_{280}$ +256°, $[\alpha]_{270}$ +273°, $[\alpha]_{260}$ +385°.

α-Amyrone (XXXII) (D. H. R. Barton), R. D. in methanol (*c* 0.12): $[\alpha]_{700}$ +72°, $[\alpha]_{589}$ +107°, $[\alpha]_{305}$ +1146°, $[\alpha]_{297.5}$ +1104° (sh.), $[\alpha]_{282.5}$ +932°, $[\alpha]_{275}$ +969°, $[\alpha]_{272.5}$ +965°; R. D. in dioxane (*c* 0.1): $[\alpha]_{700}$ +81°, $[\alpha]_{589}$ +112°, $[\alpha]_{312.5}$ +896°, $[\alpha]_{310}$ +880°, $[\alpha]_{305}$ +942°, $[\alpha]_{287.5}$ +802°, $[\alpha]_{280}$ +904°.

Methyl β-boswellonate (XXXIII) (T. G. Halsall), R. D. in dioxane (*c* 0.1): $[\alpha]_{700}$ +65°, $[\alpha]_{589}$ +93°, $[\alpha]_{307.5}$ +878°, $[\alpha]_{280}$ +469°.

Nor-β-boswellenone (XXXIV) (T. G. Halsall), R. D. in dioxane (*c* 0.1): $[\alpha]_{700}$ +82°, $[\alpha]_{589}$ +104°, $[\alpha]_{312.5}$ +1303°, $[\alpha]_{275}$ +213°.

Lupenone (XXXV) (E. R. H. Jones), R. D. in dioxane (*c* 0.1): $[\alpha]_{700}$ +44°, $[\alpha]_{589}$ +48°, $[\alpha]_{312.5}$ +648°, $[\alpha]_{280}$ +93°.

Lupanone (XXXVI) (E. R. H. Jones), R. D. in dioxane (*c* 0.1): $[\alpha]_{700}$ +4°, $[\alpha]_{589}$ +5°, $[\alpha]_{317.5}$ +362°, $[\alpha]_{280}$ −266°.

Methyl dihydromelaleucinonate (XXXVII with additional carbomethoxyl group) (D. E. White), R. D. in dioxane (*c* 0.05): $[\alpha]_{700}$ +10°, $[\alpha]_{589}$ +16°, $[\alpha]_{312.5}$ +372°, $[\alpha]_{285}$ −200°.

Methyl sumaresinonate 3-acetate (XL), R. D. (Fig. 2) in dioxane (*c* 0.09): $[\alpha]_{700}$ +36°, $[\alpha]_{589}$ +49°, $[\alpha]_{360}$ +154° (sh.), $[\alpha]_{350}$ +148°, (infl.), $[\alpha]_{342.5}$ +161°, $[\alpha]_{327.5-325}$ +90°, $[\alpha]_{317.5}$ +232° (sh.), $[\alpha]_{312.5}$ +263° (infl.), $[\alpha]_{295}$ +435° (infl.), $[\alpha]_{290}$ +445°, $[\alpha]_{282.5}$ +430°, $[\alpha]_{280}$ +443°, $[\alpha]_{270}$ +352°.

α-Amyrin 12,13-oxide (XLI) (L. F. Fieser), R. D. (Fig. 3) in dioxane (*c* 0.05): $[\alpha]_{700}$ +50°, $[\alpha]_{589}$ +66°, $[\alpha]_{400}$ +152°, $[\alpha]_{350}$ +218°, $[\alpha]_{320}$ +268°, $[\alpha]_{300}$ +314°, $[\alpha]_{290}$ +324°, $[\alpha]_{280}$ +358°, $[\alpha]_{275}$ +402°.

13α-Ursan-3β-ol-12-one (XLIIa) (L. F. Fieser), R. D. (Fig. 3) in dioxane (*c* 0.06): $[\alpha]_{700}$ +84°, $[\alpha]_{589}$ +123°, $[\alpha]_{305}$ +1161°, $[\alpha]_{275}$ −25°.

13α-Ursan-3β-ol-12-one benzoate (XLIIb) (F. S. Spring) R. D. in dioxane (*c* 0.1): $[\alpha]_{700}$ +90°, $[\alpha]_{589}$ +111°, $[\alpha]_{305}$ +1019°, $[\alpha]_{287.5}$ +547°.

13β-Ursan-3β-ol-12-one acetate (XLIII) (L. F. Fieser), R. D. (Fig. 3) in dioxane (*c* 0.05): $[\alpha]_{700}$ +21°, $[\alpha]_{589}$ +30°, $[\alpha]_{315}$ +332°, $[\alpha]_{275}$ −670°.

13β-Oleanan-3β-ol-12-one acetate (XLIV) (O. Jeger), R. D. (Fig. 3) in dioxane (*c* 0.13): $[\alpha]_{700}$ −14°, $[\alpha]_{589}$ −17°, $[\alpha]_{297.5}$ −193°, $[\alpha]_{275}$ −68°.

15-Ketoerythrodiol diacetate (XLV), R. D. (Fig. 4) in methanol (*c* 0.09): $[\alpha]_{700}$ +11°, $[\alpha]_{589}$ +10°, $[\alpha]_{330}$ −355°, $[\alpha]_{282}$ +656°, $[\alpha]_{255}$ +533°.

9α-Methyl-Δ^{7}-ergosten-3β-ol-11-one acetate (XLVI) (G. D. Meakins), R. D. in methanol (*c* 0.09): $[\alpha]_{700}$ +16°, $[\alpha]_{589}$ +35°, $[\alpha]_{330}$ +1036°, $[\alpha]_{287.5-285}$ −860°, $[\alpha]_{250}$ −208°.

Δ^{12}-Oleanene-3β-ol-16-one (XLVII) (O. Jeger), R. D. (Fig. 4) in dioxane (*c* 0.1): $[\alpha]_{700}$ +24°, $[\alpha]_{589}$ +25°, $[\alpha]_{325}$ −986°, $[\alpha]_{282.5}$ +1035°, $[\alpha]_{275}$ +735°.

Methyl 16-keto-oleanolate (XLVIII), R. D. in methanol (*c* 0.08): $[\alpha]_{700}$ −12°, $[\alpha]_{589}$ −12°, $[\alpha]_{322.5}$ −1392°, $[\alpha]_{277.5}$ +2433°, $[\alpha]_{262.5}$ +1986°.

Methyl Δ^{12}-oleanen-3β,28-diol-16-one-29-oate 3-acetate (IL), R. D. in dioxane (*c* 0.1): $[\alpha]_{700}$ +23°, $[\alpha]_{589}$ +34°, $[\alpha]_{475}$ +40° (sh.), $[\alpha]_{321}$ −1137°, $[\alpha]_{285}$ +1650°.

Norechinocystenolone acetate (L), R. D. (Fig. 4) in dioxane (*c* 0.09): $[\alpha]_{700}$ −50°, $[\alpha]_{589}$ −92°, $[\alpha]_{322.5}$ −2710°, $[\alpha]_{316}$ −2115°, $[\alpha]_{311}$ −2500°, $[\alpha]_{277.5}$ +1796°, $[\alpha]_{272.5}$ +1653°.

Methyl 16-keto-oleanonate (LII) (C. R. Noller) R. D. in dioxane (*c* 0.13): $[\alpha]_{700}$ +1°, $[\alpha]_{589}$ 0°, $[\alpha]_{322.5}$ −1653°, $[\alpha]_{315}$ −1011°, $[\alpha]_{312.5}$ −1102°, $[\alpha]_{279}$ +1869°, $[\alpha]_{272.5}$ +1615°.

Methyl Δ^{12}-Oleanen-3,16-dione-28-ol-29-oate (LIV), R. D. in dioxane (*c* 0.12): $[\alpha]_{700}$ +35°, $[\alpha]_{589}$ +47°, $[\alpha]_{450}$ +64° (sh.), $[\alpha]_{322.5}$ −1210°, $[\alpha]_{275}$ +3190°, $[\alpha]_{272.5}$ +2950°, $[\alpha]_{270}$ +3050°.

Methyl 19-keto-oleanolate 3-acetate (LV) (D. H. R. Barton), R. D. (Fig. 4) in methanol (*c* 0.07): $[\alpha]_{700}$ +68°, $[\alpha]_{589}$ +97°, $[\alpha]_{317}$ +1342°, $[\alpha]_{277}$ −765°, $[\alpha]_{270}$ −466°.

Methyl machaerate (LVI), R. D. (Fig. 5) in dioxane (*c* 0.09): $[\alpha]_{700}$ +20°, $[\alpha]_{589}$ +20°, $[\alpha]_{320}$ −1050°, $[\alpha]_{312.5}$ −698°, $[\alpha]_{310}$ −788°, $[\alpha]_{275}$ +1595°, $[\alpha]_{272.5}$ +1524°.

Δ^{12}-Oleanen-3β,16β,28-triol-22-one 3,16-diacetate 28-trityl ether (LVII), R. D. (Fig. 5) in dioxane (*c* 0.1): $[\alpha]_{700}$ −68°, $[\alpha]_{589}$ −93°, $[\alpha]_{327.5}$ −1455°, $[\alpha]_{287.5}$ +1035°, $[\alpha]_{280}$ +775°.

Δ^{12}-Oleanen-3β,16β,28-triol-22-one triacetate (LVIII), R. D. in dioxane (*c* 0.13): $[\alpha]_{700}$ −16°, $[\alpha]_{589}$ −30°, $[\alpha]_{327.5}$ −1020°, $[\alpha]_{280}$ +1043°.

22-Dehydrodumortierigenin 3-acetate (LIX), R. D. (Fig. 5) in methanol (*c* 0.06): $[\alpha]_{700}$ −34°, $[\alpha]_{589}$ −34°, $[\alpha]_{323}$ −336°, $[\alpha]_{295}$ −148°, $[\alpha]_{275}$ −321°, $[\alpha]_{273}$ −302°.

Trisnorlupanonyl acetate (LX) (E. R. H. Jones), R. D. (Fig. 5) in dioxane (*c* 0.1): $[\alpha]_{700}$ +1°, $[\alpha]_{589}$ +3°, $[\alpha]_{335}$ +1069°, $[\alpha]_{292.5}$ −730°, $[\alpha]_{285}$ −666°.

28-Hydroxytrisnorlupanonyl diacetate (LXI), R. D. in methanol (*c* 0.09): $[\alpha]_{700}$ +4°, $[\alpha]_{589}$ +15°, $[\alpha]_{330}$ +601°, $[\alpha]_{287.5}$ −646°, $[\alpha]_{270}$ −498°.

Trisnorketone from methyl melaleucate acetate (LXII with carbomethoxyl group) (D. E. White), R. D. in dioxane (*c* 0.04): $[\alpha]_{700}$ +1°, $[\alpha]_{589}$ +6°, $[\alpha]_{327.5}$ +574°, $[\alpha]_{290}$ −517°.

21-Ketotrisnorhopane (LXIII) (T. G. Halsall), R. D. in dioxane (*c* 0.1): $[\alpha]_{700}$ +74°, $[\alpha]_{589}$ +136°, $[\alpha]_{322.5}$ +1969°, $[\alpha]_{305}$ +691°.

Gypsogenin methyl ester (LXVI), R. D. (Fig. 6) in dioxane (*c* 0.1): $[\alpha]_{700}$ +46°, $[\alpha]_{589}$ +112°, $[\alpha]_{325}$ +620°, $[\alpha]_{280}$ +253°.

Methyl quillaiate (LXVII) (O. Jeger), R. D. (Fig. 6) in dioxane (*c* 0.1): $[\alpha]_{700}$ +24°, $[\alpha]_{589}$ +86°, $[\alpha]_{327.5}$ +457°, $[\alpha]_{277.5}$ +17°, $[\alpha]_{275}$ +32°.

Gummosogenin (LXVIII), R. D. (Fig. 6) in dioxane (*c* 0.1): $[\alpha]_{700}$ +20°, $[\alpha]_{589}$ +43°, $[\alpha]_{425-400}$ +77° (broad peak), $[\alpha]_{340}$ −137°, $[\alpha]_{277.5}$ +978°, $[\alpha]_{275}$ +966°.

Friedelan-x-one (LXIXb) (R. M. Gascoigne), R. D. (Fig. 6) in dioxane (*c* 0.07): $[\alpha]_{700}$ +100°, $[\alpha]_{589}$ +148°, $[\alpha]_{322.5}$ +3314°, $[\alpha]_{280}$ −2353°, $[\alpha]_{275}$ −2321°.

Friedelan-y-one (LXIXc) (R. M. Gascoigne), R. D. (Fig. 6) in dioxane (c 0.05): $[\alpha]_{700}$ −23°, $[\alpha]_{589}$ −15°, $[\alpha]_{322.5}$ −700°, $[\alpha]_{280}$ +664°, $[\alpha]_{275}$ +592°.

Methyl glycyrrhetate 3-acetate (LXX), R. D. (Fig. 7) in dioxane (c 0.1): $[\alpha]_{700}$ +70°, $[\alpha]_{589}$ +113°, $[\alpha]_{394}$ +294°, $[\alpha]_{380}$ +231°, $[\alpha]_{369-367.5}$ +309°, $[\alpha]_{362.5}$ +287°, $[\alpha]_{287.5}$ +1558°, $[\alpha]_{282.5}$ +1362°.

11-Keto-α-amyrin acetate (LXXI) (F. S. Spring), R. D. (Fig. 7) in dioxane (c 0.11): $[\alpha]_{700}$ +49°, $[\alpha]_{589}$ +91°, $[\alpha]_{410}$ +194° (sh.), $[\alpha]_{380}$ +36°, $[\alpha]_{369}$ +158°, $[\alpha]_{362.5}$ +91°, $[\alpha]_{350}$ +549°, $[\alpha]_{277.5}$ +2990°, $[\alpha]_{275}$ +2896°.

Δ^{12}-18α-Oleanen-3β-ol-11-one acetate (LXXII) (F. S. Spring), R. D. (Fig. 7) in dioxane (c 0.1): $[\alpha]_{700}$ +46°, $[\alpha]_{589}$ +65°, $[\alpha]_{450}$ +91° (sh.), $[\alpha]_{375}$ −522°, $[\alpha]_{365}$ −252°, $[\alpha]_{360}$ −371°, $[\alpha]_{310}$ +2157°, $[\alpha]_{300}$ +1827°.

Methyl 18α-glycyrrhetate (LXXIII) (F. S. Spring), R. D. in dioxane (c 0.1): $[\alpha]_{700}$ +62°, $[\alpha]_{589}$ +76°, $[\alpha]_{450}$ +111° (infl.), $[\alpha]_{440}$ +114° (sh.), $[\alpha]_{377.5}$ −341°, $[\alpha]_{367.5}$ −133°, $[\alpha]_{360}$ −204°, $[\alpha]_{317.5}$ +1836° (infl.), $[\alpha]_{317.5}$ +1836°, $[\alpha]_{275}$ +2964°.

11-Ketodumortierigenin (LXXIV), R. D. (Fig. 8) in dioxane (c 0.08): $[\alpha]_{700}$ −2°, $[\alpha]_{589}$ −17°, $[\alpha]_{425}$ −70°, $[\alpha]_{410}$ −58°, $[\alpha]_{382.5}$ −183°, $[\alpha]_{374}$ −138°, $[\alpha]_{367.5}$ −180°, $[\alpha]_{352.5}$ −46°, $[\alpha]_{350}$ −48°, $[\alpha]_{340}$ +101°, $[\alpha]_{337.5}$ +57°, $[\alpha]_{332.5}$ +83°, $[\alpha]_{331}$ +71°, $[\alpha]_{327.5}$ +100°, $[\alpha]_{297.5}$ −262°, $[\alpha]_{295}$ −258°, $[\alpha]_{292.5}$ −270°, $[\alpha]_{287.5}$ −232°, $[\alpha]_{285}$ −248°, $[\alpha]_{282.5}$ −238°.

$\Delta^{9(11)}$-Oleanen-3β-ol-12-one acetate (LXXV) (F. S. Spring), R. D. (Fig. 8) in dioxane (c 0.1): $[\alpha]_{700}$ +45°, $[\alpha]_{589}$ +62°, $[\alpha]_{380}$ +720°, $[\alpha]_{370}$ +598°, $[\alpha]_{365}$ +651°, $[\alpha]_{337.5}$ −284°, $[\alpha]_{336}$ −280°, $[\alpha]_{327.5}$ −424°, $[\alpha]_{277.5}$ +251°.

$\Delta^{9(11)}$-Oleanen-3β,28-diol-12-one diacetate (LXXVI),[77] R. D. in dioxane (c 0.25 (700–360 mμ), 0.055 (360–335 mμ)): $[\alpha]_{700}$ +39°, $[\alpha]_{589}$ +45°, $[\alpha]_{378}$ +656°, $[\alpha]_{355}$ +547°, $[\alpha]_{360}$ +568, $[\alpha]_{325}$ −325°, $[\alpha]_{285}$ +67°.

$\Delta^{9(11)}$-Ursen-3β-ol-12-one acetate (LXXVII) (F. S. Spring), R. D. in dioxane (c 0.09): $[\alpha]_{700}$ +52°, $[\alpha]_{589}$ +101°, $[\alpha]_{380}$ +1417°, $[\alpha]_{372.5}$ +1339°, $[\alpha]_{366}$ +1381°, $[\alpha]_{325}$ −1428°, $[\alpha]_{322.5}$ −1417°, $[\alpha]_{320}$ −1422°, $[\alpha]_{277.5}$ −560°.

$\Delta^{9(11)}$-18α-Oleanen-3β-ol-12-one acetate (LXXVIII) (F. S. Spring), R. D. (Fig. 8) in dioxane (c 0.09): $[\alpha]_{700}$ +96°, $[\alpha]_{589}$ +113°, $[\alpha]_{470}$ +154° (sh.), $[\alpha]_{370}$ −710°, $[\alpha]_{307.5}$ +3118° (sh.), $[\alpha]_{302.5}$ +3130° (infl.), $[\alpha]_{277.5}$ +3720°, $[\alpha]_{275}$ +3708°.

$\Delta^{9(11),14}$-Taraxeradien-3β-ol-12-one acetate (LXXIX), R. D. (Fig. 8) in dioxane (c 0.15): $[\alpha]_{700}$ −31°, $[\alpha]_{589}$ −46°, $[\alpha]_{550}$ −51° (infl.), $[\alpha]_{375}$ +1417°, $[\alpha]_{370-362.5}$ +1250° (sh.), $[\alpha]_{325}$ −3583°, $[\alpha]_{305}$ −2924°.

Iso-α-amyradien-3β-ol-12-one (LXXX) (O. Jeger), R. D. in dioxane (c 0.11): $[\alpha]_{700}$ −16°, $[\alpha]_{589}$ −13°, $[\alpha]_{362.5}$ +1989°, $[\alpha]_{305}$ −4641°, $[\alpha]_{285}$ −4562°.

$\Delta^{11,13(18)}$-Oleadien-3-one (LXXXI) (D. H. R. Barton), R. D. in dioxane (c 0.06): $[\alpha]_{700}$ −62°, $[\alpha]_{589}$ −82°, $[\alpha]_{400}$ −273°, $[\alpha]_{350}$ −527°, $[\alpha]_{320}$ −853°, $[\alpha]_{300}$ −1404°, $[\alpha]_{290}$ −2142°, $[\alpha]_{280}$ −3294°, $[\alpha]_{275}$ −3820°.

Methyl dehydro-oleanonate (LXXXII) (D. H. R. Barton), R. D. (Fig. 9) in dioxane (c 0.05): $[\alpha]_{700}$ −142°, $[\alpha]_{589}$ −176°, $[\alpha]_{400}$ −488°, $[\alpha]_{350}$ −892°, $[\alpha]_{320}$ −1478°, $[\alpha]_{300}$ −2364°, $[\alpha]_{290}$ −3416°, $[\alpha]_{280}$ −5296°, $[\alpha]_{275}$ −5992°.

Methyl isodehydro-oleanonate (LXXXIII) (D. H. R. Barton), R. D. (Fig. 9) in dioxane (c 0.03): $[\alpha]_{700}$ +77°, $[\alpha]_{589}$ +137°, $[\alpha]_{400}$ +540°, $[\alpha]_{350}$ +920°, $[\alpha]_{320}$ +1530°, $[\alpha]_{300}$ +2003°, $[\alpha]_{290}$ +2280°, $[\alpha]_{280}$ +2840°, $[\alpha]_{275}$ +3270°.

$\Delta^{9(11),12}$-Ursadien-3-one (LXXXIV) (D. H. R. Barton), R. D. (Fig. 9) in dioxane (c 0.1): $[\alpha]_{700}$ +238°, $[\alpha]_{589}$ +388°, $[\alpha]_{322.5}$ +6749°, $[\alpha]_{310}$ +4390.

Methyl dehydro-oleanolate acetate (background rotation for LXXXII) (D. H. R. Barton), R. D. in dioxane (c 0.15): $[\alpha]_{700}$ −80°, $[\alpha]_{589}$ −117°, $[\alpha]_{400}$ −512°, $[\alpha]_{350}$ −975°, $[\alpha]_{320}$ −1648°, $[\alpha]_{300}$ −2764°, $[\alpha]_{290}$ −3870°, $[\alpha]_{280}$ −5429°.

Methyl isodehydro-oleanolate (background rotation for LXXXIII) (D. H. R. Barton), R. D. in dioxane (c 0.098): $[\alpha]_{700}$ +134°, $[\alpha]_{589}$ +198°, $[\alpha]_{400}$ +641°, $[\alpha]_{350}$ +1088°, $[\alpha]_{320}$ +1609°, $[\alpha]_{300}$ +2321°, $[\alpha]_{290}$ +2913°, $[\alpha]_{280}$ +3660°.

$\Delta^{9(11),12}$-Ursadien-3β-ol (background rotation for LXXXIV) (D. H. R. Barton), R. D. in dioxane (c 0.10): $[\alpha]_{700}$ +234°, $[\alpha]_{589}$ +370°, $[\alpha]_{400}$ +1462°, $[\alpha]_{350}$ +3094°, $[\alpha]_{320}$ +7078°, $[\alpha]_{315}$ +7182°.

Zeorinone (D. H. R. Barton), R. D. in dioxane (c 0.105): $[\alpha]_{700}$ +10°, $[\alpha]_{589}$ +25°, $[\alpha]_{390-380}$ +58° (broad peak), $[\alpha]_{370-365}$ +36°) (sh.), $[\alpha]_{325}$ −164°, $[\alpha]_{287.5}$ +398°, $[\alpha]_{275}$ +347°.

DETROIT, MICH.

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[77] Unpublished work in this laboratory by Dr. G. Krakower.

[CONTRIBUTION FROM THE DANIEL SIEFF RESEARCH INSTITUTE, THE WEIZMANN INSTITUTE OF SCIENCE]

Unsaturated Macrocyclic Compounds. VIII.[1] Oxidation of Terminal Diacetylenes to Large Ring Polyacetylenes with Cupric Acetate in Pyridine. Synthesis of Five New Macrocyclic Rings[2]

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The oxidative coupling of octa-1,7-diyne (IIa) with cupric acetate in pyridine has been shown to yield not only the cyclic dimer IIIa, but also the cyclic trimer Va, tetramer VIIa, pentamer IXa and higher cyclic polyacetylenes. Corresponding cyclic polyacetylenes have been obtained from nona-1,8-diyne (IIb), hepta-1,6-diyne (IIc) and deca-1,9-diyne (IId). Five new alicyclic ring systems (the 27-, 36-, 40-, 45- and 54-membered ones) have been prepared by this new method for constructing macrocyclic compounds, by which large rings can be prepared directly in one step from simple starting materials. Full hydrogenation of the cyclic polyacetylenes leads to the corresponding saturated hydrocarbons. The melting point behavior of the seven new cyclic paraffins thus obtained (the 20-, 21-, 27-, 36-, 40-, 45- and 54-membered ones) are briefly discussed.

The oxidative coupling of certain terminal diacetylenes of type II by means of oxygen in the presence of cuprous chloride and ammonium chloride in aqueous ethanol to yield cyclic "dimers" of type III besides linear products was described in parts III[3] and IV[4] of this series. We were beginning to study this type of coupling of terminal acetylenes in homogeneous media and also to investigate various reactions of the cyclic tetraacetylenes III when Eglinton and Galbraith[5] made the interesting announcement that oxidation of tetradeca-1,13-diyne (II, $n = 10$) with cupric acetate in methanol and pyridine under conditions of high dilution gives rise to a mixture of the cyclic monomer and the cyclic dimer (III, $n = 10$) in comparatively high yield.

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[1] For part VII, see F. Sondheimer, Y. Amiel and Y. Gaoni, THIS JOURNAL, **81**, 1771 (1959).

[2] Presented in part at the 16th International Congress of Pure and Applied Chemistry, Paris, July, 1957 (Congress Handbook, Division of Organic Chemistry, p. 156).

[3] F. Sondheimer and Y. Amiel, THIS JOURNAL, **79**, 5817 (1957).

[4] F. Sondheimer, Y. Amiel and R. Wolovsky, *ibid.*, **79**, 6263 (1957).

[5] G. Eglinton and A. R. Galbraith, *Chemistry & Industry*, 737 (1956).