920. *Infrared Spectra of Steroidal Sapogenins having Oxygen Substituents in the F-Ring.*

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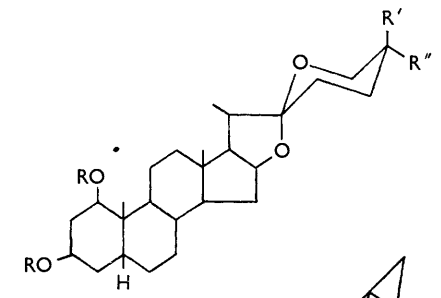
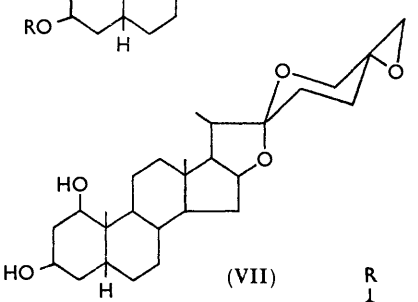
The infrared spectra of steroidal sapogenins having oxygen substituents in the F-ring have been measured from 1100 to 800 cm.$^{-1}$ and are discussed in relation to those of the ordinary sapogenins. Characteristic bands are assigned to these sapogenins.

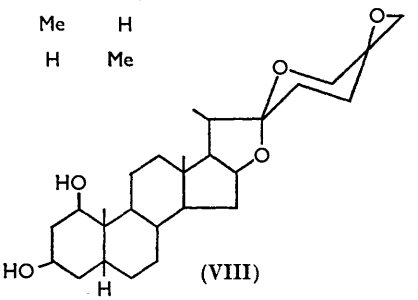
THE infrared spectra of steroidal sapogenins have been investigated by Jones [1] and Wall *et al.*,[2] and about twenty absorption bands [1] between 1350 and 875 cm.$^{-1}$ have been designated as characteristic of the spiroketal side-chains. In particular, four bands [2] ~980 (A-band), 920 (B-band), 900 (C-band), and 860 cm.$^{-1}$ (D-band) have been ascribed to the



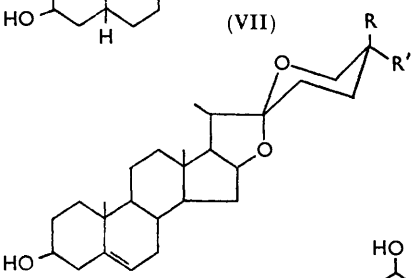
	R	R′	R″
(I)	H	Me	OH
(II)	H	OH	Me
(III)	H	CH_2·OH	H
(IV)	H	H	CH_2·OH
(V)	Ac	CH_2·OH	OH
(VI)	Ac	OH	CH_2·OH
(XI)	H	Me	H
(XII)	H	H	Me



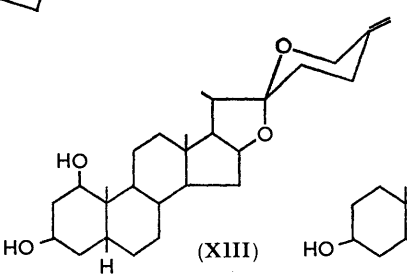
(VII)



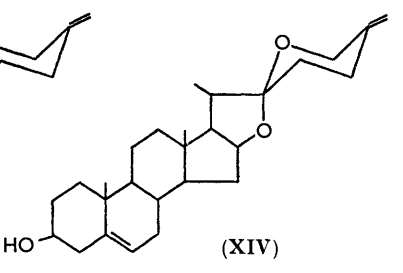
(VIII)



(IX) R = CH_2·OH, R′ = H
(X) R = H, R′ = CH_2·OH



(XIII)



(XIV)

properties of the E- and the F-ring, being distinctive for the sapogenins of the 25L(normal)- and 25D(iso)-series. With 25L-sapogenins, the B-band has a stronger absorptivity than the C-band. In 25D-sapogenins this relationship is reversed. Moreover, 25L-sapogenins show the A- and the D-band at 987—984 and ~850 cm.$^{-1}$, whereas 25D-sapogenins have these bands at 981—976 and ~860 cm.$^{-1}$, respectively. These assignments played an important part in the structural studies of the F-rings of the sapogenins.

[1] Jones, *J. Amer. Chem. Soc.*, 1953, **75**, 158.
[2] Wall, Eddy, Clenman, and Klump, *Analyt. Chem.*, 1952, **24**, 1337.

As already reported,[3,4] three new sapogenins, reineckiagenin (I), isoreineckiagenin (II), and isocarneagenin (IV), were isolated from *Reineckia carnea* Kunth. by our group. In structural studies, it was observed that the infrared spectra of the first two had undergone a considerable change and the spectrum of the third diverged in the region between 1100 and 800 cm.$^{-1}$, when compared with the spectra of the ordinary sapogenins mentioned above. We first assumed that these sapogenins had a hydroxyl group in the E- or the F-ring or an opened F-ring, since the infrared spectra of 23-bromosapogenins [5] and 20-iso-sapogenins [6] differed from those of ordinary sapogenins. Later it was established that our three sapogenins all had a hydroxyl or a hydroxymethyl group attached to ring F.

The structures of narthogenin (IX) and isonarthogenin (X), isolated from *Metanarthecium luteo-viride* Maxim.,[7] were easily elucidated on the basis that the infrared spectrum of the latter was very similar to that of isocarneagenin (IV), which has a 27-hydroxyl group. Furthermore, during the study of *Reineckia carnea* Kunth. we synthesised the following sapogenins having hydroxyl groups or an epoxide group attached to ring F: carneagenin (III), convallamarogenin-25,27-diols (V and VI), and convallamarogenin-25,27-epoxides (VII and VIII).

We wished to examine whether the sapogenins (I—X), containing oxygen substituents in the F-ring, show the above-mentioned four bands characteristic of the ordinary sapogenins, and to examine the differences between the 25L- and 25D-sapogenins. For comparison, rhodeasapogenin (25L) (XI) and isorhodeasapogenin (25D) (XII) were chosen. The infrared spectra are shown in Fig. 1 and the Table.

Experimental.—The spectra were measured from 1100 to 800 cm.$^{-1}$ by means of a Nihon Bunko double-monochromatic infrared spectrophotometer, model 201-B with sodium chloride prisms.

Since most of the compounds are insoluble in carbon disulphide, the spectra of chloroform solutions were taken in a 0·25 mm. cell. With compounds (II), (V), (VI), (IX), and (XII), the sample (1·5—3·0 mg.) was dissolved in 0·2 ml. of chloroform. With compounds (I), (III), (IV), (VII), (VIII), (X), and (XI), saturated solutions were used. As compounds (III), (IV), (VII), (VIII), and (X) were only slightly soluble in chloroform, their spectra were measured also in Nujol mull.

Results and Discussion.—*25-Hydroxy-sapogenins* (I vs. II). As shown in Fig. 1 and the Table, the spectra of reineckiagenin (I) and isoreineckiagenin (II) show characteristic bands at 1008, 921, and 848 cm.$^{-1}$ and at 1010, 976, 938, 889, and 846 cm.$^{-1}$, respectively. They differ from the spectra of ordinary sapogenins (XI and XII) (Fig. 1). In the region near 980 cm.$^{-1}$, at which the strongest band (A-band) of the latter appears, compound (I) has a very weak band at around 980 cm.$^{-1}$ and its isomer (II) has only a weak band at 976 cm.$^{-1}$.

Characteristic bands between 1010 and 800 cm.$^{-1}$ ($CHCl_3$ solution).

Sapogenin	Wave number (cm.$^{-1}$) (transmittance, %)						
Reineckiagenin (I)	1008 (68)	—	—	921 (67)	—	—	848 (82)
Isoreineckiagenin (II)	1010 (53)	976 (58)	938 (56)	—	889 (48)	—	846 (74)
Carneagenin (III)	995 (72)	967 (73)	—	917 (73)	893 (76)	—	843 (77)
Isocarneagenin (IV)	1011 (72)	968 (77)	—	910 (77)	887 (82)	863 (83)	848 (83)
Narthogenin (IX)	995 (43)	960 (44)	—	911 (49)	—	863 (74)	836 (72)
Isonarthogenin (X)	1015 (69)	957 (72)	—	905 (73)	—	860 (81)	836 (81)
(V)	1022 (55)	982 (59)	940 (70)	—	887 (74)	860 (70)	—
(VI)	1012 (50)	977 (69)	—	918 (59)	—	—	840 (76)
(VII)	1004 (75)	—	—	917 (74)	—	—	830 (80)
(VIII)	1006 (73)	—	—	922 (75)	880 (76)	—	—
(XI)	—	985 (57)	—	914 (64)	891 (76)	—	845 (79)
(XII)	—	979 (30)	—	915 (66)	895 (46)	861 (65)	—

[3] Takeda, Okanishi, Minato, and Shimaoka, *Tetrahedron Letters*, 1962, 1107.
[4] Takeda, Okanishi, Minato, and Shimaoka, *Tetrahedron*, 1963, **19**, 759.
[5] Dickson and Page, *J.*, 1955, 447.
[6] Eddy, Barnes, and Fenske, *Analyt. Chem.*, 1955, **27**, 1067.
[7] Minato and Shimaoka, *Chem. and Pharm. Bull.* (*Japan*), in the press.

The compounds (I) and (II) give bands at 848 and 846 cm.$^{-1}$, respectively, which correspond to the D-bands of ordinary 25L-sapogenins. However, with reineckiagenin (I), there is a band at 921 cm.$^{-1}$ which has a stronger absorptivity than the others, whereas a band at 889 cm.$^{-1}$ is the strongest for isoreineckiagenin (II). This result is in good

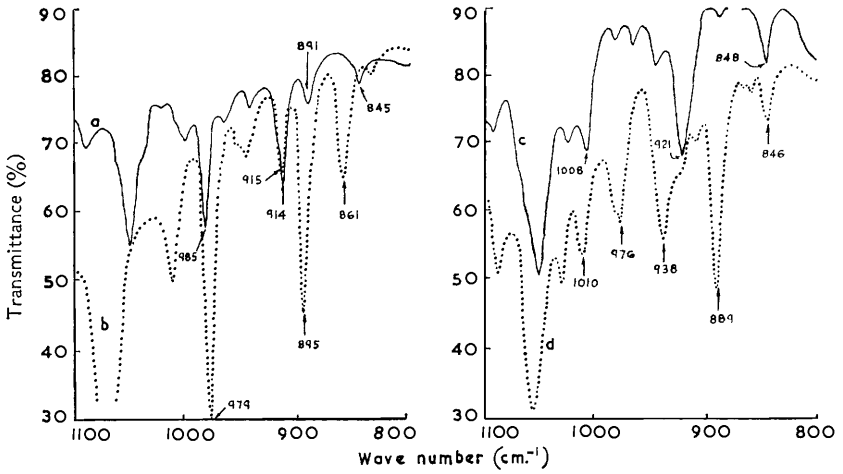


FIG. 1. Infrared spectra of (a) (XI), (b) (XII), (c) (I), and (d) (II) in $CHCl_3$.

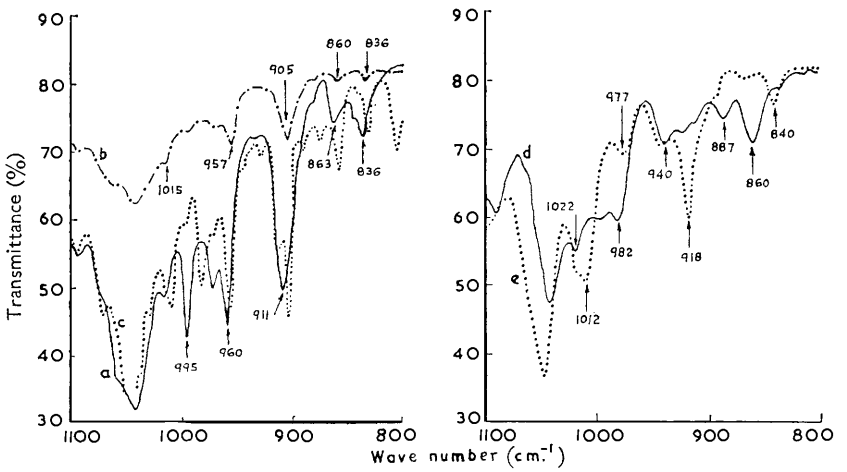


FIG. 2. Infrared spectra of (a) (IX), (b) (X), (d) (V), and (e) (VI), all in $CHCl_3$, and (c) (X) in Nujol.

agreement with the relationship obtained from the relative intensities of B- and C-bands of ordinary 25L- and 25D-sapogenins, and is very useful in distinguishing between 25L- and 25D-hydroxy-sapogenins.

27-*Hydroxy-sapogenins* (III vs. IV, *and* IX vs. X). The characteristic bands of these compounds are shown in the Table and Fig. 2. None of the compounds has a strong band near 980 or at 900—890 cm.$^{-1}$. Especially, it is very difficult to find bands at 900—890 cm.$^{-1}$ with narthogenin (IX) and isonarthogenin (X). These compounds thus differ from ordinary sapogenins. Moreover, all four compounds have a strong band at 905—920 cm.$^{-1}$ which suggests they are 25L-sapogenins. Here it is clearly impossible to discuss the stereochemistry at C-25 by use of the characteristic four bands of the ordinary sapogenins.

The spectra [4] of carneagenin (III) show a band at 843 cm.$^{-1}$ in chloroform solution, and bands at 860 and 843 cm.$^{-1}$ (the latter the stronger) in Nujol. The spectra [4] of isocarneagenin (IV) show bands at 863 and 848 cm.$^{-1}$ in chloroform solution, and at 862 and 843 cm.$^{-1}$ (the former the stronger) in Nujol. Narthogenin (IX) and isonarthogenin (X) have bands near 860 and 836 cm.$^{-1}$, and the relationship of the intensities of these two bands is similar to that between (III) and (IV). However, as compounds (III), (IV), (IX), and (X) are only slightly soluble in chloroform, this relation should not be used to distinguish between 25L- and 25D-sapogenins having a 27-hydroxyl group.

Characteristic of 27-hydroxy-sapogenins is that the spectra of 25L-sapogenins (III and IX) show a strong band at 995 cm.$^{-1}$ whereas those of 25D-sapogenins (IV and X) show instead a strong band near 1010 cm.$^{-1}$. [The band of compound (X) at 1015 cm.$^{-1}$ is indistinct in chloroform solution.] This observation is useful for elucidation of the stereochemistry of 27-hydroxy-sapogenins.

25,27-*Dihydroxy-sapogenins* (V vs. VI). As shown in the Table and Fig. 2, compound (V) has characteristic bands at 982 and 860 cm.$^{-1}$, the latter being the position of the D-band of the ordinary 25D-sapogenins, in spite of the fact that compound (V) is a 25L-sapogenin.

The characteristic bands of compound (VI) are those at 1012, 918, and 840 cm.$^{-1}$, and there is no strong band near 980 or 900 cm.$^{-1}$. Moreover, it is suggestive of a 25L-sapogenin that this spectrum includes a strong band at 918 cm.$^{-1}$ and a band at 840 cm.$^{-1}$, although the compound is a 25D-sapogenin.

From these results, it is obvious that in the compounds (V and VI) the characteristic four bands of the ordinary sapogenins have undergone remarkable changes. Therefore, a band at 918 cm.$^{-1}$ in (VI) may be used only to distinguish between 25L- and 25D-25,27-dihydroxy-sapogenins.

25,27-*Epoxy-sapogenins* (VII vs. VIII). The characteristic bands of compound (VII) appear at 1004 and 917 cm.$^{-1}$, and those of the stereoisomer (VIII) at 1006, 922, and 880 cm.$^{-1}$ (see Table). Although neither compound has a strong band near 980 cm.$^{-1}$, both show a strong band near 920 cm.$^{-1}$ which suggests that they are 25L-sapogenins. Therefore, while it is impossible to use the four bands of the ordinary sapogenins for the elucidation of the stereochemistry of ring F, a fairly strong band at 880 cm.$^{-1}$ in (VIII) may be useful to distinguish between 25L- and 25D-25,27-epoxy-sapogenins.

Conclusions.—(i) For all sapogenins having oxygen substituents in ring F, the intensity of the absorption band near 980 cm.$^{-1}$ is less than for the ordinary sapogenin, or this band is absent. As this is also observed with 20-isosapogenins,[6] 23-bromosapogenins [5] and $\Delta^{25(27)}$-sapogenins, convallamarogenin,[4,8] (XIII), and (XIV),[7] the four characteristic bands assigned by Wall and Jones are not applicable to sapogenins having the substituents in ring E or F.

(ii) Although the ordinary sapogenins seldom have strong bands near 1000 cm.$^{-1}$, most of the compounds (I—X) have fairly strong bands in this region. Especially, 25L-27-hydroxy-sapogenin (III or IX) has a characteristic strong band at 995 cm.$^{-1}$.

(iii) Compounds (I—X) all have a strong band at 920—890 cm.$^{-1}$, like the ordinary sapogenins. Moreover, it is possible for 25-hydroxy-sapogenins (I or II) to distinguish the stereochemistry at C-25 by use of the strongest band in this region. On the other hand, all the other compounds (III—X) show the pattern of the ordinary 25L-sapogenin, with a strong band at 920—910 cm.$^{-1}$. The $\Delta^{25(27)}$-sapogenins (XIII) and (XIV) also have a strong band at 918 and 920 cm.$^{-1}$, respectively. Thus the distinction between 25L- and 25D-sapogenins by means of the bands at 920—890 cm.$^{-1}$ should not be applied to sapogenins in which the 25-methyl group is replaced by other groups, but only to ordinary sapogenins having a 25-methyl group.

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[8] Tschesche, Schwarz, and Snatzke, *Chem. Ber.*, 1961, **94**, 1699.