PARTICIPATION OF 19-ESTER GROUPS IN HYPOBROMOUS ACID ADDITIONS TO 2,3- AND 5,6-UNSATURATED STEROIDS*

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Hypobromous acid action upon the 2,3-unsaturated acetoxy derivative *Ia* results in the formation of two products, the bromohydrin *IVa* and the cyclic ether *VI* as a product of the participation of ether oxygen of the ester group. Both these compounds are formed from the 2α,3α-bromonium ion *XIIIa*. Under the same conditions the 5,6-unsaturated 19-acetoxy derivative *IIa* afforded a mixture of the following products: Bromohydrin *Xa* as the product of a normal reaction course and the isomeric bromohydrin *VIIa* arising by intramolecular interaction with the carbonyl oxygen of the 19-acetoxy group. Both these compounds are formed from the 5α,6α-bromonium ion *XVIIIa*. The epimeric 5β,6β-bromonium ion *XVIIa* gives rise to the bromohydrin *XIa*. The mechanism of these reactions, difference in behavior of both olefins *I* and *II* and the competition between ambident neighboring group participation and external nucleophile attack is discussed.

As part of a broader program of studying neighbouring group participation in electrophilic additions to steroid olefins we demonstrated[1-5] participation of hydroxyl and methoxyl groups in the course of hypobromous acid addition and Woodward hydroxylation. When structurally analogous epoxides were treated with acids, the epoxide ring was also cleaved with the participation of the neighboring methoxyl and hydroxyl group[6-9]. Competition between the intramolecular and external nucleophile was generally observed[6]. In the cases mentioned above, the characteristic feature of the reaction of the internal nucleophile is that the reaction center is attacked by the oxygen of the hydroxyl or methoxyl group.

In the present paper we deal with the participation of an acetoxy group in hypobromous acid addition to the double bond of analogous model substances *Ia* and *IIa*. The 19-acetoxy group as an internal nucleophile offers one more competitive possibility than the previously investigated groupings[5,6]: The reaction center may be attacked by the ether oxygen or by the carbonyl oxygen of the ester grouping. Attack by an external nucleophile is an alternative for participation and constitutes the third possible reaction pathway. In order to provide supporting evidence for carbonyl

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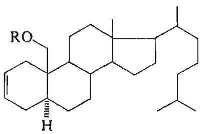
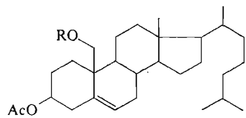
group participation, the same reaction was applied to ethyl carbonates *Ib* and *IIb* since these compounds should yield stable cyclic carbonates as a result of carbonyl group participation[10].

For description of the participating process leading to ring formation we consider desirable to describe the kind of participating atom before the reaction, and the size of the ring formed. We propose the following notation: Participating atom (in parentheses), nature of electrons bound to this atom before the reaction (superscript) and the size of the ring resulting from the reaction (figure before the parentheses). Thus, participation of a hydroxyl oxygen in a reaction leading to a 5-membered ring is described as $5(O)^n$ participation, participation of the carbonyl oxygen in a reaction leading to a 6-membered ring as $6(O)^{\pi,n}$ participation, *etc.*

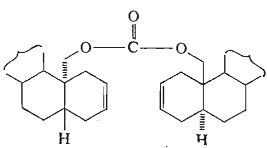
The acetate *Ia* was prepared by acetylation of the alcohol[4] *Id*; the acetoxy derivative *IIa* is a known[11] compound. The ethyl carbonates *Ib* and *IIb* were synthesized by treatment of the alcohols[4,12] *Id* and *IId* with ethyl chloroformate in pyridine. Whereas the 5,6-unsaturated alcohol *IId* reacted in a comparatively smooth reaction, the 2,3-unsaturated alcohol *Id* gave a mixture of the desired and slightly predominating ethyl carbonate *Ib*, and of the carbonate *III*.



Ia, R = CH_3CO
Ib, R = C_2H_5OCO
Ic, R = CH_3
Id, R = H

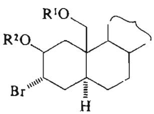


IIa, R = CH_3CO
IIb, R = C_2H_5OCO
IIc, R = CH_3
IId, R = H

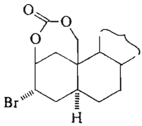


III

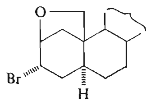
Hypobromous acid, generated *in situ* from N-bromoacetamide and perchloric acid in aqueous dioxane, gave from *Ia* a mixture of the bromohydrin *IVa* and the cyclic ether *VI* (Table I). Similarly, the ethyl carbonate *Ib* afforded the bromohydrin *IVb* and the compound *IVe*. Formation of the cyclic ether *VI* could not be observed in this case (Table I). As reported previously[4,5], the methoxy and hydroxy derivatives *Ic* and *Id*, when treated with hypobromous acid under the same conditions, yielded the cyclic ether *VI* (Table I) as the sole product.



IVa, $R^1 = CH_3CO$, $R^2 = H$
IVb, $R^1 = C_2H_5OCO$, $R^2 = H$
IVe, $R^1 = H$, $R^2 = C_2H_5OCO$



V



VI

The second acetoxy derivative *IIa* gave the following three bromohydrins on treatment with hypobromous acid: *VIIa*, *Xa* and *XIa* (Table II). The last one is rather unstable and spontaneously gives the epoxide *XIIa* in the course of working up the reaction mixture. The ethyl carbonate *IIb* gave analogous products *VIIb*, *Xb*, *XIb* (the latter converted spontaneously to *XIIb*), and, in addition, the cyclic carbonate *VIII* (Table II). As reported earlier[4,5], the same reaction of the methoxy derivative *IIc* affords a mixture of the cyclic ether *IX* and the epoxide *XIIc*, whereas the alcohol *IId* gave solely the cyclic ether *IX* (Table II).

The structure of the bromohydrin *IVa* is supported by the ^{1}H-NMR spectrum and was finally proved by chemical means. Presence of the 19-acetoxy group is revealed by a singlet of an acetate methyl and by the position of the AB-system of both 19-protons. The signals of the equatorial 2α- and 3β-protons are well resolved after treatment with trichloroacetyl isocyanate (Table III). These findings leave two alternative structures for consideration: 2β-OH, 3α-Br derivative (*IVa*) or the iso-

TABLE I

Yields of Products of Hypobromous Acid Addition to the Olefins *Ia*, *Ib*

Starting compound	Products, % of the total yield			Total yield, %	Ref.
	IV	*IVe*	*VI*		
Ia	12	0	88	90	—
Ib	52	48	0	87	—
Ic	0	0	100	96	5
Id	0	0	100	95	4

TABLE II

Yields of Products of Hypobromous Acid Addition to the Olefins *IIa*, *IIb*

Starting compound	Products, % of the total yield					Total yield, %	Ref.
	VII	*VIII*	*IX*	*X*	*XII*		
IIa	78	0	0	12	10	86	—
IIb	53	29	0	6	12	91	—
IIc	0	0	65	0	35	88	5
IId	0	0	100	0	0	97	4

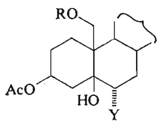
TABLE III

^{1}H-NMR Data of the Products of Hypobromous Acid Addition to the Olefins *Ia*, *Ib*, *IIa*, *IIb*

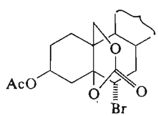
Compound	18-H	19-H[a]	2-H ($W_{1/2}$)	3-H ($W_{1/2}$)	6-H ($W_{1/2}$)
IVa	0·65	4·39	4·20 m	4·36 m	—
			5·17 m (7)[b]	4·49 m (7)[b]	—
IVb	0·68	4·47	4·25 to 4·45 m		—
			5·18 m (7)[b]	4·51 m (7)[b]	—
IVe	0·63	3·78	5·02 m (7)	4·43 m (7)	—
		4·41[b,c]	5·02 m (7)[b]	4·41 m[b,d]	—
VIIa	0·63	4·35	—	5·25 m (8)	4·64 m (25)
			—	5·25 m (8)[b]	5·45 m (25)[b]
VIIb	0·64	4·42	—	5·24 m (9)	4·64 m (25)
			—	5·24 m (9)[b]	5·37 m (25)[b]
VIIe	0·63	4·40	—	5·23 m (8)	—
VIII	0·65	4·34	—	5·12 m (8)	4·43 m (25)
Xa	0·63	4·58	—	5·38 m (25)	4·12 m (7)
		4·58[b]	—	5·38 m (25)[b]	5·36 m (7)[b]
XIIa	0·57	4·33	—	5·00 m (30)	2·97 d (J = 3·3)
XIIb	0·61	4·42	—	4·98 m (30)	2·98 d (J = 3·9)

[a] Center of the AB system. [b] The values obtained after treatment with trichloroacetyl isocyanate. [c] Overlaped by signals of 3-H. [d] Overlaped by signals of 19-H.

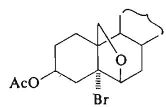
meric 2β-Br, 3α-OH bromohydrin. The latter compound was prepared by another method[13] and its structure was proved unequivocally; it is not identical with the compound now prepared from *Ia*. This is an indirect confirmation of the structure *IVa* for the product discussed. The structure of the bromohydrin *IVb* was proved in an analogous manner. The structure of the compound *IVe* was also established on the basis of ^{1}H-NMR and IR data. The ethyl carbonate group is still present (IR band at 1744 cm^{-1}; ^{1}H-NMR: 1·23 t, 4·18 q) but the AB system of both 19-protons is characteristically sensitive to trichloroacetyl isocyanate treatment. Thus, the ethyl carbonate group cannot be located at $C_{(19)}$. Signals of two equatorial protons in positions 2 and 3 demonstrate the presence of 2β and 3α-substituents. The cyclic ether *VI* is identical with the authentic sample prepared in a different manner[4,5].



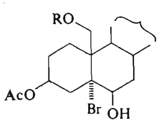
VIIa, $R = CH_3CO$, $Y = Br$
VIIb, $R = C_2H_5OCO$, $Y = Br$
VIIe, $R = CH_3CO$, $Y = H$



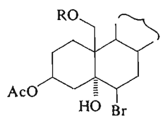
VIII



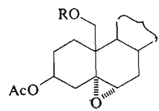
IX



Xa, $R = CH_3CO$
Xb, $R = C_2H_5OCO$



XIa, $R = CH_3CO$
XIb, $R = C_2H_5OCO$
XIc, $R = CH_3$



XIIa, $R = CH_3CO$
XIIb, $R = C_2H_5OCO$
XIIc, $R = CH_3$

The structure of the bromohydrin *VIIa* follows mainly from its ^{1}H-NMR spectrum (Table III). The presence of two acetate methyl signals and unchanged chemical shift of the 19-protons AB-system demonstrate that the compound retains its 19-acetoxy group. The broad multiplet at 4·64 ppm is associated with the 6β-proton. The nature of the 6α-substituent was proved by chemical means: Raney-nickel reduction of *VIIa* yielded a tertiary alcohol *VIIe*. The tertiary character and the 5β-configuration (3α-H, $W_{1/2} = 8$ Hz) of the hydroxyl group in *VIIe* follows from its ^{1}H-NMR spectrum.

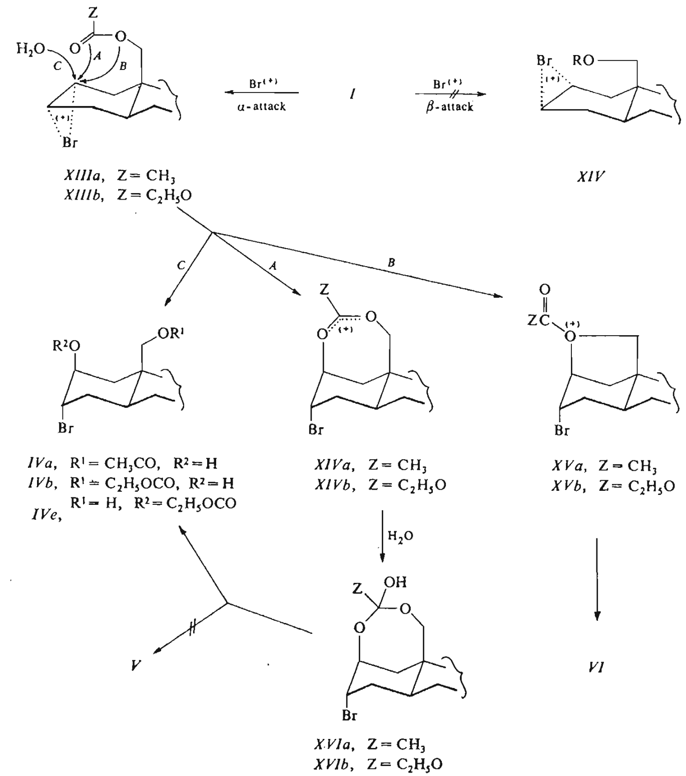
The structure of the bromohydrin *VIIb* was proved analogously. The ^{1}H-NMR spectrum of the cyclic carbonate *VIII* (Table III) has features similar to the spectra of the bromohydrins *VIIa* and *VIIb* and demonstrates the 6α-configuration of the bromine atom and *cis*-junction of the rings A and B. The compound *VIII* is inert to trichloroacetyl isocyanate treatment, and its IR spectrum shows the characteristic absorption of the —O—CO—O— grouping (1768 cm^{-1}), whereas the band of OH grouping is absent. No signals of the ethoxyl group are present in the ^{1}H-NMR spectrum. All these facts, coupled with characteristic chemical shift of the 19-protons, prove the presence of a cyclic carbonate group attached to 5β and 19-positions. The ^{1}H-NMR spectrum of the bromohydrin *Xa* reveals the presence of a 19-acetoxy group and of a 6β-hydroxyl group (a narrow multiplet of the 6α-H, shifted toward the lower field on treatment with trichloroacetyl isocyanate). Similar arguments prove the equatorial conformation of the 3β-acetoxy group and the presence of a 5α-bromine atom. The tentative structure of *Xb* is based on analogy and TLC migration rate. The epoxides *XIIa* and *XIIb* are identical with compounds prepared by direct epoxidation of olefins *IIa* and *IIb* (ref.[13,14]).

Addition of hypobromous acid to 2,3-unsaturated 19-acetoxy derivative *Ia* commences by formation of the 2α,3α-bromonium ion *XIIIa*. The rate of formation of the epimeric 2β,3β-bromonium ion *XIVa* is either negligible compared with the rate of formation of the 2α,3α-ion *XIIIa*, or its opening by subsequent nucleophile attack proceeds much less rapidly.

Stereoelectronic control of opening the 2α,3α-bromonium ion *XIIIa* should lead to a diaxial derivative so that the cleavage should occur at $C_{(2)}$ by an attack from the β-side. There are three possibilities that can accommodate these requirements: *1*) Attack by the carbonyl oxygen of the ester group with formation of an intermediate *XIVa* containing a seven-membered ring, *i.e.* $7(O)^{\pi,n}$ participation (path *A*). This cation would lead to bromohydrin *IVa via XVIa*. *2*) Attack by the ether oxygen of the ester group. In this case the intermediate *XVa* contains a five-membered ring, the reaction should be classified as a $5(O)^n$ participation (path *B*) and would yield the cyclic ether *VI*. *3*) Attack by water as external nucleophile (path *C*) again leading to the bromohydrin *IVa*.

In the case of the acetoxy derivative *Ia* we isolated the bromohydrin *IVa* and the cyclic ether *VI* in 1 : 9 ratio (Table I); obviously, the $5(O)^n$ participation predominates. It is pertinent to note that, under identical conditions, analogous methoxy derivative *Ic* and hydroxy derivative *Id* give exclusively[4,5] the cyclic ether *VI*. The lower yield of this ether from the acetate *Ia* may be attributed to decreased electron density on the ether oxygen of the ester grouping resulting in its lesser nucleophility; competitive participation of carbonyl oxygen, or reaction with external nucleophile may be assumed to be well possible. Since the bromohydrin *IVa* can be a product of either of two reactions (path *A* or *C*), the product analysis alone cannot provide information of the mode of its formation.

In order to obtain some evidence concerning this question, addition of hypobromous acid was applied to ethyl carbonate *Ib*. Analogously to the acetate *Ia*, the following routes may be envisaged for reaction of the 2α,3α-bromonium ion *XIIIb*: Attack of external nucleophile (water, path *C*), $7(O)^{\pi,n}$ participation of the carbonyl oxygen (path *A*), and $5(O)^n$ participation of the ether oxygen of the ester group (path *B*). Apart from these three routes, also $7(O)^n$ participation of the ethoxyl oxygen may be considered in this instance. On the other hand, no product of $5(O)^n$



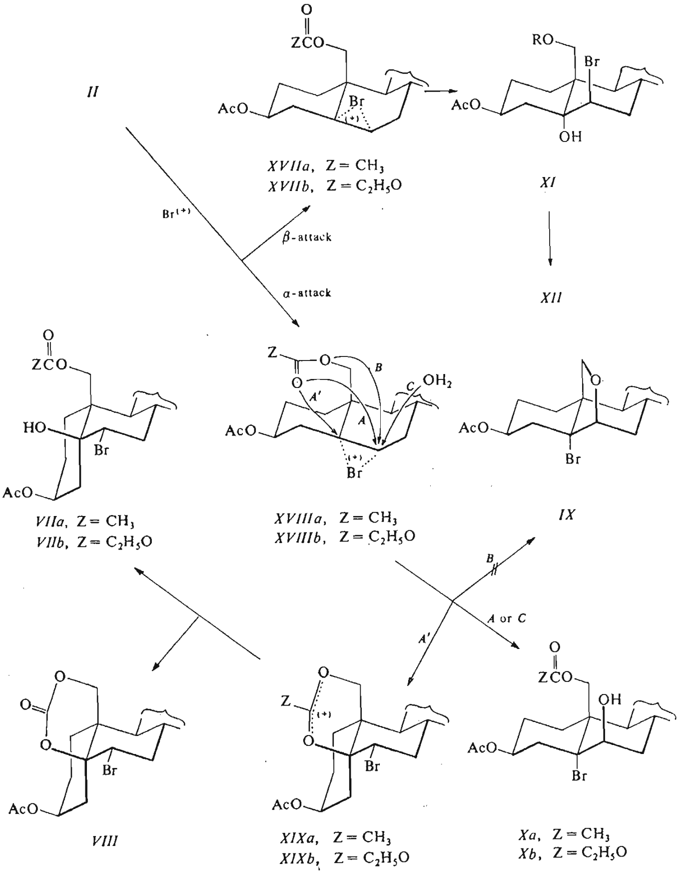
participation (cyclic ether *VI*) or of $7(O)^n$ participation (cyclic carbonate *V* or 2β-ethoxy derivative) was observed. The fact that $(O)^n$ participation is not operative at all in this instance is presumably due to further decrease of electron density at the ether oxygens. The intermediary cation *XIVb*, formed by $7(O)^{\pi,n}$ participation (path *A*) is hydrated to the unstable derivative *XVIb* which gives rise to two compounds, *IVb* and *IVe*; the third possible product, cyclic carbonate *V* is not formed. Of course, the bromohydrin *IVb* may also be formed *via* and external attack by a molecule of water and the above experiments cannot rule out this route. However, we know from analogies that five- and six-membered cyclic ions similar to the seven-membered ion *XIVb* are cleaved more or less symmetrically. The same tendency may be reasonaby assumed also for *XIVb*; then the ratio of the reaction products indicates that formation of the bromohydrin *IVb* is predominantly due to $7(O)^{\pi,n}$ participation (path *A*). The attack of an external nucleophile is likely to occur only to a limited extent. Another possible mode of formation of *IVe* might be an intramolecular migration of the acyl group but this pathway was ruled out since the ester *IVb* remains intact in the presence of 10% perchloric acid in dioxane solution.

A different situation exists in the case of the 5,6-unsaturated 19-acetoxy derivative *IIa*. Both epimeric bromonium ions *XVIIa* and *XVIIIa* are likely to be formed. External attack by water on 5β,6β-bromonium ion *XVIIa* gives the bromohydrin *XIa* which yields the epoxide *XIIa* spontaneously. Its content in the reaction products amounts to 10%. This behavior is in line with the previously observed[5] formation of the epoxide *XIIc* from the 19-methoxy derivative *IIc* (Table II).

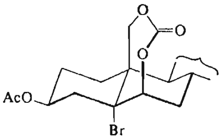
The 5α,6α-bromonium ion *XVIIIa* may be opened in two ways: Stereoelectronic aspects require preferential cleavage at $C_{(6)}$ leading to the 5α,6β-diaxial product whereas according to Markovnikov rule the cleavage should occur at $C_{(5)}$. With common 19-unsubstituted steroids the cleavage proceeds almost exclusively[15] at $C_{(6)}$. In our case, the bromonium ion *XVIIIa* can undergo cleavage at $C_{(6)}$ in three ways: *1*) By participation of the carbonyl oxygen of the acetoxy group, *i.e.* $7(O)^{\pi,n}$ participation (path *A*), which would yield the bromohydrin *Xa*. *2*) By the attack of ether oxygen of the acetoxy group, *i.e.* $5(O)^n$ participation (path *B*) yielding the five-membered cyclic ether *IX*. *3*) By an attack of water as external nucleophile (path *C*) giving the same bromohydrin *Xa* as by path *A*.

Whereas with 19-methoxy and 19-hydroxy derivatives *IIc* and *IId* solely path *B* is operative and the only product of the cleavage of the 5α,6α-bromonium ion type *XVIII* is the cyclic ether *IX* (Table II), in the case of the acetoxy derivative *IIa* the path *B* is not operative at all and some external attack by water (path *C*) or $7(O)^{\pi,n}$ participation of the carbonyl oxygen of the ester group (path *A*) yield the bromohydrin *Xa*. Again, decreased electron density on the ether oxygen of the ester group is obviously responsible for this behavior. Differentiation between two possible modes of formation (pathway *A* or *C*) of the bromohydrin *Xa* was not possible at this stage and was made by using the ethyl carbonate *IIb* in favor of the pathway *C*.

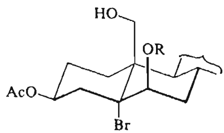
The only product of cleavage of the bromonium ion *XVIIIa* at $C_{(5)}$ is the bromohydrin *VIIa* which could be isolated in nearly 80% yield. The reaction proceeds with $6(O)^{\pi,n}$ participation of the carbonyl group *via* a six membered cyclic intermediate *XIXa* (path *A'*).



In order to verify the above mechanism of the addition to the double bond in position 5,6 we subjected the ethyl carbonate *IIb* to the same reaction. We obtained analogous by-products *Xb* and *XIIb*, the main products being *VIIb* and *VIII*. The bromohydrin *Xb* should be formed from the 5α,6α-bromonium ion *XVIIIb* either by reaction with water as an external nucleophile (path *C*) or by $7(O)^{\pi,n}$ participation of the carbonyl oxygen of the ester grouping (path *A*). Since no other products corresponding to the latter route (*i.e.* the 6β,19-cyclic carbonate *XX* with a seven-membered ring or the compound *XXI* with the $C_2H_5OCO_2$-grouping at 6β-position) were isolated, we prefer path *C* as the prevailing route of bromohydrin *Xb* formation.



XX



XXI, $R = OCOC_2H_5$

Formation of the compounds *VIIb* and *VIII* proves $6(O)^{\pi,n}$ participation of the ester carbonyl. Of course, another route to their formation, $6(O)^n$ participation of the ethoxyl oxygen, may be taken into consideration. However, assumption of the $6(O)^{\pi,n}$ participation also in the instance of the ethyl carbonate *IIb* is supported by the fact that the total yield of *VIIb* and *VIII* from *IIb* (53% and 29%) is almost identical with the yield of the bromohydrin *VII* from the acetate *IIa* (78%). In the latter case only the $6(O)^{\pi,n}$ participation is possible.

Reactions of the 5α,6α-bromonium ion *XVIII* demonstrate that the $6(O)^{\pi,n}$ participation can reverse the normal reaction course in favor of a diequatorial product (contrary to stereoelectronic requirements) and is even able to suppress the $5(O)^n$ participation.

In all cases of neighboring group participation described in the present paper the participating group was approaching the reaction center from a position approximately perpendicular to the plane of the original double bond. This arrangement was secured by the axial conformation of the $C_{(10)}-C_{(19)}$ linkage. For the cases of compounds *Ia*–*Ic* and *IIa*–*IIc* the reactivities of the participating ester groups may then be arranged in the following sequence:

$$6(O)^{\pi,n} > 5(O)^n > 7(O)^{\pi,n} \geqq \text{external nucleophile attack}$$

$7(O)^n$ Participation was not observed. A generalization is hardly possible since additional factors, such as proximity to the reaction center *etc.* doubtless play an important role [5,6] and exact comparison of these influences would require much more experimental material.

EXPERIMENTAL

Melting points were determined on a Kofler blcok. Analytical samples were dried at 50°C/0·2 Torr (26 Pa). Optical measurements were carried out in chloroform with an error of ±3°. The IR spectra were recorded on a Zeiss UR 20 spectrometer in tetrachloromethane. The ^{1}H-NMR spectra were recorded on a Tesla BS 467 instrument (60 MHz) in deuteriochloroform at 30°C with tetramethylsilane as internal reference. Chemical shifts are given in ppm. Apparent coupling constants (in Hz) were obtained from a first order analysis. The identity of samples prepared

TABLE IV

Analytical and Physical Data of Products of Hypobromous Acid Additions to Olefins *Ia*, *Ib*, *IIa*, *IIb*

Compound	Formula (m.w.)	Calculated/Found			M.p., °C $[\alpha]_D^{20}$
		% C	% H	% Br	
IVa	$C_{29}H_{49}BrO_3$ (519·6)	67·03 66·88	9·50 9·43	15·38 15·29	163–165 +45°
IVb	$C_{30}H_{51}BrO_4$ (555·7)	64·84 64·96	9·25 9·31	14·38 14·57	137–139 +61°
IVe	$C_{30}H_{51}BrO_4$ (555·7)	64·84 64·62	9·25 9·18	14·38 14·71	81–83 +52°
VI	$C_{27}H_{45}BrO$ (465·6)	69·66 69·71	9·74 9·62	17·16 17·48	98–99[a] +36°
VIIa	$C_{31}H_{51}BrO_5$ (583·7)	63·79 63·58	8·81 8·49	13·69 13·81	159–160 +36°
VIIb	$C_{32}H_{55}BrO_7$ (631·7)	60·84 60·73	8·78 8·85	12·65 12·46	oil +23°
VIII	$C_{30}H_{47}BrO_5$ (567·6)	63·48 63·44	8·35 8·56	14·08 14·31	oil −6°
Xa	$C_{31}H_{51}BrO_5$ (583·7)	63·79 63·67	8·81 8·93	13·69 13·46	oil −19°
XIIa	$C_{31}H_{50}O_5$ (502·7)	74·06 74·15	10·02 9·93	— —	oil[b] −49°
XIIb	$C_{32}H_{54}O_6$ (534·8)	71·87 71·63	10·18 10·12	— —	106–108 −30°

[a] In accordance with the literature[4,5]. [b] In accordance with the literature[14].

by different routes was checked by mixture melting point determination, by thin layer chromatography (TLC) and by infrafed and ^{1}H-NMR spectra. Usual work up of an ethereal solution means washing the solution with 5% aqueous hydrochloric acid solution, water, 5% aqueous potassium hydrogen carbonate solution, water, drying with sodium sulfate and evaporation of the solvent *in vacuo*.

Addition of Hypobromous Acid to the Compounds *Ia*, *Ib*, *IIa*, *IIb*

The unsaturated compound (0·5 mmol) was dissolved in dioxane (5 ml) and water (0·5 ml) and treated with 10% perchloric acid (0·4 ml) and N-bromoacetamide (80 mg, 0·6 mmol) for 45 min at room temperature. The mixture was diluted with water and the product extracted with ether. The etheral solution was washed with water, a 5% aqueous potassium hydrogen carbonate solution, aqueous sodium thiosulfate solution, water, then dried with sodium sulfate and evaporated. The residue was chromatographed on four preparative silica gel plates (20 × 20 cm) using a mixture of light petroleum, ether and acetone (80 : 10 : 10) as eluent. The products were crystallized from aqueous acetone, or aqueous ethanol. Analytical and physical data of the isolated compounds are given in Table IV.

5α-Cholest-2-en-19-ol 19-Acetate (*Ia*)

The alcohol[4] *Id* (600 mg) was dissolved in pyridine (5 ml) and treated with acetic anhydride (2 ml) at room temperature overnight. The mixture was decomposed with ice, the product taken up in ether, and the ethereal solution was worked up as usual to yield the oily acetate *Ia* (583 mg), $[\alpha]_D^{20}$ +43° (*c* 2·0). For $C_{29}H_{48}O_2$ (428·7) calculated: 81·25% C, 11·29% H; found: 81·17% C, 11·32% H.

5α-Cholest-2-en-19-ol 19-Ethyl Carbonate (*Ib*)

The alcohol[4] *Id* (500 mg) was dissolved in pyridine (5 ml) and treated with ethoxycarbonyl chloride (0·7 ml) at 0°C for 3 h. The mixture was decomposed with ice, the product extracted with ether and the ethereal solution was worked up as usual. The residue was chromatographed on a silica gel column (30 g) using a mixture of light petroleum and benzene (90 : 10) as eluent. Collection and evaporation of the fractions containing a polar component yielded the crude carbonate *Ib* (243 mg) which on crystallization from a mixture of acetone, methanol and water afforded the pure *Ib* (162 mg), m.p. 66–67°C, $[\alpha]_D^{20}$ +44° (*c* 1·7). For $C_{30}H_{50}O_3$ (458·7) calculated: 78·55% C, 10·99% H; found: 78·64% C, 11·02% H.

5-Cholestene-3β,19-diol 3-Acetate 19-Ethyl Carbonate (*IIb*)

The alcohol[12] *IId* (1·5 g) was dissolved in pyridine (8 ml) and treated with ethoxycarbonyl chloride (2 ml) at 0°C for 3 h. The mixture was decomposed with ice, the product taken up in ether and the ethereal solution was worked up as usual. The residue was chromatographed on a silica gel column (50 g) using a mixture of light petroleum and ether (97 : 3) as eluent. The lipophilic fractions were collected and evaporated to yield the crude carbonate *IIb* (1·1 g) which on crystallization from a mixture of acetone, methanol and water afforded the pure *IId* (723 mg), m.p. 120–121°C, $[\alpha]_D^{20}$ −51° (*c* 2·2). For $C_{32}H_{54}O_5$ (518·8) calculated: 74·09% C, 10·49% H; found: 74·02% C, 10·33% H.

Bis(5α-cholest-2-en-19-yl) Carbonate (*III*)

The lipophilic fractions from the chromatography of the reaction products of the alcohol *Id* with ethoxycarbonyl chloride were collected and evaporated to yield the crude carbonate *III* (212 mg), which on crystallization from a mixture of acetone, methanol and water afforded the pure *III* (147 mg), m.p. 157–158°C, $[\alpha]_D^{20}$ +55° (*c* 1·6). ^{1}H-NMR spectrum: 0·67 (3 H, s, 18-H. For $C_{55}H_{90}O_3$ (799·3) calculated: 82·65% C, 11·35% H; found 82·28% C, 11·24% H.

5β-Cholestane-3β,5,19-triol 3,19-Diacetate (*VIIe*)

The bromohydrin *VIIa* (20 mg) was dissolved in ethanol (2 ml), Raney nickel (50 mg) was added and the mixture was stirred at 70°C for 7 h. The inorganic material was separated by filtration, washed with methanol and acetone, the filtrate evaporated under reduced pressure, the residue was dissolved in ether and the ethereal solution was worked up as usual. The residue was chromatographed on one preparative silica gel plate (10 × 20 cm) using double development with a mixture of light petroleum, ether and acetone (80 : 10 : 10). Corresponding zones were collected, the product *VIIe* was isolated by elution with ether as an oily material (10·6 mg), $[\alpha]_D^{20}$ +44° (*c* 1·3). For $C_{31}H_{52}O_5$ (504·8) calculated: 73·77% C, 10·38% H; found: 73·56% C, 10·31% H.

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