PART II : SECTION A

REVIEW ON THE CHEMISTRY AND MOLECULAR
REARRANGEMENTS OF STERoidal AND
TRITERPENOID EPoxIDES
Molecular rearrangements in organic chemistry generally involve those reactions where molecules undergo some changes in their structures and assume a new one by virtue of a change in their atomic disposition. The great diversity of rearrangement phenomena both in the steroidal and triterpenoid field makes it difficult to include all their aspects. However, in line with our present work, a brief discussion on the rearrangement of steroidal and triterpenoid epoxides will be presented here.

**Various Reagents for Epoxidation:**

A variety of reagents have been employed for epoxidation. Amongst them alkaline hydrogen peroxide, osone, chromic acid and peroxo acids, especially m-chloroperbenzoic acid are the usual epoxidising agents. Direct epoxidation of olefins over a suitable catalyst has also been observed e.g., monoepoxidation of dienes with t-butyl hydroperoxide over the catalyst Mo-hexacarbonyl. Sodium perborate solution has also been used as an epoxidising agent. In the last few years boron promoted epoxidation and β-epoxidation with ferric acetylacetonate and hydrogen peroxide have found considerable importance. Another mode of epoxidation
involves cyclohydroxylation, which has acquired importance because of steric selectivity. The utility of the latter method is however limited due to complicated side products and abnormal reactions.

Excellent reviews of the conversion of various olefinic systems into epoxide functions are available and instances of peroxo acid epoxidation among the higher terpenoids and particularly steroids are known.

**Mechanism of Epoxidation:**

Pioneering works by Lynch and Pausacker, Vitmauer and Swern, Woodward and coworkers led to exclusive information regarding the reactivity and stereoselectivity of epoxidation by peracids. The above studies and those of Ogata and Tabushi established that peroxo acids were essentially electrophilic by nature whereas the olefinic component acted as a nucleophile in these reactions. The 'molecular' mechanism of epoxidation by peracids was first suggested by Bartlett and as invoked by Campbell and coworkers could be represented as:

\[
\text{C} + \text{O} = \text{C} \rightarrow \text{C} = \text{O} \rightarrow \text{C} + \text{R}
\]
The above mechanism was modified to explain the neighbouring group effect.

Important advances in the molecular mechanisms had later been developed from the elegant studies of Huisgen.\textsuperscript{21a} He stressed that in alkylated acyclic and cyclic olefins 1,3-dipolar addition reaction took place. Kvart \textit{et al.}\textsuperscript{21b} also proposed a 1,3-dipolar mechanism.
The following points are to be considered in selecting an acceptable mechanism for olefin epoxidation:

(a) The nature of epoxidising agent and electronic effect of substituents on its reactivity.
(b) The electronic effect of substituents on the reactivity of the olefinic component.
(c) Stereochemical factors affecting the reactivity of olefins.
(d) Solvent effects.
(e) Neighbouring group effects.

Stereochemical Requirements for Epoxidation:

The configurational and conformational requirements of epoxidation can be best understood by applying these reactions to steroids. Since the upper or β-face of the steroid system in the A/B trans configuration is somewhat screened by the two angular methyl groups, epoxidation occurs preferentially from the less hindered α-side. In the epoxidation of steroids having A/B cis fusion and containing the double bond in ring- A, the angular methyl groups do not interfere with the approach of the reagent from the β-side (probably due to folding back of ring- A), but the B ring, especially the Cβ-methylene group, interferes with approach from the α-side; such steroids, therefore, give β-epoxides.
Selectivity in Reactions of Epoxides:

Epoxides are very reactive group of compounds and offer a wide variety of possibilities in synthesis. Through their ring opening reactions they represent two functional groups on adjacent carbon atoms. Some excellent reviews of the chemistry of epoxides have appeared during the last decade \cite{17,24}. Some selected reactions of epoxides will be discussed to illustrate the features controlling the site of opening of the epoxide ring.

When unsymmetrically substituted epoxides (1) are treated with acidic reagents, two products (2) and (3) are theoretically possible.

\[
\begin{align*}
R-\underset{\text{OH}}{\text{O}}-\underset{\text{H}}{\text{CH-CH}_2} & \overset{\text{H}_2\text{O}}{\longrightarrow} \text{OH} & \text{R-CH-CH}_2\text{O}_2\text{H} \\
\text{(1)} & & \text{R-CH-CH}_2\text{X} \\
& & \text{R-CH-CH}_2\text{OH}
\end{align*}
\]

Opening of the ring occurs in two distinct ways depending on the substrate and the reagent. With HBr, protonation of epoxide oxygen leads to selective cleavage of C-O bond in accordance with the Markownikoff's rule. In the transition state the weaker of the two C-O bonds opens up with concomitant attack of Br\textsuperscript{-} ion from the rear side of the molecule. It is very difficult to explain the different factors leading to
regioselectivity in epoxide ring opening. Substituent effects have been considered to consist of a combination of inductive, field, resonance and polarisability effects. Most epoxide ring opening reactions are of SN2 or even of SN1 type. In all cases bond breaking is relatively more important in the transition state than in a normal bimolecular substitution reaction due to strain in the three membered oxirane ring. Furst and Plattner noted that the ring opening in steroidal epoxide was regioselective, the major product being diaxial.

In a recent study Hart and Shih showed the homoallylic participation in the acid catalysed rearrangement of an \( \alpha, \beta \)-epoxyketone. The rearrangement of (4) and (5) occurred in acid exclusively with vinyl migration. When the vinyl group and epoxide ring were trans (5) rearrangement was much faster than with the cis isomer (4), owing to homoallylic participation during the epoxide ring opening. However, the rearrangement products in both instances were identical, i.e., a 1:4-mixture of cis (6) and trans-2-acetyl-5-vinyl-2,3,4,5-tetramethyl-3-cyclopentenones (7).
Epoxide Rearrangement:

Inspection of models showed that in 1,2-disubstituted compounds of cyclohexane derivatives, "movement apart" or "bending away" of the trans-1,2-placed (e,e) groups and "approach" of the cis-1,2-placed (e,a) groups were much more facile, since it led to a flattening of the chair conformation towards the flexible form against a relatively soft potential barrier. The opposite movement of the same 1,2-groups would require increased puckering of the chair against a potential barrier. Thus the adjacent (e,a) bends in a cyclohexane could be fairly readily brought into a plane to make the required half-chair, which was virtually impossible for the (e,e) bends. Hence it seemed that 6-membered ring 1,2-epoxides existed in a half-chair conformation, having a cis linkage. In this form the conformation adopted was a slightly distorted chair rather than a true half-chair.

The epoxide ring which resembled a double bend electronically in many respects, opened up largely diaxially under nucleophilic or electrophilic attack.
Epoxides were known to react with a wide variety of reagents, both protic and aprotic. The reactions often showed a significant rearrangement in the entire molecule besides Markownikoff and anti-Markownikoff additions and E1 and E2 types of elimination reactions. All these rearrangements usually involved 1,2-hydride and methyl shifts. Large number of evidences of ring expansion and contraction had also been observed. It was found that epoxide rearrangement with simple mineral acids or Lewis acids took place with the initial formation of a carbocation followed by group migration and isomerisation, typical of a backbone or retropinacolelic rearrangement. Such changes might be attributed to some intracyclic strain in the molecule.

Some selected reactions of steroidal and triterpenoid epoxides catalysed mainly by BF$_3$-etherate and aqueous perchloric acid in line with our present work have been discussed next.

Rearrangement of Steroidal Epoxides Catalysed by Boron trifluoride etherate:

The course of epoxide cleavage by BF$_3$-etherate complex depended besides other factors on the nature of medium employed. The medium determined the extent of electrophilicity of the acid and therefore its effectiveness, because of the probability of a chemical coordination between them. Thus the treatment of BF$_3$-etherate on epoxides in ether-benzene mixture gave fluoroxydrins due to reduced electrophilicity, the
epoxide cleavage taking place upon a concerted attack of the fluoride ion. In benzene, however, these fluorohydrins had been shown to undergo rapid backbone rearrangement with $BF_3$. The formation of such fluorohydrins were in accordance with the generalisation made by Parker and Isaacson earlier that ring opening usually took a trans diaxial course.

Studies on steroidal epoxides showed that the simple 5β,6β- (8) and 5α, 6α-epoxides (9) afforded 6-exo steroids (10) and (11) respectively with stereospecific hydride migration. Epoxide cleavage occurred selectively at the more substituted C5-position.

Stereoselective rearrangements of 1,2-oxides involving 1,2-hydride and methyl shifts were extensively demonstrated in the steroid field. That
the rearrangement of epoxides to the corresponding ketones involved 1,2-hydride shift was first demonstrated in the conversion of \(3\beta\)-acetoxy-
\(9\alpha\), \(11\alpha\)-oxide-\(\Delta^7,22\)-ergostadiene (12) to the corresponding \(11\)-keto-\(9\alpha\)-
compound (13) by boron trifluoride in ether. However, in the less basic
medium benzene, the more stable product (14) was obtained.

Obviously the stereochemistry of these thermodynamic and kinetic products
depended on the effective role of the solvent, and dictated the
mechanistic pathway to be traversed\(^{29d, 32}\).
Hembest and Wrigley\textsuperscript{33} in similar studies of steroidal 4,5- and 9,11-epoxides in benzene had indicated the products to be ketones with a Valden inversion at the site of departure of the epoxide oxygen.

Guest and coworkers\textsuperscript{29(a, d)} noted the difference in product orientation when the \(3\beta\)-acetoxy group was replaced by a \(3\beta\)-hydroxy group in the steroidal \(5\alpha, 6\alpha\)-epoxides.

The latter series reacted predominantly via the \(C_2-O\) cleavage, leading in some cases, to extensive migration of methyl and hydride groups in backbone type rearrangement.
The product (15) represented an epimerisation at C-6 which was not expected, but had been explained to occur through either a \( \text{C}_{10} \) or a \( \text{C}_{8} \) carbonium ion as shown below.
Guest et al.\textsuperscript{29c} also studied the effect of BF$_3$ on the 9\(\alpha\),10\(\alpha\)-steroidal epoxides.

\[ \text{Diene 294, 32} \]

In certain epoxy steroids, proton loss from the initially generated carbocation, subsequent elimination of water from the resultant allylic alcohol, and finally double bond migration under acidic influence, yielded dienes \textsuperscript{29d,32}.

Among the epoxides which underwent such rearrangements were 8\(\alpha\), 9\(\alpha\)-, 8\(\alpha\), 14\(\alpha\)- and 7\(\alpha\), 8\(\alpha\)-epoxy steroids.
The initial formation of a carbocation was not always followed by proton abstraction pathway only but might involve concomitant methyl group migrations, in the presence of other factors, mostly steric. Some reactions of 9,11-epoxides offered interesting results. Thus ApSimon and coworkers\textsuperscript{34} showed that whereas lanostane-9\(\alpha\),11\(\alpha\)-epoxides were unreactive towards BF\(_3\), a 4,4-dimethyl \(\Delta^5\)-9\(\alpha\),11\(\alpha\)-oxide (16) rearranged to the 9\(\beta\)-methyl derivative (17) due to stabilisation of the developing cationic centre by the 5,6-double bond.
The above rearrangement followed a single pathway via the allylic tertiary carbocation at C\textsubscript{10}. Methyl group migration to an adjacent cationic centre was best induced when the former was anti-periplanar with respect to the opening end of the epoxide, facilitating a \textit{trans} attack.

The position of unsaturation arising in consequence of methyl rearrangement depended largely on the particular system involved. It was observed that whenever conjugation could result with another unsaturated grouping, this invariably occurred.

Complete backbone rearrangements involving transitory but potential carbocation centres at C\textsubscript{2}, C\textsubscript{10}, C\textsubscript{9}, C\textsubscript{8}, C\textsubscript{14}, and C\textsubscript{13}, resulting in a 13(17)-unsaturation by 1,2-hydride and methyl shifts were known to take place. Thus 3\textalpha-acetoxy-4\textbeta, 5\textalpha-epoxy-4\textbeta-methyl compound (18) with BF\textsubscript{3} gave the backbone rearranged product (19) in 90% yield\textsuperscript{35}. 

\[
\begin{array}{c}
\text{(6)} \quad \text{BF}_3 \\
\text{C}_6\text{H}_6
\end{array}
\] 

\[
\text{(17)}
\]
It seemed reasonable that the epoxide 18 should open up at C₅ remote from the acetoxy group, but the subtlety of the factor controlling the rearrangement was indicated by the effect of treating the isomeric 3β-acetoxy-4α, 5α-epoxide 20 with BF₃, leading to 21 and 22.
The action of BF₃ on steroidal epoxides often proceeded with ring contraction⁴⁷. Thus both the α- and β-epoxides of cholest-4-en-3-one (23) rearranged to the epimeric aldehyde (24).

Though it was not yet fully clear why some epoxides underwent partial rather than complete rearrangement, Cozen et al.³⁸-⁴⁰ had shown that the electronic influence of substituents in ring B was important with regard to C₉-0 bond cleavage³⁸, as well as those factors inhibiting hydride migration from C₈ to C₉ thereby yielding Δ⁹-compounds³⁹.

Cozen and coworkers⁴⁰ carried out BF₃ catalysed rearrangements on a number of steroidal systems to re-establish all the foregoing observations of this complex reaction pathway. One such rearrangement was with 4,5-epoxy-5β-cholestane (25) in benzene for 2 minutes. The products isolated showed a predominant C₉-0 bond cleavage with the formation of 5α-fluoro-cholestan-4β-ol (26), 5α-cholestan-4-one (27), cholesta-3,5-diene (28), cholesta-4,6-diene (29), the complete backbone rearranged product (30) and the partially rearranged product (31).
BF₃ - etherolé/benzene
2 minutes

(25)

(26) + (27) + (28)

(29) + (30) + (28)
Rearrangement of Triterpenoid Epoxides Catalysed by Boron trifluoride etherate:

The studies on the rearrangement of triterpene epoxides are not as numerous as those encountered in the steroidal field. The progress recorded during the last few years, however, promised to open new vistas in the biogenetic predictions and synthetic achievements in triterpenoid chemistry.

This was quite expected since these oxide functions had the capacity to provide the necessary thermodynamic driving force, in the presence of protic and aprotic reagents, to start up an intramolecular addition and abstraction reaction, resulting in an overall skeletal change.

A classical example of 1,2-methyl shift was observed in BF$_3$-etherate catalysed rearrangement of 1,2-epoxy-lupan-3-one (32) in benzene affording (33).
Perox acids were known to initiate rearrangements in the molecule containing an epoxide ring, but the reaction usually proceeded in a different path and consequently a different product was obtained when the same epoxide was treated with a Lewis acid.

Sengupta et al. showed that friedelan-3\(\alpha\), 4\(\alpha\)-epoxide (34) when treated with BF\(_3\)-etherate in benzene underwent molecular rearrangement with the concomitant opening of the epoxide ring. The products were identified as 18-iso-\(\alpha\)-oleana-3(5),12-diene (35), olean-12-en-3\(\alpha\)-ol (36), 18-isoolean-12-en-3\(\alpha\)-ol (37), olean-13(18)-en-3\(\alpha\)-ol (38) and glut-5(10)-en-3\(\alpha\)-ol (39).

Apsimon and coworkers, in their study of triterpenoid epoxides to elucidate possible structural features directing the rearrangement pathway, undertook the study of the cleavage of (34) with Lewis acids in an anticipation to isolate products of extensive backbone rearrangement of the \(\beta\)-amyrin type (40), although they did not rule out the possibility of rearrangement to intermediate compounds. However, with gaseous BF\(_3\), they obtained glut-5(10)-en-3\(\alpha\)-ol (39) as the only isolable product. The authors in giving a mechanistic interpretation favoured an intramolecular proton abstraction pathway, where the only base available to aid in the proton removal, was the epoxide oxygen atom.
Hopene-I oxide (41) on treatment with hydrochloric acid in ethanol gave hepa-15,17(21)-diene (42) while Hopene-II oxide (43) gave 11,13(18)-diene (44).

But a completely different course of reaction path was followed when (41) was treated with BF$_3$-etherate in CHCl$_3$, a diene (45) and a ketone (46) being isolated in 85% and 15% yields respectively. The conversion of (41) to hepa-12, 17-diene (45) was novel, as it involved a double migration (or single 1,3-shift) of a methyl group.
In the case of hopene-II oxide (43), only the novel ketone of the type (47) was obtained.  

![Chemical structures](image-url)
Thus it was observed that protic and Lewis acids gave completely different results. In the former, a large amount of proton acceptor, helped to terminate the reaction without much rearrangement. This was probably brought about by the initial formation of the protonated epoxide (48) which on cleavage at C-17 gave the allylic alcohol (49). The latter by dehydration and rearrangement gave the more stable diene (50).

The formation of the conjugated diene (44) was shown to have been formed by the cleavage of the protonated epoxide (51) to give an allylic alcohol (52), followed either by the 1,4-elimination of water, or by the formation of the 12,18-diene which then isomerised to the more stable diene (44).
The behaviour of the two epoxides with Lewis acid was novel. Due to steric factors the cleavage of the $C_{17}$-$O$ bond would be favoured over cleavage at $C_{21}$ (because in the latter case, the OH group would have to be axial with respect to the six-membered ring) and in the absence of a good proton acceptor the formation of the ion (53) resulted. Now two possible routes existed, the usual 1,2-shift of the isopropyl group leading to the ketone (46) or a possible concerted rearrangement—elimination of the $C_{18}$-methyl and $C_{13}$-hydrogen leading to the diene (45). The latter was favourable since the non-bonding interaction between the two cis-axial methyl groups at $C_{14}$ and $C_{18}$ would be relieved.
In the absence of a good proton acceptor and in the less polar medium, the borontrifluoride-epoxide complex (54), however, instead of losing a proton, preferentially underwent a bond migration, leading to the ketone (47) via the intermediate (55).
The rearrangements and their mechanistic interpretations could well be utilised in establishing the absolute stereochemistry of the epoxide ring as well as predicting other stereochemical features in triterpenoid epoxides. As for example different names i.e., dendropanoxide, epoxyglutinane and campanulin were attributed to a triterpene oxide, C_{30}H_{50}O. Two alternative structures, DiB-friedoolean-3,10-oxide (56) and DiB-friedoolean-3,5-oxide (57) had been proposed in the triterpene series.

Treatment of campanulin with HCl-EtOH followed by acetylation gave glut-5(10)-em-3β-yl-acetate (58) as the sole isolable product, from which Rangaswami et al. assigned 3,10-oxide linkage to campanulin (56), but with BF_{3}-Et_{2}O in ether it afforded a mixture of alcohols which on acetylation and fractional crystallisation furnished proportionally a large amount of glut-5(10)-em-3β-yl-acetate (58) and a lesser amount of a mixture of (58) and glut-5-em-3β-yl-acetate (59), thereby favouring the presence of a 3,5-oxide linkage rather than a 3,10-oxide.
Recently Block et al. \cite{49} modified their structure for campanulin as 3β-friedelein-3,10-oxide (56) from NMR studies.

The above behaviour could be rationalised by assuming two mechanisms operating simultaneously during the opening of the oxide ring, one involving the usual generation of a tertiary carbocation at C-10 followed by elimination of a proton at C-5 to give (58) (Path b), and the other involving concerted migration of C-5 proton to C-10 followed by trans elimination of the axial proton at C-6, yielding thereby (59) (Path a).
The structure of dendropamoxide was finally settled as DAB-friedoolean-3,10β-oxide (56) by X-ray studies. Recently, dendropamoxide (56) was synthesized from friedelin (60), which was first converted into friedelen-3-one (61). The latter with m-chloroperbenzoic acid gave α-epoxide (34) and β-epoxide (62). The latter in ether was treated with BF₃-etherate at -10° to furnish dendropamoxide (56).
Action of Aqueous Perchloric Acid on Epoxides:

Cleavage of an epoxide to a diol with HCl or H₂SO₄ in aqueous acetone might proceed poorly because of conversion to a chlorohydrin or a sulfate ester. Perchloric acid was satisfactorily used as an epoxide cleaving reagent and there were a number of examples of epoxide ring opening by aqueous perchloric acid in the steroid field. For example, a solution of 5α, 6α-epoxide (63) in tetrahydrofuran when treated with 30% perchloric acid for 7 hours at 22°C gave the tetrol (64).

\[
\begin{align*}
(63) & \xrightarrow{\text{aq. HClO₄, THF}} (64)
\end{align*}
\]

Akhrem et al. showed that in 16, 17α-epoxy-16β-methyl-pregn-5-en-3β-ol-20-one (65), the epoxide ring opened by perchloric acid in dioxane to give the 16-methyl-Δ¹⁵-17α-hydroxy steroid (66).
Sengupta et al. \textsuperscript{43} showed that when 3,4-epoxyfriedelane (34) was treated with aqueous perchloric acid in tetrahydrofuran, the epoxide ring opened up without any molecular rearrangement to yield only friedelan-3\(\beta\),4-\(\alpha\)-diol (67).
Bernstein et al.\textsuperscript{58} showed that 3,20-bis-ethylenedioxy-5\(\alpha\),6\(\alpha\)-epoxypregnane 11\(\beta\),17\(\alpha\),21-triol (68) when treated with 70\% perchloric acid in methanol for 4 hours at room temperature furnished only 11\(\beta\),17\(\alpha\),21-trihydroxy-allopregnane-3,6,20-trione (69). However, when the reaction was carried out with 10\% perchloric acid in methanol for only 35 minutes the same epoxide (68) gave 20-ethylenedioxy-5\(\alpha\),11\(\beta\),17\(\alpha\),21-tetrahydroxy-6\(\beta\)-methoxypregnane-3-ene (70).
Examples of the reaction of steroidal epoxides with aqueous perchloric acid where no molecular rearrangement occurred were found in the work of Tschesche et al.\textsuperscript{59}. They observed that when the 16\textendash\en-20\textendash\one-14,15\textendash epoxide (71) was treated with aqueous perchloric acid in dioxane 14\(\beta\), 15\(\alpha\)-dihydroxy-3\(\beta\),12\(\beta\)-diacetoxy-5\(\alpha\),14\(\beta\)-pregn-16\textendash\en-20\textendash\one (72) was obtained.

Ring opening of steroidal 5\(\alpha\),6\(\alpha\)-epoxide (73) without any backbone rearrangement occurred when it was treated with perchloric acid in ethyl methyl ketone containing a little water at room temperature. The product was the trans diaxial glycol (74). From a study of kinetics it was observed that addition of water inhibited the cleavage probably by lowering the concentration of the protonated epoxide which was formed initially\textsuperscript{1a}. 
Steroidal $11\alpha,12\alpha$-epoxide (75) also gave the \textit{trans}-dianial glycol (76) on cleavage with perchloric acid$^{34a}$. 
An interesting feature in the rearrangement of steroidal epoxides was that involving a transannular hydrogen transfer\textsuperscript{29d,32}. The conversion of \( \beta,11\beta \)-epoxy cortical steroid (77) to the \( \Delta 8(14) \)-11\( \beta \)-hydroxy compound (78) with cold 60\% perchloric acid was explained to have proceeded via the protonated species (79), by way of transannular hydride transfer from \( C_4 - \alpha \) to \( C_\gamma - \alpha \) with simultaneous extrusion of the \( C_8 - \beta \) hydrogen.

\begin{center}
\begin{tikzpicture}
\node[draw,shape=circle] (A) at (0,0) {\( R \)};
\node[draw,shape=circle] (B) at (1,0) {\( H \)};
\node[draw,shape=circle] (C) at (2,0) {\( HO \)};
\node[draw,shape=circle] (D) at (3,0) {\( H \)};
\node[draw,shape=circle] (E) at (4,0) {\( HO \)};
\node[draw,shape=circle] (F) at (5,0) {\( H \)};
\node[draw,shape=circle] (G) at (6,0) {\( HO \)};
\node[draw,shape=circle] (H) at (7,0) {\( H \)};
\node[draw,shape=circle] (I) at (8,0) {\( HO \)};
\node[draw,shape=circle] (J) at (9,0) {\( H \)};
\node[draw,shape=circle] (K) at (0,-1) {\( C \)};
\node[draw,shape=circle] (L) at (1,-1) {\( H \)};
\node[draw,shape=circle] (M) at (2,-1) {\( HO \)};
\node[draw,shape=circle] (N) at (3,-1) {\( H \)};
\node[draw,shape=circle] (O) at (4,-1) {\( HO \)};
\node[draw,shape=circle] (P) at (5,-1) {\( H \)};
\node[draw,shape=circle] (Q) at (6,-1) {\( HO \)};
\node[draw,shape=circle] (R) at (7,-1) {\( H \)};
\node[draw,shape=circle] (S) at (8,-1) {\( HO \)};
\node[draw,shape=circle] (T) at (9,-1) {\( H \)};
\node[draw,shape=circle] (U) at (10,0) {\( \text{\( \Delta 8(14) \)-11\( \beta \)-hydroxy compound (78)} \)};
\node[draw,shape=circle] (V) at (11,0) {\( \text{\( C_4 - \alpha \)) to \( C_\gamma - \alpha \) with simultaneous extrusion of the \( C_8 - \beta \) hydrogen.}};
\draw (A) -- (B) -- (C) -- (D) -- (E) -- (F) -- (G) -- (H) -- (I) -- (J);
\draw (K) -- (L) -- (M) -- (N) -- (O) -- (P) -- (Q) -- (R) -- (S) -- (T);
\draw (A) -- (U);
\end{tikzpicture}
\end{center}

Such a 1,3-shift was more probable since classical 1,2-Wagner shift would not have produced (78) but its \( C_\delta \)-epimer.
PART II : SECTION B

PRESENT WORK (THEORETICAL)
REARRANGEMENT OF
Glyc-5\(\alpha\),6\(\alpha\)-Oxido-3\(\beta\)-yl-Acetate

Scope of the present work

In the last few decades a number of organic chemists utilised the three membered epoxide ring as an unique intermediate for the generation of two hetero atoms on the vicinal positions by basic or acidic reagents. While doing this they explored a wide varieties of interesting phenomena leading to partial or complete backbone rearrangements, ring contraction or expansion as the epoxide ring was cleaved with protic (e.g., aqueous HClO\(_4\)) and aprotic reagents (e.g., BF\(_3\)-etherate). Thus they presented a lot of information regarding the stereochemistry of the formation of epoxide ring and its opening.

Among other factors the nature of the reagent and the functional groups in the neighbourhood of the three membered oxirane ring share a major part in the stereochemistry of the epoxide ring opening.

It is of interest to note that Corey et al.\(^{60}\) described a new type of oxidative rearrangement of a pentacyclic triterpene where a thermodynamically less stable carbon skeleton than the initial skeleton was formed.
Thus in the conversion of (80) → (81) there was an intrinsic driving force which overcame the energetically unfavourable change in the arrangement of carbon and hydrogen and the skeletal rearrangement could be considered as "powered" by the oxidation.
Kitagawa et al. used the above single step photo-oxidation procedure as a method of epoxidation. Thus oleaneic acid (82) and erythrediol (83) in acid media led to the corresponding 11α,12α-epoxy derivatives.
The steric bindings of epoxide reactivity have led to stereoselective products in most cases, so that such rearranged products usually have fewer non-bonding interactions than the starting materials. A number of interesting cases of ring opening of triterpenoid epoxides followed by molecular rearrangements have been cited earlier. Many of such rearrangements have been reported in recent years. In 1978 from this laboratory Sengupta et al. reported the effect of 7-keto function on such epoxide rearrangement taking the $3\alpha,4\alpha$-epoxy friedelan-7-one as a model compound. Berti et al. have studied the opening of the epoxide ring with various reagents.

Encouraged by these interesting aspects as well as results of similar contemporary works, the present study of the molecular rearrangements of glut-5$\alpha$,6$\alpha$-epoxy-3$\beta$-yl-acetate (84) with boron trifluoride etherate in anhydrous benzene and also with aqueous perchloric acid was undertaken. From the present investigations some interesting and novel rearrangements have been demonstrated by the characterisation of a number of products from physical data. Mechanistic interpretations have also been forwarded to explain their formation.

Preparation of Glut-5$\alpha$,6$\alpha$-oxide-3$\beta$-yl-acetate (84) from Glutemel (85):

The starting material for the preparation of the epoxide (84) was glutemel (85) which was isolated from the bark of *Euphorbia royleana*.
Glut-5-en-3β-ol (85), m.p. 203-206° (Lit. 68 m.p. 206-208°) was acetylated as usual with a mixture of acetic anhydride and pyridine to yield glut-5-en-3β-yl-acetate (86), m.p. 188-192°. The desired epoxide (84) m.p. 216-218°, $\delta_{c}^{13}$ +47.6° (CHCl$_3$) was then prepared by treating (86) with m-chloroperbenzoic acid in chloroform and crystallising the product from a mixture of chloroform and acetone.
Infrared spectrum (Fig. 1) of Compound (84):

The IR spectrum showed peaks at 1730 cm\(^{-1}\) and 1260 cm\(^{-1}\) (acetate group) and at 1360 cm\(^{-1}\) and 1380 cm\(^{-1}\) (gem dimethyl). Bands in the region 800-900 cm\(^{-1}\) may be attributed to the presence of the epoxy function.

PMR spectrum (Fig. 2) of Compound (84):

PMR spectrum showed an unresolved multiplet (1 H) centred around \(\delta 4.83\) ppm due to the axial proton at C-3 bearing the acetoxy group and a singlet (3 H) at \(\delta 2.1\) ppm due to the acetoxy methyl group. The signal due to the proton on C-6 appeared as a quartet (1 H) around \(\delta 3.1\) ppm. The coupling constants for this C-6 proton with J value of 3 HZ arising from axial-equatorial interactions (\(\phi_{ae} \approx 60^\circ\)) and with J value of 4 HZ arising from axial-axial interactions (\(\phi_{aa} \approx 180^\circ\)) were observed. The low J value (4 HZ) of axial-axial interactions was due to the fact that the axial protons at C-6 and C-7 were not exactly coplanar due to distortion arising out of the exirane ring and hence the dihedral angle was very close to 60°. The signals for the remaining eight tertiary methyl groups appeared in the region between \(\delta 0.75\) and \(\delta 1.16\) ppm.

Mass spectrum (Fig. 3) of Compound (84): Chart I

The mass spectrum showed the molecular ion peak at \((M^+ 484)\) which agreed well with the molecular formula \(C_{32}H_{52}O_3\). Elimination of acetic acid (60 units) and methyl group (15 units) from \((M^+ 484)\) gave peaks
Treatment of (84) with aqueous perchloric acid in tetrahydrofuran for 8 h at room temperature gave two significant products along with the unchanged starting material. The least polar product (~20%) was a non-conjugated diene, m.p. 208-210°, $[\alpha]_D^{20} +11.8^\circ$ (CHCl$_3$) which was shown to be glut-5,12-dien-3β-yl-acetate (90) based on spectral data. It showed only end absorption in the UV. The next product in order of polarity was identified as the unchanged starting material (84). The most polar
CHART 1

m/e 469 (47.17%)

$M^+ - CH_2$  
$\equiv O$  
$\rightarrow$  
\(-\text{AcOH}\)

C_{22}H_{32}O_3  
$M^+ 484 (100\%)$

m/e 119 (23.10%)

m/e 135 (18.84%)

m/e 205 (54.04%)

m/e 22 (8.45%)
crystalline product was a new diol, shown to be friedel-3-en-2 β,6β-diol (91a), m.p. 280-285°C, $\delta^D_{CHCl_3}$ +8°C (CECI). The corresponding diacetate (91b) had m.p. 262-268°C.

The structures of these rearranged products were established on the basis of physical data discussed below.
Infrared spectrum (Fig. 4) of Compound (90):

The IR spectrum of the compound (90) showed bands at 1730 cm\(^{-1}\) and 1255 cm\(^{-1}\) (acetate) and at 1380 cm\(^{-1}\) and 1360 cm\(^{-1}\) (gem dimethyl). The band at 840 cm\(^{-1}\) may be attributed to the presence of two trisubstituted double bonds in the molecule.

PMR spectrum (Fig. 5) of Compound (90):

The PMR spectrum of the compound (90) showed a singlet (3 H) at \(\delta 1.95\) ppm due to the acetoxy methyl group. The olefinic protons at C-6 and C-12 appeared as two broad peaks (1 H each) centred around \(\delta 5.1\) and \(\delta 5.95\) ppm. A quartet (1 H) centred around \(\delta 4.6\) ppm was due to the \(\alpha\) -H at C-3. The coupling constants for this C-3 axial proton with J value of 10 HZ arising from axial-axial interactions (\(\phi_{aa} \approx 180^\circ\)) and with J value of 6 HZ arising from axial-equatorial interactions (\(\phi_{ae} \approx 60^\circ\)) were observed. The signals for the remaining eight tertiary methyl groups appeared in the region between \(\delta 0.8\) and \(\delta 1.05\) ppm.

Mass spectrum (Fig. 6) of Compound (90): Chart 2

The mass fragmentation pattern of the compound (90) was in good agreement with the structure (90). The base peak appeared at m/e 406 (M\(^+\) - 60). A peak at m/e 391 was formed by the elimination of methyl group (13 units) from m/e 406. The other peaks at m/e 259, m/e 205,
m/e 171 and m/e 132 corresponded to the fragments (92), (93), (94) and (95) respectively.

**Formation of Compound (90):**

Nucleophilic attack by water on the protonated epoxide (96) led to anti-Markownikoff opening furnishing first the diol (97). As soon as the diol (97) was formed, in the acid medium the tertiary hydroxyl group attached to C-5 was smoothly dehydrated to give the intermediate classical carbocation (98). It may be mentioned here that D:A-friedellean-3β,4β-epoxide (62) also rearranged to dendrepanoxide (96) through similar classical carbocation (62a)52.
This carbocation (98) now became the starting point of a series of methyl and hydride shifts analogous to the well-known backbone rearrangement of friedel-3-ene\textsuperscript{53,69,70} to give the product (99). The hydroxyl group attached to C-6 in (99) was now in favoured orientation to eliminate a molecule of water to give the product (90). The mechanistic interpretation for the formation of (90) is shown in the following Scheme 1.
Scheme 1

101
Infrared spectra (Fig.7) of the Diol (91a) and its Diacetate (91b) (Fig.8):

The IR spectrum (Fig.7) of the compound (91a) showed a broad band at 3340 cm\(^{-1}\) (OH). The spectrum showed no bands for acetoxy function. The spectrum (Fig.8) of the diacetate (91b) of the diol (91a) showed bands at 1735 cm\(^{-1}\) and 1243 cm\(^{-1}\) characteristic of acetoxy group. Bands at 1375 cm\(^{-1}\) and 1360 cm\(^{-1}\) indicated the presence of a gem-dimethyl group. The band at 840 cm\(^{-1}\) may be attributed to the presence of a trisubstituted double bond.

FMR spectrum (Fig.9) of the Diol (91a):

FMR spectrum of (91a) showed an ill-defined multiplet (1 H) around 5 5.5 ppm due to the olefinic proton at C-3, a broad peak (2 H) at 5 3.25 ppm was due to the two hydroxyl protons which disappeared on D\(_2\)O exchange; a multiplet (1 H) at 5 3.45 ppm was due to the proton attached to C-6 bearing the hydroxyl group. The spectrum showed no signal for acetoxy function thus indicating that deacetylation had taken place. Another multiplet (1 H) around 5 4.25 ppm was characteristic of the allylic proton attached to C-2. Eight tertiary methyl groups appeared in the region 5 1.0 to 1.3 ppm.

FMR spectrum (Fig.10) of the Diacetate (91b):

FMR spectrum of the compound (91b) showed two sharp singlets (3 H each) at 5 1.9 and 5 1.95 ppm due to two acetoxy groups attached to C-2 and C-6. The signal of \(\alpha\)-H at C-2 and that of the olefinic
proton at C-3 merged and appeared as a multiplet (2 H) around 8 5.3 ppm.

The chemical shift of the methine proton at C-2 is expected to fall in the olefinic region \(^{75}\). The axial \(\alpha\) -H at C-6 appeared as a quartet with J value of 7 Hz (axial-equatorial interaction, \(\phi_{ae} \approx 60^\circ\)) and with J value of 11 Hz (axial-axial interaction, \(\phi_{aa} \approx 180^\circ\)). The methyl group attached to the olefinic bond at C-4 appeared slightly in the downfield region 8 1.3 ppm due to the deshielding effect of the double bond. The remaining seven tertiary methyl groups appeared in the region 8 0.75 to 8 1.3 ppm.

**Mass spectrum (Fig 11) of the Diol (91a) : Chart 3**

The mass spectrum showed the molecular ion peak (\(M^+\)) at m/e 442 which agreed well with the molecular formula \(C_{30}H_{50}O_2\). The base peak appeared at m/e 424 (\(M^+ - 18\)). The other prominent peaks were at m/e 409 (m/e 424 - \(CH_3\)), m/e 406 (m/e 424 - \(H_2O\)) and m/e 391 (m/e 406 - \(CH_3\)). The peaks at m/e 205, m/e 135 and m/e 119 were characteristic of the fragments (87), (88) and (89) respectively.

**Formation of the Compound (91a) :**

The formation of relatively small amount (\(\sim 10\%\)) of the diol (91a) with an axial C-5 methyl group involving a 1,3-diaxial interaction with the C-9 methyl group and the cleavage of the epoxide ring in one direction were of interest. Though the acetoxy group in (84) was not in preferred orientation for easy trans elimination — being catalysed by the acid still it was eliminated as a molecule of acetic acid to give
Scheme 2

(84) \[\rightarrow \text{Acoh} \rightarrow \text{H}^+\]

(100)

(101) \[\rightarrow \text{H}_2\text{O} \rightarrow \text{OH}_2\]

(102)

(91a)
the intermediate product (100). That the compound (91a) had no acetoxy group was supported from the IR (Fig. 7) and PMR spectra (Fig. 9). Now nucleophilic attack by water on the protonated oxepide (101) led to anti-Markownikoff opening furnishing the intermediate diol (102). Immediately after accepting a proton from the medium, the tertiary hydroxyl group at C-5 in (102) became a good leaving group. Attack of a molecule of water at C₂, shift of the electron pair between C₃ and C₄ and shift of the β-Me group from C₄ to C₃ took place in a synchronous step with the elimination of a molecule of water from C-5 (102). Thus the resulting product was the en-diol (91a). The suggested mechanistic pathway is shown in Scheme 2.

Evidences in favour of the formation of (91a) are well documented in literature. Recently Halsall et al. 71 while reporting the structure of 3-exoclerodane (103) put forward a similar mechanistic interpretation to support such type of rearrangement responsible for the formation of (103).
The migration of the C-4 β-methyl group was prompted by the presence of a β-hydroxy group at C-3 which provided a source of electrons. Another example was the isolation by Halsell et al.\textsuperscript{72} of 6α-hydroxy-4β,5β-dimethyl-cholestan-3-one (104) from the treatment of 5α,6α-epoxy-4,4-dimethylcholestan-3β-ol (105) with borontrifluoride-ether complex.

\[
\begin{array}{c}
\text{HO} \\
\text{C8H17} \\
\text{O} \\
\end{array}
\begin{array}{c}
\text{BF}_3 - \text{Et}_2\text{O} \\
\end{array}
\begin{array}{c}
\text{C8H17} \\
\text{O} \\
\text{OH} \\
\end{array}
\]

(105)  \hspace{1cm} (106)

Whitlock et al.\textsuperscript{73} isolated the ketone (106), as one of the products, from the decalin epoxide (107).

\[
\begin{array}{c}
\text{HO} \\
\text{C8H17} \\
\text{O} \\
\end{array}
\begin{array}{c}
\text{BF}_3 - \text{Et}_2\text{O} \\
\end{array}
\begin{array}{c}
\text{C8H17} \\
\text{O} \\
\text{OH} \\
\end{array}
\]

(107)  \hspace{1cm} (106)
Rearrangement of the Epoxide (84) with Boron trifluoride Etherate:

Treatment of the epoxide (84) with BF₃-etherate in anhydrous benzene for 30 min gave two significant products. The less polar one obtained in a variable yield of 30-40% was a transoid conjugated diene, m.p. 210-215° which was identified as glut-1(10),5-dien-3β-yl-acetate (108)(Lit. 7) 209-210° based on spectral data and comparison with an authentic specimen. The more polar rearrangement product eluted from the column with a mixture of pet ether and benzene (1:4) as a major fraction was found to be glut-5(10)-en-3β-acetoxyl-6α-ol (109a), m.p. 232-235°. It underwent smooth acetylation with a mixture of acetic anhydride and pyridine to furnish the corresponding acetate (109b), m.p. 135-160°.
FIG. 12. UV SPECTRUM OF GLUTA-1(10), 5- DIH T- 
~ 3 β-YL-ACETATE (108)
UV spectrum (Fig. 12) of the Diene (108):

Ultraviolet spectrum of the conjugated diene (108) in 95% alcohol showed absorption maxima at 232 nm (ε = 16,500), 238 nm (ε = 18,000) and 246 (inflection) nm (ε = 11,000) which suggested the presence of a transoid conjugated diene system.

Infrared spectrum (Fig. 13) of the Diene (108):

The IR spectrum showed a peak at 860 cm⁻¹ attributable to trisubstituted double bond. It also showed bands at 1730 cm⁻¹ and 1245 cm⁻¹ (acetate) and at 1380 cm⁻¹ and 1365 cm⁻¹ (gem dimethyl group).

PMR spectrum (Fig. 14) of the Diene (108):

The PMR spectrum of (108) showed a sharp singlet (3 H) at δ 1.95 ppm due to the acetoxy methyl group. The olefinic protons at C-1 and C-6 appeared as two broad peaks (1 H each) centred around δ 5.1 and δ 5.55 ppm. A quartet (1 H) centred around δ 4.6 ppm was due to the axial -H at C-3. The coupling constants (J) of 10 Hz arising from axial-axial interaction (φ nn = 180°) and of 6 Hz arising from axial-equatorial interaction (φ ne = 60°) were observed. The signals for the remaining eight tertiary methyl groups appeared in the region δ 0.8 to δ 1.05 ppm.

Mass spectrum (Fig. 15) of the Diene (108): Chart 4

The molecular ion peak (M⁺) at m/e 466 agreed well with the molecular formula C₃₂H₅₀O₂. The base peak appeared at m/e 406 (M⁺ - 60).
Chart 4

m/e 253
(3.79%)

m/e 188
(15.96%)

-16

m/e 135
(15.55%)

m/e 205
(5.05%)

m/e 11
(2.57%)
Appearance of the prominent peaks at m/e 171 corresponding to the ion (110), at m/e 253 corresponding to the ion (111) and at m/e 205 corresponding to the ion (87) suggested that the compound was glut-1(10),5-dien-3β-yl-acetate (108).

Infrared spectra (Fig. 16) of the Compound (109a) and its Acetate (109b) (Fig. 17):

The compound glut-5(10)-en-3β-acetoxy-6α-ol (109a) showed IR bands (Fig. 16) at 3400 cm\(^{-1}\) (OH). The bands at 1740 cm\(^{-1}\) and 1245 cm\(^{-1}\) were characteristic of the acetoxy group. The corresponding acetate i.e., glut-3β,6α-diacetoxy-5(10)-ene (109b) showed IR peaks (Fig. 17) at 1735 cm\(^{-1}\) and 1250 cm\(^{-1}\) (acetate) and at 1380 cm\(^{-1}\) and 1365 cm\(^{-1}\) (gem dimethyl).

PMR spectrum (Fig. 18) of the Diacetate (109b):

PMR spectrum showed two sharp singlets (3 H each) at δ 1.9 and δ 2.0 ppm due to the two acetoxy methyl groups attached to C-3 and C-6. Absence of any olefinic proton in the spectrum indicated tetrasubstituted
nature of the double bond. The signal for the $\alpha$ -H at C-3 and that for $\beta$ -H at C-6 merged and appeared as a broad multiplet (2 H) centred around $\delta$ 5.2 ppm. The remaining eight tertiary methyl groups appeared in the region $\delta$ 0.8 to $\delta$ 1.1 ppm.

**Mass spectrum (Fig. 19) of the Diacetate (109b) : Chart 5**

The base peak appeared at m/e 466 ($\text{M}^+$ - 60). Other characteristic peaks appeared at m/e 406 (m/e 466 - 60), m/e 391 (m/e 406 - 15). The peaks at m/e 171 and at m/e 253 corresponded to the fragments (112) and (113) respectively.

![Formulae](image)

**Formation of (108) and (109a) :**

In a non-polar solvent like benzene borontrifluoride etherate gave the intermediate ion-pair (114) in a cage of solvent. The carbocation in (114) can lead to the stabilised intermediate (115), by elimination of the C$_{10}$-hydrogen. This compound, glut-5(10)-en-3$\beta$-acetoxy-6$\alpha$-ol (109a) has indeed been isolated as a major product. However, the formation of the stable transoid diene (108) in this reaction could only be explained by
the elimination of one of the hydrogens at C-1 from the intermediate product (115). The mechanism of the epoxide cleavage and the formation of the resulting rearranged products is depicted in Scheme 3.

Scheme 3
PART II : SECTION C

PRESENT WORK (EXPERIMENTAL)
Extraction of Glut-5-en-1β-ol (85) from the stem of Euphorbia reyleana

Air dried powdered stem of E. reyleana (1.2 Kg) was exhaustively extracted with benzene for 20 h. The resinous mass (66 g) obtained after the removal of benzene was digested with ether and filtered. The ether solution was washed with ice-cold 5% KOH (5x100 ml) and then with ice-cold water until the aqueous layer was neutral and finally dried over anhydrous sodium sulphate and evaporated to furnish a neutral material (37 g). The latter was digested with pet ether (500 ml) and allowed to stand overnight. The crystalline solid (20 g) that separated out was filtered. The pet ether soluble and pet ether insoluble fractions were separated by filtration. The crystalline solid was mostly taraxerol.

Examination of the Pet ether Soluble Part:

The above pet ether solution (500 ml) after the separation of the crude solid (mainly taraxerol) was placed over a column of silica gel (400 g) and the column was eluted with different solvent mixtures as shown in Table 1.
### Table 1

Each fraction collected was 50 ml in volume.

<table>
<thead>
<tr>
<th>Fractions</th>
<th>Eluant</th>
<th>Residue after removal of solvent</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 - 4</td>
<td>Pet ether</td>
<td>Mil</td>
</tr>
<tr>
<td>5 - 10</td>
<td>Pet ether</td>
<td>Oil</td>
</tr>
<tr>
<td>11 - 16</td>
<td>Pet ether : Benzene (4:1)</td>
<td>Oil</td>
</tr>
<tr>
<td>17 - 22</td>
<td>Pet ether : Benzene (3:2)</td>
<td>Yellow gum and solid</td>
</tr>
<tr>
<td>23 - 31</td>
<td>Pet ether : Benzene (1:4)</td>
<td>Oil</td>
</tr>
<tr>
<td>32 - 45</td>
<td>Benzene</td>
<td>Mil</td>
</tr>
</tbody>
</table>

Fractions 17-31 of the above chromatogram (Table 1) were combined to give a partially crystalline solid (11 g) which was subjected to rechromatography over a column of silica gel (200 g). The column was eluted with different solvent mixtures as shown in Table 2.

### Table 2

Each fraction collected was 50 ml in volume.

<table>
<thead>
<tr>
<th>Fractions</th>
<th>Eluant</th>
<th>Residue after removal of solvent</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 - 5</td>
<td>Pet ether</td>
<td>Mil</td>
</tr>
<tr>
<td>6 - 10</td>
<td>Pet ether</td>
<td>Yellow oil</td>
</tr>
<tr>
<td>11 - 12</td>
<td>Pet ether : Benzene (4:1)</td>
<td>Yellow oil</td>
</tr>
<tr>
<td>13 - 19</td>
<td>Pet ether : Benzene (4:1)</td>
<td>Solid, m.p. 200-203°</td>
</tr>
<tr>
<td>20 - 25</td>
<td>Pet ether : Benzene (3:2)</td>
<td>Oil</td>
</tr>
<tr>
<td>26 - 35</td>
<td>Pet ether : Benzene (2:3)</td>
<td>Oil</td>
</tr>
<tr>
<td>36 - 40</td>
<td>Benzene</td>
<td>Mil</td>
</tr>
</tbody>
</table>
Glut-5-en-3β-ol (85):

The crystalline solid (2.8 g), m.p. 200-203° from fractions 13-19 of the above chromatogram (Table 2) on crystallisation from a mixture of chloroform and acetone gave glut-5-en-3β-ol (85), m.p. 203-206° (Lit. m.p. 206-208°).

Acetylation of Glut-5-en-3β-ol (85):

Glut-5-en-3β-ol (85; 1 g), m.p. 203-206° was heated with distilled pyridine (10 ml) and acetic anhydride (10 ml) on a steam bath for 3 h and the reaction mixture was allowed to stand overnight at room temperature. The solid that separated out from the reaction mixture was filtered and washed with dil. HCl to remove pyridine and finally with water till neutral. The crude acetate (1.2 g) was taken in pet ether (60-80°) and placed over a column of silica gel (200 g). Elution of the column with pet ether-benzene mixture (9:1) afforded a solid which on crystallisation from a mixture of chloroform and acetone furnished pure glut-5-en-3β-yl-acetate (86), m.p. 188-192° (Lit. m.p. 188-192°).

Epoxidation of Gluteryl Acetate (86): Glut-5α,6α-oxide-3β-yl-acetate (84):

Glut-5-en-3β-yl-acetate (86; 1 g) was treated with m-chloroperbenzoic acid (1.05 g) in spectral grade chloroform (35 ml) and stirred for 8 h at 0°C. The completion of the reaction was monitored by TLC in CHCl₃(100). The chloroform layer was washed successively with 2(N)H₂SO₄ containing a few crystals of KI, dilute Na₂S₂O₃ solution and finally
with water till neutral. The organic phase was dried over anhydrous Na$_2$SO$_4$ and evaporated. The solid (1 g) was taken in a minimum amount of benzene and placed over a column of silica gel (20 g). The column was eluted with different solvent mixtures as depicted in Table 3.

**Table 3**

<table>
<thead>
<tr>
<th>Fractions</th>
<th>Eluent</th>
<th>Residue after removal of solvent</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 - 4</td>
<td>Pet ether</td>
<td>Nil</td>
</tr>
<tr>
<td>5 - 10</td>
<td>Pet ether : Benzene (9:1)</td>
<td>Solid A, m.p. 245-250°</td>
</tr>
<tr>
<td>11 - 16</td>
<td>Pet ether : Benzene (9:1)</td>
<td>Nil</td>
</tr>
<tr>
<td>17 - 26</td>
<td>Pet ether : Benzene (4:1)</td>
<td>Solid B, m.p. 210-212°</td>
</tr>
<tr>
<td>27 - 32</td>
<td>Pet ether : Benzene (3:2)</td>
<td>Nil</td>
</tr>
<tr>
<td>33 - 40</td>
<td>Benzene</td>
<td>Nil</td>
</tr>
</tbody>
</table>

Examination of the Solid B: Glut-5α,6α-oxide-3β-yl-acetate (84):

The crystalline solid (B; 0.8 g), m.p. 210-212° from fractions 17-26 of the above chromatogram (Table 3) on crystallisation from a mixture of chloroform and acetone gave pure crystals of glut-5α,6α-oxide-3β-yl-acetate (84); m.p. 216-218°; $\sqrt[\Delta ]{D} +47.6°(\text{CHCl}_3)$.

**Found:** C, 79.55; H, 10.48

**Calculated for C$_{32}$H$_{32}$O$_3$:** C, 79.28; H, 10.81%

IR, PMR and Mass spectra have been discussed in the theoretical section.
Treatment of Glut-5α,6α-oxide-3β-yl-acetate (84) with Aqueous Perchloric Acid

A solution of the epoxide (84; 1.6 g) in tetrahydrofuran (80 ml) was treated with aqueous perchloric acid (3N, 11 ml) and the mixture was stirred for 3 h at room temperature. Then the reaction mixture was washed with distilled water till neutral. The organic layer was dried over anhydrous Na₂SO₄ and evaporated. The crude mass (1.5 g) was taken in a minimum amount of benzene and placed over a column of silica gel (100 g). The column was eluted with different solvent mixtures as shown in Table 4.

Table 4

<table>
<thead>
<tr>
<th>Fractions</th>
<th>Eluent</th>
<th>Residue after removal of solvent</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 - 3</td>
<td>Pet ether</td>
<td>Nil</td>
</tr>
<tr>
<td>4 - 10</td>
<td>Pet ether</td>
<td>Solid A, m.p. 195-200°</td>
</tr>
<tr>
<td>11 - 15</td>
<td>Pet ether : Benzene (9:1)</td>
<td>Nil</td>
</tr>
<tr>
<td>26 - 30</td>
<td>Pet ether : Benzene (3:2)</td>
<td>Nil</td>
</tr>
<tr>
<td>31 - 35</td>
<td>Pet ether : Benzene (1:4)</td>
<td>Nil</td>
</tr>
<tr>
<td>36 - 42</td>
<td>Benzene</td>
<td>Solid C, m.p. 270-278°</td>
</tr>
<tr>
<td>43 - 50</td>
<td>Benzene : Chloroform (9:1)</td>
<td>Nil</td>
</tr>
</tbody>
</table>
Examination of Solid A: Gluta-5,12-dien-3β-yl-acetate (90):

The solid (A; 0.25 g), m.p. 195-200° from fractions 3-10 of the above chromatogram (Table 4) on crystallisation from a mixture of chloroform and methanol gave pure crystals of gluta-5,12-dien-3β-yl-acetate (90), m.p. 208-210°, $\alpha \theta \delta \gamma (\text{CHCl}_3)$.

Found: C, 82.28; H, 10.85
Calculated for $C_{32}H_{30}O_2$: C, 82.34; H, 10.80%.

IR, PNM and Mass spectra have been discussed in the theoretical section.

Examination of Solid B: Gluta-5α,6α-oxide-3β-yl-acetate (84):

The solid (B; 0.8 g), m.p. 212-215° from fractions 16-25 of the above chromatogram (Table 4) on crystallisation from a mixture of chloroform and acetone furnished gluta-5α,6α-oxide-3β-yl-acetate (84), m.p. 216-218° which was found to be identical (m.m.p. and Co-TLC) with an authentic specimen.

Examination of Solid C: Friedel-3-en-2β,6β-diol (91a):

The solid (C; 0.3 g), m.p. 270-278° from fractions 36-42 of the above chromatogram (Table 4) on crystallisation from a mixture of chloroform and methanol yielded friedel-3-en-2β,6β-diol (91a), m.p. 280-285°, $\alpha \theta \delta \gamma (\text{CHCl}_3)$.

IR, PNM and Mass spectra have been discussed in the theoretical section.
Acetylation of Friedel-3-om-2β,6β-diol (91a) : Friedel-2β,6β-diacectoxy-3-one (91b)

Friedel-3-om-2β,6β-diol (91a; 0.1 g), m.p. 280–283° was heated with pyridine (1 ml) and acetic anhydride (1 ml) on a steam bath for 3 h. The reaction mixture was allowed to stand overnight at room temperature and then poured into ice-cold water. The solid that separated out was filtered and washed with dil. HCl to remove pyridine and finally with water till neutral. The solid when crystallised from a mixture of chloroform and methanol gave pure crystals of friedel-2β,6β-diacectoxy-3-one (91b), m.p. 262–268°.

Found : C, 77.43; H, 10.29.
Calculated for C_{34}H_{34}O_{4} : C, 77.92; H, 10.33%.

IR, PMR have been discussed earlier.

Treatment of Glut-5α,6α-oxide-3β-yl-acetate (84) with Berenstrifluoride-ether complex :

Glut-5α,6α-oxide-3β-yl-acetate (84; 0.2 g) was treated with BF₃-etherate (0.2 ml) in dry benzene (15 ml) and stirred for 30 minutes at room temperature, when the mixture became pale yellow. The reaction mixture was neutralised with solid NaHCO₃ and then washed with water till neutral. The organic layer was dried over anhydrous Na₂SO₄ and evaporated. The crude mass (0.25 g) was taken in a minimum amount of benzene and placed over a column of silica gel (20 g). The column was eluted with different solvent mixtures as shown in Table 9.
Table 5

Each fraction collected was 20 ml in volume

<table>
<thead>
<tr>
<th>Fractions</th>
<th>Eluent</th>
<th>Residue after removal of solvent</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 - 3</td>
<td>Pet ether</td>
<td>Vaxy material</td>
</tr>
<tr>
<td>4 - 8</td>
<td>Pet ether</td>
<td>Nil</td>
</tr>
<tr>
<td>9 - 15</td>
<td>Pet ether : Bensene (9:1)</td>
<td>Solid A, m.p. 190-200°</td>
</tr>
<tr>
<td>16 - 20</td>
<td>Pet ether : Bensene (9:1)</td>
<td>Nil</td>
</tr>
<tr>
<td>21 - 25</td>
<td>Pet ether : Bensene (4:1)</td>
<td>Nil</td>
</tr>
<tr>
<td>26 - 30</td>
<td>Pet ether : Bensene (3:2)</td>
<td>Nil</td>
</tr>
<tr>
<td>31 - 42</td>
<td>Pet ether : Bensene (1:4)</td>
<td>Solid B, m.p. 228-230°</td>
</tr>
<tr>
<td>43 - 50</td>
<td>Bensene</td>
<td>Nil</td>
</tr>
</tbody>
</table>

Examination of Solid A: Glut-1(10),5-dien-3β-yl-acetate (108)

The solid (A; 0.08 g), m.p. 190-200° from fractions 9-15 of the above chromatogram (Table 5) on crystallisation from a mixture of chloroform and acetone gave pure crystals of glut-1(10),5-dien-3β-yl-acetate (108), m.p. 210-215° (lit.74 m.p. 209-210°); $\text{CHCl}_3 + 37.7°$ (CHCl3). Mixed m.p. with an authentic specimen did not show any depression.

Found: C, 82.09; H, 10.73.

Calculated for $\text{C}_{32}\text{H}_{30}\text{O}_2$: C, 82.34; H, 10.80%.

UV, IR, PMR and Mass spectra have been discussed in the theoretical section.
Examination of Solid B: Glut-5(10)-en-6α-hydroxy-3β-yl-acetate (109a)

The solid (B; 0.12 g), m.p. 228-230° from fractions 31-42 of the above chromatogram (Table 5) on crystallisation from a mixture of chloroform and methanol gave pure glut-5(10)-en-6α-hydroxy-3β-yl-acetate (109a), m.p. 232-235°; $\alpha D + 129.6°$ (CHCl₃).

Acetylation of Glut-5(10)-en-6α-hydroxy-3β-yl-acetate (109a): Glut-3β,6α-diactoxy-5(10)-one (109b)

Glut-5(10)-en-6α-hydroxy-3β-yl-acetate (109a, 0.1 g), m.p. 232-235° was heated with pyridine (1 ml) and acetic anhydride (1 ml) on a steam bath for 3 h. The reaction mixture was allowed to stand overnight at room temperature and then poured into ice-cold water. The solid that separated out was filtered and washed with dil. HCl to remove pyridine and finally with water till neutral. The solid when crystallised from a mixture of chloroform and methanol furnished pure crystals of glut-3β,6α-diactoxy-5(10)-one (109b), m.p. 155-160°, $\alpha D + 158.2°$ (CHCl₃).

Found: C, 77.08; H, 10.49.

Calculated for C₃₄H₄₄O₄: C, 77.52; H, 10.33%.

IR, PMR and Mass spectra have been discussed in the theoretical section.
PART II : SECTION D

REFERENCES


22(a). L. F. Fieser, Experientia, 6, 312 (1950).


