Dry Ozonation of Friedelane and Friedelin[1)]

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Dry ozonation of friedelane afforded 18β,19β-epoxyfriedelane, 19-oxofriedelane, 16-oxofriedelane, 21-oxofriedelane, friedelin, and a new compound, 15-oxofriedelane. Friedelin, on dry ozonation, gave 3,16-dioxofriedelane, 3,19-dioxofriedelane, and new compounds, 18β,19β-epoxyfriedelan-3-one and 3,15-dioxofriedelane. It was shown that the oxidation occurred at D and E rings regioselectively in the dry ozonation.

It has been known that ozone reacts slowly with saturated hydrocarbons in solution to give alcohols and ketones.[2)] Mazur *et al.*[3-6)] and Beckwith *et al.*[7,8)] have demonstrated that ozone adsorbed on silica gel reacts efficiently with saturated hydrocarbons,[3,4)] *t*-alcohols,[4)] bromides,[5)] acetates,[4,7,8)] bromo acetate,[6)] and ketone.[8)] This procedure, named dry ozonation, has been developed as a useful synthetic method for stereoselective hydroxylation of tertiary carbon atoms of organic compounds. Recently this dry ozonation reaction has been shown to be also applicable to oxidative conversion of primary amines to nitro compounds.[9)]

Hitherto only a few investigations on functionalization of unactivated carbon atoms in triterpene skeletons have been reported[10,11)] in contrast with investigations on the steroidal compounds.[12)] In connection with the studies on synthesis of friedelane derivatives, the dry ozonation reaction was applied to functionalization of an unactivated carbon atom of a friedelane skeleton. It is shown that friedelane (**1**) and its 3-oxo derivative, friedelin (**2**), on dry ozonation, gave 15-, 16-, and 21-oxo derivatives.

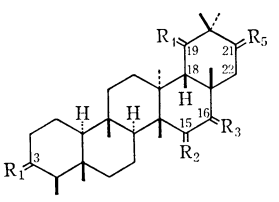
Friedelane (**1**)[13)] was adsorbed on silica gel (*ca.* 100 times weight of **1**). The silica gel was then cooled to −78 °C and saturated with ozone at this temperature. After warming to room temperature, the reaction products were eluted from the silica gel and examined by TLC. It was shown that the starting material was completely consumed and only a complex mixture of unidentified polar products with extremely low R_f value was detected. No spot corresponding to mono-oxygenated products such as tertiary alcohols or ketones was observed on the TLC. Beckwith *et al.*[7)] reported that a substrate adsorbed on silica gel was oxidized with ozone generated by desorption from the silica gel, and not directly with adsorbed ozone. And they pointed the importance of the maintenance of a high partial pressure of ozone during the warm-up period.

To obtain optimum conditions for the formation of the mono-oxygenated products, dependence of reaction temperature and ozone concentration on their yields was examined. The reaction at higher temperature increased in the conversion of friedelane and in the formation of the unidentified products, but decreased in the yields of the mono-oxygenated products. It was found that the following reaction temperature gave a fairly good result for the formation of the mono-oxygenated products, although the conversion yield of friedelane was less than 20%. The silica gel saturated with ozone at −78 °C was kept at −65 to −60 °C and ozone was desorbed gradually by sweeping with a slow stream of nitrogen at this temperature range, and then the silica gel was warmed up to room temperature. Ozone concentration was shown to be independent of the yields and silica gel (Wakogel C 200; 10 g) was saturated enough with a flow of 3% ozone in oxygen at flow rate of 50 ml/min for 1 h at −78 °C.

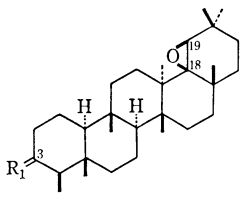
Under these conditions, friedelane (**1**; 100 mg) adsorbed on silica gel (10 g) was oxidized with ozone. The unchanged friedelane (**1**: 82 mg) was recovered and a mixture (*ca.* 19 mg; corresponding to 18% conversion) of mono-oxygenated products was obtained and was subjected to separation by preparative TLC, alumina column, and/or HPLC.

18β,19β-Epoxyfriedelane[14)] (**3**; yield[15)] 48%), 19-oxofriedelane[14)] (**4**; yield[15)] 2%), 16-oxofriedelane[16)] (**5**; yield[15)] 11%), and friedelin (**2**; yield[15)] 0.8%) were obtained and identified by comparison with their authentic samples, respectively. Two new carbonyl compounds (**6** and **7**) were also obtained in 11 and 1% yields,[15)] respectively.

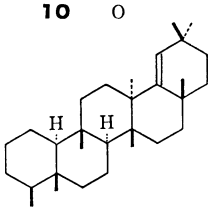
The compound (**6**), $C_{30}H_{50}O$, mp 239—240 °C, showed a carbonyl absorption at 1700 cm^{-1} in the IR spectrum and an AB quartet signal at δ_A 2.15 and δ_B



	R_1	R_2	R_3	R_4	R_5
1	H_2	H_2	H_2	H_2	H_2
2	O	H_2	H_2	H_2	H_2
4	H_2	H_2	H_2	O	H_2
5	H_2	H_2	O	H_2	H_2
6	H_2	O	H_2	H_2	H_2
6-d_2	H_2	O	D_2	H_2	H_2
7	H_2	H_2	H_2	H_2	O
8	H_2	O	O	H_2	H_2
11	O	H_2	H_2	O	H_2
12	O	H_2	O	H_2	H_2
13	O	O	H_2	H_2	H_2



	R_1
3	H_2
10	O



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2.50 (J_{AB}=18 Hz) in the PMR spectrum. These observations indicate the presence of a grouping ■–CO–CH_2–■ (■ refers to a quaternary carbon atom). The carbonyl group of this compound was inferred to be located either at C-15 or C-16 from the characteristic fragment peaks in the high resolution mass spectrum[17] (Fig. 1). The spectral data of the carbonyl compound (**6**) was different from those of 16-oxofriedelane (**5**).[16] Therefore, the ketone (**6**) was deduced to be 15-oxofriedelane.

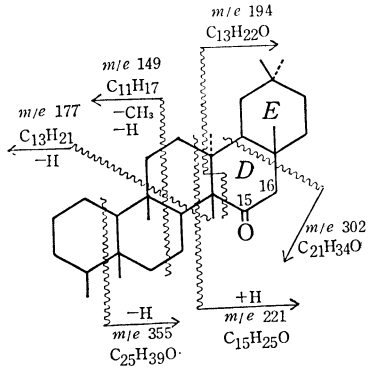

Fig. 1.

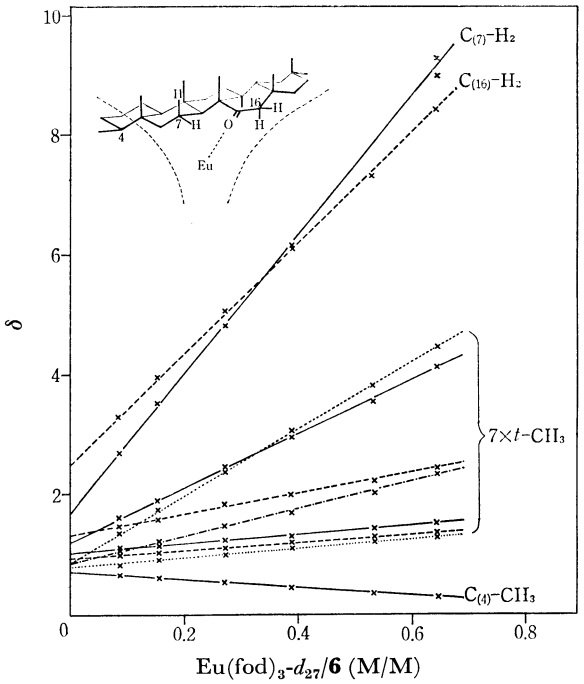

Fig. 2. Induced paramagnetic shifts for 15-oxofriedelane (**6**) in a 5% (w/v) in $CDCl_3$.

This conclusion was confirmed by spectral and chemical evidence. The intact friedelane-framework without skeletal rearrangement during the reaction was shown for **6** by its reduction under forced Wolff-Kishner conditions to afford friedelane (**1**). The carbonyl group at C-15 is so hindered that a half amount of **6** was left unchanged even though under these reduction conditions. On tretament with sodium deuterioxide, the compound (**6**) gave a deuteriated product (**6**-d_2), whose molecular ion peak was observed at *m/e* 428. In PMR measurement of **6** using Eu(fod)$_3$-d_{27} as a shift reagent, a doublet due to a secondary methyl group at C-4 suffered an upfield shift and a multiplet due to a methylene group caused condsierable downfield shift, which was much larger than that for the α-methylene protons (at C-16) adjacent to the carbonyl group (Fig. 2). Provided that the carbonyl group locates at C-15 and the shift reagent is associated with the carbonyl oxygen atom, these observations were reasonably expalined. The secondary methyl group at C-4 which would be placed outside of a cone area suffered upfield shift. The methylene group which caused downfield shift could be assigned to $C_{(7)}$–H_2 because of the nearest proximity of the shift reagent.

Oxidation with selenium dioxide, the compound (**6**) gave 15,16-dioxofriedelane (**8**), mp 280—281 °C, IR 1720 and 1700 cm^{-1}, MS *m/e* 440 (M^+). The dione (**8**) was shown to be identical with that obtained from 16-oxofriedelane (**5**) by the same treatment.

The other carbonyl compound (**7**), mp 237—240 °C, $[\alpha]_D$+117°, was shown to possess a grouping ■–CO–CH_2–■ based on the IR spectrum (1720 cm^{-1}) and on an appearance of a doublet as an H_A-part (δ 2.60, d, J=12 Hz) of an AB quartet in the PMR spectrum. In the PMR spectrum using Eu(fod)$_3$-d_{27} as a shift reagent, an H_B-part of the AB

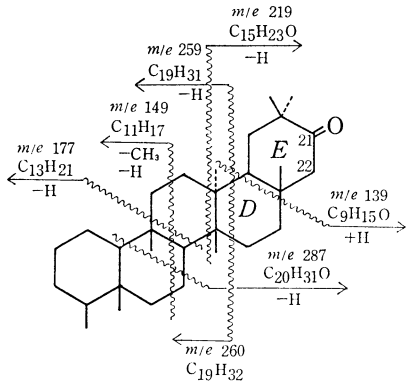

Fig. 3.

quartet was observed. The investigation on the fragmentation pattern in the high resolution mass spectrum revealed that the carbonyl group of **7** must locate on either D or E ring, that is, on either 15-, 16-, 19-, 21-, or 22 carbon atom[17] (Fig. 3). Thus the structure of **7** could be either 21- or 22-oxofriedelane, because the remaining three compounds had been already identified as the products of this reaction.

Courtney and Gascoigne isolated several friedelane derivatives from *Siphonodon australe* Benth.,[18] one of which was shown to be 3,21-dioxofriedelane.[19] In this structure determination, 21-oxofriedelane was prepared and the melting point (241—242 °C), $[\alpha]_D$ value (+152°), and the main fragment peaks (*m/e* 259, 177, and 149) were described.[18,20] On the other hand, 22-oxofriedelane has not been reported yet. Unfortunately direct comparison could not be made because no authentic 21-oxofriedelane left in Courtney's laboratory. However, the physical constants and mass fragmentation pattern were nearly

the same as those of the authentic 21-oxofriedelane. From these facts together with the spectral data, it is probable that the compound (**7**) would be 21-oxofriedelane (**7**), not 22-oxofriedelane.

Although 18β,19β-epoxyfriedelane (**3**) was obtained as the main product in the dry ozonation of friedelane (**1**), the epoxide (**3**) could be considered to be a secondary reaction product formed from friedel-18-ene (**9**) by oxidation with ozone. Initial attack of ozone to a methine hydrogen atom at C-18 would give unstable 18β-hydroxyfriedelane, which could be immediately dehydrated to form friedel-18-ene (**9**). It is known that the methine hydrogen atom at C-18 is susceptible to reaction with bromine to give friedel-18-ene (**9**)[13,21] through 18-bromofriedelane which could not be isolated, and that friedel-18-ene (**9**) in solution is easily epoxidized by ozone.[14,22]

Dry ozonation of friedel-18-ene (**9**) under the same conditions as above, gave the epoxide (**3**) in 53% yield together with the unchanged **9** (in 12% yield) and unidentified polar materials. 19-Oxofriedelane (**4**), however, could not be detected in the reaction mixture. This implies that 19-oxofriedelane (**4**) would be produced by direct insertion of ozone into $C_{(19)}$–H followed by oxidation, not through friedel-18-ene (**9**).

Friedelin (**2**) was then subjected to dry ozonation under the same conditions as above. However eaxmination of the reaction mixture by TLC showed that most of the starting material (**2**) remained unchanged. The low reactivity seems to be due to the presence of an electron-withdrawing carbonyl group at C-3.[4,5] After saturation with ozone at −78 °C, the silica gel was warmed to −15 °C and ozone was desorbed by sweeping with a stream of nitrogen at this temperature. The reaction mixture was separated as before.

Friedelin (**2**) was recovered in 32% yield. 3,16-Dioxofriedelane[16] (**12**; yield[15] 3%), a new epoxy ketone (**10**; yield[15] 12%), and a mixture of two diketones (**11** and **13**) were obtained. The epoxy ketone (**10**), $C_{30}H_{48}O_2$, mp 266—269 °C (with decomposition), showed a carbonyl absorption band at 1710 cm^{-1} and a singlet at δ 2.56 in the PMR spectrum, which could be easily assignable to a 19α-H by comparison with that (δ 2.56, s) of 18β,19β-epoxyfriedelane (**3**). The epoxy ketone (**10**) was subjected to the Birch reduction, the Jones oxidation, and then the Huang-Minlon reduction to afford 19-oxofriedelane (**4**). Thus the epoxy ketone (**10**) was shown to be formulated as 18β,19β-epoxyfriedelan-3-one.

The mixture of diketones (**11** and **13**), giving one spot on TLC, was separated by HPLC to afford **11** (yield[15] 1%), mp 264—266 °C, IR 1708 and 1680 cm^{-1} and **13** (yield[15] 3%), mp 280.5—281.5 °C, IR 1710 and 1700 cm^{-1}. On the Huang-Minlon reduction, the mixture (**11** and **13**) gave a mixture of 19-oxofriedelane (**4**) and 15-oxofriedelane (**6**). Therefore, the structutes of the diketones (**11** and **13**) were determined to be 3,19- and 3,15-dioxofriedelanes, respectively.

The dry ozonation of both friedeleane (**1**) and friedelin (**2**) resulted in the preferential introduction of a carbonyl group into hindered positions such as 15-, 16-, 19-, and 21-carbon atoms. These findings seem to be important and useful for synthesis of these carbonyl compounds hitherto unaccessible by other synthetic procedures. The reason why these sterically hindered ketones were produced is explained as follows.[7,8] If A ring moiety of friedelane (**1**) is preferentially adsorbed on the surface of silica gel due to sterical accessibility and a carbonyl group on A ring of friedelin (**2**) is apt to combine with the adsorbent, and if these molecules are ordered ideally in a close-packed array, it would be expected that the terminal moiety of these molecules, D or E ring, would be exposed for the attack by ozone.

Experimental

General Procedures. IR spectra were measured in KBr disk using a Hitachi EPI-G2 spectrometer. CD and ORD measurements were carried out on a JASCO Model J-20 spectrometer. Optical rotations were measured on a JASCO DIP-SL polarimeter. Mass spectra were taken on a Hitachi RMU-6-Tokugata mass spectrometer and high resolution mass spectra on a Hitachi RMH-2 mass spectrometer operating at 70 eV with a direct inlet system. The relative intensity observed in low resolution mass spectra was expressed in % in the parentheses. PMR spectra were measured using a JEOL 4H-100 (100 MHz) or a Hitachi R-20 (60 MHz) spectrometer. Chemical shifts were expressed in δ downfield from TMS as an internal standard, and coupling constants in Hz. HPLC analyses were carried out at room temperature using a Liquid Chromatograph Model ALC/GPC 202/401 (Waters Assoc.) with an RI detector (column: μ-Porasil 1/8(inch)×1(foot); pressure *ca.* 500 psi). GLC was carried out using a Shimadzu Gas Chromatograph 4APF equipped with a hydrogen flame ionization detector (column: OV-1 at 280 °C). Ozone was generated from an Ozonizer Model O-1-2 (Nippon Ozon) and silica gel (Wakogel C-200) was used for adsorbent. Analytical TLC was carried out on Kieselgel G (E. Merck, Darmstadt) and Alumina B-10-F (Wako) in 0.25 mm thickness, and preparative TLC on Kieselgel PF_{254} (E. Merck, Darmstadt) in 0.5 mm thickness. Wakogel C-200 (Wako) and Activated Alumina (Showa Chem.) were used for column chromatography. Melting points were measured on a Mel-temp capillary melting point apparatus (Laboratory Devices) and were uncorrected.

*Dry Ozonation of Friedelane (**1**).* Silica gel (10 g) was mixed with a solution of friedelane (**1**; 100 mg) in hexane (20 ml) and shaken well. After the solvent was removed in a rotary evaporator, the silica gel was heated at 100 °C for 1 h and then deactivated with water (0.4 ml). The silica gel was placed in a reaction vessel, cooled to −78 °C and saturated with ozone at a flow rate of 50 ml/min for 1 h. The reaction vessel was maintained at −65 to −60 °C and a slow stream of nitrogen was passed through the silica gel for 1.5 h and then the vessel was warmed gradually to room temperature. The silica gel, on which the reaction products were adsorbed, was placed on the top of a column of silica gel (1 g), and hexane (200 ml) was eluted to afford the unchanged friedelane (**1**; 82 mg). Successive elution with benzene (150 ml) gave a mixture (*ca.* 19 mg) of monooxygenated friedelanes, which showed six spots on TLC (SiO_2). The mixture was further separated by preparative TLC (3 plates (20×20 cm), developed with hexane–benzene (1:1); detection: iodine) to give six components with R_f 0.7, 0.65, 0.5, 0.4, 0.25, and 0.2. The least polar fraction [9 mg; mp 268—271 °C; IR 1000, 940, and 920 cm^{-1}; PMR

δ 2.56 (1H, s); MS *m/e* (%) 426 (M^+; 33), 411 (11), 297 (17), 257 (28), 149 (78), and 135 (100)] was identified to be 18β,19β-epoxyfriedelane (**3**) by comparison with an authentic sample.[14] The structure of the second component was left undetermined because of paucity of the material. The third product [0.4 mg; mp 230—231 °C; IR 1675 cm^{-1}; PMR δ 2.17 (1H, s); MS *m/e* (%) 426 (M^+; 10), 411 (18), 259 (36), 217 (30), 139 (100), and 149 (28)] was shown to be 19-oxofriedelane (**4**).[14]

The fourth component with R_f 0.4 (**6**; 2 mg) was shown to be 15-oxofriedelane (**6**) based on spectral data and chemical conversion (*vide infra*). The fifth component (**5**) was found to contain a small quantity of unidentified material by TLC (Al_2O_3) and the mass spectrum. This dry ozonation was repeated seven times and the component with R_f 0.25 was collected. The combined material (23 mg) was subjected to separation by column chromatography on alumina (10 g). Elution with hexane–benzene (2:1) afforded 16-oxofriedelane[16] [**5**; 14 mg, mp 270—272 °C; IR 1680 cm^{-1}; PMR δ 0.78, 0.84, 0.95, 1.05, 1.17, 1.28 (each 3H, s; *t*-Me), 2.15 and 2.37 (2H, ABq, J=19 Hz; $C_{(15)}$–H_2); MS *m/e* 426 (M^+; 21), 411 (17), 274 (8), 259 (20), 149 (100), and 109 (75)] and a mixture of unidentified alcohols (7 mg).

Although the sixth component was inferred to be a mixture from the PMR spectrum, no separation could be attained by TLC (Al_2O_3). The HPLC examination (solvent system: 1.5% ether-hexane; flow rate: 0.9 ml/min) revealed that the fraction consisted of 21-oxofriedelane (**7**; 0.2 mg, R_t 17 min) and friedelin (**2**; 0.15 mg, R_t 20 min). The material (18 mg), obtained by repeating the dry ozonation of friedelane (each 250 mg, 12 times), was subjected to separation by HPLC under the same conditions as above to afford friedelin (**2**; 4 mg) and 21-oxofriedelane [**7**; 6 mg, mp 237—240 °C; $[\alpha]_D$ +117° (*c* 0.12, $CHCl_3$); ORD $[\alpha]_{280}$ −2320° and $[\alpha]_{325}$ +3490°; IR 1720 cm^{-1}; PMR δ 2.60 (1H, d, J=12 Hz; $C_{(22)}$–H); MS *m/e* (%) 426 (M^+; 3), 411 (7), 259 (22), 217 (16), 177 (15), and 149 (100); High resolution mass spectrum: *m/e* 426.3878 ($C_{30}H_{50}O$), 411.3646 ($C_{29}H_{47}O$), 287.2383 ($C_{20}H_{31}O$), 260.2483 ($C_{19}H_{32}$), 259.2420 ($C_{19}H_{31}$), 219.1835 ($C_{15}H_{23}O$), 177.1602 ($C_{13}H_{21}$), 149.1330 ($C_{11}H_{17}$), and 139.1115 ($C_9H_{15}O$). The fragmentation patterns were shown in Fig. 3].

*15-Oxofriedelane (**6**).* Mp 239—240 °C (recrystallized from ethyl acetate); $[\alpha]_D$ +38° (*c* 1.5, $CHCl_3$); CD $[\theta]_{300}$ −215 (*c* 0.1, dioxane); IR 1700 cm^{-1}; PMR δ 0.77, 0.86, 0.89, 0.95, 1.00, 1.20, 1.32 (each 3H, s, *t*-Me), 2.15 and 2.50 (2H, ABq, J=18 Hz; $C_{(16)}$–H_2); MS *m/e* (%) 426 (M^+; 19), 411 (90), 393 (64), 355 (10), 221 (54), 194 (100), 177 (20), and 149 (41); High resolution mass spectrum: *m/e* 426.3874 ($C_{30}H_{50}O$), 411.3681 ($C_{29}H_{47}O$), 355.2912 ($C_{25}H_{39}O$), 302.2569 ($C_{21}H_{34}O$), 221.1941 ($C_{15}H_{25}O$), 194.1646 ($C_{13}H_{22}O$), 177.1665 ($C_{13}H_{21}$), and 149.1343 ($C_{11}H_{17}$). Found: C, 84.73; H, 11.89%. Calcd for $C_{30}H_{50}O$: C, 84.44; H, 11.81%. The fragmentation patterns in the high resolution mass spectrum and PMR spectral data using Eu(fod)$_3$-d_{27} as a shift reagent were given in Figs. 1 and 2.

*Wolff-Kishner Reduction of 15-Oxofriedelane (**6**).* A mixture of sodium (100 mg) in diethylene glycol (5 ml) was heated at 180 °C under a nitrogen atmosphere. To the solution, anhydrous hydrazine (1 ml) and 15-oxofriedelane (**6**; 13 mg) were added and the mixture was refluxed overnight. After excess of hydrazine was removed by distillation, the reaction mixture was heated under reflux at 210 °C overnight. After usual treatment, the reaction product was subjected to separation by preparative TLC, developed with hexane–benzene (1:1) to afford friedelane (**1**; 2 mg), mp 248.5—249 °C together with the unchanged starting material (**6**; 2 mg).

*Treatment of 15-Oxofriedelane (**6**) with Sodium Deuterioxide.* A mixture of 15-oxofriedelane (**6**; 2 mg) and sodium deuterioxide prepared from sodium (10 mg) and deuterium oxide (0.5 ml) in dioxane (1 ml) was heated under reflux for 14 h under nitrogen. The reaction mixture was poured into water, extracted with benzene–ether, washed with dilute hydrochloric acid and successively with aqueous sodium hydrogencarbonate, and then dried over magnesium sulfate. This procedure was repeated twice to give deuteriated 15-oxofriedelane, which was found to consist of 15-oxofriedelane-d_2 (**6**-d_2; 90.2%), -d_1 (7.1%), and -d_0 (2.6%) by mass spectrometry.

*Conversion of 15-Oxofriedelane (**6**) into 15,16-Dioxofriedelane (**8**).* A mixture of 15-oxofriedelane (**6**; 5 mg) and selenium dioxide (17 mg) in acetic acid (5 ml) was heated under reflux for 6 h. Since TLC examination of the reaction mixture showed that a considerable amount of the starting material was left unchanged, heating was continued for 16 h after addition of selenium dioxide (5 mg). After cooling and removal of metallic selenium, the reaction mixture was extracted with ether and worked up as usual to give a residue, which was subjected to separation by preparative TLC (developed with benzene). The unchanged 15-oxofriedelane (**6**; *ca.* 1 mg) was recovered and 15,16-dioxofriedelane [**8**; 2 mg, mp 280—281 °C; IR 1720 and 1700 cm^{-1}; PMR δ 0.78, 0.86, 0.96, 1.02, 1.20, 1.39, and 1.54 (each 3H, s, *t*-Me); MS *m/e* (%) 440 (M^+; 94), 412 (70), 288 (98), 260 (100), and 177 (53)] was obtained.

*Conversion of 16-Oxofriedelane (**5**) into 15,16-Dioxofriedelane (**8**).* i) A mixture of 16-oxofriedelane (**5**; 4 mg) and selenium dioxide (17 mg) in acetic acid (5 ml) was heated under reflux (bath temperature 135 °C) for 6 h. After additional selenium dioxide (10 mg) was added, the reaction mixture was heated under reflux (bath temperature 150 °C) overnight. The same treatment and purification as above gave unchanged 16-oxofriedelane (**5**; *ca.* 1 mg) and 15,16-dioxofriedelane [**8**; 2 mg, mp 280—280.5 °C; IR 1720 and 1700 cm^{-1}; PMR δ 0.78, 0.86, 0.96, 1.02, 1.20, 1.39, and 1.54 (each 3H, s, *t*-Me); MS *m/e* (%) 440 (M^+; 94), 425 (9), 412 (70), 288 (98), 260 (100), and 177 (53)]. ii) A mixture of 16-oxofriedelane (**5**; 5 mg), selenium dioxide (18 mg), and dioxane (2 ml) in a sealed tube was heated at 180 °C for 4 h. After usual treatment, 15,16-dioxofriedelane (**8**) was obtained nearly quantitatively.

*Dry Ozonation of Friedel-18-ene (**9**).* Friedel-18-ene (**9**) was prepared from friedelane (**1**) according to the known procedures[13] and purified by passing through a column of silica gel impregnated with 30% silver nitrate. The purity of the friedel-18-ene (**9**) was examined by GLC, which confirmed the absence of friedelane (R_t 4.3 and 3.7 min for **1** and **9**, respectively).

Friedel-18-ene (**9**; 125 mg) was adsorbed on silica gel (13 g) and oxidized with ozone by the same procedures as above. The reaction product (127 mg), obtained from the silica gel-product mixture by elution with ethyl acetate, was subjected to separation by column chromatography of silica gel (15 g) and eluted with hexane (100 ml), hexane–benzene (3:1, 40 ml), benzene (100 ml), and then with ethyl acetate (100 ml). From the hexane fraction, friedel-18-ene (**9**; 15 mg) was recovered and the fraction eluted with hexane–benzene gave 18β,19β-epoxyfriedelane (**3**; 60 mg). A mixture (*ca.* 5 mg), obtained from the benzene fraction, showed three spots on TLC, but none of the products corresponding to these spots was identical with any one of the products obtained by the dry ozonation of friedelane (**1**).

Dry Ozonation of Friedelin (2). Friedelin (**2**; 420 mg) in chloroform (150 ml) was adsorbed on silica gel (50 g) and the solvent was removed in a rotary evaporator. The silica gel was cooled to −78 °C and saturated with ozone for 2 h under the same conditions as above. A slow stream of nitrogen was passed through the silica gel kept at −15 °C, and the temperature was raised to room temperature.

The reaction product (450 mg), eluted from the silica gel with ethyl acetate, was dissolved in benzene and passed through a column of silica gel (40 g). Elution was carried out with the following solvents: benzene (500 ml), benzene–ether (10:1, 500 ml), and ethyl acetate (500 ml). From the benzene fraction, friedelin (**2**; 70 mg) was recovered. The fraction (168 mg), eluted with benzene–ether, gave three spots on TLC (SiO_2) and subjected to separation by preparative TLC (15 plates (20×20 cm), developed with benzene–chloroform–ether (20:2:1), detection: iodine) to afford three fractions with R_f 0.45, 0.38, and 0.25.

The least polar fraction gave an epoxy ketone (**10**; 50 mg), mp 266—269 °C (with decomposition); $[\alpha]_D$ −6° (*c* 1.2, $CHCl_3$); IR 1710, 1115, 1080, 920, and 835 cm^{-1}; PMR δ 2.0—2.5 (3H, m, $-\underline{CH_2}-CO-\underline{CH}-$) and 2.56 (1H, s; $C_{(13)}$–H); MS *m/e* (%) 440 (M^+; 24), 425 (7), 368 (16), 311 (17), 154 (100), and 127 (99); Found: C, 81.65; H, 10.93%. Calcd for $C_{30}H_{48}O_2$: C, 81.76; H, 10.98%.

The second fraction with R_f 0.38 was shown to be a mixture of two components by HPLC (solvent system: 15% ether–hexane, flow rate: 0.5 ml/min) and separated into 3,19-dioxofriedelane (**11**; 4 mg, R_t 21 min) and 3,15-dioxofriedelane (**13**; 12 mg, R_t 24 min). *3,19-Dioxofriedelane (**11**)*: Mp 264—266 °C; IR 1708 and 1680 cm^{-1}; PMR δ 2.0—2.5 (3H, m; $-\underline{CH_2}-CO-\underline{CH}-$) and 2.20 (1H, br s; $C_{(18)}$–H); MS *m/e* (%) 440 (M^+; 9), 425 (11), 422 (5), 407 (3), 273 (25), 231 (16), 191 (11), and 139 (100). *3,15-Dioxofriedelane (**13**)*: Mp 280.5—281.5 °C; $[\alpha]_D$ +20° (*c* 0.67, $CHCl_3$); IR 1710 and 1700 cm^{-1}; PMR δ 2.16 and 2.55 (2H, ABq, J=19 Hz; $C_{(16)}$–H_2); MS *m/e* (%) 440 (M^+; 52), 425 (59), 422 (12), 407 (29), 355 (48), 201 (58), and 194 (100).

The third fraction with R_f 0.25 was identified to be 3,16-dioxofriedelane[16] (**12**; 13 mg), mp 294—295.5 °C; IR 1720 and 1690 cm^{-1}; PMR δ 0.73, 0.97, 1.05, 1.20, 1.29 (each 3H, s, *t*-Me), 0.90 (6H, s, 2×*t*-Me), and 1.8—2.6 (5H, m; $C_{(2)}$–H_2, $C_{(4)}$–H, and $C_{(15)}$–H_2); MS *m/e* (%) 440 (M^+; 48), 425 (52), 355 (36), 273 (29), 220 (43), 219 (33), 163 (31), and 109 (100).

*Conversion of 18β,19β-Epoxyfriedelan-3-one (**10**) into 19-Oxofriedelane (**4**).* A solution of 18β,19β-epoxyfriedelan-3-one (**10**; 19 mg) in ethylamine (30 ml) was placed in a flask equipped with a Dry Ice-condenser, and lithium (30 mg) and *t*-butyl alcohol (1 drop) were added with stirring. Blue color of the solution faded within 1 h and aqueous solution of ammonium chloride (300 mg) and then water were added. The reaction product was extracted with chloroform and washed with dilute hydrochloric acid, sodium hydrogencarbonate solution, and brine, and dried over sodium sulfate. Evaporation gave a residue (20 mg), which was dissolved in benzene–ether (10:1) and filtered through a column of silica gel to give a diol (19 mg).

A solution of the diol (19 mg) in acetone (50 ml) was cooled with ice-bath and the Jones reagent (0.2 ml) was added to the solution with stirring at 2 °C for 2 h and the stirring was continued at 20 °C for 3 h. Excess of the oxidizing reagent was destroyed by addition of methanol and the product was extracted with chloroform. The crude material, obtained by usual treatment, was purified by preparative TLC (2 plates (20×20 cm), developed with benzene–ether (10:1), detection:iodine) followed by recrystallization from ethyl acetate to give 3,19-dioxofriedelane (**11**; 14.5 mg), mp 255—257 °C; IR 1708 and 1680 cm^{-1}; PMR δ 2.20 (1H, br. s; $C_{(18)}$–H) and 2.0—2.5 (3H, m; $C_{(2)}$–H_2 and $C_{(4)}$–H).

A mixture of 3,19-dioxofriedelane (**11**; 13 mg), above obtained, hydrazine hydrate (2 ml), and sodium hydroxide (200 mg) in diethylene glycol (30 ml) was heated under reflux for 3 h. Excess of the hydrazine was removed by slow distillation until the temperature of the vapor reached to 205 °C, and the heating was continued for 4.5 h. After usual work-up, the product was dissolved in benzene and purified by passing through a column of alumina to afford 19-oxofriedelane (**4**; 4 mg), mp 230—231 °C; IR 1675 cm^{-1}; PMR δ 2.20 (1H, s; $C_{(18)}$–H); MS *m/e* (%) 426 (M^+; 9), 411 (18), 259 (36), 217 (29), 149 (27), and 139 (100).

*Reduction of a Mixture of 3,19- and 3,15-Dioxofriedelanes (**11** and **13**).* A mixture (6 mg) of 3,19- and 3,15-dioxofriedelanes (**11** and **13**), obtained as the second fraction with R_f 0.38 in the dry ozonation of friedelin (**2**) (*vide supra*), was heated under reflux with hydrazine hydrate (2 ml), potassium hydroxide (200 mg), and diethylene glycol (20 ml) for 2 h under a nitrogen atmosphere. Excess of the hydrazine was distilled off until the vapor temperature reached to 205 °C, and the mixture was refluxed for 4.5 h. Usual treatment and separation by preparative TLC (1 plate (20×20 cm), developed with hexane–benzene (1:1), detection: iodine) gave 19-oxofriedelane (**4**; 1 mg) and 15-oxofriedelane (**6**; 2 mg). *19-Oxofriedelane (**4**)*: Mp 230.5—232 °C; IR 1675 cm^{-1}; MS *m/e* (%) 426 (M^+; 10), 411 (17), 259 (36), 217 (30), 149 (30), and 139 (100). *15-Oxofriedelane (**6**)*: Mp 238—238.5 °C; IR 1700 cm^{-1}; MS *m/e* (%) 426 (M^+; 20), 411 (90), 393 (65), 355 (10), 221 (53), 194 (100), 177 (20), and 149 (39).

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