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STUDIES ON SESQUITERPENOIDS—III[1]

SOME DERIVATIVES OF GUAIOL[2]

KEN'ICHI TAKEDA, HITOSHI MINATO and SATOKO NOSAKA
Research Laboratory, Shionogi & Co. Ltd., Osaka, Japan

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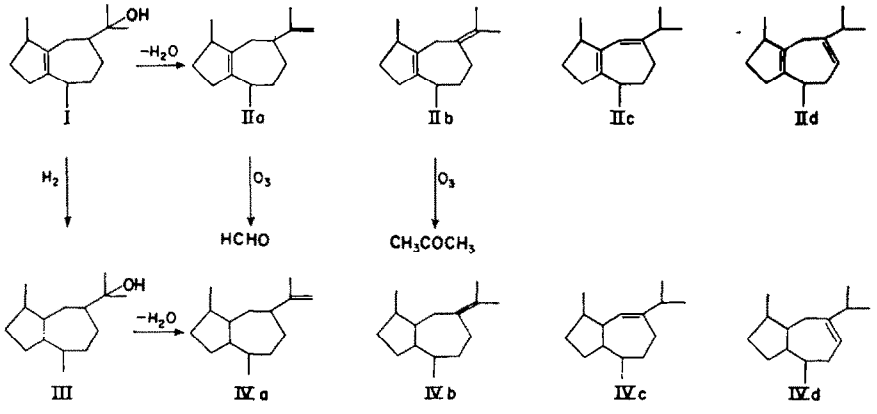
Abstract—When guaiol was dehydrated with such reagents as thionyl chloride–pyridine, phosphorus oxychloride–pyridine or potassium bisulphate, the isopropenyl derivative (IIa) was always obtained as a main product, together with a small amount of IIb. Catalytic reduction of IIa in alkaline media afforded α-dihydroguaiene (V), while in neutral or acid media it gave a mixture of V and its double bond isomer (VI).

THE structure of guaiol, $C_{15}H_{26}O$ (I), a well known sesquiterpene alcohol isolated from the Guaiacum wood oil,[3] was completely established by Plattner and his collaborators.[4] As the hydroxyl group in guaiol is a tertiary one, guaiol is easily dehydrated by means of the various dehydrating reagents and this reaction has been studied by many authors.[5,6] In this reaction only a mixture of the unsaturated substances (IIb, IIc and IId),[5] so-called "guaiene", b.p. 128–130°/12 mm, n_D^{20} 1·5022, $[\alpha]_D$ −16·8°, was obtained, but no precise structural elucidation of each compound has been given in the literature.

Plattner and his co-workers[4] also examined on the dehydration reaction of dihydroguaiol (III), which was obtained by the catalytic hydrogenation of guaiol with Raney nickel under high pressure, and a mixture of the unsaturated hydrocarbons, designated



[1] Part II: Hitoshi Minato, *Chem. Pharm. Bull.* To be published.
[2] An outline of this paper was reported at the I.U.P.A.C. Symposium on the Chemistry of Natural Products in Sydney, Australia, 23 August 1960.
[3] Guaiol was purchased from Polak & Schwarz's Essence-Fabriken, New York.
[4] [a] A. St. Pfau and Pl. A. Plattner, *Helv. Chim. Acta* **19**, 858 (1936); [b] Pl. A. Plattner and L. Lemay, *Ibid.* **23**, 897 (1940); [c] Pl. A. Plattner and G. Magyar, *Ibid.* **24**, 191 (1941); [d] *Ibid.* **25**, 581 (1942); [e] Pl. A. Plattner, *Ibid.* **24**, 283E (1941).
[5] O. Wallach, *Liebigs Ann.* **279**, 395 (1894); A. Gandurin, *Ber. Dtsch. Chem. Ges.* **41**, 4359 (1908); L. Ruzicka, S. Pontalti and Fr. Balas, *Helv. Chim. Acta* **6**, 855 (1923).
[6] J. Pliva and F. Šorm, *Coll. Czech. Chem. Comm.* **14**, 274 (1949).

as "dihydroguaiene", was obtained. They assumed that the so-called "dihydroguaiene" is a mixture of IVb, IVc and IVd from the results of ozonolysis of this "dihydroguaiene".

In the present paper, we wish to report the results of the dehydration reaction of guaiol with various reagents, and furthermore, some interesting findings on the reduction products of "α-guaiene" (IIa).

(1) *Dehydration reaction of guaiol*

When guaiol was dehydrated with thionyl chloride in pyridine at 60° and the products were carefully fractionated* and the following fractions were obtained (*cf.* Table 1).

TABLE 1. DEHYDRATION PRODUCTS OF GUAIOL

Entry no.	Fraction no. on distill.	Boiling point	n_D^{20}	Ratio of peak height at 9·3 min : 11·3 min	$[\alpha]_D$	Yield (ml)
		Dehydration with $SOCl_2$-pyridine				
1	1	78–79°/2·5 mm	1·4958	1 : 0	−64·5°	2·5
2	2	78–79°/2·5 mm	1·4958	1 : 0·034	—	5·7
3	3	78–79°/2·5 mm	1·4963	1 : 0·056	—	18·3
4	4	79–81°/2·5 mm	1·4969	1 : 0·107	−55·1°	5·0
5	5	81–83°/3 mm	1·5045	1 : 0·477	—	5·7
6	6[a]	87–92°/3 mm	1·5053	1 : 0·495	—	11·9
		Dehydration with $POCl_3$-pyridine				
7	—	82–84°/3 mm	1·4991	1 : 0·262	—	—
		Dehydration with $KHSO_4$				
8	1	96–97°/3·5 mm	—	1 : 0·475 : 0·296[b]	—	6·54
9	2	97–98°/3·5 mm	—	1 : 0·775 : 0·552[b]	—	20·63
10	3	98–100°/3·5 mm	—	1 : 1·480 : 1·06[b]	—	11·36
11	entry 7 + 10 1 : 1	—	—	1 : 0·559 : 0·285[b]	—	—

[a] Fraction no. 6 was the residue of the distillation, and redistillated. This fraction showed the shoulder at 250 mμ (ε 780) in U.V. and the weak absorption band at 3491 cm^{-1} (OH) and 1709 cm^{-1} (C=O) in I.R. spectra.

[b] Ratio of peak height at 9·3 min : 11·3 min : 12·3 min.

Each fraction was examined by gas chromatography and spectroscopic methods. As shown in Table 1, Fraction no. 1 showed only one peak at the retention time of 9·3 min in the gas chromatogram, and Fractions nos. 2–5 all showed two peaks at retention times of 9·3 min and 11·3 min. The infra-red spectrum of each fraction showed three absorption bands at 3100 (=C—H), 1645 (C=C) and 884 cm^{-1} corresponding to the $>C=CH_2$ type double bond. The ratio of the peak height at 9·3 min and 11·3 min in the gas chromatogram and the intensity of each three absorption bands in the infra-red spectrum both gradually decreased according to the increase in the fraction number.

Purified Fraction no. 1 showed absorption bands at 3100, 1645 and 884 cm^{-1} corresponding to the isopropenyl functions in the infra-red spectrum, but no other characteristic band corresponding to the conjugated diene or the trisubstituted double

* See experimental.

bond in both the infra-red and the ultra-violet spectrum, and showed the following physical data: b.p. 78–79°/2·5 mm, n_D^{20} 1·4958, d_4^{20} 0·8999, $[\alpha]_D^{19}$ −64·5°. Formaline was obtained as its dimedon-derivative when it was ozonized under usual conditions. On the other hand, this substance was easily hydrogenated to a dihydro derivative and the reduction product no longer showed an absorption band corresponding to the isopropenyl functions. Although the isopropenyl type dehydration product of guaiol was hitherto unknown in the literature,[7] the constitution of this substance has been shown to be IIa from the above-mentioned results, and the name "α-guaiene" will be given to this substance.

As the substance having a peak at a retention time of 11·3 min afforded acetone by ozonolysis and the infra-red and the ultra-violet spectrum of this substance showed no band corresponding to the conjugated diene system or the trisubstituted double bond, this substance was assumed to be IIb, the structure of which has been already reported by Plattner and other authors.

The results of the dehydration reaction of guaiol with phosphorus oxychloride in pyridine were very similar to those obtained when thionyl chloride was used (*cf.* Table 1). When potassium bisulphate was used as a dehydrating reagent, it gave more complicated results. In this case, each fraction showed three peaks at retention times of 9·3 min, 11·3 min and 12·3 min in the gas chromatogram (*cf.* Table 1). It has been proved that the former two peaks are identical with those of Fraction no. 2, the thionyl chloride–pyridine dehydration product, when a mixed sample (entry 11 on Table 1) was examined by gas chromatography (*cf.* Fig. 1).

Although the infra-red spectrum of each fraction was similar to that of IIa, the intensity of each three absorption bands corresponding to the isopropenyl functions all decreased. Moreover, each fraction showed two more new weak bands at 865 and 834 cm^{-1} in the infra-red spectrum.

From these observations, the substance having a peak at a retention time of 12·3 min may be a new substance, but it was impossible to obtain this substance in a pure state. However, it may be concluded that when potassium bisulphate was used the dehydration product of guaiol mainly consisted of α-guaiene and IIb together with a small amount of the substance of an unknown structure.

(2) *Catalytic hydrogenation of α-guaiene*

On catalytic hydrogenation of α-guaiene, 1 mole of hydrogen was taken up smoothly and a reduction product corresponding to the dihydro derivative was obtained. When α-guaiene was reduced in ethyl acetate with palladium charcoal as a catalyst under usual conditions, it gave a colourless mobile oil, b.p. 79·5°/2 mm, n_D^{20} 1·4889. The analytical values of this oil are in good agreement with the formula $C_{15}H_{26}$ and all the absorption bands corresponding to the isopropenyl group disappeared in the infra-red spectrum. However, this product showed a considerable positive rotatory power, $[\alpha]_D^{21}$ +52·9°, in spite of the fact that the starting material showed a negative rotation, $[\alpha]_D^{19}$ −64·5°. These results suggest the migration of the double bond between C—1 and C—5 in α-guaiene. We now questioned the purity of the reduced oil and examined it by gas chromatography (cf. Table 2). This oil showed two peaks at retention times of 8·8 min and 11·25 min in the gas chromatogram and it

[7] G. Chiurdoglu and M. Descamps, *Tetrahedron* **8**, 271 (1960). It was described that guaiol (I) was dehydrated to give IIa with an acid catalyst, but its details have not been reported in this paper.

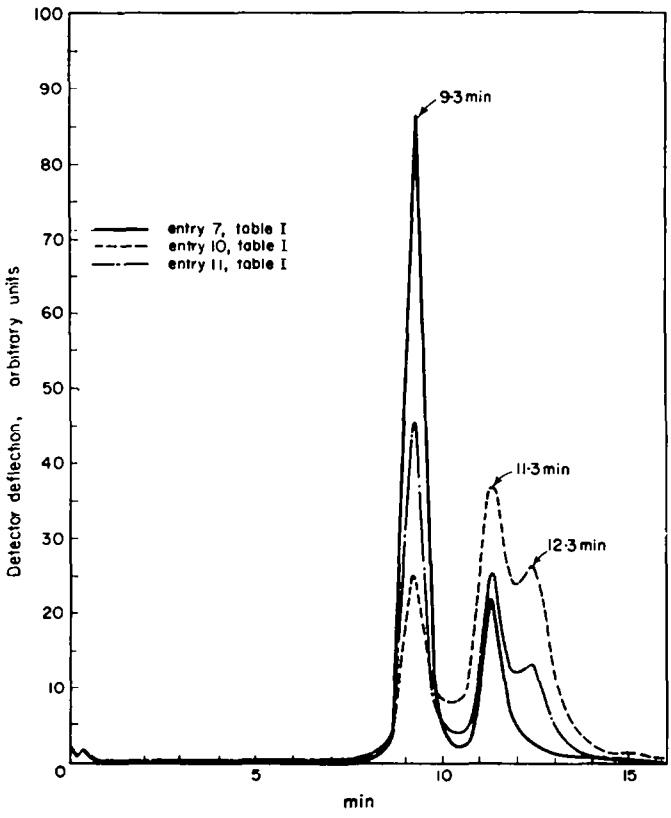
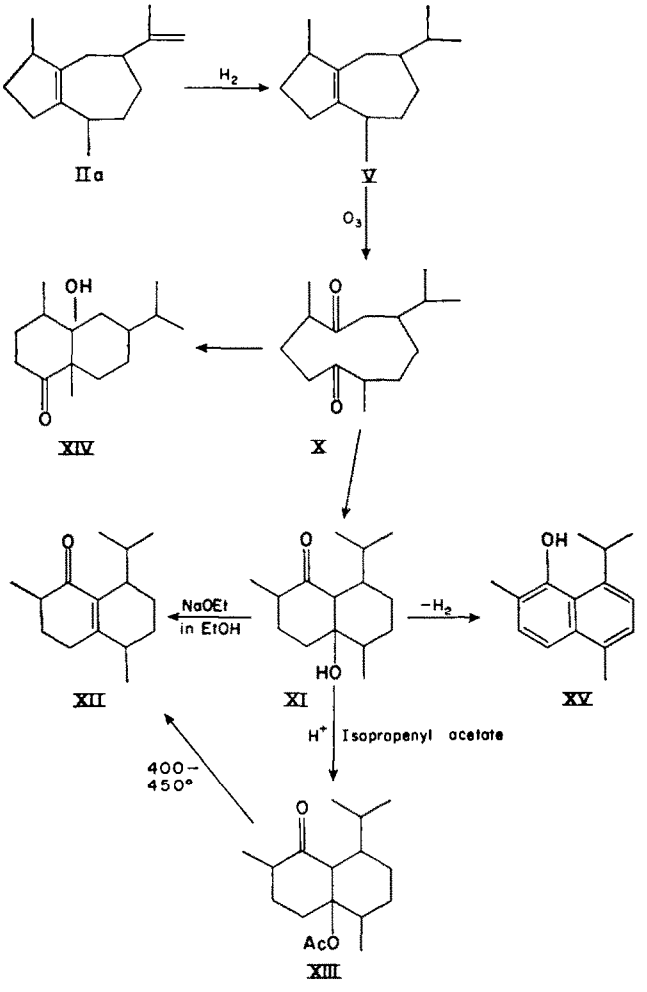


FIG. 1. Gas chromatogram of dehydration products of guaiol.

TABLE 2. HYDROGENATION PRODUCTS OF α-GUAIENE

Entry no.	Catalyst	Solvent	Ratio of peak height at 8·8 min : 11·25 min	$[\alpha]_D$	n_D^{20}
1	10% Pd/C	Ethylacetate	1 : 1·43	+52·9°	1·4889
2	10% Pd/C	Ethylacetate	1 : 1·59	+59·3°	1·4905
3	10% Pd/C	Acetic acid	1 : 1·37	—	—
4	5% Pd/$CaCO_3$	Acetone	1 : 1·56	—	—
5	Raney Ni	Xylene	1 : 0·9	—	—
6	Raney Ni	Dioxane-MeOH NaOH	1 : 0	−30·2°	1·4879
7	10% Pd/C	Dioxane-MeOH KOH	1 : 0	—	—

indicated that the reduced oily substance is a mixture of two components, as expected. By gas chromatographic examination it was proved that in all cases when reduction of α-guaiene was carried out under acid or neutral conditions, it afforded a mixture of two components as in the above-mentioned case, whereas under alkaline conditions it gave only one substance and this showed a peak at the retention time of 8·8 min only. The purified reduction product, obtained under alkaline conditions, showed the following constants, b.p. 104–106°/5 mm, n_D^{20} 1·4879, d_4^{20} 0·8877, $[\alpha]_D^{23}$ −30·2°, and the analytical data of this substance coincides well with those of dihydroguaiene. The infra-red spectrum of this compound no longer showed an absorption band corresponding to the isopropenyl group but a strong band at 1664 cm^{-1} corresponding to the C=C double bond was observed in the Raman spectrum. This compound is considered to be the anticipated dihydroguaiene represented by structure V, since it may be expected that the double bond migration will not occur under such alkaline conditions and the value of the optical rotation is also reasonable. This structure was further confirmed chemically as mentioned below.



When an unpurified oily diketone (X), ν C=O 1710 cm^{-1}, obtained by ozonolysis of the afore-mentioned reduction product, was treated with acetic acid under reflux for 1 hr, or with 0·1 N solution of sodium methoxide in methanol under reflux for 1 hr, or by heating at 190–200° without a solvent, in all cases it afforded the same crystalline ketol (XI), $C_{15}H_{26}O_2$, m.p. 147–149°, $[\alpha]_D^{22}$ +88·6°. Although the infra-red spectrum of this substance showed the presence of the hydroxyl group, ν O—H 3406 cm^{-1}, it gave no acetate under usual conditions but a monoacetate (XIII), m.p. 130–131°, when it was treated with isopropenyl acetate in the presence of *p*-toluenesulphonic acid. In spite of the presence of an absorption band at 1692 cm^{-1} corresponding to the six-membered ring ketone in the infra-red spectrum, it gave neither a semicarbazone nor a 2,4-dinitrophenylhydrazone when reacted in the usual manner. From these observations it was assumed that the hydroxyl group in this ketol is a tertiary one and that the position of the ketone is very sterically hindered. On treatment with 5 per cent sodium ethoxide in ethanol under reflux for 4 hr, the ketol underwent dehydration to produce α,β-unsaturated ketone (XII), b.p. 115–116°/2 mm, whose ultra-violet spectrum showed a maximum at 247·5 mμ (ε 11·200) and the infra-red spectrum also showed absorption bands at 1665 and 1622 cm^{-1} indicating the presence of the α,β-unsaturated ketone. This α,β-unsaturated ketone was also obtained by pyrolysis of the acetoxyketone (XIII) at 400–450°. Since the structure XIV for this ketol was excluded from the two possible alternatives by virtue of the results of the above-mentioned dehydration reaction, the structure of this compound was assumed to be 10-hydroxy-2,5-dimethyl-8-isopropyldecalone-1 (XI). In order to confirm this assumption the foregoing ketol was subjected to dehydrogenation with palladium charcoal at 300–350°, and the anticipated 2,5-dimethyl-8-isopropyl-1-naphthol (XV) was isolated as the sole product. The identity of the dehydrogenation product was evidenced as its picrate, m.p. 135–136° and the trinitrobenzene adduct, m.p. 136–137°. The results of the ultra-violet and the infra-red spectra also satisfied the structure of XV (*cf.* Fig. 2).

Now as the correctness of the assumed structure V for the reduction product of α-guaiene under alkaline conditions, was proved from these experimental results, we wish to give the name "α-dihydroguaiene"* to this compound.

Next we examined another reduction product of α-guaiene having a peak at a retention time of 11·25 min in the gas chromatogram. As this compound is considered to be a double bond isomer of α-dihydroguaiene (V), the possible structures of the isomer will be represented as VI-IX. Although it was impossible to obtain this isomer in a pure state, we finally obtained an isomer rich fraction from the Podbielniak column distillation of the dihydroguaiene mixture. This fraction, b.p. 87–89°/2·5 mm, showed two peaks at retention times of 8·8 min and 11·25 min in the gas chromatogram and the ratio of the peak height at 8·8 min to 11·25 min of this fraction is about 1 : 3. Since the Raman spectrum of this fraction showed a strong double bond absorption at 1664 cm^{-1} but its infra-red spectrum showed no band corresponding to the tri-substituted double bond, numbers VIII and IX out of the four possible structures are therefore excluded for this compound.

Ozone oxidation of the above-mentioned fraction gave an oily substance (XVI),

* In 1908, Gandurin[5] also reported a substance corresponding to the dihydro derivative of guaiene, which was obtained from guaiol by the action of zinc dust at 220°. This substance, b.p. 122°/11 mm, n_D^{20} 1·4982, d_4^{20} 0·8914, $[\alpha]_D^{18·5}$ −26·65°, seems to be identical with the α-dihydroguaiene obtained by us.

b.p. 115–120°/1·6 mm. This product showed negative results to Fehling's and Tollen's reagents, and showed absorption bands at 1709 (C=O) and 1410 cm $^{-1}$ (—CH_2—CO—). The results of the spectroscopic examination and the aldehyde-test showed that this

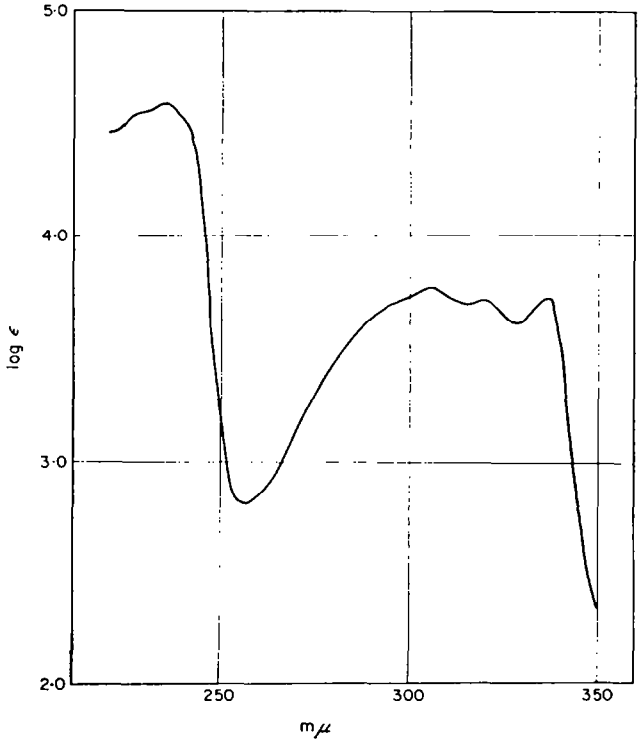
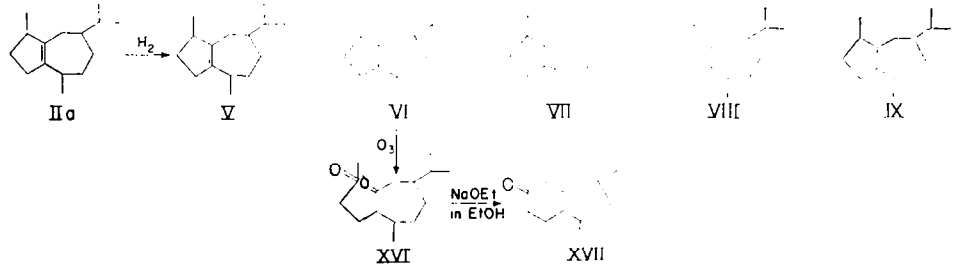


FIG. 2. Absorption max (mμ) and log ε of 2,5-dimethyl-8-isopropylnaphthol-1 (XV). (In ethanol.)

oxidation product has neither a five-membered ring ketone nor an aldehyde function. Since structures VII, VIII and IX for this isomer do not satisfy the above-mentioned results, structure VI is the most likely. An α,β-unsaturated ketone (XVII) having an

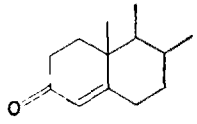


absorption band at 244·5 mμ in the ultra-violet spectrum was formed when the ozone oxidation product was treated with an alkali (*cf.* Chart 3). The absorption band at 244·5 mμ is in agreement with the band of the type XVII[8,9] and this result also supports

[8] Calculated value of 4-ene-3-one in steroids is 244 mμ. L. F. Fieser and M. Fieser, *Steroids* p. 19. Reinhold, New York (1959).
[9] M. Palmade and G. Ourisson, *Bull. Soc. Chim. Fr.* 886 (1958).

the assumed structure VI for the isomeric dihydroguaiene. It is interesting to note that the double bond migration from the C—1 : C—5 position occurs under such mild conditions.

Stereochemical examination of the decalolone derivative (XI) and further confirmation of the structure of VI are now under investigation in our laboratory.



EXPERIMENTAL

The Shimadzu G.O-IA Vapor Fractomer was used for all gas chromatographic determinations. For the analysis of products, a column, 3 m in length with a 6 mm i.d., consisting of Silicone 550 on fire brick (20 to 40 mesh) was operated at 200° with a flow rate of 100 ml/min of hydrogen.

All melting points were measured by use of Kofler block ("mono-scope" Hans Bock Co. Ltd., Frankfurt am Main, Germany) and corrected.

α-Guaiene (IIa)

(1) *Dehydration of guaiol* (I) *with thionyl chloride–pyridine.* Thionyl chloride (47·7 g, 1·38 equiv.) was added dropwise to a solution of guaiol (64·5 g) in pyridine (300 ml) with stirring at 5–10° for 30 min. After the mixture was left 30 min at 4–5°, heated at 55–65° for 1 hr with protection from moisture. Then the mixture was evaporated into about one-fifth *in vacuo*, poured onto a mixture (200 g) of ice and water, and extracted with ether. The ether extract was washed with 2 N H_2SO_4, water and 2 N Na_2CO_3, dried (Na_2SO_4) and evaporated giving a deep brown soiled oil (56 g). The residue was purified to some extent by distillation, and moreover redistilled through a column, 300 mm high with a 10 mm i.d., packed with single turn helices no. 20 (stainless steel), to furnish six fractions (see Table 1).

Fraction 1 was pure α-guaiene (IIa), a colourless mobile oil, b.p. 78–79°/2·5 mm, n_D^{20} 1·4958, d_4^{20} 0·8999, $[\alpha]_D^{19}$ −64·5° (±2°) (c 3·584, dioxane), ν_{max}^{film} 3100, 1645 and 884 cm^{-1}; retention time, 9·3 min. (Found: C, 87·65; H, 11·76. $C_{15}H_{24}$ requires: C, 88·16; H, 11·84%).

In Fractions 2–5, the data of gas chromatography indicated the presence of IIa and IIb, retention times of which are 9·3 and 11·3 min respectively, and the ratio of these peak heights was noted in Table 1. Fraction 6 was the residue of rectification, and redistilled by usual manner. This fraction showed the shoulder at 250 mμ (ε 780) in the ultra-violet and weak absorption bands at 3491 and 1709 cm $^{-1}$ in the infra-red spectrum, whereas in the gas chromatogram it showed no peaks except those at 9·3 and 11·3 min.

(2) *Dehydration of guaiol* (I) *with phosphorous oxychloride–pyridine.* $POCl_3$ (8·8 g, 1·2 equiv.) was added dropwise to a solution of guaiol (10·6 g) in pyridine (90 ml) with stirring at room temp. The mixture was refluxed for 2 hr, and worked up as described above.

(3) *Dehydration of guaiol* (I) *with potassium bisulphate.* A mixture of guaiol (46·5 g) and fused potassium bisulphate (28·5 g) was heated at 160–165° under slightly reduced pressure for 30 min, and worked up as described in the case of (1).

Ozonolyses of α-guaiene (IIa) *and guaiene mixture*

(a) IIa (1·02 g) in carbontetrachloride (15 ml) was ozonized at 0°, and the issuing gas was passed through two bottles containing water (A) (ice bath). The solution of ozonide was decomposed by heating with water (40 ml), and then an alcohol solution of dimedone was added to a half of this aqueous solution (B). The remaining solution of ozonide was distilled and the volatile ketone was trapped in aqueous *p*-nitrophenylhydrazine acetate solution (C). The presence of formaldehyde in the aqueous solution (A) was proved as its dimedone-derivative (223 mg). As this dimedone-derivative (50 mg) also was obtained from (B), the total yield was 323 mg (22·1%). Formaldehyde-dimedone derivative was recrystallized from ethanol as colourless needles, m.p. 191–192°, undepressed on admixture with the authentic sample. From (C) acetone-*p*-nitrophenylhydrazone was not obtained at all.

(b) Guaiene (1·02 g, the ratio of peak heights at 9·3 and 11·3 min was 1 : 0·17) was ozonized as described above. The total yield of the formaldehyde-dimedone derivative was 252 mg (17·3%). Acetone-*p*-nitrophenylhydrazone was recrystallized from ethanol as yellowish orange needles (98 mg, 10·2%), m.p. 147–149°, undepressed on admixture with the authentic sample.

Dihydro-α-guaiene (V)

(1) *Hydrogenation of* IIa *under alkaline condition.* Raney Ni catalyst (35 g) was added to a solution of IIa (18·7 g) in dioxane (200 ml) and methanol (50 ml) containing 2 ml of 50% aqueous sodium hydroxide. The mixture was reduced by catalytic hydrogenation at room temp and atmospheric pressure. When 2100 ml (1·05 moles) of hydrogen had been absorbed, the reaction stopped, and the catalyst and the solvent were removed. The residue was extracted with ether, washed with water, dried (Na_2SO_4) and evaporated leaving a colourless oil (18·5 g). This oil was distilled at 79–80°/2 mm (or 104–106°/5 mm) giving V (17·9 g), n_D^{20} 1·4879, d_4^{20} 0·8877, $[\alpha]_D^{33}$ −30·2° (±2°) (c 1·866, dioxane). V showed no characteristic absorption band in the infra-red spectrum, and showed only one peak at a retention time, 8·8 min in the gas chromatogram (see Table 2). (Found: C, 87·14; H, 12·70. $C_{15}H_{26}$ requires: C, 87·30; H, 12·70%).

(2) *Hydrogenation of* IIa *under neutral condition.* Ten per cent palladized charcoal catalyst (630 mg) was added to a solution of IIa (6·27 g) in ethyl acetate (60 ml). The mixture was reduced by catalytic hydrogenation at room temp and atmospheric pressure. When 858 ml (1·13 moles) of hydrogen had been absorbed, the reaction stopped, and the mixture was worked up as described above leaving a colourless oil (6·0 g). This oil was distilled at 79·5°/2 mm giving a mixture (4·5 g) of V and VI, n_D^{20} 1·4889, $[\alpha]_D^{21}$ +52·9° (c 8·80, dioxane), which was almost identical with V in the infra-red spectrum. The data of gas chromatography indicated two peaks at retention times of 8·8 and 11·25 min and the ratio of the peak heights was 1 : 1·43.

(3) *Hydrogenation of* IIa *under acid condition.* A mixture of 10% palladized charcoal catalyst (100 mg) and IIa (1 g) in glacial acetic acid (20 ml) was reduced catalytically at room temp and atmospheric pressure yielding a colourless oil (856 mg). This oil was distilled at 90–92·5°/3·5 mm giving a mixture (640 mg) of V and VI. The ratio of the peak heights at 8·8 and 11·25 min was 1 : 1·37.

Ozonolysis of α-dihydroguaiene (V)

A solution of V (6 g) in ethyl acetate (20 ml) was treated at −75° with oxygen–ozone stream containing 3 to 3·2 wt.% ozone. After 1·5 molar equivalents of ozone was passed through the solution, it coloured blue, and then the solution was allowed to stand at −75° for 30 min. Subsequently, the solvent was removed under high vacuum at room temp. To a solution of the residue in acetic acid (30 ml) was added zinc dust (2 g) in small portions with stirring (ice bath), during which time the temp was kept below 20°, and then the mixture was negative to colour test for zinc iodide–starch paper. The solution was evaporated *in vacuo*, extracted with ether, washed with water, saturated potassium bicarbonate solution and water, dried (Na_2SO_4) and evaporated giving a yellow oil (X) (5·7 g). ν_{max}^{film} 1710 cm^{-1}.

10-*Hydroxy*-2,5-*dimethyl*-8-*isopropyldecalone*-1 (XI)

(1) A solution of crude X (4·9 g) in glacial acetic acid (25 ml) was refluxed for 1 hr. The solution was evaporated, extracted with ether, washed with water, saturated potassium bicarbonate solution and water and dried (Na_2SO_4). The residue obtained upon removal of the solvent was crystallized with the addition of petroleum ether or ether. Recrystallization from petroleum ether–ether gave XI as fine colourless needles (1·91 g, 38·6%), m.p. 147–149°, $[\alpha]_D^{22}$ +88·6° (±2°) (c 0·979, ethanol), ν_{max}^{Nujol} 3406, 1692, 1012 and 998 cm^{-1} (Found: C, 75·25; H, 10·88. $C_{15}H_{26}O_2$ requires: C, 75·58; H, 11·00%).

(2) Crude X (835 mg) was heated at 190–210° (oil bath) for 1·5 hr. The remaining brown thick oil was recrystallized with the addition of ether giving colourless needles (223 mg, 26·8%), m.p. 146–147°. The crystalline substance was shown to be XI by mixed melting point (146–148°).

(3) To a solution of Na (23 mg) in methanol (10 ml) was added crude X (238 mg). The mixture was refluxed in nitrogen atmosphere for 40 min, then evaporated *in vacuo*, extracted with ether, washed with water, dried (Na_2SO_4) and evaporated giving colourless needles (53 mg), m.p. 147°, $[\alpha]_D^{21}$ +92·9° (±4°) (c 0·692, ethanol), which was shown to be XI by mixed melting point (147–148°).

Treatment of XI *with glacial acetic acid*

A solution of XI (134 mg) in glacial acetic acid (3 ml) was refluxed for 1 hr. The mixture was evaporated *in vacuo*, extracted with ether, washed with water, saturated potassium bicarbonate solution and water, dried (Na_2SO_4) and evaporated leaving XI (125 mg).

Treatment of XI *with* 0·1 N *sodium methoxide in methanol*

To a solution of Na (23 mg) in methanol (10 ml) was added XI (199 mg). The mixture was refluxed in nitrogen atmosphere for 2 hr. This mixture was worked up as described already giving XI (155 mg).

Dehydrogenation of 10-*hydroxy*-2,5-*dimethyl*-8-*isopropyldecalone*-1 (XI)

A mixture of XI (500 mg) and 20% palladized charcoal (250 mg) was heated at 300–350° (bath temp) for 2 hr, during which time ca. 100 ml (1·9 moles) of hydrogen was generated. The residue was extracted with petroleum ether and washed with Claisen's solution. The acid fraction gave a pale yellow oil (16 mg) and from the neutral fraction a pale yellow oil (370 mg) was obtained. This neutral oil was distilled giving a colourless oil (270 mg), b.p. 112–114°/0·2 mm, and gave a picrate as brownish red needles, m.p. 135–136° (recrystallized from ethanol three times) which was identical with a picrate of 2,5-dimethyl-8-isopropyl-naphthol-1 (XV).[4d] (Found: C, 57·12; H, 4·57; N, 9·67. $C_{15}H_{18}O \cdot C_6H_3O_7N_3$ requires: C, 56·88; H, 4·77; N, 9·48%).

The picrate (160 mg) was dissolved in petroleum ether–ether (1:1), and filtered through a column of alumina (3 g). From the filtrate was obtained a colourless oil (58 mg). To a solution of this oil in ethanol (0·5 ml) was added a solution of 1,3,5-trinitrobenzene (66 mg) in ethanol (5 ml). A trinitrobenzene adduct, vermilion needles, m.p. 136–137° (recrystallized from ethanol three times), which was identical with a trinitrobenzene adduct of XV,[4d] was obtained. The spectra of XV, ν_{max}^{film} 3473, near 3400 (broad) and 1218 cm^{-1} (for phenol); λ_{max}^{alc} 235·5 (ε 37·950), 305·5 (ε 6275), 320 (ε 5520) and 337 mμ (ε 5780) (see Fig. 2).

10-*Acetoxy*-2,5-*dimethyl*-8-*isopropyldecalone*-1 (XIII)

The preferred method of acetylation was with isopropenyl acetate: a mixture of this reagent (1 ml), *p*-toluenesulphonic acid monohydrate (1·2 mg) and ketol (XI) (102 mg) was heated (steam bath) for 4 hr with protection from moisture. The mixture was neutralized with a solution of a few pieces of sodium acetate in water (3 ml), evaporated *in vacuo*, extracted with ether, washed with water, saturated potassium bicarbonate solution and water, dried (Na_2SO_4) and evaporated giving colourless needles (116 mg). Recrystallization from petroleum ether gave XIII as colourless needles, m.p. 130–131°, $[\alpha]_D^{18}$ +85·5° (±2°) (c 1·00, ethanol), ν_{max}^{Nujol} 1724, 1703, 1260, 1238 and 1017 cm.$^{-1}$ (Found: C, 73·02; H, 10·03. $C_{17}H_{28}O_3$ requires: C, 72·82; H, 10·06%).

2,5-*Dimethyl*-8-*isopropul*-Δ^{9-10}-*decalone*-1 (XII)

(1) *By dehydration of* XI. To a solution of Na (460 mg) in ethanol (10 ml) was added XI (104 mg). The solution was refluxed in nitrogen atmosphere for 4 hr, then evaporated *in vacuo*, extracted with ether, washed with water, dried (Na_2SO_4) and evaporated leaving a pale yellow oil (88·1 mg). The residue was distilled at 115–116°/2 mm yielding a colourless oil, $[\alpha]_D^{21}$ −30·5° (±2°) (c 1·898, dioxane), λ_{max}^{alc} 247·5 mμ (ε 11200), ν_{max}^{film} 1665 and 1622 cm^{-1}. (Found: C, 81·46; H, 11·01. $C_{15}H_{24}O$ requires: C, 81·76; H, 10·98%).

(2) *By pyrolysis of acetoxy-ketone* (XIII). The apparatus consisted of a quartz-tube, 200 mm high with a 10 mm i.d., packed with Pyrex ball, 2–3 mm dia. was used. XIII (500 mg) was added at the rate of 15–20 mg/min to the top of the pyrolysis tube heated at 400–450°, during which time the addition was conducted in an inert atmosphere by introducing a slow stream of nitrogen at the top of the tube. The pyrolysate was dissolved in ether, washed with water, saturated potassium bicarbonate and water, dried (Na_2SO_4) and evaporated leaving a colourless oil (420 mg). The residue was crystallized with the addition of petroleum ether giving the starting material (90 mg). The mother liquid was distilled at 114–116°/2 mm yielding a colourless oil (160 mg), which was shown to be identical with XII by infrared comparison, but showed $[\alpha]_D^{21}$ −9·2° (±3°) (c 0·837, dioxane), λ_{max}^{alc} 247·5 mμ (ε 9170).

Ozonolysis of the VI*-rich fraction*

A solution of VI (1·48 g, the ratio of the peak heights at 8·8 and 11·25 min was 1 : 2·97) in ethyl acetate (20 ml) was ozonized at −75° in the usual manner. After removal of the solvent under diminished pressure at room temp, zinc dust (1 g) was added in small portions to a solution of the ozonide in glacial acetic acid (8 ml) with stirring (ice bath), and then the mixture was filtered, evaporated *in vacuo*, extracted with ether, washed with water, 2 N NaOH and water, dried (Na_2SO_4) and evaporated giving a pale yellow oil (1·22 g). This oil was distilled at 116–120°/1·5 mm giving XVI (609 mg), ν_{max}^{film} 1709, 1410, 1388 and 1369 $cm,^{-1}$ which showed negative results to Fehling's and Tollen's reagents and positive result to iodoform-test for CH_3CO-group.

Treatment of XVI *with* 0·1 N *sodium methoxide in methanol*

To a solution of Na (23 mg) in methanol (10 ml) was added XVI (287 mg). The mixture was refluxed in nitrogen atmosphere for 2 hr giving a yellow oil (203 mg), which was distilled at 96–97°/0·5 mm yielding XVII (172 mg), λ_{max}^{alc} 244·5 mμ (ε 10850).

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