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Structure and Absolute Configuration of Kusunol[1]

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A new sesquiterpenic alcohol, kusunol, has been isolated from camphor blue oil, the high boiling fraction of the essential oil of camphor tree, *Cinnamomum camphora* (Lauraceae). The carbon skeleton and the positions of the double bond and the tertiary hydroxyl group have been deduced from the chemical and physico-chemical studies, which, together with its transformation to α-vetivone and nootkatone, have further permitted the allocation of the absolute stereostructure I to this sesquiterpenoid.

Camphor tree, *Cinnamomum camphora* (LINNÉ) SIEBOLD (Lauraceae), growing in Japan and China was once the solely available source of the commercial camphor. Therefore, the essential oil has been extensively under investigation since olden times. The high boiling fraction of the oil is called camphor blue oil which has been widely recognized to contain sesquiterpenic alcohols.[3] However, the number of alcohols which have been adequately characterized is rather limited; the presence of nerolidol,[4] elemol, guaiol, α-cadinol, juniper camphor,[5] and β-eudesmol[6] being reported. Receltly we have studied on the sesquiterpenic components of the oil and isolated a new alcohol which has been named kusunol. We now wish to report the results of our investigation which show that kusunol has stereostructure I.

Camphor blue oil was fractionated by distillation. The sesquiterpenic alcohol portion provided on alumina chromatography followed by silica gel chromatography kusunol of molecular formula $C_{15}H_{26}O$ as a colorless oil.

As the oxygen function kusunol contains a free hydroxyl, shown by the infrared absorption at 3370 cm^{-1} and by the formation of a monoacetate (II) along with a dehydration product, the diene (III), on refluxing with acetic anhydride in the presence of sodium acetate. Occurrence of dehydration during the treatment with acetic anhydride indicates the hydroxyl group to be tertiary. This is confirmed by the nuclear magnetic resonance (NMR) spectrum which exhibits no proton signal attributed to a hydrogen on a hydroxyl-bearing carbon. A signal equivalent to six protons as a singlet at 1.11 ppm suggests that the hydroxyl is oriented on a carbon carrying two methyl groups. This assignment is verified by the fact that the previous dehydration product (III) has an isopropenyl group as indicated by its spectral properties (ν 3100, 1645, and 882 cm^{-1}, and δ 1.68 and 4.60 ppm).

In the NMR spectrum of kusunol a doublet at 0.86 ppm for a secondary methyl and a singlet at 0.91 ppm for a tertiary methyl were also visible. Kusunol further disclosed an NMR signal equivalent to one proton at 5.22 ppm arising from a vinyl proton, showing the presence of a trisubstituted double bond.

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[1] This paper forms Part XXI in the series on Sesquiterpenoids. Preceding paper, Part XX: H. Hikino, Y. Sakurai, and T. Takemoto, *Chem. Pharm. Bull.* (Tokyo), **16**, 827 (1968).

[2] Location: *Kita-4-bancho, Sendai.*

[3] For historical aspects of the research, see E. Gildemeister and F. Hoffmann, "Die Ätherischen Öle," Vol. V, Academy Verlag, Berlin, 1959, p. 46.

[4] N. Hirota and M. Hiroi, *Koryo*, **No. 70**, 23 (1963).

[5] S. Hayashi, K. Yano, N. Hayashi, and T. Matsuura, Abstract of the 8th Symposium on the Chemistry of Terpenes, Essential Oils and Aromatics, Sendai, p. 113 (1964).

[6] S. Hayashi, N. Hayashi, T. Matsuura, and K. Yano, Abstract of the 9th Symposium on the Chemistry of Terpenes, Essential Oils and Aromatics, Kumamoto, p. 54 (1965).

It was noticed here that the infrared and NMR data of kusunol closely resembled those of eremoligenol (XIX).⁷⁾ However, precise comparison of the properties of both alcohols and their derivatives showed them to be different.

That kusunol indeed contained the only one ethylenic linkage was shown by its conversion to the monoepoxide (IV) with perbenzoic acid. Treatment of the epoxide (IV) with boron trifluoride yielded the oxido–alcohol (V) which on chromic acid oxidation furnished the oxido–ketone (VI). This showed infrared absorption at 1720 and 1425 cm^{-1}, indicating the presence of a carbonyl in a six–membered or larger ring, and revealing the presence of a methylene flanking the carbonyl. Formation of the bridged oxide (V) from the epoxy–alcohol (IV) can be well explained by the assumption that the reaction proceeded with incipient fission of the $O–C_{(10)}$ bond with concomitant back–side attack of the (C–11) hydroxyl. Therefore, the oxide ring in the epoxy–alcohol (IV) is α–oriented, since the β–configuration of the hydroxy–isopropyl group at C–7 has later been established (*vide infra*). In addition, the epoxide (IV) was reduced with lithium aluminum hydride to give mainly the tertiary alcohol (VII) together with a small amount of the secondary alcohol (VIII) which on chromic acid oxidation afforded the ketone (IX). The infrared spectral properties (ν 1713 and 1400 cm^{-1}) of the ketone (IX) are also consistent with the above observation. Ozonolysis of kusunyl acetate (II) gave the acetoxy keto–aldehyde (X) whose ketonic carbonyl absorbed at 1712 cm^{-1} attributable to a six–membered or larger ring ketone. Consequently, the above spectral evidence coupled with the presence of two methyl and an isopropyl led to the conclusion that kusunol possesses a six/six–membered ring system. Further, the nature of the four methyl groups implied that the ring system participated in the known eremophilane or eudesmane skeleton. This was verified by dehydrogenation of kusunol giving eudalene (XI). The possibility of the situation of the trisubstituted double bond at C–6:C–7 and C–7:C–8 in either skeleton was excluded by the observations that the two ethylene bonds in the diene (III) were not conjugated, and that the epoxide (IV) on treatment with boron trifluoride afforded the oxido–alcohol (V). Therefore, kusunol may be an eremophil–1(10)–en–11–ol or an eremophil–9–en–11–ol.

Oxidation of kusunol with *tert*–butyl chromate yielded the cyclohexenone (XII) (ν 1675 and 1620 cm^{-1}). Alkali treatment of the ketol (XII) failed to give a dehydrated product, a conjugated ketone. This observation suggests that the carbonyl group is not present at a β–position to the C–11 hydroxyl group (*i.e.*, C–8). The ketol (XII) was reduced with lithium and liquid ammonia to give the cyclohexanone (XIII) (ν 1713 cm^{-1}), which on dehydration by phosphorus oxychloride in pyridine afforded a mixture of two unsaturated ketones. One (XIV) was revealed to contain an isopropylidene grouping by means of the NMR evidence (δ 1.69 ppm). The other one (XV) has an isopropenyl group as indicated by the spectral properties (ν 3096, 1646, and 889 cm^{-1}, and δ 1.71 and 4.69 ppm). The unconjugated nature of the carbonyl group with the newly formed isopropylidene in the enone (XIV) unambiguously precluded the possibility of the situation of the carbonyl at C–8. In addition, catalytic hydrogenation of the unsaturated ketone (XV) furnished the saturated ketone (XVI), which was not identical with any of the four stereoisomers at C–7 and C–10 of the 4α(H),5β–eremophilan–8–ones (XX).⁸⁻¹⁰⁾ These results indicate the location of the ethylenic linkage of kusunol to be at C–1:C–10 but not at C–9:C–10. Therefore, kusunol is represented by formula I but exclusive of stereochemistry.

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8) L.H. Zalkow, F.X. Markley, and C. Djerassi, *J. Am. Chem. Soc.*, **82**, 6354 (1960).

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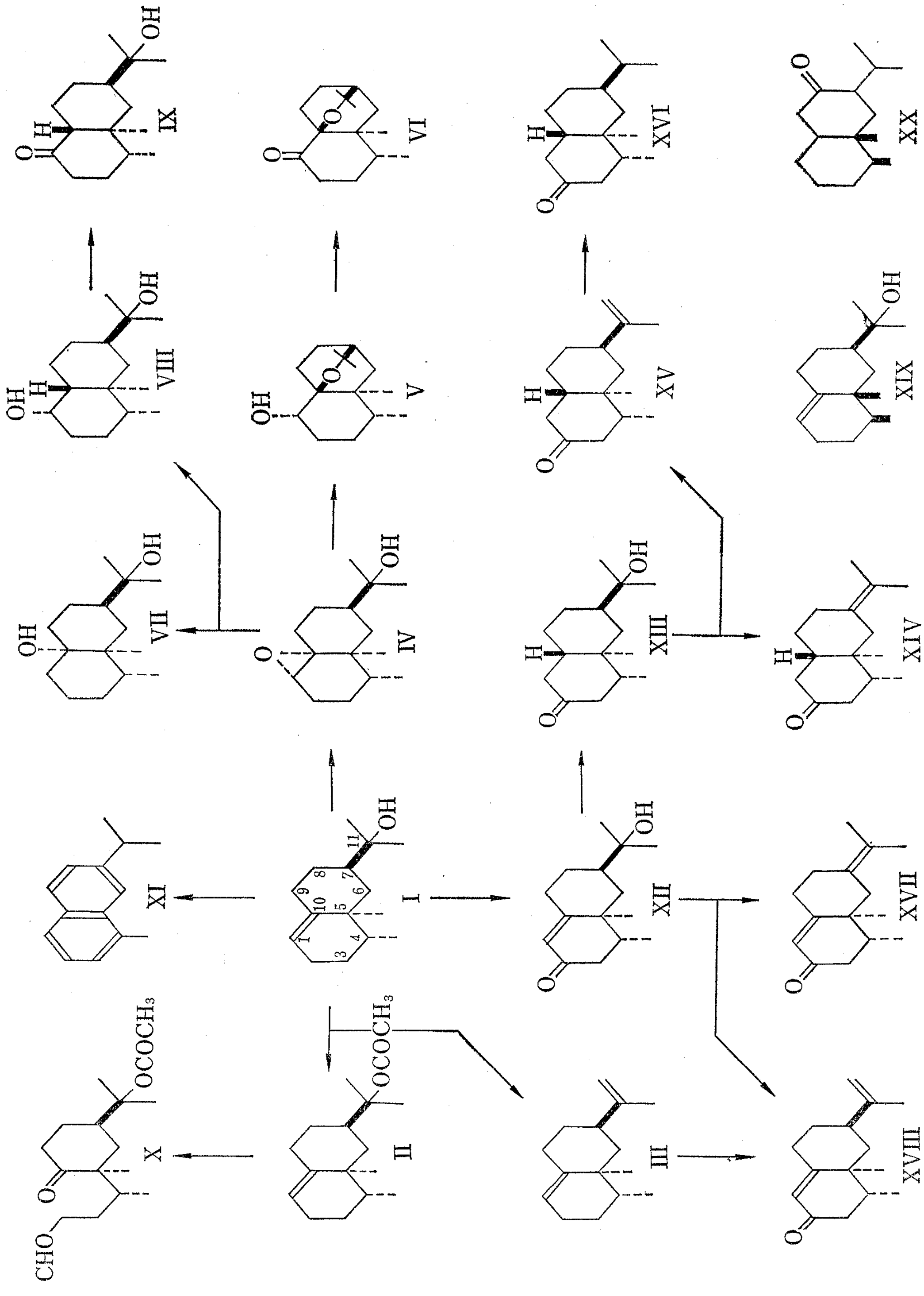
The circular dichroism curve of the enone (XII) showing a negative Cotton effect ($[\theta]_{max}$ -1690) resembles those ($[\theta]_{max}$ -4460 ± 400[11]) of Δ^4-3-oxo-steroids, and that ($[\theta]_{max}$ -2300) of α-vetinone (XVII), whose structure proof has already been reported.[12,13]

This observation suggests the C-5 methyl group to be α-oriented. This was supported by the optical rotatory dispersion curve of the saturated ketone (XVI) exhibiting a positive Cotton effect (a $+45$) which is similar to that of cholestan-3-one (a $+65$[14]). The configuration



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[13] J.A. Marshall and N.H. Anderson, *Tetrahderon Letters*, 1611 (1967).

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of the C–4 methyl group in kusunol was deduced as follows. When the C–4 methyl group in the cyclohexenone (XII) is β–oriented, it is situated relatively near the center of the diamagnetic anisotropy cone of the enone system. On the other hand, when the C–4 methyl occupies an α–configuration, it is located inside the paramagnetic anisotropy cone. Therefore, a 4β–methyl resonance is predicted to occur in a higher field than a 4α–methyl resonance. Further, the shielding effect on the methyl protons on passing from a non–polar solvent to an aromatic solvent must be different depending upon the configuration of the methyl group. In reality, the C–4 methyl resonance of the enone (XII) absorbs at 0.98 ppm and suffers appreciable upfield shifts ($\Delta^{CCl_4}_{C_6H_6}$ +0.34 ppm and $\Delta^{CCl_4}_{C_5H_5N}$ +0.19 ppm) on passing from carbon tetrachloride to benzene and pyridine solution. These values are consistent with those (δ 1.02 ppm, $\Delta^{CCl_4}_{C_6H_6}$ +0.40 ppm, and $\Delta^{CCl_4}_{C_5H_5N}$ +0.19 ppm) observed for the 4α–methyl of α–vetivone (XVII), suggesting the α–configuration of the C–4 methyl group in the enone (XII), *viz.* kusunol. The stereochemistry of kusunol was finally confirmed by dehydration of the unsaturated ketol (XII) with phosphorus oxychloride in pyridine leading to a mixture of dienones. Separation by means of chromatography furnished a dienone with an isopropylidene grouping (δ 1.74 ppm) and a dienone with an isopropenyl group (ν 3096, 1646, and 886 cm^{-1}, and δ 1.73 and 4.68 ppm). The former was identified as α–vetivone (XVII). The latter was more conveniently prepared by oxidizing the diene (III) with *tert*–butyl chromate, and identified as the known nootkatone (XVIII).15,16) Hence, kusunol is represented by the stereoformula I.

Now, it is noted that, in addition to the sesquiterpenoids which have hitherto been recognized as the constituents, camphor oil contains a different type of sesquiterpenoid having the two methyl groups in the α–configuration, kusunol, which must be formed by another biosynthetic pathway.

After completion of this work, there came to our attention the announcement of the structural elucidation of valerianol isolated from *Valeriana officinalis* LINNÉ; the same conclusion for the structure of the alcohol being reached by their investigation.17) Kusunol and valerianol seem to be identical, but direct comparison of both alcohols has not been performed.18)

Experimental19)

Isolation of Kusunol——Camphor blue oil was fractionally distilled through a spinning band column to give a high–boiling fraction, bp 150—170° (4 mmHg), which was submitted to alumina chromatography followed by silica gel chromatography yielding kusunol (I) as a colorless oil, $[\alpha]_D$ +111.5° (c=3.7). *Anal.* Calcd. for $C_{15}H_{26}O$: C, 81.02; H, 11.79. Found: C, 80.92; H, 11.63. IR (liquid) cm^{-1}: 3370 (hydroxyl), 1662 (double bond). NMR: doublet (3H) at 0.86 (J=6, $C\underline{H}_3$–CH⟨), singlet (3H) at 0.91 ($C\underline{H}_3$–C⋞), singlet (6H) at 1.11 (($C\underline{H}_3)_2C(OH)$–), multiplet (1H) at 5.22 (W(h/2)=9, –CH_2–C$\underline{H}$=C⟨).

Acetylation of Kusunol——Kusunol (519 mg) was dissolved in Ac_2O (4 ml) and AcONa (500 mg) added. The mixture was refluxed for 2.5 hr, warmed with water, and extracted with ether. The product (625 mg) was chromatographed over silica gel (15 g).

Elution with light petroleum and distillation under reduced pressure gave the diene (III) as a colorless oil (17 mg), $[\alpha]_D$ +73.4° (c=5.3), IR (liquid) cm^{-1}: 3100, 1645, 882 (vinylidene), NMR: doublet (3H) at 0.77 (J=7, $C\underline{H}_3$–CH⟨), singlet (3H) at 0.94 ($C\underline{H}_3$–C⋞), triplet (3H) at 1.68 (J=1, $C\underline{H}_3$–C=CH_2), quadruplet (2H) at 4.60 (J=1, $C\underline{H}_2$=C–CH_3), multiplet (1H) at 5.23 (W(h/2)=9, –CH_2–C$\underline{H}$=C⟨).

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15) H. Erdtman and Y. Hirose, *Acta Chem. Scand.*, **16**, 1311 (1962).

16) W.D. McLeod, Jr., *Tetrahedron Letters*, 4779 (1965).

17) G. Jommi, J. Křepinský, V. Herout, and F. Šorm, *Tetrahedron Letters*, 677 (1967).

18) We have sent a sample of kusunol to Prof. V. Herout, Czechoslovak Academy of Science, for identification with valerianol, but have not yet received the result.

19) Melting points are uncorrected. Specific rotations were determined in $CHCl_3$ solution. NMR spectra were run at 60 Mcps in CCl_4 solution unless otherwise stated. Chemical shifts are expressed in ppm downward from internal Me_4Si, and coupling constants (J) and band widths at half height (W(h/2)) in cps.

Successive elution with light petroleum–benzene (10:1) and distillation under diminished pressure afforded kusunyl acetate (II) as a colorless oil (520 mg), $[\alpha]_D$ +102.5° (c=4.2). *Anal.* Calcd. for $C_{17}H_{28}O_2$: C, 77.22; H, 10.67. Found: C, 76.97; H, 10.45. IR (liquid) cm^{-1}: 1728, 1238 (acetoxyl). NMR: doublet (3H) at 0.79 (J=7, $C\underline{H}_3{-}CH\langle$), singlet (3H) at 0.90 ($C\underline{H}_3{-}C\lessdot$), singlet (6H) at 1.34 ($(C\underline{H}_3)_2C(OCOCH_3){-}$), singlet (3H) at 1.89 ($C\underline{H}_3{-}CO{-}O{-}$), multiplet (1H) at 5.21 (W(h/2)=9, $-CH_2{-}C\underline{H}{=}C\langle$).

Epoxidation of Kusunol——Kusunol (1.40 g) and BzO_2H (0.8 g) in $CHCl_3$ (28 ml) were kept at room temperature for 20 min. The mixture was washed with 10% NaOH solution and then with water, dried, and evaporated to give the residue (1.78 g) which in light petroleum was chromatographed over silica gel (40 g). Elution with benzene–AcOEt (10:1) afforded the α–epoxide (IV) as a colorless oil (664 mg), $[\alpha]_D$ +48.0° (c=3.1). *Anal.* Calcd. for $C_{15}H_{26}O_2$: C, 75.58; H, 11.00. Found: C, 75.68; H, 10.98. IR (liquid) cm^{-1}: 3440 (hydroxyl). NMR: doublet (3H) at 0.70 (J=6, $C\underline{H}_3{-}CH\langle$), singlet (3H) at 0.94 ($C\underline{H}_3{-}C\lessdot$), singlet (6H) at 1.12 ($(C\underline{H}_3)_2C(OH){-}$), quadruplet (1H) at 2.81 (J_1=5, J_2=3, $-CH_2{-}\underset{\diagdown O \diagup}{C\underline{H}{-}C}\langle$).

Reaction of the Epoxide with Boron Trifluoride——The epoxy–alcohol (IV) (414 mg) in benzene (5 ml) was allowed to react with $BF_3 \cdot Et_2O$ (0.2 ml) at room temperature for 2 min. After isolation in the customary way, the product (437 mg) was chromatographed over silica gel (15 g). Elution with benzene gave a crystalline mass (161 mg) which was crystallized from light petroleum to afford the oxido–alcohol (V) as colorless needles, mp 140—141.5°, $[\alpha]_D$ +49.6° (c=2.1). *Anal.* Calcd. for $C_{15}H_{26}O_2$: C, 75.58; H, 11.00. Found: C, 75.48; H, 10.78. IR (KBr) cm^{-1}: 3450 (hydroxyl).

Oxidation of the Oxido-alcohol with Chromium Trioxide-Pyridine Complex——The oxido–alcohol (V) (15 mg) was oxidized by allowing it to stand overnight at room temperature in a mixture of CrO_3 (30 mg) and pyridine (0.2 ml). Isolation in the usual manner gave the oxido–ketone (VI) as a colorless oil. IR (CCl_4) cm^{-1}: 1720 (cyclohexanone), 1425 (methylene next to carbonyl). NMR: singlet (3H) at 0.70 ($C\underline{H}_3{-}C\lessdot$), doublet (3H) at 0.86 (J=7, $C\underline{H}_3{-}CH\langle$), singlets (3H each) at 1.26, 1.29 ($-C(C\underline{H}_3)_2{-}O{-}$).

Reduction of the Epoxide with Lithium Aluminum Hydride——The epoxide (IV) (476 mg) was stirred at room temperature for 3 hr in ether (16 ml) containing $LiAlH_4$ (150 mg). Upon isolation, the product (509 mg) was chromatographed on silica gel (15 g).

Benzene–AcOEt (5:1) eluted a crystalline mass (228 mg) which on crystallization from light petroleum gave the diol (VII) as colorless needles, mp 47—49°, $[\alpha]_D$ +17.1° (c=3.5). *Anal.* Calcd. for $C_{15}H_{28}O_2$: C, 74.95; H, 11.74. Found: C, 75.34; H, 11.74. IR (CCl_4) cm^{-1}: 3680, 3500 (hydroxyl). NMR: doublet (3H) at 0.74 (J=6, $C\underline{H}_3{-}CH\langle$), singlet (3H) at 0.84 ($C\underline{H}_3{-}C\lessdot$), singlet (6H) at 1.12 ($(C\underline{H}_3)_2C(OH){-}$).

Benzene–AcOEt (10:3) eluted a crystalline mass (30 mg) which was crystallized from AcOEt to give the diol (VIII) as colorless needles, mp 187—189°. IR (KBr) cm^{-1}: 3360 (hydroxyl).

Oxidation of the Diol with Chromium Trioxide-Pyridine Complex——To a CrO_3–pyridine complex (made from CrO_3 (30 mg) and pyridine (0.1 ml)) was added the diol (VIII) (18 mg) in pyridine (0.1 ml). The mixture was let standing at room temperature for 2 hr and treated in the usual manner to yield the product (13 mg), which was shown by thin–layer chromatography to be a mixture of an oxidation product and the starting material. Chromatography over silica gel (2 g) and elution with benzene–AcOEt (10:1) gave the keto–alcohol (IX) as a colorless oil which crystallized on standing. IR (CCl_4) cm^{-1}: 3640, 3540 (hydroxyl), 1713 (cyclohexanone), 1400 (methylene α to carbonyl).

Ozonolysis of Kusunyl Acetate——Kusunyl acetate (II) (240 mg) was dissolved in AcOEt (10 mg) and a stream of ozonized oxygen passed through at 0° for 1 hr. The mixture was hydrogenated over Pd–C (5%, 150 mg), the catalyst filtered off, and the solvent evaporated. The residue (265 mg) was chromatographed over silica gel (7 g), Elution with benzene–AcOEt (5:1) gave the acetoxy ketoaldehyde (X) as a colorless oil. IR (CCl_4) cm^{-1}: 1730 (acetoxyl, aldehyde), 1712 (cyclohexanone).

Dehydrogenation of Kusunol with Selenium——Kusunol (321 mg) and Se (668 mg) were heated together at 290—320° for 2 hr. The product was extracted with ether, and the ethereal solution was washed with 10% NaOH solution, dried, and evaporated to leave a liquid (253 mg). The light petroleum soluble portion of this liquid was chromatographed on alumina (5 g). Light petroleum eluted an oil (72 mg), which was treated with picric acid in EtOH and crystallized from EtOH to give the picric acid complex of eudalene (XI) as yellow needles, mp 89°. The identity was confirmed by the usual criteria.

Oxidation of Kusunol with *tert*-Butyl Chromate——To kusunol (1.07 g) in CCl_4 (15 ml) was added a mixture of *tert*–butyl chromate solution (solution B,20) 20 ml), AcOH (7 ml), and Ac_2O (2.5 ml) under stirring at 70° during the period of 45 min. Stirring was continued for a further 4 hr. The mixture was cooled at 0°, oxalic acid solution (10%, 40 ml) added, and oxalic acid (3 g) added. After the stirring at room temperature for 30 min, the reaction mixture was extracted with $CHCl_3$. Working up as usual gave the product (809 mg) which was applied to silica gel (20 g) in benzene. The fraction (184 mg) eluted with benzene–AcOEt (5:1) was collected and distilled under reduced pressure to yield the unsaturated keto–alcohol (XII) as a colorless oil, $[\alpha]_D$ +141.5° (c=3.9), CD (c=0.099, dioxane): $[\theta]_{344}$ −1100, $[\theta]_{330}$ −1690, $[\theta]_{317}$ −1610, $[\theta]_{307}$ −1030 (inflection). *Anal.* Calcd. for $C_{15}H_{24}O_2$: C, 76.22; H, 10.24. Found: C, 75.96; H, 9.98. IR

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20) R.V. Oppenauer and H. Oberrauch, *Anales Asoc. Quim. Arg.*, **37**, 246 (1949) (*C.A.*, **44**, 3909 (1950)).

(CCl_4) cm^{-1}: 3640, 3450 (hydroxyl), 1675, 1620 (cyclohexenone), 1416 (methylene next to carbonyl). NMR: doublet (3H) at 0.98 ($J=6$, $C\underline{H}_3{-}CH\langle$), singlet (3H) at 1.08 ($C\underline{H}_3{-}C\leqslant$), singlets (3H each) at 1.12, 1.14 ($(C\underline{H}_3)_2C(OH){-}$), singlet (1H) at 5.61 ($-CO-C\underline{H}=C\leqslant$). NMR ($C_6H_6$): doublet (3H) at 0.64 ($J=6$, $C\underline{H}_3{-}CH\langle$), singlet (3H) at 0.71 ($C\underline{H}_3{-}C\leqslant$), singlet (6H) at 0.98 ($(C\underline{H}_3)_2C(OH){-}$), NMR ($C_5H_5N$): doublet (3H) at 0.79 ($J=6$, $C\underline{H}_3{-}CH\langle$), singlet (3H) at 0.97 ($C\underline{H}_3{-}C\leqslant$), singlet (6H) at 1.32 ($(C\underline{H}_3)_2C(OH){-}$), singlet (1H) at 5.88 ($-CO-C\underline{H}=C-$).

Attempted Treatment of the Unsaturated Keto-alcohol with Alkali——The ketol (XII) (53 mg) in MeOH (5 ml) was refluxed with NaOH solution (5%, 0.25 ml) under N_2 for 1 hr. Upon isolation the product (50 mg) was shown to be the starting ketol (XII) by the usual criteria.

Reduction of the Cyclohexenone with Lithium and Liquid Ammonia——The cyclohexenone (XII) (285 mg) in ether (5 ml) was added to a solution of Li (0.3 g) in liquid ammonia (50 ml). After 30 min, NH_4Cl (0.3 g) was added and the ammonia allowed to evaporate. Recovered by the addition of water and ether, the product (291 mg) after chromatography on silica gel (3 g), elution with benzene, and distillation under reduced pressure afforded the saturated keto-alcohol (XIII) as a colorless oil (159 mg). ORD ($c=0.064$, MeOH): ϕ_{305}^{peak} +2370, $\phi_{270}^{\text{trough}}$ −1960. *Anal.* Calcd. for $C_{15}H_{26}O_2$: C, 75.58; H, 11.00. Found: C, 75.48; H, 11.39. IR (CCl_4) cm^{-1}: 3650, 3150 (hydroxyl), 1713 (cyclohexanone), 1418 (methylene adjacent to carbonyl). NMR singlet (3H) at 0.90 ($C\underline{H}_3{-}C\leqslant$), doublet (3H) at 0.91 ($J=6$, $C\underline{H}_3{-}CH\langle$), singlet (6H) at 1.11 ($(C\underline{H}_3)_2C(OH){-}$).

Dehydration of the Keto-alcohol with Phosphorus Oxychloride in Pyridine——The keto-alcohol (XIII) (159 mg) in pyridine (1 ml) was treated with $POCl_3$ (0.2 ml) at room temperature for 2 hr. Upon isolation, the product (153 mg) was chromatographed over silica gel (3 g) impregnated with $AgNO_3$ (5%).

Elution with light petroleum–benzene (10:3) and distillation under reduced pressure afforded the unsaturated ketone (XIV) as a colorless oil (51 mg), $[\alpha]_D$ +71.3° ($c=3.5$). *Anal.* Calcd. for $C_{15}H_{24}O$: C, 81.76; H, 10.98. Found: C, 81.49; H, 10.82. IR (CCl_4) cm^{-1}: 1718 (cyclohexanone), 1416 (methylene α to carbonyl) NMR: singlet (3H) at 0.75 ($C\underline{H}_3{-}C\leqslant$), doublet (3H) at 0.94 ($J=6$, $C\underline{H}_3{-}CH\langle$), singlet (6H) at 1.69 ($(C\underline{H}_3)_2C=C\langle$).

Further elution with light petroleum–benzene (1:1) and distillation under diminished pressure gave the unsaturated ketone (XV) as a colorless oil (57 mg), $[\alpha]_D$ +54.4° ($c=3.1$). *Anal.* Calcd. for $C_{15}H_{24}O$: C, 81.76; H, 10.98. Found: C, 81.28; H, 10.81. IR (CCl_4) cm^{-1}: 3096, 1646, 889 (vinylidene), 1716 (cyclohexanone), 1417 (methylene next to carbonyl). NMR: doublet (3H) at 0.90 ($J=6$, $C\underline{H}_3{-}CH\langle$), singlet (3H) at 0.97 ($C\underline{H}_3{-}C\leqslant$), singlet (3H) at 1.71 ($C\underline{H}_3{-}C=CH_2$), singlet (2H) at 4.69 ($C\underline{H}_2{-}C=CH_3$).

Catalytic Hydrogenation of the Unsaturated Ketone over Platinum in Methanol——The unsaturated ketone (XV) (35 mg) in MeOH (10 ml) was hydrogenated over PtO_2 (15 mg). After the consumption of *ca.* 1 mole of H_2, the catalyst was filtered off, and the solvent evaporated. The product (33 mg) was filtered through silica gel (1.5 g). The fraction eluted with light petroleum–benzene (5:1) was distilled under reduced pressure to furnish the saturated ketone (XVI) as a colorless oil, ORD ($c=0.103$, MeOH): ϕ_{303}^{peak} +2300, $\phi_{268}^{\text{trough}}$ −2210. *Anal.* Calcd. for $C_{15}H_{26}O$: C, 81.02; H, 11.79. Found: C, 81.12; H, 11.62. IR (CCl_4) cm^{-1}: 1715 (cyclohexanone), 1415 (methylene adjacent to carbonyl). NMR: singlet (3H) at 0.89 ($C\underline{H}_3{-}C\leqslant$), multiplet (9H) in the range 0.8—1.0 ($C\underline{H}_3{-}CH\leqslant$).

The 2,4-dinitrophenylhydrazone, prepared in the customary manner ($NH_2NHC_6H_3(NO_2)_2{-}H_2SO_4{-}$EtOH), crystallized from EtOH as orange needles, mp 96—97°.

Dehydration of the Unsaturated Ketone with Phosphorus Oxychloride in Pyridine——The unsaturated keto-alcohol (XII) (123 mg) in pyridine (0.5 ml) was allowed to react with $POCl_3$(0.1 ml) at room temperature. After 1 hr, the product (95 mg) was isolated in the usual way, and chromatographed over $AgNO_3$–impregnated silica gel (5%, 2 g).

Elution with benzene gave an oil (22 mg) which was distilled under reduced pressure to yield the dienone (XVII) as a colorless oil, IR (CCl_4) cm^{-1}: 1673, 1618 (cyclohexenone). NMR: singlet (3H) at 0.98 ($C\underline{H}_3{-}C\leqslant$), doublet (3H) at 1.02 ($J=6$, $C\underline{H}_3{-}CH\langle$), singlet (6H) at 1.74 ($(C\underline{H}_3)_2C=C\langle$), singlet (1H) at 5.65 ($-CO-C\underline{H}-C\langle$). NMR ($C_6H_6$): doublet (3H) at 0.62 ($J=6$, $C\underline{H}_3{-}C\langle$), singlet (3H) at 0.66 ($C\underline{H}_3{-}C\leqslant$), singlet (6H) at 1.53 ($(C\underline{H}_3)_2C=C\langle$. NMR ($C_5H_5N$): doublet (3H) at 0.83 ($J=6$, $C\underline{H}_3{-}CH\langle$), singlet (3H) at 0.84 ($C\underline{H}_3{-}C\langle$), singlet (6H) at 1.64 ($(C\underline{H}_3)_2C=C\langle$), singlet (1H) at 5.85 ($-CO-C\underline{H}=C\langle$). The identity with the natural α-vetivone was confirmed by TLC, IR and NMR comparison.

Successive elution with benzene afforded an oil (11 mg) which on distillation under diminished pressure furnished the dienone (XVIII) as a colorless oil. IR (CCl_4) cm^{-1}: 3096, 1646, 886 (vinylidene), 1673, 1620 (cyclohexenone). NMR: doublet (3H) at 0.94 ($J=6$, $C\underline{H}_3{-}CH\langle$), singlet (3H) at 1.11 ($C\underline{H}_3{-}C\leqslant$), singlet (3H) at 1.73 ($C\underline{H}_3{-}C=CH_2$), singlet (2H) at 4.68 ($C\underline{H}_2=C-CH_3$), singlet (1H) at 5.63 ($-CO-C\underline{H}=C\langle$. Identification with the dienone (XVIII) obtained by oxidation of the diene (III) (*vide infra*) was carried out by TLC, IR and NMR comparison.

Oxidation of the Diene with *tert*-Butyl Chromate——A mixture of *tert*-butyl chromate solution(solution B,[20]) 12 ml), AcOH (4 ml), and Ac_2O (1.5 ml) was added dropwise with stirring to the diene (III) (533 mg) in CCl_4 (10 ml) at 70° over 30 min and the mixture was allowed to stand at 70° under stirring for 30 min. Upon isolation in the usual manner, the product (369 mg) was chromatographed over silica gel (8 g). Elution with light petroleum–benzene (1:1) afforded an oil (104 mg) which was distilled under reduced pressure to give the dienone (XVIII) as a colorless oil, $[\alpha]_D$ +165.0° (c=6.2). IR (CCl_4) cm^{-1}: 3096, 1646, 886 (vinylidene), 1673, 1620 (cyclohexenone). NMR: doublet (3H) at 0.94 (J=6, $C\underline{H}_3$–CH<), singlet (3H) at 1.11 ($C\underline{H}_3$–C<), singlet (3H) at 1.73 ($C\underline{H}_3$–C=CH_2), singlet (2H) at 4.68 ($C\underline{H}_2$=C–CH_3), singlet (1H) at 5.63 (–CO–C$\underline{H}$=C<). NMR (C_6H_6): doublet (3H) at 0.54 (J=6, $C\underline{H}_3$–CH<), singlet (3H) at 0.66 ($C\underline{H}_3$–C<), singlet (3H) at 1.56 ($C\underline{H}_3$–C=CH_2), singlet (2H) at 4.69 (broad, $C\underline{H}_2$=C–CH_3).

The 2,4-dinitrophenylhydrazone, prepared in the customary manner ($NH_2NHC_6H_3(NO_2)_2$–H_2SO_4–EtOH), crystallized from AcOEt as red needles, mp 156—157°, which undepressed on admixture with the 2,4-dinitrophenylhydrazone of the natural nootkatone.

The semicarbazone, prepared in the usual way ($NH_2NHCONH_2 \cdot HCl$–AcONa–EtOH–H_2O), crystallized from EtOH as colorless prisms, mp 196—198°, which showed no mp depression on admixture with the semicarbazone of the natural nootkatone. The IR spectra were also identical.

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Addendum (October 1967)

After the submission of this paper, Prof. V. Herout informed us in his private communication that the infrared spectra of kusunol and valerianol are essentially identical. Now we are glad to accept the term valerianol for our alcohol.