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96. Hiroyuki Inouye, Takuo Okuda, Yasubumi Hirata, Naotaka Nagakura,*1 and Masao Yoshizaki*2 : Structure of Catalpalactone, a New Phthalide from *Catalpa* Wood.*3

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Catalpalactone, $C_{15}H_{14}O_4$, a new type of phthalide derivative has been isolated from the wood of *Catalpa ovata* G. Don and *C. bignonioides* Walt, and its structure has been determined to be represented by the formula (I).

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Catalpa ovata G. Don (Japanese name "Kisasage," Fam. Bignoniaceae) is a tall tree whose beans have been used as a diuretic in Japan. While the constituents of this species have been the subject of a number of investigations, there is only one report concerning the constituents of the wood presented by Imamura *et al.*, who isolated β-sitosterol, vanillic acid, ferulic acid, and cerotic acid, and identified some other constituents by paper chromatography.[1)]

The present authors have isolated a new type of phthalide which they propose to name catalpalactone (I). It was obtained from the wood of *Catalpa ovata*, and also from the wood of *Catalpa bignonioides* Walt. (Japanese name "America-kisasage"). The phthalide was isolated from the neutral fraction of the methanolic extract of the wood after removing the precipitate which was positive to Liebermann-Burchard test. Purification by chromatography on a charcoal column followed by recrystallization from methanol yielded dimorphic forming colorless crystals, m.p. 105~106°, or m.p. 110~111°, with no optical rotation.*4

The analysis, and the mass spectrum which showed the molecular ion peak at m/e 258 indicate the molecular formula to be $C_{15}H_{14}O_4$. The spectra, UV λ_{max}^{EtOH} mμ (log ε) : 275 (3.21), 282 (3.20), IR $\nu_{max}^{CHCl_3}$ cm^{-1} : 1615, 1600, and NMR*5 (τ) : 2.0~2.6 (m, 4H) (Fig. 1), and the formation of phthalic acid by the oxidation with potassium permanganate indicates the presence of an *o*-disubstituted phenyl group in the molecule. The NMR spectrum also shows two singlets of methyl protons at 8.66τ and 8.53τ. Among the remaining four hydrogens in the molecule, one is shown at 3.57τ (1H) as a broad singlet, and another appears at 3.17τ (1H) as a triplet (J=5 c.p.s.) in which each peak appears as a fine doublet (J=1 c.p.s.). This small splitting has been shown by the double-resonance method to be due to the coupling with the proton shown at 3.57τ. The presence of a double bond is also indicated by the IR band at 1660 cm^{-1} (in $CHCl_3$), and this double bond is shown to be trisubstituted by the following observation : Hydrogenation of catalpalactone over palladium-charcoal catalyst yielded dihydrocatalpalactone (II), $C_{15}H_{16}O_5$, m.p. 153~154°, together with the major product, tetrahydrocatalpalactonic acid (III). The NMR spectrum of II shows the disappearance of the

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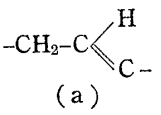
*3 A preliminary report of this work has been published : Tetrahedron Letters, **1965**, 1261.
*4 The compound showed no optical rotation by the optical rotatory dispersion measurement.
*5 NMR spectra were determined on a Varian Associates recording spectrometer (A-60) at 60 Mc. using $CDCl_3$ as the solvent. Chemical shifts were recorded in τ values, using tetramethylsilane as the internal reference.

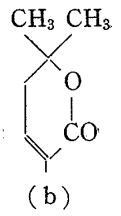
1) H. Imamura, M. Suda : J. Wood Research Soc. Japan, 8, 127 (1962).

signal at 3.17τ in the NMR of I, while a proton is still shown at 3.68τ (d, J=3 c.p.s.). A methylene signal appears at 7.46τ in I as a diffused doublet (J=5 c.p.s.), whose coupling with the olefinic proton at 3.17τ has been confirmed by the decoupling experiment. The trisubstituted double bond would then be in the partial structure (a).


(a)

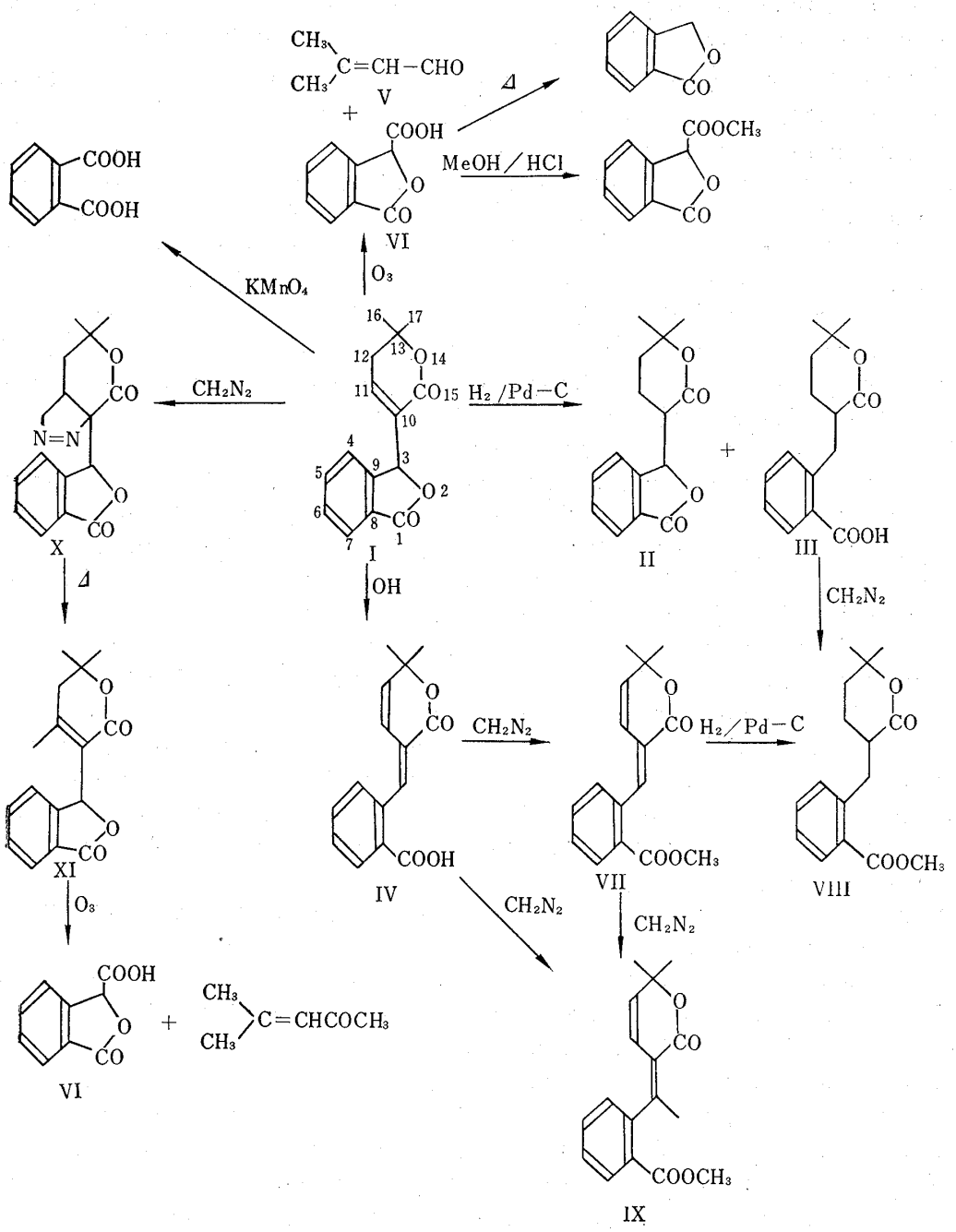
The presence of a γ-lactone and another carbonyl group in catalpalactone is shown by IR bands at 1768 cm^{-1} and 1710 cm^{-1} (in $CHCl_3$) although I failed to react with 2,4-dinitrophenylhydrazine and other carbonyl reagents. Catalpalactone was hydrolyzed with barium hydroxide and the resulting solution was lyophilized to give a solid residue which showed no carbonyl band in the IR spectrum besides new peaks due to carboxylate anion at 1545 cm^{-1} and 1400 cm^{-1}. Accordingly, the absorption at 1710 cm^{-1} in catalpalactone is assignable to either an α,β-unsaturated ester or an α,β-unsaturated δ-lactone. Neutralization of the aqueous solution of the lyophilized hydrolysate resulted in both recovery of catalpalactone and production of an acid (IV), $C_{15}H_{14}O_4$, m.p. 138~139°, which was named catalpalactonic acid. This acid IV was also produced in high yield by heating catalpalactone with potassium hydroxide in water or ethanol. The UV spectrum, λ_{max}^{EtOH} 302 mμ (log ε 4.11) is indicative of the production of a new conjugated system which will include the phenyl group. The carboxylic absorptions (3300~2500 cm^{-1} and 1685 cm^{-1}) and the α,β-unsaturated carbonyl band (1715 cm^{-1}) are shown in the IR spectrum (in KBr), while the absorption of the γ-lactone is absent. Two olefinic protons are exhibited in the NMR spectrum at 3.60τ and 4.09τ (J_{AB}=10 c.p.s.) in an AB system, and the methylene protons are absent. These spectral evidences in addition to the identity of the molecular formula of IV with that of catalpalactone indicate that the acid IV was formed through an elimination reaction. It is indicated by these results of the neutralization of the hydrolysate that the α,β-unsaturated carbonyl group in catalpalactone belongs to the δ-lactone group, and not to the ester.

By ozonolysis of catalpalactone, β,β-dimethylacrolein (V) and phthalide-3-carboxylic acid (VI) were produced both in high yield. Therefore, catalpalactone is a C-3 substituted phthalide in which the substituent contains an α,β-unsaturated δ-lactone. The NMR signal at 3.57τ in catalpalactone is now assigned to the C-3 proton of the phthalide moiety. Since the partial structure (a) can be extended to the structure (b), the structure of catalpalactone is shown by (I). The production of phthalide-3-carboxylic acid on the ozonolysis must be attributed to decarboxylation of the intermediate product which may be an α-ketocarboxylic acid or its ester. The structure of catalpalactonic acid is now shown by either the structure (IV) or its geometric isomer. A broad singlet at 1.73τ in the NMR spectrum of IV is assignable to the C-3 proton. The low field shift of this signal is attributable to the paramagnetic anisotiopy effect by the benzene ring.


(b)

When IV was treated with ethereal solution of diazomethane for a few minutes, the ester (VII), $C_{16}H_{16}O_4$ m.p. 100.5~101° was produced. An AB quartet of olefinic protons is shown in the NMR spectrum at 3.57τ and 4.08τ (J=11 c.p.s.). Each of the two peaks centered at 4.08τ show further splitting (J=2 c.p.s.). These splittings which are analogous to those observed in the NMR spectrum of IV are considered to be the result of the long-range coupling of the olefinic proton at C-11 with the C-3 proton.

The structural relationship between IV and III was established by the hydrogenation. Two-mole equivalent of hydrogen was absorbed during the hydrogenation of the ester VII over palladium-charcoal catalyst, and the resulting ester (VIII), $C_{10}H_{20}O_4$, m.p. 85~86°, which shows no olefinic proton signal in the NMR spectrum was identical with the formerly obtained methyl ester of III.



A further methylation was found to occur at C-3 of the ester Ⅶ on the prolonged treatment with diazomethane. While the ester Ⅶ was the only product when the methylation of Ⅳ was terminated in a few minutes, overnight treatment of either Ⅳ or Ⅶ yielded another ester (Ⅸ), $C_{17}H_{18}O_4$, m.p. 121~122°. The NMR spectrum of Ⅸ (Fig. 1) shows a singlet of vinylic methyl proton at 7.41τ, and the absence of C-3 proton. Each peak of the AB quartet at 4.23τ and 4.47τ (J=10 c.p.s.), unlike those in Ⅳ and Ⅶ, shows no further splitting. These data indicate that the C-3 hydrogen in Ⅳ and Ⅶ has been substituted by a methyl group during the prolonged treatment with diazomethane. Although such a substitution of an olefinic hydrogen by a methyl group under the ordinary reaction condition with diazomethane would be rather unusual, an example of analogous reaction of methyl-2-oxopyran-5-carboxylate with diazomethane has been reported.[2)]

2) J. Fried, R.C. Elderfield: J. Org. Chem., **6**, 577 (1941).

When catalpalactone was treated with ethereal solution of diazomethane for a few hours, a pyrazoline derivative (X), $C_{10}H_{16}O_4N_2$, m.p. 163° (decomp.) was obtained. The product shows an infrared absorption band at 1560 cm^{-1} which is indicative of a grouping -N=N-, and the UV absorption, λ_{max}^{EtOH} 324 mμ (log ε, 2.26) is in the range of that of 1-pyrazoline.[3] The C-3 proton of the phthalide is shown as a singlet at 3.62τ, and the olefinic proton is not shown in the NMR spectrum. A methyl signal appears at 9.35τ while another methyl peak is shown at 8.71τ. The upfield shift of one methyl will have been caused by the pyrazoline ring formation. Pyrolysis of X gave 11-methylcatalpalactone (XI), $C_{16}H_{16}O_4$, m.p. 204~205°. The presence of a vinylic methyl (8.18τ) and the absence of the olefinic hydrogen in the product are shown by the NMR spectrum. The methylene signal appears as a broad singlet at 7.53τ. The structure XI was confirmed further by ozonolysis which yielded phthalide-3-carboxylic acid and mesityl oxide.

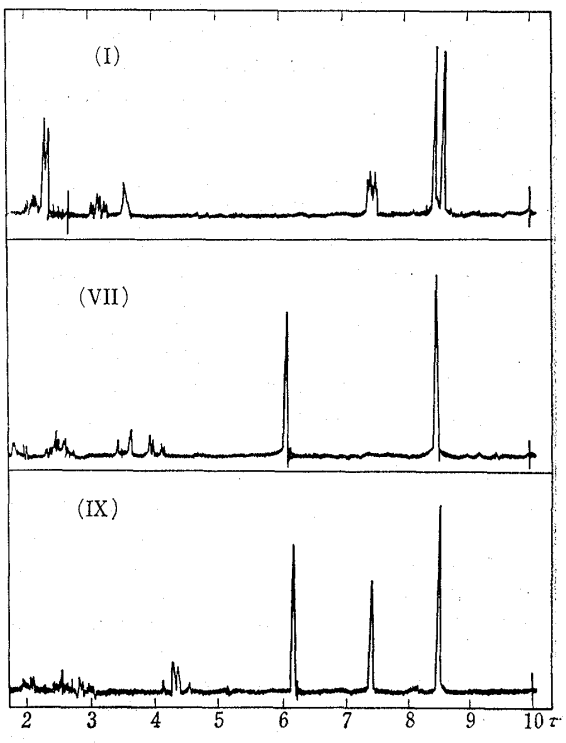


Fig. 1. Nuclear Magnetic Resonance Spectra of Catalpalactone (I), and Derivatives (VII) and (IX)

The mass spectrum*6 of catalpalactone has shown some remarkable ratio of the intensites of peaks: A strong M-18 peak at m/e 240 and a weak molecular ion peak at m/e 258 were exhibited although the structure I of catalpalactone has no hydroxyl group. The ratio of the intensity of the former peak to the base peak at m/e 133, which is assignable to an ion arising from the phthalide moiety by the fission between C_3 and C_{10}, was 46%*6a) and 73%,*6b) while the ratio of the latter peak to the base peak was about 2%*6a) and 4%.*6b) A strong M-18 peak (m/e 242) and a weak molecular ion peak (m/e 260) were also shown in the mass spectrum of dihydrocatalpalactone II. However, such unexpected ratio of the intensities of the molecular peak to the M-18 peak was not shown in the spectra of methyl catalpalactonate VII, and its tetrahydro derivative VIII.

Experimental*7

Isolation of Catalpalactone (I)——a) From the wood of *Catalpa ovata*: The finely ground wood (2.4 kg.) was refluxed four times each with 3.5 L. of MeOH for 4 hr. The combined extract was concentrated *in vacuo* to give a viscous residue which was re-extracted four times with 300 ml. portions of boiling benzene. The precipitate from the cooled benzene solution, which is positive to Liebermann-Burchard test, was filtered off. The filtrate was washed with 5% Na_2CO_3 (100 ml.), 1% NaOH (150 ml.), and water successively, and then dried over Na_2SO_4. Benzene was distilled to give a residue which on standing deposited crude crystals of (I). Yield: 5.4 g. (0.22%). The crude crystals were dissolved in MeOH, and the solution was passed through a column of a mixture of activated charcoal (Shirasagi, 5 g.) and Celite (5 g.). The eluate was concentrated *in vacuo*, and the residue was recrystallized from benzene, and then from MeOH. Slow crystallization from MeOH gave colorless plates, m.p. 105~106°(Crystal A). *Anal.* Calcd. for $C_{15}H_{14}O_4$: C, 69.75;

*6 The mass spectra were obtained with a Hitachi mass spectrometer, Model RMU 6D, *a*) equipped with direct inlet system (Compounds I and II: ion accel. voltage 1800 V; ionizing voltage 80 eV), and *b*) using an all-glass inlet system (Compounds I, VII, and VIII: ion accel. voltage 1800 V; ionizing voltage 70 eV).

*7 The melting points are uncorrected.

3) T.V. Van Auken, K.L. Rinehart Jr.: J. Am. Chem. Soc., 84, 3736 (1962).

H, 5.46. Found: C, 70.10; H, 5.31. IR ν_{max}^{Nujol} cm^{-1}: 1760, 1710, 1615, 1600, 1390, 1350, 1325, 1300, 1290, 1270, 1220, 1180, 1145, 1105, 1060, 990, 980, 910, 890, 875, 822, 730.

Quick evaporation of MeOH from the solution of catalpalactone on the boiling water bath gave crystals, m.p. 110~111°(Crystal B). *Anal.* Calcd. for $C_{15}H_{14}O_4$: C, 69.75; H, 5.46. Found: C, 69.60; H, 5.60. IR ν_{max}^{Nujol} cm^{-1}: 1765, 1700, 1615, 1600, 1380, 1345, 1305, 1290, 1220, 1180, 1135, 1105, 1060, 1000, 980, 945, 910, 860, 740.

The supersaturated solution of Crystal A was seeded with Crystal B to yield crystals which were identified with Crystal B by the melting points and the IR spectra (*vice versa*). Infrared spectra of Crystal A and Crystal B in $CHCl_3$ were identical: 1768, 1710, 1660, 1615, 1600 cm^{-1}.

b) From the wood of *Catalpa bignonioides*: Extraction of the finely ground wood (1.7 kg.) and the isolation of (I) were carried out in the identical way to those of *C. ovata*. Recrystallization from MeOH gave colorless crystals, m.p. 105~106° (2.3 g., 0.14%), which were identified with (I), extracted from the wood of *C. ovata*, by mixed fusion and IR spectra.

Potassium Permanganate Oxidation of Catalpalactone (I)——To a solution of (I) in 0.1*N* NaOH (100 ml.) was added potassium permanganate (4 g.) in portions during 3 hr. The excess of $KMnO_4$ was decomposed with MeOH, and the precipitate was filtered. The filtrate was neutralized with dil. HCl, and then was evaporated to yield a residue which was recrystallized from a mixture of ether and pet. ether to give needles, m.p. 196~197°. Yield: 0.4 g. *Anal.* Calcd. for $C_8H_6O_4$: C, 57.83; H, 3.64. Found: C, 57.69; H, 3.69. The product was identified with authentic phthalic acid by mixed fusion, and IR spectra.

Phthalic acid obtained above was sublimed to give crystals, m.p. 129~130°, which were identified with authentic phthalic anhydride. *Anal.* Calcd. for $C_8H_4O_3$: C, 64.87; H, 2.72. Found: C, 64.51; H, 2.94.

Catalytic Hydrogenation of Catalpalactone (I)——a) Dihydrocatalpalactone (II): A solution of catalpalactone (1 g.) in EtOH (50 ml.) was stirred in the hydrogen atmosphere over palladium-charcoal catalyst prepared from 5% $PdCl_2$ (2 ml.) and activated charcoal (Darco G-60, 750 mg.) for 2 hr. to absorb 220 ml. (*ca.* 2.5 mole) of hydrogen. Catalyst was filtered, and the filtrate was concentrated *in vacuo*. The residue was dissolved in ether, washed with 5% Na_2CO_3 (60 ml.), and the ether solution was dried over Na_2SO_4. Evaporation of ether gave crystalline residue which was recrystallized from EtOH to give colorless plates, m.p. 153~154°. Yield: 30 mg. *Anal.* Calcd. for $C_{15}H_{16}O_4$: C, 69.21; H, 6.20. Found: C, 69.28; H, 6.25. UV λ_{max}^{EtOH} mμ (log ε): 228 (4.00), 274 (3.22), 281 (3.22). IR $\nu_{max}^{CHCl_3}$ cm^{-1}: 1765, 1714, 1600. NMR (τ): 8.03~8.48 (m, 4H), 6.79~7.26 (m, 1H), 3.68 (d, J=3 c.p.s., 1H), 1.97~2.60 (m, 4H).

b) Tetrahydrocatalpalactonic acid (III) and methyl ester (VIII): The washing with 5% Na_2CO_3 in the above procedure was neutralized with HCl, and extracted with ether. The ether solution was dried over Na_2SO_4, and ether was distilled to give an oily residue (III). Yield: 0.6 g. The residue was treated with ethereal diazomethane, and the product was recrystallized from ether to give colorless plates, m.p. 86~87°. Yield: 0.4 g. UV λ_{max}^{EtOH} mμ (log ε): 231 (3.93), 280 (3.12). IR $\nu_{max}^{CHCl_3}$ cm^{-1}: 1710, 1600. NMR (τ): 8.16~8.43 (m, 4H), 6.70~7.42 (m, 2H), 6.22~6.35 (m, 1H). *Anal.* Calcd. for $C_{16}H_{20}O_4$: C, 69.54; H, 7.30. Found: C, 69.83; H, 7.07.

Hydrolysis of Catalpalactone (I)——a) Catalpalactone (1 g.) was dissolved in 3% solution of KOH in EtOH (30 ml.), and the mixed solution was refluxed for 2 hr. The solvent was distilled *in vacuo*, the residue was dissolved in a small amount of water, and the solution was acidified to give a crystalline precipitate. Recrystallization from either benzene or ether gave colorless plates of catalpalactonic acid (IV), m.p. 138~139°. Yield: 0.8 g. *Anal.* Calcd. for $C_{15}H_{14}O_4$: C, 69.75; H, 5.46. Found: C, 70.17; H, 5.48. UV λ_{max}^{EtOH} mμ (log ε): 302 (4.11). Analogous treatment of (I) with 3% aqueous solution of KOH gave an identical product.

b) Catalpalactone (I) (1 g.) in a solution of $Ba(OH)_2$ (2.7 g.) was warmed on a boiling water bath for 2 hr. After cooling, the resulting solution was washed with $CHCl_3$ to remove catalpalactone, concentrated *in vacuo*, and the remaining water in the residue was removed by lyophilization to give white solid barium salt. IR ν_{max}^{KBr} cm^{-1}: 1545, 1400.

The barium salt was dissolved in water, and 5% HCl was added to make the solution slightly acidic. Crystalline precipitate was filtered, and was recrystallized from ether to give colorless crystals, m.p. 138~139°, which were identified with catalpalactonic acid (IV) by mixed melting point and IR spectra. Yield: 0.7 g. The aqueous mother liquor was extracted with AcOEt, the AcOEt layer was dried over Na_2SO_4, and the solvent was distilled. The residue was chromatographed on a column of silicic acid (Mallinckrodt, 100 Mesh, 40 g.) using $CHCl_3$ as eluant. The eluate was concentrated, and was treated with activated charcoal, and then the solvent was distilled to give a crystalline residue which was recrystallized from MeOH to give colorless plates, m.p. 105~106°. Yield: 50 mg. The product was identified with catalpalactone by mixed melting point and thin-layer chromatography.

Methylation of Catalpalactonic Acid (IV)——a) An ethereal solution of diazomethane was added to a solution of catalpalactonic acid (IV) (0.8 g.) in ether. Three minutes later, the excess of diazomethane was destroyed by adding HOAc, and the solvent was distilled. The residue was recrystallized to give colorless plates of the methyl catalpalactonate (VII), m.p. 100.5~101°. Yield: 0.5 g. *Anal.* Calcd. for $C_{16}H_{16}O_4$: C, 70.57; H, 5.92. Found: C, 70.68; H, 5.92. IR $\nu_{max}^{CHCl_3}$ cm^{-1}: 1715, 1658, 1598.

b) An excess of ethereal solution of diazomethane was added to a solution of (IV) (1 g.) in ether, and the mixture was left to stand overnight. The solvent was distilled and the residue was recrystallized from

ether to give colorless plates of (IX), m.p. 121～122°. Yield: 0.7 g. *Anal.* Calcd. for $C_{17}H_{18}O_4$: C, 71.31; H, 6.34. Found: C, 71.33; H, 6.35. IR $\nu_{max}^{CHCl_3}$ cm^{-1}: 1705, 1650, 1590. Analogous overnight treatment of methyl catalpalactonate (VIII) with the ethereal solution of diazomethane yielded the product which was identified with (IX) by mixed melting point and IR spectra.

Hydrogenation of Methyl Catalpalactonate (VII)——The ester (VIII) (900 mg.) was hydrogenated in EtOH (100 ml.) over palladium-charcoal catalyst prepared from 5% $PdCl_2$ (1.5 ml.) and activated charcoal (Darco G-60, 700 mg.) for 1 hr. to absorb two-mole equivalent of hydrogen. Catalyst was filtered, solvent was distilled *in vacuo*, and the residue was recrystallized from ether to give colorless plates, m.p. 85～86°, which were identified with the methyl ester of tetrahydrocatalpalactonic acid by mixed melting point and IR spectra. Yield: 500 mg.

Ozonolysis of Catalpalactone (I)——Ozonized O_2 was passed through the solution of catalpalactone (1 g.) in $CHCl_3$ (60 ml.) at −50～−55° for 2 hr. Water (20 ml.) was added after the solution had been left to stand to reach the room temperature. After standing overnight, the solution was steam distilled, the distillate was extracted with $CHCl_3$, and the $CHCl_3$ solution was dried over Na_2SO_4. The residual solution of the steam distillation was made slightly alkaline with Na_2CO_3, and was extracted with AcOEt to recover (I). The aqueous solution was then acidified with HCl, and was extracted with AcOEt. The AcOEt solution was dried over Na_2SO_4.

a) β,β-Dimethylacrolein: The $CHCl_3$ solution of the steam-distillate was evaporated to give an oily residue (200 mg.) which was dissolved in warm EtOH, and a solution of 2,4-dinitrophenylhydrazine in aqueous EtOH containing H_2SO_4 was added. The mixture was warmed, and after cooling, red precipitate was filtered. This was chromatographed on a column of silicic acid (25 g.) using $CHCl_3$ as eluant. A further purification by recrystallization from aqueous MeOH gave red needles, m.p. 181.5～182° (decomp.). Yield: 240 mg. *Anal.* Calcd. for $C_{11}H_{12}O_4N_4$: C, 50.00; H, 4.58; N, 21.20. Found: C, 50.36; H, 4.75; N, 21.06. The product was identified with 2,4-dinitrophenylhydrazone of synthetic β,β-dimethylacrolein by mixed fusion and IR spectra.

b) Phthalide-3-carboxylic acid (VI): The dried AcOEt solution from the acidified residual solution of the steam distillation was distilled to give a residue (0.5 g.) which was chromatographed on a column of silicic acid (40 g.) eluting with $CHCl_3$, and then with a mixture of $CHCl_3$ and MeOH (95:5). Crystalline residue obtained from the mixed solvents was recrystallized from a mixture of AcOEt and $CHCl_3$ to give colorless plates, m.p. 149～150°, which were identified with the synthetic phthalide-3-carboxylic acid by mixed melting point and IR spectra. Yield: 0.2 g. *Anal.* Calcd. for $C_9H_6O_4$: C, 60.68; H, 3.40. Found: C, 60.42; H, H, 3.23.

Phthalide-3-carboxylic acid (50 mg.) obtained above was treated with ethereal solution of diazomethane for 30 min., and the product was purified by passing it through a column of silicic acid (8 g.) using a mixture of $CHCl_3$ and MeOH (98:2) as eluant. Recrystallization from a mixture of ether and pet. ether gave needles, m.p. 49～50°, which were identified by mixed melting point and IR spectra with authentic methyl phthalide-3-carboxylate. *Anal.* Calcd. for $C_{10}H_8O_4$: C, 62.50; H, 4.20. Found: C, 62.20; H, 4.46.

Phthalide-3-carboxylic acid (50 mg.) obtained above was heated at 180～190° in a sealed tube to complete bubbling. After cooling, crystalline residue was sublimed *in vacuo* in a bath heated to 100～120°. The sublimate was recrystallized to give crystals, m.p. 71～72°, which were identified with authentic phthalide by mixed fusion and IR spectra. Yield: 15 mg. *Anal.* Calcd. for $C_8H_6O_2$: C, 71.63; H, 4.51. Found: C, 71.66; H, 4.56.

Pyrazoline Derivative of Catalpalactone (X)——To a solution of (I) (500 mg.) in ether an excess of ethereal solution of diazomethane was added. Colorless crystals started to precipitate 3 hr. later. After standing overnight, crystals were filtered and recrystallized from MeOH to give needles, m.p. 163° (decomp.). Yield: 150 mg. *Anal.* Calcd. for $C_{16}H_{16}O_4N_2$: C, 63.99; H, 5.37; N, 9.33. Found: C, 64.13; H, 5.60; N, 9.53. UV λ_{max}^{EtOH} mμ (log ε): 228 (4.01), 275 (3.18), 282 (3.19), 324 (2.26). IR ν_{max}^{KBr} cm^{-1}: 1772, 1705, 1592, 1560. NMR (τ): 9.35 (s, 3H), 8.71 (s, 3H), 7.9～8.5 (m, 3H), 5.16～5.33 (m, 2H), 3.62 (s, 1H).

11-Methylcatalpalactone (XI)——The pyrazoline derivative (X) (100 mg.) was heated in a bath of 170° to complete bubbling. The residue was recrystallized from MeOH to give colorless plates, m.p. 204～205°. Yield: 60 mg. *Anal.* Calcd. for $C_{16}H_{16}O_4$: C, 70.57; H, 5.92. Found: C, 70.80; H, 6.02. UV λ_{max}^{EtOH} mμ (log ε): 227.5 (4.26), 275 (3.25), 282 (3.23). IR ν_{max}^{Nujol} cm^{-1}: 1760, 1693, 1645, 1610. NMR (τ): 8.18 (broad singlet, 3H), 7.53 (s, 2H), 3.39 (broad singlet, 1H).

Ozonolysis of 11-Methylcatalpalactone (XI)——Ozonized O_2 was passed through a solution of 11-methylcatalpalactone (2 g.) in $CHCl_3$ (50 ml.) at −50～−55° for 3 hr. Water (20 ml.) was added after the solution was left to stand to reach the room temperature, and the mixture was left to stand overnight, and then steam distilled.

a) Phthalide-3-carboxylic acid: The residual solution of the steam distillation was made slightly alkaline with Na_2CO_3, and was extracted with AcOEt. The AcOEt solution was dried over Na_2SO_4, the solvent was distilled, and the residue was recrystallized from MeOH to give crystals which were identified with the starting material. The aqueous layer was made weakly acidic with 5% HCl, extracted with AcOEt, and

the organic layer was dried over Na_2SO_4. The solvent was evaporated to give a residue which was recrystallized to give colorless plates, m.p. 146~148°. Yield: 150 mg. The product was identified with phthalide-3-carboxylic acid by mixed fusion and IR comparison. *Anal.* Calcd. for $C_9H_6O_4$: C, 60.68; H, 3.40. Found: C, 60.80; H, 3.62.

b) Mesityl oxide: The distillate of the steam distillation was extracted with $CHCl_3$, and the $CHCl_3$ solution was dried over Na_2SO_4. Evaporation of the solvent yielded an oily residue which was dissolved in warm EtOH, and a solution of 2,4-dinitrophenylhydrazine in aqueous EtOH containing H_2SO_4 was added. The mixture was warmed, and red precipitate was filtered after cooling. This was chromatographed on a column of silicic acid (30 g.) eluting with $CHCl_3$. A further purification by recrystallization from $CHCl_3$ yielded red crystals, m.p. 197~198° (decomp.), which were identified with 2,4-dinitrophenylhydrazone of synthetic mesityl oxide by mixed melting point and IR spectra. *Anal.* Calcd. for $C_{12}H_{14}O_4N_4$: C, 51.79; H, 5.07; N, 20.14. Found: C, 51.79; H, 5.09; N, 20.44.

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