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75. **Hiroshi Watanabe**: Studies on Azulenes. VIII.[1] Troponoids from Azulenogens: Oxidation of Hydroazulenones with Selenium Dioxide.

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In the previous paper of this series, a result of oxidation of some hydroazulenes with selenium dioxide was reported. Thus Δ^9-octahydroazulene (I) gave 1-oxo-Δ^9-octahydroazulene (III) and $\Delta^{4,9}$-hexahydroazulene (II) gave 4,5-cyclopentatropone (V) via 6-oxo-$\Delta^{4,9}$-hexahydroazulene (IV).

In the main course of the reaction of (II), selenium dioxide oxidized the most active methylene group at C-6 of cyclopentacycloheptane ring, giving a tropone derivative as the final product. However, tropolone derivative, which was anticipated if the intermediate compound (IV) was oxidized at its methylene group at C-7, was not obtained.

Several works on the selenium dioxide oxidation of cycloheptenones having a carbonyl group conjugated with double bonds have been reported. Cook and Somerville,[2] Treibs and Meyer,[3] and Campbell and Slater[4] reported to have obtained *o*-diketones, (VI′), (VII′), and (VIII′), by selenium dioxide oxidation of (VI), (VII), and (VIII), respectively. Further, the tropolone derivatives, (VII″) and (VIII″), were also prepared by further oxidation of (VII′) and (VIII′) with the same reagent. However, in these cases the original cycloheptenones commonly involved double bonds contained in aromatic (benzene or furan) systems.

In the present series of experiments selenium dioxide oxidation was applied on several types of hydroazulenones and some different types of reactions were seen to occur depending on the structure of starting materials.

(IX) was oxidized with selenium dioxide in several kinds of solvents under various conditions and resulted in resinous materials with poor yield of the desired products. However, when hot ethanolic solution of (IX) was added dropwise into equimolar amount of selenium dioxide in ethanol, a gentle reaction occurred. After distillation of the reaction mixture, the distillate was taken up in ether and the neutral portion was separated by shaking the ethereal solution with 1% sodium carbonate. The neutral product, on purification by repeated distillation, gave a pale orange oil (X), b.p$_{0.01}$ 100~102°, $C_{10}H_{12}O_2$, in 47% yield. A pyridine solution of this product (X), when added with hydroxylamine hydrochloride, gave a water-soluble dioxime, which furnished a nickel complex salt (XIV) $C_{10}H_{13}O_2N_2 \cdot Ni_{1/2}$,[5] as pinkish orange fine crystals. This complex showed similar absorption maxima(λ_{max} 258 and 405 mμ) in ultraviolet range with those of nickel dimethylglyoxime (λ_{max} 258 and 402 mμ). Thus the product is an *o*-diketone.

The acidic portion of the product which was soluble in carbonate solution gave crystals and, after successive recrystallization from benzene and ligroine, orange yellow, small pillared crystals (XI), m.p. 168~169°, $C_{10}H_{10}O_2$, were obtained in 2.2% yield. The product (XI) was inert to carbonyl reagents, but colored green with ferric chloride in ethanol and furnished a complex salt with cupric ion, $C_{10}H_9O_2 \cdot Cu_{1/2}$, showing the typical properties of tropolonoids.

The occurrence of these products from this reaction can be so interpreted that, in

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[1] This paper constitutes part of a series entitled "Studies on Azulenes" by T. Ukita. Part VII. H. Watanabe: This Bulletin, **5**, 426(1957).

[2] J.W. Cook, A.R. Somerville: Nature, **163**, 410(1949).

[3] W. Treibs, W. Meyer: Ber., **87**, 1197(1954).

[4] A.D. Campbell, S.N. Slater: J. Chem. Soc., **1952**, 4353.

[5] M. Ishidate: Microchim. Acta, **3**, 283(1938).

the first stage of oxidation, the *o*-diketone was produced by the oxidation of methylene adjacent to the carbonyl group and a tropolone compound (XI) resulted by subsequent dehydrogenation. Thus, this type of reaction was shown generally to occur when a seven-membered ring contained an α,β-unsaturated carbonyl group independent of the double bond, whether it is involved in an aromatic system or not.

The same oxidation reaction was porformed on the cyclopentacycloheptane-type compounds containing a dienone system.

Recently, Tamelen and Hildahl[6] reported that the oxidation of cyclohepta-2,4-dienone (XVIII) with the same reagent gave tropone (XIX) instead of tropolone (XX) even under several controlled reaction conditions.

A similar result was encountered by the author, as reported in the previous paper of this series, that selenium dioxide oxidized $\Delta^{4,9}$-hexahydroazulene (II) to a tropone compound (V) via a dienone (IV) without a trace of tropolonoid product.

Some years ago, Ukita[7] reported a keto-diene derivative of cyclopentacycloheptane which was derived from kessoglycol monoacetate (XV) after its oxidation with chromium trioxide and treatment of its intermediate, acetyl ketone (XVI), with 3% sodium hydroxide solution. At that time, a structure of (XIIa) was proposed for the keto-diene, which contains an $\alpha,\beta:\gamma,\delta$-unsaturated ketone, from its maximum absorption spectra in the ultraviolet range. However, for the dienone, an alternative structure (XIIb) will also be possible. When the ultraviolet absorption spectrum of this compound is examined by the generallized rule deduced by Woodward and Fieser on the relationship between chemical structure and ultraviolet absorption spectra of keto-dienes, a more reasonable structure of the keto-diene derived from kessoglycol derivative would be represented by (XIIa) instead of (XIIb), as originally proposed by Ukita.

From the oxidation products of (XIIa) with selenium dioxide in dioxane, an acidic oily product with $b.p._{0.2}$ 135~145° was obtained. On setting aside the oil, a fair amount of crystals separated out. After successive recrystallization from 50% ethanol and ligroine the pure product (XIII), which melted at 157~158° and showed a molecular formula $C_{12}H_{14}O_2$, was obtained in 5.2% yield of the theoretical. (XIII) showed characteristic properties of tropolonoid, coloring green with ferric chloride in ethanolic solution, gave no condensation product with several carbonyl reagents, and showed ultraviolet absorption maxima specific for tropolone derivative (Fig. 1).

No troponoid compound was detected in the neutral fraction separated from the

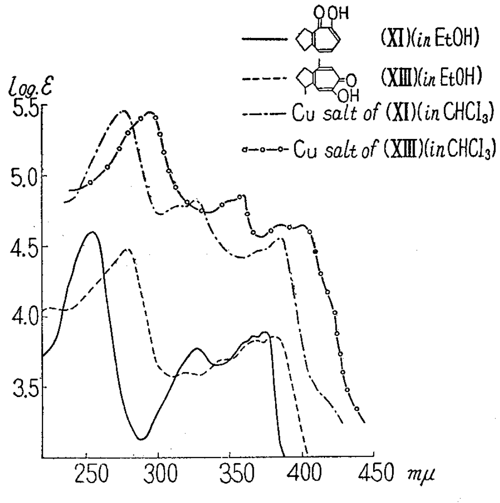

Fig. 1.
Ultraviolet Absorption Spectra

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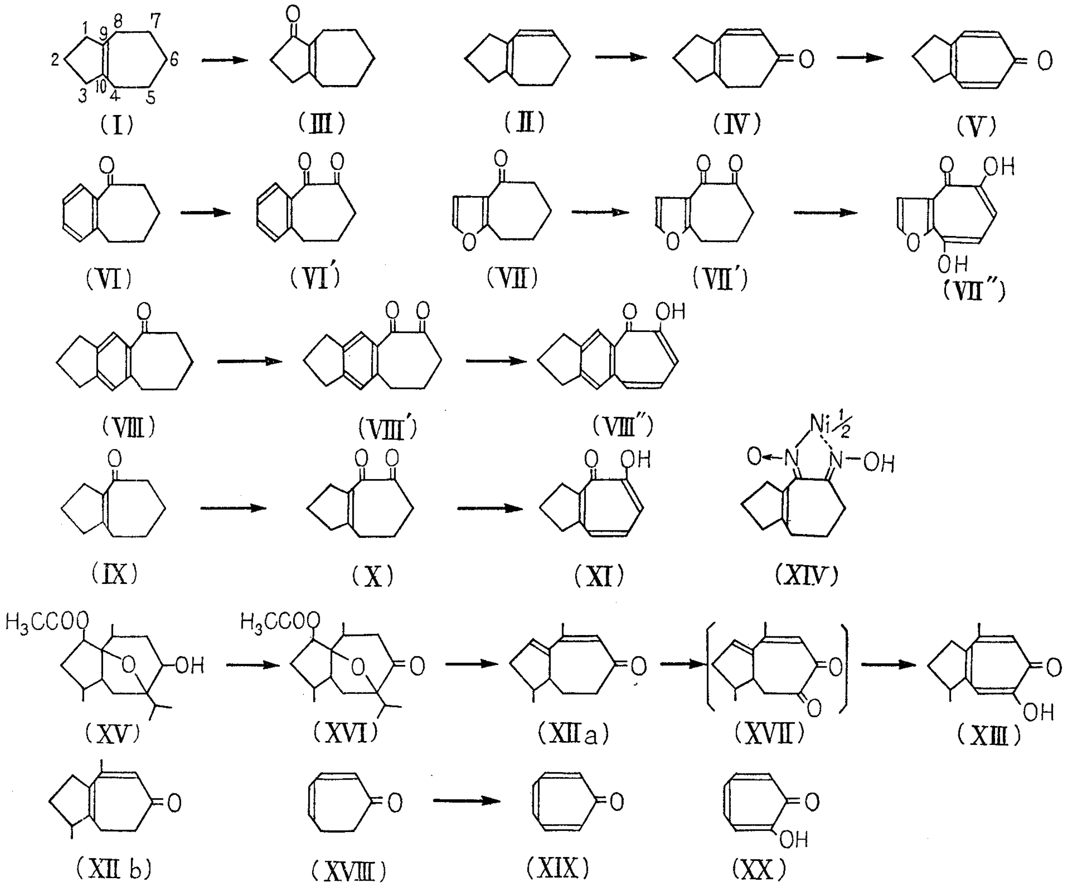
6) E. E. Tamelen, G. T. Hildahl: J. Am. Chem. Soc., **78**, 4405(1956).
7) T. Ukita: J. Pharm. Soc. Japan, **64**, 285(1944).



oxidation mixture.

Differing from the mode of action of the oxidation of (II) to tropone derivative (V), via (IV), as reported in the previous paper, (XIIa) was oxidized under the same condition to tropolone derivative (XIII) which should be produced via the intermediate *o*-diketo-diene represented by the structure (XVII).

The results of these reactions show that the seven-membered ring compounds which have conjugated, unsaturated carbonyl group are oxidized by selenium dioxide in a different way depending upon the type of distribution of the unsaturated carbonyl system in the structure. When the carbonyl group has only a conjugated double bond, the oxidation occurs in the first step, at the methylene group adjacent to the carbonyl group, giving an unsaturated *o*-diketone and subsequent dehydrogenation derives the latter to the tropolone derivative (type A reaction). On the other hand, in seven-membered ring compounds having an $\alpha,\beta:\gamma,\delta$-dienone, when the two double bonds are arranged homoannular, the oxidation proceeds to give a tropone derivative by direct dehydrogenation reaction instead of giving *o*-diketone. Thus, in the case of the reaction of (XIIa) to (XIII), in which the double bond at γ,δ-position in the keto-diene system is exocyclic, the oxidation should occur similarly as in the case of type A reaction to give *o*-diketone (presumably represented by (XVII)) and subsequent migration of exocyclic double bond into the seven-membered ring results in a tropolone derivative.

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Experimental

Oxidation of 4-Oxo-Δ^9-octahydroazulene (IX) with SeO_2—To a boiling solution of 5.5 g. of freshly distilled (I) (b.p$_{15}$ 126~128°) in 20 cc. EtOH, 4.1 g. of SeO_2 in 60 cc. EtOH was added dropwise during 5 hrs. and boiling was continued for additional 2 hrs. After filtration of precipitated Se and evaporation of the solvent, the residue was dissolved in ether to remove insoluble pitch. After removal of the solvent, the residual oil was distilled (b.p$_{0.2}$ 120~145°). An ether solution of the orange-red distillate was centrifuged to separate Se still present. The ether solution was shaken 5 times with 1% Na_2CO_3 solution to liberate acidic compound. After washing Na_2CO_3 solution with ether, it was neutralized with H_2SO_4 to separate a precipitate which was recrystallized from benzene and then from ligroine. It gave 0.13 g. of orange-yellow, small pillared crystals (XI), m.p. 168~169°; yield, 2.2%. EtOH solution of (XI) colored green with $FeCl_3$. *Anal.* Calcd. for $C_{10}H_{10}O_2$: C, 74.10; H, 6.17. Found : C, 73.98; H, 6.09. U.V. λ_{max}^{EtOH} mμ (log ε) : 255(4.60), 328(3.78), 375(3.89).

Copper complex salt : A $CHCl_3$ solution of (XI) was shaken with a satd. aq. solution of $Cu(AcO)_2$ and the solvent was removed by evaporation. Recrystallization of the residual crystals from ligroine yielded green-yellow crystals of copper complex of (XI). It did not melt under 260°. U.V. $\lambda_{max}^{CHCl_3}$ mμ (log ε) : 278(5.45), 328(4.83), 335(4.55). *Anal.* Calcd. for $C_{10}H_9O_2Cu_{1/2}$: C, 62.24; H, 4.69; Cu, 16.46. Found : C, 61.98; H, 4.57; Cu, 16.08. I.R. ν_{max}^{Nujol} : 1597 cm^{-1} (C=O for Cu-salt of tropolone).

The ether solution of neutral product, which did not transfer to 1% Na_2CO_3 solution on above treatment, was dried and ether was removed. Repeated distillation of the residue gave 2.80 g. of pale orange, oily diketo-ene (X), b.p$_{0.01}$ 100~102°; yield, 47%. *Anal.* Calcd. for $C_{10}H_{12}O_2$: C, 73.17; H, 7.32. Found : C, 73.37; H, 7.51. I.R. ν_{max}^{Capil} : 1680, 1694 cm^{-1} (C=O of *o*-diketo-ene).

To a solution of 100 mg. of (X) dissolved in 5 cc. of EtOH, 2 cc. of aq. solution of 90 mg. $NH_2OH \cdot HCl$ and 2 cc. of pyridine were added. The mixture was boiled on a water bath for 4 hrs. After the reaction was completed, the cooled reaction mixture was added with 20 cc. of water, filtered once, and the filtrate was added with 5% aq. solution of $Ni(AcO)_2$. The separated crystalline precipitate was the dioxime nickel complex salt (XIV). *Anal.* Calcd. for $C_{10}H_{13}O_2N_2Ni_{1/2}$: C, 54.00; H, 5.84; N, 12.59; Ni, 13.17. Found : C, 53.78; H, 5.86; N, 12.32; Ni, 13.41. U.V. λ_{max}^{EtOH} mμ (log ε): 258(4.05), 402(3.45).

Oxidation of 1,4-Dimethyl-6-oxo-$\Delta^{3,4}$-hexahydroazulene (XIIa) with SeO_2—To a solution of 3.90 g. of keto-diene (XIIa) dissolved in 30 cc. of dioxane, a solution of 2.50 g. of SeO_2 in a small amount of water and 10 cc. of dioxane was added slowly and the reaction mixture was kept at room temperature for 1 week. Then the reaction mixture was warmed on a water bath for 2 hrs. After cool, Se that separated out was removed by filtration and dioxane was removed from the filtrate by evaporation *in vacuo*. The residue was added with ether and the insoluble dark brown pitch and Se were removed by centrifugation. The clear ethereal solution obtained was repeatedly shaken with 3% Na_2CO_3 solution. The alkaline solution was neutralized with dil. H_2SO_4 and the acidic oily product was taken up in ether. After drying, ether was evaporated and the residue was distilled to give 0.85 g. of an oil, b.p$_{0.2}$ 135~145°. On keeping in an ice box, a fair amount of crystals separated out from the oil. The crystals were recrystallized successively from 5% EtOH and ligroine to give 0.32 g. of orange yellow needles (XIII), m.p. 157~158°; yield, 5.2%. *Anal.* Calcd. for $C_{12}H_{14}O_2$: C, 75.79; H, 7.37. Found : C, 75.52, 75.94; H, 7.48, 7.31. U.V. λ_{max}^{EtOH} mμ (log ε) : 225(4.08), 291(4.48), 368(3.83), 382(3.86).

Copper complex salt of (XIII) : Greenish yellow crystals (from ligroine), m.p. >260°. U.V. $\lambda_{max}^{CHCl_3}$ mμ (log ε) : 296(5.45), 350(4.86), 405(4.65). I.R. ν_{max}^{Nujol} 1598 cm^{-1} (C=O for Cu-salt of tropolone). *Anal.* Calcd. for $C_{12}H_{13}O_2Cu_{1/2}$: C, 65.22; H, 5.89; Cu, 14.40. Found : C, 65.10; H, 5.72; Cu, 14.67.

On distillation of the neutral portion separated from acidic product (XIII), 0.55 g. of oil, b.p$_{0.2}$ 110~130°, and 0.6 g. of resinous residue were obtained, which were not characterized.

Summary

Selenium dioxide oxidation of hydroazulenones furnished tropolone derivatives. Thus, 3,4-cyclopentatropolone was obtained from 4-oxo-Δ^9-octahydroazulene via 4,5-dioxo-Δ^9-octahydroazulene, and further, 6-methyl-4,5-(1-methylcyclopenta)tropolone was obtained from 1,4-dimethyl-6-oxo-$\Delta^{3,4}$-hexahydroazulene.

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