The Reaction of Tropoids and Quinone Derivatives. II. Reaction of Several Tropolones and p-Benzoquinone

By Shuichi SETO and Humio SATO

(Received June 13, 1961)

Preceding paper of this series[1] reported the reaction of several kinds of tropolones and *p*-benzoquinone dibenzenesulfonimide. The use of *p*-benzoquinone in place of *p*-benzoquinone dibenzenesulfonimide results in rather complicated reactions but under certain reaction conditions, products having a tropolone ring were found to be formed. The present paper reports on the structure of products obtained by the reaction of tropolone and its bromo derivatives with *p*-benzoquinone.

A solution of tropolone and *p*-benzoquinone dissolved in methanol containing a small amount of acetic acid afforded at room temperature, orange crystals (A) and colorless crystals (B). Analytical values of B corresponded to the molecular formula of $C_{13}H_{10}O_4$ and, from its coloration to ferric chloride and ultraviolet absorption spectrum, it was found to retain the tropolone ring. Methylation of B with diazomethane afforded a monomethyl ether (C) and dimethyl ether (D). Hydrolysis of C reverted it to B, but that of D afforded a monomethyl ether (E) different from C. C and D do not show the characteristic coloration to ferric chloride but E does so. Methylation of B with dimethyl sulfate, in the presence of potassium hydroxide afforded monomethyl ether (E), whose further methylation with diazomethane gave D. These facts show that B possesses two hydroxyl groups, one of which is phenolic and the other is the hydroxyl in the tropolone ring. In order to determine the structure of B, the tropolone ring was made to undergo rearrangement to form a benzoic acid derivative. D was led to the 2-bromotropone derivative through the hydrazino derivative[2] and treated with alkali to form a benzoic acid derivative which showed no depression of the melting point on admixture with 4-(4′-methoxyphenoxy)benzoic acid (VII)[3] and ultraviolet absorption spectra of these two substances were in good agreement. Consequently, the foregoing 2-bromotropone and hydrazino derivatives would respectively be 2-bromo-5-(4′-methoxyphenoxy) tropone (VI) and 2-hydrazino-5-(4′-methoxyphenoxy)tropone (V). The methyl ethers, C, D and E would then be 2-methoxy-5-(4′-hydroxyphenoxy)tropone (II), and 2-methoxy-5-(4′-methoxyphenoxy)-tropone (III), and 5-(4′-methoxyphenoxy)-tropolone (IV). It has therefore been proved that B is 5-(4′-hydroxyphenoxy)tropolone (I).

The analytical values of the orange crystals (A) agreed with the formula of $C_{13}H_8O_4$ and this substance was also found to retain the tropolone ring from its coloration to ferric chloride and ultraviolet absorption spectrum. Its infrared spectrum exhibited absorption of $\nu_{C=O}$ of *p*-benzoquinone at 1657 and 1651 cm^{-1}. These facts suggest that A is a compound formed by carbon-carbon bonding of tropolone and *p*-benzoquinone. As for the position of its bonding, there is only one possible position in *p*-benzoquinone but three positions, 3, 4 and 5, are possible in the tropolone ring. It was proved, by the experiments to be iterated below, that the bonding position in the tropolone ring is at 3 and that A is 3-(*p*-benzoquinonyl)tropolone (VIII).

Catalytic reduction of A over palladium-carbon or treatment with sodium dithionite affords a dihydroxyphenyltropolone (IX), whose methylation with dimethyl sulfate gives dimethoxyphenyltropolone (X). X forms two kinds of 2-methoxytropone derivative (XI and XII) by treatment with diazomethane which indicates that the aryl group is bonded to a position other than 5 in the tropolone ring. Similar to the foregoing case, 2-methoxytropone (XI) was led to 2-chlorotropone (XIV) via 2-hydrazinotropone (XIII) and alkali treatment of XIV gave a benzoic acid derivative (F). F was identified with 2-(2′, 5′-dimethoxyphenyl)-benzoic acid (XV), synthesized by the following route, by mixed fusion and comparison of infrared and ultraviolet absorption spectra.

In accordance with the preparation of 4-(2′,-5′-dihydroxyphenyl)acetophenone from 4-aminoacetophenone and *p*-benzoquinone[4], the diazonium salt obtained from methyl anthranilate was reacted with *p*-benzoquinone, in the

---

[1] S. Seto, H. Yamazaki and Y. Nishiyama, This Bulletin, 33, 1081 (1960).

[2] S. Seto, *Sci Repts. Tohoku Univ., First Ser.*, 37, 292 (1953).

[3] C. R. Harrington, *Biochem. J.*, 20, 300 (1926).

[4] G. A. Reynolds and J. A. VanAllen, "Organic Syntheses", 34, 1 (1954).

presence of sodium hydrogencarbonate and reduction of its product with sodium dithionite afforded colorless crystals (G), whose analytical values corresponded to the formula of $C_{13}H_8O_3$ and which formed phthalic acid by oxidation with potassium permanganate. Methylation of G with dimethyl sulfate in the presence of potassium carbonate gave a monomethyl ether. Therefore G would be 2-hydroxybenzo[c]coumarin (XVI) and its monomethyl ether, 2-methoxybenzo[c]coumarin (XVII). Methylation of XVI with dimethyl sulfate with heating in the presence of potassium hydroxide, resulted in opening of the lactone ring to form 2-(2′, 5′-dimethoxyphenyl)benzoic acid (XV).

Since the structure of F is 2-(2′, 5′-dimethoxyphenyl)benzoic acid, the structure of A would be 3-(*p*-benzoquinonyl)tropolone (VIII).

The reduction product of A, 3-(2′, 5′-dihydroxyphenyl)tropolone (IX), easily undergoes dehydration when warmed with *p*-toluenesulfonic acid and changes into 2-hydroxybenzofuro[2, 3-b]tropone (XVIII). This reaction also supports the above structure. Methylation of XVIII with dimethyl sulfate in the presence of potassium carbonate, affords 2-methoxybenzofuro[2, 3-b]tropone (XIX).

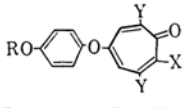
3-Bromotropolone also undergoes reaction with *p*-benzoquinone to form *p*-benzoquinonyl-3-bromotropolone (XX) whose catalytic reduction over palladium-carbon or treatment with sodium dithionite affords a dihydroxyphenyl derivative (XXI). Hydrogenolysis of XXI in ethanol containing diethanolamine, with palladium-carbon catalyst, gives 3-(2′, 5′-dihydroxyphenyl)tropolone (IX). Consequently, XX is proved to be 3-bromo-7-(*p*-benzoquinonyl)tropolone.

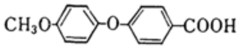
Methylation of XXI with dimethyl sulfate in acetone, in the presence of potassium carbonate, results in rearrangement of the tropolone ring to benzoic acid and 2-methoxy-7-bromobenzo[c]coumarin (XXIV) is obtained. Treatment of XXI with *p*-toluensulfonic acid affords 2-hydroxy-7-bromobenzofuro[2, 3-b]tropone (XXII) and its methylation as above produces 2-mehoxy-7-bromobenzofuro[2, 3-b]tropone (XXIII) and dimethyl ether (XXV) of 3-bromo-7-(2′, 5′-dihydroxyphenyl)tropolone (XXI) without such a rearrangement.

The ultraviolet absorption spectra of benzocoumarin derivatives and benzofuro-tropone derivatives are similar in the wavelength of absorption maxima but there is a distinct difference in the infrared spectra of these two series. The infrared spectra of benzocoumarin derivatives show strong absorptions in the range of 1690∼1720 cm^{-1} (at 1696 cm^{-1} in XVI, at 1709 cm^{-1} in XVII, and at 1721 cm^{-1} in XXIV) while that of benzofuro-tropone derivatives does not show any absorption in this region.

Reaction of 3, 7-dibromotropolone with *p*-benzoquinone first precipitated crystals of 3, 7-dibromotropolone and methylation of its mother liquor, without purification, with dimethyl sulfate in the presence of potassium hydroxide and fractional crystallization of the potassium salt of its product afforded 3, 7-dibromo-5,(4′-methoxyphenoxy)tropolone (XXVII). The structure of XXVII is clear from its analytical values and formation of 5-(4′-methoxyphenoxy)-tropolone (IV) by its hydrogenolysis. Consequently, the product obtained by the reaction of 3, 7-dibromotropolone and *p*-benzoquinone would be 3, 7-dibromo-5-(4′-hydroxyphenoxy)-tropolone (XXVI).

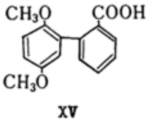
Reaction of *p*-benzoquinone and tropolones in the presence of a weak base affords a product corresponding to 1 : 1 molar compound of *p*-benzoquinone and tropolone. This compound does not show the properties of a tropolone



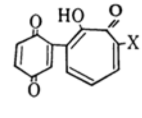


VII

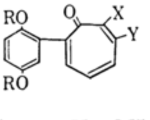
I : R=H, X=OH, Y=H
II : R=H, X=OCH$_3$, Y=H
III : R=CH$_3$, X=OCH$_3$, Y=H
IV : R=CH$_3$, X=OH, Y=H
V : R=CH$_3$, X=NHNH$_2$, Y=H
VI : R=CH$_3$, X=Br, Y=H
XXVI : R=H, X=OH, Y=Br
XXVII : R=CH$_3$, X=OH, Y=Br



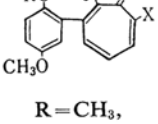
XV



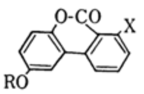
VIII : X=H
XX : X=Br



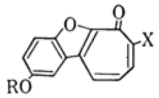
IX : R=H, X=OH, Y=H
X : R=CH$_3$, X=OH, Y=H
XI : R=CH$_3$, X=OCH$_3$, Y=H
XIII : R=CH$_3$, X=NHNH$_2$, Y=H
XIV : R=CH$_3$, X=Cl, Y=H
XXI : R=H, X=OH, Y=Br



XII : R=CH$_3$, X=H
XXV : R=H, X=Br



XVI : R=X=H
XVII : R=CH_3, X=H
XXIV : R=CH_3, X=Br



XVIII : R=X=H
XIX : R=CH_3, X=H
XXII : R=H, X=Br
XXIII : R=CH_3, X=Br

derivative. Examinations are now under way on its structure.

Experimental[5]

3-(*p*-Benzoquinonyl)tropolone (VIII) and 5-(4′-Hydroxyphenoxy)tropolone (I).—A solution of 5 g. of tropolone, 2.1 g. of *p*-benzoquinone, and 2 ml. of acetic acid dissolved in 10 ml. of methanol was allowed to stand in a room temperature. After several hours, orange crystals precipitated out. After standing for 4 days, the orange crystals (A) (1.58 g.), m. p. 160~165°C, were collected, washed with methanol, and recrystallized from ethyl acetate to 1.3 g. of 3-(*p*-benzoquinonyl)tropolone (VIII), m. p. 169~170°C.

Found : C, 68.24 ; H, 3.52. Calcd. for $C_{13}H_8O_4$: C, 68.42 ; H, 3.57%. λ_{max}^{MeOH} mμ (logε) : 242 (4.45), 328(3.87), 335(3.88), 361(3.66), 376(3.71).

The filtrate left after separation of A was allowed to stand and 0.52 g. of colorless crystals (B), m. p. 195~197°C, precipitated out. Recrystallization of B from methanol afforded 5-(4′-hydroxyphenoxy)-tropolone (I) as colorless crystals, m. p. 196~197°C.

Found : C, 67.82 ; H, 4.38. Calcd. for $C_{13}H_{10}O_4$: C, 67.91 ; H, 4.49%. λ_{max}^{MeOH} mμ (log ε) : 238 (4.54), 340 (4.24), 390 (3.91), 410 (3.83).

The filtrate left after separation of B was evaporated and sublimation of its residue at 80°C (bath temperature) at 2 mmHg, afforded 2.5 g. of recovered tropolone.

Reaction of I and Diazomethane.—Ether solution of diazomethane was added to 0.1 g. of I suspended in methanol and the mixture was allowed to stand over night. The crystals that precipitated out were collected and recrystallized from a mixture of benzene and acetone to give 2-methoxy-5-(4′-hydroxyphenoxy)tropone (II) as pale yellow prisms, m. p. 164~166°C. Yield, 60 mg.

Found : C, 68.82 ; H, 5.30. Calcd. for $C_{14}H_{12}O_4$: C, 68.84 ; H, 4.95%. λ_{max}^{MeOH} mμ (log ε) : 231 (4.48), 330 (4.10).

II did not show any coloration with ferric chloride.

The filtrate left after separation of II was evaporated to dryness, the residue was dissolved in benzene, and the solution was purified by passing through an alumina column. From its effluent, 2-methoxy-5-(4′-methoxyphenoxy)tropone (III) was obtained as pale yellow crystals, m. p. 89~91°C. Yield, 30 mg.

Found : C, 70.20 ; H, 5.21. Calcd. for $C_{15}H_{14}O_4$: C, 69.75 ; H, 5.46%. λ_{max}^{MeOH} mμ (log ε) : 234 (4.53), 330 (4.16).

III also did not undergo coloration with ferric chloride.

Hydrolysis of II.—A mixture of 10 mg. of II in 0.1 ml. of 2 N sodium hydroxide and 0.1 ml. of methanol was heated on a water bath for 1 hr., methanol was evaporated, and residual solution was acidified with dilute hydrochloric acid. The precipitate that formed was collected and sublimed at 200°C (bath temperature) at 1.5 mmHg, from which 5 mg. of colorless crystals, m. p. 192~193°C, was obtained. This showed no melting point depression on admixture with I.

Hydrolysis of III.—The same treatment as above of 20 mg. of III afforded 15 mg. of 5-(4′-methoxyphenoxy)tropolone (IV), m. p. 129~130°C.

Found : C, 68.62 ; H, 4.83. Calcd. for $C_{14}H_{12}O_4$: C, 68.84 ; H, 4.95%. λ_{max}^{MeOH} mμ (log ε) : 235 (4.50), 345(4.23), 390 (3.82).

Methylation of I with Dimethyl Sulfate.—A mixture of 0.2 g. of I, 0.6 g. of potassium hydroxide, and 5 ml. of water was heated on a water bath and 0.2 g. of dimethyl sulfate was added while stirring. After 30 min., the reaction mixture was cooled, acidified with dilute hydrochloric acid, and the precipitate thereby formed was collected. The prodct was sublimed at 200°C (bath temperature) and 1.5 mmHg, and the sublimate was recrystallized from benzene-petroleum ether mixture to give 150 mg. of colorless crystals, m. p. 128~129°C, undepressed on admixture with IV obtained by hydrolysis of III.

Reaction of IV and Diazomethane.—Ether solution of diazomethane was added to a solution of 0.1 g. of IV dissolved in 15 ml. of ether and the solution was allowed to stand over night. The solvent was evaporated and the residue was sublimed at 200°C (bath temperature) and 1.5 mmHg. The sublimate was recrystallized from ether to give 75 mg. of pale yellow crystals, m. p. 89~90°C, undepressed on admixture with III.

2-Hydrazino-5-(4′-methoxyphenoxy)tropone (V).—A mixture of 80 mg. of III and 30 mg. of hydrazine hydrate (80%) in 0.4 ml. of methanol was warmed on a water bath for 30 min., methanol was evaporated, and the residue was diluted with a small amount of water. The precipitate that formed was collected and recrystallized from methanol to 55 mg. of yellow crystals, m. p. 123~124°C.

Found : C, 64.92 ; H, 5.48 ; N, 11.19. Calcd. for $C_{14}H_{14}O_3N_2$: C, 65.10 ; H, 5.46 ; N, 10.85%. λ_{max}^{MeOH} mμ (log ε) : 231 (4.22), 250 (4.30), 348 (4.12), 424 (3.89).

2-Bromo-5-(4′-methoxyphenoxy)tropone (VI).—A solution of 0.5 g. of copper sulfate dissolved in 0.8 ml. of water with heating was maintained at 120°C and a mixture of 50 mg. of V and 0.5 ml. of concentrated hydrobromic acid was added to it while

---

[5] All melting points are not corrected. Microanalyses were carried out by Misses Yôko Endô and Yukiko Endô of this Institute. Measurements of ultraviolet and infrared spectra were made respectively by a Hitachi EPU-2A type spectrophotometer and by a Perkin-Elmer Model 21 infrared spectrophotometer in potassium bromide disk.

stirring. A vigorous evolution of nitrogen occurred and the liquid turned black. After maintaining the mixture at 120°C for 5 min., it was cooled, 5 ml. of water and 30 ml. of chloroform were added, and the whole was shaken thoroughly. The mixture was filtered, chloroform layer was separated from the filtrate, and dried over anhydrous sodium sulfate. The dried chloroform solution was purified by passage through an alumina column and the product obtained from its effluent was recrystallized from petroleum ether, affording 30 mg. of pale yellow crystals, m. p. 95~97°C.

Found: C, 55.15; H, 3.99. Calcd. for $C_{14}H_{11}O_3Br$: C, 54.72; H, 3.61%. λ_{max}^{MeOH} mμ (log ε): 225 (4.48), 247 (4.30), 341 (4.19).

Rearrangement Reaction of VI with Alkali.—A mixture of 10 mg. of VI in 0.5 ml. of dioxane and 0.5 ml. of 0.2 N sodium hydroxide was heated on a water bath for 1 hr., the solvent was evaporated in reduced pressure, and the residue was treated with activated carbon after dilution with 0.2 ml. of water. The pale yellow aqueous solution so obtained was acidified with dilute sulfuric acid and this was allowed to stand over night in an ice chamber. The crystals that separated out were collected and sublimed at 160°C (bath temperature) and 2 mmHg, affording 5 mg. of colorless crystals, m. p. 173~174°C, underpressed on admixture with 4-(4′-methoxyphenoxy)benzoic acid (VII), m. p. 176~176.5°C, prepared through a known process[3]. The ultraviolet absorption spectra of these two compounds were also in good agreement.

λ_{max}^{MeOH} mμ (log ε): 252 (4.22).

3-(2′, 5′-Dihydroxyphenyl)tropolone (IX).—a) A solution of 0.4 g. of sodium dithionite dissolved in 2 ml. of water was added while stirring into 0.2 g. of VIII, reduced to a powder in a mortar, suspended in 5 ml. of water and the mixture was warmed to 40°C. The color of the suspension changed from orange to yellow. After stirring for 10 min., the mixture was cooled, the precipitation was collected by filtration, and washed with water to 0.2 g. of a yellow substance, m. p. 285°C. Recrystallization from methanol afforded 0.18 g. of pale yellow microcrystals, m. p. 289~290°C.

Found: C, 67.29; H, 4.14. Calcd. for $C_{13}H_{10}O_4$: C, 67.82; H, 4.38%. λ_{max}^{MeOH} mμ (log ε): 227 (4.34), 330 (4.00), 375 (3.88)

b) A solution of 0.1 g. of VIII dissolved in 50 ml. of ethanol in the presence of 40 mg. of palladium-carbon was shaken in hydrogen atmosphere at room temperature. When the absorption of hydrogen ceased, the catalyst was filtered off and the filtrate was concentrated, affording 95 mg. of pale yellow crystals, m. p. 288~290°C, undepressed on admixture with the product obtained in a).

3-(2′, 5′-Dimethoxyphenyl)tropolone (X).—A solution of 0.6 g. of sodium hydroxide in 5 ml. of water was added to a mixture of 0.1 g. of IX and 0.5 g. of dimethyl sulfate while stirring. After stirring the mixture for 30 min. at room temperature and for 1 hr. on a water bath, the reaction mixture was cooled and shaken with 5 ml. of ether. The yellow crystals that separated out were collected, dissolved in 2 ml. of water, and the solution was acidified with dilute hydrochloric acid. The oil that separated solidified into crystals, when allowed to stand in an ice box. The crystals were collected, sublimed at 200°C (bath temperature) and 2 mmHg, and the sublimate was recrystallized from ether-petroleum ether mixture to 60 mg. of pale yellow needles, m. p. 82~84°C.

Found: C, 69.56; H, 5.16. Calcd. for $C_{15}H_{14}O_4$: C, 69.75; H, 5.46%. λ_{max}^{MeOH} mμ (log ε): 225 (4.41), 325 (3.96), 350 (3.86), 372 (3.84).

Reaction of X and Diazomethane.—Ether solution of diazomethane was added to 0.26 g. of X dissolved in 10 ml. of ether and the mixture was allowed to stand over night. The crystals that separated out were collected and recrystallized from acetone to 140 mg. of pale yellow needles, m. p. 145~146°C.

Found: C, 70.39; H, 5.73. Calcd. for $C_{16}H_{16}O_4$: C, 70.57; H, 5.92%. λ_{max}^{MeOH} mμ (log ε): 223 (4.26), 320 (3.83), 350(3.79).

The ether solution left after separation of foregoing crystals was evaporated to remove excess of diazomethane, passed through a column of alumina, and the column was eluted with ether. From the initial effluent, 70 mg. of colorless crystals, m. p. 116~117°C, was obtained and later fraction afforded 20 mg. of crystals, m. p. 145°C.

Crystals of m. p. 116~117°C.

Found: C, 70.24; H, 5.90. Calcd. for $C_{16}H_{16}O_4$: C, 70.57; H, 5.92%. λ_{max}^{MeOH} mμ (log ε): 223 (4.44), 325 (4.05).

Neither of these two kinds of crystals colored with ferric chloride. Assuming from their solubility, shape of their ultraviolet absorption spectra, and ease or difficulty of elution in chromatography, the structure of these products was assumed to be 2-methoxy-7-(2′, 5′-dimethoxyphenyl)tropone (XI) for the product of m. p. 145~146°C and 2-methoxy-3-(2′, 5′-dimethoxyphenyl) tropone (XII) for that of m. p. 116~117°C.

2-Hydrazino-7-(2′, 5′-dimethoxyphenyl)tropone (XIII).—A mixture of 70 mg. of methoxytropone (XI) of m. p. 145~146°C, 1 ml. of methanol, and 80 mg. of hydrazine hydrate (80%) was warmed on a water bath for 30 min., cooled, and crystals that separated out were collected. Recrystallization from methanol gave 55 mg. of yellow prisms, m. p. 194~195°C.

Found: C, 65.74; H, 5.50; N, 10.66. Calcd. for $C_{14}H_{16}O_3N_2$: C, 66.16; H, 5.92; N, 10.29%. λ_{max}^{MeOH} mμ (log ε): 223 (4.24), 252 (4.19), 345 (3.93), 412 (4.01).

2-Chloro-7-(2′, 5′-dimethoxyphenyl)tropone (XIV).—To a solution of 0.4 g. of crystalline copper sulfate in 1 ml. of water and maintained at 120°C, a mixture of 50 mg. of XIII in 0.5 ml. of concentrated hydrochloric acid was added while stirring, the mixture was cooled after 5 min., and 10 ml. of water and 20 ml. of chloroform were added. This mixture was shaken thoroughly, filtered, and the chloroform layer was separated from the filtrate. After drying over anhydrous sodium sulfate, the chloroform layer was passed through an alumina column and the solvent was evaporated from effluents. The crystalline residue was recrystallized from petroleum ether to 45 mg. of pale yellow prisms, m. p. 114~115°C.

Found: C, 65.25; H, 4.72. Calcd. for $C_{15}H_{13}O_3Cl$: C, 65.08; H, 4.74%. λ_{max}^{MeOH} mμ (log ε): 265 (3.92), 320 (3.95).

Rearrangement Reaction of XIV with Alkali.—A mixture of 40 mg. of XIV, 2 ml. of water, 0.2 g. of sodium hydroxide, and 1 ml. of ethanol was heated on a water bath for 2 hr., ethanol was evaporated, and the residual solution was extracted with ether to remove neutral substance. The aqueous layer was acidified with dilute hydrochloric acid, extracted with ether to collect an acid substance, and the ether extract was esterified by addithon of ether solution of diazomethane. The product therefrom was purified through an alumina column, the column was eluted with ether, and the initial eluate afforded 30 mg. of colorless oil.

A mixture of this oily product with 0.1 g. of sodium hydroxide, 5 ml. of water, and 2 ml. of methanol was refluxed on a water bath for 3 hr., methanol was evaporated, and the residue was treated with activated carbon. The solution so obtained was acidified with dilute hydrochloric acid and the crystals that separated out were recrystallized from 50% methanol to 15 mg. of colorless needles, m. p. 152~153°C, undepressed on admixture with 2-(2′, 5′-dimethoxyphenyl)benzoic acid (XV) prepared in a different way. Infrared spectra of these two were in good agreement.

2-Hydroxybenzo[c]coumarin (**XVI**).—A solution of 1.38 g. of sodium nitrite in 6.6 ml. of water was added to a mixture of 3.8 g. of methyl anthranilate hydrochloride, 4 ml. of concentrated hydrochloric acid, and 2 g. of ice, while stirring under cooling, to effect diazotization and the pale yellow solution so obtained was added dropwise into a suspension of 2 g. of *p*-benzoquinone in a mixture of 3.4 g. of sodium hydrogencarbonate, 5 ml. of water, and 5 g. of ice, while stirring under ice-cooling. Vigorous evolution of carbon dioxide and nitrogen was noticed. The dropwise addition was made during about 1 hr., the mixture was stirred at room temperature for a further 1 hr., and the yellow solid that separated was collected by filtration. This yellow solid was difficult to purify, so that it was dissolved in 20 ml. of chloroform, a solution of 5 g. of sodium dithionite in 50 ml. of water was added to it while stirring, the mixture was stirred for 1 hr., and allowed to stand over night. The colorless crystals that separated out were collected and washed with a small amount of chloroform and water to give 2.5 g. of colorless crystals, m. p. 195~198°C. Recrystallization from methanol-benzene mixture raised the melting point to 218~220°C.

Found: C, 72.45; H, 3.79. Calcd. for $C_{13}H_8O_3$: C, 73.58; H, 3.80%. λ_{max}^{MeOH} mμ (log ε): 230 (4.54), 263 (4.11), 317 (3.81), 325 (3.82).

Oxidation of XVI with Potassium Permanganate.—A solution of 1 g. of XVI dissolved in 4 ml. of pyridine with 12 ml. of 5% aqueous solution of potassium permanganate added was warmed on a water bath for 2 hr., and evaporated to dryness in a reduced pressure. The residue was diluted with 5 ml. of water, filtered, and the filtrate was acidified with dilute hydrochloric acid. This was extracted with ethyl acetate, the solvent was evaporated from this extract, and 0.1 ml. of acetic anhydride was added to its residue. After warming this mixture on a water bath the product was sublimed at 60°C (bath temperature) and 20 mmHg, and 60 mg. of colorless prisms, m. p. 129~131°C, was obtained, showing no depression of the melting point on admixture with phthalic anhydride.

2-Methoxybenzo[c]coumarin (**XVII**).—A mixture of 0.8 g. of XVI, 25 ml. of acetone, 1.7 g. of dimethyl sulfate, and 4.5 g. of potassium carbonate was refluxed for 2 hr. while stirring, acetone was evaporated in a reduced pressure, and 10 ml. of water was added to the residue. The crystals were collected by filtration, dissolved in methanol, and treated with activated carbon. Evaporation of methanol afforded 0.7 g. of colorless needles, m. p. 118~119°C.

Found: C, 74.20; H, 4.41. Calcd. for $C_{14}H_{10}O_3$: C, 74.33; H, 4.46%. λ_{max}^{MeOH} mμ (log ε): 231 (4.62), 260 (4.14), 270 (4.06), 316 (3.88), 326 (3.88).

2-(2′, 5′-Dimethoxyphenyl)benzoic Acid (**XV**).—To 1.2 g. of XVI being stirred on a water bath, a solution of 2.24 g. of potassium hydroxide in 10 ml. of water and 1.26 g. of dimethyl sulfate were added in four portions at an interval of 30 min. The mixture was heated for 1 hr. after the final addition, cooled, and extracted with ether to remove neutral substane. The aqueous layer was acidified with dilute hydrochloric acid, the solid (0.73 g.) that separated was collected, and dissolved in ether. Ether solution of diazomethane was added to it to effect esterification and the product was purified by passage through an alumina column.

The oily product (0.5 g.) so obtained was hydrolyzed with 0.75 g. of sodium hydroxide in 5 ml. each of methanol and water by heating on a water bath for 1 hr., methanol was evaporated from the reaction mixture, and the aqueous solution was extracted with benzene to remove neutral substance. This aqueous solution was treated with activated carbon, acidified with dilute hydrochloric acid, and 0.32 g. of colorless crystals that separated out was recrystallized from 50% methanol to colorless needles, m. p. 152~154°C.

Found: C, 69.92; H, 4.85. Calcd. for $C_{15}H_{14}O_4$: C, 69.75; H, 5.46%. λ_{max}^{MeOH} mμ (log ε): 305 (3.65).

2-Hydroxybenzofuro[2, 3-b]tropone (**XVIII**).—A mixture of 70 mg. of IX and 0.2 g. of *p*-toluenesulfonic acid was heated in an oil bath at 110~120°C, by which the solution turned red, heated for 20 min., and cooled. The reaction mixture solidified into a pale yellow mass, 2 ml. of water was added to it, and the solid was collected by filtration. Recrystallization from acetone-methanol mixture afforded 60 mg. of pale yellow prisms, m. p. 287~290°C.

Found: C, 72.76; H, 3.63. Calcd. for $C_{13}H_8O_3$: C, 73.58; H, 3.80. λ_{max}^{MeOH} mμ (log ε): 275 (4.61), 325 (4.40).

2-Methoxybenzofuro[2, 3-b]tropone (**XIX**).—A mixture of 0.17 g. of XVIII in 10 ml. of acetone, 0.4 g. of dimethyl sulfate, and 2 g. of potassium carbonate was refluxed for 1 hr. with stirring. Acetone was evaporated from this mixture, 10 ml. of water was added to the residue, and 0.12 g. of insoluble substance so obtained was recrystallized from methanol to 80 mg. of colorless needles, m. p. 179∼180°C.

Found: C, 73.80; H, 4.46. Calcd. for $C_{14}H_{10}O_3$: C, 74.33; H, 4.46%. $\lambda_{\max}^{\text{MeOH}}$ mμ (log ε): 267 (4.38), 325 (4.22).

3-Bromo-7-(*p*-benzoquinonyl)tropolone (XX).—A mixture of 3 g. of 3-bromotropolone, 1 g. of *p*-benzoquinone, 10 ml. of methanol, and 1 ml. of acetic acid was warmed slightly to effect solution and allowed to stand over night, by which orange plate crystals separated out. After standing the mixture for 2 days, 0.82 g. of crystals were collected and recrystallized from a mixture of methanol and ethyl acetate to give orange scales (XX), m. p. 175∼181°C.

Found: C, 50.82; H, 2.63. Calcd. for $C_{13}H_7O_4Br$: C, 50.82; H, 2.30%. $\lambda_{\max}^{\text{MeOH}}$ mμ (log ε): 255 (4.51), 338 (3.99), 408 (3.91).

The mother liquor left after removal of the orange plate was evaporated and the residue was sublimed at 120°C (bath temperature) and 1 mmHg, from which 2 g. of 3-bromotropolone was recovered.

3-Bromo-7-(2′, 5′-dihydroxyphenyl)tropolone (XXI).—a) To a suspension of 0.2 g. of XX, reduced to a powder in a mortar, in 5 ml. of water, a solution of sodium dithionite in 2 ml. of water was added while stirring at 40°C, by which color of the suspension changed from orange to yellow. After stirring for 20 min., the mixture was cooled, and filtered to collect a pale yellow powder, which was washed with water. Recrystallization from methanol afforded 0.18 g. of pale yellow crystals, m. p. 237∼240°C.

Found: C, 50.21; H, 2.95. Calcd. for $C_{13}H_9O_4Br$: C, 50.48; H, 2.93%. $\lambda_{\max}^{\text{MeOH}}$ mμ (log ε): 260 (4.34), 330 (3.98), 385 (3.80), 408 (3.77).

b) A suspension of 0.1 g. of XX in 100 ml. of ethanol and added with 50 mg. of palladium-carbon was shaken in hydrogen atmosphere. Absorption of hydrogen ceased after 2 hr. The catalyst was filtered off and evaporation of the filtrate afforded 90 mg. of pale yellow crystals, m. p. 240∼242°C, undepressed on admixture with the product obtained by the method a).

Hydrogenolysis of XX.—A mixture of 0.1 g. of XX, 0.1 ml. of diethanolamine, and 50 mg. of palladium-carbon in 100 ml. of ethanol was shaken in hydrogen atmosphere. The catalyst was filtered off, when absorption of hydrogen ceased, 0.2 ml. of acetic acid was added to the filtrate, and the solution was evaporated to dryness. To its residue, 5 ml. of water was added, insoluble matter was collected, and recrystallized from a mixture of methanol and ethyl acetate to give 60 mg. of pale yellow crystals, m. p. 288∼289°C, undepressed on admixture with IX.

2-Hydroxy-7-bromobenzofuro [2, 3-b] tropone (XXII).—A mixture of 0.27 g. of XX and 0.81 g. of *p*-toluenesulfonic acid was heated at 125°C while stirring for 20 min., by which the solution turned red. This was cooled, 5 ml. of water was added, and insoluble matter was collected by filtration. This was washed with water and 0.26 g. of crude crystals melting at 288∼290°C so obtained was recrystallized from methanol to give crystals of m. p. 300∼303°C.

Found: C, 53.44; H, 2.50. Calcd. for $C_{13}H_7O_3Br$: C, 53.61; H, 2.42%. $\lambda_{\max}^{\text{MeOH}}$ mμ (log ε): 280 (4.54), 334 (4.23).

2-Methoxy-7-bromobenzofuro [2, 3-b] tropone (XXIII).—a) Ether solution of diazomethane was added to 0.12 g. of XXII suspended in 10 ml. of methanol and the mixture was allowed to stand for 2 days. The mixture was evaporated and the residue was fractionally crystallized from methanol. From the sparingly soluble portion, 65 mg. of XXII was recovered. An easily soluble portion afforded 40 mg. of pale yellow needles (XXIII), m. p. 222∼224°C.

Found: C, 55.06; H, 2.95. Calcd. for $C_{14}H_9O_3Br$: C, 55.09; H, 2.97%. $\lambda_{\max}^{\text{MeOH}}$ mμ (log ε): 278 (4.52), 330 (4.18).

b) A mixture of 0.37 g. of XXII in 20 ml. of acetone, 0.8 g. of dimethyl sulfate, and 4 g. of potassium carbonate was refluxed for 1 hr. while stirring, acetone was evaporated from the reaction mixture, and the residue was diluted with 10 ml. of water, separating 0.34 g. of insoluble matter, m. p. 150∼190°C. This was dissolved in methanol, treated with activated carbon, and fractional recrystallization afforded 80 mg. of pale yellow needles, m. p. 223∼225°C, undepressed on admixture with XXIII prepared by the method a).

Easily soluble portion afforded 50 mg. of pale yellow crystals, m. p. 118∼120°C, which was assumed to be XXV from the shape of its ultraviolet absorption spectrum, its analytical values and no coloration with ferric chloride.

Found: C, 53.32; H, 3.87. Calcd. for $C_{15}H_{13}O_4Br$: C, 53.41; H, 3.88%. $\lambda_{\max}^{\text{MeOH}}$ mμ (log ε): 220 (4.26), 256 (4.37), 334 (4.08), 380 (3.84).

2-Methoxy-7-bromobenzo[c]coumarin (XXIV).—A mixture of 170 mg. of XXI, 12 ml. of acetone, 0.6 g. of dimethyl sulfate, and 1.1 g. of potassium carbonate was refluxed for 2 hr. while stirring, acetone was evaporated from the reaction mixture, and 5 ml. of water was added to the residue. The insoluble matter was collected, dissolved in methanol, and treated with activated carbon. Evaporation of the filtrate afforded 80 mg. of colorless crystals, m. p. 176∼177°C.

Found: C, 54.91; H, 3.08. Calcd. for $C_{14}H_9O_3Br$: C, 55.09; H, 2.97%. $\lambda_{\max}^{\text{MeOH}}$ mμ (log ε): 238 (4.51), 268 (4.06), 330 (3.93).

Hydrogenolysis of XXIII.—A solution of 30 mg. of XXIII dissolved in 100 ml. of ethanol, added with 30 mg. of sodium acetate and 20 mg. of palladium-carbon, was shaken in hydrogen atmosphere, the catalyst was filtered off when absorption of hydrogen ceased, and the filtrate was evaporated in a reduced pressure. To its residue, 2 ml. of water was added, insoluble matter was collected, and recrystallized from methanol to 10 mg. of crystals melting at 175∼178°C, alone and in admixture with XIX.

Hydrogenolysis of XXIV.—XXIV (20 mg.) was treated in the same manner as in hydrogenolysis of XXIII and 10 mg. of crystals, m. p. 113∼117°C, was obtained. It showed no depression of the melting point on admixture with XVII.

Reaction of 3, 7-Dibromotropolone and *p*-Benzoquinone.—A mixture of 3 g. of 3, 7-dibromotropolone, 1 g. of *p*-benzoquinone. 30 ml. of methanol, and

2 ml. of acetic acid was heated at 60°C for 5 hr., cooled to the room temperature, and 1.14 g. of crystals, m. p. 146~152°C, was obtained. This was found by admixture to be the starting tropolone. Concentration of the filtrate left after separation of these crystals afforded 1.27 g. of recovered 3, 7-dibromotropolone.

This filtrate was evaporated to dryness, 13 ml. of 5 N potassium hydroxide and 7 g. of dimethyl sulfate were added to its residue, and the mixture was heated on a water bath for 8 hr. while stirring. When cooled, 1.25 g. of yellow potassium salt separated which was dissolved in 100 ml. of water, dark insoluble matter was filtered off, and the filtrate was concentrated to 50 ml. On cooling this solution, 0.4 g. of the salt was obtained. This salt was suspended in water, acidified with dilute hydrochloric acid, and the separated crystals were collected. Recrystallization from methanol gave 0.15 g. of pale yellow crystals, m. p. 130~135°C. This is 3, 7-dibromo-5-(4′-methoxyphenoxy) tropolone (XXVII).

Found: C, 41.47; H, 2.79. Calcd. for $C_{14}H_{10}O_4Br_2$: C, 41.80; H, 2.51%. $\lambda_{\max}^{\mathrm{MeOH}}$ mμ (log ε): 268 (4.49), 348 (4.10), 446 (3.90).

Hydrogenolysis of XXVII.—A mixture of 30 mg. of XXVII, 30 mg. of potassium hydroxide, and 40 ml. of water, with 30 mg. of palladium-carbon added, was shaken in hydrogen atmosphere until absorption of hydrogen had ceased. The catalyst was filtered off, the filtrate was acidified, and the crystals that separated out were collected to 10 mg. of crystals melting at 125~127°C, alone and on admixture with 5-(4′-methoxyphenoxy) tropolone (IV).

Summary

Reaction of tropolone and *p*-benzoquinone was carried out in methanol containing acetic acid and the structure of products so obtained was determined. Tropolone gave 5-(4′-hydroxyphenoxy)tropolone and 3-(*p*-benzoquinonyl)-tropolone, 3-bromotropolone gave 3-bromo-7-(*p*-benzoquinonyl)tropolone, and 3, 7-dibromotropolone gave 3, 7-dibromo-5-(4′-hydroxyphenoxy)tropolone by this reaction. Benzofurotropones were derived from benzoquinonyltropolones.

In order to prove the structure of the product by admixture, benzocoumarin derivative was prepared by the reaction of the diazonium salt of anthranilate and *p*-benzoquinone.

The present work was aided by financial assistance from the Sankyo Co., Ltd. The authors are indebted to Mr. Yusaku Ikegami for infrared spectral analyses.

The Chemical Research Institute of
Non-Aqueous Solutions
Tohoku University
Katahira-cho, Sendai