Isomerization of 4,8,13-Duvatriene-1,3-diols (I) to 3,8,13-Duvatriene-1,5-diols (II).—A hexane solution of 216 mg. of α-I was added to a 20 × 75 mm. chromatographic column of acid-washed alumina (Merck). After α-I had been allowed to contact the adsorbent for 40 hr., elution was attempted using hexane–ether mixtures. Elution with ether yielded 20 mg. (9%) of material with infrared absorption identical with that of α-II. Starting material, α-I, 170 mg., was recovered by elution with ether containing 2% methanol.

Using the same procedure, β-I was converted to β-II in 20% yield.

Acknowledgment.—The authors are indebted to R. F. Walsh for technical assistance, to T. C. James for extraction of tobacco, and to Drs. M. Senkus and C. E. Teague, Jr., for helpful discussions.

The Mitomycin Antibiotics. Synthetic Studies. I. Synthesis of Model Quinones

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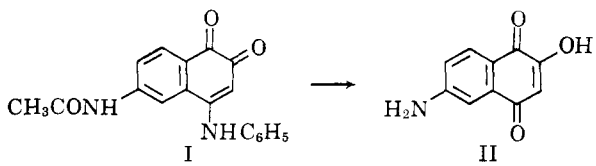
Certain Bz(benz)-amino-substituted 2-hydroxy-1,4-naphthoquinones and 5-hydroxy-6-methyl-substituted indoloquinones, including a pyrrolo[1,2-*a*]indoloquinone, have been prepared. Their pertinence as ultraviolet models for mitomycin degradation products is discussed.

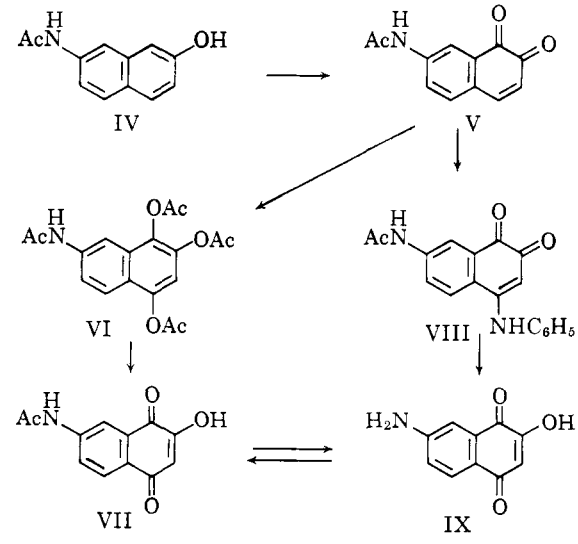
In the course of an investigation concerning the structure of the mitomycin group of antibiotics, Webb and collaborators isolated degradation products which were apparently amino-substituted 2-hydroxy-3-methyl-1,4-quinones.[1] In this paper we wish to report the synthesis of several naphtho- and indoloquinones prepared as ultraviolet models of these degradation products. One of the partial structures originally suggested for these products contained a 1,4-naphthoquinone nucleus and, therefore, we undertook the synthesis of the four possible Bz-amino-2-hydroxy-1,4-naphthoquinones. Although three of these compounds and a potential close precursor to the fourth had already been reported by Kehrmann and his collaborators,[2] it was desirable to devise more convenient pathways for the preparation of three of the compounds in view of the difficult and tedious procedures which the Kehrmann group had utilized. In particular, it appeared that the use of the Fremy's salt (potassium nitrosodisulfonate) procedure[3] for the conversion of phenolic compounds to quinones might lead to considerably shortened sequences.

The unknown 6-amino-2-hydroxy-1,4-naphthoquinone (II) was prepared by hydrolysis, according to the procedure of Thomson,[4] of the known[2a] 6-acetamido-4-anilino-1,2-naphthoquinone (I).



I II

7-Amino-2-hydroxy-1,4-naphthoquinone (IX)[2b] was prepared as follows. 7-Amino-2-naphthol (III)[5] was converted to the *N*-acetyl derivative IV *via* *O*,*N*-diacetylation of the hydrochloride in aqueous solution, followed by de-*O*-acetylation in dilute alkali. The previously reported[5] acetylation in pyridine was found difficult to repeat. Oxidation of IV with Fremy's salt afforded an 89% yield of 7-acetamido-1,2-naphthoquinone (V). This conversion previously required three steps.[2d] Attempts to elaborate the 2-hydroxy-1,4-quinone system *via* Thiele acetylation of V followed by hydrolysis and oxidation of the tetraacetate VI were unpromising. The Thiele acetylation gave erratic results and the yield of VI was never better than 18%, although subsequent alkaline hydrolysis of VI followed by ferric chloride oxidation gave a 96% yield of the 7-acetamido derivative VII. A superior route was provided by the addition of aniline to V. The resulting 7-acetamido-4-anilino-1,2-naphthoquinone (VIII), formed in 40% yield by the procedure of Kehrmann and Wolff,[2d] then was hydrolyzed in sulfuric acid directly to the desired IX, obtained in 76% yield after partition chromatography. Compound IX could be *N*-acetylated to VII; VII could be hydrolyzed to IX.



Preparation of 8-amino-2-hydroxy-1,4-naphthoquinone (XIII)[2e] was accomplished by similar procedures: Fremy's salt oxidation of 8-acetamido-2-naphthol (X), addition of aniline to the resulting 8-acetamido-1,2-

(1) J. S. Webb, D. B. Cosulich, J. H. Mowat, J. B. Patrick, R. W. Broschard, W. E. Meyer, R. P. Williams, C. F. Wolf, W. Fulmor, C. Pidacks, and J. E. Lancaster, *J. Am. Chem. Soc.*, **84**, 3185 (1962).

(2) (a) F. Kehrmann and M. Matis, *Ber.*, **31**, 2413 (1898); (b) F. Kehrmann and G. Steiner, *ibid.*, **33**, 3280 (1900); (c) F. Kehrmann and G. Steiner, *ibid.*, **33**, 3285 (1900); (d) F. Kehrmann and H. Wolff, *ibid.*, **33**, 1538 (1900); (e) F. Kehrmann and E. Misslin, *ibid.*, **34**, 1224 (1901); (f) F. Kehrmann and A. Denk, *ibid.*, **33**, 3295 (1900).

(3) (a) H. Teuber and G. Jellinek, *ibid.*, **85**, 95 (1952); (b) H. Teuber and G. Thaler, *ibid.*, **91**, 2253 (1958); (c) H. Teuber and G. Staiger, *ibid.*, **89**, 489 (1956).

(4) R. H. Thomson, *J. Org. Chem.*, **13**, 874 (1948).

(5) L. Raiford and W. Talbot, *J. Am. Chem. Soc.*, **49**, 559 (1927).

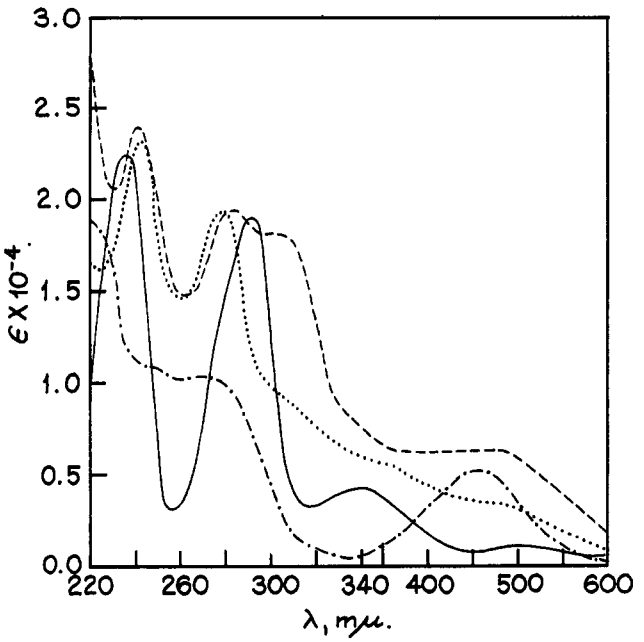
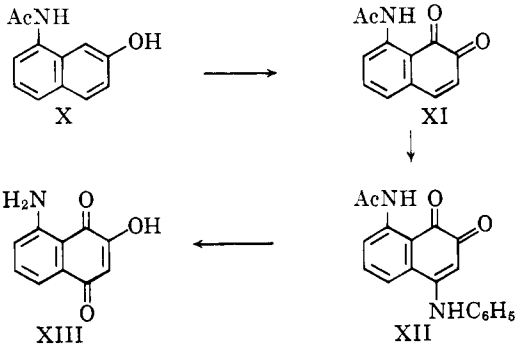


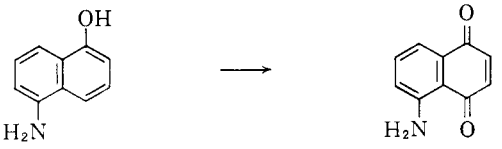
Fig. 1.—Ultraviolet absorption spectra in methanol: ———, 2-aminomitosene-1,7-diol; – – – –, 6-amino-2-hydroxy-1,4-naphthoquinone (II); . . . . , 7-amino-2-hydroxy-1,4-naphthoquinone (IX); — · —, 8-amino-2-hydroxy-1,4-naphthoquinone (XIII).

naphthoquinone (XI) and hydrolysis of the 4-anilino derivative XII to XIII.

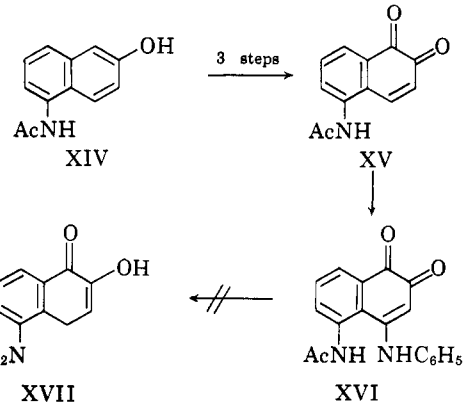


We were unable to devise a successful alternate preparation for the known[2c] 5-amino-2-hydroxy-1,4-naphthoquinone XVII. In contrast to the facile Fremy's salt oxidation of the 7- and 8-acetamido-2-naphthols, this oxidation was unsuccessful with 5-acetamido-2-naphthol (XIV).[6] However, the desired *o*-quinone XV was obtained from XIV by the three-step procedure of Kehrmann and Denk.[2f] Addition of aniline to XV then afforded the 4-anilino-*o*-quinone XVI. Despite the successful hydrolysis of the other three acetamido-4-anilino-1,2-naphthoquinones, XVI could not be hydrolyzed to XVII.[7] Since at about this time the naphthoquinone hypothesis was abandoned,

(6) An interesting sidelight to the Fremy's salt oxidation studies was the observation that 5-amino-1-naphthol undergoes a facile selective oxidation of the phenolic ring to give 5-amino-1,4-naphthoquinone in high yield.



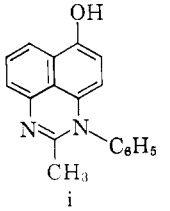
However, 8-amino-2-naphthol does not react with Fremy's salt under the same conditions.



further attempts to prepare this particular naphthoquinone model were discontinued.

Comparison of the ultraviolet absorption spectra of the three Bz-amino-2-hydroxy-1,4-naphthoquinones with the spectra of the 2-hydroxy-1,4-quinone degradation product revealed no close similarity (Fig. 1); this observation in conjunction with other evidence led Webb and co-workers[1] to abandon the original postulation that the degradation products were naphthoquinones. Indoloquinone structures for the degradation products were then proposed[1] and the synthesis of appropriate model indoloquinones was undertaken. One pertinent indoloquinone had already been reported in the literature, namely, ethyl 5-hydroxy-2,6-dimethyl-4,8-dioxo-3-indolecarboxylate (XVIII) and we repeated the synthesis of this compound as described by Teuber and Thaler[3b] with some modification in the final step[8] (see Experimental section). Although XVIII was a reasonably good ultraviolet model for the hydroxy-*p*-quinone degradation products (Fig. 2 and 3), the carboxylate function of the former was obviously not present in the latter. An indoloquinone substituted only with alkyl groups seemed to be a more pertinent model. We, therefore, prepared 5,6,7,8-tetrahydro-3-hydroxy-2-methyl-1,4-carbazoledione (XX) from the known[3c] 5,6,7,8-tetrahydro-2-methyl-3,4-carbazoledione (XIX) by prolonged treatment with 0.1 *N* sodium hydroxide solution. The near identity of the ultraviolet absorption spectrum of XX with that of 2-aminomitosene-1,7-diol[9] in acid (Fig. 2) and in alkali (Fig. 3)

(7) Since XVI is the only isomer that has the acetamido group in close proximity to the 4-anilino group, it is possible that this acetamido group either inhibits the hydrolysis or participates in the hydrolytic reaction forming alkali-insoluble products. Ring closures involving acetamido groups attached to *o*-quinone systems have been observed by Senoh and Witkop [*J. Am. Chem. Soc.*, **81**, 6222 (1959)]. Also, Sander reported that the

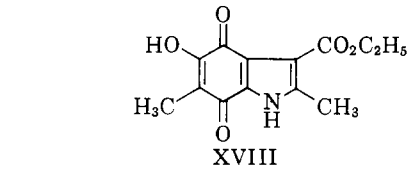


i

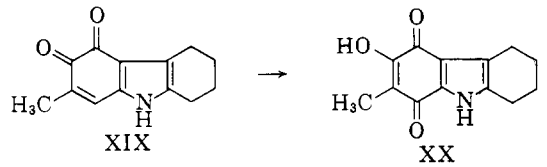
pyrimidine derivative i was formed by the stannous chloride–hydrochloric acid reduction of 5-acetamido-1,4-naphthoquinone-4-anil [*Ber.*, **58**, 824 (1925)].

(8) Considerable difficulty was encountered in repeating the elaboration of *o*-quinone to hydroxy-*p*-quinone in methanolic hydrochloric acid. The procedure that we finally utilized was derived from the observation of Mr. V. J. Kerr that prolonged aging in 0.1 *N* hydrochloric acid or 0.1 *N* sodium hydroxide produced the change in ultraviolet absorption characteristic of the desired elaboration.

(9) The trivial name "mitosene" has been proposed [ref. 1] for the structure 2,3-dihydro-9-hydroxymethyl-6-methyl-1*H*-pyrrolo[1,2-*a*]indole-5,8-dione carbamate.



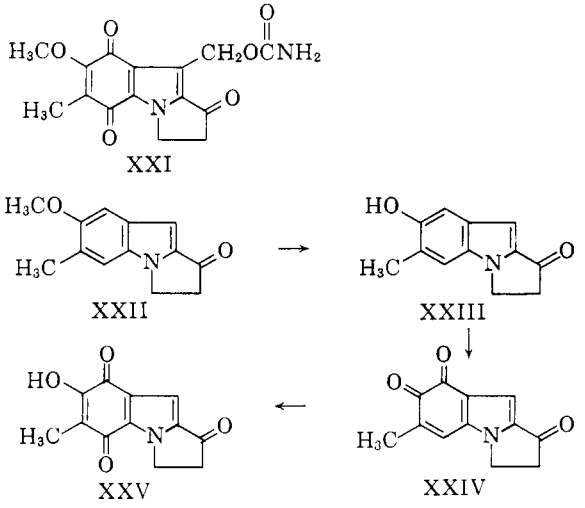
XVIII



XIX XX

afforded significant support for the proposed indoloquinone structure.[1]

Finally, a mitomycin A degradation product with an ultraviolet absorption spectrum significantly different from the above hydroxyindoloquinones (compare Fig. 3 with Fig. 4) was postulated by Webb and co-workers[1] to possess the 1-oxopyrrolo[1,2-*a*]indoloquinone structure XXI. Therefore, we undertook the synthesis of the closely related model compound XXV from 2,3-dihydro-7-methoxy-6-methyl-1-oxo-1*H*-pyrrolo-[1,2-*a*]indole (XXII).[10] Cleavage of the methoxy group in XXII was effected by treatment with aluminum chloride in refluxing xylene and the resulting phenolic product XXIII was oxidized with Fremy's salt to the corresponding *o*-quinone XXIV. Prolonged treatment of XXIV with 0.1 *N* hydrochloric acid furnished the hydroxy-*p*-quinone XXV. The ultraviolet absorption spectrum of the latter compound closely resembled that of the mitomycin A degradation product XXI (Fig. 4).[11]



XXI XXII XXIII XXV XXIV

Experimental

General.—Melting points are uncorrected. Ultraviolet spectra were determined in methanol using a Cary recording spectrophotometer. Infrared spectra were determined in potassium bromide disks on a Perkin–Elmer spectrophotometer (Model 21). Solutions were dried over magnesium sulfate.

6-Amino-2-hydroxy-1,4-naphthoquinone (II).—A solution of 0.52 g. of 6-acetamido-4-anilino-1,2-naphthoquinone (I)[2a] in 10 ml. of concentrated sulfuric acid was cautiously diluted with 20 ml. of water and the mixture was heated at mild reflux for 10 min. After cooling, the resulting brown solution was neutralized to pH 6 with 20% sodium hydroxide solution. The brown precipitate, which formed immediately, was collected and dried. The crude 6-amino-2-hydroxy-1,4-naphthoquinone (II) (0.32 g.) was purified by partition chromatography. It was dissolved in 20 ml. of the lower and 20 ml. of the upper phase of the system cyclohexane–dioxane–water (10:15:2) and mixed thoroughly with 40 g. of Celite[12] diatomaceous earth. This mixture was packed on a column which had been prepared from 250 g. of Celite diatomaceous earth and 125 ml. of the lower phase of the solvent system just described. The column (3.8 × 60 cm.) was eluted with the upper phase of the solvent system and the effluent was passed through a recording spectrophotometer which had been set at 300 mμ. The ultraviolet absorbing material was contained in the

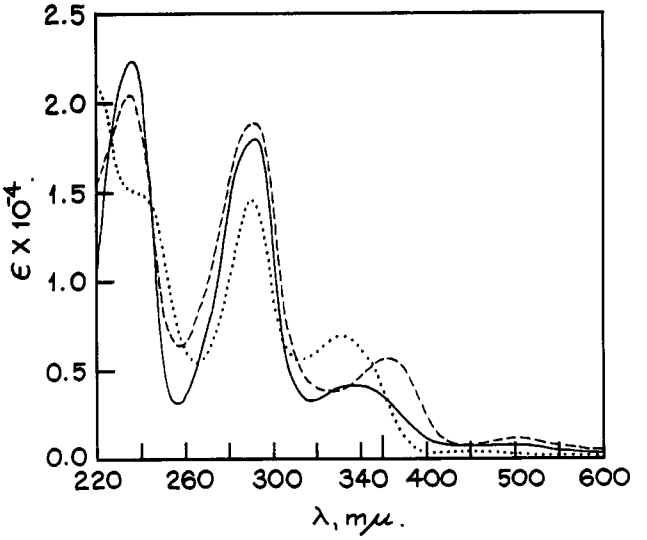


Fig. 2.—Ultraviolet absorption spectra in 0.1 *N* hydrochloric acid: ———, 2-aminomitosene-1,7-diol; – – – –, 5,6,7,8-tetrahydro-3-hydroxy-2-methyl-1,4-carbazoledione (XX); . . . ., ethyl 5-hydroxy-2,6-dimethyl-4,8-dioxo-3-indolecarboxylate (XVIII).

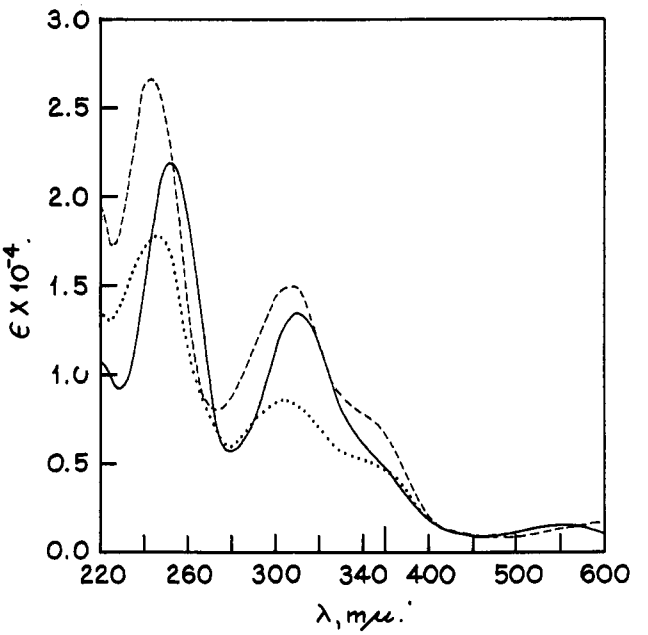


Fig. 3.—Ultraviolet absorption spectra in 0.1 *N* sodium hydroxide: ———, 2-aminomitosene-1,7-diol; – – – –, 5,6,7,8-tetrahydro-3-hydroxy-2-methyl-1,4-carbazoledione (XX); . . . ., ethyl 5-hydroxy-2,6-dimethyl-4,8-dioxo-3-indolecarboxylate (XVIII).

(10) G. R. Allen, Jr., J. F. Poletto, and M. J. Weiss, to be published.

(11) The ultraviolet absorption spectra of hydroxy-*p*-quinones is nearly identical with those of the corresponding methoxy-*p*-quinones in acid and neutral solution. In dilute alkali the spectra of hydroxy-*p*-quinones undergo bathochromic shifts, but those of methoxy-*p*-quinones do not. In the present work only the neutral solution comparison was made since both XXI and XXV decompose in dilute alkali.

(12) Celite is the trademark of Johns-Manville Corporation for diatomaceous earth products.

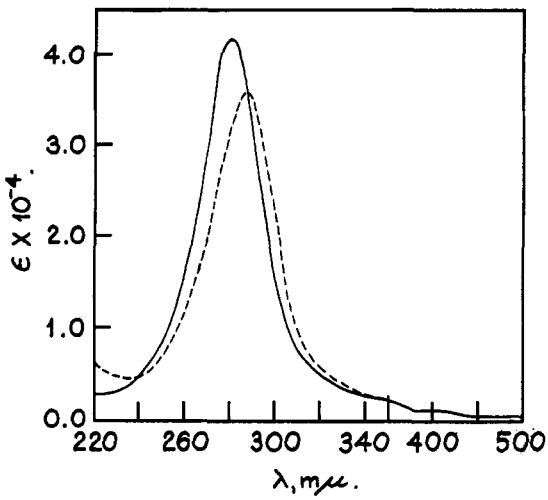


Fig. 4.—Ultraviolet absorption spectra in methanol: ——— 7-hydroxymitosen-1-one (XXI); – – – –, 2,3-dihydro-7-hydroxy-6-methyl-1,5,8-trioxo-1*H*-pyrrolo[1,2-*a*]indole (XXV).

second hold-back volume (410 ml.). Concentration *in vacuo* afforded 0.25 g. (78%) of red-brown solid which did not melt below 320°; λ_{max} 2.78, 2.86, 2.94, 6.06, 6.28 μ; 242 (ε 24,000), 293 (ε 19,500), 309 (ε 18,500), 340 (ε 8,600), 465 (ε 6,500) mμ; (see Fig. 1); pK_a 5.10.

Anal. Calcd. for $C_{10}H_7NO_3$ (189.16): C, 63.49; H, 3.73; N, 7.41. Found: C, 63.44; 63.38; H, 4.40, 4.34; N, 7.25.

7-Acetamido-2-naphthol (IV).—A solution of 24.0 g. of 7-amino-2-naphthol (III)[5] in 280 ml. of water and 14 ml. of concentrated hydrochloric acid was treated with 24 ml. of acetic anhydride and a cold solution of 34.0 g. of sodium acetate and 0.50 g. of sodium hydrosulfite in 100 ml. of water. The precipitate of 7-acetamido-2-acetoxynaphthalene was collected on a filter, washed with water, and pressed dry. Without further purification, it was dissolved in a solution of 350 ml. of water and 56 ml. of 10% sodium hydroxide. A small amount of insoluble material was removed by filtration and the filtrate was acidified with 3 *N* hydrochloric acid. The white precipitate was collected, washed with water, and dried. This procedure afforded 23.3 g. (77%) of 7-acetamido-2-naphthol (IV), m.p. 227–232° (lit.,[5] m.p. 232°).

7-Acetamido-1,2-naphthoquinone (V).—An ice-cooled solution of 9.0 g. (0.045 mole) of 7-acetamido-2-naphthol (IV) in 200 ml. of methanol was added rapidly, with stirring, to an ice-cooled solution of 27.0 g. (0.10 mole) of Fremy's salt in 2 l. of water and 400 ml. of 0.167 *M* potassium dihydrogen phosphate. The brick-red quinone, which precipitated immediately, was collected, washed well with water, and dried. This procedure afforded 8.5 g. (88.5%) of 7-acetamido-1,2-naphthoquinone (V), m.p. 214–215°. Recrystallization from methanol raised the melting point to 223° (lit.,[2d] m.p. 224°); λ_{max} 2.96, 6.02 μ; 247 (ε 34,000), 272 (ε 19,500), 320 (ε 1,750), 335 (ε 1,950), 455 (ε 1,600) mμ.

7-Acetamido-2-hydroxy-1,4-naphthoquinone (VII).—To a stirred, ice-cooled mixture of 20 ml. of acetic anhydride and 10 drops of concentrated sulfuric acid was added 1.0 g. of 7-acetamido-1,2-naphthoquinone (V). After 20 min., when all of the quinone had dissolved, the resulting dark solution was poured into ice–water. The yellow oil that separated was extracted into 50 ml. of ethyl acetate. After successive washes with water, potassium bicarbonate solution (until the acetic acid was removed), and water, the extract was dried, filtered, and diluted with 50 ml. of ether. A white powder precipitated. It was washed with ether and dried; yield 0.29 g. (17.5%); m.p. 225–227°; λ_{max} 3.03, 5.68, 6.02 μ. Without further purification this 7-acetamido-1,2,4-triacetoxynaphthalene (VI) was dissolved in a solution of 0.34 g. of potassium hydroxide in 10 ml. of ethanol. The solution was kept under nitrogen for 10 min., then diluted with 25 ml. of water and acidified with 3 ml. of 3 *N* hydrochloric acid. A solution of 1.0 g. of ferric chloride in 15 ml. of water and 1 ml. of concentrated hydrochloric acid was added. The yellow precipitate of 7-acetamido-2-hydroxy-1,4-naphthoquinone (VII) was collected, washed with water, and dried. This procedure afforded 0.18 g. (17% over-all) of material with m.p. 239–240° dec.; λ_{max} 2.78, 2.94, 5.95, 6.05 μ; 233 (ε 12,500), 268 (ε 25,000), 292 (ε 13,000), 344 (ε 3,700), 410 (ε 1,400) mμ.

Anal. Calcd. for $C_{12}H_9NO_4$ (231.20): C, 62.34; H, 3.92; N, 6.06. Found: C, 61.96; H, 4.27; N, 6.26.

7-Amino-2-hydroxy-1,4-naphthoquinone (IX).—This compound was prepared by the procedure utilized for 6-amino-2-hydroxy-1,4-naphthoquinone (II, see above). From 1.70 g. of 7-acetamido-4-anilino-1,2-naphthoquinone (VIII)[2d] there was obtained after partition chromatography of the hydrolysis product (contained in hold-back volumes 1.5–2.5, recording spectrophotometer set at 280 mμ) an 0.80 g. (76%) yield of 7-amino-2-hydroxy-1,4-naphthoquinone (IX), red-brown solid, no melting below 320°; λ_{max} 2.78, 2.86, 3.03, 6.06 μ; 243 (ε 23,000), 281 (ε 19,000), 305 (ε 9,000), 360 (ε 6,000), 500 (ε 4,000) mμ (see Fig. 1).

Interconversion of 7-Amino-2-hydroxy-1,4-naphthoquinone (IX) and 7-Acetamido-2-hydroxy-1,4-naphthoquinone (VII).—To a stirred suspension of 50 mg. of 7-amino-2-hydroxy-1,4-naphthoquinone in 2 ml. of water containing three drops of concentrated hydrochloric acid was added a solution of 160 mg. of sodium acetate in a little water, followed by 0.15 ml. of acetic anhydride. The solid soon dissolved and then a yellow precipitate formed. After 12 hr., the mixture was filtered and the washed filter cake was dissolved in 3% sodium hydroxide solution. Upon acidification with 3 *N* hydrochloric acid, a yellow precipitate was formed. It had an infrared spectrum which was superimposable with that of 7-acetamido-2-hydroxy-1,4-naphthoquinone (VII) prepared *via* the tetraacetate (VI) (both samples were 0.375% in potassium bromide disks).

To a solution of 50 mg. of 7-acetamido-2-hydroxy-1,4-naphthoquinone (VII), prepared *via* the tetraacetate (VI) in 2 ml. of concentrated sulfuric acid was cautiously added 4 ml. of water. The resulting mixture was boiled 5 min., cooled, and diluted with 5 ml. of water. The brown solution was made slightly alkaline with 10% sodium hydroxide (dark red solution), then a few drops of dilute sulfuric acid were added to cause the precipitation of 7-amino-2-hydroxy-1,4-naphthoquinone (IX), which was collected, washed well with water, and dried. It had an infrared spectrum which was superimposable with that of the compound prepared *via* VIII (both samples were 0.375% potassium bromide disks).

8-Acetamido-1,2-naphthoquinone (XI).—To a suspension of 10 g. (0.05 mole) of 8-acetamido-2-naphthol (X) in a solution of 11.3 g. of potassium dihydrogen phosphate in 1000 ml. of ice–water was added 30 g. of Fremy's salt. The resulting suspension was stirred at 5° overnight. At the end of the reaction period, the brick-red product was collected on a filter, washed with water, and dried at 38° (125 mm.), yielding 5.9 g. (55%) of 8-acetamido-1,2-naphthoquinone. An additional 2.0 g. (18%) was obtained by extraction of the mother liquors with methylene chloride, desiccation of the extracts, and concentration to dryness. The product is soluble in most organic solvents, but darkens on standing in solutions; λ_{max} 2.91, 6.09 μ; 251 (ε 13,800), 440 (ε 3,200) mμ. Although a satisfactory analysis could not be obtained for this compound, it was suitable for use in the preparation of subsequent compounds.

8-Amino-2-hydroxy-1,4-naphthoquinone (XIII).—To a suspension of 5.0 g. of 8-acetamido-1,2-naphthoquinone (XI) in 50 ml. of ethanol was added with stirring 5 ml. of aniline. Stirring was continued for 10 min., then 10.85 ml. of a solution 1.5 *M* in chromic anhydride and 4.5 *M* in sulfuric acid was added with stirring during about 20 min. with external cooling. Stirring was continued for an additional 10 min., then the product was collected on a filter, washed successively with 20 ml. of water, 20 ml. of ethanol, and 30 ml. of methylene chloride, and dried in a vacuum oven. The crude 8-acetamido-4-anilino-1,2-naphthoquinone (XII) weighed 7.7 g. Its insolubility in organic solvents precluded convenient purification by standard techniques. A satisfactory analysis could not be obtained and the material was used without further purification. It was converted to 8-amino-2-hydroxy-1,4-naphthoquinone (XIII) by the procedure utilized for 6-amino-2-hydroxy-1,4-naphthoquinone (II, see above). From 6.5 g. of XII was obtained after partition chromatography of the hydrolysis product [the second colored band (orange) that developed was collected] a 0.6 g. yield of 8-amino-2-hydroxy-1,4-naphthoquinone (XIII), m.p. 230–233° (lit.,[2e] m.p. 225°, sublimes with decomposition); λ_{max} 2.94, 3.00, 6.16 μ; 221 (ε 19,000) sh., 252 (ε 11,000) sh., 277 (ε 10,000), 480 (ε 5,100) mμ (see Fig. 1).

Anal. Calcd. for $C_{10}H_7NO_3$ (189.16): C, 63.5; H, 3.7; N, 7.4; CH_3CO, 0. Found: C, 63.9; 63.4, 63.8; H, 4.2, 4.2, 4.1; N, 7.3; CH_3CO, 0.6.

5-Acetamido-4-anilino-1,2-naphthoquinone (XVI).—Aniline (6 ml.) was added to a stirred suspension of 6.1 g. of 5-acetamido-1,2-naphthoquinone (XV) in 20 ml. of ethanol. The quinone dissolved on addition of the aniline and immediately a brown precipitate separated from the dark solution. This precipitate was collected on a filter, washed with 20 ml. of ethanol in several portions, and dried in a vacuum desiccator, yield 5.1 g. (72%), no melting below 320°; λ_{max} 2.95, 5.95, 6.04 μ; 260 (ϵ 19,000), 296 (ϵ 12,000), 410 (ϵ 4,900).

Anal. Calcd. for $C_{18}H_{14}N_2O_3$ (306.31): C, 70.6; H, 4.6; N, 9.2. Found: C, 70.8; H, 5.2; N, 8.9.

Ethyl 5-Hydroxy-2,6-dimethyl-4,7-dioxo-3-indolecarboxylate (XVIII).—This compound was prepared by a variation of the known method.[3b] A solution of 0.20 g. of 2,6-dimethyl-3-carbethoxy-4,5-indoloquinone[3b] in 1 l. of methanol was added to 9 l. of 0.1 *N* aqueous hydrochloric acid. After 7 days at 25°, the mixture was extracted with two 1-l. portions of ether. The extract was washed with water, dried, and concentrated to afford 0.21 g. of red solid, m.p. 215–235°. Recrystallization from benzene afforded 0.076 g. (36%) of red crystals, dec. at 250° (lit.,[3b] dec. at 250°); λ_{max} 3.11, 5.88, 6.17 μ; 220 (ϵ 21,000), 241 (ϵ 15,000), 291 (ϵ 14,500), 330 (ϵ 6,900), 450 (ϵ 540) mμ (see Fig. 2 and 3 for acid and alkali ultraviolet curves).

5,6,7,8-Tetrahydro-3-hydroxy-2-methyl-1,4-carbazoledione (XX).—A solution of 100 mg. of 5,6,7,8-tetrahydro-2-methyl-3,4-carbazoledione (XIX)[3c] in 1 l. of methanol was added to 9 l. of 0.1 *N* sodium hydroxide. After 18 hr. the resulting green solution had changed to blue. It was then acidified with 3 *N* hydrochloric acid until it turned pink and extracted with 2 l. of ether (in excess of the ether required to saturate the aqueous solution). The ether extract was washed with water, dried, and concentrated. The residue was recrystallized from acetone–benzene; copper-colored plates which did not melt below 330° were obtained. Yield 50 mg. (47%); λ_{max} 2.96, 6.15 μ; 232 (ϵ 19,000); 301 (ϵ 19,000); 360 (ϵ 4,400); 500 (ϵ 1,200) mμ (see Fig. 2 and 3 for acid and alkali ultraviolet curves).

Anal. Calcd. for $C_{13}H_{13}NO_3$ (231.24): C, 67.52; H, 5.67; N, 6.06. Found: C, 67.44; H, 5.74; N, 6.26.

2,3-Dihydro-7-hydroxy-6-methyl-1-oxo-1*H*-pyrrolo[1,2-*a*]indole (XXIII).—A mixture of 645 mg. (3 mmoles) of 2,3-dihydro-7-methoxy-6-methyl-1-oxo-1*H*-pyrrolo[1,2-*a*]indole (XXII),[9] 800 mg. (6 mmoles) of anhydrous aluminum chloride, and 20 ml. of xylene was stirred in a nitrogen atmosphere and heated at reflux temperature for 5 hr. It was cooled and decomposed with ice and dilute hydrochloric acid and extracted into ethyl acetate. The ethyl acetate solution was washed with water, dried, and concentrated. The glassy solid residue (536 mg.) was purified by partition chromatography (see above) on 850 g. of Celite diatomaceous earth with the system heptane–ethyl acetate–methanol–water (70:30:15:6). The recording spectrophotometer was set at 330 mμ. The product was contained in hold-back volumes 3.5–5.0. Concentration of this effluent afforded 139 mg. (23%) of 2,3-dihydro-7-hydroxy-6-methyl-1-oxo-1*H*-pyrrolo[1,2-*a*]indole (XXIII); orange powder, m.p. 255° dec.; λ_{max} 3.05 (s), 5.95 (s) μ; 332 (ϵ 20,000) mμ.

Anal. Calcd. for $C_{12}H_{11}NO_2$ (201.22): C, 71.62; H, 5.51; N, 6.96. Found: C, 71.99, 71.70; H, 6.08, 5.82; N, 6.73.

2,3-Dihydro-6-methyl-1,7,8-trioxo-1*H*-pyrrolo[1,2-*a*]indole (XXIV).—To a solution of 268 mg. (1 mmole) of Fremy's salt in 20 ml. of 0.167 *M* potassium dihydrogen phosphate solution and 40 ml. of water was added a solution of 100 mg. (0.5 mmole) of 2,3-dihydro-7-hydroxy-6-methyl-1-oxo-1*H*-pyrrolo[1,2-*a*]indole (XXIII) in 25 ml. of acetone. The Fremy's salt was decolorized instantly and the dark red solution that formed was diluted with 65 ml. of water and extracted with 200 ml. of ethyl acetate. This extract was washed with brine, dried, and concentrated. The residue was purified by partition chromatography (see above) on 56 g. of Celite with the system heptane–ethyl acetate–methanol–water (50:50:15:6). The recording spectrophotometer was set at 300 mμ. The product was contained in hold-back volumes 3.8–5.5. Concentration of the effluent afforded 30 mg. (28%) of 2,3-dihydro-6-methyl-1,7,8-trioxo-1*H*-pyrrolo-[1,2-*a*]indole (XXIV), red prisms, dec. 230°; λ_{max} 5.7 (s), 6.0 (s) μ; 300 (ϵ 19,000), 510 (ϵ 750) mμ.

Anal. Calcd. for $C_{12}H_9NO_3$ (215.20): C, 66.97; H, 4.22; N, 6.51. Found: C, 66.96; H, 4.62; N, 5.57.

2,3-Dihydro-7-hydroxy-6-methyl-1,5,8-trioxo-1*H*-pyrrolo-[1,2-*a*]indole (XXV).—A solution of 15 mg. of 2,3-dihydro-6-methyl-1,7,8-trioxo-1*H*-pyrrolo[1,2-*a*]indole (XXIV) in 150 ml. of methanol was mixed with 1350 ml. of 0.1 *N* hydrochloric acid solution. The resulting pink solution was kept at 25° and its ultraviolet absorption spectrum was determined at intervals. After 10 days it had λ_{max} 290 mμ and it was yellow. The solution was saturated with salt and extracted with 500 ml. of ether. This extract was dried and concentrated. Crystallization of the residue from acetone afforded 2.8 mg. (17%) of 2,3-dihydro-7-hydroxy-6-methyl-1,5,8-trioxo-1*H*-pyrrolo[1,2-*a*]indole (XXV), yellow needles; m.p. 265° dec.; λ_{max} 3.05 (m), 5.8 (s), 6.0 (s), 6.10 (s) μ; 289 (ϵ 19,000) mμ (see Fig. 4); violet solution in dilute alkali.

Anal. Calcd. for $C_{12}H_9NO_4$ (231.20): C, 62.34; H, 3.92. Found: C, 63.26; H, 4.44.

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