peared at 49.3, 48.3, 47.1, and 46.9 ppm, respectively. Owing to the steric interaction between the C-1 OR and C-13 hydrogens, these four compounds must be shifted over toward the cis form (**2**), because the C-6 signal always appears at a lower field (~δ 51.4, as shown above), when the system exists in the *trans*-quinolizidine form. It seems that the conformation of tetrahydroprotoberberines having a substituent at C-1 position is governed by the degree of steric interaction between the C-1 substituent and C-13 hydrogens. The chemical shift due to C(6) would depend upon the position of equilibrium between cis form **2** and trans form **1**. Therefore it was estimated that (−)-capaurimine (**8**) exists as a mixture of cis and trans in the equilibrium. This is consistent with the observation of weak absorptions in the region of 2800–2700 cm^{-1} of the ir spectrum of (−)-capaurimine in solution[17] and the finding by Shamma and his coworkers that (−)-capaurimine showed an intermediate rate for methiodide formation as compared with the cis and trans model compounds.[18] Estimation of the position of equilibrium by the ^{13}C chemical shifts have been recently reported.[19,20]

It is probably worthwhile to mention the difference of the C(8) chemical shifts between the 9,10- and 10,11-substituted tetrahydroprotoberberines. The C(8) of the 9,10-substituted compounds appeared at a higher field than 54.0 ppm, while the C(8) of the 10,11-substituted ones resonates at a lower field than 57.0 ppm. The steric perturbation by the C-9 substitutent caused this difference, a fact which is useful for the structure determination of the natural products.

Experimental Section

Ir spectra were taken in chloroform or potassium bromide with a Hitachi EPI-3 recording spectrometer. Proton NMR spectra were taken with a JNM-PS-100 spectrometer operating at 100 MHz. ^{13}C NMR spectra were obtained in deuteriochloroform (0.3–0.7 *M*) with a JNM-PFT-100 system equipped with a JNM-PS-100 spectrometer operating at 25.15 MHz. Optical rotations were measured with a JASCO PIP-SL automatic polarimeter.

Racemization of (−)-*O*-Methylcapaurine (7). To a suspension of 30 mg of Adams catalyst in 10 ml of methanol which was previously saturated with hydrogen, 30 mg of (−)-*O*-methylcapaurine (**7**) was added. The mixture was shaken for 50 hr at room temperature and atmospheric pressure. After filtration of the catalyst, the combined filtrate and washing were evaporated and the residue was recrystallized from methanol to give 20 mg of (±)-*O*-methylcapaurine as colorless needles, mp 142–144° (lit.[21] mp 140–142°), $[\alpha]^{25}D$ 0° (MeOH). The ir (in $CHCl_3$) and NMR (in $CDCl_3$) spectra were superimposable on those of (−)-*O*-methylcapaurine.

Racemization of (−)-Capaurine (4). To a suspension of 60 mg of Adams catalyst in 10 ml of methanol which was previously saturated with hydrogen, 60 mg of (−)-capaurine (**4**) was added and the mixture was shaken for 96 hr under the same condition as above and worked up as before to give 40 mg of (±)-capaurine, mp 207–209° (from methanol) (lit.[21] mp 208°), $[\alpha]^{25}D$ 0° (methanol). The ir (in $CHCl_3$) and NMR (in $CDCl_3$) spectra were superimposable on those of the optically active compound (**4**).

Acknowledgments. We wish to express our gratitude to Dr. K. Takahashi and Dr. T. Honda, Pharmaceutical Institute, Tohoku University, for their help in the preparation of samples. We also thank Dr. T. Kobari, Mitsui Pharmaceutical Co. Ltd., Miss R. Kato and Miss R. Suenaga of this institute, and Mr. m. Kunugi of JEOL Ltd. for the spectral measurements.

Registry No.—(−)-**4**, 478-14-8; (±)-**4**, 478-15-9; (±)-**5**, 56437-89-9; (−)-**6**, 30758-82-8; (−)-**7**, 6033-73-4; (±)-**7**, 6033-71-2; (−)-**8**, 30758-81-7; (±)-**9**, 56437-90-2; (±)-**10**, 52346-06-2; (±)-**11**, 52346-07-3; (±)-**12**, 56437-91-3; (±)-**13**, 13407-95-9; (±)-**14**, 36295-42-8; (±)-**15**, 29074-38-2; (±)-**16**, 7762-76-7.

Supplementary Material Available. The ir spectra in potassium bromide for compounds (±)-**4**, **-7**, **-10**, **-12**, and **-13** and (−)-**4**, **-6**, **-7**, and **-8** will appear following these pages in the microfilm edition of this volume of the journal. Photocopies of the supplementary material from this paper only or microfiche (105 × 148 mm, 24× reduction, negatives) containing all of the supplementary material for the papers in this issue may be obtained from the Business Office, Books and Journals Division, American Chemical Society, 1155 16th St., N.W., Washington, D.C., 20036. Remit check or money order for $4.00 for photocopy or $2.50 for microfiche, referring to code number JOC-75-3280.

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A New Synthesis of Benzo[*a*]pyrene-6,12-quinone[1]

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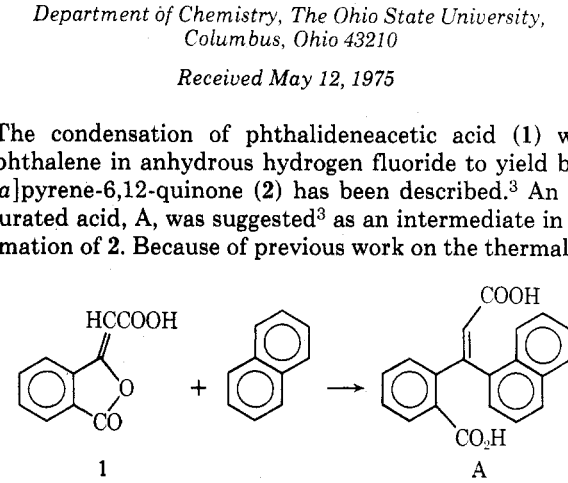
Received May 12, 1975

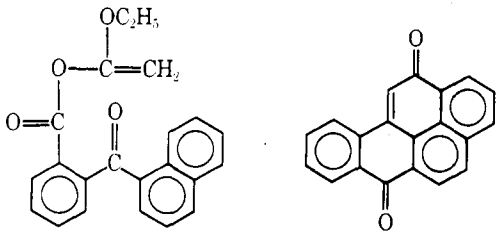
The condensation of phthalideneacetic acid (**1**) with naphthalene in anhydrous hydrogen fluoride to yield benzo[*a*]pyrene-6,12-quinone (**2**) has been described.[3] An unsaturated acid, A, was suggested[3] as an intermediate in the formation of **2**. Because of previous work on the thermal re-



1 A

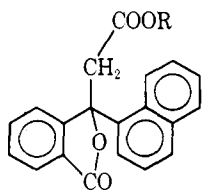
arrangement of 1-ethoxyvinyl esters of *o*-benzoylbenzoic acids[4] we were led to study the pyrolysis of 1-ethoxyvinyl *o*-(1-naphthoyl)benzoate (**3**) in the hope of obtaining **4**, a compound which might be convertible to A. Although we were unable to obtain A by pyrolysis of **4** or of the hydrolysis product **5**, we did obtain 3-carboethoxymethyl-3-(1-naphthyl)phthalide (**4**), which could be hydrolyzed to 3-(*o*-carboxyphenyl)-3-hydroxy-3-(1-naphthyl)propanoic acid (**5**) and reduced to ethyl 3-(*o*-carboxyphenyl)-3-(1-

naphthyl)propanoate (6) in high yields. Both 4 and 5 could be cyclized to 2 in good yield by anhydrous HF. Attempts to cyclize 6 or 6a to a dihydrodiketone analogous to 2 were

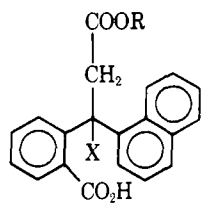


3

2

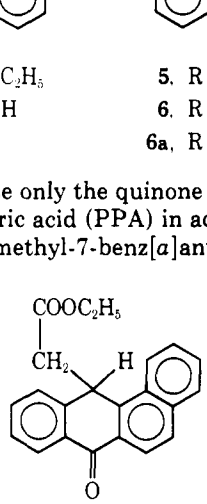


4, R = C_2H_5
4a, R = H



5, R = H; X = OH
6, R = C_2H_5; X = H
6a, R = X = H

unsuccessful because only the quinone 2 was obtained with HF or polyphosphoric acid (PPA) in addition to quantities of 12-carboethoxymethyl-7-benz[a]anthrone (7). If any



7

dihydroketone is formed it must be dehydrogenated in the reaction medium.

Thus, although our original objective to prepare A was unsuccessful, we have been able to effect a new synthesis of 2 and to provide a route which may be useful in preparing derivatives of benzo[a]pyrene. The new synthesis involves an intermediate which is closely related to the postulated intermediate, A, in the benzo[a]pyrene-6,12-quinone synthesis referred to.[3] However, judging from the fact that the synthesis involving 1 gave appreciable yields only in the case of naphthalene,[3] we believe that the present synthesis offers more versatility.

Experimental Section[5]

1-Ethoxyvinyl 2-(1-Naphthoyl)benzoate* (3). To a solution at −5° of 12.6 g (0.18 mol) of ethoxyacetylene[6] and 0.5 g of mercuric acetate in 100 ml of methylene chloride was added a solution of 16.6 g (0.06 mol) of 2-(1-naphthoyl)benzoic acid,[7] mp 164–167°, in 500 ml of dry CH_2Cl_2 during 30 min while maintaining the temperature below 0°. After 2 hr at room temperature the solvent was removed on a rotary evaporator under reduced pressure and the residue was crystallized from ethyl acetate–petroleum ether (bp 30–60°) to yield 20.76 g (92%) of 3, mp 86–87°, ir bands similar to those of 1-ethoxyvinyl o-benzoylbenzoate.[4] In attempts to purify crude 3 by column chromatography on silica gel, it was converted mainly (ca. 80%) into the n,ψ anhydride[8] of 2-(1-naphthoyl)benzoic acid, mp and mmp 200–201°. The authentic anhydride* was prepared in 79% yield (+15% of recovered keto acid) by treating 5 mmol of ethoxyacetylene with 10 mmol of keto acid in CH_2Cl_2 without mercuric acetate. A pure sample, mp 202–203°, ir bands at 5.6, 5.78, and 6.0 μ, was prepared by recrystallization from ethyl acetate–petroleum ether.

3-Carboethoxymethyl-3-(1-naphthyl)phthalide* (4). In the best of several experiments in which time and temperature of pyrolysis and method of isolation of product were varied, 15.0 g of 3 was heated at 170–180° for 12 hr. Vacuum distillation at 0.5 mm yielded a distillate (12 g) which was recrystallized from methanol to yield 7.6 g (50%) of 4, mp 140–141°, ir bands at 5.68 and 5.8 μ. No pure compound was isolated from the mixture remaining in the mother liquors.

3-(o-Carboxyphenyl)-3-hydroxy-3-(1-naphthyl)propanoic Acid (5). A solution of 6.9 g of 4 in 50 ml each of water and methanol containing 8 g of NaOH was refluxed for 3 hr. The solvents were evaporated and an aqueous solution of the residue was extracted with ether (discarded). Acidification afforded crude acid which was recrystallized from benzene–petroleum ether to yield 6.5 g (92%) of 5: mp 222–224° dec; NMR (Me_2SO-d_6) δ 2.45 (s, 2, CH_2), 6.1 (s, 1, OH), 7.2–8 (m, 11, ArH). Although the C, H analysis was 0.4 low for both C and H, 5 was completely converted into 4a on heating with dilute HCl.

3-(Carboxymethyl)-3-(1-naphthyl)phthalide* (4a). On heating 5 with 6 N HCl for 2 hr a solid was obtained which afforded pure 4a, mp 206–208, broad ir band from 5.7 to 5.9 μ, in almost quantitative yield.

Ethyl 3-(o-Carboxyphenyl)-3-(1-naphthyl)propanoate* (6). A stirred mixture of 4.5 g of 4 and 30 g of zinc (activated by stirring with 10% HCl followed by washing with water, acetone, and anhydrous ether) in 150 ml of glacial acetic acid was held at reflux for 96 hr. After a usual work-up 4.3 g (96%) of 6, mp 132–133°, ir 5.82 and 5.95 μ, NMR ($CDCl_3$, Me_4Si) δ 1.02 (t, J = 7 Hz, 3, CH_3CH_2), 3.15 (d, J = 7.5 Hz, 2, CH_2CH), 4.0 (q, J = 7 Hz, 2, CH_3CH_2), and 6.5 (t, J = 7.5 Hz, 1, CH_2CH), was obtained by crystallization from benzene–petroleum ether.

3-(o-Carboxyphenyl)-3-(1-naphthyl)propanoic Acid* (6a). Alkaline hydrolysis followed by acidification afforded 6a, mp 205–207°, in almost quantitative yield after recrystallization from benzene–petroleum ether.

Benzo[a]pyrene-6,12-quinone (2). A. HF Cyclizations. To about 50 g of liquid HF condensed in a 200-ml stainless steel bomb[9] held at −10° by a cooling bath was added 1.0 g of 5. The sealed bomb was held at 40–45° for 40 hr. The contents (cooled to below 0°) were poured into ice water and the product was worked up as usual to yield 0.65 g (77%) of 2, mp 320–322° (lit.[3] mp 327° in a block after sublimation and recrystallization). In a similar experiment 1.4 g of 4 was converted into 0.7 g (62%) of 2. Similarly, 0.7 g of 6 afforded 45% of 2 and 0.25 g (38%) of 7,* mp 115–117°, ir bands at 5.8 and 6.05 μ.

B. PPA Cyclizations. A mixture of 2.5 g of 6 and 100 ml of PPA was stirred at 80° for 24 hr and then poured on ice. After the usual work-up there was obtained 1.7 g (72%) of 7 and 0.4 g (20%) of 2 (much less soluble, slower moving on silica gel chromatography), mp 320–324°. Similarly, when 0.64 g of 6a was held at 80° with 40 ml of PPA for 4 hr, there was obtained 0.45 g (80%) of 2 but no dihydrodiketone.

Registry No.—2, 3067-12-7; 3, 56437-61-7; 4, 56437-60-6; 4a, 56437-59-3; 5, 56437-58-2; 6, 56437-57-1; 6a, 56437-56-0; 7, 56437-55-9; ethoxyacetylene, 927-80-0; 2-(1-naphthoyl)benzoic acid, 5018-87-1; 2-(1-naphthoyl)benzoic acid n,ψ-anhydride, 56437-54-8.

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(5) All melting points and boiling points are uncorrected. Microanalyses by M-H-W Laboratories, Garden City, Mich. The term "worked up in the usual way" means that an ether–benzene solution of the products was washed with suitable aqueous solutions to remove certain impurities, and with saturated salt solution, and dried by dripping through a cone of anhydrous magnesium sulfate. The solvents were then removed by distillation or by use of a rotary evaporator. All new compounds whose analysis agrees with the theoretical within ±0.3% are marked with an asterisk.
(6) Obtained from the Farchan Laboratories, Willoughby, Ohio 44094, and redistilled, bp 50–52°, just before use.
(7) P. H. Groggins and H. P. Newton, *Ind. Eng. Chem.*, **22**, 157 (1930). In our experience, the isolation of pure 2-(1-naphthoyl)benzoic acid, mp 170–172°, is not so easy as implied in this article. Several recrystallizations from toluene are required before acid of mp 164–167° can be obtained.
(8) See ref 4 for discussion concerning the n,ψ structure for the anhydride of o-benzoylbenzoic acid.
(9) Model 4753 from the Parr Instrument Co., Moline, Ill. 61265.