the C-19 methyl group but has no unsaturation in ring A. The desired compound was prepared using 17-oxo-5α-estran-3α-ol[6] as the starting material. The enol diacetate IIIa was prepared without difficulty and was treated with perbenzoic acid, to yield the epoxy compound V, which was not isolated, but was directly hydrolyzed and rearranged with methanolic sodium hydroxide to the 16-keto-17β,3α-diol VIa.[3,5] The diacetate VIb prepared from VIa was then deacetoxylated with zinc in acetic acid[7] to yield the desired 16-oxo-5α-estran-3α-ol acetate VIc which was hydrolyzed to the free 3-hydroxy compound, VId.

The new 19-nor 16-ketone upon exposure to the usual conditions of exchange with isopropenyl acetate yielded the enol diacetate IIIb in a yield comparable to the corresponding androstan-16-one compound. The structure of the new enol diacetate was assigned by analogy to the enol diacetate obtained from the corresponding C-19 derivative,[4] with enolization occurring towards C-17, although it is possible that a small percentage of the isomeric Δ^{15}-enol acetate was also present. The results obtained confirm what might have been predicted, that the aromatic nature of ring A accounts for the difference observed in ring D and that "buttressing"[2] effects of the C-19 methyl group are immaterial as far as this aspect of ring D chemistry is concerned.

There appears to be no obvious reason for the failure of the C-16 ketone with an aromatic ring A to enolize and yield an enol acetate, in contrast to the corresponding ring A saturated compounds. It is possible that an extension of the conformational argument used to explain the lesser enolization of C-16 ketone *vs.* C-17 ketone in the androstane series[5] can be applied. By this rationale, the stability difference between the C-16 and C-17 ketones is magnified in the presence of an aromatic ring A due to long-range conformational effects. The resultant greater energy difference between the C-16 ketone and its enol in the ring A aromatic compound will then account for the lack of formation of the enol acetate. Admittedly, the angular distortions due to these long-range conformational effects are not apparent from models, but they may be of a more subtle nature and also the models are not adequately representational of ring D conformation.

Experimental[8]

5α-Estr-16-ene-3α,17-diol Diacetate (IIIa).—To a solution of 2.8 g. of 3α-hydroxy-5α-estran-17-one in 30 ml. of isopropenyl acetate was added 5 ml. of isopropenyl acetate containing 0.1 ml. of H_2SO_4. The solution was allowed to distil slowly, so that after 1.5 hr. 10 ml. of distillate was collected. Another 15 ml. of isopropenyl acetate containing 0.02 ml. of H_2SO_4 was then added, and the solution was concentrated to half volume by slow distillation during 1.5 hr. The reaction mixture was cooled and diluted with 200 ml. of ethyl ether and was then washed with cold sodium bicarbonate solution and water. After drying, the solvent was removed and the residue was taken up in hot petroleum ether (b.p. 30–60°) and filtered through a short (5 g.) acid-washed alumina column. Concentration of the petroleum ether gave 2.6 g. of IIIa, m.p. 158–162°, $[\alpha]^{24}D$ −145°.

Anal. Calcd. for $C_{22}H_{32}O_4$: C, 73.30; H, 8.95. Found: C, 73.42; H, 9.21.

16-Oxo-5α-estrane-3α,17β-diol (VIa).—A solution of 2.0 g. of enol diacetate IIIa in 25 ml. of chloroform was allowed to stand with a 10% excess of perbenzoic acid at 5° for 20 hr. The solution was then washed with 0.1 *N* NaOH solution and water, dried, and evaporated. The colorless oily residue containing the epoxide V was dissolved in 250 ml. of methanol, and 120 ml. of 1 *N* NaOH solution was added. After standing at room temperature for 72 hr., the reaction mixture was concentrated to one-third volume *in vacuo* and extracted well with ether, which was washed with water, dried, and evaporated. The residue was chromatographed on silica. Elution with chloroform and crystallization from dilute methanol gave the VIa, m.p. 160–164°.

Anal. Calcd. for $C_{18}H_{28}O_3$: C, 73.93; H, 9.65. Found: C, 74.10; H, 9.43.

The diacetate VIb prepared in the usual manner resisted crystallization.

16-Oxo-5α-estran-3α-ol (VId).—A solution of 750 mg. of oily diacetate VIb in 90 ml. of acetic acid and 4 ml. of acetic anhydride was refluxed with 40 g. of zinc dust for 24 hr. The metal was filtered off and washed well with hot ethanol. The filtrate was concentrated under vacuum, diluted with water, and extracted with ether. The ether was washed with 5% sodium bicarbonate solution and then water, dried, and evaporated. The residue was chromatographed on acid-washed alumina. Elution with 4:1 petroleum ether–benzene and crystallization from petroleum ether–acetone gave 140 mg. of 16-oxo-5α-estran-3α-ol acetate (VIc), m.p. 90–92°, $[\alpha]^{24}D$ −138°.

Anal. Calcd. for $C_{20}H_{30}O_3$: C, 75.43; H, 9.50. Found: C, 75.24; H, 9.28.

The acetate VIc was hydrolyzed in the usual manner in refluxing methanolic potassium hydroxide to give, after work-up and crystallization from acetone–petroleum ether, VId, m.p. 153–155°, $[\alpha]^{24}D$ −140°.

Anal. Calcd. for $C_{18}H_{28}O_2$: C, 78.21; H, 10.21. Found: C, 77.92; H, 9.82.

5α-Estr-16-ene-3α,16-diol Diacetate (IIIb).—A 50-mg. sample of VIc was dissolved in 6 ml. of isopropenyl acetate and 0.2 ml. of a solution prepared from 0.1 ml. of H_2SO_4, and 5 ml. of isopropenyl acetate was added. The reaction solution was slowly distilled so that one-third of the volume distilled in 1.5 hr. An additional 3 ml. of isopropenyl acetate and 0.1 ml. of the catalyst solution was added, and the slow distillation was continued for another 1.5 hr. The work-up and chromatography were carried out as described above to give 24 mg. of crystalline enol diacetate IIIb, m.p. 139–142°. Recrystallization from petroleum ether gave the analytical sample, m.p. 142–145°.

Anal. Calcd. for $C_{22}H_{30}O_4$: C, 73.71; H, 8.44. Found: C, 73.46; H, 8.53.

(7) R. S. Rosenfeld and T. F. Gallagher, *J. Am. Chem. Soc.*, **77**, 4367 (1955).

(8) Melting points were determined on a Fisher-Johns block and are uncorrected. Analyses were by Spang Laboratory, Ann Arbor, Mich.

7-Phenyldibenz[*a*,*h*]anthracene and Benzo[*e*]naphtho[1,2-*b*]pyrene[1,2]

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There have been three general methods applied to the preparation of dibenz[*a*,*h*]anthracene derivatives. The first which was developed by Clar,[4] is based on the Elbs reaction in which an appropriate ketone is converted to the dibenz[*a*,*h*]anthracene by pyrolysis. This method affords by far the most rapid and economical method known for the synthesis of the parent hydrocarbon but is not entirely satisfactory for the preparation of its derivatives since cleavage often occurs during pyrolysis. No substituents can be put in the

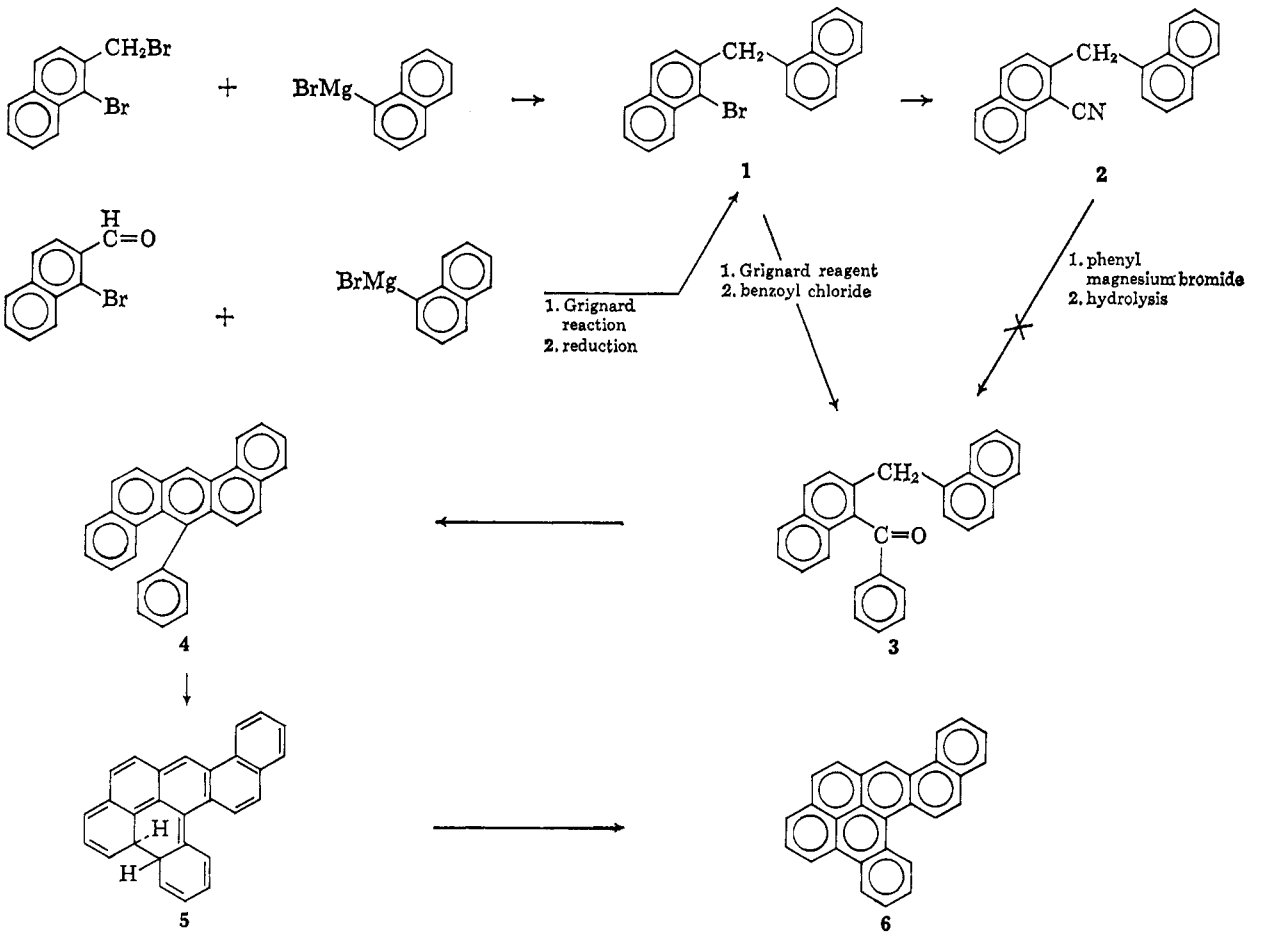
(1) The nomenclature used in this paper is that presented in the "Definitive Rules for Nomenclature of Organic Chemistry," *J. Am. Chem. Soc.*, **82**, 5545 (1960).

(2) Presented before the Division of Organic Chemistry at the Southeastern Regional Meeting of the American Chemical Society, Charlotte, N. C., Nov. 1963.

(3) Abstracted in part from the M.S. Thesis of P. D. H. presented to the Virginia Polytechnic Institute, 1962. National Defense Education Act Fellow, 1960–1963; Eastman Kodak Fellow, 1963–1964.

(4) E. Clar, *Ber.*, **62**, 350 (1929).

CHART I



meso position since, as shown by Fieser and Newman,[5] groups attached to the methyl group that is involved in ring closure are cleaved during the high-temperature reaction. A second method is based on the reaction of dibenz[*a*,*h*]anthraquinone and an appropriate Grignard reagent followed by reduction of the resultant carbinol to the hydrocarbon. This method is limited to the preparation of derivatives with substituents in both of the *meso* positions.[6] A third method is based on the reaction of 2-(1-naphthoyl)-1-naphthoic acid with an appropriate Grignard reagent and the cyclization of the resulting lactone to the corresponding anthrone followed by reduction and dehydration to the hydrocarbon.[7] In addition to these rather general procedures, several specific synthetic routes[8] have accounted for the remainder of the limited number of dibenz[*a*,*h*]anthracenes which have been prepared.

An aromatic cyclodehydration procedure[9] which has been used to prepare anthracenes and benz[*a*]anthracenes has not been extended to the preparation of dibenz[*a*,*h*]anthracenes. It is believed that this procedure may facilitate the preparation of many dibenz[*a*,*h*]anthracene derivatives.

The synthetic procedures used to prepare 7-phenyldibenz[*a*,*h*]anthracene and benzo[*e*]naphtho[1,2-*b*]pyrene are shown in Chart I.

The older approach to 1-bromo-2-(1-naphthylmethyl)naphthalene[10] (**1**) involves the reaction of 1-bromo-2-naphthaldehyde with 1-naphthylmagnesium bromide to give a mixture which, on reduction, affords an over-all yield of 14%[11] of **1**. An improved method was developed which involves the coupling of 1-naphthylmagnesium bromide with 1-bromo-2-bromomethylnaphthalene to give a 32%[11] yield of **1** using a recently devised procedure.[12] The nitrile **2** was prepared from **1** in 80% yield using a Rosenmund–von Braun reaction.

An attempt to prepare the ketone **3** by the interaction of **2** with phenylmagnesium bromide followed by hydrolysis failed. The nitrile **2** is badly sterically hindered as evidenced by its failure to hydrolyze when subjected to usual acid hydrolysis. When **2** was treated with a mixture of 48% hydrobromic acid and glacial acetic acid in a sealed tube at 180°, the product, surprisingly, was dibenz[*a*,*h*]anthracene. It was suspected that the strong conditions effected the hydrolysis of the nitrile to the corresponding acid followed by ring closure and reduction to the final observed product. Since the yield of fully aromatic product was always less than 50%, it may be that organic material functioned as a reducing agent.

In order to check this possibility, the acid, 2-(1-naphthylmethyl)-1-naphthoic acid, was prepared by carbonation of the Grignard reagent of **1** and, when treated under the same experimental conditions as the

(5) L. Fieser and M. Newman, *J. Am. Chem. Soc.*, **58**, 2376 (1936).
(6) J. Cook, *J. Chem. Soc.*, 491 (1931).
(7) L. Fieser and G. Kilmer, *J. Am. Chem. Soc.*, **61**, 462 (1939).
(8) L. Hornig, *ibid.*, **74**, 4572 (1952); J. Cook, *J. Chem. Soc.*, 3273 (1931); H. Creech and W. Franks, *J. Am. Chem. Soc.*, **60**, 127 (1938).
(9) C. K. Bradsher, *ibid.*, **62**, 486, 1077 (1940).
(10) E. A. Evans, *J. Chem. Soc.*, 2797 (1957).
(11) Based on 1-bromo-2-bromomethylnaphthalene.
(12) F. A. Vingiello, S. G. Quo, and J. E. Sheridan, *J. Org. Chem.*, **26**, 3202 (1961).

nitrile (2), it gave dibenz[*a*,*h*]anthracene in essentially the same yield.

A second approach to the preparation of ketone **3** succeeded. A 67% yield of **3** was realized when the Grignard reagent of **1** was allowed to react with benzoyl chloride. It is interesting to note that, owing to the hindered nature of **3**, "direct" addition works well.

While a mixture of hydrobromic–acetic acids at 180° effected the quantitative conversion of 2-(1-naphthylmethyl)-1-naphthophenone (**3**) to 7-phenyldibenz[*a*,*h*]-anthracene (**4**), a 40% yield was effected by simply heating **3** with glacial acetic acid. The hydrocarbon **4** reacted with TNF[13] to give an adduct which melted at 211–212° but unfortunately appeared to be relatively unstable and decomposed when attempts were made at recrystallization.

All attempts to dehydrogenate **4** to **6** failed and either starting material was recovered or **5** was isolated. The use of known dehydrogenation agents such as $AlCl_3$ and $AlCl_3$–$SnCl_4$ in benzene or as melts resulted in recovery of starting material or, at best, a yield of 30% of a dihydro compound which is most likely **5**. Although a structure for the dihydro compound **5** has not been thoroughly established, the tentatively assigned structure is consistent with the elemental analysis and the ultraviolet data which suggest strongly that the benz[*a*]anthracene portion of the molecule is not aromatic. The 260–300-mμ region of the spectrum is devoid of the typical sharp peaks characteristic of the aromatic benz[*a*]anthracene system.[14] Selenium, a known aromatization reagent, was incorporated into the reaction mixture in an attempt to prepare **6**. This still gave only the dihydro compound **5** but the yield was 50% and the product was easier to isolate. Small amounts of water in the benzene caused the reaction to fail and only starting material was recovered. The substitution of pyridine for benzene had a like effect. A stable 1:1 adduct formed between **5** and TNF.[13] When **5** was treated with DDQ[15] in benzene, a 70% yield of the fully aromatic **6** was isolated. A stable 1:1 adduct formed between **6** and TNF.[13]

The phenyl ring in **4** is nonplanar with the dibenz[*a*,*h*]anthracene moiety. As we proceed to **5** and finally to **6** this ring is forced more nearly into a planar arrangement. It is interesting to note that this is reflected in the color changes as we proceed from **4** to **5** to **6**. The color changes from white to yellow-orange to red, a bathochromic shift consistent with increasing conjugation. The corresponding TNF[13] adducts also reflect this change in planarity. The adduct of **4** is red, melts at 212°, and is unstable; the adduct of **5** is black, melts at 237°, and is stable; the adduct of **6** is black, melts at 275°, and is also stable.

Experimental[16–18]

1-Bromo-2-(1-naphthylmethyl)naphthalene (1). A. From 1-Bromo-2-naphthaldehyde.—This compound was prepared in 14% yield using essentially the procedure of Evans.[19] The required aldehyde was prepared in 54% yield from 1-bromo-2-bromomethylnaphthalene and this was allowed to react with 1-naphthylmagnesium bromide. The product was reduced to 1-bromo-2-(1-naphthylmethyl)naphthalene using a suspension of aluminum chloride and lithium aluminum hydride in ether.

B. From 1-Bromo-2-bromomethylnaphthalene.—A Grignard reagent was prepared from 3.2 g. (0.15 g.-atom) of magnesium turnings and 32 g. (0.15 mole) of 1-bromonaphthalene in 150 ml. of dry ether. When most of the magnesium had reacted, the ether was replaced with benzene and 30 g. (0.1 mole) of 1-bromo-2-bromomethylnaphthalene in 200 ml. of dry benzene was added. The mixture was refluxed for 14 hr., cooled, and decomposed with 100 ml. of 10% hydrochloric acid. The organic layer was separated, washed with water, dried, and concentrated. The residual oil was distilled under reduced pressure and the product was collected as a viscous, greenish yellow oil, b.p. 200–240° (0.8 mm.). The oil was crystallized from petroleum ether (b.p. 30–60°) and purified by elution chromatography,[20] yielding 11.0 g. (32%) of pure product, m.p. 96–97° (lit.[19] m.p. 96–97°).

2-(1-Naphthylmethyl)-1-naphthonitrile (2).—A mixture of 10.0 g. of **1**, 10.0 g. of cuprous cyanide, a crystal of cupric sulfate, and 25 ml. of dry pyridine was heated at 180° for 1 hr. and then at 250° for 15 hr. The mixture was then poured into 200 ml. of ammonium hydroxide and stirred. The ammoniacal solution was extracted with benzene and the benzene extracts were washed with water and dried over magnesium sulfate. The benzene was replaced with ethanol; the solution was treated with charcoal and allowed to cool giving white needles of **2**, 6.8 g. (80%), m.p. 121–123°. The product was recrystallized to a constant melting point of 123–124° from ethanol.

Anal. Calcd. for $C_{22}H_{15}N$: C, 90.07; H, 5.15; N, 4.78. Found: C, 89.94; H, 5.12; N, 4.62.

2-(1-Naphthylmethyl)-1-naphthophenone (3).—A Grignard reagent was prepared in ether from 4.0 g. (0.01 mole) of 1-bromo-2-(1-naphthylmethyl)naphthalene (**1**) and 0.26 g. (0.012 g.-atom) of magnesium turnings. When the reaction was complete, the solution was boiled and the ether was allowed to distil while a solution of 1.4 g. (0.015 mole) of benzoyl chloride in 100 ml. of dry benzene was added slowly. When the boiling point of the solution reached 75°, the solution was diluted with 50 ml. of dry benzene and refluxed for 3 hr. The reaction mixture was then cooled and decomposed with cold dilute sulfuric acid, and the organic layer was separated, washed with 10% sodium carbonate solution, then water, dried, and concentrated. The oil was crystallized from ethanol. The brown prisms were dissolved in ethanol–benzene, treated with charcoal, and allowed to crystallize giving 2.6 g. (67%) of **3**, m.p. 185–187°.

The analytical sample was obtained by recrystallization from ethanol–benzene giving white needles, m.p. 187–187.5°.

Anal. Calcd. for $C_{28}H_{20}O$: C, 90.29; H, 5.41. Found: C, 90.44; H, 5.17.

7-Phenyldibenz[*a*,*h*]anthracene (4).—A mixture of 2.0 g. of **3**, 30 ml. of glacial acetic acid, and 15 ml. of 48% hydrobromic acid was sealed in a Carius tube and heated in a Carius furnace at 180° for 2 hr. The mixture was cooled and extracted with benzene and the extract was washed with water, 10% sodium carbonate solution, and again with water, dried, and concentrated. Brown crystals formed when the oil was treated with ethanol and allowed to stand. This solid was recrystallized from ethanol–benzene (charcoal) giving small white crystals, m.p. 251–253°, 1.8 g. (95%).

The analytical sample was obtained by recrystallization from ethanol–benzene, m.p. 254°.

Anal. Calcd. for $C_{28}H_{18}$: C, 94.88; H, 5.12. Found: C, 94.89; H, 5.51.

The wave length maxima for **4** are λ 340, 326, 300, 290, and 279 mμ.

Dibenz[*a*,*h*]anthracene. A. From Cyclization of Nitrile.—A mixture of 0.5 g. of **2**, 30 ml. of glacial acetic acid, and 15 ml. of 48% hydrobromic acid was sealed in a Carius tube and heated in a Carius furnace at 180° for 4 hr. The product was isolated as has been described above for **4**. Dibenz[*a*,*h*]anthracene was obtained: m.p. 262–264° (lit.[21] m.p. 260–261°), 0.16 g. (35%).

(13) 2,4,7-Trinitrofluorenone.

(14) The authors appreciate the constructive comments of the referee regarding the structure of **5**.

(15) 2,3-Dichloro-5,6-dicyanobenzoquinone.

(16) *All boiling points are uncorrected. All melting points were taken on a Fisher-Johns melting apparatus and are corrected.*

(17) All analyses were carried out by Geller Laboratories, Bardonia, N. Y., except those marked with an asterisk which were performed by Galbraith Laboratories, Knoxville, Tenn.

(18) The infrared data were taken on a Beckman Model IR-5 spectrophotometer. The ultraviolet data were taken on a Beckman Model DK-2A spectrophotometer using a 1-cm. quartz cell and ethanol as the solvent.

(19) E. A. Evans, *J. Chem. Soc.*, 2797 (1957).

(20) The chromatography column used in this investigation was 18 × 275 mm. packed with Fisher's basic alumina, Brockman activity I, 80–200 mesh. The eluent was petroleum ether (b.p. 30–60°).

(21) E. A. Evans, *J. Chem. Soc.*, 2792 (1957).

B. From Cyclization of Acid.—A mixture of 0.5 g. of 2-(1-naphthylmethyl)-1-naphthoic acid, prepared by carbonating the Grignard reagent of 1, 30 ml. of glacial acetic acid, and 15 ml. of 48% hydrobromic acid was treated as has been described above under A, and the product was isolated similarly. Dibenz[*a,h*]-anthracene was obtained: m.p. 259–262°, 0.18 g. (40%).

10a,10b-Dihydrobenzo[*e*]naphtho[1,2-*b*]pyrene (5).—A mixture of 0.5 g. of 7-phenyldibenz[*a,h*]anthracene, 1.0 g. of $AlCl_3$, 0.5 g. of selenium powder, and 50 ml. of dry benzene was heated under reflux for 15 min. The reaction mixture was cooled and the complex mixture was decomposed with dilute hydrochloric acid and extracted with benzene. The benzene solution was concentrated and chromatographed on neutral alumina.[20] The first band, a colorless blue fluorescent band, was discarded. The second band, a yellow green fluorescent band, was collected and the solvent was removed giving orange needles, m.p. 186–187°, 0.25 g. (50%), of 5.

Anal. Calcd. for $C_{23}H_{18}$: C, 94.88; H, 5.12. Found: C, 94.39; H, 5.31.

The wave length maxima for 5 are λ 325, 285, and 252 mμ.

TNF Adduct of 5.—The adduct was prepared by mixing hot benzene–ethanol solutions of 5 and TNF. The product was obtained as fine black needles, m.p. 232–233°, from benzene–ethanol.

Anal. Calcd. for $C_{41}H_{23}N_3O_7$: C, 73.52; H, 3.47; N, 6.28. Found: C, 73.16; H, 3.86; N, 6.84.

Benzo[*e*]naphtho[1,2-*b*]pyrene (6).—A mixture of 0.50 g. of 5, 0.50 g. of DDQ,[15] and 35 ml. of dry benzene was heated under reflux for 20 hr. The solution was cooled and diluted with 150 ml. of benzene. The solution was washed with 10% NaOH and then with water, dried over $MgSO_4$, and concentrated. The concentrate was chromatographed on alumina.[20] The third band (reddish orange) which was eluted from the column was collected and gave red needles, m.p. 265–267°, 0.35 g. (70%). The analytical sample, m.p. 266–267°, was prepared by first subliming the material *in vacuo* and then recrystallizing the sublimate from benzene–ethanol.

Anal. Calcd. for $C_{28}H_{16}$: C, 95.42; H, 4.58. Found*: C, 95.32; H, 4.42.

The wave length maxima for 6 are λ 390 336, 319, 307, 275, and 263 mμ.

TNF Adduct of 6.—This adduct was prepared essentially as was the adduct of 5, m.p. 275–276°.

Anal. Calcd. for $C_{41}H_{21}N_3O_7$: C, 73.76; H, 3.17; N, 6.29. Found*: C, 73.79; H, 3.33; N, 5.79.

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The Formation and Rearrangement of 8a-Amino-4a,5,6,7,8,8a-hexahydro-4H-1-benzopyrans

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The reaction of enamines derived from alicyclic ketones with acrolein to give bicyclic amino ketones was first reported by Stork and Landesman.[1] The versatility of the reaction and its use in the synthesis of medium-size rings was studied in detail by Untch,[2] but only a limited investigation of the possible reaction intermediates was described.

Our interest in N-phenylpiperazyl Mannich bases as potential analgetic agents led us to synthesize a series of 2-(4-phenyl-1-piperazyl)bicycloalkanones (Table II). This report is concerned with the isolation and rearrangement of aminohexahydrobenzopyran intermediates (Table I) formed in the reaction of certain enamines with α,β-unsaturated carbonyl compounds.

The reaction of acrolein with 1-(1-cyclohexen-1-yl)-4-phenylpiperazine in dry benzene at 10° resulted in the formation of a crystalline compound, m.p. 117–118°. The elemental analysis indicated that addition of acrolein to the enamine had taken place. The infrared spectrum ($CHCl_3$) showed no carbonyl band, but a sharp band of medium intensity was present at 1660 cm.$^{-1}$. This suggested that we were dealing with the aminohexahydrobenzopyran derivative I. Confirmatory evidence for this structure was provided by the n.m.r. spectrum ($CDCl_3$) which showed resonance peaks at τ = 3.87 (doublet) and 5.41 (multiplet) p.p.m. due to the 2- and 3-protons of the dihydropyran nucleus. An analogous addition reaction occurs with aldehyde enamines and α,β-unsaturated aldehydes.[3] As expected, compound I is very unstable in the presence of acid; immediate and practically quantitative decomposition to N-phenylpiperazine hydrochloride and 3-(2-oxocyclohexyl)propionaldehyde[4] occurs upon treatment with dilute hydrochloric acid at 0°.

The formation of aminohexahydrobenzopyran derivatives seems to be general for the reaction of cyclohexanone enamines with acrolein. We found that in the case of the previously reported 2-morpholinobicyclo[3.3.1]nonan-9-one,[1] the aminohexahydrobenzopyran was the precursor. After a solution of acrolein and 4-(1-cyclohexen-1-yl)morpholine in dry benzene had been allowed to stand at room temperature for a few hours, the solvent was removed *in vacuo* to give a liquid whose infrared spectrum showed the typical enol ether band at 1660 cm.$^{-1}$. Vacuum distillation converted this material into the bicyclic amino ketone.

That the stereochemical requirements for formation of aminohexahydrobenzopyran intermediates are quite stringent was shown by the fact that 1-(1-cyclopenten-1-yl)-4-phenylpiperazine and 1-(1-cyclohepten-1-yl)-4-phenylpiperazine on reaction with acrolein gave the bicyclic amino ketones VI and VII (Table II) directly. Furthermore, when 1-(1-cyclohexen-1-yl)-4-phenylpiperazine was allowed to react with cinnamaldehyde, no intermediate was isolated; the bicyclic amino ketone VIII was obtained in good yield from benzene solution.

When compound I was heated in dimethylformamide–triethylamine solution, a mixture of isomeric bicyclic amino ketones (II and III) was formed in 84% yield. The infrared spectrum now exhibited a strong ketone carbonyl band at 1710 cm.$^{-1}$; the band at 1660 cm.$^{-1}$ in compound I was absent. Unequivocal proof of structure for II was obtained by degradation to 4-cyclooctene-1-carboxylic acid and formation of the known carboxamide.[1] An attempt was made to degrade compound III by this method, but no cyclooctenecarboxylic acid could be detected.

Results obtained from column and thin layer chromatography indicated that the bicyclic amino ketone mixture consisted of at least 75% II, m.p. 129–130°. Compound III, m.p. 100–101°, could be isolated in yields ranging from 5 to 20%. The stereochemistry

(1) G. Stork and H. K. Landesman, *J. Am. Chem. Soc.*, **78**, 5129 (1956).
(2) Karl G. Untch, Ph.D. Thesis, Columbia University, 1959; Microfilm 60-1163, University Microfilms, Inc., Ann Arbor, Mich.
(3) G. Opitz and I. Löschmann, *Angew. Chem.*, **72**, 523 (1960).
(4) J. Colonge, J. Dreux, and M. Thiers, *Bull. soc. chim. France*, 370 (1959).