The Syntheses of 4b,5a-Dihydrodibenz[3,4:5,6]anthra[1,2-*b*]oxirene and 4b,5a-Dihydro-5*H*-dibenz[3,4:5,6]anthra[1,2-*b*]azirine

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The syntheses of the *K*-oxide and *K*-imine derivatives of dibenz[*a,j*]anthracene (**1**) are described. The parent hydrocarbon **1** that was obtained as a side product in the Elbs pyrolysis of (2-methyl-1-naphthyl)-1′-naphthylmethanone (**10**) was oxidized to 3-(2-formylphenyl)-3-phenanthrenecarboxaldehyde (**3**). Treatment of the dialdehyde with tris(dimethylamino)phosphine gave 4b,5a-dihydrodibenz[3,4:5,6]anthra[1,2-*b*]oxirene (**4**). Reaction of the oxirane with sodium azide followed by triethyl phosphite cyclization of the mixture of *trans* azido-alcohols so formed, yielded mainly 4b,5a-dihydrodibenz[3,4:5,6]anthra[1,2-*b*]azirine (**5**).

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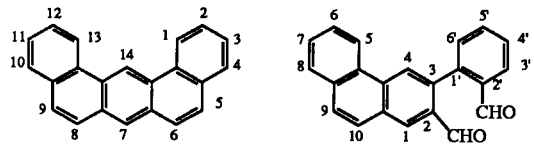
In the course of our study on active metabolites of carcinogenic polycyclic aromatic hydrocarbons, we have previously synthesized various imines derived from benz[*a*]anthracene [1-5], chrysene [6,7], benzo[*g*]chrysene [7], benzo[*c*]phenanthrene [5], benzo[*a*]pyrene [1] and dibenz[*a,h*]anthracene [1,8]. Most of these aziridines have already been subjected to biological tests and proved to have substantially higher mutagenic potencies than the corresponding arene oxides [9]. As we noticed that neither the K-region imine nor the corresponding oxide derivative of the fairly carcinogenic dibenz[*a,j*]anthracene has ever been prepared (although the syntheses of the bay region diol epoxides of this hydrocarbon have lately been reported [11,12]), we found it interesting to complete our selection of K-region metabolites by synthesizing 4b,5a-dihydrodibenz[3,4:5,6]anthra[1,2-*b*]oxirene (**4**) and its respective arene imine **5**.

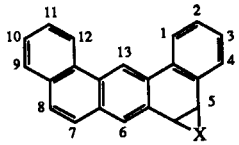
The parent hydrocarbon **1** was oxidized by osmium tetroxide in pyridine [13] in 72% yield. Further oxidation of the *cis*-5,6-dihydro-5,6-dibenz[*a,j*]anthracenediol (**2**), so formed, with sodium metaperiodate, gave smoothly the dialdehyde **3**. Treatment of the dialdehyde with tris(dimethylamino)phosphine afforded 80% of **4**. Nucleophilic ring opening of the oxirane moiety of **4** by azide ion furnished a 1:1 mixture (as evidenced by pmr spectroscopy) of *trans*-6-azido-5,6-dihydro-6-dibenz[*a,j*]anthranol (**6**) and *trans*-5-azido-5,6-dihydro-5-dibenz[*a,j*]anthranol (**7**). Triethyl phosphite cyclization [2] of **6** and **7** afforded a mixture of 71% of 4b,5a-dihydrodibenz[3,4:5,6]anthra[1,2-*b*]azirine (**5**) and 7% of the two phosphoramidates **8** and **9** (*Cf.* [2]). Separation between the latter compounds (that could not be converted into **5** by pyrolysis) and the imine was accomplished by column chromatography on type III deactivated alumina.

It is noteworthy, that although (2-methyl-1-naphthyl)-1′-naphthylmethanone (**10**) was claimed to form after 5 hours at 430° mainly dibenz[*a,h*]anthracene (**11**) accompanied by *ca.* 10% of benzo[*a*]naphthacene (**12**) owing to initial rearrangement into (2-methyl-1-naphthyl)-2′-naphthylmethanone (**13**) [14], we found that **10** yields a mixture of **11** and **1** (free of **12**) when heated at 420° for just 45 minutes. Thus, although the yield of **1** in this process is only 2%, its easy separation from sparingly soluble **11**, still makes the simple Elbs reaction of **10** an attractive synthesis of **1**.

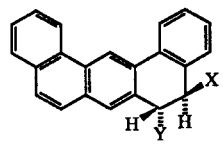
Scheme



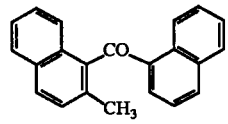
1 **3**



4, X = O
5, X = NH



6, X = OH Y = N_3
7, X = N_3 Y = OH
8, X = OH Y = NHP(O) $(OC_2H_5)_2$
9, X = NHP(O) $(OC_2H_5)_2$ Y = OH



10

EXPERIMENTAL

cis-5,6-Dihydro-5,6-dibenz[*a,j*]anthracenediol (**2**).

By a modification of Cook's hydrocarbon oxidation [13], a mixture of 1.0 g of **1**, 1.0 g of osmium tetroxide and 35 ml of dry pyridine was stirred in the dark under exclusion of air for 5 days. The mixture was then treated for 3 hours with 20 ml of an aqueous 10% sodium bisulfite solution. Addition of excessive water furnished 810 mg (72%) of **2** as colorless crystals, mp

227-228° (lit [13] 226-228°); ir (nujol): 3290 cm^{-1} (OH); pmr (hexadeuteriodimethyl sulfoxide): 300 MHz δ 4.702 (d, 1H, $J_{5,6}$ = 3.1 Hz, H5 or H6), 4.824 (d, 1H, $J_{5,6}$ = 3.1 Hz, H5 or H6), 7.337-7.998 (m, 8H, Ar*H*), 8.079 (s, 1H, H7), 8.340 (dd, 1H, $J_{1,2}$ = 8 Hz, $J_{1,3}$ = 2 Hz, H1), 9.087 (dd, 1H, $J_{11,13}$ = 2.2 Hz, $J_{12,13}$ = 8.1 Hz, H13), 9.208 (s, 1H, H14).

3-(2-Formylphenyl)-2-phenanthrenecarboxaldehyde (**3**).

To a mixture of 750 mg of **2** in 1 l of methanol was added a solution of 5 g of sodium metaperiodate in 300 ml of water. The mixture was stirred under nitrogen at room temperature for 48 hours. The methanol was removed under reduced pressure and the residue was extracted with dichloromethane. After the usual workup, the residue was chromatographed on silica gel using hexane-ether mixtures (containing from 10 to 60% of ether) as eluent, there was obtained 621 mg (83%) of **3** as pale yellow crystals, mp 60-61°; ir (nujol): 1670 cm^{-1} (C=O); pmr (deuteriochloroform): 300 MHz δ 7.180-7.682 (m, 5H, H4', H5', H6, H7, H8), 7.818 (d, 2H, $J_{9,10}$ = 7.4 Hz, H9, H10), 7.873 (dd, 1H, $J_{4',6'}$ = 1.9 Hz, $J_{5',6'}$ = 7.9 Hz, H6'), 8.050 (dd, 1H, $J_{3',4'}$ = 8.9 Hz, $J_{3',5'}$ = 1.9 Hz, H3'), 8.509 (s, 1H, H1), 8.516 (s, 1H, H4), 8.545 (dd, 1H, $J_{5,6}$ = 9.4 Hz, $J_{5,7}$ = 2.5 Hz, H5), 9.828 (s, 1H, C*H*O), 9.952 (s, 1H, C*H*O); ms: (70 eV, 120°) m/e (relative intensity) 310 ($M^{+\cdot}$, 10), 282 ($C_{21}H_{14}O^{+\cdot}$, 30), 281 ($C_{21}H_{13}O^{+}$, 100), 265 ($C_{21}H_{13}^{+}$, 4); 252 ($C_{20}H_{12}^{+\cdot}$, 30), 181 ($C_{13}H_{9}^{+}$, 22), 176 ($C_{14}H_{8}^{+\cdot}$, 10), 140 ($C_{11}H_{8}^{+\cdot}$, 11), 126 ($C_{10}H_{6}^{+\cdot}$, 14).

Anal. Calcd. for $C_{22}H_{14}O_2$: C, 85.14; H, 4.55. Found: C, 84.92; H, 4.80.

4b,5a-Dihydrodibenz[3,4:5,6]anthra[1,2-*b*]oxirene (**4**).

A solution of 600 mg of **3** and 370 mg of tris(dimethylamino)-phosphine in 15 ml of dry benzene was refluxed under nitrogen for 3 hours. Upon slow cooling, **4** separated as colorless leaflets. The filtered crystals were washed with a 1:1 mixture of hexane and ether to yield 453 mg (80%) of the analytically pure epoxide, mp 144-145°; ir (nujol): 1150 cm^{-1} (C-O); uv (chloroform): λ max (log ε) 286 (4.30), 298 (4.04), 3.04 (4.18), 308 (4.13), 326 (4.16), 368 (2.38), 370 (2.61), 380 (2.21), 384 nm (2.28); pmr (deuteriochloroform): 300 MHz δ 4.551 (d, 1H, $J_{4b,5a}$ = 3.9 Hz, H4b or H5a), 4.655 (d, 1H, $J_{4b,5a}$ = 3.9 Hz, H4b or H5a), 7.378-7.753 (m, 7H, H2, H3, H7, H8, H9, H10, H11), 7.885 (d, 1H, $J_{3,4}$ = 7.5 Hz, H4), 8.070 (s, 1H, H6), 8.377 (d, 1H, $J_{1,2}$ = 8 Hz, H1), 8.755 (d, 1H, $J_{11,12}$ = 7 Hz, H12), 9.341 (s, 1H, H13); ms: (70 eV, 125°) m/e (relative intensity) 294 ($M^{+\cdot}$, 100), 278 ($C_{22}H_{14}^{+\cdot}$, 17), 265 ($C_{21}H_{13}^{+}$, 43), 202 ($C_{16}H_{10}^{+\cdot}$, 2), 132 ($C_9H_8O^{+\cdot}$, 14), 119 ($C_8H_7O^{+}$, 3).

Anal. Calcd. for $C_{22}H_{14}O$: C, 89.77; H, 4.79. Found: C, 89.86; H, 5.00.

Reaction of **4** with Sodium Azide.

A mixture of 150 mg of **4**, 3 g of sodium azide, 50 ml of acetone and 25 ml of water was stirred under nitrogen at room temperature for 3 days. The acetone was removed under reduced pressure (<40°) and the resulting precipitate was extracted with dichloromethane. The dried organic solution was concentrated and chromatographed on silica gel using ether-hexane mixtures (containing from 10 to 60% ether) as eluent. The first fraction of 31 mg of fully aromatized material was followed by 92 mg (54%) of a 1:1 mixture of the *trans*-azido alcohols **6** and **7**, mp (of **6** + **7**) 195° dec; ir (nujol): 3320 (OH), 2115 cm^{-1} (N_3); pmr (hexadeuteriodimethyl sulfoxide): 200 MHz δ 4.734 (br s, 0.5H, changes to d, $J_{4b,5a}$ = 4.5 Hz by addition of deuterium oxide, C*H*OH of **6** or **7**), 4.850 (d, .5H, $J_{4b,5a}$ = 4.3 Hz, C*H*N_3 of **6** or **7**), 4.930 (br s, 0.5H, changes to d, $J_{4b,5a}$ = 4.3 Hz by addition of deuterium oxide, C*H*OH of **6** or **7**), 5.028 (d, 0.5 H, $J_{4b,5a}$ = 4.5 Hz, C*H*N_3 or **6** or **7**), 6.235 (br s, 1H, disappears upon addition of deuterium oxide, O*H*), 7.401-8.015 (m, 8H, Ar*H*), 8.124 (s, 1H, H6 of **6** and **7**), 8.425 (dd, 1H, $J_{1,2}$ = 8.1 Hz, $J_{1,3}$ = 2.2 Hz, H1 of **6** and **7**), 9.120 (d, 1H, $J_{11,12}$ = 7.6 Hz of **6** and **7**), 9.270 (s, 0.5H, H13 of **6** or **7**), 9.288 (s, .5H, H13 of **6** or **7**); ms: (70 eV, 175°) m/e (relative intensity) 337 ($M^{+\cdot}$, 45), 309 ($C_{22}H_{15}NO^{+\cdot}$, 27), 295 ($C_{22}H_{15}O^{+}$, 13), 281 ($C_{21}H_{13}O^{+}$, 100), 279 ($C_{21}H_{11}O^{+}$, 20), 266 ($C_{21}H_{14}^{+\cdot}$, 23), 264 ($C_{21}H_{12}^{+\cdot}$, 5), 252 ($C_{20}H_{12}^{+\cdot}$, 32), 250 ($C_{20}H_{10}^{+\cdot}$, 10).

Anal. Calcd. for $C_{22}H_{15}N_3O$: C, 78.32; H, 4.48. Found: C, 77.99; H, 4.66.

4b,5a-Dihydro-5*H*-dibenz[3,4:5,6]anthra[1,2-*b*]azirine (**5**).

Into a boiling solution of 50 mg of the above mixture of **6** and **7** in 15 ml of dichloromethane, was injected 30 μl of triethyl phosphite. The mixture was stirred under nitrogen at reflux for 24 hours. The solvent was removed under reduced pressure and the resulting oil was treated with an ice-cold mixture of 2 ml of dry ether and 10 ml of hexane. Agitation and cooling with an ice bath for 1 hour furnished yellow crystals of a mixture of **5**, **8** and **9**. Column chromatography on type III alumina (deactivated with 5% of water) with mixtures of hexane and ether (60-95% ether) as eluent gave 321 mg (71%) of **5** in the first fraction, mp 162-165° (from a mixture of benzene and methanol); ir (nujol): 3420 cm^{-1} (N-H); uv (chloroform): λ max (log ε) 288 (4.27), 290 (4.27), 300 (4.11), 316 (4.16), 322 (4.24), 368 (2.36), 376 nm (2.48); pmr (deuteriochloroform): 200 MHz δ 3.664 (d, 1H, $J_{4b,5a}$ = 4.7 Hz, H4b or H5a), 3.800 (d, 1H, $J_{4b,5a}$ = 4.7 Hz, H4b or H5a), 7.388-7.922 (m, 8H, H2, H3, H4, H7, H8, H9, H10, H11), 8.070 (s, 1H, H6), 8.403 (d, 1H, $J_{1,2}$ = 8.1 Hz, H1), 8.792 (d, 1H, $J_{11,12}$ = 7.9 Hz, H12), 9.390 (s, 1H, H13); ms: (70 eV, 150°) m/e (relative intensity) 293 ($M^{+\cdot}$, 100), 279 ($C_{22}H_{15}^{+}$, 11), 278 ($C_{22}H_{14}^{+\cdot}$, 23), 265 ($C_{21}H_{13}^{+}$, 82), 154 ($C_{11}H_8N^{+}$, 30), 139 ($C_{11}H_7^{+}$, 18), 126 ($C_{10}H_6^{+\cdot}$, 62).

Anal. Calcd. for $C_{22}H_{15}N$: C, 90.07; H, 5.15; N, 4.77. Found: C, 89.82; H, 4.99; N, 5.01.

trans-(5,6-Dihydro-5-hydroxydibenz[*a,j*]anthracene-6-yl)phosphoramidic Acid Diethyl Ester (**8**), and *trans*-5,6-Dihydro-6-hydroxydibenz[*a,j*]anthracene-5-yl)phosphoramidic Acid Dimethyl Ester (**9**).

The second fraction that was eluted from the column consisted of 7 mg (11%) of a mixture of **8** and **9**, mp (of **8** + **9**) 90-93° dec; ir (nujol): 3610 cm^{-1} (NH), 3360 cm^{-1} (OH); pmr (deuteriochloroform): 200 MHz δ 1.086 (m, 6H, CH_3), 3.629 (m, 4H, CH_2), 4.132 (d, 0.4H, $J_{5,6}$ = 8.0 Hz, H5 of **8** or H6 or **9**), 4.235 (d, 0.6H, $J_{5,6}$ = 8.2 Hz, H5 of **8** or H6 of **9**), 4.563 (d, 0.4H, $J_{5,6}$ = 8.0 Hz, H5 of **9** or H6 of **8**), 4.747 (d, 0.6H, $J_{5,6}$ = 8.2 Hz, H5 of **9** or H6 of **8**), 7.418-7.913 (m, 9H, Ar*H*), 8.018 (s, 0.4H, H7 of **8** or **9**), 8.054 (s, 0.6H, H7 of **8** or **9**), 8.764 (d, 1H, $J_{12,13}$ = 7.4 Hz, H13), 9.018 (s, 0.4H, H14 of **8** or **9**), 9.035 (s, 0.6H, H14 of **8** or **9**); ms: (70 eV, 200°) m/e (relative intensity) 429 [(M-H_2O)$^{+\cdot}$, 8], 402 ($C_{24}H_{21}NO_3P^{+}$, 1), 308 ($C_{22}H_{14}NO^{+}$, 2), 307 ($C_{22}H_{13}NO^{+\cdot}$, 3), 293 ($C_{22}H_{15}N^{+\cdot}$, 100), 265 ($C_{21}H_{13}^{+}$, 47), 252 ($C_{20}H_{12}^{+\cdot}$, 2).

Anal. Calcd. for $C_{26}H_{26}NO_4P$: C, 69.79; H, 5.86; N, 3.13. Found: C, 69.77; H, 5.78; N, 3.40.

Elbs Pyrolysis of (2-Methyl-1-naphthyl)-1'-naphthylmethanone (**10**).

A quantity of 80 g of **10** was heated at 420±2° for 45 minutes and the resulting oil was flash distilled at 1 mm. To the distillate

which solidified was added 150 ml of cold chloroform. The insoluble material (15.0 g, 20%) was found to be pure dibenz[*a,h*]-anthracene (**11**) [13]. The chloroform soluble fraction was chromatographed on silica gel using hexane as eluent to give as the first fraction 0.16 g of **11** and as the second fraction 1.25 g (2%) of **1** that proved identical in every respect with an authentic sample of **1** prepared according to Harvey *et al.* [15].

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