

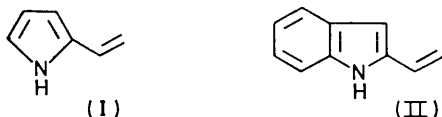
## Synthesis of Indoles and Carbazoles: Diels–Alder Reactions of Nitrovinyl-pyrroles and -benzindoles

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Diels–Alder reaction conditions have been employed to prepare indoles, benz[e]indoles, benzo[a]carbazoles, naphth[e]indoles, dibenzo[a,i]carbazoles, dibenzo[a,g]carbazoles, benzo[a]naphtho[i]carbazoles, and benzo[a]naphtho[g]carbazoles from nitrovinylpyrroles and nitrovinylbenzindoles with various dienophiles.

VINYLPYRROLES [*e.g.* (I)] and indoles [*e.g.* (II)] contain a diene system which is effective in Diels–Alder reactions

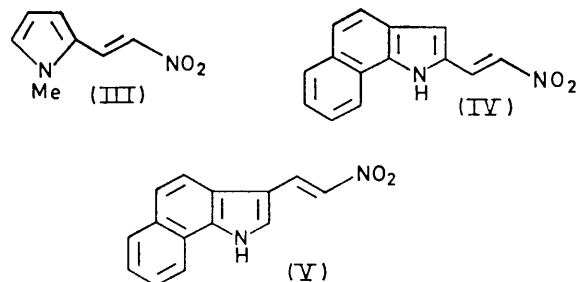


with various active dienophiles such as maleic anhydride, benzoquinone, naphthoquinone, tetracyanoethylene, dimethyl acetylenedicarboxylate, *etc.* This method represents a new route for the synthesis of polynuclear indole molecules.<sup>1</sup> However, it is of limited applicability owing to the inherent instability and scarcity of synthetic pathways to the vinylindoles. However, nitrovinyl systems have been found to be better dienes than the corresponding vinyl analogues.<sup>2</sup> We have used various nitrovinyl analogues [*e.g.* (III)–(V)],

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<sup>1</sup> W. E. Noland, W. C. Kuryla, and R. F. Lange, *J. Amer. Chem. Soc.*, 1959, **81**, 6010.

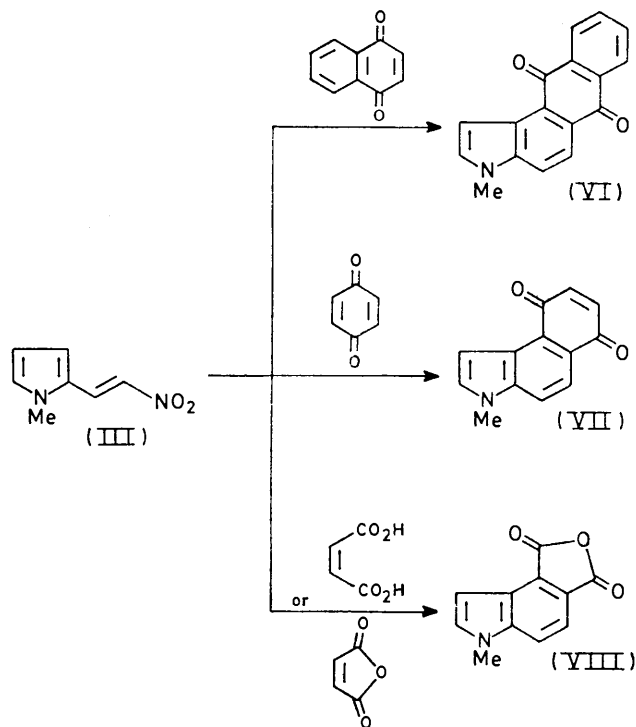
which are stable and readily available from a condensation of the corresponding carboxaldehydes with nitromethane, in a convenient route to various indoles and benzindoles (carbazoles).



Condensations of compound (III) (Scheme 1), with naphthoquinone and benzoquinone yielded, respectively, the naphth[2,3-*e*]indole (VI) and the benz[*e*]indole (VII),

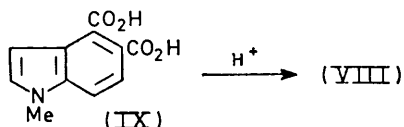
<sup>2</sup> W. E. Noland, K. Sivasankaran, and S. P. Hiremath, personal communication.

whereas condensations with maleic anhydride and maleic acid both yielded *N*-methylindole-4,5-dicarboxylic anhydride (VIII). The maleic acid adduct (IX), which



SCHEME 1

is believed to be formed, may have cyclised to the anhydride in the acidic medium created by the elimination of nitrous acid (see later) during the condensation.

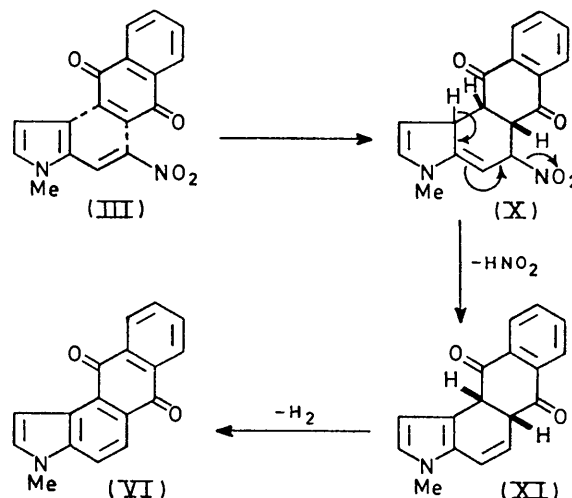


This process (Scheme 2) is believed to follow the normal Diels-Alder [4 + 2] cycloaddition pathway to form, for example, (X), which subsequently must lose nitrous acid *en route* to (XI). The appearance of a brownish gas within minutes of reaction commencement is considered as evidence for the formation of nitrous acid which decomposes into a mixture of NO<sub>2</sub> and NO (2HNO<sub>2</sub> → NO<sub>2</sub> + NO + H<sub>2</sub>O). The fully aromatized product [*e.g.* (VI)] then arises *via* a simple dehydrogenation.

Extension of this annulation procedure to 2-(β-nitrovinyl)- (IV) and 3-(β-nitrovinyl)-benz[*g*]indole (V) yields benzocarbazole systems. The nitrovinyl compounds were prepared from ethyl benz[*g*]indole-2-carboxylate<sup>3</sup> (XII) *via* either saponification<sup>3</sup> (XIV) followed by

copper chromite-quinoline decarboxylation<sup>3</sup> (XV), Vilsmeier formylation<sup>4</sup> (XVII), and nitromethane condensation (V) or lithium aluminium hydride reduction (XIII), manganese dioxide oxidation (XVI) and nitromethane condensation (IV). Decarboxylation of benz[*g*]indole-2-carboxylic acid with copper chromite-quinoline produced higher yields than the reported<sup>3</sup> method.

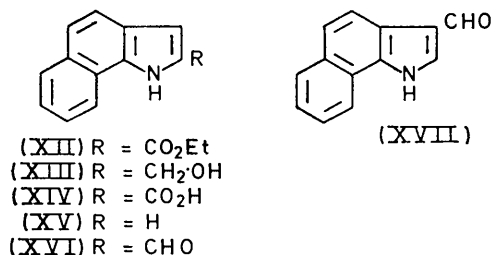
Compounds (IV) and (V) reacted as expected with benzoquinone and naphthoquinone (Scheme 3), and (V) formed the anhydride adduct (XX) with both maleic acid and maleic anhydride in a manner analogous to that already discussed above [*i.e.* (IX)]. The structures of all the adducts were in good agreement with their mass spectral data. A mechanism similar to that



SCHEME 2

outlined in Scheme 2 is believed to operate in these cycloadditions.

Condensation of (V) with dimethyl acetylenedicarboxylate yielded dimethyl 8-nitrobenzo[*a*]carbazole-9,10-dicarboxylate (XXIV), the only product of this study in which the nitro-group is retained. Small amounts of nitro-compounds were also detected by



mass spectrometry in the products from the reactions of (IV) and (V) with benzoquinone [peaks at *M* + 46 (18 and 2%, respectively)]. In general, the yields of the Diels-Alder adducts were greater in the 3-series (V) than the 2-series (IV).

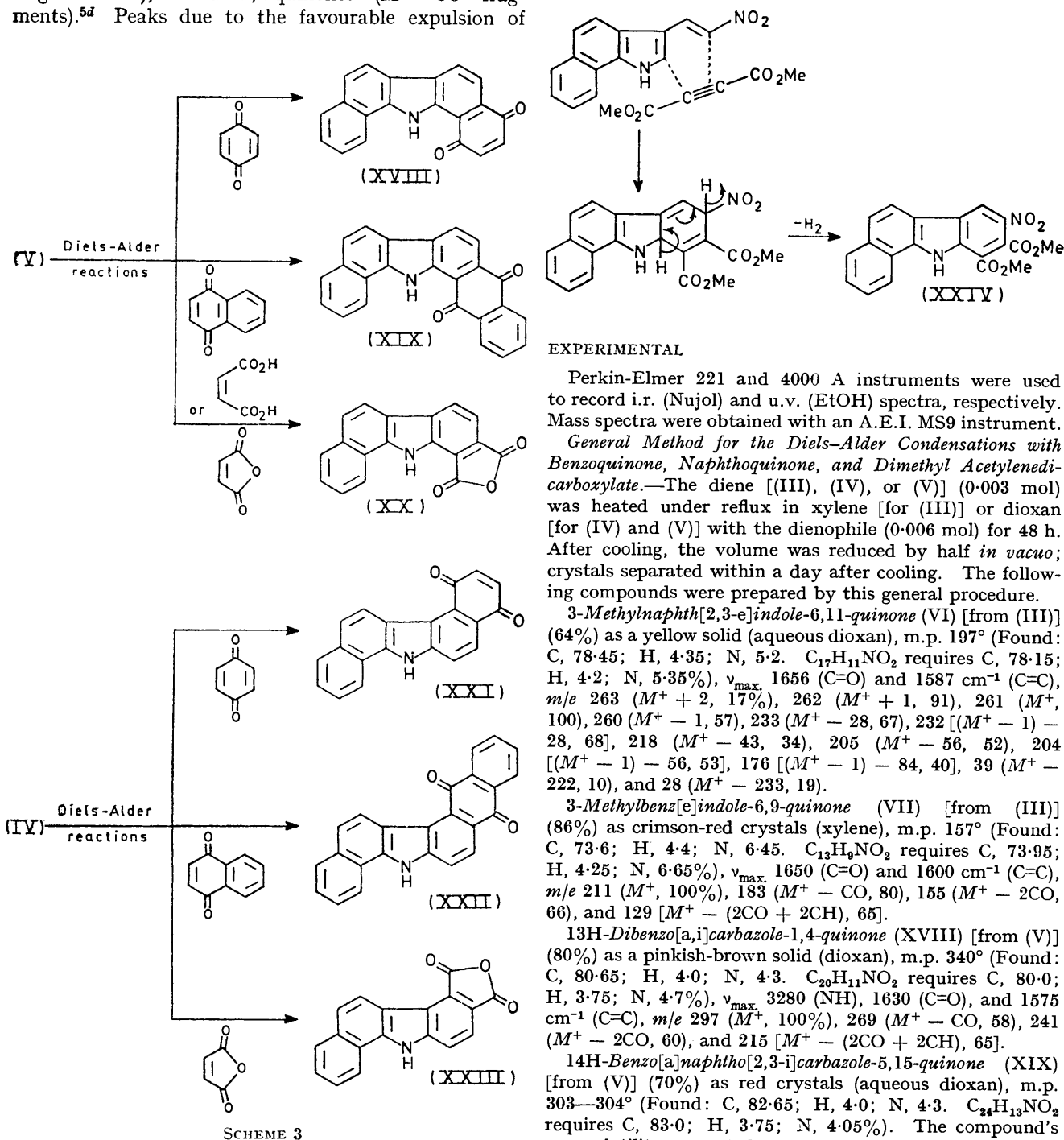
The mass spectrum of compound (VI) (see Experimental section) conforms with the characteristic features

<sup>3</sup> H. N. Rydon and S. Siddappa, *J. Chem. Soc.*, 1951, 2462.

<sup>4</sup> G. F. Smith, *J. Chem. Soc.*, 1954, 3843.

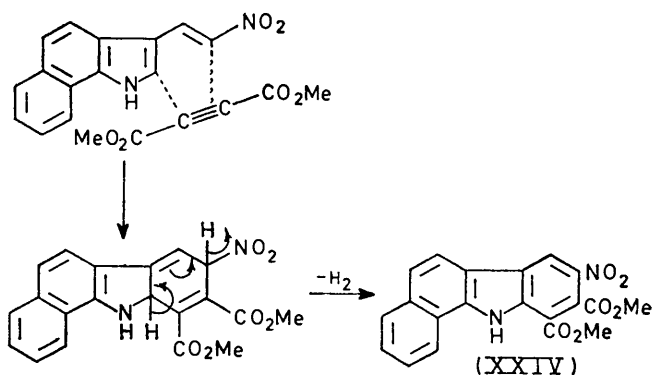
of pyrroles<sup>5a</sup> (peaks at  $m/e$  28 and 39), methyl-substituted indoles (abundant  $M - 1$  peaks due to  $\beta$ -bond fragmentation),<sup>5b</sup> and 1,4-quinones ( $M - CO$  fragments).<sup>5d</sup> Peaks due to the favourable expulsion of

are probably due to the reduction of the quinone to the hydroquinone<sup>5c</sup> inside the spectrometer inlet.



hydrogen cyanide<sup>5c</sup> from the  $M - 1$  species [ $(M - 1) - 27$ ] and the loss of acetylene from the styryl ions<sup>5c</sup> are also apparent. The intense  $M + 1$  and  $M + 2$  peaks

<sup>5</sup> H. Budzikiewicz, C. Djerassi, and D. H. Williams, 'Mass Spectrometry of Organic Compounds,' Holden-Day, San Francisco, 1967, (a) pp. 596 and 597, (b) p. 610, (c) p. 611, (d) pp. 527-537, (e) p. 118.



#### EXPERIMENTAL

Perkin-Elmer 221 and 4000 A instruments were used to record i.r. (Nujol) and u.v. (EtOH) spectra, respectively. Mass spectra were obtained with an A.E.I. MS9 instrument.

*General Method for the Diels-Alder Condensations with Benzoquinone, Naphthoquinone, and Dimethyl Acetylenedicarboxylate.*—The diene [(III), (IV), or (V)] (0.003 mol) was heated under reflux in xylene [for (III)] or dioxan [for (IV) and (V)] with the dienophile (0.006 mol) for 48 h. After cooling, the volume was reduced by half *in vacuo*; crystals separated within a day after cooling. The following compounds were prepared by this general procedure.

*3-Methylnaphth[2,3-e]indole-6,11-quinone* (VI) [from (III)] (64%) as a yellow solid (aqueous dioxan), m.p. 197° (Found: C, 78.45; H, 4.35; N, 5.2.  $C_{17}H_{11}NO_2$  requires C, 78.15; H, 4.2; N, 5.35%),  $\nu_{\max}$  1656 (C=O) and 1587  $cm^{-1}$  (C=C),  $m/e$  263 ( $M^+ + 2$ , 17%), 262 ( $M^+ + 1$ , 91), 261 ( $M^+$ , 100), 260 ( $M^+ - 1$ , 57), 233 ( $M^+ - 28$ , 67), 232 [ $(M^+ - 1) - 28$ , 68], 218 ( $M^+ - 43$ , 34), 205 ( $M^+ - 56$ , 52), 204 [ $(M^+ - 1) - 56$ , 53], 176 [ $(M^+ - 1) - 84$ , 40], 39 ( $M^+ - 222$ , 10), and 28 ( $M^+ - 233$ , 19).

*3-Methylbenz[e]indole-6,9-quinone* (VII) [from (III)] (86%) as crimson-red crystals (xylene), m.p. 157° (Found: C, 73.6; H, 4.4; N, 6.45.  $C_{13}H_9NO_2$  requires C, 73.95; H, 4.25; N, 6.65%),  $\nu_{\max}$  1650 (C=O) and 1600  $cm^{-1}$  (C=C),  $m/e$  211 ( $M^+$ , 100%), 183 ( $M^+ - CO$ , 80), 155 ( $M^+ - 2CO$ , 66), and 129 [ $M^+ - (2CO + 2CH)$ , 65].

*13H-Dibenzo[a,i]carbazole-1,4-quinone* (XVIII) [from (V)] (80%) as a pinkish-brown solid (dioxan), m.p. 340° (Found: C, 80.65; H, 4.0; N, 4.3.  $C_{20}H_{11}NO_2$  requires C, 80.0; H, 3.75; N, 4.7%),  $\nu_{\max}$  3280 (NH), 1630 (C=O), and 1575  $cm^{-1}$  (C=C),  $m/e$  297 ( $M^+$ , 100%), 269 ( $M^+ - CO$ , 58), 241 ( $M^+ - 2CO$ , 60), and 215 [ $M^+ - (2CO + 2CH)$ , 65].

*14H-Benzo[a]naphtho[2,3-i]carbazole-5,15-quinone* (XIX) [from (V)] (70%) as red crystals (aqueous dioxan), m.p. 303-304° (Found: C, 82.65; H, 4.0; N, 4.3.  $C_{24}H_{13}NO_2$  requires C, 83.0; H, 3.75; N, 4.05%). The compound's non-volatility prevented measurement of its mass spectrum.

*7H-Dibenzo[a,g]carbazole-1,4-quinone* (XXI) [from (IV)] (47%) as reddish-brown crystals (dioxan), m.p. >340° (Found: C, 79.8; H, 3.6; N, 4.4.  $C_{20}H_{11}NO_2$  requires C, 80.0; H, 3.75; N, 4.7%),  $\nu_{\max}$  3320 (NH), 1630 (C=O), and 1580  $cm^{-1}$  (C=C),  $m/e$  297 ( $M^+$ , 100%), 263 ( $M^+ - CO$ , 58), 241 ( $M^+ - 2CO$ , 60), and 215 [ $M^+ - (2CO + 2CH)$ , 65].

*5H-Benzo[a]naphtho[2,3-g]carbazole-8,13-quinone* (XXII)

[from (IV)] (50%) as red crystals (dioxan), m.p.  $>300^\circ$  (Found: C, 82.75; H, 3.5; N, 4.2.  $C_{24}H_{13}NO_2$  requires C, 83.8; H, 3.75; N, 4.05%).

*Dimethyl 8-nitrobenzo[a]carbazole-9,10-dicarboxylate* (XXIV) [from (V)] (50%) as yellow crystals (aqueous dioxan), m.p.  $260^\circ$  (Found: N, 7.3.  $C_{20}H_{14}N_2O_6$  requires N, 7.4%),  $m/e$  378 ( $M^+$ ), 362 ( $M^+ - O$ ), 332 ( $M^+ - NO_2$ ), and 260 [ $M^+ - (CO_2Me)_2$ ].

*General Method for the Diels-Alder Condensations with Maleic Anhydride and Maleic Acid.*—The diene [(III), (IV), or (V)] (0.003 mol) was heated under reflux in xylene [for (III)] or dioxan [for (IV) and (V)] with the dienophile (0.006 mol) for 8 h [(III)] or 48 h [(IV) and (V)]. The solid which resulted on cooling or on concentration of the solution was filtered off, washed with water, dried, and recrystallized. The following products were obtained.

*N-Methylindole-4,5-dicarboxylic anhydride* (VIII) [from (III) and maleic acid or maleic anhydride] (40–46%) as yellow needles (xylene), m.p.  $204^\circ$  (Found: C, 65.45; H, 3.55; N, 6.9.  $C_{11}H_7NO_3$  requires C, 65.65; H, 3.5; N, 6.95%),  $\nu_{max}$  1800 and  $1740\text{ cm}^{-1}$  (anhydride),  $m/e$  201 ( $M^+$ , 100%), 185 ( $M^+ - O$ , 3), 157 ( $M^+ - CO_2$ , 70), and 129 [ $M^+ - (CO)_2O$ , 71].

*Benzo[a]carbazole-9,10-dicarboxylic anhydride* (XX) [from (V) and maleic acid or maleic anhydride] (66%) as yellow crystals (aqueous dioxan), m.p.  $343^\circ$  (Found: N, 4.3.  $C_{18}H_{11}NO_4$  requires N, 4.6%),  $m/e$  287 ( $M^+$ , 100%) and 215 [ $M^+ - (CO)_2O$ , 83].

*Benzo[a]carbazole-7,8-dicarboxylic anhydride* (XXIII) [from (IV) and maleic anhydride] (60%) as yellow crystals (dioxan), m.p.  $330^\circ$  (Found: C, 70.65; H, 3.45; N, 4.85.  $C_{18}H_{11}NO_4$  requires C, 70.8; H, 3.6; N, 4.6%),  $m/e$  287 ( $M^+$ , 100%).

*Benz[g]indole* (XV).—Benz[g]indole-2-carboxylic acid (10 g, 0.0474 mol), mixed with copper chromite (1 g) and suspended in quinoline (75 ml), was heated to  $215^\circ$  (internal temp.) for 2 h. The product was poured into ice-water containing hydrochloric acid (80 ml) and repeatedly extracted with ether. The combined extracts were washed [2N-HCl,  $NaHCO_3$  (50%), and water] and distilled to leave the product (XV) (6.8 g, 86%), m.p.  $179^\circ$  (lit.,<sup>3</sup>  $170\text{--}180^\circ$ ).

*Benz[g]indole-3-carbaldehyde* (XVII).—Phosphoryl chloride (9.6 g, 0.05 mol) was added dropwise with stirring to dimethylformamide (16 g, 0.22 mol) in a flask protected from atmospheric moisture, the temperature being kept at  $10\text{--}20^\circ$ . Benz[g]indole (8.35 g, 0.05 mol) in dimethylformamide was slowly added with stirring, the temperature of the mixture being kept at  $20\text{--}30^\circ$ . The mixture was kept at  $35^\circ$  for 45 min, then poured on crushed ice, and the clear solution was treated at  $20\text{--}30^\circ$  with a solution of sodium hydroxide (9.5 g, 0.24 mol) in water (50 ml) at such a rate that the solution was always acidic, until about three quarters of the alkali had been added. The last quarter was added in one portion and the solution was quickly

boiled for 1 min and cooled. The product was filtered off and washed with water. Crystallization from aqueous methanol gave the *aldehyde* (XVII) (0.5 g, 50%), m.p.  $168^\circ$  (Found: C, 80.0; H, 4.6; N, 7.2.  $C_{13}H_9NO$  requires C, 80.3; H, 4.45; N, 7.45%),  $\nu_{max}$  3448 (NH), 1655 (C=O), and  $1585\text{ cm}^{-1}$  (C=C).

*3-( $\beta$ -Nitrovinyl)benz[g]indole* (V).—The aldehyde (XVII) (0.6 g, 0.003 mol), nitromethane (4.61 g, 0.075 mol), and ammonium acetate (0.2 g, 0.0028 mol) were heated gently under reflux for 0.5 h. On cooling, dark ruby crystals slowly separated. Crystallization from methanol gave orange *crystals* (V) (0.7 g, 97%), m.p.  $227^\circ$  (decomp.) (Found: C, 70.55; H, 4.45; N, 11.45.  $C_{14}H_{10}N_2O_2$  requires C, 70.6; H, 4.25; N, 11.75%),  $\nu_{max}$  3335 (NH), 1613 (C=C), and  $1325\text{ cm}^{-1}$  ( $NO_2$ ).

*Benz[g]indole-2-methanol* (XIII).—To a suspension of lithium aluminium hydride (0.8 g) in ether (40 ml), a solution of ethyl benz[g]indole-2-carboxylate (4.26 g, 0.0178 mol) in tetrahydrofuran (25 ml) was added at a rate sufficient to maintain gentle refluxing. The solution was stirred for 2 h before quenching with brine, drying, and evaporating to obtain a white crystalline *solid* (XIII) (3.4 g, 96.6%), m.p.  $149\text{--}150^\circ$  (from benzene) (Found: C, 79.45; H, 5.7; N, 7.4.  $C_{13}H_{11}NO$  requires C, 79.2; H, 5.6; N, 7.1%),  $\nu_{max}$  3420 (NH), 3150 (OH), and  $1470\text{ cm}^{-1}$  (C=C).

*Benz[g]indole-2-carbaldehyde* (XVI).—Benz[g]indole-2-methanol (1 g, 0.005 mol) and manganese dioxide (4 g) were stirred in methylene chloride (50 ml), tetrahydrofuran (25 ml), and ethylene dichloride (25 ml) for 72 h. Filtration, and evaporation of the solvent, gave (XVI) (0.84 g, 85%), which crystallized from benzene as pinkish *needles*, m.p.  $190^\circ$  (Found: C, 80.25; H, 4.35; N, 7.05.  $C_{13}H_9NO$  requires C, 80.0; H, 4.6; N, 7.2%),  $\nu_{max}$  3390 (NH), 1650 (C=O), and  $1580\text{ cm}^{-1}$  (C=C).

*2-( $\beta$ -Nitrovinyl)benz[g]indole* (IV).—The aldehyde (XVI) (0.6 g, 0.003 mol), nitromethane (4.61 g, 0.075 mol), and ammonium acetate (0.2 g, 0.0028 mol) were heated gently under reflux for 0.5 h. On cooling, dark ruby crystals slowly separated. Crystallization from absolute ethanol gave orange *needles* (IV) (0.6 g, 83%), m.p.  $240^\circ$  (decomp.) (Found: C, 70.45; H, 4.05; N, 11.4.  $C_{14}H_{10}N_2O_2$  requires C, 70.6; H, 4.25; N, 11.75%),  $\nu_{max}$  3340 (NH), 1625 (C=C), and  $1335\text{ cm}^{-1}$  ( $NO_2$ ).

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