1 × 25 in. silica gel column, eluting with ethyl acetate. The resulting material (450 mg) was further purified by preparative tlc (silica gel PF_{254}, using 97:3 chloroform–methanol to elute) and the product was recrystallized to give 230 mg (42%) of **11**: mp 159–162° (analytical sample mp 161.5–163°); ir (Nujol) 1725, 1710, 1640 cm^{-1}; uv max (95% EtOH) 366 nm (ε 14,300); nmr ($CDCl_3$) δ 1.37 (t, 3), 3.95 (s, 3), 4.35 (q, 2), 5.15 (s, 2), 7.10 (s, 1), 7.60 (m, 4); mass spectrum *m/e* 313 (M^+).

Anal. Calcd from $C_{17}H_{15}NO_5$: C, 65.17; H, 4.82; N, 4.47. Found: C, 65.20; H, 4.73; N, 4.29.

***N*,*N*-Dimethyl-3-cyanoquinaldamide (9b).**—To a suspension of 10.12 g (62.1 mmol) of the sodium enolate of ethyl 3-cyanopyruvate was added 40 ml (86.8 mmol) of 2.17 *N* methanolic hydrochloric acid. The suspension was stirred for 15 min and the solvent was removed *in vacuo*. The resulting mixture was suspended in 80 ml of chloroform and filtered, and the solvent was removed *in vacuo* to give an orange oil. This crude cyano keto ester was dissolved in 200 ml of absolute ethanol containing a catalytic quantity of HCl, and a solution of 10.97 g (91 mmol) of *o*-aminobenzaldehyde in 50 ml of absolute ethanol was added. The reaction mixture was stirred at 25° for 7 days. The solution was made basic with ethanolic sodium ethoxide, and the solvent was removed *in vacuo*. The residue was stirred three times with 250-ml portions of ether, the suspensions being filtered each time. The combined ether extracts were evaporated, and the semisolid residue was crystallized from ether to give 4.40 g (32%) of ethyl 3-cyanoquinaldate: mp 130–132°; ir (Nujol) 2220, 1720 cm^{-1}.

Anal. Calcd for $C_{13}H_{10}N_2O_2$: C, 69.01; H, 4.46; N, 12.38. Found: C, 69.24; H, 4.52; N, 12.60.

A solution of ethyl 3-cyanoquinaldate (967 mg, 4.28 mmol) in 4 ml of dimethylamine was stirred with a Dry Ice–acetone condenser for 1 hr and then diluted with 15 ml of absolute ethanol. The reaction mixture was stirred for 16 hr at 25°. The solvent was removed *in vacuo* and the resulting solid was recrystallized from ethyl acetate to give 645 mg (67%) of **9b**: mp 139–141; ir (Nujol) 2220, 1655 cm^{-1}.

Anal. Calcd for $C_{13}H_{11}N_3O$: C, 69.32; H, 4.92; N, 18.66. Found: C, 69.55; H, 5.04; N, 18.25.

Methyl 2-Carbomethoxy-3-carbethoxy-5-(*N*,*N*-dimethylamino)-5-(3-cyano-2-quinolyl)penta-2,4-dienoate (3e).—A solution of 555 mg (2.92 mmol) of triethyloxonium fluoroborate and 553 mg (2.38 mmol) of amide **9b** in 7 ml of methylene chloride was stirred for 48 hr at 25°. A solution of the triester anion was prepared by adding 876 mg (3.81 mmol) of triester **1b** dropwise to a suspension of sodium hydride (213 mg of 50% dispersion, 4.44 mmol) in 2 ml of dimethylformamide at 25° and then stirring for 30 min. This solution was then added at 0° to the methylene chloride solution prepared above. After stirring for 5 min, methylene chloride (*ca.* 25 ml) was added and the solution was washed with four 25-ml portions of water. The organic layer was dried and evaporated to give 1.3 g of crude product. Purification by preparative tlc (silica gel PF_{254}, eluting with 1:1 ethyl acetate–benzene) afforded 539 mg (52%) of **3e** as an unstable oil: ir (liquid) 2220, 1730, 1690 cm^{-1}; uv max (95% EtOH) 425 nm (ε 27,000); nmr ($CDCl_3$) δ 0.80 (t, 3), 2.88 (q, 2), 2.92 (s, 6), 3.57 (s, 3), 3.78 (s, 3), 6.13 (s, 1), 7.93 (m, 4), 8.67 (s, 1); mass spectrum *m/e* 437 (M^+).

7-Carbethoxy-8-carbomethoxy-9-oxo-11(*H*)-indolizino[1,2-6]-quinoline (13).—To 340 mg (0.78 mmol) of **3a** was added 5 ml of ethanolic W-2 Raney nickel, and the suspension was hydrogenated at atmospheric pressure for 15 hr. The reaction mixture was filtered through Celite and the solvent was removed *in vacuo* to give 216 mg of crude material. The product was purified by preparative tlc (silica gel PF_{254}, eluted with ethyl acetate) to give 30 mg (11%) of an insoluble solid: mp 280–284°; ir (Nujol) 1730, 1720, 1660, 1620, 1610 cm^{-1}; uv max (95% EtOH) 372 nm (ε 9700).

Anal. Calcd for $C_{20}H_{16}N_2O_5$: mol wt, 364.10592. Found:[16] mol wt, 364.10593.

Registry No.—**3a**, 33707-20-9; **3b**, 33707-21-0; **3c**, 33707-22-1; **3d**, 33703-23-2; **3e**, 33666-43-2; **4a**, 33707-24-3; **4b**, 33707-25-4; **4c**, 33707-26-5; **5a**, 33707-27-6; **5b**, 33707-28-7; **6**, 33707-29-8; **7**, 33707-30-1; **9a**, 26487-08-1; **9b**, 33707-32-3; **11**, 33707-33-4; **13**, 33707-34-5; ethyl 3-cyanoquinaldate, 33707-35-6.

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(16) We thank R. Graham Cooks, Purdue University, for this measurement.

Synthesis of *N*-Alkyl-3-carboxy-4-pyridones

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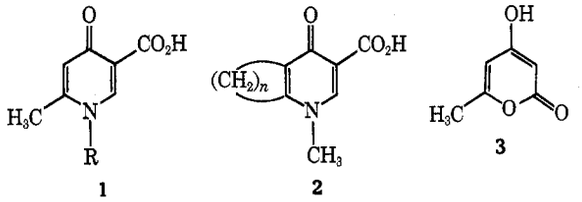
The synthesis of several *N*-alkyl-3-carboxy-4-pyridones is described beginning with substituted 4-hydroxy-2-pyrones. Several of the pyrones are prepared by a new synthesis involving the condensation of a morpholine enamine with carboethoxyacetyl chloride to give a diketo ester. The diketo ester is cyclized with sodium methoxide in dimethylformamide to afford the 4-hydroxy-2-pyrone. The 4-hydroxy-2-pyrones react with the dimethyl acetal of dimethylformamide in a new reaction to introduce a 3-dimethylaminomethylene moiety. Rearrangement of this intermediate with primary amines leads to the title compounds.

In this paper we report the synthesis of several *N*-alkyl-3-carboxy-4-pyridones of types **1** and **2**. A convenient starting material for the preparation of **1** should be **3**. We planned to introduce an aldehyde or related functionality in position **3** after which rearrangement with ammonia or primary amines should yield **1**.

This type of rearrangement has been done with ammonia and dehydroacetic acid (**4** to **6**) when the temperature of the reaction did not exceed 100°.[1] A side product was the decarboxylated pyridone. According to Schut and coworkers[2] only the decarboxylated compound is isolated when dehydroacetic acid is treated with primary amines. In our case the major product was always the pyridonecarboxylic acid.

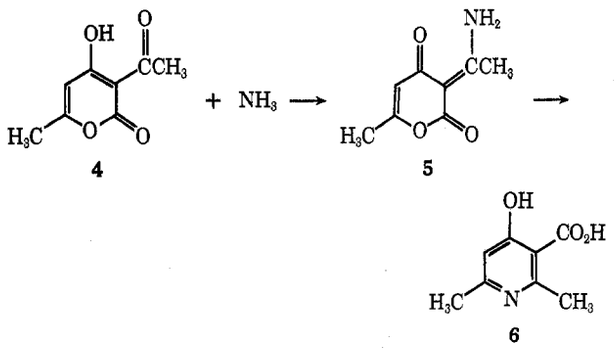


R = H, alkyl

Introduction of the aminomethylene functionality into the 3 position of a 4-hydroxy-2-pyrone was accomplished by using the dimethyl acetal of dimethylformamide, a compound known to react with active methy-

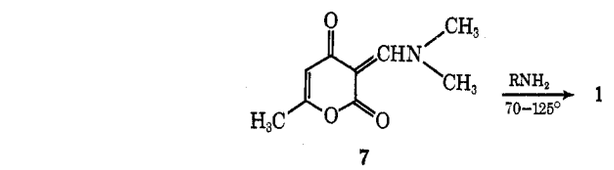
(1) J. N. Collie, *J. Chem. Soc.*, **77**, 971 (1900).

(2) R. N. Schut, W. G. Stryeker, and T. M. H. Lin, *J. Org. Chem.*, **28**, 3046 (1963).

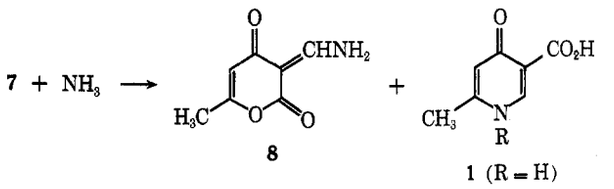


lene groups.[3] This procedure was chosen because of its simplicity, its mild reaction conditions, the ease of work-up, and the high yields obtained. The reaction is conducted at room temperature or below in dioxane and the product crystallizes from solution. This reaction, not previously reported, should prove useful for the placement of various groups in the 3 position of 4-hydroxy-2-pyrones.

Reaction of **3** with dimethylformamide dimethyl acetal yielded **7**, which, when treated with ammonia or primary amines, gave **1** either at temperatures below 100° or at 125° (using boiling Methyl Cellosolve).

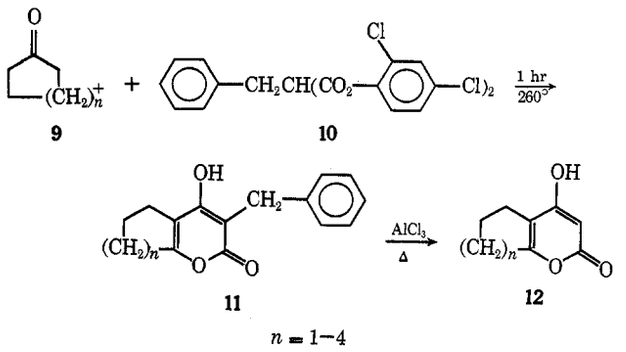


Reaction of **7** with ammonia at room temperature allowed the isolation of an intermediate (**8**) in 73% yield. Work-up of the filtrate yielded 9% of **1** (R = H).



Support for the structural assignment of **8** rests on the elemental analysis and the strong similarities in the infrared and nmr spectra of **7** and **8**.

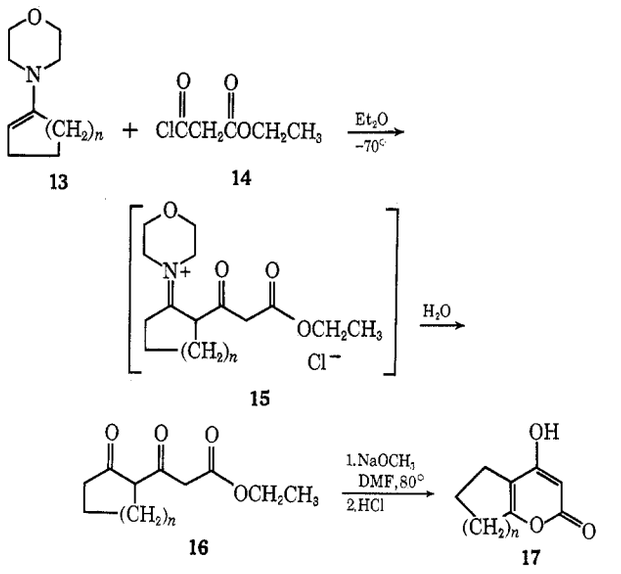
Pyridones of type **2** were synthesized by the same procedure. The necessary 4-hydroxy-2-pyrones have been described by Ziegler, *et al.*,[4] who carried out the following reaction sequence.



(3) L. Fieser and M. Fieser, "Reagents for Organic Synthesis," Vol. 2, Wiley-Interscience, New York, N. Y., 1969, p 154.

(4) E. Ziegler, H. Junek, and E. Nolken, *Monatsh. Chem.*, **89**, 678 (1958).

While Ziegler's method appeared to be a good one, it was of interest to examine the synthesis of **12** and its homologs by reaction of the morpholine enamine of the appropriate ketone with carboethoxyacetyl chloride followed by base-induced ring closure of the intermediate diketo esters as shown below.



After many unsuccessful attempts to synthesize **16** (n = 2), where solvents such as benzene and chloroform were used, we found that ether was the solvent of choice probably because the intermediate salt **15** precipitates from ether, thereby preventing side reactions. The diketo ester **16** is formed when water is added to the ethereal suspension. Under these conditions, the formation of diketo esters was found to be quite general. These esters were all viscous liquids which resisted crystallization and could not be distilled; so they were used directly in their crude state to prepare the pyrone.

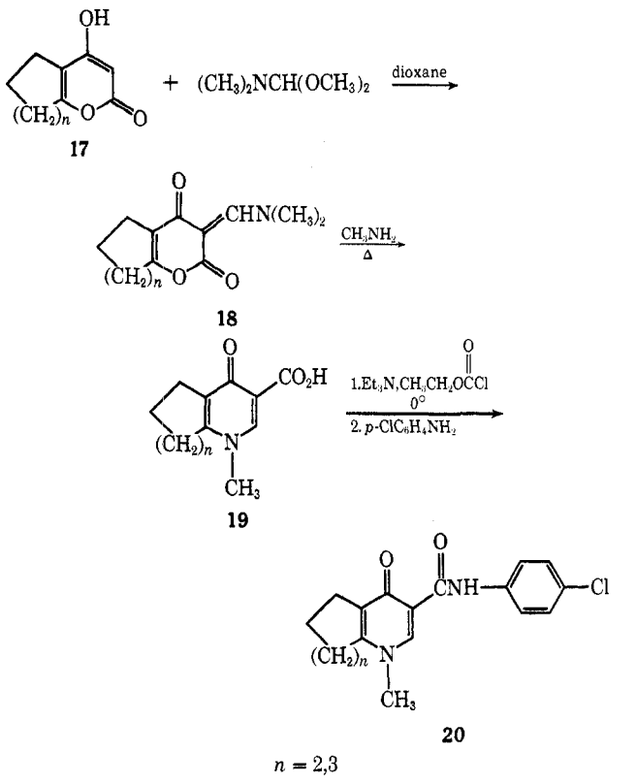
The ring closure of **16** to **17** remained elusive for a time; conditions such as sodium ethoxide in ethanol, cold concentrated sulfuric acid, and acetic anhydride containing a few drops of sulfuric acid all failed; starting material was recovered in all cases. We found that use of sodium methoxide (1 equiv) in dry dimethylformamide at 80–85° caused the desired reaction to take place. The yield of pyrone appears to depend greatly on ring size, although the relationship is only qualitative because of the crude state of the diketo esters; for example, when n = 1 only 3% of pyrone was obtained while 37 and 61% yields were obtained where n = 2 and n = 3, respectively. This constitutes a new method for the preparation of 4-hydroxy-2-pyrones.

These last two pyrones (n = 2, 3) were then treated with the dimethyl acetal of dimethylformamide to give the enamines **18**, which were converted to the pyridones **19** and thence to the amides **20**.

Experimental Section

Nmr spectra were determined on a Varian A-60 spectrometer; chemical shifts are reported in τ values in parts per million using tetramethylsilane (TMS) as an internal standard. Infrared spectra were recorded on a Perkin-Elmer grating infrared spectrophotometer. All melting points are uncorrected.

Preparation of Enamines.—The morpholine enamine of cyclo-



heptanone was obtained in 64% yield by use of titanium tetrachloride.[5] All other enamines were prepared by the more usual method.

3-(Dimethylaminomethylene)-4-oxo-6-methyl-2-pyrone (7).—A suspension of 25 g (0.2 mol) of 4-hydroxy-6-methyl-2-pyrone and 44 g (0.37 mol) of *N*,*N*-dimethylformamide dimethyl acetal in 100 ml of reagent-grade *p*-dioxane was stirred until a brown solution had formed; the solution was left overnight in the refrigerator. The suspension which formed was filtered and the solid was recrystallized from 2-propanol to afford 26 g (72%) of **7**: mp 152–154°, beige crystals; ir (Nujol) 1690, 1660 cm^{-1}; nmr (DMSO) τ 7.83 (s, 3 H, C-methyl), 6.73 (s, 3 H, N-methyl), 6.48 (s, 3 H, N-methyl), 4.33 (s, 1 H, olefinic), and 1.68 (s, 1 H, olefinic).

Anal. Calcd for $C_9H_{11}NO_3$: C, 59.66; H, 6.12; N, 7.73. Found: C, 59.46; H, 6.38; N, 7.53.

3-(Aminomethylene)-4-oxo-6-methyl-2-pyrone (8).—To a solution of pyrone **7** (26 g, 0.144 mol) in 50 ml of water was added 50 ml of concentrated ammonia. The solution was cooled in an ice–water bath; crystallization occurred shortly thereafter. The suspension was quickly filtered and the solid which was isolated was dried to give 16 g (73%) of **8**, mp 211–213° dec, which was analyzed without further purification: ir (Nujol) 3300 (NH_2), 3170 (NH_2), 1720, 1670 cm^{-1}; nmr (DMSO) τ 7.88 (s, 3 H, C-methyl), 4.28 (s, 1 H, olefinic), 1.72 (s, 1 H, olefinic), 1.33 (d, 1 H, NH), and −1.17 (d, 1 H, NH).

Anal. Calcd for $C_7H_7NO_3$: C, 54.90; H, 4.61; N, 9.15. Found: C, 54.90; H, 4.68; N, 9.10.

The filtrate was evaporated *in vacuo* and the residue was dissolved in hot 2-propanol. Crystallization took place upon acidification with acetic acid and cooling to afford 2 g (9%) of 6-methyl-4-pyridone-3-carboxylic acid (1, R = H), mp 266–267° dec.

6-Methyl-4-(1*H*)-pyridone-3-carboxylic Acid (1, R = H).—A solution of **7** (14.5 g, 0.08 mol) in 100 ml of Methyl Cellosolve was refluxed for 3 hr while a slow stream of ammonia was bubbled into the solution. The solution was evaporated under reduced pressure and the residue was dissolved in 50 ml of water. Careful acidification with glacial acetic acid gave a suspension which was cooled and filtered to afford 6 g (49%) of 1 (R = H), mp 267–268° dec, ir (Nujol) 1660 cm^{-1}. The compound was analyzed without further purification.

Anal. Calcd for $C_7H_7NO_3$: C, 54.90; H, 4.61; N, 9.15. Found: C, 55.11; H, 4.37; N, 9.04.

(5) H. Weingarten, J. P. Chupp, and W. A. White, *J. Org. Chem.*, **32**, 3246 (1967).

In the same way 1 (R = CH_3) was prepared in 55% yield.

1,6-Dimethyl-4-pyridone-3-carboxylic Acid (1, R = CH_3).—3-(Dimethylaminomethylene)-4-oxo-6-methyl-2-pyrone (111 g, 0.613 mol) was dissolved in 100 ml of water; aqueous methylamine (40%, 300 ml) was added. A precipitate formed immediately and the suspension was heated on a steam bath for 15 min until a solution had formed. After standing for 30 min, the solution was evaporated to about two-thirds of its original volume. The remaining solution was acidified with acetic acid (taking care not to add excess acid for the product will redissolve again), cooled, and filtered. The dried pyridone weighed 77 g (75%), mp 227–228° (231–232° after recrystallization from 95% ethanol), ir (Nujol) 1710, 1670 cm^{-1}.

Anal. Calcd for $C_8H_9NO_3$: C, 57.58; H, 5.43; N, 8.38. Found: C, 57.89; H, 5.36; N, 8.33.

1-(*n*-Butyl)-6-methyl-4-pyridone-3-carboxylic Acid (1, R = *n*-C_4H_9).—Using Methyl Cellosolve as the reaction medium, this analog was prepared in 44% yield, mp 138–139° (recrystallized from water), ir (Nujol) 1715, 1675 cm^{-1}.

Anal. Calcd for $C_{11}H_{15}NO_3$: C, 63.14; H, 7.23; N, 6.70. Found: C, 63.28; H, 7.25; N, 6.58.

4-Hydroxycyclohexa[*b*]-2-pyrone (17, *n* = 2).—The morpholine enamine of cyclohexanone (127.5 g, 0.76 mol) was dissolved in 1000 ml of dry ether. The solution was stirred and cooled to −70° (Dry Ice–acetone bath). The enamine may partially crystallize as a white solid. Carboethoxyacetyl chloride (115 g, 0.76 mol) was added dropwise over a 1-hr period while maintaining the temperature in a range of −50 to ∼−70°. The mixture was warmed slowly to room temperature and stirred for 16 hr. Water (500 ml) was then added slowly; after stirring for a few minutes the ethereal layer was isolated, dried over anhydrous $MgSO_4$, filtered, and evaporated to afford 145 g of a viscous liquid. Attempts to induce crystallization or to effect purification by distillation were unsuccessful; so the crude liquid was used as such; a broad carbonyl band at 1750–1700 cm^{-1} and sharp band at 1030 cm^{-1} are present in the infrared spectrum (neat) of all the diketo esters.

The viscous liquid (145 g), presumed to be impure ethyl 2-keto-2-(2-ketocyclohexyl)propionate, was dissolved in dry dimethylformamide (500 ml). Sodium methoxide (37.8 g, 0.7 mol) was added all at once to the stirred solution. There was a slight exotherm and a small quantity of solid formed after a few minutes. The mixture was stirred and heated at 80–90° for 4 hr. After cooling, the reaction mixture was poured into 1200 ml of ice water. After extraction with methylene dichloride (three 300-ml portions) the aqueous phase was acidified (concentrated HCl). A white solid soon precipitated and was isolated and dried. The yield of **17** was 42 g (37%), mp 212–217°. Recrystallization from methanol afforded large, rectangular crystals: mp 225–228° (lit.[4] mp 222–223°); ir (Nujol) 3350, 1650, 1610 cm^{-1}; nmr (DMSO) τ 8.27 (m, 4 H, aliphatic), 7.57 (m, 4 H, allylic), −2.8 (1 H, hydroxyl), 4.67 (s, 1 H, olefinic).

3-(Dimethylaminomethylene)-4-ketocyclohexa[*b*]-2-pyrone (18, *n* = 2).—4-Hydroxycyclohexa[*b*]-2-pyrone (8.3 g, 0.05 mol) was suspended in 50 ml of anhydrous 1,4-dioxane. The dimethyl acetal of dimethylformamide (7.5 g, 0.063 mol) was added all at once and the suspension immediately turned yellow. The flask was swirled for a few minutes until a clear yellow solution formed and was placed in the refrigerator. After 3 hr the suspension which had formed was filtered and the solid was washed with 20-30 ml of dry dioxane. The dried solid weighed 9 g (80%) and melted with decomposition at 185–190°. An analytical sample was prepared by recrystallization from 2-propanol, mp 190–193°, as a light yellow solid: ir (Nujol) 1668, 1653 cm^{-1}; nmr ($CDCl_3$) τ 8.3 (m, 4 H, aliphatic), 7.63 (m, 4 H, allylic), 6.63 and 6.55 (s, 6 H, N-methyl), and 1.72 (s, 1 H, olefinic).

Anal. Calcd for $C_{12}H_{15}NO_3$: C, 65.14; H, 6.83; N, 6.33. Found: C, 65.36; H, 6.77; N, 6.34.

3-Carboxy-*N*-methylcyclohexa[*b*]-4-pyridone (19, *n* = 2).—Reaction of **18** (*n* = 2) with aqueous methylamine, using the same procedure as in the case of 1 (R = CH_3), afforded the product in 60% yield, mp 281–283° dec (recrystallized from methanol), ir (Nujol) 1700 and 1630 cm^{-1}.

Anal. Calcd for $C_{11}H_{13}NO_3$: C, 63.75; H, 6.32; N, 6.76. Found: C, 63.63; H, 6.21; N, 6.67.

3-(*p*-Chlorophenylcarbamyl)-*N*-methylcyclohexa[*b*]-4-pyridone (20, *n* = 2).—3-Carboxy-*N*-methylcyclohexa[*b*]-4-pyridone (5 g, 0.024 mol) was slurried in 50 ml of benzene while triethylamine (2.4 g, 0.024 mol) was added. Ethyl chloroformate (2.6 g, 0.024 mol) was slowly added to the cooled suspension. In 5 min, a

solution of *p*-chloroaniline (3.1 g, 0.024 mol) in 40 ml of benzene was added. After stirring for 90 min the suspension was filtered and the solid obtained was washed with water and dried to give 4.5 g (52%) of a white solid, mp 265–267°. An analytical sample was prepared by recrystallization from ethanol, mp 265–267°, ir (Nujol) 1685, 1630 cm^{-1}.

Anal. Calcd for $C_{17}H_{17}ClN_2O_2$: C, 64.45; H, 5.41; N, 8.84. Found: C, 64.31; H, 5.40; N, 8.70.

4-Hydroxycyclopenta[*b*]-2-pyrone (17, *n* = 1).—The diketo ester (19 g), prepared in 49% crude yield from the morpholine enamine of cyclopentanone and carboethoxyacetyl chloride, was dissolved in dry dimethylformamide (100 ml). Sodium methoxide (5.4 g, 0.1 mol) was added to the solution, which was then heated for 20 hr at 75–80°. Work-up gave 0.4 g (3%) of the product: mp 188° dec (lit.[4] mp 191–195° dec); ir (Nujol) 3350, 1650, 1610 cm^{-1}; nmr (DMSO) τ 7.93 (m, 2 H, aliphatic), 7.38 (m, 4 H, allylic), 4.77 (s, 1 H, olefinic), and −1.5 (s, 1 H, hydroxyl).

4-Hydroxycyclohepta[*b*]-2-pyrone (17, *n* = 3).—The morpholine enamine of cycloheptanone (36.2 g, 0.2 mol) was dissolved in 200 ml of ether. After the solution had been cooled to −70° (Dry Ice–acetone bath), carboethoxyacetyl chloride (31 g, 0.2 mol) dissolved in 50 ml of ether was added dropwise. When addition was complete (*ca.* 30 min) the temperature of the mixture, now at −50°, was raised to room temperature. Water (200 ml) was added and the suspension was stirred for 15 min. The ethereal layer was isolated, dried ($MgSO_4$), and evaporated to afford 39 g of a yellow oil.

A solution was prepared of 39 g of the oil in 250 ml of dry dimethylformamide. When sodium methoxide (10.8 g, 0.2 mol) was added, a solid formed immediately and the suspension was heated at 80° for 5 hr. When cooled the suspension was poured into ice water (1000 ml). A light yellow solid (7 g) precipitated and was isolated. The filtrate was extracted with methylene dichloride (300 ml) and then acidified (concentrated HCl). A flocculent precipitate that formed was isolated, washed with water, and dried to give 12 g of a light yellow solid. The infrared spectra of both solids were identical. The combined solids were recrystallized from dioxane to give a white solid: 18 g (59%); mp 183–185° (lit.[4] mp 181–183°); ir (Nujol) 3350, 1650, 1610 cm^{-1}; nmr (DMSO) τ 8.33 (m, 6 H, aliphatic), 7.4 (m, 4 H, allylic), 4.67 (s, 1 H, olefinic), and −3.37 (s, 1 H, hydroxyl).

3-(Dimethylaminomethylene)-4-ketocyclohepta[*b*]-2-pyrone (18, *n* = 3).—Pyrone **17** (*n* = 3, 10.6 g, 0.04 mol) was suspended in 70 ml of anhydrous 1,4-dioxane. Following addition of the dimethyl acetal of dimethylformamide (8.8 g, 0.074 mol), the suspension was swirled until solution was complete. For 3 days the solution was let stand at room temperature. Isolation of the crystalline material and recrystallization from 2-propanol gave 4.2 g (30%) of a white solid, mp 164–166°, ir (Nujol) 1700, 1645 cm^{-1}.

Anal. Calcd for $C_{13}H_{17}NO_3$: C, 66.36; H, 7.21; N, 5.95. Found: C, 66.23; H, 7.20; N, 5.90.

3-Carboxy-*N*-methylcyclohepta[*b*]-4-pyridone (19, *n* = 3).—Following the same procedure for the synthesis of **19** (*n* = 2), the desired product was prepared in 95% yield, mp 225–230°, as white needles after one recrystallization from methanol, ir (Nujol) 1710, 1645 cm^{-1}.

Anal. Calcd for $C_{12}H_{15}NO_3$: C, 65.14; H, 6.33; N, 6.8. Found: C, 64.88; H, 6.32; N, 6.77.

3-(*p*-Chlorophenylcarbamoyl)-*N*-methylcyclohepta[*b*]-4-pyridone (20, *n* = 3).—Following the identical procedure for synthesis of **20** (*n* = 2), 3.5 g (0.016 mol) of 3-carboxy-*N*-methyl-1*H*-cyclohepta[*b*] 4-pyridone afforded 2.1 g (40%) of the amide **20**, mp 255–258°, as a white solid. The melting point was unchanged after one recrystallization from ethanol; ir (Nujol) 1690, 1630 cm^{-1}.

Anal. Calcd for $C_{18}H_{19}ClN_2O_2$: C, 65.35; H, 5.80; N, 8.47. Found: C, 64.95; H, 5.73; N, 8.13.

Registry No.—**1** (R = H), 33821-58-8; **1** (R = CH_3), 33821-59-9; **1** (R = *n*-C_4H_9), 33821-60-2; **7**, 33821-61-3; **8**, 33821-62-4; **18** (*n* = 2), 33821-63-5; **18** (*n* = 3), 33821-64-6; **19** (*n* = 2), 33821-65-7; **19** (*n* = 3), 33821-66-8; **20** (*n* = 2), 33821-67-9; **20** (*n* = 3), 33821-68-0.

Acknowledgment.—The authors wish to thank Mrs. Florence Burnley for recording the nmr spectra and Mr. W. David Weir for the synthesis of several intermediates.

The Photochemistry of Substituted 1,5-Hexadien-3-ones

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The effects of methyl group substitution on the photochemistry of the 1,5-hexadien-3-one system has been examined, with particular emphasis on the intramolecular cycloaddition reaction to form the bicyclo[2.1.1]hexan-2-one system. Monosubstituted compounds **12**, **13**, **15**, **17**, and **18** and disubstituted compounds **14**, **16**, and **19** were studied. These structural changes were found to have profound effects on the photochemical reactions shown by these compounds, but few general trends of reactivity with substitution could be discerned. It appears that each system is unique in its behavior. The results obtained are rationalized on the basis of present knowledge of the mechanisms of photochemical reactions.

In a previous publication we described an approach to the bergamotene sesquiterpenes starting from readily available bicyclo[3.1.1]heptane precursors.[1] Because of the nature of the method used, this synthesis was limited to the formation of representatives of the cis series, *e.g.*, *cis*-β-bergamotene (**1**). The stereospecific nature of the synthesis was useful for the establishment of the absolute stereochemistry of the cis bergamotenes,[1] but could not be used for the synthesis of members of the trans series, *e.g.*, *trans*-α-bergamotene (**2**).[1,2] A method which appeared to have promise for the simultaneous synthesis of both cis and trans material was suggested by the report that direct irradiation of myrcene (**3**) afforded β-pinene (**4**) in low yield.[3] The major product formed in this reaction is the cyclobutene **5**.

In order to avoid the formation of products such as **5**, we decided to replace the diene chromophore of **3** with the enone system. However, we found the irradiation of the three model compounds **6**, **7**, and **8** to be unsuccessful as a method for the formation of the bicyclo[3.1.1]heptan-2-one system. No evidence could be found for the formation of cyclic products of any type, a result which is substantiated by an independent study of the photochemistry of **7**.[4]

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