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# CONDENSATIONS OF DEHYDROACETIC ACID AT THE 6-METHYL POSITION[1]*

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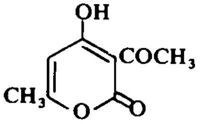
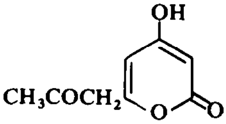
**Abstract**—Dehydroacetic acid in the presence of two equivalents of sodium amide in liquid ammonia underwent methylation at the acetyl methyl position. In contrast, treatment of dehydroacetic acid with three equivalents of sodium amide converted it to a trianion which underwent condensations with electrophiles predominantly at the 6-Me position. The condensations included alkylation with alkyl halides, carbonyl addition with benzophenone, conjugate addition with chalcone, and acylation with aromatic esters. The benzoylation product was converted by acid treatment into 2,4-dihydroxy-6-methylbenzophenone. Methylation of both the 6-methyl and the acetyl methyl positions was accomplished by treatment of dehydroacetic acid trianion with excess methyl iodide.

DEHYDROACETIC acid (3-acetyl-4-hydroxy-6-methyl-2-pyrone or 2-acetyl-3,5-dihydroxy-2,4-hexadienoic acid, δ-lactone) was originally prepared over 100 years ago by Geuther.[2] A controversy arose concerning its structure, which was resolved in 1924 when Rassweiler and Adams[3] obtained evidence supporting Feist's proposed structure **1**[4] and disproving Collie's formulation **2**.[5] More recent structural studies have been concerned with tautomerism of **1**.[6]


**1**


**2**

The reactions of dehydroacetic acid with electrophiles include O-alkylation at the 4-position effected with the silver salt,[6a,c,7] aldol and acylation reactions at the 3-acetyl Me group,[8,9] and halogenation at an unspecified position.[7b,c,10] No reactions at the 6-methyl position have been reported. In this paper are presented examples of alkylation, carbonyl and conjugate additions, and acylation of dehydroacetic acid at that position.[1]

The addition of dehydroactic acid to two equivalents of sodium amide in liquid ammonia gave a clear, green solution, presumably of dianion **1′**. Treatment with

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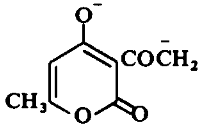
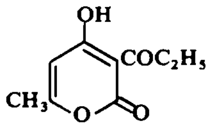
methyl sulfate gave a small amount of alkylation (22% by NMR); it occurred exclusively at the 3-acetyl Me position to give 3.* Because of the low yield, the product was not isolated. Its identity was determined by NMR comparison with authentic pyrone 3.[11] Treatment of the dianion with benzyl chloride or methyl benzoate gave no detectable reaction. The low yield with methyl sulfate and the failure of the other two reagents to react suggest that our tentative assignment of 1′ as the structure of the dianion must be regarded with some reservation.

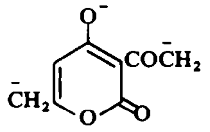


1′

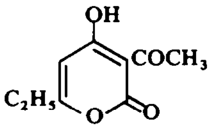


3

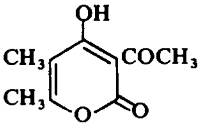
In contrast to the results with the disodium salt, treatment of dehydroacetic acid with three equivalents of sodium amide in liquid ammonia gave a yellow suspension. Alkylation with methyl chloride occurred rapidly. NMR analysis of the crude reaction product showed that it contained mainly 6α-methylation product 4 with lesser amounts of 5-methylation product 5 and dehydroacetic acid (1). On the basis of this evidence it is concluded that the yellow trisodium salt is probably structure 1″. None of acetyl methylation derivative 3 was detected. The yields of 4 and 5 calculated from the NMR spectrum were 76 and 6%, respectively. Some of pyrone 4 was isolated in essentially pure condition by column chromatography, but the small amount of 5 contained in the mixture could not be purified.



1″



4



5

The structure of 4 was indicated by comparison of the NMR spectrum with that of dehydroacetic acid (1). In the spectrum of 1 the acetyl Me group appears at 2·68 ppm and the 6-Me group at 2·27 ppm. The assignments of the two Me groups rest on the observable allylic coupling between the 6-Me hydrogens and the 5-proton. In the spectrum of 4 the acetyl signal remains, but the 6-Me signal has been replaced by a methylene multiplet.

The identity of unisolated pyrone 5 was established by NMR comparison with authentic material. Synthesis of the latter was accomplished by carboxylation of the dianion of 3-methyl-2,4-pentanedione, cyclization of the resulting acid with anhydrous

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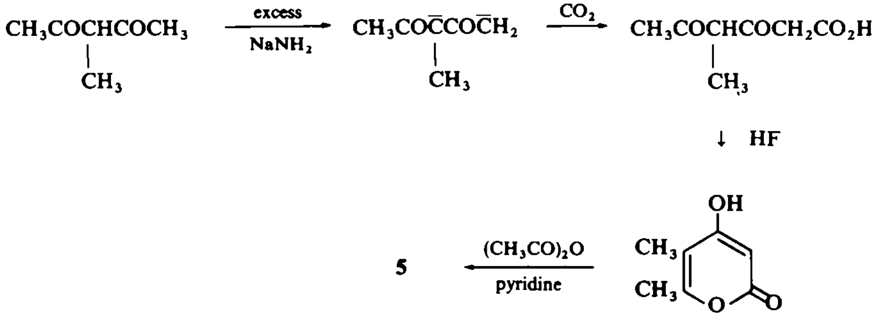
* This reaction was carried out with a mixture of mono- and disodium salts of dehydroacetic acid to ensure the absence of trianionic species.

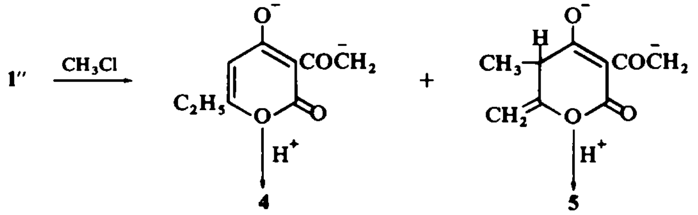
hydrogen fluoride, and subsequent C-acetylation of the 4-hydroxy-2-pyrone in pyridine (Scheme A).

SCHEME A

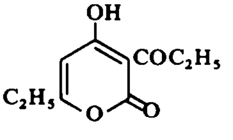


The formation of 5 was not anticipated in the methylation of trianion 1″. Apparently there is significant competition between the 5 position and the 6α position for methyl chloride. Alkylation at the 5 position must be followed by tautomerism of the proton at that position in order to form 5 (see Scheme B). It seems likely that this tautomerism occurred when the reaction mixture was acidified.

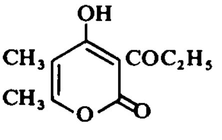
SCHEME B



Treatment of trianion 1″ with excess methyl iodide afforded dimethylation product 6 resulting from alkylation at both the 6-Me and the acetyl Me positions. The product was isolated in 60% yield. A minor amount of a 5-methylation product, either 5 or 7 was detected by NMR but was not isolated.

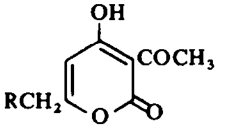


6

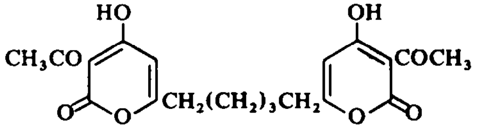


7

Trianion 1″ was monoalkylated with n-propyl bromide and with benzyl chloride to give the 6α derivatives 8 in yields of 72 and 58%, respectively. No alkylation was detected at the 5 position or at any other site. The structures of the products were substantiated by independent syntheses involving acetylation of the 6-alkyl-4-hydroxy-2-pyrones. Treatment of trianion **1″** with 1-bromo-3-chloropropane gave 64% of the corresponding bis(pyrone) **9**.

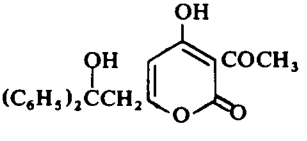


**8a**: R = $n$-$C_3H_7$
**b**: R = $C_6H_5CH_2$

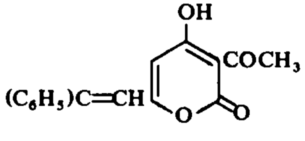


**9**

An aldol-type condensation was effected with benzophenone. Addition of the ketone gave immediate formation of a heavy, grey precipitate. The reaction mixture was neutralized by addition to a solution of ammonium chloride in liquid ammonia.* Carbinolpyrone **10** was obtained in 62% yield. Brief treatment with concentrated sulfuric acid converted it to the unsaturated pyrone **11**.

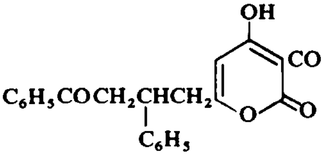


**10**

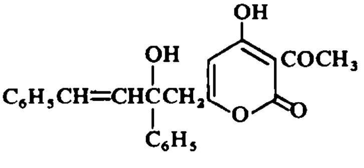


**11**

The trianion of dehydroacetic acid might attack chalcone either at the β-carbon to give **12** or at the carbonyl carbon to give **13**. Only the former product was isolated; it was obtained in 28% yield. The IR spectrum showed it contained an aromatic ketone (1680 $\text{cm}^{-1}$). The NMR spectrum indicated that the 5 hydrogen (5·78 ppm) was the only vinyl hydrogen present. The compound was insensitive to cold, concentrated sulfuric acid.



**12**



**13**

Condensation of trianion **1″** with methyl benzoate and with methyl anisate gave the corresponding phenacylpyrones **14a** and **b**. The optimum stoichiometry for the reaction was found to be two equivalents of trianion per equivalent of ester. This stoichiometry reflects reionization of the initial adduct, which is a dianion, by a

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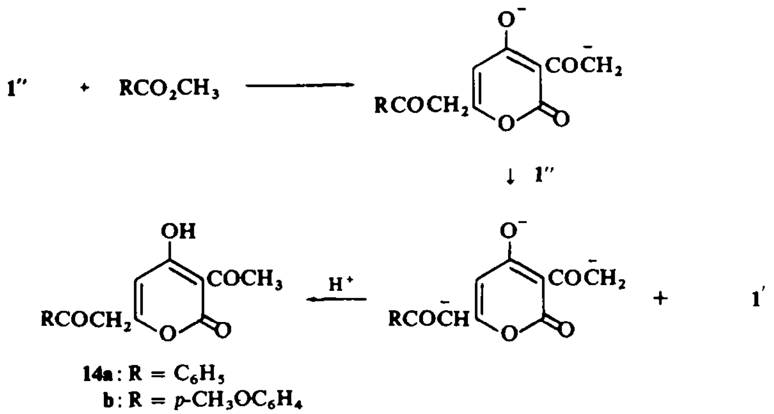
* This procedure was employed in order to avoid the possibility of reaction reversal in the presence of catalytic amounts of base. In some cases such a procedure is required if an adduct is to be obtained, see Ref. 12.

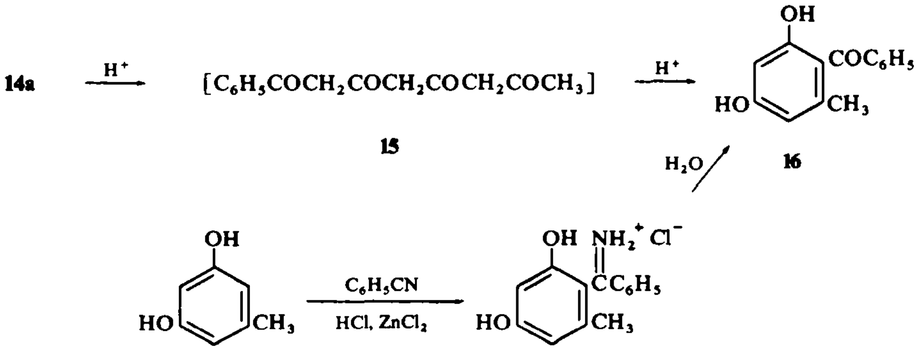
second equivalent of trianion 1″ to give a new trianion (Scheme C). The new trianion is stabilized by one more carbonyl group than is 1″ and consequently is unreactive. On the basis of this stoichiometry, 55 and 67% yields were obtained of **14a** and **b**, respectively.

Scheme C

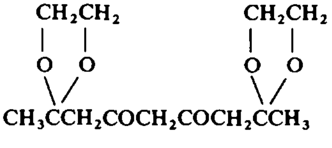


The acylation reaction (Scheme C) is of particular interest because the products (**14**) can be considered to be protected 1,3,5,7-tetraketones. In an attempt to effect conversion to a tetraketone a mixture of **14a**, hydrochloric acid, and acetic acid was refluxed. None of tetraketone **15** was obtained. However, it presumably was formed since 24% of the derived acylresorcinol **16** was isolated (see Scheme D). The structure proof of **16** rests on an independent synthesis by the method of Hoesch involving acid-catalyzed addition of benzonitrile to orcinol (see Scheme D).[13]

Scheme D



Collie effected the conversion of dehydroacetic acid to orcinol by treatment with base.[14] The yield was very low. Acid treatment of dehydroacetic acid affords good yields of either 4-hydroxy-6-methyl-2-pyrone or 2,6-dimethyl-4-pyrone, depending upon the conditions employed.[15] Linear poly-β-carbonyl compounds were postulated by Birch and Donovan to be precursors in the biosynthesis of many phenolic compounds.[16] Considerable difficulty has been experienced in attempts to synthesize these and related compounds. The general approach that has been employed by a number of groups involves masking one or more of the carbonyl groups as enol ethers or ketals during synthesis (i.e. **17**).[17] This method appears very promising. However, the problems associated with removal of the protective groups have not yet been resolved.



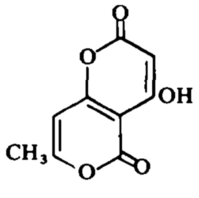
$$\mathrm{CH_3\overset{\overset{CH_2CH_2}{\overset{|\quad|}{O\quad O}}}{C}CH_2COCH_2COCH_2\overset{\overset{CH_2CH_2}{\overset{|\quad|}{O\quad O}}}{C}CH_3}$$

**17**

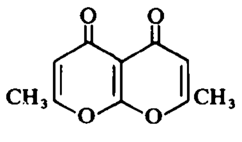
Some success has been experienced recently in the direct synthesis of poly-β-carbonyl compounds. One tetraketone, 1,7-diphenyl-1,3,5,7-heptanetetrone, has been synthesized by two routes, and was found to be relatively stable. One method involved benzoylation of 1-phenyl-1,3,5-hexanetrione in the presence of strong bases;[18] the other utilized reduction and hydrolysis of a bis(isoxazole).[19] Neither method has been explored with structural variants; in particular tetraketone **15** has not been synthesized yet.[18–20]

A reasonably general method for the preparation of 3,5,7-triketo acids has been reported.[21] Trianions of 2,4,6-triketones have been carboxylated at the 1 position. In most cases the triketo acids could be isolated and purified, although the method worked only poorly with the lower aliphatic triketones. Under appropriate conditions the triketo acids undergo cyclizations to form phenolic derivatives of the resorcylic acid and acylphloroglucinol types.

As an alternative to investigation of poly-β-carbonyl compounds themselves, several groups have studied the chemistry of complex pyrones such as **18** and **19**.[22]



**18**



**19**

Hydrolysis of the ether and lactone linkages of these compounds leads to poly-β-carbonyl systems. Under the conditions required for ring opening, recyclization occurs rapidly to form phenolic products, and as a consequence the acyclic poly-carbonyl compounds have not been detected during the course of these reactions. The present work provides pyrones **14**, which represent a new class of compound for the study of aromatization reactions, such as the formation of **16** reported herein.

## EXPERIMENTAL[*]

*Dehydroacetic acid* (**1**) was obtained from Eastman Organic Chemicals Co. and was dried before use; NMR ($CDCl_3$) $\delta$ 2·27 (d, 3, $J$ = 1 Hz, 6-$CH_3$), 2·68 (s, 3, $CH_3CO$), 5·95 (q, 1, $J$ = 1 Hz, 5-H), 16·7 (s, 1, enol).

*Methylation of disodiodehydroacetic acid* (**1′**). Dehydroacetic acid (0·05 mole) was added to 0·083 mole sodium amide (prepared from 1·9 g Na) in liquid ammonia to give a green soln. The mixture was treated with $Me_2SO_4$ (6·3 g, 0·05 mole) and after 30 min ether was added and the ammonia was evaporated. The suspension was shaken with dil HCl and the ethereal soln was separated, dried ($MgSO_4$), and evaporated. An NMR spectrum of the residue indicated that it was a mixture of **1** and **3**. The NMR spectrum of **3** was identical with that of material prepared below. The ratio of NMR areas of the propionyl methyl of **3** and the combined 6-Me groups of **1** and **3** was 1:7. This reflects a 22% conversion of dianion **1′** to **3**.

*Independent synthesis of pyrone* **3**. 4-Hydroxy-6-methyl-2-pyrone was acylated with propionic anhydride by the procedure of Kögl and Salemink[11] to give **3**, m.p. 103·5–104·5° (Lit.[11] m.p. 101–102°); NMR ($CDCl_3$) $\delta$ 2·37 (s, 3, 6-$CH_3$), 5·97 (s, 1, 5-H), and 16·9 (s, 1, enol).

*Monomethylation of trisodiodehydroacetic acid* (**1″**). To a suspension of 0·165 mole sodium amide (prepared from 3·8 g Na) in 700 ml anhyd, liquid ammonia was added 8·4 g (0·05 mole) dehydroacetic acid. After 1 hr, 3·5 g (0·07 mole) MeCl was added as a gas to the yellow-brown suspension. After 15 min, the ammonia was evaporated on the steam bath with simultaneous addition of anhyd ether to afford a final volume of ca. 400 ml. The ethereal suspension was washed with dil HCl and the aqueous soln was re-extracted with ether. The combined ethereal solns were dried ($MgSO_4$) and evaporated under reduced press to leave 7·82 g of a solid residue, m.p. 30–42°. The NMR spectrum indicated that it was a mixture of 88% of **4**, 7% of **5** and 5% dehydroacetic acid; no 4-hydroxy-6-methyl-3-propionyl-2-pyrone was detected. The contained yield was 76%. Chromatography of 1·1 g of the material on silicic acid with elution by either–hexane (40:60, v/v) followed by sublimation and recrystallization from EtOH–water gave 0·62 g (44% overall yield) of 4, m.p. 47–48° (Lit.[11] b.p. 145–151°/12 mm); IR (KBr) 1730, 1640, 1560, and 1450 $cm^{-1}$; NMR ($CDCl_3$) $\delta$ 1·3 (*t*, 3, $J$ = 7·5 Hz, $C_2H_5$), 2·6 (*q*, 2, $J$ = 7·5 Hz, $C_2H_5$), 2·65 (s, 3, $CH_3CO$), 5·98 (s, 1, 5-H) and 16·7 (s, 1, enol). The NMR spectrum showed that the material was free of dehydroacetic acid but still contained a trace of **5**. (Found: C, 59·33; H, 5·58. Calc. for $C_9H_{10}O_4$: C, 59·34; H, 5·53%.)

A comparable reaction in which MeI was substituted for MeCl gave 8·6 g of crude product, m.p. 46–60°. NMR analysis indicated it consisted of 89–92% of **4**, 2–5% of **5** and 6% of dehydroacetic acid. Purification of the product was not attempted.

*Independent synthesis of 3-acetyl-4-hydroxy-5,6-dimethyl-2-pyrone* (**5**). To 0·076 mole sodium amide (prepared from 1·76 g Na) in 300 ml liquid ammonia was added 2·5g (0·022 mole) 3-methyl-2,4-pentanedione.[23] Carboxylation was effected by the general method[24] described previously to give 1·5 g 4-methyl-3,5-dioxohexanoic acid as a liquid. Treatment of this material with anhyd, liquid HF gave 0·9 g (29% yield overall) 4-hydroxy-5,6-dimethyl-2-pyrone, m.p. 201–204° and 204–206° after recrystallization from EtOH–water; IR (KBr) 1675, 1630, 1550, 1500, 1260 $cm^{-1}$; NMR (DMSO-$d_6$ and $CDCl_3$) $\delta$ 1·85 (s, 3, 5-Me), 2·18 (s, 3, 6-Me), and 4·62 (s, 1, 3-H). (Found: C, 60·28; H, 5·81. Calc. for $C_7H_8O_3$; C, 60·00; H, 5·75%).

A mixture of 0·35 g of the pyrone, 2·5 ml $Ac_2O$, and 0·25 ml pyridine was heated at 180° for 2·5 hr in a sealed tube. The cooled mixture was poured onto ice. The ppt was sublimed to give 0·050 g (11% yield) of **5**, m.p. 73–75°; IR (KBr) 1745, 1640, 1610, and 1550 $cm^{-1}$; NMR ($CDCl_3$) $\delta$ 1·95 (s, 3, 5-Me), 2·3 (s, 3, 6-Me), 2·68 (s, 3, $CH_3CO$), and 16·8 (s, 1, enol). (Found: C, 59·57; H, 5·58. Calc. for $C_9H_{10}O_4$: C, 59·34; H, 5·53%).

*Dimethylation of trisodiodehydroacetic acid* (**1″**). To a suspension of 0·05 mole of **1″** prepared from 8·4 g dehydroacetic acid and 0·165 mole sodium amide) in 700 ml liquid ammonia was added 14·2 g (0·1 mole) MeI. After 10 min, the ammonia was evaporated on the steam bath with simultaneous addition of ether. The ethereal suspension was washed with dil HCl and with water, dried ($MgSO_4$), and evaporated to leave 9·4 g of **6**, m.p. 55–63°. The NMR spectrum indicated that the material was mainly **6** but contained ca. 10% of 5-methylation product **5** or **7**. Recrystallization of a portion of the crude material from EtOH–water gave essentially pure **6** (overall yield 60%), m.p. 67–69° and after further recrystallization m.p.

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[*] All m.ps unless otherwise noted were taken with a Thomas–Hoover apparatus in unsealed capillaries and are corrected. Elemental analyses were performed by Galbraith Laboratories, Inc., Knoxville, Tenn. IR spectra were obtained with a Beckman IR-10 Spectrophotometer. NMR spectra were determined with a Varian A-60 Spectrometer. TMS was employed as an internal standard. The NMR spectrometer was purchased with funds obtained from the National Science Foundation.

71–71·5° (Lit.[25] m.p. 72°), IR (KBr) 1735, 1655, 1580, 1400, 920, and 835 cm$^{-1}$; NMR ($CDCl_3$) 1·17 (t, 3, $J = 7{\cdot}5$ Hz, $CH_3$), 1·24 (t, 3, $J = 7{\cdot}5$ Hz, $CH_3$), 2·54 (q, 2, $J = 7{\cdot}5$ Hz, 6-$CH_2$), 3·1 (q, 2, $J = 7{\cdot}5$ Hz, 3-$CH_2$), 5·93 (s, 1, 5-H), and 16·8 (s, 1, enol).

3-*Acetyl-6-butyl-4-hydroxy-2-pyrone* (**8a**). To a suspension of 0·082 mole sodium amide (prepared from 1·9 g Na) in 500 ml anhyd, liquid ammonia was added 4·25 g (0·025 mole) dehydroacetic acid. After 1 hr, 3·70 g (0·030 mole) n-propyl bromide was added in anhyd ether. The pale yellow suspension was stirred for 30 min, 5·5 g $NH_4Cl$ was added and the ammonia was evaporated on the steam bath. Ether, ice and HCl were added. The layers were separated and the aqueous layer was extracted several times with ether. The combined ethereal extracts were dried ($MgSO_4$) and evaporated to give 3·8 g (72% yield) of **8a** m.p. 62–69° and 75·5–77° after recrystallization from EtOH (Lit.[11] m.p. 77°); IR (KBr) 1725, 1620, 1565, 1440, 985; NMR ($CDCl_3$) $\delta$ 2·65 (s, 3, $CH_3CO$), 5·93 (s, 1, 5-H), and 16·8 (s, 1, enol).

The mixture m.p. of this material with independently prepared **8a** (see below) was undepressed. Their NMR spectra were identical.

*Independent synthesis of pyrone* **8a**. To a suspension of 0·108 mole sodium amide (prepared from 2·5 g Na) in 400 ml anhyd, liquid ammonia was added 7·1 g (0·05 mole) 2,4-octanedione dissolved in a small amount of anhyd ether. After 0·5 hr, the ammonia was evaporated on the steam bath with simultaneous addition of anhyd ether. The ethereal suspension was refluxed briefly to ensure removal of ammonia. Carbonyl sulfide was then bubbled through the soln.* After 15 min the suspension was poured into a mixture of ice and excess HCl. The layers were separated and the ether layer was extracted with 5% $NaHCO_3$ aq. The bicarbonate extract was neutralized with cold, dil HCl. The resulting gummy suspension was extracted with ether. The ethereal extract was dried ($MgSO_4$) and evaporated under reduced press to give 1·95 g (23% yield) 6-butyl-4-hydroxy-2-pyrone as an oil that crystallized in the freezer, m.p. 42–54° and 58·5–60° after recrystallization from water (Lit.[11] m.p. 58·5°). The original ether layer was subsequently dried ($MgSO_4$) and evaporated to give an additional 2·1 g (48% total yield) 6-butyl-4-hydroxy-2-pyrone.

A mixture of 1·0 g of the pyrone, 1·0 g acetyl chloride and 0·12 ml conc $H_2SO_4$ was heated at 130° for 20 min. The dark soln was poured onto ice and extracted with ether. The ethereal soln was extracted with 5% $Na_2CO_3$ aq. The alkaline extract was acidified and extracted with ether. The extract was dried ($MgSO_4$) and evaporated to give 0·72 g (57% yield) of **8a**, m.p. 72–75° and 77–78·5° after sublimation.

3-*Acetyl-4-hydroxy-6-phenethyl-2-pyrone* (**8b**). To a suspension of 0·05 mole of the trianion of dehydroacetic acid (prepared as for **8a**) was added 6·4 g (0·05 mole) benzyl chloride. The ammonia was evaporated and ether, ice, and HCl were added. The solid at the interface was removed by filtration. The ether layer was separated and extracted with 10% $K_2CO_3$ aq. The extract was acidified and re-extracted with ether. The ethereal soln was dried ($MgSO_4$) and evaporated to leave a yellow solid. This combined with the initial solid gave 10·5 g of crude product, m.p. 75–82°. Crystallization from EtOH gave 7·3 g (58%) of **8b** m.p. 85–89° and 92–93° after recrystallization from benzene; IR (KBr) 1710, 1650, 1550, 1450, and 1000 cm$^{-1}$; NMR ($CDCl_3$) $\delta$ 2·65 (s, 3, $CH_3CO$), 5·86 (s, 1, 5-H), and 16·7 (s, 1, enol). (Found: C, 69·84; H, 5·52. Calc. for $C_{15}H_{14}O_4$: C, 69·76; H, 5·46%).

A mixture m.p. of this material with independently synthesized **8b** (see below) was undepressed. The IR spectra were identical.

*Independent synthesis of pyrone* **8b**. A mixture of 0·7 g 4-hydroxy-6-phenethyl-2-pyrone,[24] 5·0 g $Ac_2O$ and 0·5 ml pyridine was heated at 170° for 2 hr in a sealed tube. The mixture was poured into ice water to give 0·62 g (84% yield) of **8b**, m.p. 80–85°. Treatment with charcoal in EtOH and recrystallization from EtOH–water gave m.p. 92·5–93·5°.

6,6′-*Pentamethylene-bis*(3-*acetyl-4-hydroxy-2-pyrone*) (**9**). By the procedure employed for **8a**, 0·05 mole of 1″ in liquid ammonia was treated with 3·94 g (0·025 mole) 1-bromo-3-chloropropane in 10 ml ether to give 6·05 g (64% yield) of **9**, m.p. 142–147·5° and 156–157·5° after treatment with charcoal and recrystallization from EtOH; IR (KBr) 1735, 1650, 1560, 1460, and 1000 cm$^{-1}$; NMR ($CDCl_3$) $\delta$ 2·67 (s, $CH_3CO$), 5·97 (s, 5-H), and 16·5 (s, enol). (Found: C, 60·50; H, 5·34. Calc. for $C_{19}H_{20}O_8$: C, 60·64; H, 5·36%).

3-*Acetyl-6-(2,2-diphenyl-2-hydroxyethyl)-4-hydroxy-2-pyrone* (**10**) *and* 3-*acetyl-6-(2,2-diphenylvinyl)-4-hydroxy-2-pyrone* (**11**). To a suspension of trisodiodehydroacetic acid in 500 ml liquid ammonia (prepared from 4·1 g (0·024 mole) dehydroacetic acid and 0·082 mole sodium amide) was added 4·7 g (0·026 mole) benzophenone dissolved in anhyd ether. The grey suspension was stirred for 15 min and poured into 100 ml liquid ammonia containing 5 g $NH_4Cl$. The ammonia was evaporated and the solid that remained

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* This new method for the preparation of 4-hydroxy-2-pyrones has been applied to the synthesis of 4-hydroxy-6-phenacyl-2-pyrone. The details will be published shortly.

was filtered, washed with water, and air-dried to give 5·25 g (62% yield) of **10**, m.p. 170–173° and 182·5–183·5° after recrystallization from benzene; IR (KBr) 1705, 1650, 1570, and 1455 cm$^{-1}$; NMR (acetone-$d_6$) $\delta$ 2·57 (s, 3, $CH_3CO$), 3·1 (s, 1, 6β-OH), 3·47 (m, 2, 6-$CH_2$), 5·77 (s, 1, 5-H), and 16·6 (s, 1, enol). (Found: C, 72·04; H, 5·20. Calc. for $C_{21}H_{18}O_5$: C, 71·99; H, 5·18%).

Pyrone **10** (1·0 g) was added to 10 ml conc $H_2SO_4$ at 6°. After the material had dissolved, the soln was poured onto ice and the resulting yellow solid was filtered and air-dried to give 0·85 g (90% yield) of **11**; m.p. 134–134·5° and 135–135·5° after recrystallization from EtOH, IR (KBr) 1740, 1610, 1550 and 1450 cm$^{-1}$; NMR ($CDCl_3$) $\delta$ 2·60 (s, 3, $CH_3CO$), 5·53 (s, 1, 5-H), 6·58 (s, 1, 6-vinyl) and 16·4 (s, 1, enol). (Found: C, 76·04; H, 5·00. Calc. for $C_{21}H_{16}O_4$: C, 75·89; H, 4·85%).

3-*Acetyl-6-(4-oxo-2,4-diphenylbutyl)-4-hydroxy-2-pyrone* (**12**). To a suspension of 0·025 mole of **1**″ (formed from 0·082 mole sodium amide and 4·25 g (0·025 mole) dehydroacetic acid) was added an ethereal soln of 5·2 g (0·025 mole) chalcone. After 75 min the ammonia was evaporated with simultaneous addition of ether. The ethereal suspension was washed with water. Acidification of the washings afforded a semi-solid material that was separated by decantation. Trituration with ether gave 2·6 g (28% yield) of **12** as a white powder, m.p. 115–124° and 136–140° after recrystallization from benzene; IR (KBr) 1740, 1680, 1640, 1560, and 990 cm$^{-1}$; NMR ($CDCl_3$) $\delta$ 2·61 (s, 3, $CH_3CO$), 2·75–3·00 (m, 2, chain-$CH_2$), 3·28–3·44 (m, 2, chain-$CH_2$), 3·50–4·13 (m, 1, chain-CH), 5·78 (s, 1, 5-H), 7·2–8·0 (m, 10, $C_6H_5$), and 16·6 (s, 1, enol). Further recrystallization of **12** from benzene–hexane gave crystals having a double m.p.: m.p. 123·5–125° and 139·5–140·5°. (Found: C, 73·42; H, 5·36. Calc. for $C_{23}H_{20}O_5$: C, 73·39; H, 5·36%).

Pyrone **12** was recovered unaltered after treatment with cold, conc $H_2SO_4$.

3-*Acetyl-4-hydroxy-6-phenacyl-2-pyrone* (**14a**). To a suspension of 0·05 mole of **1**″ (prepared from 8·4 g (0·05 mole) of **1** and 0·165 mole sodium amide) in 500 ml liquid ammonia was added 3·4 g (0·025 mole) methyl benzoate in a small volume of ether. After 30 min the ammonia was evaporated on the steam bath. Ether was added and the mixture was extracted with cold water. The aqueous soln was acidified affording 6·5 g of a yellow solid, m.p. 129–133°. After removal of dehydroacetic acid by sublimation the residue was recrystallized from EtOH yielding 3·75 g (55%) of **14a**, m.p. 137·5–138·5°; IR (KBr) 1720, 1695, 1650, 1560, 1450, and 1010 cm$^{-1}$; NMR ($CDCl_3$) $\delta$ 2·67 (s, 3, $CH_3CO$), 4·20 (s, 2, $CH_2$), 6·17 (s, 1, 5-H), and 16·9 (s, 1, enol). (Found: C, 66·00; H, 4·55. Calc. for $C_{15}H_{12}O_5$: C, 66·17; H, 4·44%).

3-*Acetyl-4-hydroxy-6-(4-methoxyphenacyl)-2-pyrone* (**14b**). By the same procedure, 4·2 g (0·025 mole) methyl anisate was condensed with 0·05 mole of **1**″ to give 11·5 g of crude product. After sublimation of unaltered **1**, 6·8 g of **14b** remained, m.p. 116–119·5°. Recrystallization from EtOH–water gave (67% yield) analytically pure material, m.p. 124·5–125·5°; IR (KBr) 1730, 1685, 1610, 1555, 1460, 1265, 1180 and 1015 cm$^{-1}$; NMR ($CDCl_3$) $\delta$ 2·64 (s, 3, $CH_3CO$), 3·9 (s, $CH_3O$), 4·13 (s, 2, $CH_2$), 6·18 (s, 1, 5-H), 7–8 (2 × d, 4, $J$ = 9 Hz, *p*-subst phenyl), 16·8 (s, 1, enol). (Found: C, 63·54; H, 4·62. Calc. for $C_{16}H_{14}O_6$: C, 63·57; H, 4·67%).

6-*Methyl-2,4-dihydroxybenzophenone* (**16**). A soln of 1·0 g of **14a**, 15 ml conc HCl, and 35 ml AcOH was refluxed for several hr until TLC showed that little starting material remained. The soln was poured onto ice. After standing 16 hr, 0·069 g of unaltered **14a** was removed by filtration. The filtrate was extracted with ether. The ethereal soln was dried ($MgSO_4$) and concentrated to give 0·779 g of a red oil which was chromatographed on 10 g silicic acid. Elution with ether-hexane (20:80, v/v) gave 0·203 g (24% yield) of **16**, m.p. 138·5–140° and m.p. 139–140° after recrystallization from chloroform (Lit.[13] m.p. 141°); IR (KBr) 1650, 1625, 1600, 1585, 1470, 1260, 1170, and 1135 cm$^{-1}$; NMR ($CDCl_3$) $\delta$ 1·87 (s, $CH_3$). The compound gave a brown-black enol test with $Fe(NO_3)_3$ and a pink color with tetrazotized benzidine. (Found: C, 73·70; H, 5·32. Calc. for $C_{14}H_{12}O_3$: C, 73·67; H, 5·30%).

An authentic sample of **16**, m.p. 139–141°, was prepared by the method of Hoesch.[13] The mixture m.p. of the two samples was undepressed; the materials were spectrally identical.

## REFERENCES

[1] For a preliminary communication, see T. M. Harris and C. M. Harris, *Chem. Commun.* 699 (1966).

[2] A. Geuther, *Z. Chem., Jena* **2**, 8 (1866); *Chem. Zentr.* **11**, 801 (1866).

[3] C. F. Rassweiler and R. Adams, *J. Am. Chem. Soc.* **46**, 2758 (1924).

[4] F. Feist, *Liebigs Ann.* **257**, 253 (1890).

[5] J. N. Collie, *J. Chem. Soc.* **59**, 179 (1891).

[6] [a] J. A. Berson, *J. Am. Chem. Soc.* **74**, 5172 (1952);
[b] S. Forsen and M. Nilsson, *Arkiv. Kemi* **17**, 523 (1961);
[c] E. E. Royals and J. C. Leffingwell, *J. Org. Chem.* **30**, 1255 (1965).

[7] [a] J. N. Collie and H. R. LeSeur, *J. Chem. Soc.* **65**, 254 (1894);
[b] W. H. Perkin, *Ibid.* **51**, 484 (1887);
[c] A. Oppenheim and H. Precht, *Ber. Dtsch. Chem. Ges.* **9**, 323, 1099 (1876).

[8] N. J. Hale, *J. Am. Chem. Soc.* **33**, 1119 (1911); R. H. Wiley, C. H. Jarboe, and H. G. Ellert, *Ibid.* **77**, 5102 (1955); A. J. Birch, D. W. Cameron, and R. W. Rickards, *J. Chem. Soc.* 4395 (1960); N. S. Vul'fson, E. V. Savenkova, and L. B. Senyavina, *J. Gen. Chem. U.S.S.R.* (*Engl. trans.*) **34**, 2766 (1964).

[9] P. F. G. Praill and A. L. Whitear, *Proc. Chem. Soc.* 112 (1961).

[10] F. Feist, *Ber. Dtsch. Chem. Ges.* **25**, 315 (1892).

[11] F. Kögl and C. A. Salemink, *Rec. Trav. Chim.* **71**, 779 (1952).

[12] C. R. Hauser and P. J. Hamrick, *J. Am. Chem. Soc.* **81**, 3144 (1959).

[13] K. Hoesch, *Ber. Dtsch. Chem. Ges.* **48**, 1122 (1915).

[14] J. N. Collie, *J. Chem. Soc.* **63**, 329 (1893); *Ibid.* **91**, 1806 (1907); and J. N. Collie and W. S. Meyers, *Ibid.* **63**, 122 (1893).

[15] J. N. Collie, *Ibid.* **59**, 607 (1891); and *Ibid.* **59**, 617 (1891).

[16] A. J. Birch and F. W. Donovan, *Austral. J. Chem.* **6**, 360 (1952).

[17] [a] A. J. Birch, P. Fitton, D. C. C. Smith, D. E. Steere, and A. R. Stelfox, *J. Chem. Soc.* 2209 (1963);
[b] H. Stetter and S. Vestner, *Chem. Ber.* **97**, 169 (1964);
[c] U. Schmidt and M. Schwochau, *Monatsh.* **98**, 1492 (1967);
[d] G. Bram, *Tetrahedron Letters* 4069 (1967).

[18] M. L. Miles, T. M. Harris and C. R. Hauser, *J. Am. Chem. Soc.* **85**, 3884 (1963); K. G. Hampton, T. M. Harris, C. M. Harris and C. R. Hauser, *J. Org. Chem.* **30**, 4263 (1965).

[19] G. Casnati, A. Quilico, A. Ricca and P. VitaFinzi, *Tetrahedron Letters* 233 (1966).

[20] See also, E. M. Kaiser, S. D. Work, J. F. Wolfe and C. R. Hauser, *J. Org. Chem.* **32**, 1483 (1967).

[21] T. M. Harris and R. L. Carney, *J. Am. Chem. Soc.* **89**, 6734 (1967).

[22] T. Money, I. H. Qureshi, G. B. Webster and A. I. Scott, *Ibid.* **87**, 3004 (1965); T. Money, J. L. Douglas and A. I. Scott, *Ibid.* **88**, 624 (1966); L. Crombie, D. E. Games and M. H. Knight, *Chem. Commun.* 355 (1966); L. Crombie and A. W. G. James, *Ibid.* 357 (1966); P. F. Hedgecock, P. F. G. Praill and A. L. Whitear, *Chem. & Ind.* 1268 (1966). F. W. Comer, T. Money and A. I. Scott, *Chem. Commun.* 231 (1967); J. L. Douglas and T. Money, *Canad. J. Chem.* **45**, 1990 (1967); T. Money, F. W. Comer, G. R. B. Webster, I. G. Wright and A. I. Scott, *Tetrahedron* **23**, 3435 (1967); J. L. Douglas and T. Money, *Ibid.* **23**, 3545 (1967); R. Bentley and P. M. Zwitkowits, *J. Am. Chem. Soc.* **89**, 676 (1967).

[23] A. W. Johnson, E. Markham and R. Price, *Org. Syntheses* **42**, 75 (1962); *Ibid.* **45**, 68 (1965).

[24] T. M. Harris and C. M. Harris, *J. Org. Chem.* **31**, 1066 (1966).

[25] H. von Pechmann and F. Negar, *Liebigs Ann.* **273**, 186 (1893).