tures as a catalyst.[6] Table I lists yields of crude trimer obtained at various temperatures with three different ratios of nitrile to hydrogen chloride. It is interesting to note that with a nitrile to hydrogen chloride ratio of 4 or 5 to 1 there is a marked decrease in yield as the temperature of reaction is raised. With lower ratios this effect is less pronounced. We interpret this an indication that the initial step in the trimerization is a rapid, reversible equilibrium between the nitrile and hydrogen chloride, which is shifted toward the two components as the temperature increases.

TABLE I

Millimoles		Ratio	Temp., °C.	Recovery, Millimiles		% Recovery	% Yield
CF_3CN[a]	HCl[a]			Gas[a]	Liq.[b]		
32.35	8.1	4.0	[c]	11.6	26.9	95.3	83.3
32.41	8.1	4.0	100		15.0		46.3
31.81	7.7	4.1	100	26.5	11.8	97.0	37.0
32.08	6.3	5.1	150	32.5	5.3	98.3	16.4
32.58	6.4	5.1	150	32.9	4.5	96.1	13.9
31.9	15.7	2.0	[c]	16.0	25.6	87.4	80.0
32.4	16.2	2.0	100	22.9	21.9	92.1	67.6
32.1	32.2	1.0	[c]	20.3	30.2	78.7	94.1
32.9	32.2	1.0	100		28.2		85.7
31.7	32.1	1.0	125	36.7	23.8	94.8	75.0
33.0	32.7	1.0	150	37.1	24.7	94.1	74.9
32.7[d]	32.1	1.0	[c]	33.1	18.8	80.2	57.7

[a] Calculated from P-V-T measurements assuming an ideal gas. [b] Millimoles of nitrile appearing as trimer. [c] Room temperature which varied from about 10 to 30°. [d] This experiment was run in a 100-ml. Parr high-pressure hydrogenation bomb.

EXPERIMENTAL

Trifluoroacetonitrile was prepared by dehydration of trifluoroacetamide according to the procedure of Gilman and Jones.[7] Hydrogen chloride and boron trifluoride were taken from Matheson Co. cylinders, frozen in liquid nitrogen in a glass trap and outgassed to remove a small amount of noncondensable material.

Trimerizations were effected in a 25-ml. bomb made from a $5^1/_2$-in. length of 1-in. diameter stainless steel rod with a $^5/_8$-in. hole drilled to a depth of 5 in. The end was threaded to take a No. 55-660 Matheson needle valve. A $^1/_{16}$-in. thick Teflon gasket was used to ensure a vacuum-tight seal. The outlet of the needle valve was fitted with an 18-mm. brass ball which allowed direct connection to a standard glass vacuum manifold. The reactants were measured as gases in a calibrated bulb with a Wallace and Tiernan model FA 160 absolute pressure gage having a range of 0–400 mm. of Hg. They were condensed in the previously evacuated and outgassed bomb by means of liquid nitrogen. The valve was then closed, the bomb allowed to warm to room temperature and maintained at the specified temperature for 18–20 hr. Temperatures between 100 and 150° were maintained to ±5° by a stirred oil bath. The bomb was then cooled to room temperature, if necessary, and reconnected to the vacuum manifold. The contents were pumped slowly through two traps in series, the first at −78° and the second at −196°. The amount of material in the −196° trap (listed in Table I as millimoles of recovered gas) was measured gasometrically. Infrared analysis showed it to consist mainly of HCl with varying amounts of unreacted nitrile. In many of the spectra a very weak doublet appeared at 5.5–5.6μ in the C=C or C=N region. This band is, at present, unassigned and could be due to traces of either a by-product or of one of the reaction intermediates. Several attempts at concentration of the species responsible were unproductive. The material from the −78° trap was vacuum distilled into a tared tube and weighed. It consisted primarily of trimer contaminated by a little HCl, which could be removed either by washing with aqueous sodium carbonate or by vacuum distilling the vapors through a small bed of ascarite. The latter proved to be more convenient on a small scale. Linde Molecular Sieve type 5A was less effective. A typical sample of trimer had n_D^{25} 1.32208, $d_{23.5}$ 1.595 (reported n_D^{25} 1.3161,[5] 1.3231[3]; d_{25} 1.593[5]; d_{26} 1.5857[3]).

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[6] R. T. Foster, U.S. Patent **2,375,545** (1945), reports preparation of 2,4,6-tris(trichloromethyl)-1,3,5-triazine together with monomer and tetramer by passing chlorine and and acetonitrile over carbon impregnated with halides of zinc, copper, or an alkaline earth metal at 200–400°.

[7] H. Gilman and R. G. Jones, *J. Am. Chem. Soc.*, **65**, 1458 (1943).

Kojic Acid and α-Chloro-α-deoxykojic Acid in Reactions Catalyzed by Sulfuric Acid and Potassium Acetate

L. L. Woods[1] and P. A. Dix

Received February 11, 1959

In several previous communications[2,3] new reactions of 4-pyrones have been revealed by attempting to ascertain to what extent these compounds exhibit an aromatic character. To this end it was decided to determine if nuclear hydroxy-4-pyrones such as kojic acid and α-chloro-α-deoxykojic acid would participate in the Pechmann[4] reaction.

The reaction of kojic acid with citric, malic, and maleic acids in the presence of concentrated sulfuric acid reveals that the Pechmann reaction does take place to form pyrono-coumarins but the products are highly contaminated compounds which are difficult to isolate and still more difficult to purify. Compound I was the only one produced in anything like satisfactory purity and yields. Infrared data were not sufficient for a decision as to the true nature of such a complicated compound, due to the fact that the pyrone carbonyl, nonnuclear carbonyl, lactone groupings, and esters all absorb frequencies in the near vicinity of each other. However, the formation of coumarins by the reaction of phenols with malic acid and under Pechmann conditions is well known and no further investigation on the nature of the compound is presented due to the fact that the syn-

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[1] The person to whom all communications regarding this paper should be directed.

[2] L. L. Woods, *J. Am. Chem. Soc.*, **77**, 3161 (1955).

[3] L. L. Woods, *J. Org. Chem.*, **22**, 341 (1957).

[4] R. Adams, *Org. Reactions*, **7**, 1 (1954).

TABLE I

Acyl Derivatives of α-Chloro-α-deoxykojic Acid

No.		M.P., °C.	% Yield	Formula	Calcd. Carbon	Calcd. Hydrogen	Found Carbon	Found Hydrogen
$\mathrm{II_A}$	Acetate	96–97	94	$C_8H_7ClO_4$	47.42	3.48	47.64	3.70
$\mathrm{II_B}$	Cinnamate	150	98	$C_{15}H_{11}ClO_4$	61.97	3.81	61.84	3.64
$\mathrm{II_C}$	Phenoxyacetate	96–97	100	$C_{14}H_{11}ClO_5$	57.05	3.76	56.87	3.97
$\mathrm{II_D}$	Benzoate	119–120[a]	89	$C_{13}H_9ClO_4$	58.99	4.18	58.79	3.97

[a] Agrees well with 117–118° reported by T. Yabuta, *J. Chem. Soc.*, **125,** 575 (1924).

TABLE II

No.	Compound	Acyl Der.	M.P., °C.	Formula	Calcd. Carbon	Calcd. Hydrogen	Calcd. Chlorine	Found Carbon	Found Hydrogen	Found Chlorine
$\mathrm{III_A}$	2-(Acetoxymethyl)-6-methylpyrano [3, 2-*b*] pyran-4, 8-dione	Kojic acid acetate	102 & 105[a]	$C_{12}H_{10}O_6$	57.60	4.02		57.12	4.36[b]	
$\mathrm{III_B}$	2-(Chloromethyl)-6-methylpyrano [3, 2-*b*]-pyran-4,8-dione	$\mathrm{II_A}$	106	$C_{10}H_7ClO_4$	52.99	3.11	15.64	52.61	4.23	15.47[c]
$\mathrm{III_C}$	2-(Chloromethyl)-6-methyl-7-phenoxypyrano-[3,2-*b*]pyran-4,8-dione	$\mathrm{II_C}$	102–103	$C_{16}H_{11}ClO_5$	60.29	3.47	11.12	59.99	3.74	10.94

[a] See preparation of compound VI from V. [b] Second run: C, 57.74; H, 3.97. [c] Second run: C, 52.84; H, 4.43; Cl, 15.49.

thesis was abandoned because the reaction did not lend itself to the preparation of the homologs of 2-hydroxymethylpyrano[3,2-*b*]pyran-4,6-dione (I).

Since the Pechmann reaction with kojic acid and α-chloro-α-deoxykojic acid left much to be desired it was decided to try the effect of fused potassium acetate on acyl derivatives of the two pyrones mentioned above. It was visualized that if the potassium acetate could effect a rearrangement of the acyl radical in the 5 position, then a Kostanecki-Robinson[5] type of cyclization might then be induced.

In order to demonstrate the postulated reaction, some new acyl derivatives of α-chloro-α-deoxykojic acid were prepared to be used as starting materials. These compounds were listed in the $\mathrm{II_{A-D}}$ series.

The postulated effect of fused potassium acetate on the acyl derivative was supported by experiment in two of the three compounds tested as witnessed by formation of compounds $\mathrm{III_A}$, $\mathrm{III_C}$; but $\mathrm{III_B}$, unaccountably, was unsatisfactory since its hydrogen was 1.1–1.3% high.

In order to verify the suggested course of the reaction, a compound previously reported[6] and described as being *principally* 2-acetoxymethyl-5-hydroxy-6-acetyl-4-pyrone (V) was prepared. This time the compound was rigorously purified and compared with IV, the product obtained by rearrangement of kojic acid diacetate. The compounds were found to be identical by mixture melting point and infrared spectra.

The cyclization procedure used to prepare compounds of the $\mathrm{III_{A-C}}$ series was applied to compound V. A cyclized product VI identical with $\mathrm{III_A}$ was obtained. Compound VI had a somewhat higher melting point than the original $\mathrm{III_A}$ but since no depression was observed in the mixture melting point and since neither compound showed any difference in infrared spectra, there is no doubt that they are the same substance.

TABLE III

Significant Infrared Absorption Bands[a] ($Cm.^{-1}$)

$\mathrm{III_A}$	1235, 1453, 1629, 1667, 1739
$\mathrm{III_B}$	1379, 1429, 1637, 1669, 1751
$\mathrm{III_C}$	1605, 1639, 1672, 1761, 1497

[a] Infrared spectra determined from KBr pellets on Beckman IR-5 instrument.

EXPERIMENTAL[7]

Preparation of 2-hydroxymethylpyrano[3,2-b]pyran-4,6-dione, [I]. Seven and one tenth g. (0.05 mole) of kojic acid was thoroughly mixed with 20 ml. of concentrated sulfuric acid. To this mixture was added 6.7 g. of malic acid (0.05 mole). The mixture was shaken and the flask immersed in an oil bath at 120–130° and heated at this temperature for 3 hr.

Occasional shaking of the flask appeared to assist the reaction. At the termination of the reaction period the mixture was cooled, 100 ml. of water was added, the solution nearly neutralized with sodium bicarbonate, and then extracted with three 100-ml. portions of ethyl acetate. Evaporation of the solvent over a steam bath left the product, 6.7 g., which was recrystallized twice from absolute ethanol, m.p. 174–175°.

Anal. Calcd. for $C_9H_6O_5$, C, 55.69; H, 3.11. Found: C, 55.29; H, 3.16.

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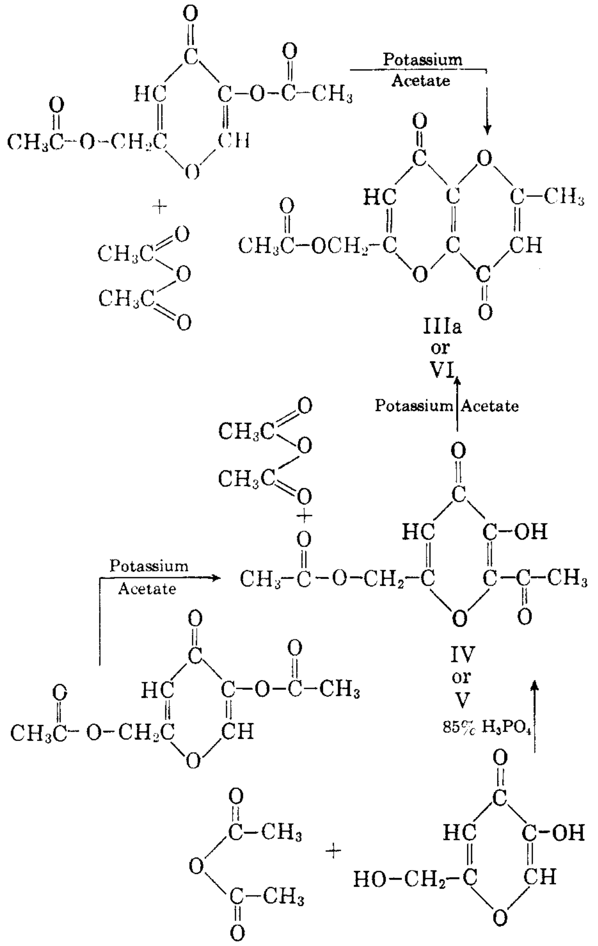
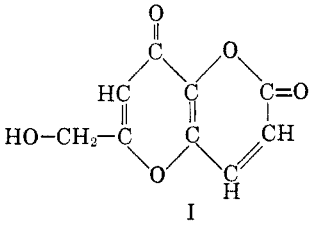
(5) R. C. Elderfield, *Heterocyclic Compounds,* John Wiley and Sons, New York, N. Y., 1951, Vol. 2, pp. 176, 234.

(6) L. L. Woods, *J. Am. Chem. Soc.*, **75,** 3608 (1953).

(7) All analyses and molecular weight determinations were performed by Dr. Carl Tiedcke, Teaneck, N. J. Melting points were run on a Fisher-Johns melting point assembly.

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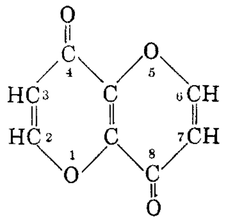
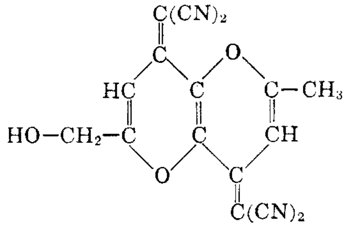

Pyrano[3,2-*b*]pyran-4,8-dione
Basic structure III_{A-C} series


Malononitrile derivative III_A

The infrared spectrum was determined on a Beckman IR-5 instrument. KBr pellet gave the following significant absorption bands: 1757 (broad), 1667, 1656, 1613 cm.$^{-1}$

Preparation of acyl derivatives of α-chloro-α-deoxykojic acid [II_{A-C} *series*]. To 100 ml. of benzene was added 0.06 mole of chlorodeoxykojic acid followed by 0.06 mole of the acyl halide. The mixture was usually refluxed 2 hr., but for the benzoyl derivative the reflux period was overnight, the solution filtered through a hot funnel, and the benzene removed over a steam bath. The analytical samples were all recrystallized twice from boiling heptane. Compounds of this series are listed in Table I.

Preparation of pyrano [3,2-b]-pyran 4,8-diones [III_{A-C} *series*]. Equal weights (12 g.) of the acylated pyrone (II_{A-D} series and kojic acid diacetate), potassium acetate, and acetic anhydride were mixed and the flask loosely stoppered with cotton. The mixtures were in each case heated for 2 hr. in a Fisher Hi-Temp oil bath at 120–130°. The melts were cooled, diluted with about 50 ml. of water, the solution neutralized with sodium bicarbonate, and then chilled. The precipitate was filtered with suction and dried in air. Crude yields from the three experiments exceeded theoretical slightly because of entrapped salts, which also added to the difficulty of drying the precipitates. Analytical samples were obtained by recrystallizing the compounds twice from absolute ethanol. Table II lists the products of this series. The cinnamic and benzoic acyl derivatives of α-chloro-α-deoxykojic acid failed to cyclize.

Malononitrile derivative of III_A. One g. each of III_A and malononitrile were refluxed together in 10 ml. of acetic anhydride for 30 min. The solution was diluted with 50 ml. of water, neutralized with sodium bicarbonate, and the solution extracted with benzene. Evaporation of the solvent produced 1.6 g. of red crystals. Recrystallization of the compound from 100 ml. of boiling heptane produced flesh-colored crystals, m.p. 101–102°.

Anal. Calcd. for $C_{13}H_{10}N_4O_4$: N, 16.18. Found: N; 15.97.

Repeated attempts to obtain a malonitrile derivative[8] from I_A or coumarin failed.

2-Acetoxymethyl-5-hydroxy-6-acetyl-4-pyrone [*IV*]. A mixture consisting of 12 g. of kojic acid diacetate and 12 g. of potassium acetate was heated at 130–135° for 90 min. in a Fisher Hi-Temp oil bath. The mixture was then cooled, diluted with 50 ml. of water, and the resulting solution extracted with ethyl acetate. Evaporation of the solvent produced 3.3 g. of brown crystals. The material was recrystallized twice from ethanol and then sublimed, m.p. 137.5°. The compound gave an immediate and intense red coloration with a 2% solution of ferric chloride.

Anal. Calcd. for $C_{10}H_{10}O_6$: C, 53.10; H, 4.45; mol. wt., 226.19. Found: C, 52.74; H, 4.25; mol. wt., 217, 211, 229, 223 (Rast).

A sample of 2-acetoxymethyl-5-hydroxy-6-acetyl-4-pyrone (V) was prepared by a procedure previously described[6] but this time the compound was purified by suspending a sample in a dilute sodium bicarbonate solution to remove all traces of acetic acid and dried in air. The first half of the analytical sample, 1 g., was sublimed and this sublimate discarded. The sublimate of the residual portion of the sample was retained. The compound gave a red coloration with $FeCl_3$ and melted at 137°. The mixture m.p. with compound IV was 136–138°, infrared spectra of compounds IV and V were identical.

A mixture consisting of 12 g. each of compound V, fused potassium acetate, and acetic anhydride was heated for 2 hr. at 120–130° in an oil bath to prepare 2-acetoxymethyl-6-methylpyrano[3,2-b]pyran-4,8-dione (VI) by an alternate route. The resulting compound (8.5 g.) was purified by extracting about 2 g. with 100 ml. of boiling heptane. The solvent was discarded. The residue was extracted with a second 100-ml. portion of heptane which upon chilling gave colorless prisms, m.p. 105°. A mixture melting point of 102–103°

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(8) L. L. Woods, *J. Am. Chem. Soc.*, **80**, 1440 (1958).

was determined using samples of VI and III$_A$. The two compounds gave identical infrared spectra.

Anal. Calcd. for $C_{12}H_{10}O_6$: C, 57.60; H, 4.02. Found: C, 57.92; H, 3.52.

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Structure Proof of 2,6-Di-*t*-butylpyridine-3-sulfonic Acid by Proton Magnetic Resonance

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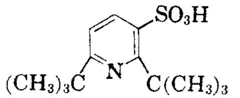
Received February 12, 1959

In contrast to ordinary pyridine bases, 2,6-di-*t*-butylpyridine undergoes ready sulfonation[1] by sulfur trioxide in liquid sulfur dioxide at −10°. Because of the large steric effect anticipated for a sulfonic acid substituent ortho to a *t*-butyl group, the original authors suggest that perhaps the substituent enters the pyridine ring in the 4- position rather than in the 3- position, as is customary for simple pyridine bases under vigorous conditions. Recently den Hertog[2] found that this sulfonic acid is rather inert to hydrolysis, and from this and from the properties of the hydrolysis product he concluded that it must be the 3- and not the 4- derivative. Although the likelihood of a molecular rearrangement during the hydrolysis is considered small, it seemed worthwhile to test this conclusion by examining the nuclear magnetic resonance (NMR) spectrum of the sulfonic acid itself. The results show unequivocally that the material is indeed the 3-sulfonic acid.

The NMR technique is particularly helpful when chemical evidence is available that rules out all but a small number of structures for the unknown material. In the present instance, it was anticipated that a decision between formulas I and II could readily be made because the difference in symmetry of these two structures should lead to several clearcut differences in their NMR spectra.



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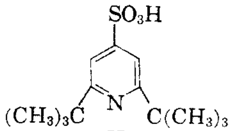

II

Structure I contains a pair of structurally nonequivalent protons attached to the ring. These should give rise to two resonance signals, each perhaps split into a doublet by their mutual electron-coupled spin-spin interaction. In structure II, the ring protons are equivalent and should produce a single, sharp peak. Similarly, I has two nonequivalent *t*-butyl groups, while both are equivalent in II. Thus structure I should show a second pair of peaks, each about nine times as strong as one of the ring-proton signals, while structure II should have only one strong peak at the field-value corresponding to methyl protons. The acid hydrogen in either molecule should contribute an additional peak comparable in strength with that of the ring-protons.

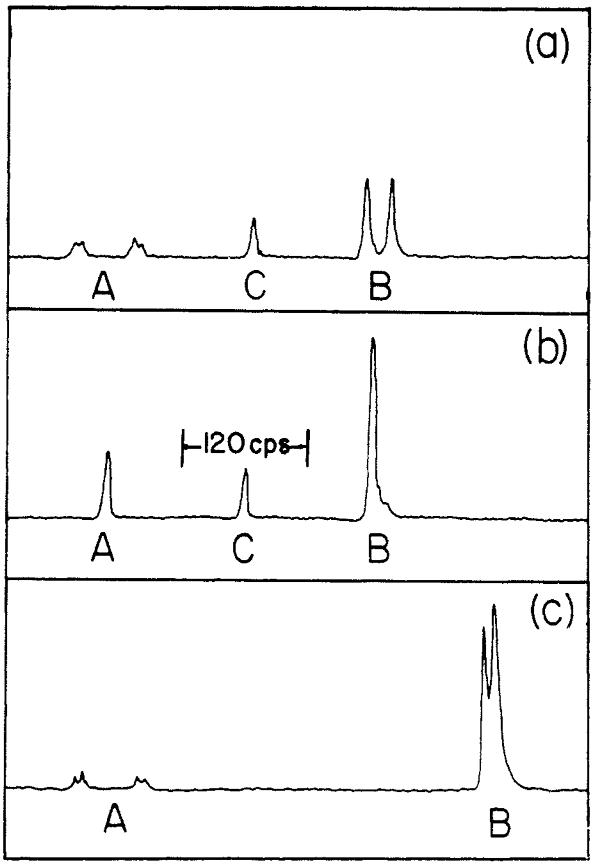

Fig. 1. NMR spectra of the sodium salts of 2,6-lutidine-3-sulfonic acid (a) and of 2,6-lutidine-4-sulfonic acid (b) in D_2O, and spectrum of 2,6-di-*t*-butylpyridine-3-sulfonic acid in liquid SO_2 (c). Peaks at A are due to ring protons, at B to methyl or *t*-butyl group protons, and at C to H_2O. The magnetic field increases towards the right for each trace.

To confirm this reasoning, we first obtained the spectra of authentic samples[3] of the two 2,6-lutidinesulfonic acids analogous to I and II. The spectra, shown in Figs. 1(a) and 1(b), have precisely the anticipated features. The samples consisted of solutions containing 2 moles of the acid

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[1] H. C. Brown and B. Kanner, *J. Am. Chem. Soc.*, **75**, 3865 (1953).

[2] H. J. den Hertog, *Chem. Weekblad*, **53**, 560 (1957).

[3] R. F. Evans and H. C. Brown, to be published.