2-Bromo-3-methylanisole, mp 33–36° (lit.[19] mp 35.5–36.5°), was obtained in 85% yield by the Sandmeyer reaction on 18.6 g of 2-amino-3-methylanisole using the sulfuric acid procedure.[21]

2-Bromo-3-methoxybenzyldimethylamine (XI), bp 112–114° (2.1 mm), was prepared in 55% yield by alkylation of dimethylamine with α,2-dibromo-3-methoxytoluene which, in turn, was prepared in 62% yield by the Wohl–Ziegler reaction of 31.5 g of 2-bromo-3-methylanisole.

Anal. Calcd for $C_{10}H_{14}BrNO$: C, 44.19; H, 5.77; N, 5.74. Found: C, 44.03; H, 5.81; N, 6.00.

2-Dimethylaminomethyl-6-methoxytriphenylcarbinol (Xa) was prepared by treatment of 4.50 g (0.18 mole) of 2-bromo-3-methoxybenzyldimethylamine (XI) with 15 ml (0.025 mole) of *n*-butyllithium in 125 ml of ether for 4 hr as described for the metalations of the ring-substituted benzyldimethylamines. The resulting lithioamine was added to a boiling solution of 0.025 mole of benzophenone in ether and allowed to stand for 4 hr.[5a] After a work-up as described above for the carbinolamines, there was isolated 5.05 g (80%) of Xa, mp 106–107°. A mixture melting point of this adduct and that obtained from the metalation of IXa was undepressed, mp 105–107°. Also, the infrared spectra of the two samples were superimposable.

Preparation of 2-Dimethylamino-5-methoxytriphenylcarbinol (XII).—4-Methoxy-2-methylbromobenzene, bp 106–109° (11 mm) [lit.[22] bp 108.5° (12 mm)], was obtained in 64% yield from the Sandmeyer reaction of 0.025 mole of 4-methoxy-2-methylaniline. This halide was converted by the Wohl–Ziegler reaction in 65% yield to 2-bromo-5-methoxybenzyl bromide which, in turn was treated with excess anhydrous dimethylamine to afford 2-bromo-5-methoxybenzyldimethylamine, bp 116–119° (1.8 mm), in 90% yield.

Anal. Calcd for $C_{10}H_{14}BrNO$: C, 44.19; H, 5.77; N, 5.74. Found: C, 44.48; H, 6.00; N, 5.69.

This bromoamine (2.50 g, 0.01 mole) was treated with 7 ml (0.011 mole) of *n*-butyllithium and 0.011 mole of benzophenone essentially as described for the metalations of the ring-substituted benzyldimethylamines to afford 1.35 g (47%) of XII, mp 118–119° after recrystallization from hexane. A mixture melting point of XII with Xa melted at 91–119°.

Anal. Calcd for $C_{23}H_{25}NO_2$: C, 79.50; H, 7.25; N, 4.03. Found: C, 79.65; H, 7.42; N, 3.91.

Deuteration of Amines IIIa, Va, and IXa.—The results of these reactions are summarized in Table III. The details are given below. The *o*-lithioamine, obtained by treating 0.025 mole of the appropriate amine with 0.03 mole of *n*-butyllithium for 1 hr as described above for the lithiations of the ring-substituted amines, was added to a stirred mixture of 0.05 mole of deuterium oxide (99.8% deuterium) in 100 ml of anhydrous ether. After stirring for 1 hr, the reaction mixture was worked-up as described for isolation of the carbinolamines to afford an oil which was distilled (see footnotes *b*, and *d* of Table III).

Cyclizations of Carbinolamines through Methiodides to Form Phthalans.—The results of these reactions are summarized in Tables IV and V. The details are given below.

Carbinolamines IIIc, VIa–c, and Xa, b were treated with excess methyl iodide in acetonitrile, and the resulting methiodides were recrystallized from this solvent. These methiodides were thermally cyclized at 200–210° for 15 min as described previously[12] to afford the cyclic ethers which were recrystallized from the appropriate solvents (see Table IV).

Registry No.—Butyllithium, 109-72-8; benzophenone, 119-61-9; II, 6969-98-8; IIIaD, 10126-18-8; IVa, 10169-24-1; IVb, 10126-19-9; IVc, 10126-20-2; VaD, 10126-21-3; VIa, 10126-22-4; VIb, 10126-23-5; VIc, 10126-24-6; VIII, 10126-25-7; IXaD, 10126-26-8; Xa, 10126-27-9; Xb, 10126-28-0; XI, 10126-29-1; XII, 10126-30-4; XV, 10126-31-5; XVI, 10126-32-6; XVIb, 10126-33-7; XVIc, 10126-34-8; XVIIa, 10126-35-9; XVIIb, 10126-36-0; 2-bromo-5-methoxybenzyldimethylamine, 10126-37-1.

(21) A. I. Vogel, "Textbook of Practical Organic Chemistry," 3rd ed, Longmans, Green and Co., New York, N. Y., 1956, p 602.

(22) R. Pschorr, *Ann.*, **391**, 50 (1912).

Acetylation and Cyclization of 1,3,5-Triketones with Acetic Anhydride by Boron Fluoride to Form Acyl-4-pyrones. Conversion into Acyl-4-pyridones. Mass Spectroscopy[1]

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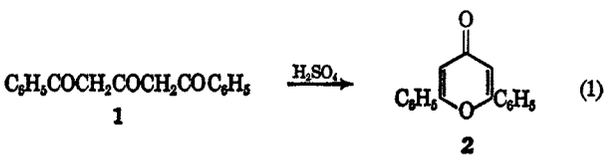
Received November 8, 1966

Acetylations and cyclizations of 1,5-diphenyl-1,3,5-pentanetrione, 1-phenyl-1,3,5-hexanetrione, and *o*-hydroxybenzoylacetone were effected with acetic anhydride by means of boron fluoride to form the corresponding acylpyrones, the last compound being a chromone. The first two products were subsequently converted to corresponding acylpyridones. Mass spectroscopy was employed to elucidate structures.

1,3,5-Triketones are known to be cyclized readily by acids such as cold, concentrated sulfuric acid[2] or liquid hydrofluoric acid[3] to form 4-pyrones. For example, triketone **1** affords pyrone **2** (eq 1).



1 **2** (1)

We have now found that certain 1,3,5-triketones can be acetylated and cyclized with acetic anhydride by boron fluoride to form acyl(acetyl or benzoyl)-4-pyrones. Thus, triketone **1** was converted in 90% yield to the acylpyrone **4a** which was subsequently converted to the acylpyridone **5a** (Scheme I). Isomeric structures **4b** and **5b** for these products, respectively, were eliminated by spectral methods (see below).

That the triketone did not first undergo cyclization to form pyrone **2** which was then acetylated was shown by failure of **2** to undergo acetylation under similar conditions. That the product was indeed an acylpyrone, not acetylated triketone **3** which was presumably formed initially (see Scheme I), was supported by analysis, by a negative enol test, and by similarity of the absorption spectra and other properties to those of known 4-pyrones.

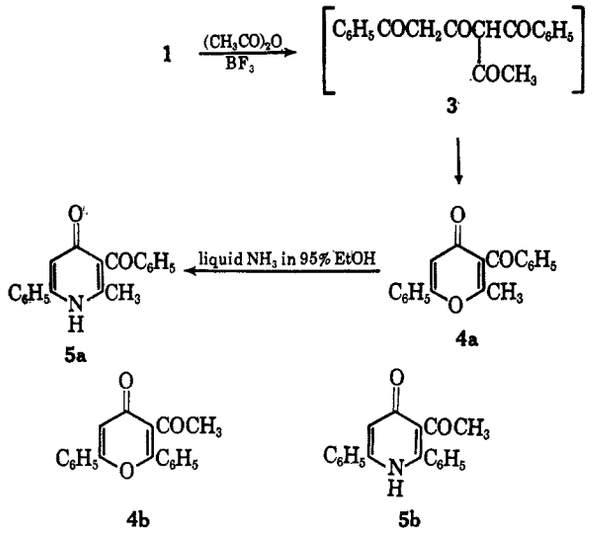
Interestingly, this acetylation–cyclization of triketone **1** with acetic anhydride and boron fluoride differs from the reaction of a β-diketone such as acetylacetone

(1) Supported by Public Health Service Research Grant No. CA 04455-07 from the National Cancer Institute and by the National Science Foundation.

(2) R. J. Light and C. R. Hauser, *J. Org. Chem.*, **25**, 538 (1960); M. L. Miles, T. M. Harris, and C. R. Hauser, *ibid.*, **30**, 1007 (1965).

(3) K. G. Hampton, T. M. Harris, C. M. Harris, and C. R. Hauser, *ibid.*, **30**, 4263 (1965).

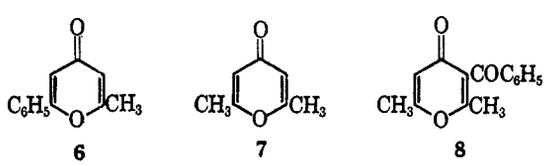
SCHEME I



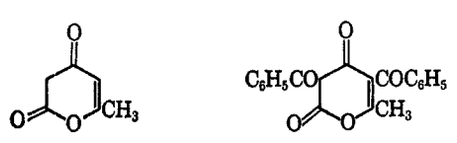
or benzoylacetone with these reagents, since the β-diketone is merely converted to its boron difluoride complex.[4] The initial acetylation of **1** is reminiscent of the well-known[5] acetylation of a ketone to form a β-diketone, for example, that of acetophenone to afford the boron difluoride complex of benzoylacetone, which is decomposed with hot sodium acetate solution (eq 2). However, sodium acetate treatment is not required for isolation of the acylpyrone in the present case (see the Experimental Section).

$$C_6H_5COCH_3 \xrightarrow[2.\ CH_3COONa]{1.\ (CH_3CO)_2O} C_6H_5COCH_2COCH_3 \qquad (2)$$

The two possible acylpyrones (**4a** and **4b**) could not be synthesized independently. Thus, attempts to benzoylate pyrone **6**, and to acetylate pyrone **2**, with the corresponding acid chlorides by means of trifluoroacetic acid to form **4a** and **4b**, respectively, were unsuccessful; this method has been employed for the analogous benzoylation of pyrone **7** to form **8**.[6]



It might appear that our acylpyrone, mp 155–155.5°, has structure **4b**, since Woods and Dix[6] have reported that benzoylation of lactone **9**, and subsequent acid-catalyzed hydrolysis and decarboxylation of the resulting dibenzoyl derivative **10**, affords acylpyrone **4a** melting at 124–125°. However, they gave no structural proof for their product; surprisingly the precursor to their product appeared to be tetraketone **3**, which we believe is the precursor to our acylpyrone.



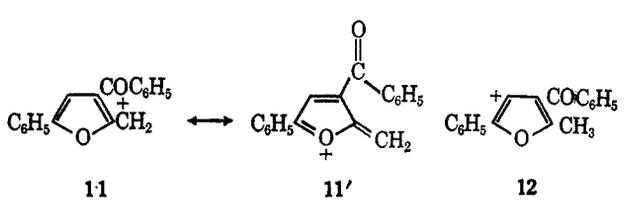
Actually, evidence is presented below that our acylpyrone has structure **4a**, and the acylpyridone has structure **5a**. This evidence consisted mainly of mass spectral determinations, which are summarized in Table I along with related data. This table shows

TABLE I

RELATIVE INTENSITIES IN THE MASS SPECTRA OF 4-PYRONES AND 4-PYRIDONES

m/e	**2**	**7**	**4a**	**5a**	**21a**	**22a**
M^+	44	24	71	70	88	54
M + 1	0	3	0	0	17	9
M − 1	0	0	55	75	16	0
M − 15	0	0	0	0	21	100
M − 28	100	18	0	0	5	0
M − 29	0	18	100	3	4	1
M − 77	0	0	2	23	0	0
105	38	0	46	43	17	1
104	0	0	0	7	0	2
102	84	0	16	13	16	5
77	74	0	90	100	27	10
67	0	0	30	11	57	5
43	4	100	49	0	100	21
42	1	10	1	9	2	6
15	2	20	3	1	11	4

that the spectrum of the acylpyrone contained both acetyl (*m/e* 43) and benzoyl (*m/e* 105) fragments. These fragments might have arisen from the rings of either **4a** or **4b** since they were also obtained from pyrones **2** and **7**[7] which have no acetyl or benzoyl side chains. However, the acylpyrone afforded an M − 29 fragment which supports **4a**, not **4b**, since this fragment has been observed with pyrone **7** and various others (see below) which contain a 2-methyl group, but not with pyrone **2** where this 2-methyl group is absent. This M − 29 fragment is presumably due to **11** or **12**; structure **11** is more likely since it should not only possess greater resonance stability (*e.g.*, **11′**) than **12**, but also because the related 2,5-dimethylfuran appears to lose hydrogen from a methyl group rather than from the ring.[7,8] Moreover, the spectrum of the



acylpyrone showed an M − 77 fragment which appears to have arisen from the benzoyl group in **4a**, since this fragment was not observed with pyrones **2** or **7** which have no benzoyl side chain. The relative intensity of the phenyl (*m/e* 77) as well as the benzoyl (*m/e* 105) fragments were greater in the benzoylpyrone **4a** than in

(4) Apparently triketone **1** undergoes acetylation before such a complex can be formed; the mechanism of the process is being investigated.

(5) See C. R. Hauser, F. W. Swamer, and J. T. Adams, *Org. Reactions*, **13**, 98 (1954).

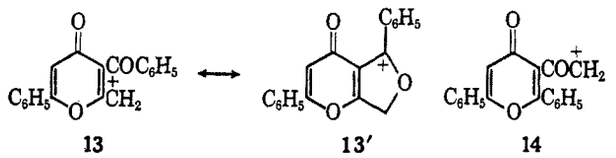
(6) L. L. Woods and P. A. Dix, *J. Org. Chem.*, **26**, 2588 (1961).

(7) The mass spectrum of this compound and of the corresponding 3,5-dimethyl isomer have been reported; see P. Beak, T. H. Kinstle, and G. A. Carls, *J. Am. Chem. Soc.*, **86**, 3833 (1964). Our results confirm those reported in this paper.

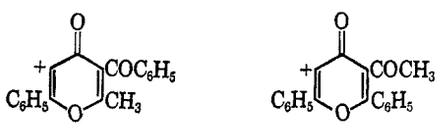
(8) See H. Budzikiewicz, C. Djerassi, and D. H. Williams, "Interpretation of Mass Spectra of Organic Compounds," Holden Day, Inc., San Francisco, Calif., 1964, p 227.

2, and were much greater than those in acetylpyrones (see below).

Also, the spectrum of the acylpyrone contained an M − 1 fragment which presumably arises from structure **13** although **14** and **15a,b** are also possible. Structure **13** is favored because methyl ketones do not readily lose α hydrogen (M − 1)[9] as would occur in **14** and also because **13** possesses more resonance stabilization than does **15a** or **15b**. Presumably, acylpyrone **4a** exhibits this M − 1 peak (**13**) while 2,6-dimethylpyrone **7** does not because of the existence of canonical form **13′**; such a corresponding "cyclic ether" is not possible in **7** since it does not contain an acyl group.



13 **13′** **14**



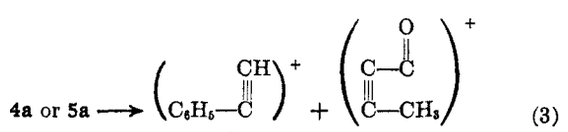
15a **15b**

Additional strong evidence supporting **4a**, not **4b**, was that the acylpyrone (as well as **2** and **7**) did not exhibit loss of a methyl group from the parent molecule (M − 15); such a fragmentation was found only in acylpyrones having an acetyl side chain (see below).

Similarly, the mass spectrum of the acylpyridone (see Table I) showed a benzoyl fragment (*m/e* 105), which could have arisen only from the side chain of **5a**, not from the ring of **5b**; indeed, a fragment for an acetyl side chain (*m/e* 43) of **5b** was not observed. Moreover, the spectrum contained fragments **16a** (*m/e* 104) and **16b** (*m/e* 42), which must have arisen from cleavage of the pyridone ring of **5a**. Also, fragments were observed to indicate the 2-methyl group (M − 29), the phenyl group (*m/e* 77, relatively large) and for M − 1. These results show conclusively that the acylpyridone was **5a**, not **5b**.

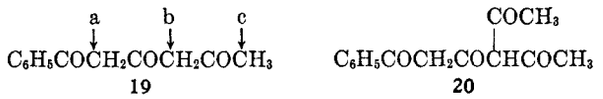
$(C_6H_5C{\equiv}NH)^+$ **16a** $(CH_3C{\equiv}NH)^+$ **16b**

Previously,[10] certain substituted 4-pyrones have been shown to fragment to substituted acetylenes under electron bombardment, and substituted pyridones would presumably do likewise. Thus, it is not surprising that *m/e* 102 (**17**) and *m/e* 67 (**18**) fragments were present in the mass spectrum of both acylpyrone **4a** and acylpyridone **5a**. These fragments would arise from scission of the unbenzoylated and the benzoylated sides of these molecules, respectively (eq 3). Although *m/e* 102 might have also arisen from **4b** and **5b**, *m/e* 67 could only have arisen from **4a** or **5b**. This latter conclusion is supported by the absence of an *m/e* 67 (**18**) fragment in the spectrum of **7**, a 4-pyrone which does not contain an acyl group.



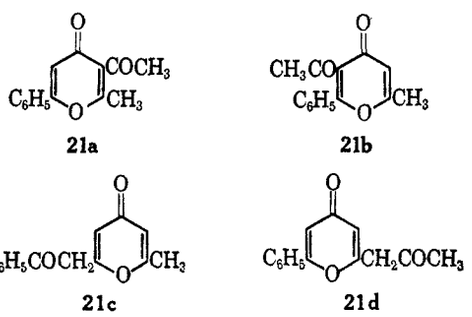
4a or **5a** → **17** + **18** (3)

Next, 1,3,5-triketone **19** was similarly acetylated and cyclized with acetic anhydride by boron fluoride in 52% yield to form an acyl-4-pyrone, which was subsequently converted to an acyl-4-pyridone. That the acetylation product isolated was indeed an acylpyrone and not an acetylated triketone such as **20** was supported by analysis, by a negative enol test, and by similarity of the absorption spectra and other properties to those of known 4-pyrones.



19 **20**

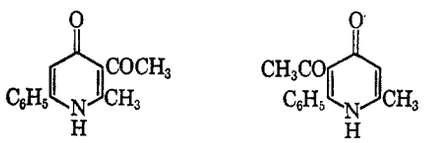
Whereas the acetylation of triketone **1** could occur at only one position, that of **19** might take place at a, b, or c. Evidently, acetylation involved position b to form tetraketone **20** since the acylpyrone obtained was shown to have structure **21a**. However, this acylpyrone (**21a**) had to be distinguished from acylpyrones **21b** and **8**, and from **21c** and **21b**, which might have arisen through acetylation at positions a and c, respectively.



21a **21b** **21c** **21d**

The nmr spectrum of the acylpyrone obtained failed to show chemical shifts which would be predicted for the methylene groups of **21c** and **21d**; therefore, the compound did not have either of these structures. The mass spectrum of the acylpyrone (see Table I) showed the presence of fragments **17** (*m/e* 102) and **18** (*m/e* 67), which supports **21a**, not **8** or **21b**. The presence of both of these fragments shows that the acyl group is adjacent to a methyl group as in **21a** rather than to a phenyl group as in **21b**. Conversely, the fragment *m/e* 102 must have arisen from an acylpyrone that contained a phenyl group in the 6 position and a hydrogen in the 5 position. The *m/e* 102 fragment could not have arisen from pyrone **8** since this compound contains a 6-methyl rather than a 6-phenyl group; also, **8** is a known compound[6] which melted much lower than our compound.

Similarly, the acylpyridone was shown to have the analogous structure **22a**, not the other structures corresponding to acylpyrones **8**, **21b**, **21c**, or **21d**; of these latter structures, only **22b** need to be considered. The mass spectrum of the acylpyridone (see Table I) contained fragments owing to **17** (*m/e* 102) and **18**



22a **22b**

(9) See ref 8, p 6.

(10) See, for example, C. S. Barnes and J. L. Occolowitz, *Australian J. Chem.*, **17**, 975 (1964).

(m/e 67) indicating that the acetyl group is adjacent to a methyl rather than to a phenyl group as in **22a**.

It should be pointed out that the present acylpyrone **21a** and acylpyridone **22a** were the only ones of the six compounds studied (see Table I) which exhibited an M − 15 fragment. This fragmentation is presumably due, therefore, to scission of a methyl group from the acetyl side chain of the compounds rather than scission of this group from the position α to the ether linkage.

Incidentally, the nmr spectra of several of the above pyrones are in agreement with the structural assignments. The results, listed in Table II, confirm that

TABLE II

NMR SPECTRA OF SELECTED PYRONES. TYPES OF HYDROGENS AND CHEMICAL SHIFTS (δ, PPM)

Pyrone[a]	Methyl	Vinyl
2	...	6.8
7	2.24	6.03
4a	2.35	6.8
21a	2.5, 2.6	6.76

[a] Each compound exhibited appropriate chemical shifts due to aromatic hydrogens.

both acylpyrones **4a** and **21a** contain phenyl moieties in the 6 position. Thus, 2,6-diphenylpyrone (**2**) as well as acylpyrones **4a** and **21a** exhibited a peak owing to the 5-vinyl hydrogen at δ 6.76–6.8 whereas the corresponding 5-vinyl hydrogen in 2,6-dimethylpyrone **7** lay upfield at δ 6.03.

On the other hand, the relative positions of the methyl groups in acylpyrones **4a** and **21a** could not be unequivocally assigned by nmr since the chemical shift of this group in **4a** (δ 2.35) lay between those owing to the ring methyl of 2,6-dimethylpyrone **7** (δ 2.24) and the ring and ketomethyls of acetylpyrone **21a** (δ 2.5 and 2.6). Differentiation of the two latter peaks was not possible.

Interestingly, 50-cps sweeps of each of the pyrones listed in Table II afforded very broad peaks. The spectrum of pyrone **7** contained poorly resolved multiplets for both the methyl and vinyl hydrogens which presumably are due to coupling between the 2,3 and the the 2,5 positions. However, the corresponding peaks in acylpyrones **4a** and **21a** were merely broadened, and resolution into distinct multiplets could not be accomplished. This lack of definite multiplicity is ascribed to the absence of coupling between a 2-methyl group and a 3-vinyl hydrogen since the latter hydrogen is not present in these compounds. The broadening that is observed is thus apparently due only to weak long-range coupling between the 2-methyl groups and the 5-vinyl hydrogens.

Similarly, the infrared and ultraviolet spectra of the above acylpyrones and acylpyridones are in agreement with the structural assignments. Thus, Table III, which contains this spectral data, shows that the infrared spectrum of **4a** contained a band assigned to the side-chain carbonyl group at 5.98 μ[11] while that of the corresponding acylpyridone (**5a**) had a similar band at 5.99 μ. These values are somewhat shifted from those of acetylpyrone **21a** (5.88 μ) and acetylpyridone **22a** (5.92 μ). Also, the ultraviolet spectra of both

(11) L. J. Bellamy, "The Infrared Spectra of Complex Molecules," 2nd ed, John Wiley and Sons, Inc., New York, N. Y., 1958, p 132.

TABLE III

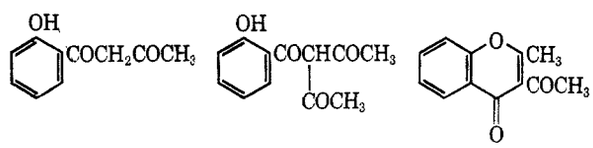
INFRARED AND ULTRAVIOLET SPECTRA OF SELECTED PYRONES AND PYRIDONES

Compd	Bands, μ	Bands, λ_{max} mμ (log ϵ)
2[a]	6.05, 6.17, 6.28, 6.36	254 (4.31)
		281 (4.36)
4a	5.98, 6.05, 6.16, 6.25, 6.32	266 (4.46)
5a	5.99, 6.18, 6.31, 6.62	250 (4.56)
6[a]	6.00, 6.19	272 (4.31)
21a	5.88, 6.04, 6.17	268 (4.32)
22a	5.92, 6.12, 6.22, 6.32, 6.61	252 (4.50)

[a] Reference 2.

4a and **21a** are more similar to 2-methyl-6-phenyl-4-pyrone (**6**) than to 2,6-diphenyl-4-pyrone (**2**).

Finally, *o*-hydroxybenzoylacetone (**23**) was acetylated and cyclized with acetic anhydride by boron fluoride to form the known[12] chromone (**25**) in approximately 50% yield; presumably, the hydroxy triketone (**24**) was an intermediate.



23 **24** **25**

The previous preparation of chromone **25** appears to have involved treatment of hydroxy β-diketone **23** with acetic anhydride and anhydrous sodium acetate (but no boron fluoride); however, the yield was not reported. We failed to isolate any chromone **25** when the trihydrate of sodium acetate was employed instead of the anhydrous salt.

Experimental Section[13]

Acetylation and Cyclization of 1,5-Diphenyl-1,3,5-pentanetrione (1) to Form Acylpyrone 4a.—Triketone **1**[2] (13.31 g, 0.05 mole) was dissolved in 10.21 g (0.1 mole) of acetic anhydride and 75 ml of 1,2-dichloroethane. After cooling in an ice bath, the solution was stirred and saturated (as evidenced by evolution of copious, white fumes) with commercial boron fluoride which was first bubbled through concentrated sulfuric acid. The ice bath was removed, and the reaction mixture was stirred for an additional 4 hr; it was then poured, with stirring, into a solution of 27.4 g (0.2 mole) of sodium acetate trihydrate in 100 ml of water. The 1,2-dichloroethane was removed by distillation until the vapor temperature reached 90°. Cooling precipitated 13.0 g (90%) of 2-methyl-3-benzoyl-6-phenyl-4H-pyran-4-one (**4a**), mp 151–154° after recrystallization from acetone, and 155–155.5° after two additional recrystallizations.

Anal. Calcd for $C_{19}H_{14}O_3$: C, 78.61; H, 4.86. Found: C, 78.95; H, 4.94.

When the experiment was repeated essentially as described above and the reaction mixture was worked-up without employing sodium acetate trihyrate solution, acylpyrone **4a** was obtained in 86% yield.

(12) W. Baker and V. S. Butt, *J. Chem. Soc.*, 2142 (1949).

(13) Melting points were taken on a Mel-Temp capillary melting point apparatus. Infrared spectra were determined with a Perkin-Elmer Model 21 recording infrared spectrophotometer using potassium bromide disks. Ultraviolet spectra were determined with a Perkin-Elmer Model 202 ultraviolet–visible spectrophotometer using 2×10^{-5} M solutions in 95% ethanol with a 1-cm sample cell. The nmr spectra were determined with a Varian Associates A-60 spectrometer using deuteriochloroform as the solvent and tetramethylsilane as the internal standard. Mass spectra were determined on a Bendix time-of-flight spectrometer, Model 14. The authors wish to acknowledge the assistance of Dr. John Ruth of the Liggett and Myers Tobacco Co., for obtaining the mass spectra. Elemental analyses were by Dr. Ing A. Schoeller, Mikro-Labor, Kronach, West Germany.

When triketone **1** was treated with acetic anhydride but no boron fluoride, only **1** was recovered upon subsequent treatment with sodium acetate solution.

Conversion of Acylpyrone 4a to Acylpyridone 5a.—To a solution of 1.02 g of acylpyrone **4a** in 25 ml of 95% ethanol, was added commercial anhydrous liquid ammonia until the flask grew cold. The solution was evaporated to dryness, and the entire process was repeated. The remaining oil solidified on treatment with a small amount of acetone to afford 0.74 g (73%) of 2-methyl-3-benzoyl-6-phenyl-4(1H)-pyridone (**5a**), mp 267–269°.

Anal. Calcd for $C_{19}H_{15}NO_2$: C, 78.87; H, 5.23; N, 4.84. Found: C, 78.89; H, 5.22; N, 4.86.

Acetylation and Cyclization of 1-Phenyl-1,3,5-hexanetrione (19) to Form Acylpyrone 21a.—This reaction of triketone **19**[2] was effected essentially as described for the acetylation of triketone **1**. After neutralization with excess sodium acetate solution, the layers were separated and the 1,2-dichloroethane layer was dried (magnesium sulfate). The solvent was removed and the residue was recrystallized from 95% ethanol to give 2-methyl-3-acetyl-6-phenyl-4*H*-pyran-4-one (**21a**) in 52% yield; it melted at 137–141° and at 147–148° after recrystallization from 95% ethanol.

Anal. Calcd for $C_{14}H_{12}O_3$: C, 73.67; H, 5.30. Found: C, 73.58; H, 5.50.

Conversion of Acylpyrone 21a to Acylpyridone 22a.—A solution of 1.0 g of acylpyrone **21a** in 25 ml of 95% ethanol was treated with anhydrous liquid ammonia essentially as described above for that of **4a** to afford 0.15 g (16%) of 2-methyl-3-acetyl-6-phenyl-4(1H)-pyridone (**22a**), mp 207–210°, and 214–214.5° after recrystallization from acetone.

Anal. Calcd for $C_{14}H_{13}NO_2$: C, 73.99; H, 5.77; N, 6.16. Found: C, 73.90; H, 5.88; N, 6.41.

Acetylation and Cyclization of *o*-Hydroxybenzoylacetone (23) to Form Chromone 25.—This reaction was effected essentially as described for triketone **1** employing 4.0 g (0.0225 mole) of hydroxy β-diketone **23**[14] and 7.0 g (0.068 mole) of acetic anhydride in 75 ml of 1,2-dichloroethane. After stirring for 18 hr, the reaction mixture was decomposed with a solution of 18.5 g of sodium acetate trihydrate in 50 ml of water, and the 1,2-dichloroethane was removed by distillation until the vapor temperature reached 90°. The remaining mixture was refluxed for 1 hr and then cooled overnight to precipitate 2.15 g of crude product (mp 75–80°), a thin layer chromatogram of which showed a single component with no starting material present. Two recrystallizations from cyclohexane afforded 2.0 g (approximately 50%) of 2-methyl-3-acetylchromone (**25**), mp 89–90° (lit.[12] mp 89°); a mixture melting point with starting compound **23** (mp 95°) was only 68–75°. The product failed to give an enol test with ethanolic ferric chloride; its structure was supported by its nmr spectrum.

Anal. Calcd for $C_{12}H_{10}O_3$: C, 71.28; H, 4.99. Found: C, 71.36; H, 4.86.

When the reaction was repeated essentially as described above except for the absence of boron fluoride, only the starting hydroxy β-diketone (**23**) was recovered.

Registry No.—Acetic anhydride, 108-24-7; boron fluoride, 7637-07-2; **4a**, 10037-16-8; **5a**, 10037-17-9; **21a**, 10037-18-0; **22a**, 10037-19-1; **25**, 10037-20-4; **2**, 1029-94-3; **7**, 1004-36-0; **6**, 1013-99-6.

(14) C. G. Badcock, F. M. Dean, A. Robertson, and W. B. Whalley, *J. Chem. Soc.*, 903 (1950).

Chain Tautomerism of Thiazolidines[1]

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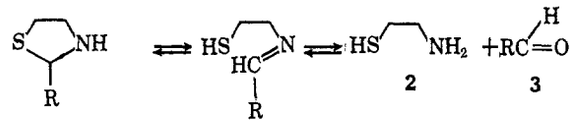
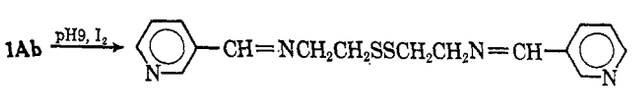
A novel reaction of 2-phenylthiazolidine (**1Aa**) with mercaptoacetic ester (**4a**) or acid (**4b**) to form a thiazolidone (**5**) is described. By alkylation of the thiazolidine (**1Aa**) under alkaline conditions, imino sulfides (**7**) are obtained. Oxidation of **1Ac** by bubbling oxygen through a dimethyl sulfoxide (DMSO) solution constitutes a new oxidation of thiazolidines to disulfides in a neutral medium. These reactions extend this previously limited area of chain-tautomeric thiazolidine chemistry. Prelminary work suggests that these reactions are catalyzed by acidic or basic conditions analogous to the ring–chain tautomerism (mutarotation) of sugars.

Our interest in the chain-tautomeric chemical behavior of iminothiophenes[3] suggested examination of a system, for which the nitrogen function in relation to sulfur is incorporated in a heterocyclic ring, rather than being an exocyclic imino group. Thiazolidines **1A** offer such a situation, and indeed their chain-tautomeric ramifications have been recognized.[4] For the most part, however, the chemistry of thiazolidines has not characterized an intact chain tautomer (**1B**) but rather the aminothiol (**2**) and carbonyl (**3**) precursors of thiazolidine **1A**, as derivatives.[5] Only recently has a disulfide corresponding to **1Bb** been observed.[6]



1Aa, R = C_6H_5
b, R = 3-C_5H_4N
c, R = *p*-ClC_6H_4



We wish now to report several new examples of chain-tautomeric thiazolidine chemistry, which significantly extend this area of dual product formation, consistent with chain tautomer **1B**. In past investigations of the stability or dual reactivity of **1A** emphasis has been on the incipient thiol function of **1B**. A novel aspect of the current investigation is concerned with the imino function. The discovery by Troutman and Long[7] that ethyl mercaptoacetate (**4a**) reacts with alkylamine-derived Schiff bases to form thiazolidones prompted us to attempt the interception of **1B** through its imino function in such a reaction. Conditions

(1) Presented before the 21st Annual Northwest Regional Meeting, Vancouver, B. C., Canada, June 1966. For Paper III on Tautomerism see G. W. Stacy, T. E. Wollner, and T. R. Oakes, *J. Heterocyclic Chem.*, **3**, 51 (1966).

(2) From the Ph.D. Thesis of P. L. Strong, Washington State University, June 1965. National Defense Education Act Fellow, 1961–1964.

(3) (a) G. W. Stacy, A. J. Papa, F. W. Villaescusa, and S. C. Ray, *J. Org. Chem.*, **29**, 607 (1964); (b) G. W. Stacy, F. W. Villaescusa, and T. E. Wollner, *ibid.*, **30**, 4074 (1965).

(4) J. M. Sprague and A. H. Land, "Heterocyclic Compounds," Vol. 5, R. C. Elderfield, Ed., John Wiley and Sons, Inc., New York, N. Y., 1957, p 701.

(5) S. Ratner and H. T. Clarke, *J. Am. Chem. Soc.*, **59**, 200 (1937).

(6) T. P. Johnston and A. Gallagher, *J. Org. Chem.*, **27**, 2452 (1962).

(7) H. D. Troutman and L. M. Long, *J. Am. Chem. Soc.*, **70**, 3436 (1948).