336, 326, 320, 292, 276, 170, 154, 126, 110, 44; proton nmr, multiplet at 198 cps; fluorine nmr, multiplets assigned to dioxazine XVI at 3495 (2-CF_2Cl), 4129 (2-CF_3), and 4517 cps (6-CF_3's), multiplets assigned to dioxazine XVII at 3774 (6-CF_2Cl), 4274 (2-CF_3's), and 4398 cps (6-CF_3). (The relative areas of each set of multiplets indicated the composition of 1:2 dioxazine XVI to dioxazine XVII.)

Anal. Calcd for $C_8H_3ClF_{11}NO_3$: Cl, 8.74; N, 3.45. Found: Cl, 8.64; N, 3.64.

From Ketone Mixture.—Reaction of hexafluoroacetone (15 g, 0.09 mole), chloropentafluoroacetone (17 g, 0.09 mole), methyl isocyanate (10 g, 0.175 mole), and cesium fluoride (1 g) at 100° for 8 hr gave 28 g of product. Analysis by glpc indicated the following composition: I, 18.2%; II, 17.2%; X, 39.8%; XI, 2.9%; XII, trace; XIII, trace; XVI and XVII, 21.4%.

Registry No.—I, 13619-24-4; II, 13619-25-5; III, 13619-26-6; IV, 13639-87-7; V, 13619-27-7; VI, 13639-88-8; VII, 13618-60-5; X, 13618-61-6; XI, 13618-62-7; XII, 13618-63-8; XIII, 13618-64-9; XIV, 13618-65-0; XV, 13639-89-9; XVI, 13618-66-1; XVII, 13618-67-2.

4-Aroylbenzils and Related Compounds

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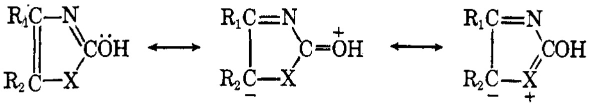
A number of *ortho*-mono- and -diacylated benzils have been reported in the literature,[1-5] but *para*-mono- and -diacylated benzils are unknown. We have previously shown that 4,5-diphenyl-2-imidazolone[6] and 4,5-diphenyloxazoles[7] undergo electrophilic substitution in the *para* position of the phenyl group(s), and are smoothly oxidized by bromine in acetic acid to benzils. The acylation of these heterocycles has now been investigated in order to provide a convenient pathway to the *para*-acylated benzils.

Attempted acylation of either 2-methyl-4,5-diphenyl-, 2,4,5-triphenyl, 4,5-diphenyl-, or 2,5-diphenyloxazole and 2-methyl-4,5-diphenyl- or 4,5-diphenylimidazole under different conditions (eq 1, X = O or



(1)

NH) furnished only starting materials. The presence of an oxygen atom at C_2 would increase the electron density of C_4 (C_5) and should facilitate acylation. When 4,5-diphenyl-2-imidazolone was treated with benzoyl chloride in nitrobenzene in the presence of anhydrous aluminium chloride or in nitromethane with silver perchlorate,[8] only starting material was recovered. However, the imidazolone was monoacylated by heating it with various aromatic acids in polyphosphoric acid at 140–150°. The products were frequently difficult to purify and were then oxidized directly to the benzils in poor yield (see Tables I and II).

TABLE I

ACYLATION OF 4,5-DIPHENYL-2-IMIDAZOLONE (A) AND 4,5-DIPHENYL-2-OXAZOLONE (B) TO THE CORRESPONDING 4(5)-BENZOYLATED PRODUCTS

Starting material	Acylating acid	Yield, %	Mp, °C	Recrystn solvent	Formula	Registry no.	Calcd, % C	Calcd, % H	Calcd, % N	Found, % C	Found, % H	Found, % N
A	Benzoic	68	145–147	Dil EtOH	$C_{22}H_{16}N_2O_2$	13342-52-4	77.7	4.7	8.2	77.5	4.5	8.1
B	Benzoic	97	239–240	EtOH	$C_{22}H_{15}NO_3$	13342-53-5	77.5	4.4	4.1	77.5	4.4	4.1
A	*p*-Bromobenzoic[a]		240–260			13342-54-6						
B	*p*-Bromobenzoic[a]	90	260–263	Dil AcOH	$C_{22}H_{14}BrNO_3$	13342-55-7	62.9	3.3	3.3	62.7	3.2	3.3
B	*p*-Chlorobenzoic	95	252–255	AcOH	$C_{22}H_{14}ClNO_3$	13342-56-8	70.3	3.7	3.7	69.9	3.6	3.8
A	*p*-Nitrobenzoic[b]	61	291–294	Dil EtOH		13342-57-9						
B	*p*-Nitrobenzoic[a]		215–230			13342-58-0						
A	3,4-Dichlorobenzoic											
B	3,4-Dichlorobenzoic	81	266–268	Dil DMFA	$C_{22}H_{13}Cl_2NO_3$	13342-60-4	64.4	3.2	3.4	64.1	3.1	3.3

[a] Product could not be purified and was oxidized directly to the benzil. [b] The crude product was refluxed with EtOH–concentrated HCl (1:1) for 1 hr, the solution evaporated, and the solid washed with sodium bicarbonate solution. The product was oxidized directly to the benzil.

High yields of monoacylated oxazolones were obtained when 4,5-diphenyl-2-oxazolone (I) was heated with an aromatic acid in the presence of polyphosphoric acid. The monoacylated oxazolones were oxidized to their corresponding benzils in excellent yield (see Tables I and II).

The oxidation of the oxazolone (I) by bromine in acetic acid in the presence and absence of anhydrous sodium acetate buffer was investigated to establish optimum conditions for benzil formation. The maximum yield of benzil was obtained when the oxidation was carried out under reflux in the presence of aqueous acetic acid. These conditions were then used for the oxidation of the acylated oxazolones.

The structure of the acylated benzils was determined by cleavage of the benzil with cyanide ion[7] to give the corresponding *p*-benzoylbenzoic acids and benzaldehyde. The unknown *p*-(4 chlorobenzoyl)benzoic acid was reduced with Raney alloy in alkaline solution to give *p*-diphenylmethanecarboxylic acid. Hence the acylated oxazolone was designated 5(4)-*p*-aroylphenyl-

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(1) K. Brand and H. Ludwig, *Ber.*, **53**, 809 (1920).

(2) K. Brand and F. W. Hoffman, *ibid.*, **53**, 815 (1920).

(3) D. Ivanov and D. I. Dalev, *Ann. Univ. Sofia, Livre 2*, **33**, 305 (1937); *Chem. Abstr.*, **32**, 3371^8 (1938).

(4) C. F. Koelsch and C. D. Le Claire, *J. Am. Chem. Soc.*, **65**, 754 (1943).

(5) C. F. H. Allen and J. A. Van Allen, *ibid.*, **70**, 2069 (1948).

(6) H. Greenberg, T. van Es, and O. G. Backeberg, *J. Org. Chem.*, **31**, 3951 (1966).

(7) T. van Es and O. G. Backeberg, *J. Chem. Soc.*, 1371 (1963).

(8) H. Burton and P. F. G. Praill, *J. Chem. Soc.*, 522, 529 (1951).

Table II

Oxidation of Acylated 4,5-Diphenyl-2-imidazolones (C) and 4,5-Diphenyl-2-oxazolones (D) to the Corresponding 4-Benzoylated Benzils

4-Benzoylated benzil	Registry no.	Yield, % From C	Yield, % From D	Mp, °C	Recrystn solvent	Formula	Calcd, % C	Calcd, % H	Calcd, % N	Found, % C	Found, % H	Found, % N	Quinoxaline, mp, °C	Recrystn solvent	Registry no.	Formula	Calcd, % N	Found, % N
4-Benzoyl	13342-61-5		81	59–62									149–150	EtOH	13318-40-6	$C_{27}H_{18}N_2O$	7.3	7.2
4-(*p*-Bromobenzoyl)	13342-62-6	38	99	152–155	Dil EtOH	$C_{21}H_{13}BrO_3$	64.1	3.3		64.2	3.5		175–176	Dil AcOH	13342-66-0	$C_{27}H_{17}BrN_2O$	6.0	5.8
4-(*p*-Chlorobenzoyl)	13342-63-7		98	144–145	EtOH	$C_{21}H_{13}ClO_3$	72.3	3.7		72.2	4.1		167–169	Dil AcOH	13342-67-1	$C_{27}H_{17}ClN_2O$	6.7	6.4
4-(*p*-Nitrobenzoyl)	13342-64-8	72	72	138–139	Dil EtOH	$C_{21}H_{13}NO_5$	70.2	3.6	3.9	70.0	3.7	4.1	178–180	Dil AcOH	13342-68-2	$C_{27}H_{17}N_3O_3$	9.8	9.8
4-(3,4-Dichlorobenzoyl)	13342-65-9	11	99	122–124	Dil EtOH	$C_{21}H_{12}Cl_2O_3$	65.8	3.1		65.8	3.4		153–154	Dil AcOH	13342-69-3	$C_{27}H_{16}Cl_2N_2O$	6.2	6.0

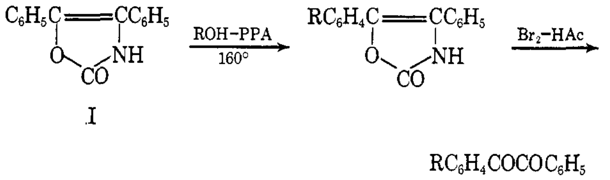
Table III

Preparation of 4,5-Diphenyl-2-oxazolones

Benzoin	2-Oxazolone	Registry no.	Yield, %	Mp, °C	Recrystn solvent	Formula	Calcd, % C	Calcd, % H	Calcd, % N	Found, % C	Found, % H	Found, % N
Benzoin	4,5-Diphenyl[a]	5014-83-5	94	203–207	MeOH							
4,4′-Dichloro	4,5-Di-(*p*-chlorophenyl)	13342-71-7	92	226–227	MeOH	$C_{15}H_9Cl_2NO_2$	58.9	2.9	4.6	58.8	2.7	4.5
4,4′-Dibromo	4,5-Di-(*p*-bromophenyl)[a]	13342-72-8	94	216–218	MeOH							
4′-Chloro	5-*p*-Chlorophenyl-4-phenyl[b]	13342-73-9	91	236–238	Dil EtOH	$C_{15}H_{10}ClNO_2$	66.3	3.7	5.2	66.5	3.8	5.0
4′-Sulphonamido	5-*p*-Sulphonamidophenyl-4-phenyl[b]	13342-74-0	92	264–266	Dil EtOH	$C_{15}H_{12}N_2O_4S$	57.0	3.8	8.9	56.8	3.6	9.0

[a] See ref 9. [b] This structure is proposed on the assumption that the reaction occurred by the same mechanism as that put forward by Gompper.[9]

4(5)-phenyl-2-oxazolone. The reaction proceeded according to eq 2 where R = C_6H_5CO, *p*-ClC_6H_4CO, *p*-BrC_6H_4CO, 3,4-$Cl_2C_6H_3CO$, and *p*-$NO_2C_6H_4CO$.



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$RC_6H_4COCOC_6H_5$ (2)

Gompper[9] has described the preparation of a number of substituted 2-oxazolones. Some of his methods gave poor results in our hands. We have now found that by heating the appropriate benzoin and urethane in the presence of polyphosphoric acid, a number of substituted 4,5-diphenyl-2-oxazolones could be prepared in high yield (see Table III). This method failed, however, when acid-labile substituents such as methoxy or acetamino were present in the benzoin.

Experimental Section

Melting points were determined in an electrically heated copper block and are uncorrected. Known compounds were identified by mixture melting points.

Acylations of 4,5-Diphenyl-2-imidazolone.—4,5-Diphenyl-2-imidazolone (2.0 g), the appropriate benzoic acid (4.0 g), and polyphosphoric acid (20 g) were stirred at 140–150° for 2 hr and then poured into water. The solid which separated was stirred with a saturated solution of sodium bicarbonate and the crystallized from the solvent given in Table I. The product was oxidized by refluxing with glacial acetic acid (75 ml), 2 *M* bromine in acetic acid (15 ml), water (7.5 ml), and anhydrous sodium acetate (10 g) for 1.5 hr. The reaction mixture was poured into water and the solid crystallized from the appropriate solvent.

Fission of *p*-Benzoylbenzil.—The benzil (0.314 g, 0.001 mole) was refluxed with methanol (20 ml) and potassium cyanide (0.03 g). Sodium hydroxide (10 ml, 0.1 *N*) was slowly added during 30 min. The reaction mixture was concentrated under reduced pressure, diluted with water, and filtered. The filtrate was acidified to give *p*-benzoylbenzoic acid (0.18 g), mp 197–198° (from water) (lit.[10] mp 194–195°). Benzaldehyde was isolated from the solution as its 2,4-dinitrophenylhydrazone.

The Oxidation of 4,5-Diphenyl-2-oxazolone (I).—The oxazolone (I) (2.37 g, 0.01 mole) in glacial acetic acid (25 ml) was refluxed for 2 hr with 2 *M* bromine in acetic acid (10 ml, 0.02 mole) and water (0.20 ml) to give a quantitative yield of benzil.

Acylation of 4,5-Diphenyl-2-oxazolone (I).—The oxazolone (I) (2.0 g), the appropriate benzoic acid (3.0 g), and polyphosphoric acid (20 g) were heated with stirring at 160° for 3 hr, then poured into water. The solid which separated was stirred with saturated sodium bicarbonate solution and crystallized from the solvent given in Table I. The acylated oxazolones (0.01 mole) were oxidized as described above to give the acylated benzils (see Table II).

Fission of *p*-(4-Chlorobenzoyl)benzil.—The benzil was cleaved with potassium cyanide as described for *p*-benzoylbenzil to give *p*-(4-chlorobenzoyl)benzoic acid, mp 275°.

Anal. Calcd for $C_{14}H_9ClO_3$: C, 64.5; H, 3.5. Found: C, 64.7; H, 3.7.

The above acid (0.270 g, 0.001 mole) was dissolved in hot sodium hydroxide (2 *N*, 40 ml) and Raney alloy (1.0 g) was added in small portions to the stirred solution at 80–90°. The reaction mixture was filtered and the filtrate acidified to give *p*-diphenylmethanecarboxylic acid (0.14 g), mp 157–158° (from dilute alcohol) (lit.[11] mp 155–156°).

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(10) S. Goldschmidt, A. Sadler, E. Gelber, H. Schüssler, and A. Vogt, *ibid.*, **61**, 835 (1928).

(11) C. Liebermann, *ibid.*, **45**, 1207 (1912).

Preparation of 2-Oxazolones.—The appropriate benzoin (2.0 g), urethan (3.0 g), and polyphosphoric acid (10 g) were heated with stirring at 160° for 2 hr and then poured into water. The solid was crystallized from a suitable solvent (see Table III).

Acknowledgment.—H. G. thanks the South African Council for Scientific and Industrial Research for a bursary. The authors thank Mr. F. D. Wayne for some of the experimental work.

The Synthesis of the Pyrido[2,1-*a*]isoindole System by an Intramolecular Photochemical Cyclization[1,2]

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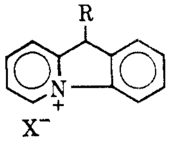
Aqueous solutions of 2-bromo-N-benzylpyridinium salts (IV), on irradiation with ultraviolet light, cyclize intramolecularly to afford pyrido[2,1-*a*]isoindolium salts (II). The cyclization failed only if a nitro group was present on the benzyl ring of the salt (IV). Pyrido[2,1-*a*]isoindolium bromide may be obtained in lower yield by irradiating N-(2′-bromobenzyl)pyridinium bromide (V). Treatment of pyrido[2,1-*a*]isoindolium salts (II) with carbonate ion led to the unstable and light-sensitive pyrido[2,1-*a*]isoindoles (III) of interest as examples of a pseudo-aromatic system.

Although at the time this work was undertaken several samples of the related pyrido[1,2-*a*]indolium salts (I) were known,[3] the literature afforded no examples of pyrido[2,1-*a*]isoindolium salts (II).[4] This system (II) was of interest since it was expected to behave as a "super fluorene," the methylene protons being more acidic (owing to the adjacent, positively charged nitrogen atom) than those of fluorene. On basification of the salt, it would be expected that the corresponding pyrido[2,1-*a*]insoindole (III) would be obtained. Irradiation of certain halogenated aromatic molecules with ultraviolet light brings about homolytic cleavage of the carbon–halogen bond and cyclization. An example is the formation of phenanthrene derivatives from iodostilbenes.[5] A similar cyclization, though not photochemical, is the synthesis of dibenzothiophene from the reaction of phenyl *o*-bromophenyl sulfide, methyl magnesium iodide, and colbaltous chloride.[6]



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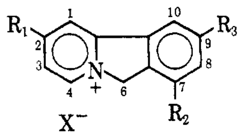
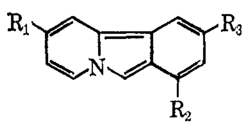
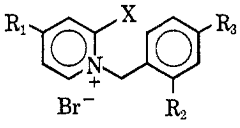


II



III



IV

It was decided to attempt the synthesis of pyrido[2,1-*a*]isoindolium salts by irradiation of appropriate N-benzyl-2-bromopyridinium salts (IV, X = Br). When an aqueous solution of N-benzyl-2-bromopyridinium bromide (IV, $R_1 = R_2 = R_3 = H$; X = Br)[7] was irradiated with an ultraviolet source, a change in the ultraviolet spectrum of the salt (IV, $R_1 = R_2 = R_3 = H$; X = Br) occurred and a spectrum of the type expected[8] for an azoniafluorene derivative was observed. After irradiation had continued for 5 hr, the reaction mixture afforded a salt (50% yield) which had all the characteristics of the expected pyrido[2,1-*a*]isoindolium bromide (II, $R_1 = R_2 = R_3 = H$; X = Br). The structure was confirmed by elemental analysis and nmr spectrum. The ease with which the cyclization occurred was surprising in view of the participation of the nonbonding electrons of the bromine atom in the conjugated system of the pyridinium ring.[9] No evidence was found to suggest that any dimerization had occurred as did in the case of N-substituted pyridones[10] and aminopyridines.[11]

When the pyridoisoindolium salt (II, $R_1 = R_2 = R_3 = H$) was treated with aqueous sodium carbonate, a vivid yellow-green solid precipitated. The structure of this product, which was obtained in quantitative yield, was proven to be pyrido[2,1-*a*]isoindole (III, $R_1 = R_2 = R_3 = H$) by elemental analysis and by its nmr spectrum which shows the presence of aromatic protons only, in the range σ (ppm) 8.97–7.27. This molecule (III, $R_1 = R_2 = R_3 = H$) is interesting in that it has a peripheral conjugated ring system. Further, if the cross-links are regarded as producing relatively small perturbations so that the Hückel $4n + 2\ \pi$ electron rule[12] may be applied,[13] the molecule (III, $R_1 = R_2 = R_3 = H$) has 14 π electrons (including the pair from the nitrogen) and should have some aromatic character. It can thus be considered somewhat analogous to 14-annulene. The nmr spectrum of the molecule (III, $R_1 = R_2 = R_3 = H$) does, in fact, by the

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(1) This work was described in a preliminary communication: A. Fozard and C. K. Bradsher, *Tetrahedron Letters*, 3341 (1966).

(2) This research was supported by a grant (CA-05509) from the National Cancer Institute of the National Institutes of Health.

(3) R. Robinson and J. E. Saxton, *J. Chem. Soc.*, 976 (1952).

(4) Subsequent to completion of this work, but prior to its publication, the synthesis of 7,9-dinitropyrido[2,1-*a*]isoindole and some derivatives was described by W. Augstein, Doctoral Dissertation, Giessen, 1966, p 28.

(5) S. M. Kupchan and H. C. Wormer, *J. Org. Chem.*, **30**, 3792 (1965).

(6) M. Tecco, *Chem. Commun.*, 555 (1965).

(7) B. R. Baker and F. J. McEvoy, *J. Org. Chem.*, **20**, 118 (1955).

(8) The new spectrum showed a marked similarity to that of fluorene. See R. A. Friedel and M. Orchin, "Ultraviolet Spectra of Aromatic Compounds," John Wiley and Sons, Inc., New York, N. Y., 1951, No. 311.

(9) A long wavelength band of the ultraviolet spectrum of the quaternary salt (IV, $R_1 = R_2 = R_3 = H$; X = Br) is shifted 20 $m\mu$ to longer wavelengths compared with that of N-benzylpyridinium bromide. This would suggest some participation of nonbonding electrons from the bromine atom in resonance of the pyridinium system with consequent strengthening of the C–Br bond.

(10) L. A. Paquette and E. Stomp, *J. Am. Chem. Soc.*, **85**, 765 (1963).

(11) E. C. Taylor and R. O. Kan, *ibid.*, **85**, 776 (1963).

(12) E. Hückel, *Z. Physik.*, **70**, 204 (1931); **76**, 628 (1932).

(13) A. Streitwieser, Jr., "Molecular Orbital Theory for Organic Chemists," John Wiley and Sons, Inc., New York, N. Y., 1961, p 288.