heptane acyloins [see N. J. Leonard et al., *J. Am. Chem. Soc.*, **76**, 630 (1954)], more recent reports on acyloin reactions involving the use of chlorotrimethylsilane as an anion trapping agent indicate that nitrogen-containing acyloins can be obtained in 90% yield: K. Ruhlmann, *Synthesis*, 236 (1971).
(18) Ground-state conformations were decided by careful examination of Buchi and space filling models and the conclusions drawn checked against experimental results obtained for related systems. (a) Cycloheptanes: J. B. Hendrickson et al., *J. Am. Chem. Soc.*, **95**, 494 (1973). (b) Azacyclooctanes: J. B. Lambert and S. A. Khan, *J. Org. Chem.*, **40**, 369 (1975).
(19) This molecule, which has been demonstrated to show activity against leukemia, has been previously synthesized by another route: P. Y. Johnson and R. Silver, *J. Heterocycl. Chem.*, 1029 (1973).
(20) Mannich and reverse Mannich reactions involving 2,2-disubstituted ketones (but not aldehydes) have been the subject of considerable debate and controversy. A discussion of this problem has been treated by G. L. Buchanan, A. C. Curran, and R. T. Wall, *Tetrahedron*, **25**, 5503 (1969), and references cited therein. *N*-Methyl dialdehyde **8** does not undergo this interesting reaction: P. Y. Johnson, unpublished results.
(21) While the particular problem of the stereochemistry of **12** could be solved using combination wet chemical–spectroscopic techniques, the frequent reoccurrence of the cis/trans diol problem in our research prompted us to seek a general, more facile approach to this problem.
(22) H. C. Brown and K. Ichikawa, *J. Am. Chem. Soc.*, **84**, 373 (1962).
(23) W. G. Dauben, G. J. Fonken, and D. S. Noyce, *J. Am. Chem. Soc.*, **78**, 2579 (1956).
(24) This statement is not a violation of the Curtin–Hammett principle,[25] which states that the ratios of products from one starting material depends only on the free energy differences of the transition states, but rather reflects the cases where E_{act} is not necessarily much larger than rotational barriers [compare an E_{act} of 8–15 kcal/mol for reduction of a carbonyl with a $\Delta G^{\ddagger}$ of 9 kcal/mol for rotation in acyclic analogs of our systems (Table II)] and where the geometry of the transition state resembles that of the ground state.
(25) For a general introduction to free-energy calculations and the Curtin–Hammett principle see (a) E. L. Eliel, N. L. Allinger, S. J. Angyal, and G. A. Morrison, "Conformational Analysis", Interscience, New York, N.Y., 1965; (b) E. L. Eliel, "Stereochemistry of Carbon Compounds", McGraw-Hill, New York, N.Y., 1962; (c) N. L. Allinger and E. L. Eliel, *Top. Stereochem.*, **1**, 1 (1967). For specific application of these principles to the reduction of acyclic acyloins see G. J. Karabatsos, *J. Am. Chem. Soc.*, **89**, 1367 (1967).
(26) While studies of hydride reductions of acyclic acyloins have been made [see (a) S. B. Bowlus and J. A. Katzenellenbogen, *J. Org. Chem.*, **39**, 3309 (1974); (b) D. J. Cram and K. R. Kopecky, *J. Am. Chem. Soc.*, **81**, 2748 (1959); (c) D. R. Boyd and M. A. McKervey, *Q. Rev., Chem. Soc.*, **22**, 95 (1968), and references cited therein] we are unable to find a similar treatment of hindered alicyclic acyloins.
(27) The reduction of 3,3,6,6-tetramethyl-2-hydroxycyclohexanone by $NaBH_4$ has been reported to give 82% cis diol: D. E. Applequist et al., *J. Am. Chem. Soc.*, **94**, 4272 (1972). Our approach predicts this result.
(28) Because of the geometries involved, a change in mechanism from least hindered attack to directed attack[29] would not alter this conclusion.
(29) M. Akhtar and S. Marsh, *J. Chem. Soc. C*, 937 (1966).
(30) H. Budzikiewicz, C. Djerassi, and D. H. Williams, "Mass Spectrometry of Organic Molecules", Holden-Day, San Francisco, Calif., 1967.
(31) (a) M. D. McCreary, D. W. Lewis, D. L., Wernick, and G. M. Whitesides, *J. Am. Chem. Soc.*, **96**, 1038 (1974); (b) H. L. Goering, J. N. Eikenberry, G. S. Koermer, and C. J. Lattimer, *ibid.*, **96**, 1493 (1974). For a review of this subject see R. E. Sievers, Ed., "Nuclear Magnetic Resonance Shift Reagents", Academic Press, New York, N.Y., 1973.
(32) While shift reagents have been used for direct determination of enantiomeric composition,[31] we have found only one report, involving epoxides, concerning the use of these reagents to distinguish meso and *dl* diastereomers: M. Kainosho, K. Ajisaka, W. H. Pirkle, and S. D. Beare, *J. Am. Chem. Soc.*, **94**, 5924 (1972).
(33) We have chosen to introduce this general nomenclature, since it provides a picture of our systems from which ^1H NMR spectra taken in the presence of chiral shift reagents can be predicted. Descriptions of our multifunctional systems in terms of enantiotopic and diastereotopic [K. Mislow and M. Raban, *Top. Stereochem.*, **1**, 1 (1967)] relationships are unwieldly when seeking fast, qualitative (cis or trans?) information.
(34) A more quantitative study of the application of chiral shift reagents as a method of determining the stereochemistry of diol systems is under study in our laboratories. Spectra presented (Figure 1) for **12a** and **12b** are included to demonstrate the feasibility and utility of this approach.
(35) Structures **17**, **18**, and **19**-*d* should be considered averages and do not imply knowledge of the exact nature of binding for these systems.
(36) Since the half-life of alkyllithium reagents in THF is ca. 10 min at 35° [R. B. Bates, L. M. Kroposki, and D. E. Potter, *J. Org. Chem.*, **37**, 560 (1972), and references cited therein], this solvent is only appropriate for alkyllithium addition reactions when the rate of addition is much faster than the rate of decomposition due to reaction with THF.
(37) The addition of methyllithium to cyclodecane-1,3-dione has been shown to give 98% cis diol: A. E. Runquist and J. A. Marshall, Northwestern University, Evanston, Ill., unpublished results.
(38) For a more quantitative treatment of related, but less hindered, *N*-*tert*-butyl-*N*,*N*-dialkylamines see (a) C. H. Bushweller et al., *J. Am. Chem. Soc.*, **96**, 3892 (1974), and references cited therein; (b) see S. Brownstein, E. Horswill, and K. U. Ingold, *J. Am. Chem. Soc.*, **92**, 7217 (1970), for a discussion of several mononeopentylamines.
(39) For comparisons of related compounds, in particular for investigations of substituent effects, measurements of $\Delta G^{\ddagger}$ are usually adequate. See L. O. Sutherland, *Annu. Rep. NMR Spectrosc.*, **4**, 71 (1971).
(40) For the use and limitations of this approximation of $\Delta G^{\ddagger}$ see (a) J. A. Pople, W. G. Schneider, and H. J. Bernstein, "High-Resolution Nuclear Magnetic Resonance", McGraw-Hill, New York, N.Y., 1959; (b) for a more precise expression, see S. Alexander, *J. Chem. Phys.*, **37**, 967 (1963).
(41) See ref 25c, p 199.
(42) (a) F. Jensen et al., *J. Am. Chem. Soc.*, **91**, 344 (1969); (b) G. W. Buchanan and J. B. Stothers, *Chem. Commun.*, 179 (1967).
(43) This contention is supported in part by the lower $\Delta G^{\ddagger}$ (7.6 kcal/mol) ($T_c = -112°$) (P. Y. Johnson, unpublished results) found for trineopentylamine. For the synthesis of trineopentylamine see ref 6.
(44) (a) J. Strating, S. Reiffers, and H. Wynberg, *Synthesis*, 209 (1971); (b) P. Y. Johnson, *Tetrahedron Lett.*, 1991 (1972).
(45) P. Y. Johnson, J. Zitsman, and C. Hatch, *J. Org. Chem.*, **38**, 4087 (1973).
(46) N. J. Leonard and P. M. Mader, *J. Am. Chem. Soc.*, **72**, 5388 (1950).
(47) For examples of C-T phenomena in related systems see (a) N. J. Leonard, T. W. Milligan, and T. L. Brown, *J. Am. Chem. Soc.*, **82**, 4075 (1960); (b) N. J. Leonard, *Rec. Chem. Prog.*, **17**, 243 (1956); (c) E. A. Fehnel and M. Carmack, *J. Am. Chem. Soc.*, **71**, 84 (1949); (d) C. G. Overgerger, P. Barkan, A. Lusi, and H. Ringsdorf, *J. Am. Chem. Soc.*, **84**, 2814 (1962); (e) L. A. Paquette and L. D. Wise, *ibid.*, **89**, 6659 (1967); (f) G. Bergson, G. Claeson, and L. Schotte, *Acta Chem. Scand.*, **16**, 1159 (1962); (g) P. Y. Johnson and G. A. Berchtold, *J. Org. Chem.*, **35**, 584 (1970).

Synthesis and Properties of 3-Amino-3-pyrazolin-5-ones

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The enamines, 1-amino-1-trichloromethyl-2,2-dicarboxyalkylethenes, reacted with hydrazine in DMF to yield 1-amino-1-hydrazino-2,2-dicarboxyalkylethenes (**2**) at 25° or 3-amino-3-pyrazolin-5-ones (**3**) at 100°. These heterocyclics react with acid halide and phenyl isocyanate to give mono (3-amino) or di (3-amino,5-hydroxy) derivatives. With isatoic acid, a 3-(*o*-aminobenzamido) compound can be made. Infrared and mass spectral data indicate considerable intra- and intermolecular hydrogen bonding in most of these compounds.

In a program concerned with the synthesis and pharmacological activities of certain enamines,[2,3] one of us converted these compounds into mono- and diaminopyrazoles.[3] Here we report on the synthesis and properties of several 3-aminopyrazole-5-ones, or in *Chemical Abstracts* terminology, 3-amino-3-pyrazolin-5-ones (**3**).[4a] Among the numerous patterns of substitution in this ring system, a few N-unsubstituted pyrazol-5-ones[4b] and 3-aminopyrazoles[4c] have been reported. Recently, Gillis and Weinkam have oxidized tautomers of 3,4-disubstituted pyrazolin-5-ones and

Table I
1-Amino-1-hydrazinoethenes, $RR'C{=}C(NH_2)NHNH_2$ (2)

Registry no.	R	R'	Formula	Yield, %	Mp, °C	Found N, %	Calcd N, %
52566-35-5	CH_3OOC	CH_3OOC	$C_6H_{11}N_3O_4$	78	126–127	22.1	22.21
1572-20-9	C_2H_5OOC	C_2H_5OOC	$C_8H_{15}N_3O_4$	81	114–115	19.6	19.34
55254-77-8	C_3H_7OOC	C_3H_7OOC	$C_{10}H_{19}N_3O_4$	76	85–86	16.7	17.01
55254-78-9	i-C_3H_7OOC	i-C_3H_7OOC	$C_{10}H_{19}N_3O_4$	73	97–98	17.1	17.01
55254-79-0	C_4H_9OOC	C_4H_9OOC	$C_{12}H_{23}N_3O_4$	78	73–75	15.5	15.37
55254-80-3	i-C_4H_9OOC	i-C_4H_9OOC	$C_{12}H_{23}N_3O_4$	83	89–90	15.4	15.37
55254-81-4	t-C_4H_9OOC	CH_3OOC	$C_9H_{17}N_3O_4$	74	68–69	18.3	18.60
55254-82-5	t-C_4H_9OOC	C_2H_5OOC	$C_{10}H_{19}N_3O_4$	76	57–58	17.1	17.01

Table II
3-Aminopyrazolin-5-ones [3-NH_2, 4-R-$C_3N_2H_2O$ (3)] and Their Monoacyl [3-R'CONH, 4-R-$C_3N_2H_2O$ (4, 5, 8, 10)] and Diacyl [3-R'CONH, 4-R, -5-R'COO-C_3N_2H (6, 7, 9)] Derivatives

R	R'	Formula	Yield, %	Mp, °C	Found C, H or (N), %		Calcd C, H or (N), %	
CH_3OOC		$C_5H_7N_3O_5$	91	256–258[a]	(26.3)		(26.74)	
C_2H_5OOC		$C_6H_9N_3O_5$	94	268–269[a]	(24.7)		(24.55)	
C_3H_7OOC		$C_7H_{11}N_3O_3$	89	283–284[a]	(22.8)		(22.69)	
i-C_3H_7OOC		$C_7H_{11}N_3O_3$	92	205–208[a]	(22.7)		(22.69)	
C_4H_9OOC		$C_8H_{13}N_3O_3$	85	310–312[a]	(21.3)		(21.09)	
i-C_4H_9OOC		$C_8H_{13}N_3O_3$	87	248–250[a]	(20.7)		(21.09)	
t-C_4H_9OOC		$C_8H_{13}N_3O_3$	76	212–213[a]	(21.0)		(21.09)	
n-C_3H_7OCO	CH_3[b]	$C_9H_{13}N_3O_4$	59	172–173	47.8	5.70	47.57	5.76
i-C_3H_7OCO	CH_3[b]	$C_9H_{13}N_3O_4$	83	284[a]	47.5	5.69	47.57	5.76
i-C_4H_9OCO	CH_3[b]	$C_{10}H_{15}N_3O_4$	87	166–167	49.8	6.03	49.78	6.26
C_2H_5OCO	C_6H_5[b]	$C_{13}H_{13}N_3O_4$	92	227–228	57.5	4.85	57.09	4.79
n-C_3H_7OCO	C_6H_5[b]	$C_{14}H_{15}N_3O_4$	67	130–131	57.9	5.10	58.12	5.23
i-C_4H_9OCO	C_6H_5[b]	$C_{15}H_{17}N_3O_4$	61	181–182	59.7	5.47	59.39	5.64
C_2H_5OOC	NHPh[b]	$C_{13}H_{14}N_4O_4$	63	232–233	53.7	4.77	53.78	4.86
n-C_3H_7OOC	NHPh[b]	$C_{14}H_{16}N_4O_4$	71	328–329	55.1	5.41	55.22	5.29
i-C_4H_9OOC	NHPh[b]	$C_{15}H_{18}N_4O_4$	68	227–228	56.3	5.89	56.61	5.70
n-C_3H_7OOC	CH_3[c]	$C_{11}H_{15}N_3O_5$	74	212–213	49.0	5.76	49.07	5.58
i-C_4H_9OOC	CH_3[c]	$C_{12}H_{17}N_3O_5$	65	219–220	50.9	6.03	50.87	6.04
C_2H_5OOC	C_6H_5[c]	$C_{20}H_{17}N_3O_5$	68	123–124	63.4	4.73	63.30	4.51
n-C_3H_7OOC	C_6H_5[c]	$C_{21}H_{19}N_3O_5$	73	108–109	64.2	5.02	64.11	4.87
i-C_3H_7OOC	C_6H_5[c]	$C_{21}H_{19}N_3O_5$	71	137–138	63.9	5.02	64.11	4.87
i-C_4H_9OOC	C_6H_5[c]	$C_{22}H_{21}N_3O_5$	70	112–113	64.8	5.15	64.85	5.19
C_2H_5OOC	NHPh[c]	$C_{20}H_{19}N_5O_5$	73	210–212	58.5	4.45	58.67	4.67
n-C_3H_7OOC	NHPh[c]	$C_{21}H_{21}N_5O_5$	69	196–197	59.6	5.14	59.57	4.99
i-C_4H_9OOC	NHPh[c]	$C_{22}H_{23}N_5O_5$	71	182–183	62.5	5.27	62.69	5.30
i-C_4H_9OOC	o-$NH_2C_6H_4$[d]	$C_{15}H_{18}N_4O_4$	66	134–135	59.5	6.68	59.73	6.79
C_2H_5OOC	o-$NH_2C_6H_4$[d]	$C_{13}H_{14}N_4O_4$	80	204–205	51.47	5.07	51.72	4.85

[a] With decomposition. The melting point appears to change with age (several months) of the sample. Recrystallization restores some of the original 3. [b] Monoacyl derivative. [c] Diacyl derivative. [d] 10.

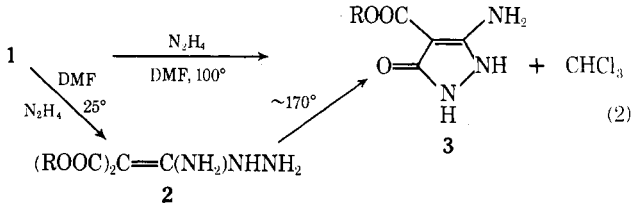
trapped the unstable diazacyclopentadienone with dienes;[5a] Junek and Aiger have treated 1,3-disubstituted pyrazol-5-ones or 3-aminopyrazoles with tetracyanoethylene and obtained condensations at the 4 position.[5b] However, actual analogs of **3** are rare; the closest examples we know are the 3-amino-4-arylazo-2-pyrazolin-5-ones,[6a] whose chemistry has been developed by Elnagdi et al.[6b]

In previous work the synthesis and some properties of the products (**1**) of eq 1 were discussed.[2] Here these enam-

$$Cl_3CCN + CH_2(COOR)_2 \xrightarrow{Na} \underset{\mathbf{1}}{(RO_2C)_2C{=}C(CCl_3)NH_2} \quad (1)$$

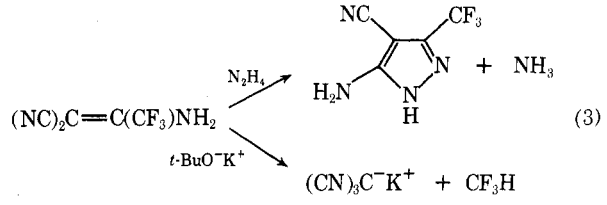
ines readily reacted with hydrazine to yield chloroform and 1-amino-1-hydrazino-2,2-dicarboxyalkylethenes (**2**) at ca. 25° (eq 2). The properties of these compounds are given in Table I.

There are perhaps two reactions which begin by looking



(2)

like precedents for eq 2 but which end up with different products.[7] In general, CCl_3^- (or CF_3^-) is not typical of



(3)

Table III
Observed Ir Frequencies[a] and Tentative Assignments for the 3-Aminopyrazolin-5-ones (3) and Their Acylation Products (4-7)[b]

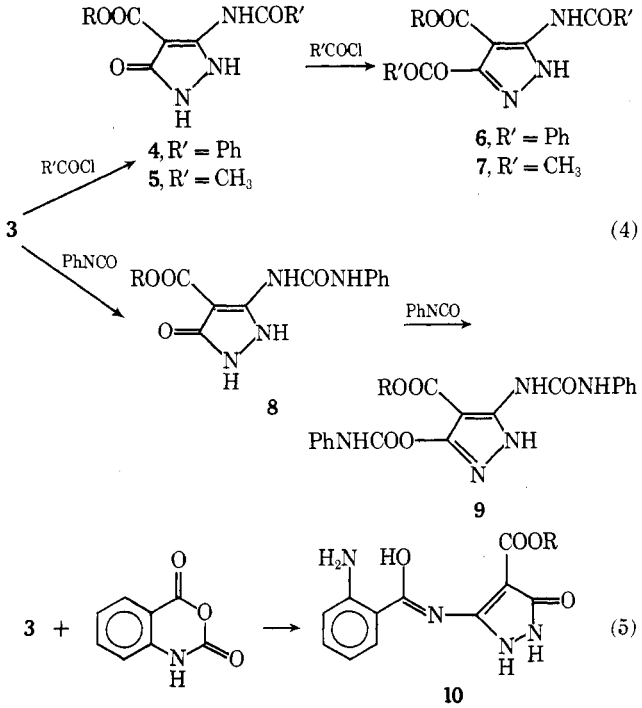
3	4 or 5	6 or 7	Tentative assignment, ν	Ref
3500 s	3490 s	3480 ± 10 m	Asymmetrical NH	9, 10
3300 ± 10 w		3300 ± 10 m	Symmetrical NH	9, 10
3220–3000 b	3400–3100 b		Intermolecular OH···N	10
2980 m, 2900 w ± 10	2990 m	3000 ± 15 m	Intramolecular OH···	11
		1750 s	5-COOR	12, 14
1685 ± 10 s	1720 ± 10 s	1690 ± 10 s	4-COOR	
	1680–1630 b	1660 s	–CON< and >C=N–	12
1610 ± 15 m	1610 m	1600 ± 10 s	Ring >C=N–	8, 11
1550 ± 10 s	1520 ± 15 s	1500 ± 10 w	Ring >C=C<	8, 9, 11, 14
1470 ± 10 m	1450 w	1450 ± 10 m	Asymmetrical $-CH_2-$ deformation	8, 9, 14, 15
1385 w	1380 ± 10 m	1400 ± 10 m	Symmetrical $-CH_2-$ deformation	8, 9, 14
1330 ± 10 m	1320 ± 10 s	1300 ± 15 s	C–N stretch	8, 9, 10, 15
1260 ± 5 w	1250 ± 10 m	1250 ± 10 s	Asymmetrical ester C–O stretch	14
1150 ± 5 s	1150 ± 10 s	1175 ± 5 m	C–N, C–C stretch	10
1100 ± 10 s	1100 ± 15 w	1135 ± 5 w	Symmetrical ester C–O stretch	14
980 ± 15 w	1000 ± 10 w	1040 ± 5 m	CH	
960 ± 15 w	970 ± 10 m	1020 ± 10 m	Heteroring	9, 10, 14
	880 ± 10 m	940 ± 15 m		
		920 ± 10 w		
810 ± 10 s	800 ± 10 m	800 ± 15 m	Heteroring	10
750 ± 15 w	760 ± 10 m	760 ± 10 m	Heteroring	
	700 ± 5 s	700 ± 5 s	Ph ring	
680 w	680 m	680 m	Heteroring	
650 ± 5 w	660 ± 10 m	660 ± 10 m	Heteroring	

[a] In reciprocal centimeters. [b] b, broad; m, medium; s, strong; w, weak.

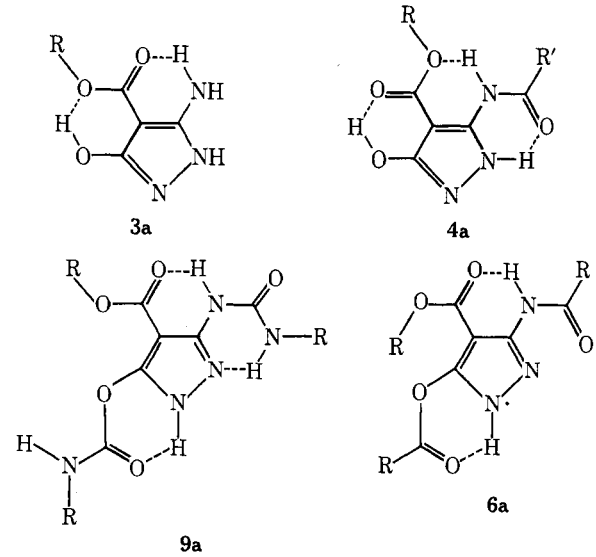
leaving groups in nucleophilic attacks at an ethylenic carbon. On the other hand, the analogy between eq 2 and the familiar haloform reaction is so close, particularly for the imine tautomer of **1**, that the formation of **2** is quite plausible.

As indicated in eq 2, the hydrazinoenamines (**2**) cyclize on heating to give pyrazolones (**3**). More conveniently, **1** and excess hydrazine in DMF at ca. 100° yielded **3**. The properties of this series are listed in Table II.

In order to characterize the pyrazolones, we prepared several derivatives (eq 4). Depending on whether 1 or 2 equiv of acid chloride or isocyanate are added, one may proceed cleanly to the mono- or disubstitution products.[4b] Likewise, isatoic anhydride acylates **3** to give a yellow product (**10**). All of these compounds (**4–10**) are described in Table II.



Spectral Data. There has been considerable interest in the tautomers and hydrogen-bonded forms of pyrazolones.[4,8] Our 3-amino compounds (**3**) and their derivatives (**4–9**) increase the possibilities in both categories. Structures **3a**, **4a**, **6a**, and **9a** depict some of the possible tautomers and types of *intramolecular* hydrogen bonds. Intermolecular hydrogen bonds, N–H···N, N–H···O, and O–H···O, must, of course, also be considered.



The preceding structural effects may be deduced in a general way from the spectra of **3–7**. Those features of the families which seem to be common are summarized in

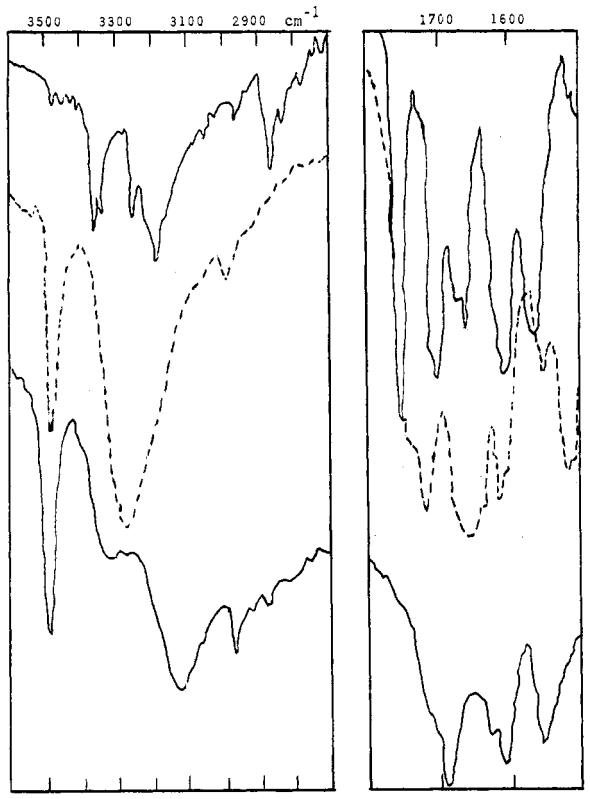
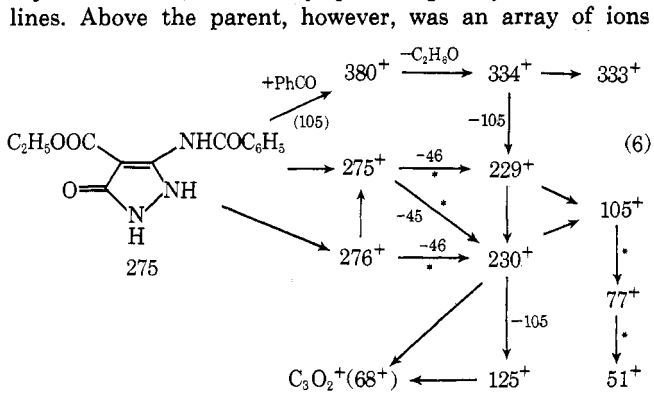


Figure 1. Infrared spectra of substituted pyrazoles (3-R'NH, 4-RCOO, 5-R'') and/or their tautomeric forms in potassium bromide pellets: lower curve, R' = R'' = H, R = *i*-C_4H_9; middle curve, R' = COPh, R = C_2H_5, R' = H; upper curve, R' = R'' = COPh, R = *n*-C_3H_7.

Table III. In the absence of a normal coordinate treatment (except for the parent pyrazole[9]) our vibrational assignments must be regarded as tentative. However, we were aided by previous work in which many of the band (group) assignments were made. This extensive experience will simply be cited here.[8-15]

In Figure 1 we show typical changes in the regions of carbonyl and no (3400–3600 cm^{-1}), intermolecular (3000–3400 cm^{-1}), and intramolecular (2000–3000 cm^{-1}) hydrogen-bonding absorptions. To begin with, the solids **3** are probably present as hydroxy tautomers, e.g., **3a**, in which inter- and intramolecular hydrogen bonds can be strong. Monoacylation, as in **4a**, appears to narrow bands in the 3300- and 2950-cm^{-1} regions and decrease the intensity of the latter substantially. Diacylation as in **6a** produces sharper but weaker peaks throughout.

Certain mass spectra of the series studied were of special interest. The solids **9** and **10** tended to crack: parent peaks were not observed. The parent ions of the mono- and diacylated solids (**4–7**) usually split along fairly conventional lines. Above the parent, however, was an array of ions carrying one or more "extra" protons or acyl groups, e.g., eq 6. It is not clear whether these ions arise from acid–base reactions in the heated probe or from the fragmentation of dimers in the source. Whatever their origin, it appears that *intermolecular* analogs of the *intramolecular* bonding pictured in **3a, 4a, 6a,** and **9a** are significant.



(6)

Several typical mass spectra are listed in the Experimental Section.

Experimental Section

1-Amino-1-hydrazino-2,2-dicarboxyalkylethenes (2) (Table 1). 1-Amino-1-trichloromethyl-2,2-dicarboxyalkylethene[1] (0.01 mol) in DMF (30 ml) was stirred as an 85% aqueous solution of hydrazine hydrate (1.5 ml) was slowly added. The mixture was stirred for 30 min more, heated briefly (3–5 min) to ca. 80°, treated with water (100 ml), and stored for ca. 12–24 hr at 0–5°. The white solid products were obtained by filtration and several recrystallizations from ethanol–water (1:1).

3-Amino-4-carboalkoxypyrazolinones (3). A stirred solution of **2** (0.1 mol) and hydrazine hydrate (20 ml) in DMF (200 ml) was heated at ca. 100° for 2 hr. Treatment of the cooled solution with ice water (100 ml) and evaporation yielded a solid which was washed with water and recrystallized from methanol. In an alternate preparation of **3**, compound **2** was quickly dissolved in refluxing phenetole (ca. 172°). Compound **3** began to separate immediately and was filtered from the cooled solution.

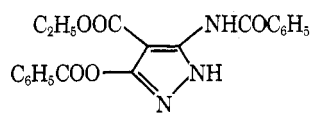
Mono- and Diacylated Derivatives (4–7) of 3. A solution of the pyrazolone **3** (0.01 mol) and benzoyl chloride (0.01 mol) in pyridine was stirred for 1 hr at ca. 70°. Evaporation of the solvent yielded a solid (**4**), which was washed with water and recrystallized from methanol. Acetyl chloride (0.01 mol) was added slowly to a solution of pyrazolone **3** (0.01 mol) in pyridine (20 ml). The mixture was stirred for ca. 1 hr more and then treated with ice water (ca. 50 ml). The viscous oil which separated crystallized at ca. −5°. It was decolorized with active carbon in and recrystallized from methanol or ethanol to give **5**.

The diacyl products were prepared by heating **3** (0.01 mol) and the appropriate acid chloride (0.02 mol) in pyridine (20 ml) at reflux for ca. 2 hr or until solution was complete. The cooled solution was treated with ice slush (100 g) and the solid (**6, 7**) which separated was recrystallized from ethanol or acetone.

Urea and Urethane Derivatives of 3. A solution of **3** (0.01 mol) and phenyl isocyanate (0.01 mol) in pyridine (20 ml) was stirred for ca. 0.2 hr at ca. 25° and 0.5 hr at reflux. The cooled solution was treated with ice slush and the solid (**8**) which separated was recrystallized from ethanol. A solution of **3** (0.01 mol) and phenyl isocyanate (0.02 mol) in pyridine (15 ml) was heated at reflux for 1 hr. On evaporation under vacuum, the solution deposited a viscous oil which was stirred with water at ca. −5°. Treatment of this material with active carbon in ethanol and recrystallization gave white crystals of **9**.

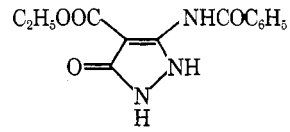
***o*-Aminobenzoylations with Isatoic Anhydride.** Reactions of 4-carboethoxy derivatives of 3- and 5-aminopyrazole were carried out. A mixture of isatoic anhydride (1.63 g, 0.01 mol),[16] pyrazole (0.01 mol), and pyridine (20 ml) was stirred at ca. 100° for 4 hr. After the colored solution was cooled and evaporated, the residue was recrystallized from ethanol to yield (**10**).

Mass Spectra. A Varian MAT CH7 instrument operated at an ionizing energy of ca. 55 eV at 100 μA was used. A few sample spectra are recorded below. Probe temperatures, *m/e* (rel intensities) and metastable transitions m* are indicated. Below the double slash (//), peaks of low relative intensity and at an arbitrary cut-off (5–8%), as well as *m/e* 32, 29, 18, and 17, were omitted.



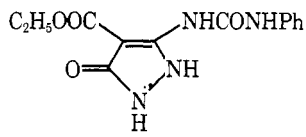
$C_{20}H_{17}O_5N_3$, 379; 160°

488 (1), 487 (3), 440 (1), 415 (1), 383 (16), 382 (68), 381 (85), //335 (27), 334 (53), 293* ± 1.5 (382, 381 → 335, 334), 276 (9), 230 (9), 229 (33), 138.5* (382, 381 → 230, 231) 107 (12), 106 (74), 105 (100), 104 (9), 83 (21), 78 (38), 77 (93), 76 (18), 68 (9), 67 (29), 56.6* ± 1 (105 → 77), 56 (5), 51 (56), 50 (10), 40 (5), 34* (77 → 51), 29.1* ± 0.6 (382, 381 → 106, 105), 29 (12)



$C_{13}H_{13}N_3O_4$, 275; 260°

382 (1), 381 (5), 380 (12), 334 (2), 333 (5), 293* (380 → 334), 276 (44), 275 (76), 230 (53), //229 (47), 191* ± 1 (275 → 230, 229), 125 (18), 106 (68), 105 (100), 103 (64), 78 (27), 77 (82), 76 (16), 69 (13), 68 (67), 56.5* (275 → 125, 105 → 77), 51 (38), 50 (15), 48* (230, 229 → 106, 105), 45 (8), 44 (22), 43 (10), 41 (13), 40.2* (275 → 105), 40 (20), 39 (80), 34* (77 → 51), 31 (13), 29 (35), 27 (24)



290; 240°

290 (1.2), 289 (0.5), 275 (0.8), 245 (0.8), 229 (1.2), 199 (0.5), //172 (10), 171 (90), 125 (42), 124 (100), 120 (16), 119 (95), 91.4* (171 → 125), 91 (71), 69.7* ± 0.5 (119 → 91), 68 (90), 65 (11), 64 (40), 63 (18), 58 (11), 51 (12), 50 (10), 45* (91 → 64), 41 (14), 40 (15), 39 (17), 38 (15), 37* (125 → 68), 27 (15)

Registry No.—1 (R = Me), 22071-01-8; 1 (R = Et), 22071-11-0; 1 (R = Pr), 22071-02-9; 1 (R = Pr-*i*), 22071-03-0; 1 (R = Bu), 55254-75-6; 1 (R = Bu-*i*), 55254-76-7; 1 (R = Bu-*t*), 40764-67-8; 1 (R = Bu-*t*; R′ = Et), 51920-23-1; 3 (R = CH_3OOC), 52566-49-1; 3 (R = C_2H_5OOC), 52565-83-0; 3 (R = C_3H_7OOC), 55254-83-6; 3 (R = *i*-C_3H_7OOC), 55254-84-7; 3 (R = C_4H_9OOC), 55254-85-8; 3 (R = *i*-C_4H_9OOC), 55254-86-9; 3 (R = *t*-C_4H_9OOC), 55254-87-0; 4 (R = C_2H_5OOC), 52566-51-5; 4 (R = *n*-C_3H_7OOC), 55254-88-1; 4 (R = *i*-C_4H_9OOC), 55254-89-2; 5 (R = *n*-C_3H_7OOC), 55254-90-5; 5 (R = *i*-C_3H_7OOC), 55254-91-6; 5 (R = *i*-C_4H_9OOC), 55254-92-7; 6 (R = C_2H_5OOC), 55254-93-8; 6 (R = *n*-C_3H_7OOC), 55254-94-9; 6 (R = *i*-C_3H_7OOC), 55254-95-0; 6 (R = *i*-C_4H_9OOC), 55254-96-1; 7 (R = *n*-C_3H_7OOC), 55254-97-2; 7 (R = *i*-C_4H_9OOC), 55254-98-3; 8 (R = C_2H_5OOC), 55254-99-4; 8 (R = *n*-C_3H_7OOC), 55255-00-0; 8 (R = *i*-C_4H_9OOC), 55255-01-1; 9 (R = C_2H_5OOC), 55255-02-2; 9 (R = *n*-C_3H_7OOC), 55255-03-3; 9 (R = *i*-C_4H_9OOC), 55255-04-4; 10, (R = Et), 55255-05-5; 10 (R = Bu-*i*), 55255-06-6; hydrazine hydrate, 10217-52-4; benzoyl chloride, 98-88-4; acetyl chloride, 75-36-5; phenyl isocyanate, 103-72-0; isatoic anhydride, 118-48-9.

References and Notes

(1) International Research and Exchange Board Scholar, 1974–1975.
(2) N. D. Bodnarchuk, B. B. Gavrilenko, and G. I. Derkach, *Zh. Org. Khim.*, **4**, 1710 (1968).
(3) B. B. Gavrilenko, N. D. Bodnarchuk, and V. V. Momot, *Zh. Org. Khim.*, **10**, 601 (1974).
(4) R. Fusco in "The Chemistry of Heterocyclic Compounds", Vol. 22, R. H. Wiley and P. Wiley, Ed., Interscience, New York, N.Y., 1967: (a) Chapter 1; (b) p 46; (c) p 76.
(5) (a) R. J. Weinkam and B. T. Gillis, *J. Org. Chem.*, **37**, 1696 (1972); (b) H. Junek and H. Aigner, *Chem. Ber.*, **106**, 914 (1973).
(6) (a) R. G. Dubenko and P. S. Pel'kis, *Zh. Org. Khim.*, 1762 (1965); *Chem. Abstr.*, **64**, 5068 (1966); **69**, 18743 (1968); (b) M. H. Elnagdi, *Tetrahedron*, **30**, 2791 (1974); M. H. Elnagdi and S. O. A. Allah, *J. Prakt. Chem.*, **315**, 1009 (1973).
(7) A. D. Josey, *J. Org. Chem.*, **29**, 707 (1964).
(8) A. R. Katritzky and P. J. Taylor in "Physical Methods in Heterocyclic Chemistry", Vol. IV, A. R. Katritzky, Ed., Academic Press, New York, N.Y., 1971, p 313 ff.
(9) A. Zecchina, L. Cerruti, S. Coluccia, and E. Borello, *J. Chem. Soc. B*, 1363 (1967).
(10) I. Dick, R. Bacaloglu, and A. Maurer, *Rev. Roum. Chem.*, **12**, 607 (1967).
(11) S. Refn, *Spectrochim. Acta*, **17**, 40 (1961).
(12) (a) P. Bouchet, J. Elguero, R. Jacquier, and J.-M. Pereillo, *Bull. Soc. Chim. Fr.*, 291 (1974); (b) J. Elguero, R. Jacquier, and G. Tarrago, *Ibid.*, 3772, 3780 (1967).
(13) A. Maquestiau, Y. Van Haverbeke, and R. Jacquerye, *Bull. Soc. Chem. Belg.*, **82**, 215, 233 (1973).
(14) H. Yasuda, *Appl. Spectrosc.*, **23**, 22 (1969).
(15) H. Dorn, G. Hilgetag, and A. Zubek, *Chem. Ber.*, **99**, 178, 183 (1966).
(16) Gift of Sherwin Williams Chemicals.

Dye-Sensitized Photooxygenation of *tert*-Butylpyrroles

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The isomeric 1,2 and 3-mono-*tert*-butylpyrroles were photooxygenated in methanol and acetone solvents using Rose Bengal and Methylene Blue singlet oxygen sensitizers. Their rates of photooxygenation are comparable to that of 2,5-dimethylfuran in methanol, but slower in acetone. Fifteen different photooxygenation products from both methanol and acetone solvents have been isolated, and their structures have been determined by spectroscopic methods. They include the expected 5-methoxy- and 5-hydroxylactams, 3-hydroxylactams, imides, pivalamide, and an unusual yellow keto lactam. The intermediate endo peroxides have been prepared at −78° and identified by low-temperature NMR.

The dye-sensitized photooxygenation of pyrroles has been the subject of recent extensive investigations,[1] especially in connection with a phototherapy method for treating neonatal jaundice due to an excess of the tetrapyrrole, bilirubin.[1,2,3] However, the first photochemical oxidation of pyrrole was reported by Ciamician and Silber in 1912:[4] photoautoxidation of pyrrole in water gave succinimide along with two unidentified crystalline compounds and a black resin. Subsequent investigations were reported by Bernheim and Morgan,[5] who found that eosin or Methylene Blue sensitized irradiation of pyrrole in water, acetone, or alcohol gave a 58% yield of an unidentified crystalline product, $C_4H_5NO_2$, mp 102.5°; and Linnel and Umar,[6] who postulated a reactive, polymerizable pyrrole endo peroxide. De Mayo and Reid[7] were the first to prove the 5-hydroxylactam structures of the products from eosin-sensitized aqueous photooxygenation of pyrrole and *N*-methylpyrrole. They accounted for their isolated photoproducts by proposing the intermediacy of an unstable endo peroxide formed by reaction of the pyrrole with singlet oxygen[8,9] [$^1O_2$] analogous to the photooxygenation of furans.[10,11] Pyrrole photooxygenations were later extended to alkylpyrroles by Lightner et al.,[1,12] and the photooxygenation of phenyl-substituted pyrroles received extensive and pioneering attention by Wasserman et al.[1,13] and Dufraisse, Rio et al.[1,14] The only reported photooxygenation study on *tert*-butylpyrroles is that of Ramasseul and Rassat,[15] who isolated hydroperoxides from 2,5-di-*tert*-butylpyrrole and 2,3,5-tri-*tert*-butylpyrrole as well as other products whose structures are reminiscent of those from 2,3,4,5-tetraphen-