The Kinetics and Mechanism of the Electrophilic Substitution of Heteroaromatic Compounds. Part XLI.[1] Nitration of 3-Hydroxy-1-phenylpyrazoles

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The kinetics have been studied for the nitration of 3-hydroxy-5-methyl-4-nitro-1-phenylpyrazole and its *N*- and *O*-methyl derivatives at the *para*-position and of 3-hydroxy-5-methyl-1-*p*-nitrophenylpyrazole and its *N*- and *O*-methyl derivatives at the 4-position. All the compounds undergo a mechanistic changeover from nitration of the free base at low acidity to nitration of the conjugate acid at high acidity. Rates are compared within the series studied and with those of other heteroaromatic compounds.

FOLLOWING our work on 1-phenyl-Δ^3-pyrazolin-5-ones [2] in the azolone series, we now report the kinetics of nitration of 1-phenyl-Δ^3-pyrazolin-3-ones. In view of the susceptibility of 3-hydroxy-phenylpyrazoles to nitration both at the 4-position of the pyrazole ring and at the *para*-position of the phenyl ring (*cf.* 1-phenyl-Δ^3-pyrazolin-5-ones),[2] we studied the second nitration of the two mononitro-derivatives (3) and (5) of 3-hydroxy-5-methyl-1-phenylpyrazole. 1-Phenyl substituted-3-hydroxypyrazoles are tautomeric [(9a) $\rightleftharpoons$ (9b)],[3] but at equilibrium the hydroxy-form is normally favoured. We included in our study the *N*-methyl compounds (4) and (6) [as models for the tautomeric form (9a)] and the methoxy-derivatives (11) and (12) [as models for (9b)]. Attempts to prepare quaternised derivatives failed, as in the Δ^3-pyrazolin-5-one series.[2]

Preparation of Compounds.—Compounds of the 4-nitro-series were prepared by direct nitration, using pentyl nitrite for the conversion (1) $\longrightarrow$ (3) [4] and nitric acid for the conversions (2) $\longrightarrow$ (4) [5] and (10) $\longrightarrow$ (11). In the 1-*p*-nitrophenyl series, compound (5) was prepared by ring closure.[6] Methylation of (5) with dimethyl sulphate and sodium hydroxide gave (6). Treatment of (10) with 1 mol. equiv. of nitric acid in sulphuric acid gave (12). All the compounds were characterised by their n.m.r. spectra (Table 1).

Nitration in mixed acid of (1), (3), and (5) gave in each case the same dinitro-derivative (7). Similarly (2), (4), and (6) each gave (8); further, (10), (11), and (12) each gave (13). The n.m.r. spectra of all the crude dinitro-products were examined for the presence of the 1-*o*-nitrophenyl and 1-*m*-nitrophenyl compounds: in no case were signals attributable to *o*- and *m*-isomers

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[4] T. Ajello, *Gazzetta*, 1940, **70**, 401 (*Chem. Abs.*, 1941, **35**, 3252[9]).
[5] L. Lederer, *J. prakt. Chem.*, 1892, **45** (2), 83 (*Brit. Abs.*, 1892, **62**, 634).
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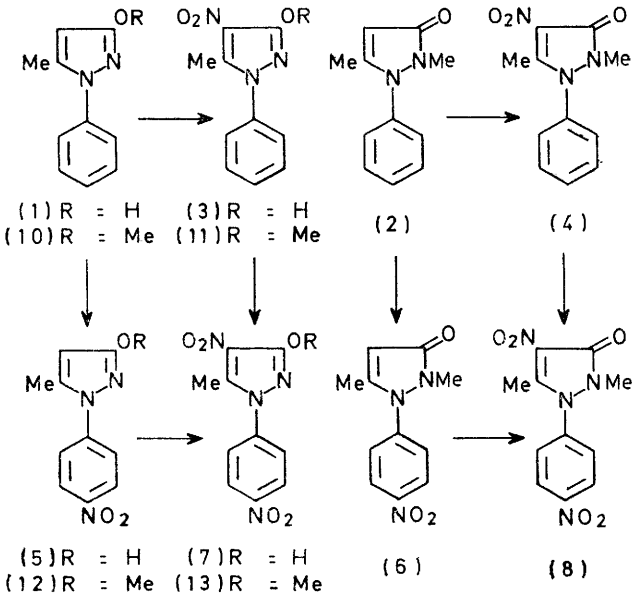
detected, and we believe that they are present to the extent of less than 5% in all cases. This is supported



by the m.p.s of the crude nitration products (Table 2), which were close to those of the pure compounds.

dimethyl-1-phenylpyrazolin-3-one, m.p. 114—115° (lit.,[5] 113°); 2,5-dimethyl-4-nitro-1-phenylpyrazolin-3-one, m.p. 212° (lit.,[5] 210°); 3-methoxy-5-methyl-1-phenylpyrazole, b.p. 130° at 4 mmHg (lit.,[3] 92—92.5° at 0.05 mmHg).

3-Hydroxy-5-methyl-4-nitro-1-phenylpyrazole.— 3-Hydroxy-5-methyl-1-phenylpyrazole (1 g) with pentyl nitrite (0.7 g) in acetone (250 ml) was kept at 20 °C for 3 days, according to the published method [4] for 3-methyl-4-nitro-1-phenyl-Δ^3-pyrazolin-5-one. The *product* (0.8 g, 66%) crystallised from acetic acid as yellow needles, m.p. 235—236° (Found: C, 55.0; H, 4.2; N, 18.9. $C_{10}H_9N_3O_3$ requires C, 54.8; H, 4.2; N, 19.2%).

3-Hydroxy-5-methyl-4-nitro-1-p-nitrophenylpyrazole.— Nitric acid (*d* 1.42; 2.1 g) and sulphuric acid (*d* 1.84; 10 ml) were added to 3-hydroxy-5-methyl-1-phenylpyrazole (2 g) at 0 °C. After 48 h at 20 °C the mixture was poured onto ice (100 g) to give the *dinitro-derivative* (2.1 g, 67%), which separated from ethanol as yellow needles, m.p. 173—174° (Found: C, 45.1; H, 3.3; N, 20.9. $C_{10}H_8N_4O_5$ requires C, 45.3; H, 3.1; N, 21.0%).

2,5-Dimethyl-1-p-nitrophenylpyrazolin-3-one.— 3-Hydroxy-5-methyl-1-*p*-nitrophenylpyrazole (0.8 g), sodium hydroxide (0.35 g), water (2 ml), and dimethyl sulphate (0.35 g) in methanol (10 ml) were heated for 1 h at 100 °C. The solution was evaporated to give the *dimethyl compound* (0.4 g, 47%), which crystallised from ethanol as pale yellow needles, m.p. 101—102° (Found: C, 56.8; H, 4.9; N, 18.3. $C_{11}H_{11}N_3O_3$ requires C, 56.6; H, 4.7; N, 18.0%).

2,5-Dimethyl-4-nitro-1-p-nitrophenylpyrazolin-3-one.— Nitric acid (*d* 1.42; 1 g) and sulphuric acid (*d* 1.84; 3 ml) were added slowly to 2,5-dimethyl-1-phenylpyrazolin-3-one (1 g) in sulphuric acid (*d* 1.84; 10 ml) at 0 °C. After 24 h at 20 °C, the mixture was added to ice (100 g) then neutralised (Na_2CO_3). The yellow precipitate was extracted with chloroform (2 × 50 ml) and the extracts were concentrated

TABLE 1

Proton n.m.r. chemical shifts (τ values) [a] and coupling constants (Hz) at 60 MHz of substituted 3-hydroxypyrazoles and 3-methoxypyrazoles in $CF_3{\cdot}CO_2H$

	Pyrazole ring position								
	1			2		3		4	
Compound	Subst.	τ	J [b]	Subst.	τ	Subst.	τ	Subst.	τ	5-Me
(1)	Ph	2.83				OH		H	4.32	8.06
(2)	Ph	2.41		Me	6.45	O		H	3.90	7.74
(3)	Ph	2.67				OH		NO_2		7.63
(4)	Ph	2.29		Me	6.35	O		NO_2		7.32
(5)	*p*-$NO_2{\cdot}C_6H_4$	1.92, 2.55	9.2			OH		H	4.27	8.01
(6)	*p*-$NO_2{\cdot}C_6H_4$	1.51, 2.12	8.7	Me	5.77	O		H	3.71	7.49
(7)	*p*-$NO_2{\cdot}C_6H_4$	1.82, 2.46	9.6			OH		NO_2		7.61
(8)	*p*-$NO_2{\cdot}C_6H_4$	1.38, 1.99	9.0	Me	6.41	O		NO_2		7.32
(10)	Ph	2.70				OMe	6.17	H	4.18	7.99
(11)	Ph	2.78				OMe	6.13	NO_2		7.33
(12)	*p*-$NO_2{\cdot}C_6H_4$	1.95, 2.56	9.0			OMe	6.15	H	4.13	7.92
(13)	*p*-$NO_2{\cdot}C_6H_4$	1.86, 2.47	9.8			OMe	6.09	NO_2		7.62

[a] Relative to internal Me_4Si for solutions in $CF_3{\cdot}CO_2H$. [b] Coupling constants (Hz) for *p*-nitrophenyl substituent.

TABLE 2

Preparative nitrations

	Prepared by further nitration of 4-nitro-compound				Prepared by further nitration of 1-*p*-nitrophenyl compound			
Nitration product	Starting material	Yield (%)	M.p. crude (°C)	M.p. recryst. (°C)	Starting material	Yield (%)	M.p. crude (°C)	M.p. recryst. (°C)
(7)	(3)	88	164—169	173—174	(5)	84	164—168	173—174
(8)	(4)	84	236—242	244—246	(6)	86	238—243	244—246
(13)	(11)	91	192—195	206—207	(12)	92	197—202	206—207

EXPERIMENTAL

Materials.—The following were prepared by the literature methods quoted: 3-hydroxy-5-methyl-1-phenylpyrazole, m.p. 167—168° (lit.,[3] 167°); 3-hydroxy-5-methyl-1-*p*-nitrophenylpyrazole, m.p. 232—233° (lit.,[6] 230—234°); 2,5-

to give the *dinitro-derivative* (0.4 g, 57%), which crystallised from ethanol as yellow needles, m.p. 244—246° (Found: C, 46.5; H, 4.1; N, 19.8. $C_{11}H_{10}N_4O_5$ requires C, 46.5; H, 3.6; N, 20.1%).

3-*Methoxy*-5-*methyl*-4-*nitro*-1-*phenylpyrazole*.—Nitric acid (*d* 1.42; 10 ml) was added dropwise at 0 °C to 3-methoxy-5-methyl-1-phenylpyrazole (1.0 g). After 12 h at 20 °C, the mixture was poured onto ice (100 g) to give the 4-*nitro-derivative* (0.75 g, 61%), which crystallised from ethanol as needles, m.p. 129—130° (Found: C, 56.4; H, 4.7; N, 17.5. $C_{11}H_{12}N_3O_3$ requires C, 56.6; H, 4.7; N, 18.0%).

3-*Methoxy*-5-*methyl*-1-p-*nitrophenylpyrazole*.—Nitric acid (*d* 1.42; 0.28 g) and sulphuric acid (*d* 1.84; 2 ml) were added dropwise to 3-methoxy-5-methyl-1-phenylpyrazole (0.6 g) in sulphuric acid (*d* 1.84; 8 ml) at 0 °C. The mixture was heated at about 50 °C for 3 h and then poured onto ice (100 g) to give the *nitro-derivative* (0.38 g, 51%), which crystallised from ethanol as pale yellow needles, m.p. 118—119° (Found: C, 56.9; H, 4.6; N, 17.8. $C_{11}H_{12}N_3O_3$ requires C, 56.6; H, 4.7; N, 18.0%).

3-*Methoxy*-5-*methyl*-4-*nitro*-1-p-*nitrophenylpyrazole*.—Premixed nitric acid (*d* 1.42; 0.6 g) and sulphuric acid (*d* 1.84; 3 ml) were added dropwise to 3-methoxy-5-methyl-1-phenylpyrazole (0.5 g) at 0 °C. The mixture was heated at 40 °C for 24 h and then poured onto ice (50 g). The separated *dinitro-compound* (0.6 g, 85%) crystallised from ethanol (charcoal) as yellow needles, m.p. 206—207° (Found: C, 46.3; H, 3.9; N, 20.1. $C_{11}H_{10}N_4O_5$ requires C, 46.5; H, 3.6; N, 20.1%).

Spectroscopy.—N.m.r. spectra were recorded at 60 MHz (Perkin-Elmer R 12 or R 24) with sample spinning. Tetramethylsilane was used as internal standard. U.v. spectra (Table 3) were determined with a Perkin-Elmer 137 instrument; individual optical densities were recorded in Spectrosil 10 mm silica cells with a Unicam SP 500 instrument.

Kinetic Determinations.—Nitric and sulphuric acids were AnalaR grade. H_0 [7] and H_R [8] values, corrected for the reaction temperatures, were taken from the scales recently established.

Nitrations were followed in u.v. cells by measuring the increase in absorption due to the dinitro-compound (as cation). All the compounds (3)—(6), (11), and (12) were followed at both high and low acidity range under pseudo-first-order conditions with a molar ratio of nitric acid to substrate of 30 : 1. Substrates were also heated in sulphuric acid under conditions as for nitration except for the absence of nitric acid; all were unchanged (u.v. spectrum).

The infinity optical densities observed and those calculated from the known extinction coefficient of the pure nitro-derivative agreed to within 4 or 5% in each case. Rate constants are defined by equations (1)—(3), and are

$$-\mathrm{d[substr.]}/\mathrm{d}t = k_2(\mathrm{obs})[\mathrm{substr.}][\mathrm{HNO_3}]_{\mathrm{stoich}} \quad (1)$$

$$\log k_2(\mathrm{fb})_T = \log k_2(\mathrm{obs})_T + m[H_0(\tfrac{1}{2}) - H_0]_T \quad (2)$$

$$\log k_2{}^* = \log k_2(\mathrm{obs}) - \log\{[NO_2{}^+]/[\mathrm{HNO_3}]_{\mathrm{stoich}}\} \quad (3)$$

expressed in l mol^{-1} s^{-1}. In these equations k_2(obs) is the observed second-order rate constant, k_2(fb) the second-order rate constant, corrected for the concentration of free base, and $k_2{}^*$ the second-order rate constant corrected for the concentration of $NO_2{}^+$.

TABLE 3

U.v. and pK_a data for substituted pyrazoles

Compound	Substituent 1	2	3	4	5	$\lambda_{max.}$/nm (log ε) Neutral species	Cationic species	λ [a]	Proton addition λ [b]	$H_0(\frac{1}{2})$	m	pK_a
(1)	Ph		OH	H	Me	257 (4.02) [c]	241 (4.09) [c]					1.79 [c]
(2)	Ph	Me	O	H	Me	258.5 (4.07) [c]	234 (4.09) [c]					1.66 [c]
(3)	Ph		OH	NO_2	Me	305 (3.76)	285 (3.73)	283	330	−3.26	0.61	−1.99
(4)	Ph	Me	O	NO_2	Me	341 (3.81)	273 (3.90)	275	340	−2.72	0.71	−1.86
(5)	*p*-NO_2·C_6H_4		OH	H	Me	308 (3.63)	288 (3.66)	250	340	−0.28	1.19	−0.33
(6)	*p*-NO_2·C_6H_4	Me	O	H	Me	325 (4.05)	300 (3.99)	265	350	−0.22	1.22	−0.27
(7)	*p*-NO_2·C_6H_4		OH	NO_2	Me	313 (4.03)	285 (3.97)		330	−3.87	0.64	−2.47
(8)	*p*-NO_2·C_6H_4	Me	O	NO_2	Me	234 (4.04)	281 (4.01)		345	−3.06	0.64	−1.96
(10)	Ph		MeO	H	Me	250.5 (4.05) [c]	241 (4.04) [c]					1.17 [c]
(11)	Ph		MeO	NO_2	Me	290 (3.85)	277 (4.02)	270	320	−3.58	0.88	−3.15
(12)	*p*-NO_2·C_6H_4		MeO	H	Me	310 (3.97)	290 (4.05)	283	330	−0.48	1.17	−0.56
(13)	*p*-NO_2·C_6H_4		MeO	NO_2	Me	320 (4.05)	290 (4.10)		330	−4.66	0.76	−3.54

[a] λ for nitration. [b] λ for pK_a. [c] Taken from ref. 3.

The H_0 value of half protonation, $H_0(\frac{1}{2})$, was measured by the spectrophotometric method, as previously described.[9] The slopes $-\mathrm{d}(\log I)/\mathrm{d}(-H_0)$ are denoted by m (see ref. 9), and were used to measure the pK_a values recorded in Table 3.

RESULTS AND DISCUSSION

The kinetic results for nitration are collected in Table 4. Plots of log k_2(obs) against $-(H_R + \log a_{H_2O})$ yield good straight lines (Figure 1). At low acidities the six compounds studied all show slopes considerably lower than unity (Table 5), indicating free base nitration; slopes corrected for the free base concentration are considerably larger (Table 5). The six compounds all showed $\mathrm{d}[\log k_2(\mathrm{obs})]/\mathrm{d}(-H_0)$ slopes in the range 0.22—0.53 over the high acidity region H_0 −9 to −10; this is typical for nitration of majority species, *i.e.* conjugate acids [10,11] (see Figure 2).

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[10] E. F. V. Scriven, Ph.D. Thesis, University of East Anglia, 1969.

[11] A. G. Burton, Ph.D. Thesis, University of East Anglia, 1971.

TABLE 4

Nitration of substituted pyrazoles in the high and low acidity region

% H_2SO_4	$-H_0$ [a]	$-(H_R + \log a_{H_2O})$ [b]	$-\log k_2$(obs)	$\log k_2$(fb)	$\log k_2^*$ [c]
3-Hydroxy-5-methyl-4-nitro-1-phenylpyrazole (3) (28 °C)					
95.89	9.97		1.032		
93.86	9.64		0.960		
91.71	9.30	21.08	0.963		−2.44
89.84	8.98	20.31	0.904		−1.60
86.93	8.57	19.14	1.303		−0.84
83.52	8.08	17.79	1.769		0.05
81.15 [d]	6.86	14.13	1.399	0.796	4.08
80.18 [d]	6.71	13.84	1.528	0.569	4.22
77.15 [d]	6.27	12.95	1.936	−0.101	4.71
73.76 [d]	5.77	12.09	2.387	−0.857	5.11
2,5-Dimethyl-4-nitro-1-phenylpyrazolin-3-one (4) (60 °C)					
96.74	9.27		1.886		
94.26	8.79		1.531		
93.52	8.66		1.639		
92.21	8.46		1.436		
89.59	8.07	17.90	1.236		0.48
88.13	7.88	17.14	1.215		1.25
86.50	7.68	16.57	1.405		1.61
85.35	7.50	16.15	1.457		2.01
83.97	7.21	15.56	1.509	1.750	2.53
82.43	7.13	14.91	1.712	1.490	2.97
80.08	6.70	13.85	1.993	0.904	3.76
78.03	6.39	13.20	2.139	0.538	4.26
76.48	6.24	12.74	2.309	0.261	4.59
3-Hydroxy-5-methyl-1-*p*-nitrophenylpyrazole (5) (28 °C)					
96.74	10.13		0.415		
95.86	9.97		0.542		
93.68	9.60		0.401		
92.43	9.40	21.35	0.434		−2.15
91.20	9.20	20.84	0.320		−1.55
89.31	8.90	20.05	0.233		−0.66
86.71	8.52	19.05	0.266		0.30
84.82	8.27	18.32	0.361		0.94
80.60	7.60	16.55	0.854	7.860	+2.20
79.09	7.33	16.00	1.146	7.247	+2.45
76.32	6.85	15.04	1.663	6.158	2.92
73.63	6.40	14.23	2.063	5.223	3.32
2,5-Dimethyl-1-*p*-nitrophenylpyrazolin-3-one (6) (40 °C)					
96.66	9.80		1.925		
94.18	9.32		1.751		
93.43	9.23		1.609		
92.08	9.02	20.09	1.521		−1.05
89.36	8.60	19.08	1.163		−0.63
88.10	8.41	18.63	1.278		−0.28
85.41	8.01	17.70	1.519		0.41
83.80	7.73	17.05	1.600	8.101	0.96
81.20	7.28	15.83	1.919	6.693	1.88
79.86	7.06	15.16	2.160	6.723	2.29
78.71	6.88	14.87	2.205	5.919	2.52
75.82	6.48	14.09	2.477	5.159	3.01
3-Methoxy-5-methyl-4-nitro-1-phenylpyrazole (11) (40 °C)					
97.39	9.97		1.979		
94.82	9.46		1.857		
92.60	9.10	20.28	1.767		−2.47
92.54	9.09	20.27	1.640		−2.34
89.90	8.67	19.28	1.606		−1.31
88.24	8.44	18.68	1.597		−0.69
88.22	8.43	18.66	1.687		−0.74
86.45	8.17	18.04	1.766		−0.18
86.23	8.13	17.97	1.853		−0.20
85.27	7.99	17.65	2.100		−0.13
83.28	7.65	16.82	2.172	1.410	0.63
82.28	7.47	16.34	2.389	1.035	0.89
80.15	7.11	15.42	2.567	0.540	1.61
79.87	7.04	15.31	2.587	0.458	1.71
77.53	6.71	14.54	2.810	−0.055	2.20

TABLE 4 *Continued*

% H_2SO_4	$-H_0$ [a]	$-(H_R + \log a_{H_2O})$ [b]	$-\log k_2$(obs)	$\log k_2$(fb)	$\log k_2^*$ [c]
3-Methoxy-5-methyl-1-*p*-nitrophenylpyrazole (12) (40 °C)					
97.28	9.95		2.091		
94.60	9.42		1.752		
93.90	9.30		1.783		
92.45	9.08	20.23	1.671		−2.28
90.68	8.80	19.58	1.550		−1.51
89.70	8.60	19.22	1.710		−1.33
88.14	8.42	18.64	1.980		−1.02
86.15	8.13	17.95	2.258		−0.61
85.02	7.93	17.57	2.625		−0.57
83.16	7.62	16.76	2.843	5.512	0.02
82.31	7.48	16.33	3.128	5.064	0.15
80.50	7.16	15.56	3.382	4.435	1.02
77.97	6.78	14.35	3.910	3.463	2.17

[a] H_0 Values are corrected [7] for temperature. [b] H_R values are corrected.[8] [c] No correction was made for the half protonation point of HNO_3 at elevated temperatures. [d] Carried out at 60 °C.

Recently we pointed out that at acidities of 70—90% H_2SO_4 $d(\log k_2)/d[-H_0(T)]$ (independent of the temperature) is <1.7 for free base but >1.7 for conjugate acid

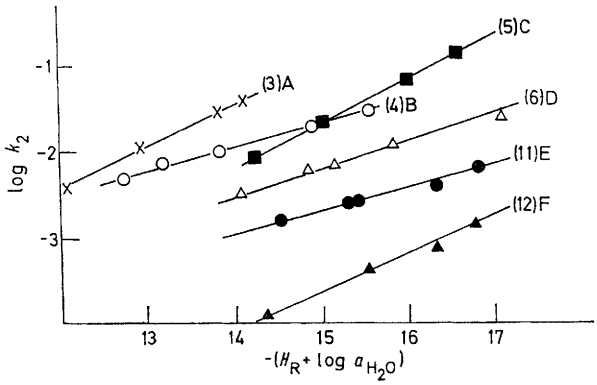


FIGURE 1 Low acidity rate profiles for the nitration of 1-phenylpyrazolin-3-ones: A, (3) at 60 °C; B, (4) at 60 °C; C, (5) at 25 °C; D, (6) at 40 °C; E, (11) at 40 °C; F, (12) at 40 °C

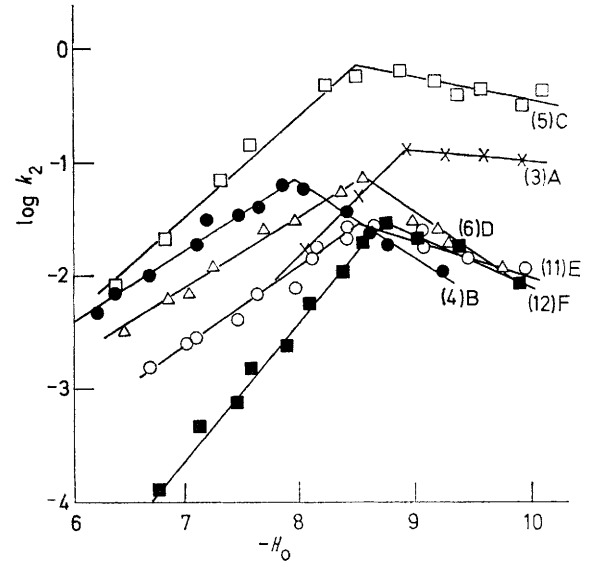


FIGURE 2 High-acidity rate profiles for the nitration of 1-phenylpyrazolin-3-ones: A, (3) at 28 °C; B, (4) at 60 °C; C, (5) at 28 °C; D, (6) at 40 °C; E, (11) at 40 °C; F, (12) at 40 °C

TABLE 5

Rate profile slopes for nitration of 5-methyl-1-phenylpyrazoles and 3-hydroxy-5-methyl-1-phenylpyrazoles

Compounds	Ring substituent(s)	Position of nitration	Low acidity region					High acidity region 92—98% H_2SO_4		
			T/°C	Slope [a]	Corr. coeff.	Slope [b]	Species reacting [c]	T/°C	Slope [d]	Species reacting [c]
(3)	4-NO_2	4′	60	0.48	0.998	0.81	F.B.	28	0.21	C.A.
(4)	4-NO_2, 2-Me	4′	60	0.28	0.998	0.53	F.B.	60	0.52	C.A.
(5)	4′-NO_2	4	28	0.54	0.999	1.13	F.B.	28	0.29	C.A.
(6)	4′-NO_2, 2-Me	4	40	0.29	0.998	0.95	F.B.	40	0.52	C.A.
(11)	4-NO_2, 3-MeO	4′	40	0.26	0.991	0.62	F.B.	40	0.24	C.A.
(12)	4′-NO_2, 3-MeO	4	40	0.43	0.995	0.84	F.B.	40	0.48	C.A.

[a] Moodie–Schofield plots. [b] Corrected for free base concentration. [c] F.B. = free base; C.A. = conjugate acid. [d] d[log k_2(obs)]/d($-H_0$) (92—98% H_2SO_4).

TABLE 6

Compd.	Ring substituents 1	2	3	4	5	Range (%)	T/°C	Range (H_0)	$\frac{d(\log k_2)}{d(-H_0)}$	log k_2 ($-6.6H_0$)	log k_2 (25 °C)[2]	Species charge	pK_a	m	log k_2^0
(a) Standard rate constants for 1-phenylpyrazolin-5-ones															
	Ph	H	Me	NO_2	O	72—78	25	6.1—7.0	1.99	−0.32	−0.32	+			−0.32
	Ph	Me	Me	NO_2	O	78—86	25	7.0—8.4	0.82	−3.37	−3.37	0	−1.9	0.62	−1.18
						89—98	25	8.8—10.4	−0.41	−1.94 [b]	−5.94 [b]	+			−5.94
	p-NO_2·C_6H_4	H	Me	H	O	74—87	40	6.1—8.3	0.99	−1.21	−2.44	0	0.25 [c]	0.7 [c]	+2.43
						89—96	40	8.5—9.7	−0.44	−0.22 [b]	−4.84 [b]	+			−4.84
	p-NO_2·C_6H_4	Me	Me	H	O	77—86	25	6.9—8.5	1.22	−4.38	−4.38	0	0.25 [c]	0.7 [c]	+0.39
						88—95	25	8.7—9.8	−0.34	−1.79 [b]	−5.79 [b]	+			−5.79
	Ph		Me	NO_2	MeO	76—82	50	6.3—7.2	2.64	−2.37	−4.36	+			−4.36
	p-NO_2·C_6H_4		Me	H	MeO	81—88	40	7.1—8.4	1.73	−4.32	−5.55	+			−5.55
(b) Standard rate constants for 3-hydroxy-1-phenylpyrazoles															
(3)	Ph		OH	NO_2	Me	81—74	60	5.8—6.9	−0.91	−1.63	−4.33	0	0.7 [d]	−1.99	−1.72
						90—96	28	9.0—10.0	−0.11	−0.99 [b]	−4.99 [b]	+			4.99
(4)	Ph	Me	O	NO_2	Me	76—86	60	6.2—7.7	0.64	−2.03	−4.73	0	0.7	−1.86	−1.90
						92—97	60	8.4—9.3	−0.53	−1.59 [b]	−6.95 [b]	+			−6.95
(5)	p-NO_2·C_6H_4		OH		Me	74—87	28	6.4—8.5	0.87	−1.84	−2.10	0	1.0 [e]	−0.33	+4.17
						89—97	28	8.9—10.1	−0.19	−0.414 [b]	−4.41 [b]	+			−4.41
(6)	p-NO_2·C_6H_4	Me	O		Me	76—88	40	6.5—8.4	0.63	−2.39	−3.62	0	1.0 [e]	−0.27	+2.71
						92—97	40	9.0—9.9	−0.52	−1.65 [b]	−6.27 [b]	+			−6.27
(11)	Ph		MeO	NO_2	Me	77—88	40	6.7—8.4	0.68	−2.91	−4.14	0	0.88	−3.15	−1.48
						92—97	40	9.1—9.9	−0.30	−1.76 [b]	−6.38 [b]	+			−6.38
(12)	p-NO_2·C_6H_4		MeO		Me	78—88	40	6.8—8.4	1.18	−4.10	−5.33	0	1.0 [e]	−0.56	+0.71
						90—97	40	8.8—9.9	−0.46	−1.74 [b]	−6.35 [b]	+			−6.35

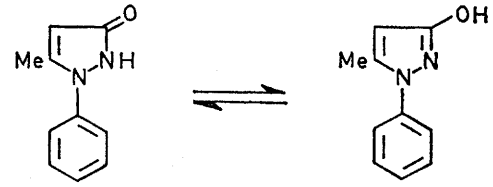
[a] $\Delta\bar{H}^{\ddagger}$ 35 kcal mol^{-1} (ref. 1). [b] Calculated from 4 + log k_2 (at 94% H_2SO_4); see ref. 1. [c] Assumed. [d] Exp. value m = 0.61. [e] Considered as typical Hammett base; experimental figure see Table 1.

reactions.[1] Application of this criterion to the present study again indicates that all the compounds are nitrated *via* the neutral form [d(log k_2)/d($-H_0$) = 0.6—1.2; Table 6].

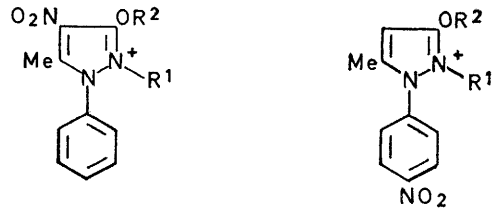
Using the standard procedure,[1] we have derived log k_2^0 values for nitration of these compounds as conjugate acids and as free bases (Table 6). The procedure has also been applied to compounds of the Δ^3-pyrazolin-5-one series, which were previously discussed in part.[2]

Nitration at the para-*Position of a* 1-*Phenyl Ring.*—A positively charged 3-hydroxypyrazole ring considerably deactivates the *para*-position of a 1-phenyl group towards nitration. This deactivation increases from the parent compound (14) (log k_2^0 −5.0), to the *N*-methyl derivative (15) (log k_2^0 −6.9), because the *N*-methyl group decreases inter-ring conjugation. *O*-Methylation of the cation (16) also has a considerable deactivating effect (log k_2^0 −6.4), presumably through reduced resonance donation from oxygen.

The effect of a positively charged Δ^3-pyrazolin-5-one ring is much smaller in the parent compound (log k_2^0 −0.3), but here the steric effect of *N*-methylation is greater (k_2^0 −5.9) and *O*-methylation (log k_2^0 −4.4) probably deactivates by both the steric and resonance modes.



(9a) (9b)



(14) R^1 = R^2 = H
(15) R^1 = Me, R^2 = H
(16) R^1 = H, R^2 = Me

(17) R^1 = R^2 = H
(18) R^1 = Me, R^2 = H
(19) R^1 = H, R^2 = Me

Nitration is considerably more rapid at the *para*-position of a 1-phenyl group in a neutral species. The log k_2^0 values for the 3-hydroxy- (3) and 3-methoxy- (11) compounds are similar (log k_2^0 −1.7 and −1.5) to that of the 1-methyl-3-hydroxypyrazole (4) (log k_2^0 −1.9).

Nitration at the 4-Position of a Pyrazole Ring.—Structures (17)—(19) are the protonated forms for (5), (6), and (12). Nitration of the pyrazolinone cations shows log k_2^0 −4.4 for the 3-derivative (17) and −4.8 for the 5-derivative. These values may be compared with log k_2^0 (−6.1) for 1,5-dimethylpyrazolium cation [12] and indicate the considerable activating influence of the hydroxy-substituent.

The rates of 4-nitration in the pyrazolinone cations are reduced by 0.8—1.9 log units on *O*- or *N*-methylation in the 3- and 5-series, by a combination of steric and electronic effects.

Nitration of the neutral pyrazolinones and their methyl derivatives is considerably faster, as expected. The rate for the 3-hydroxypyrazole (5) (log k_2^0 +4.2) is very great, possibly at encounter rate (log k_{enc} *ca.* 3) and *N*-methylation (6) reduces it by about 1.5 log units (log k_2^0 +2.7). The large reduction in rate for the *O*-methyl derivative (12) is best explained by reaction occurring on the oxo-form (9a) of (5) rather than the more prevalent hydroxy-form.

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[12] H. O. Tarhan, unpublished work.

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