# Heterocycle Stabilized Carbanions. Two Series of Anomalous Products from 1-Alkyl-4,6-diphenyl-2-pyridones

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1-Methyl-, 1-ethyl, and 1-n-butyl-4,6-diphenyl-2-pyridones with lithium di-isopropylamide yield normal products with ketone and aldehydes as electrophiles, but dimeric derivatives with acid chlorides, esters, and alkyl halides. The alkylpyridones react with ethyl- and n-butyl-lithium and an electrophile to give products resulting from alkylation at the 3- and reaction with electrophile at the 4-position. Structures are supported by spectra and reaction mechanisms discussed.

1-BENZYL-4,6-DIPHENYL-2-PYRIDONE (1a) with lithium di-isopropylamide (LDA) gives a stable α-anion (2a), which undergoes clean α-alkylation on addition of electrophiles.[1] We now show that 1-alkyl-4,6-diphenyl-2-pyridones (1b—d) when treated likewise frequently undergo anomalous dimerisations in place of the expected α-substitution.[2]

(1)   (2)
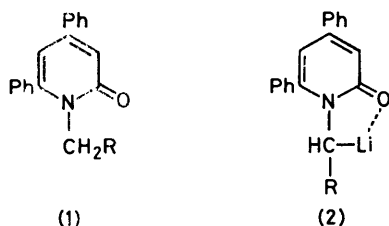
a; R = Ph
b; R = H
c; R = Me
d; R = Pr^n

Normal α-Substitution Products.—Examples of these can be obtained *via* metallation of the N-methyl-, N-ethyl-, and N-butyl-pyridones (1b—d). The reaction is carried out in the normal manner for aldehydes, ketones, and methyl iodide as electrophile. However, for ethyl benzoate as electrophile special conditions were needed: LDA was added to a mixture of the N-methylpyridone (1b) and PhCO$_2$Et, and the generated anion (2b) reacted

compound (1c) reacted *in situ* with benzophenone to give the alcohol (3c) (48%), with *p*-toluoaldehyde to give the alcohol (3d) (44%), and with methyl benzoate to

(3)   (4)
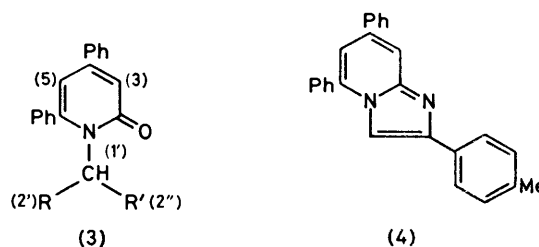
a; R = H, R' = Ph$_2$C(OH)
b; R = H, R' = COPh
c; R = Me, R' = Ph$_2$C(OH)
d; R = Me, R' = MeC$_6$H$_4$CH(OH)
e; R = Me, R' = COPh
f; R = Pr^n, R' = Ph$_2$C(OH)
g; R = H, R' = *p*-MeC$_6$H$_4$C(=NH)

give the ketone (3e) (12%). The anion (2d) thus generated from the N-butylpyridone (1d) reacted similarly with benzophenone to give the alcohol (3f) (64%).

The spectra of the α-substitution products (3a—f) (these results have been treated as a Supplementary

TABLE 1

Preparation of α-substitution products [a]

Product no.	Substituents R retained	R' introduced	Procedure	Metallation [a] time/min	Reaction [a] time/h	Yield (%)	M.p. (°C)	Crystal [b] form	Found %			Formula	Required %		
									C	H	N		C	H	N
(1c)	H	Me	B	1	10	25	108—109 [c]	Needles							
(3a)	H	Ph$_2$C(OH)	B	30	12	67	198—199	Prisms [d]	83.7	5.7	3.2	C$_{31}$H$_{25}$NO$_2$	84.0	5.6	3.1
(3b)	H	PhCO	A	30	12	25	233	Rods	82.0	5.3	3.8	C$_{25}$H$_{19}$NO$_2$	82.2	5.2	3.8
(3c)	Me	Ph$_2$C(OH)	B	30	8	48	185	Prisms	84.0	5.9	3.0	C$_{32}$H$_{27}$NO$_2$	84.0	5.9	3.1
(3d)	Me	*p*-MeC$_6$H$_4$CH(OH)	B	45	10	44	185—210 decomp.	Prisms	81.7	6.1	3.5	C$_{27}$H$_{25}$NO$_2$	82.0	6.3	3.5
(3e)	Me	PhCO	A	—	4	12	182—185	Prisms	82.3	5.6	3.4	C$_{26}$H$_{21}$NO$_2$	82.3	5.5	3.7
(3f)	Pr^n	Ph$_2$C(OH)	B	30	10	64	190	Prisms	—	—	2.9	C$_{34}$H$_{31}$NO$_2$	—	—	2.9

[a] See Experimental section. [b] From EtOH unless otherwise stated. [c] I.r. spectrum identical to specimen, m.p. 109 °C, prepared from 4,6-diphenyl-2-pyridone and ethylamine (see Experimental section). [d] From EtOAc.

immediately. By these methods benzophenone gave the alcohol (3a) (67%), ethyl benzoate gave the ketone (3b) (25%), and methyl iodide gave (1c) (25%) (Table 1). With *p*-toluonitrile the initial product (3g) cyclised spontaneously to the imidazo[1,2-*a*]pyridine (4) (20%).

Similarly, the anion (2c) generated from the N-ethyl

publication ‡) all showed ν(C=O) (pyridone) 1 640—1 650; the ketones (3b) and (3e) gave an additional ν(C=O) at 1 705 and 1 690 respectively, whilst the

‡ Sup No. 23154 (4 pp.). See Notice to Authors No. 7 (*J. Chem. Soc., Perkin Trans. 1*, 1980, Index issue) for details of the Supplementary publications scheme.

alcohols (3a), (3c—d) and (3f) had ν(OH) 3 165—3 350 cm^{-1}, and (4) gave no characteristic band. The pyridone protons 3-H and 5-H in (3a—f) gave doublets (J 2 Hz) at δ 6.42—6.88 and 6.15—6.90 respectively, as in (1a—c). In (3a—b) the residual methylene group α- to nitrogen (1'-CH$_2$) gave a singlet at δ 5.30 whilst in (3c—f) the corresponding methine proton appeared at δ 4.30—5.30 as a quartet in (3c) and (3e), a pentet in (3d), and a triplet in (3f). The couplings $J_{1',2'}$ and $J_{1',2''}$ were all 7 Hz. The methyl groups in (3c—e) gave doublets at

were usually not detected (aldehyde and ketone nucleophiles gave normal products, see above).

The only isolable products were found by microanalysis to be formed from 2 mol equivalents of (1b) and 1 mol equivalent of the electrophile. On the basis of i.r., ^{1}H, and ^{13}C n.m.r. spectra (see below) these products were assigned structure (5). Water as electrophile gave (5a), methyl iodide, ethyl iodide, benzyl bromide, and p-methylbenzyl bromide gave the alkylated products (5b—e), acetyl chloride the ketone (5f), ethyl chloro-

TABLE 2

Preparation of series I anomalous products ^{a}

Compound			Metallation time/min	Reaction time/h	Yield (%)	M.p. (°C)	Crystn. solvent ^{b}	Found %			Formula	Required %		
No.	Pyridone N-subst.	R						C	H	N		C	H	N
(5a)	Me	H	15	12	20	231—232	C$_6$H$_6$	82.4	5.7	5.2	C$_{36}$H$_{30}$N$_2$O$_3$	82.7	5.8	5.3
(5b)	Me	Me	5	12	50	287—288	PhMe	82.7	5.7	4.8	C$_{37}$H$_{32}$N$_2$O$_2$	82.8	6.0	5.2
(5c)	Me	Et	5	12	58	251—252	EtOAc	82.4	6.2	5.0	C$_{38}$H$_{34}$N$_2$O$_2$	82.9	6.2	5.1
(5d)	Me	PhCH$_2$	15	12	54	233.5—234	PhMe	83.8	5.9	4.5	C$_{43}$H$_{36}$N$_2$O$_2$	84.3	5.9	4.6
(5e)	Me	p-MeC$_6$H$_4$CH$_2$	15	12	63	236—236.5	PhMe ^{c}	83.9	6.1	4.4	C$_{44}$H$_{38}$N$_2$O$_2$	84.3	6.1	4.5
(5f)	Me	MeCO	20	12	30	266—268	EtOH	80.6	5.6	4.6	C$_{38}$H$_{32}$N$_2$O$_3$	80.8	5.7	5.0
(5g)	Me	EtOCO	15	12	44	261—262	PhMe	78.5	5.7	4.7	C$_{39}$H$_{34}$N$_2$O$_4$	78.8	5.7	4.8
(5h)	Me	PhCO	30	12	32	270—271	C$_6$H$_6$	82.0	5.5	4.4	C$_{43}$H$_{34}$N$_2$O$_3$	82.0	5.4	4.5
(5i)	Me	p-MeOC$_6$H$_4$CO	30	12	30	254—255	C$_6$H$_6$	80.2	5.4	4.2	C$_{44}$H$_{36}$N$_2$O$_4$	80.5	5.5	4.3
(5j)	Me	p-MeC$_6$H$_4$CO	30	12	16	269—270	EtOAc	82.4	5.6	4.3	C$_{44}$H$_{36}$N$_2$O$_3$	82.5	5.7	4.4
(5k)	Me	Br(CH$_2$)$_3$	30	8	54	216—217	EtOH	73.0	5.6	4.3	C$_{39}$H$_{35}$BrN$_2$O$_2$ ^{d}	72.8	5.4	4.4
(6a)	Et	Me	30	12	51	217—220	EtOH	82.8	6.7	4.9	C$_{39}$H$_{36}$N$_2$O$_2$	82.9	6.5	5.0
(6b)	Bu^n	Me	30	12	43	205—206	EtOH	82.9	7.4	4.5	C$_{43}$H$_{44}$N$_2$O$_2$	83.2	7.1	4.5

^{a} Prepared by general procedure (B). ^{b} All compounds crystallised as prisms. ^{c} By addition of light petroleum, b.p. 60—80 °C. ^{d} Found: Br, 12.3. C$_{39}$H$_{35}$BrN$_2$O$_2$ requires Br, 12.4%.

δ 1.65—1.73, whilst the methylene groups in (3f) gave a δ 1.05—1.70 multiplet and the methyl group a δ 0.70 triplet. The electrophile 2''-CH in (3d) gave a δ 6.29 doublet and the tolyl methyl group in (3d) and (4) a δ 2.25 singlet. Aromatic protons in (3a—f) and (4) gave multiplets in the region δ 6.9—7.9.

Series I Anomalous Products formed from Two Pyridone Moieties and Electrophile.—When the anion (2b) was generated in the usual way, *i.e.*, by addition of the N-methylpyridone (1b) to LDA in tetrahydrofuran (THF) at —78 °C, in the absence of electrophile, and acid chloride, ester, alkyl halide, or water electrophiles were subsequently added, the normal α-substitution products

formate the ester (5g), benzoyl, anisoyl, and toluoyl chlorides the ketones (5h—j), and 1,3-dibromopropane the product (5k) in which one bromine remained undisplaced. Yields were generally moderate (see Table 2).

When the N-ethylpyridone (1c) was treated with LDA to generate anion (2c) and then treated with methyl iodide it gave the analogous anomalous product (6a), formed from 2 mol equivalents of (1c) and 1 mol equivalent of electrophile; N-n-butylpyridone (2d) with LDA and methyl iodide likewise gave product (6b).

Series II Anomalous Products formed from Pyridone, Alkyl-lithium, and Electrophile.—The N-ethylpyridone (1c) reacted with alkyl lithiums, followed by electrophiles, to give a further series of anomalous products (7a—g) (Table 3), in which one molecule of the alkyllithium added to the 3-position of the pyridone ring, and one molecule of electrophile to the 4-position. No products resulting from formation of the α-carbanion (2c) were detected. Ethyl-lithium, with water as electrophile, gave (7a), whilst methyl iodide as electrophile gave (7b), and p-chlorobenzoyl chloride and p-toluoyl chloride gave the ketones (7c) and (7d). n-Butyllithium, with benzoyl chloride, p-chlorobenzoyl chloride, and p-toluoyl chloride as electrophiles gave the ketones (7e—g). Yields were high to moderate.

The N-butylpyridone (1d) similarly gave products (8a—g) with alkyl-lithiums followed by electrophiles (Table 3). Using ethyl-lithium, (1d) with benzoyl chloride, p-chlorobenzoyl chloride, and p-toluoyl chloride as electrophiles respectively gave ketones (8a—c) in poor to moderate yield. Using n-butyl-lithium, (1d) with benzoyl chloride, p-chlorobenzoyl chloride, p- and o-toluoyl chlorides respectively gave ketones (8d—g) in good to excellent yield.

(5)
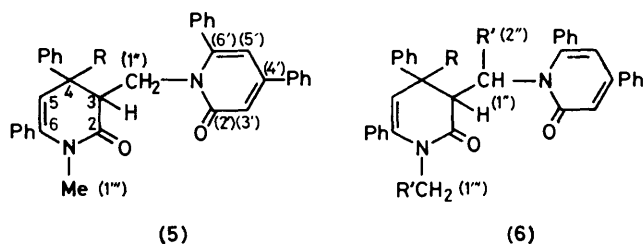
a; R = H
b; R = Me
c; R = Et
d; R = PhCH$_2$
e; R = p-MeC$_6$H$_4$CH$_2$
f; R = MeCO
g; R = EtOCO
h; R = PhCO
i; R = p-MeOC$_6$H$_4$CO
j; R = p-MeC$_6$H$_4$CO
k; R = BrCH$_2$CH$_2$CH$_2$

(6)

a; R = R' = Me
b; R' = Pr^n, R = Me

The N-methylpyridone (1b) with ethyl-lithium, and methyl iodide as electrophile, similarly gave the product (9a). With butyl-lithium and p-toluoaldehyde as electrophile, (1b) gave (9b) (Table 4). Even with these alkyl-lithiums, however, (1b) tended to give the dimeric products (5), formed via the carbanion (2b), reflecting the greater acidity of the methyl α-protons in (1b) compared with the methylene protons in (1c—d).

ducts (prepared using acid chlorides as electrophiles) showed an additional ν(C=O) 1 700—1 710, and the ester (5g) its ν(C=O) at 1 720 cm^{-1}.

In the ^{1}H n.m.r. spectra (Tables 4 and 5) the protons in the undisturbed pyridone ring in (5a—k) and (6a—b) gave 2 Hz doublets at δ 6.24—6.90 (3'-H) and 5.74—6.28 (5'-H): the corresponding signals in pyridone (1b) were at 6.79 and 6.34. The N-methyl group (1''' protons)

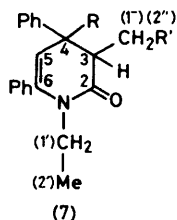## TABLE 3

Preparation of series II anomalous products ^{a}

Compound		Nucleophile derived substituent	Electrophile derived substituent						Crystallis-	Found %				Required %		
No.	Pyridone N-subst.	R'CH$_2$	R	Metallation time/min	Reaction time/h	Yield (%)	M.p. (°C)	Crystal form	ation solvent	C	H	N	Formula	C	H	N
(7a)	Et	Et	H	45	4	75	115	Prisms	EtOH			4.4	C$_{21}$H$_{23}$NO			4.6
(7b)	Et	Et	Me	30	5	84	110 b	Prisms	EtOH	82.5	7.7	4.3	C$_{22}$H$_{25}$NO	82.7	7.9	4.4
(7c)	Et	Et	p-ClC$_6$H$_4$CO	30	5	78	235—245 b	Needles	EtOH (abs.)	75.5	6.0	3.1	C$_{28}$H$_{26}$ClNO$_2$ c	75.7	5.9	3.2
(7d)	Et	Et	p-MeC$_6$H$_4$CO	45	6	69	220	Needles	EtOH (abs.)	82.6	6.8	3.3	C$_{29}$H$_{29}$NO$_2$	82.2	6.9	3.3
(7e)	Et	Bu^n	PhCO	30	8	34	152	Prisms	EtOH	82.3	6.8	3.1	C$_{30}$H$_{31}$NO$_2$	82.3	7.1	3.2
(7f)	Et	Bu^n	p-ClC$_6$H$_4$CO	45	6	47	216	Prisms	EtOH	76.3	6.4	2.9	C$_{30}$H$_{30}$ClNO$_2$ d	76.3	6.4	3.0
(7g)	Et	Bu^n	p-MeC$_6$H$_4$CO	45	8	43	195	Prisms	EtOH	82.5	7.5	3.1	C$_{31}$H$_{33}$NO$_2$	82.4	7.4	3.1
(8a)	Bu^n	Et	PhCO	45	7	58	198	Prisms	EtOH	81.9	7.0	2.8	C$_{30}$H$_{31}$NO$_2$	82.3	7.1	3.2
(8b)	Bu^n	Et	p-ClC$_6$H$_4$CO	30	7	36	204	Prisms	EtOH	76.5	6.6	3.0	C$_{30}$H$_{30}$ClNO$_2$ d	76.3	6.4	3.0
(8c)	Bu^n	Et	p-MeC$_6$H$_4$CO	30	8	32	170 b	Prisms	EtOH	82.3	7.9	2.8	C$_{31}$H$_{33}$NO$_2$	82.4	7.4	3.1
(8d)	Bu^n	Bu^n	PhCO	30	4	93	150	Needles	EtOH (abs.)	82.6	7.5	3.0	C$_{32}$H$_{35}$NO$_2$	82.5	7.6	3.0
(8e)	Bu^n	Bu^n	p-ClC$_6$H$_4$CO	30	4	62	195	Needles	EtOH	77.0	6.9	2.8	C$_{32}$H$_{34}$ClNO$_2$ e	76.9	6.8	2.8
(8f)	Bu^n	Bu^n	p-MeC$_6$H$_4$CO	30	5	84	192	Needles	EtOAc	82.6	7.6	2.9	C$_{33}$H$_{37}$NO$_2$	82.6	7.8	2.9
(8g)	Bu^n	Bu^n	o-MeC$_6$H$_4$CO	30	5	84	131	Prisms	EtOH	82.5	7.9	2.9	C$_{33}$H$_{37}$NO$_2$	82.6	7.7	2.9
(9a)	Me	Et	Me	45	10	51	147 b	Prisms	EtOH	82.3	8.1	4.5	C$_{21}$H$_{23}$NO	82.6	7.6	4.6
(9b)	Me	Bu^n	p-MeC$_6$H$_4$CH(OH)	45	12	12	207 b	Prisms	EtOH	82.0	7.5	3.1	C$_{30}$H$_{33}$NO$_2$	82.0	7.6	3.2

^{a} Prepared by general procedure (C). ^{b} Decomposes. ^{c} Found: Cl, 7.8. C$_{28}$H$_{26}$ClNO$_2$ requires Cl, 8.0%. ^{d} Found: Cl, 7.5. C$_{30}$H$_{30}$ClNO$_2$ requires Cl, 7.5%. ^{e} Found: Cl, 7.1. C$_{32}$H$_{34}$ClNO$_2$ requires Cl, 7.1%.

Spectra of Series I Anomalous Products (5) *and* (6) *(Tables* 4—6).—All products (5a—k) and (6a—b) gave ν(C=O) (pyridone) 1 650—1 660 and a further ν(C=O) 1 655—1 670 for the dihydropyridone: these bands were unresolved in some cases (Table 5). The ketone pro-

(7)

a; R' = Me, R = H
b; R = R' = Me
c; R' = Me, R = p-ClC$_6$H$_4$CO
d; R' = Me, R = p-MeC$_6$H$_4$CO
e; R' = Pr^n, R = PhCO
f; R' = Pr^n, R = p-ClC$_6$H$_4$CO
g; R' = Pr^n, R = p-MeC$_6$H$_4$CO

(8)

a; R' = Me, R = PhCO
b; R' = Me, R = p-ClC$_6$H$_4$CO
c; R' = Me, R = p-MeC$_6$H$_4$CO
d; R' = Pr^n, R = PhCO
e; R' = Pr^n, R = p-ClC$_6$H$_4$CO
f; R' = Pr^n, R = p-MeC$_6$H$_4$CO
g; R' = Pr^n, R = o-MeC$_6$H$_4$CO

(9)
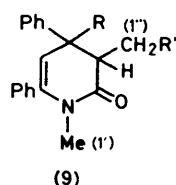
a; R = R' = Me
b; R' = Pr^n, R = p-MeC$_6$H$_4$CH(OH)

in (5a—k) gave a singlet at δ 2.76—2.91, whilst the prochiral N-ethyl group in (6a) showed an ABX$_3$ system, with δ$_A$ 2.75, δ$_B$ 3.88, δ$_X$ 0.81, J_{AB} 14 Hz and $J_{A,X}$ = $J_{B,X}$ = 7 Hz. The N-n-butyl group in (6b) gave a δ 0.65 CH$_3$ triplet, the prochiral N-CH$_2$ ABX$_2$ absorptions were probably at 2.85 and 2.50, other CH$_2$ absorbed at δ 0.8—2.0.

In the modified pyridone ring of (5b—k) and (6a—b), the 5-H signal was moved somewhat upfield to 5.28—5.72, appearing as a 1 Hz doublet due to W-coupling with 3-H. In (5a) 5-H gave a doublet at 5.40, with $J_{4,5}$ 5 Hz. The now aliphatic 3-H gave a δ 4.40—4.95 triplet in (5b—k) with symmetric 10—14 Hz couplings to the adjacent CH$_2$ protons. In (5a), 3-H showed an additional coupling ($J_{3,4}$ 4 Hz). In (6a and b) δ 3.9—4.4 (3-H) contributed to a non-first order pattern with the bridging CH signal. In (5a—k) the prochiral protons of the bridging methylene group were magnetically non-equivalent and gave two double doublets 1''a-H at δ 2.74—3.05 and 1''b-H at δ 2.84—3.45 in (5b—k), with a small geminal coupling of 0—5 Hz. In (6a, b) the bridging methine group 1''-H gave a multiplet at δ 3.9—4.4. The 2''-methyl group in (6a) gave a δ 1.95 doublet (J 7 Hz); the analogous propyl group in (6b), gave δ 0.8—2.0 2''- and 3''-methylene multiplets and an 0.65 4''-methyl triplet. The electrophile-derived methyl groups in (5b, e, i and j) and (6a, b) gave singlets at δ 1.24—1.98, 2.24 and 3.70, for those attached to 4-C, aromatic ring, and oxygen, respectively. The R-substituent methylene protons in (5d—e) were non-equivalent: they gave δ 6.43—6.45 and 6.73—6.79 doublets with J_{gem} 3—8 Hz. The ethyl groups in (5c) and (5g) gave ABX$_3$ systems with δ$_A$ 1.62, δ$_B$ 1.85, and
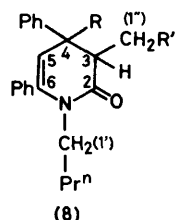
TABLE 4

^{1}H N.m.r. chemical shifts ^{a} (p.p.m. on δ scale) and coupling constants (Hz) of series I anomalous products

| No. | 4-Substituent R | Unchanged pyridone ring | | Modified pyridone ring | | | 1''-CH₂ | | |
		3'-H ^{b} (1 H, d)	5'-H ^{b} (1 H, d)	5-H ^{c} (1 H, d)	3-H ^{c} (1 H, dt)	$J_{3,1'}$	CHH (1 H, dd)	$J_{1'',1''}$	CHH (1 H, dd)
(5a)	H	6.75	6.21	5.40 ^{d}	4.82	12	3.00	5	3.45
(5b)	Me	6.78	6.24	5.60	4.90	12	2.75	5	3.12
(5c)	Et	6.80	6.25	5.60	4.90	12	2.75	<1	3.00
(5d)	PhCH₂	6.75	6.20	5.31	4.88	14	2.90	5	3.09
(5e)	p-MeC₆H₄CH₂	6.78	6.21	5.28	4.90	12	2.95	5	3.09
(5f)	MeCO	6.75	6.28	5.48	4.40	10	2.74	<1	2.86
(5g)	EtOCO	6.71	6.20	5.51	4.95	12	2.95	5	3.23
(5h)	PhCO	6.90	6.21	5.72	5.00	12	2.95	<1	3.10
(5i)	p-MeOC₆H₄CO	6.78	6.21	5.60	5.00	12	2.75	<1	2.84
(5j)	p-MeC₆H₄CO	6.78	6.21	5.60	5.00	12	3.05	5	3.24
(5k)	Br(CH₂)₃	6.71	6.19	5.50	4.88	12	2.74	5	2.98
(6a)	Me ^{e}	6.75	6.12	5.72	4.40	f	4.40	—	—
(6b)	Me ^{g}	6.24	5.74	5.57	3.90	f	3.90	—	—

^{a} Recorded in CDCl₃ with SiMe₄ as internal standard. ^{b} $J_{3',5'}$ 2 Hz. ^{c} $J_{3,5}$ 1 Hz. ^{d} $J_{3,4}$ 4 Hz and $J_{4,5}$ 5 Hz. ^{e} Derived from N-ethylpyridone. ^{f} Unresolved multiplet. ^{g} Derived from N-butylpyridone.

TABLE 5

^{1}H N.m.r. data ^{a} (continuing Table 4) and i.r. bands of Series I anomalous products

No.	4-Substituent R	Aromatic multiplet	1'''-CH₃ (3 H, s)	CH₂ CHH (1 H)	J_{gem}	CHH (1 H, m)	J_{vic}	CH₃ (3 H)	I.r. ν(C=O)/cm⁻¹ 2'-C=O	2-C=O	4R-C=O
(5a)	H	7.0—7.6 (20 H)	2.82	3.92 (dd)	—	—	—	—	1 650	1 655	—
(5b)	Me	7.1—7.6 (20 H)	2.86	—	—	—	—	1.38 (s)	1 660	1 660	—
(5c)	Et	7.1—7.6 (20 H)	2.85	1.62 (m)	22	1.85	7.3	0.62 (t)	1 655	1 665	—
(5d)	PhCH₂	7.0—7.6 (25 H)	2.80	6.43 (m)	3	6.73	—	—	1 650	1 650	—
(5e)	p-MeC₆H₄CH₂	7.0—7.6 (24 H)	2.91	6.45 (m)	8	6.79	—	2.24 (s)	1 650	1 660	—
(5f)	MeCO	7.1—7.6 (20 H)	2.78	—	—	—	—	1.90 (s)	1 655	1 655	1 710
(5g)	EtOCO	7.1—7.5 (20 H)	2.78	3.97 (m)	14	4.06	7	1.10 (t)	1 650	1 660	1 720
(5h)	PhCO	7.0—7.5 (25 H)	2.88	—	—	—	—	—	1 660	1 665	1 700
(5i)	p-MeOC₆H₄CO	7.1—7.6 (24 H)	2.76	—	—	—	—	3.70 (s)	1 660	1 670	1 700
(5j)	p-MeC₆H₄CO	7.1—7.6 (24 H)	2.76	—	—	—	—	2.24 (s)	1 655	1 670	1 700
(5k)	Br(CH₂)₃ ^{b}	7.0—7.6 (20 H)	2.81	c	—	c	—	—	1 655	1 670	—
(6a)	Me ^{d}	7.1—7.6 (20 H)	2.75 / 3.85 ^{e}	—	—	—	—	1.37 (s)	1 650	1 670	—
(6b)	Me ^{f}	6.8—7.5 (20 H)	2.45 / 2.85 ^{g}	—	—	—	—	1.24 (s)	1 650	1 660	—

^{a} Recorded in CDCl₃ with SiMe₄ as internal standard; s = singlet, t = triplet, dd = double doublet, m = multiplet. ^{b} CH₂Br, δ 3.18 (t) J 7 Hz. ^{c} Unresolved, δ 1.4—2.0 multiplet. ^{d} Derived from N-ethylpyridone. ^{e} 1'''-Et: J_{gem} 14, J_{vic} 7 Hz. ^{f} Derived from N-butylpyridone. ^{g} 1'''-Bu^n: J_{gem} 9, J_{vic} 4 Hz.

TABLE 6

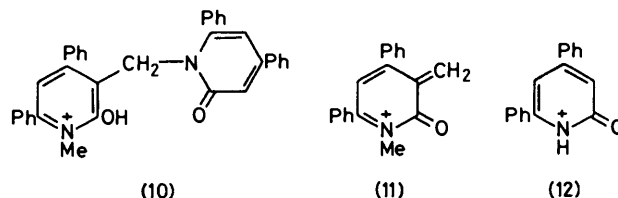^{13}C N.m.r. spectra of Series I products ^{a}

No.	R	4-R-CO (s)	2-CO (s)	2'-CO (s)	Aromatic multiplet	5-C (d)	3'-C (d)	5'-C (d)	3-C (d)	4-C (s)	1''-CH₂ (t)	1'''-CH₃ (q)	R CH₂ (t)	R CH₃ (q)
(5a)	H		167.68	163.92	150.42—125.72	123.97	115.37	107.93	65.63	48.14 ^{b}	41.03	32.40		
(5b)	Me		169.84	163.65	149.42—127.07	118.94	112.06	101.15	52.50	40.71	42.14	31.98		27.63
(5c)	Et		169.99	163.62	150.30—126.36	115.52	111.07	108.15	52.50	44.90	41.90	32.10	33.51	9.14
(5d)	PhCH₂		169.94	163.61	150.10—126.24	115.30	110.19	107.99	51.08	45.33	41.34	31.90	47.07	
(5e)	p-MeC₆H₄CH₂		169.93	163.50	150.06—126.28	115.42	110.02	108.02	51.10	45.33	41.38	31.85	46.58	20.95
(5h)	C₆H₅CO	194.65	169.45	163.80	150.26—125.87	116.04	109.55	106.41	49.78	57.56	39.99	32.17		
(5i)	p-MeOC₆H₄CO	193.15	169.49	163.74	150.26—125.75	115.24	107.84	105.20	48.81	57.42	40.25	31.93		55.24
(5j)	p-MeC₆H₄CO	194.15	169.43	163.80	150.26—126.75	115.27	107.91	105.09	48.78	57.56	41.15	31.96		21.48

^{a} In CDCl₃. ^{b} Doublet.

δ_X 0.62 for (5c) and δ_A 3.97, δ_B 4.06, and δ_X 1.10 for (5g): $J_{A,B}$ was 22 Hz in (5c) and 14 Hz in (5g), and $J_{A,X} = J_{B,X} = 7$ Hz in both cases. The assignment of the proton spectra in (5) and (6) was confirmed by double-resonance decoupling experiments, e.g. in (5b) irradiation of 3-H collapsed the 1''-CH$_2$ signals to two doublets (J 5 Hz): irradiation of either of the 1''-H positions caused the 3-H signal to become a doublet.

In the [13]C n.m.r. spectra, with off-resonance C–H information, for products (5a—d) and (5h—j) (Table 6), the undisturbed pyridone ring gave the carbonyl 2'-C as a singlet, δ 162.0—163.9 [cf. 163.78 in (1b)], vinyl carbons 3'-C and 5'-C as doublets at 107.8—115.3 and 101.2—108.2 respectively [cf. 114.9 and 107.2 in (1b)]. The signals for 4'-C and 6'-C were apparently hidden in the band of absorptions from the phenyl rings, 125.7—150.4. In the other ring the unconjugated amide carbonyl 2-C resonated further downfield as a δ 164.0—170.0 singlet; the vinyl 5-C shoulder at 115.2—124.0 as a doublet, whilst 6-C absorbed in the aromatic region. The sp^3-hybridised ring carbons 3-C and 4-C resonated at higher field, methine 3-C as a doublet δ 48.8—65.6, whilst 4-C gave a singlet at δ 40.7—48.1 for R = alkyl and at 57.4—57.6 for R = aroyl. The bridging 1''-CH$_2$ showed as a δ 40.0—43.2 triplet, and 1'''-methyl as a 31.9—34.3 quartet. In the R substituents aroyl C=O gave a singlet δ 193.2—194.7, ethyl CH$_2$ in (5c) gave a triplet at 33.5, and benzyl CH$_2$ in (5d) a triplet at 46.6—47.1. The O-methyl group of (5i) displayed a quartet at 55.2, tolyl methyls of (5e) and (5j) at 21.0—21.5, the 4-C-methyl in (5b) showed at 27.6 and that in the ethyl group of (5c) at 9.1.

The high resolution mass spectrum (these results are part of the Supplementary publication) of (5a) gave the expected molecular ion m/e 522.23, and also the (M — H)$^+$ ion (probably 10), m/e 521.21. No $M^{+\cdot}$ was seen for (5b, f, and h—j); all lost the R substituent to give the m/e 521.22 ion (10). Further loss of the pyridone moiety gave the ion (11), m/e 274.12 as the base peak in all cases. The pyridone fragment (12) m/e 247.01 was another strong ion common to all the fragmentations. For (5h—j) fairly weak acylium ions from the aroyl substituted R were observed, m/e 105.03—135.04.

(10)   **(11)**   **(12)**

Spectra of Series II Anomalous Products (7)—(9) (Tables 7—9).—The i.r. spectrum (Table 8) of all products (7), (8), and (9) showed modified pyridone ν(C=O) 1 630—1 665. The aryl ketones (7c)—(8f) gave an additional ν(C=O) 1 660—1 690, some 20—30 cm^{-1} lower than the corresponding band in Series I products.

In the [1]H n.m.r. spectra (Tables 7, 8) of products (9a, b) the residual N-methyl group (1'-CH$_3$) gave a δ 2.84—2.88 singlet. In the N-ethyl products (7a—g) the prochiral N-ethyl group gave an ABX$_3$ system with δ_A 3.75—4.08 (1'a-H), δ_B 2.80—3.30 (1'b-H), δ_X 0.70—0.95 (2'-Me), $J_{A,B}$ 14 and $J_{A,X} = J_{B,X} = 7$ Hz. Irradiation of 2'-Me decoupled 1'a-H and 1'b-H to an AB quartet.

TABLE 7

[1]H N.m.r. chemical shifts [a] (p.p.m. on δ scale) and coupling constants (Hz) of Series II anomalous products

No.	4-Substituent R	Pyridone N-subst.	Alkyl-lithium	Aromatic multiplet	5-H (1 H, d)	$J_{3,5}$	3-H (1 H)	$J_{3,1''a}$	$J_{3,1''b}$	1''a-H (1 H)	$J_{1'a,1''b}$	1''b-H (1 H)	$J_{1'',2''}$	2''-CH$_2$ or 2''-CH$_3$	$J_{2'',3''}$	3''-CH$_2$ (2 H, m)	$J_{3'',4''}$	4''-CH$_3$ (3 H, t)
(7a)	H	Et	Et	7.20—7.50 (10 H)	5.84	<1	3.52 (m)	b	b	1.60 (m)	14	1.3 (m)	7.0	1.00 (3 H, t)				
(7b)	Me	Et	Et	7.10—7.50 (10 H)	5.64	1.5	2.50 (ddd)	5	12	1.25 (m)	14	1.10 (ddd)	7.0	0.80 (3 H, t)				
(7c)	p-ClC$_6$H$_4$CO	Et	Et	7.10—7.62 (14 H)	5.73	2	3.20 (ddd)	5	11	1.50 (ddq)	14	1.15 (ddq)	7.5	0.92 (3 H, t)				
(7d)	p-MeC$_6$H$_4$CO	Et	Et	7.05—7.60 (14 H)	5.79	2	3.19 (ddd)	5	11	1.48 (ddq)	14	1.15 (ddq)	7.5	0.89 (3 H, t)				
(7e)	PhCO	Et	Bu^n	7.10—7.90 (15 H)	5.78	2	3.65 (ddd)	5	12	1.40 (m)	13	1.00— 1.38 (m)	b	1.10 (2 H, m)	b	1.30	7	0.85
(7f)	p-ClC$_6$H$_4$CO	Et	Bu^n	7.05—7.60 (14 H)	5.68	1.5	3.21 (ddd)	5	10	1.45 (ddq)	14	1.00— 1.40 (m)	b	1.0—1.4 (2 H, m)	b	1.0—1.4	6	0.73
(7g)	p-MeC$_6$H$_4$CO	Et	Bu^n	6.95—7.60 (14 H)	5.75	2	3.25 (ddd)	5	12	1.25 (m)	13	1.10 (m)	b	1.05—1.7 (2 H, m)	b	1.05—1.7	7	0.80
(8a)	PhCO	Bu^n	Et	7.00—7.80 (15 H)	5.78	2	3.30 (ddd)	5	12	1.25 (m)	13.5	1.05 (m)	7.0	0.80 (3 H, t)				
(8b)	p-ClC$_6$H$_4$CO	Bu^n	Et	7.04—7.58 (14 H)	5.64	1.7	3.13 (ddd)	4.4	10.9	1.46 (dsx)	13.7	1.06 (dsx)	7.45	0.88 (3 H, t)				
(8c)	p-MeC$_6$H$_4$CO	Bu^n	Et	7.00—7.65 (14 H)	5.75	1.5	3.30 (ddd)	5	10	1.20 (m)	13	1.02 (m)	7.5	0.80 (3 H, t)				
(8d)	PhCO	Bu^n	Bu^n	6.85—7.60 (15 H)	5.65	1.5	3.25 (ddd)	6	10	1.40 (m)	14	1.10 (m)	b	1.05—1.7 (2 H, m)	b	1.05—1.7	7	0.75
(8e)	p-ClC$_6$H$_4$CO	Bu^n	Bu^n	7.00—7.70 (14 H)	5.70	1.5	3.30 (ddd)	6	10	1.25 (m)	14	1.10 (m)	b	1.00—1.95 (2 H, m)	b	1.00—1.95	7	0.78
(8f)	p-MeC$_6$H$_4$CO	Bu^n	Bu^n	6.85—7.55 (14 H)	5.60	2	3.15 (ddd)	4	10	1.40 (m)	14	1.15 (m)	b	0.90—1.60 (2 H, m)	b	0.90—1.60	6	0.75
(8g)	o-MeC$_6$H$_4$CO	Bu^n	Bu^n	6.90—7.55 (14 H)	5.54	1	3.42 (ddd)	4.5	11	1.60 (m)	9	1.10 (m)	9	1.1—1.5 (2 H, m)	b	1.1—1.52	6	0.75
(9a)	Me	Me	Et	7.20—7.30 (10 H)	5.55	1	2.40 (m)	5	10	1.24 (m)	12	1.14 (m)	7	0.86 (3 H, t)				
(9b)	p-MeC$_6$H$_4$CH(OH)	Me	Bu^n	6.80—7.30 (14 H)	5.36	2	3.05 (m)	b	b	1.24 (m)	b	1.1— 1.5 (m)	b	1.1—1.5 (2 H, m)		1.1—1.5		0.74

[a] Recorded in CDCl$_3$ with SiMe$_4$ as internal standard; s = singlet, d = doublet, t = triplet, q = quartet, sx = sextet, ddd = double doublet of doublets, dsx = doublet of sextets, ddq = double doublet of quartets, m = complex multiplet. [b] Not distinguishable due to overlap.

TABLE 8

¹H N.m.r. data [a] (continuing Table 7) and i.r. bands of Series II anomalous products

No.	4-Substituent R	Pyridone N-subst.	Alkyl-lithium	4-Subst. CH₃	1'a-H	$J_{1'a,1'b}$	1'b-H (1 H)	$J_{1',2}$	2'-CH₂ or 2'-CH₃	3'-CH₂ (2 H)	$J_{3',4'}$	4'-CH₃ (3 H, t)	I.r. $\nu_{max.}$ (cm⁻¹) [b] 2-C=O	4R-C=O
(7a)	H	Et	Et	5.08 (t) [c]	3.77 (1 H, sx)	14	2.84 (sx)	7	0.84 (3 H, t)				1 650	
(7b)	Me	Et	Et	1.55 (s)	3.85 (1 H, sx)	14	3.30 (sx)	7	0.90 (3 H, t)				1 660	
(7c)	p-ClC₆H₄CO	Et	Et		4.08 (1 H, sx)	14	3.03 (sx)	7	0.78 (3 H, t)				1 640	1 680
(7d)	p-MeC₆H₄CO	Et	Et	2.33 (s)	4.07 (1 H, sx)	14	3.02 (sx)	7	0.77 (3 H, t)				1 640	1 680
(7e)	PhCO	Et	Buⁿ		4.00 (1 H, sx)	14	2.80 (sx)	7	0.75 (3 H, t)				1 640	1 680
(7f)	p-ClC₆H₄CO	Et	Buⁿ		4.04 (1 H, sx)	14	2.98 (sx)	7	0.75 (3 H, t)				1 640	1 680
(7g)	p-MeC₆H₄CO	Et	Buⁿ	2.30 (s)	4.00 (1 H, sx)	14	2.95 (sx)	7	0.70 (3 H, t)				1 650	1 680
(8a)	PhCO	Buⁿ	Et		3.95 (1 H, c)		2.95 (c)		1.00—1.45 (2 H, c)		7	0.70	1 630	1 685
(8b)	p-ClC₆H₄CO	Buⁿ	Et		3.98 (1 H, ddd)	13.8	2.87 (ddd)	d	e (2 H)	0.93 (sx)	7.3	0.64	1 630	1 690
8c)	p-MeC₆H₄CO	Buⁿ	Et	2.35 (s)	4.00 (1 H, c)		3.05 (c)		1.02—1.35 (2 H, c)	1.02—1.35 (c)	6	0.80	1 650	1 675
(8d)	PhCO	Buⁿ	Buⁿ		3.95 (1 H, c)	14	2.85 (c)		1.05—1.75 (2 H, c)	1.05—1.75 (c)	7	0.65	1 640	1 660
(8e)	p-ClC₆H₄CO	Buⁿ	Buⁿ		4.00 (1 H, c)	14	3.00 (c)		1.00—1.95 (2 H, c)	1.00—1.95 (c)	7	0.64	1 640	1 660
(8f)	p-MeC₆H₄CO	Buⁿ	Buⁿ	2.25 (s)	3.90 (1 H, c)	14	2.95 (c)		0.90—1.65 (2 H, c)	0.95—1.65 (c)	6	0.65	1 645	1 660
(8g)	o-MeC₆H₄CO	Buⁿ	Buⁿ	2.40 (s)	3.65 (1 H, ddd)	13	3.15 (ddd)		0.98—1.50 (2 H, c)	0.98—1.50 (c)	6	0.65	1 640	1 680
(9a)	Me	Me	Et	1.42 (s)	2.84 (3 H, s)								1 665	
9b)	p-MeC₆H₄CH(OH) f	Me	Buⁿ	2.20 (s)	2.88 (3 H, s)								1 630	

[a] Recorded in CDCl₃ with SiMe₄ as internal standard; s = singlet, d = doublet, t = triplet, q = quartet, sx = sextet, ddd = double doublet of doublets, c = complex multiplet. [b] Recorded in CHBr₃. [c] J 5 Hz. [d] $J_{1'a,2'a}$ 5.6; $J_{1'a,2'b}$ 8.8; $J_{1'b,2'a}$ 8.7; $J_{1'b,2'b}$ 6.1 Hz. [e] 2'a-H 1.22, 2'b-H 1.09 (arbitrarily assigned) $J_{2',3'}$ 7.5 Hz. [f] C-H 2.09 (s), OH 4.96 (s), v(OH) = 3 300 cm⁻¹.

TABLE 9

¹³C N.m.r. spectra [a] of Series II anomalous products

Compd. no.	R Electrophile	Pyridone N-subst.	Alkyl-lithium	2-C=O (s)	3-C (d)	4-C (s)	5-C (d)	1'-C (t)	2'-C	3'-C (t)	4'-C (q)	1''-C (t)	2''-C	3''-C (t)	4''-C (q)	R-CO (s)	4-R-Me (q)	Aromatic [b] multiplet
(7b)	Me	Et	Et	172.75	55.98	42.12	117.66	37.96	13.21 (q)			20.64	12.65 (q)				27.92	126.28—143.93
(7c)	p-ClC₆H₄CO	Et	Et	172.02	52.51	59.29	109.05	37.72	13.71 (q)			19.52	11.83 (q)			194.68		126.55—144.25
(7d)	p-MeC₆H₄CO	Et	Et	172.28	52.69	59.35	109.98	37.69	13.64 (q)			19.55	11.89 (q)			195.54	21.50	126.61—143.54
(7e)	PhCO	Et	Buⁿ	172.54	50.96	59.36	109.91	37.69	13.73 (q)			29.12	25.95 (t)	22.66	13.73	196.26		126.70—143.72
(7f)	p-ClC₆H₄CO	Et	Buⁿ	172.31	50.59	58.98	109.10	37.41	13.45 (q)			28.78	25.61 (t)	22.32	13.45	194.71		126.52—144.16
(7g)	p-MeC₆H₄CO	Et	Buⁿ	172.50	50.87	59.18	110.02	37.55	13.62 (q)			29.00	25.80 (t)	22.52	13.54	194.63	21.41	126.17—144.15
(8b)	p-ClC₆H₄CO	Buⁿ	Et	172.20	52.55	59.18	108.55	42.62	30.71	19.73	13.62	19.55	11.86 (q)			194.56		126.58—144.66
(8d)	PhCO	Buⁿ	Buⁿ	172.61	50.73	59.18	109.32	42.51	30.65	19.73	13.62	29.12	25.95 (t)	22.54	13.62	196.09		126.58—144.08
(8e)	p-ClC₆H₄CO	Buⁿ	Buⁿ	172.47	50.65	59.10	108.53	42.54	30.61	19.65	13.66	28.98	25.81 (t)	22.52	13.54	194.54		126.54—144.58
(8g)	o-MeC₆H₄CO	Buⁿ	Buⁿ	172.70	50.88	59.26	109.55	42.59	30.60	19.78	13.74	29.14	26.02 (t)	22.61	13.74	195.60	21.55	126.60—143.95

[a] In CDCl₃ with SiMe₄ as internal standard. [b] Includes 6-C signal.

In the N-n-butyl products (8a—g), both the 1'- and 2'-methylene protons formed magnetically non-equivalent pairs. The 360 MHz spectrum of (8b) was well resolved and particularly informative. It showed 1'a-H and 1'b-H as doublets of double doublets, centred on δ 3.98 and 2.87 respectively, with geminal $J_{1'a,1'b}$ 13.8 Hz and vicinal $J_{1'a,2'a}$ and $J_{1'a,2'b}$ 5.6 and 8.8 Hz and $J_{1'b,2'a}$ and $J_{1'b,2'b}$ 6.1 and 8.7 Hz. The 2'a- and 2'b-CH₂ protons gave complex multiplets centred on δ 1.22 and 1.08. The magnetically equivalent 3'-CH₂ protons gave a sextet at δ 0.93, with $J_{2',3'} \approx J_{3',4'} \approx 7$ Hz, and 4'-Me gave a δ 0.62 triplet. Irradiation of 4'-Me decoupled 3'-CH₂ to a 7 Hz triplet. Irradiation of 1'a-H or 1'b-H decoupled the other to a triplet having a further 2—3 Hz coupling, and decoupled 2'-a-H and 2'-b-H to slightly simpler patterns.

In the 220 or 100 MHz spectra of (8a) and (8c—g) the 1'a-H and 1'b-H similarly gave doublets of triplets δ 3.65—4.04 and 2.85—3.15 with $J_{1'a,1'b}$ 9—14 Hz and $J_{1',2'} \approx 7$ Hz, 2'-CH₂ and 3'-CH₂ multiplets in the region 0.9—1.3, and 4'-Me triplets 0.65—0.70.

In all products (7), (8), and (9), 5-H gave a 2 Hz doublet at δ 5.36—5.79 [double doublet in (7a)], similar to the Series I products. Proton 3-H was seen either as a finely split doublet of doublets, or an unresolved multiplet. In the ethyl-lithium derived products (7a—d) and (8a—c), 3-H and the prochiral 3-ethyl substituent form an ANMX₃ system with δ_A (3-H) 2.05—3.20, δ_N (1''-Ha) 1.20—1.48, and δ_M (1''-Hb) 1.05—1.15, (where distinguishable) δ_X (2''-CH₃) 0.80—1.07. $J_{N,M}$ is estimated to be ca. 14 Hz, $J_{A,M}$ 10—12 Hz, and $J_{A,N}$ 5 Hz. For the n-butyl-lithium products (7e—g) and (8d—g), part of an ANMX₂ (X further coupled) system, resulting from 3-H and the prochiral 3-n-butyl sub-

stituent, was visible, with δ_A (3-H) 3.15—3.65, δ_N (1″-Ha) 1.25—1.60, δ_M (1″-Hb) in the region 1.0—1.4 (overlapped with other signals) with $J_{N,M}$ estimated as 12—14, $J_{A,N}$ as 10—12, and $J_{A,M}$ as 4—6 Hz. Other methylene protons (3″-CH$_2$) in the 4-n-butyl substituents gave δ 1.0—1.4 multiplets, and 4″-CH$_3$ displayed 0.73—0.85 triplets, with $J_{3'',4''}$ 7 Hz. Irradiation of 3-H in (7d), (7f), and (8b) decoupled 5-H to a singlet and in the 3-ethyl product (7d) decoupled the two H-1″ multiplets to sextets. The toluoyl 4-substituents, R, gave δ 2.25—2.35 methyl singlets, the 4-methyl group in (7b) a 1.55 singlet, and 4-H in (7a) a triplet at 5.14. The methine proton in the 4-substituent tol-CHOH in (9b) gave a δ 4.96 doublet, coupled to OH. The aromatic protons (7)—(9) formed multiplets, δ 6.8—7.9.
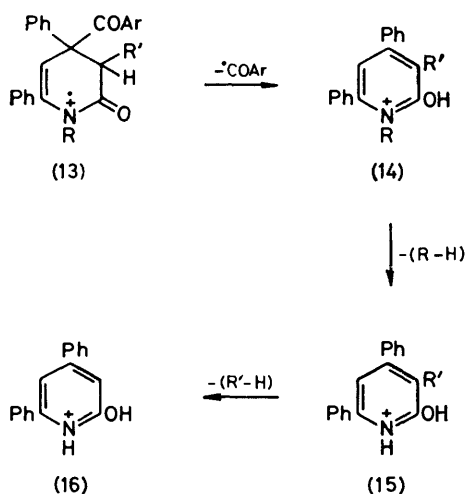
SCHEME 1

The off-resonance ^{13}C spectra of (7b—g) and (8b, d, e and g) (Table 9) showed $\delta_{C=O}$ 172.2—172.8 for 2-C, ca. 2 p.p.m. lower field than series I, with a further $\delta_{C=O}$ at 194.6—196.3 for the aryl ketones. Vinyl carbon 5-C gave a doublet at δ 108.6—110.0 [except in 4-alkyl compound (7b) δ 5-C 117.7] whilst 6-C was obscured by the clustered aromatic signals which occurred in the region δ 126.2—144.7. Quaternary 4-C gave a singlet at δ 59.0—59.4 [except in (7b); δ 4-C 42.1] and methine 3-C a doublet at δ 50.6—56.0. The methylene signals 1′-C gave triplets at δ 37.4—42.6 and 1″-C triplets at 19.5—29.1. For the compounds containing n-butyl groups, other methylene signals came in the range 19.5—30.7 (see Table 9). Methyl groups gave quartets at δ 11.8—13.7 (aliphatic) and/or 21.4—27.9 (tolyl).

The mass spectra of (7c, e, and g) and (8d—g) (these results are part of the Supplementary publication) showed intense molecular ions (13) for the N-ethyl compounds (7), but extremely weak $M^{+•}$ (13) for N-n-butyl analogues (8). Loss of H· gave $(M - 1)^+$ ions of similar abundance to $M^{+•}$ in most cases. The major fragment ions arose from $M^{+•}$ as in Scheme 1, firstly by loss of the 4-aroyl substituent to give the even-electron ions (14), which were the base peaks. Consecutive

losses of ethylene or butene from the 1- and 3-positions of (14) led first to ion (15) and then to (16). Fragmentation from $M^{+•}$ of the aroyl substituents also gave rise to more or less intense acylium ions.

Modified Anomalous Products giving Pyridones.—We sought to provide further evidence for structures (5)—(9) by constructing analogues in which the group introduced at the 4-position by the electrophile would itself be a reasonable leaving group, so as to eliminate with 3-H, thereby restoring the aromatic 2-pyridone ring. The N-methylpyridone (1b) was treated with LDA, followed by diphenyl disulphide. As anticipated, the initial product spontaneously lost thiophenol to give the pyridone (17) (Scheme 2). The N-ethylpyridone (1c) treated with ethyl-lithium followed by toluene-p-sulphonyl chloride similarly gave pyridone (18) (45%) by elimination of C$_7$H$_7$SO$_2$H from the initial Series II product.
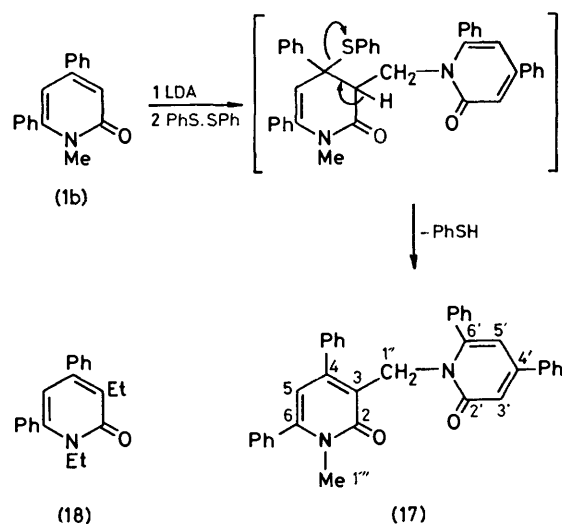

SCHEME 2

The bis-pyridone (17) gave ν(C=O) 1 650 cm^{-1} whilst (18) gave ν(C=O) 1 640 cm^{-1}. The ^{1}H n.m.r. of (17) showed a δ 3.1 (3 H) singlet for N-methyl and a 5.3 (2 H) singlet for 1″-CH$_2$, whilst 5-H gave a 5.83 (1 H) singlet. The unmodified pyridone ring disclosed 3′-H and 5′-H as 1 Hz doublets, respectively at δ 6.36, and 6.12, whilst aromatics gave a 20 H multiplet from δ 7.10—7.40. The 1,3-diethylpyridone (18) gave 5-H as a δ 5.88 singlet, and the ethyl groups as first-order patterns, 1′-CH$_2$ and 1″-CH$_2$ giving quartets respectively at δ 3.90 and 2.49, and 2′-CH$_3$ and 2″-CH$_3$ giving triplets at 1.15 and 1.07, with $J_{1',2'} = J_{1'',2''} = 7$ Hz. The 10 H aromatic multiplet extended over δ 7.05—7.75.

The ^{13}C spectrum of (17) showed two C=O singlets, at 163.9 and 161.9, both very similar to δ_C(C=O) 163.7 in (1b). Aromatics gave a band of signals δ 150.2—125.3. The vinyl carbons show as three doublets, at 114.9 (3′-C), 110.2 (5′-C), and 108.1 (5-C). By comparison, in (1b) 3-H and 5-H respectively gave δ 115.0 and 107.7 doublets. The N-methyl group in (17) gave a δ 34.3

quartet [34.1 in (1b)] and the methylene 1″-C a 43.2 triplet.

Mechanism of Formation of Anomalous Products.—The Series I products (5) are initiated by generation of the α-carbanion (2b). We suggest that this adds to the 4-position of a further molecule of pyridone (1b) giving the enolate (19), and that the key step is the rearrangement (19) ⟶ (20), an intramolecular alkylation of the enolate, forming the resonance-stabilised 1,3-diphenylallyl anion (20). Alkylation of the 4-position of (20) by electrophiles then gives the Series I products (5) (Scheme 3).

SCHEME 3
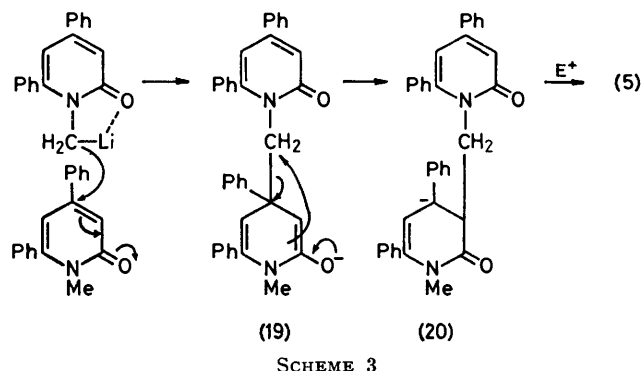
Series II products are thus formed *via* similar generation and rearrangement of the enolate (21) to the allyl anion (22).

Alternatively, direct addition could occur at the 3-position (helped by co-ordination of the lithium atom to the carbonyl oxygen) to give (20) [or (22)] without the intermediate formation of (19) [or (21)]. This interpretation has the advantage of avoiding the necessity of a preferential alkyl shift (19) ⟶ (20) or (21) ⟶ (22) when an aryl shift might be expected.
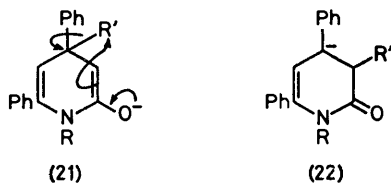
Possible Alternative Structures.—Mechanisms similar to the above could also give rise to products of structure (23) if the allyl anions (20) and (22) were alkylated in the 6-positions. Alternatively, rearrangement of the nucleophile in (19) and (21) to the 5-position could give rise to structure (24). Isomeric pyridones to (17) and (18) could be formed *via* structures (23) or (24). I.r. spectra are not useful in distinguishing structures (5)—(9) from (23) or (24): conjugated and unconjugated dihydropyridones which serve as models have similar ν(C=O).[3] We base our choice of structures (5)—(9) on the δ_C of the quaternary ring carbon, which is 40.7—48.1 where the electrophile substituent is alkyl, and 57.4—59.4 where this is aroyl. We would expect these values to be *ca.* 15—20 p.p.m. higher in (23) and (24), in which this

carbon is adjacent to nitrogen, *cf.* 4-hydroxy-1,6,6-trimethyl-2-phenylpiperidine[4] in which $\delta_{6\text{-}C}$ is 63.5 p.p.m. (OH-equatorial) or 58.9 (OH-axial).
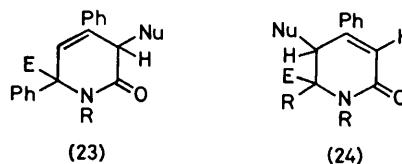
EXPERIMENTAL

M.p.s were determined using a Reichert hot-stage apparatus. Spectra were recorded with a Perkin-Elmer 297 grating i.r. spectrophotometer, a Unicam SP800 u.v. spectrophotometer; Perkin-Elmer R12 (60 MHz), Varian HA-100 (100 MHz) and JEOL FX-100 (¹³C, at 25.05 MHz) n.m.r. spectrometers; Kratos MS 25 (low resolution) and AEI MS-9 (high resolution) mass spectrometers. Other n.m.r. spectra were measured at the PCMU, Harlow (220 MHz) and the University of Edinburgh (360 MHz). Compounds were purified until observed as single spots on t.l.c. [Kieselgel GF 254 (type 60)]. Tetrahydrofuran (THF) was used freshly distilled from LiAlH₄, and alkyl-lithiums were standardised by titration[5] before use. Lithium di-isopropylamide (LDA) was generated as described in the preceding paper.[1]

1-*Ethyl*-4,6-*diphenyl*-2-*pyridone* (1c).—4,6-Diphenyl-2-pyrone[6] (3.0 g, 0.012 mol) and 70% aq. EtNH₂ (16.2 g, 0.25 mol) were heated in a Carius tube at 140 °C for 12 h. Evaporation at 50 °C and 20 mmHg, and crystallisation from EtOH gave the *pyridone* (2.0 g, 60%) as prisms, m.p. 108—109 °C (Found: C, 82.9; H, 6.2; N, 5.0. C₁₉H₁₇NO requires C, 82.9; H, 6.2; N, 5.1%); ν_max. (CHBr₃) 1 650 cm⁻¹; δ(CDCl₃) 1.15 (3 H, t, *J* 5 Hz), 3.90 (2 H, q), 6.30 (1 H, d, *J* 2 Hz), 6.78 (1 H, d, *J* 2 Hz), and 7.40 (10 H, s).

1-*Methyl*-4,6-*diphenyl*-2-*pyridone* (1b) was similarly prepared using 30% aqueous MeNH₂: it crystallised as needles (66%), m.p. 92 °C (lit.,[7] m.p. 92 °C); ν_max. (CHBr₃) 1 650 cm⁻¹; δ(CDCl₃) 3.36 (3 H, s), 6.3 (1 H, d), 6.89 (1 H, d), and 7.20—7.65 (10 H, m).

1-*n-Butyl*-4,6-*diphenyl*-2-*pyridone* (1d) was prepared by the literature method:[8] it gave prisms (65%), m.p. 94—97 °C (lit.,[8] m.p. 98—99 °C) (Found: C, 83.3; H, 6.9; N, 4.4. Calc. for C₂₄H₁₉NO: C, 83.2; H, 6.9; N, 4.6%); ν_max. (CHBr₃) 1 650 cm⁻¹; δ(CDCl₃) 0.60 (3 H, t), 0.9—1.8 (4 H, m), 3.90 (2 H, t), 6.35 (1 H, d), 6.90 (1 H, d), and 7.31—7.55 (10 H, m).

General Procedures for Metallation.—(A) LDA (4 mmol) in THF (5 ml) was added at −78 °C to a solution of the pyridone (4 mmol) and the electrophile (4—7 mmol) in THF (5 ml) at −78 °C, under dry N₂, with stirring. After having been allowed to warm to 20 °C, and stirred for t_2/h (see Table 1) the solution was evaporated at 20 mmHg and 40 °C, water (30 ml) added, and the mixture extracted with CH₂Cl₂ (3 × 25 ml); the extracts were dried (MgSO₄) and evaporated at 20 mmHg and 30 °C to give the product.

(B) To LDA (4 mmol) in THF (10 ml) under N₂ at −78 °C, with stirring, was added the pyridone (4 mmol) in THF (3 ml). After t_1/min the electrophile (4 mmol) in THF (3 ml) was added, and stirring continued for 1 h at −78 °C and t_2/h (see Tables) at room temperature. Water (1 ml) was added and the solvent evaporated at 50 °C and 20 mmHg. The residue in CH₂Cl₂ (60 ml) was washed with

brine (20 ml) and water (20 ml), and the solution dried (Na₂SO₄) and evaporated at 40 °C and 20 mmHg, to give the product.

(C) To a solution of the pyridone (4 mmol) in THF (10 ml), at −78 °C under dry N₂, with stirring, was added the alkyl-lithium (4 mmol) in hexane or ether (*ca.* 5 ml). After t_1/min the electrophile (4 mmol) in THF (5 ml) was added, and stirring continued for t_2/h (see Tables), the solution being allowed to warm to 20 °C. The solvent was evaporated at 50 °C and 20 mmHg, and water (50 ml) was added. Extraction with CHCl₃ (3 × 30 ml), drying (MgSO₄), and evaporation of the extract at 40 °C and 20 mmHg yielded the product.

2-(4-*Methylphenyl*)-5,7-*diphenylimidazo*[1,2-a]*pyridine* (4).—1-Methyl-4,6-diphenyl-2-pyridone (1.0 g, 4 mmol) was treated with 4-toluonitrile (0.44 g, 4 mmol) by general procedure (B). Purification of the product by preparative t.l.c. [Kieselgel PF 254, EtOAc–light petroleum, (b.p. 60—80 °C) (2 : 3)] gave the *title compound* (0.26 g, 19%) as pale yellow needles, m.p. 199.5—200 °C (EtOAc) (Found: C, 86.5; H, 5.5; N, 7.7. C₂₆H₂₀N₂ requires C, 86.6; H, 5.6; N, 7.8%); $\nu_{max.}$ (CHBr₃) 1 600 (C=N), 1 500, and 1 450 cm⁻¹; δ(CDCl₃) 2.3 (3 H, s), 6.95 (1 H, d, *J* 1 Hz), 7.12 (1 H, d, *J* 6 Hz), 7.30 (1 H, d, *J* 1 Hz), and 7.4—7.8 (14 H, m).

1-*Methyl*-3-(2-*oxo*-4,6-*diphenyl*-1-*pyridylmethyl*)-4,6-*diphenyl*-2-*pyridone* (17).—1-Methyl-4,6-diphenyl-2-pyridone (1.0 g, 3.8 mmol) was treated with diphenyl disulphide (0.82 g, 3.8 mmol), following general procedure (A). The product was purified by preparative t.l.c. [Kieselgel PF 254, EtOAc–light petroleum (b.p. 60—80 °C)] to give the *title pyridone* (0.18 g, 18%) as colourless prisms [toluene–light petroleum (b.p. 60—80 °C)], m.p. 132—133 °C (Found: C, 83.2; H, 5.5; N, 5.3. C₃₆H₂₈N₂O₂ requires C, 83.1; H, 5.4; N, 5.4%); $\nu_{max.}$ (CHBr₃) 1 650 cm⁻¹; δ(CDCl₃) 3.1 (3 H, s), 5.3 (2 H, s), 5.83 (1 H, s), 6.12 (1 H, d, *J* 1 Hz), 6.36 (1 H, d, *J* 1 Hz), and 7.1—7.4 (20 H, m); δ_C(CDCl₃)

34.34 (q), 43.21 (t), 107.7 (d), 108.14 (d), 110.25 (d), 114.96 (d), 115.0 (d), 125.3—150.2 (m), 161.95 (s), and 163.95 (s).

1,3-*Diethyl*-4,6-*diphenyl*-2-*pyridone* (18).—1-Ethyl-4,6-diphenyl-2-pyridone (1.0 g, 3.6 mmol) was treated with ethyl-lithium (4 mmol) and toluene-*p*-sulphonyl chloride (0.77 g, 4 mmol) following procedure (C). Crystallisation of the crude product from EtOH gave the *pyridone* (18) (0.5 g, 45%), as prisms, m.p. 109 °C (Found: C, 82.8; H, 6.6; N, 4.5. C₂₁H₂₁NO requires C, 83.1; H, 7.0; N, 4.6%); $\nu_{C=O}$ 1 640 cm⁻¹; δ 1.07 (3 H, t), 1.15 (3 H, t), 2.49 (2 H, q), 3.90 (2 H, q), 5.88 (1 H, s), and 7.1—7.4 (10 H, m).

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