A Versatile New Synthesis of Quinolines and Related Fused Pyridines. Part 5.[1] The Synthesis of 2-Chloroquinoline-3-carbaldehydes

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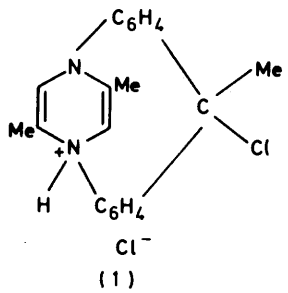
Acetanilides are converted into 2-chloroquinoline-3-carbaldehydes in good yield by the action of Vilsmeier's reagent in phosphoryl chloride solution. The reaction is shown to involve successive conversion of the acetanilide into an imidoyl chloride and then an *N*-(α-chlorovinyl)aniline. The latter enamine is diformylated at its β-position and subsequently cyclised to the chloroquinolinecarbaldehyde. The diformylated intermediates may be isolated in several cases and separately cyclised with polyphosphoric acid.

In 1896, Friedel noted the formation of a red dye on treatment of *N*-methylacetanilide with phosphoryl chloride to which he assigned the problematic structure (1).[2] This was corrected by Fischer, Müller, and Vilsmeier in 1925[3] who assigned the cyanine-dye structure (2) and argued cogently that this product derived from the self-condensation of the quinolinium salt (3). It was the realisation by Vilsmeier and Haack[4] that one molecule of *N*-methylacetanilide had acetylated a



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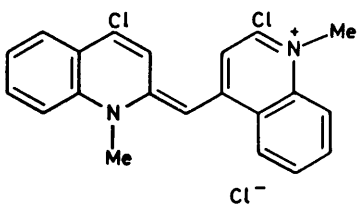

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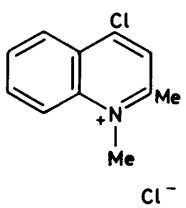
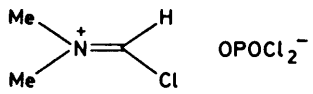


(3)

second molecule (mistakenly considered as an *ortho*-acylation, a myth still believed[5]) prior to cyclisation that led to the discovery of the Vilsmeier–Haack formylation using *N*-methylformanilide. However, the synthesis of quinolines by this approach has lain dormant. It is the intention of this and subsequent papers to establish this powerful route to quinolines, to explore its scope and mechanism, and to demonstrate the value of the products as synthetic intermediates.

Vilsmeier–Haack formylation using dimethylformamide and phosphoryl chloride involves the Vilsmeier reagent (VR) (4).[6] It is a mild electrophilic process and proceeds only with activated aromatic systems. The work particularly of Arnold's group has extended its application to the conversion of, for example, ketones into β-chloroacrylaldehyde derivatives, and alkenes into αβ-unsaturated aldehydes.[6] However, attempts to formylate acetanilides (5) and their analogues have not led to either ring or side-chain *C*-formylation[7] but

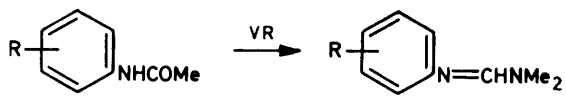


(4)

rather attack at nitrogen giving the formamidine (6) (Scheme 1).[8] That this result is an over-simplification of the facts is borne out both by the quinoline synthesis already referred to and the sequel.

The conversion of acetanilides into an imidoyl chloride (7) is well documented[9] and is efficiently catalysed by dimethylformamide, when the reaction is almost instantaneous at ambient temperature.

Our first endeavour to facilitate either ring formylation or cyclisation of a side-chain formylated acetanilide lay in substituting the benzene ring with strongly electron-donating groups. Thus 3,4,5-trimethoxy-, 3,4-dimethoxy-, 3-methoxy-, and 3-methylthio-acetanilide were each treated with dimethylformamide (3 mol equiv.) in phosphoryl chloride (7 mol equiv.) under reflux. These readily cyclised giving 5,6,7-trimethoxy-, 6,7-dimethoxy-, 6-methoxy-, and 6-methylthio-quinoline



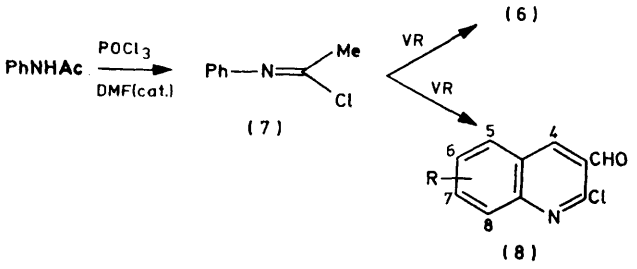
(5) (6)

Scheme 1

chloro-aldehydes (8) respectively in 92, 72, 89, and 92% yield, respectively. However, less activated acetanilides gave only formamidines (6) under these conditions. The reaction is especially noteworthy in its regiospecificity, no trace of isomeric quinoline being formed from the unsymmetrical anilides (Scheme 2).

Since formamidine (6) formation involved cleavage of the acetyl moiety, we next conducted the formylation in a sealed tube hoping to reverse the deacetylation of the

acetanilide and hence facilitate quinoline formation. In the event, this method was successful in the formation of 2-chloro-3-formylquinolines (8) (Scheme 2) but ultimately was unnecessary for efficient quinoline formation. First, however, the stoicheiometry of the reaction was



SCHEME 2

studied and the use of phosphoryl chloride as the solvent of choice (rather than dimethylformamide or a chloroalkane as commonly used) was established. Table 1

TABLE 1

Reaction of acetanilide (1 mol equiv.), dimethylformamide (3 mol equiv.), and phosphoryl chloride in a sealed tube at 120 °C for 4 h

$POCl_3$ (mol equiv.)	2-Chloro-3-formylquinoline (8) (%)
3	26
4.5	53
7	78
10	76

TABLE 2

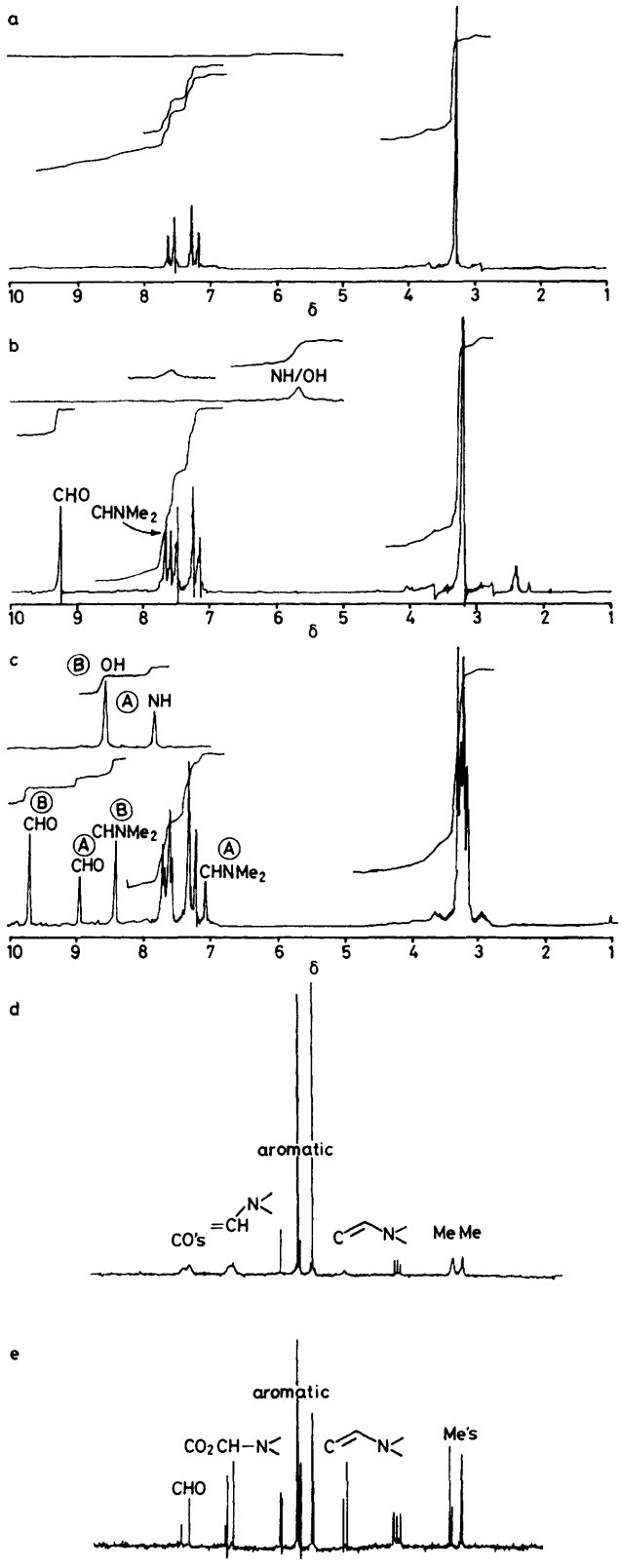
Reaction of acetanilides (1 mol equiv.), DMF (3 mol equiv.), and $POCl_3$ (7 mol equiv.) in a sealed tube

R·C_6H_4·NHAc R	T/ °C	t/ h	2-Chloro-3-formylquinoline (8) * R	(%)		Formamidine (6) * R	(%)
H	120	4	H	78	(0)		(~100)
2-Me	100	2.5	8-Me	63	(28)		
3-Me	80	2.25	7-Me	66	(64)		
4-Me	85	2.25	6-Me	74	(28)		
2-OMe	85	4	8-OMe	14			
4-OMe	100	1.25	6-OMe	10	(0)		
2-Cl	100	1.25		0		2-Cl	95
3-Cl	100	1.25	7-Cl	35		3-Cl	54
4-Cl	100	2	6-Cl	13		4-Cl	50
4-Br	100	2	6-Br	30		4-Br	50
2-NO_2	100	1.25		0		2-NO_2	64
3-NO_2	100	1.25		0		3-NO_2	66
4-NO_2	100	1.25		0		4-NO_2	72

* Yields in parentheses derive from reactions conducted in an open flask under reflux.

shows the effect of increasing quantities of the solvent on the yield of 2-chloro-3-formylquinoline (8). A variety of acetanilides were then subjected to these conditions and some to the same reaction under reflux in an open vessel (Table 2). Some significant points emerge:

(*a*) activated acetanilides react faster and in better yield to give quinolines (8) than other strongly deactivated systems giving solely formamidines;

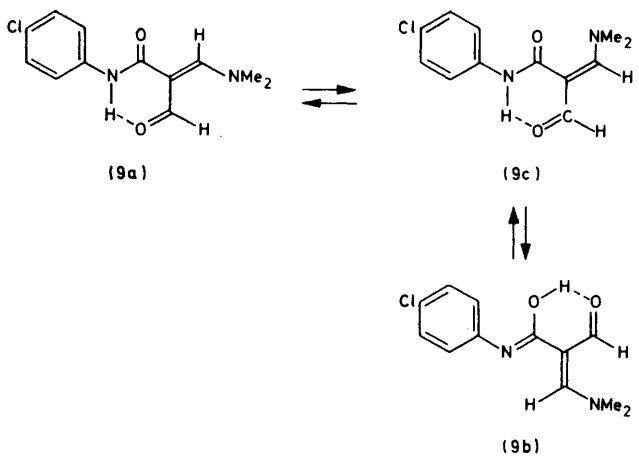


N.m.r. spectra of compound (9): a, b, and c depict ^1H n.m.r. spectra at probe temperature, 115 °C, and −40 °C respectively; d and e show the ^{13}C n.m.r. spectra at probe temperature and −60 °C respectively

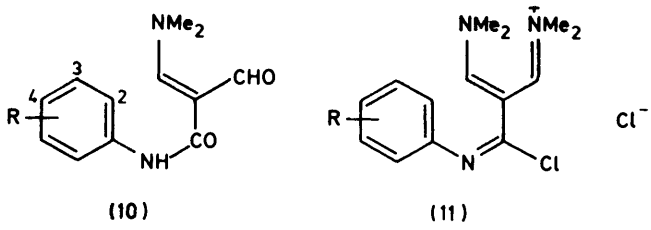
(*b*) a $+M$ substituent in the *meta*-position is especially effective and, surprisingly, gives only one quinoline isomer.

Attempts to further reinforce the possible reversible re-acetylation of the formamidine by addition of acetyl chloride or acetic acid to the sealed-tube reaction mixture were abortive, giving in the case of 4-chloroacetanilide, only 3% of the chloroquinolinealdehyde (8; R = 6-Cl) and the formamidine (5; R = 4-Cl) in 55% yield. A further product from this reaction was, however, of considerable significance in unravelling the mechanism of the quinoline formation.

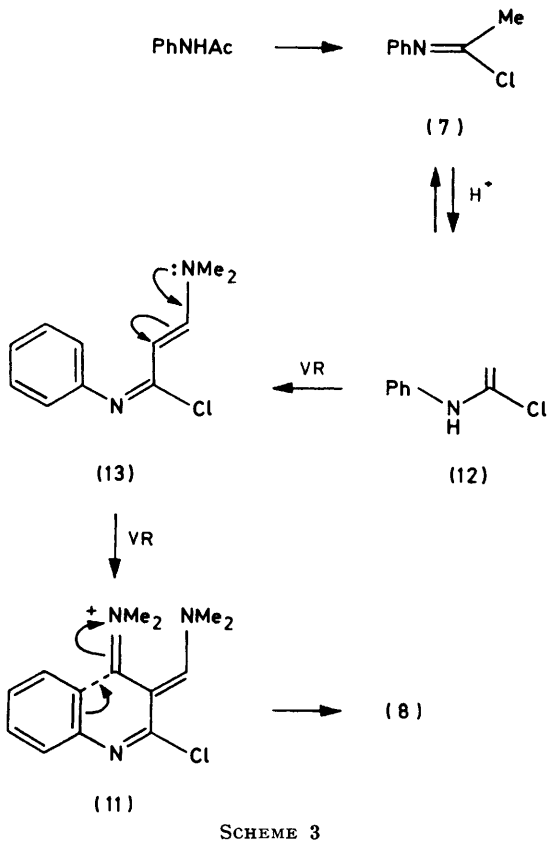
This product, $C_{12}H_{13}ClN_2O_2$, showed a broad hydrogen-bonded OH/NH absorption and an amidic carbonyl peak (1 660 cm^{-1}) in its infrared spectrum and temperature variable ^1H and ^{13}C n.m.r. spectra (see Figure). Thus at elevated temperature the ^1H n.m.r. spectrum revealed the presence of a *para*-disubstituted aromatic ring, a dimethylamino-group, an aldehyde, an NH/OH and another singlet CH group. At low temperature the NH/OH, aldehyde, and CH signals were each split into two signals in approximately a 2 : 1 ratio while at probe temperature these three signals were virtually absent due to coalescence. We account for these data either by the two tautomers (9a) and (9b) [in which (9a) is dominant] which equilibrate sufficiently rapidly at ambient temperature to allow coalescence at the n.m.r. time scale, or by the geometrical isomerism of (9a) and (9c). The ^{13}C n.m.r. spectra show similar effects as well as non-equivalence in the NMe_2 carbons due to the vinylogous amide double-bond character of the C–NMe_2 linkage. Mass-spectral data (see later) further supported the structure. The compound was isolated in 40% yield. Similar products (10) were isolated from the sealed-tube reactions (Table 2) in low yield including R = 4-Me (3%), R = 3-NO_2 (6%), and R = 4-NO_2 (16%). Later results made these intermediates available in good yields.



These *N*-aryl-3-dimethylamino-2-formylacrylamides (10) (in effect, derivatives of malondialdehyde) are clearly derived from the iminium salts (11) on work-up. The salts (11) in turn are diformylated derivatives of the imidoyl chlorides (7) derived from acetanilides and a reasonable rationalisation of the reaction may thus be formulated as in Scheme 3. This requires the tautomerism of the imidoyl chloride (7) to the enamine (12), a known phenomenon,[9a,10] probably by acid catalysis, and subsequent formylation of the enamine. The monoformylated derivative (13) is still an enamine by virtue of the NMe_2 group and thus can undergo a second attack by VR.



With this hypothesis in mind, we next studied the role



SCHEME 3

of acid catalysts on the quinoline formation. (It should be noted that HCl is formed at each formylation step, suggesting that if the imidoyl chloride–enamine tautomerism is indeed acid-catalysed, the reaction should be auto-catalytic, a fact already noted in some Vilsmeier reactions.[6])

Following an early observation of Vilsmeier,[4] we noted

a dramatic improvement in the yield of 2-chloro-6-methoxyquinoline-3-carbaldehyde (8; R = 6-OMe) (from 10 to 67% yield) when the sealed-tube reaction of *p*-methoxyacetanilide was conducted in the presence of added phosphorus pentachloride (1 mol equiv.; at 100 °C for 4 h). However no change was noted for several other cases.

p-Chloroacetanilide (5; R = 4-Cl) was the chosen substrate and the results are collected in Table 3. It is evident that side-chain formylation of acetanilides is efficiently catalysed by acids, particularly hydrochloric acid, but that the cyclisation is not facilitated by the presence of acid. Furthermore, elevation of the temperature results in diminution of the diformylated product yield (with formation of formamidine) indicating that the formamidine formation is probably irreversible. *N*-Formylation of the diformylated product (11) and subsequent cleavage of the diformylated side-chain is the likely source of the formamidines.

TABLE 3

The role of acid catalysts on the formylation of *p*-chloroacetanilide using DMF (3 mol equiv.) and $POCl_3$ (7 mol equiv.) in a sealed tube

Catalyst (mol equiv.)	*t*/h	*T*/°C	Quinoline (8; R = 6-Cl) (%)	Acrylamide (10; R = 4-Cl) (%)
	2	100	13	<25
PPA (1)	1.2	100	4	42
AcOH (1)	1.2	100	3	40
AcOH (3)	1.2	100	1	7
HCl (1)	1.2	75	2	60
HCl (1)	3	75	2	62
HCl (1)	1.2	100	6	56
HCl (3)	1.2	100	9	52
HCl (1)	2.2	140	23	0 *

* *N*-(4-Chlorophenyl)-*N'N'*-dimethylformamidine formed in 70% yield.

TABLE 4

Action of DMF (3 mol equiv.) and $POCl_3$ (7 mol equiv.) on *p*-chloroacetanilide in an open flask

t/h	*T*/°C	Added HCl (mol equiv.)	Quinoline (8; R = 6-Cl) (%)	Acrylamide (10; R = 4-Cl) (%)
1	75	0	1	73
1.5	75	0	2	69
48	20	0	0	0
3	75	1	4	66
3	60	1	0	0

Armed with this vital temperature-dependence data we next examined the formylation of acetanilides at moderate temperatures and at atmospheric pressure in an open flask. Thus *p*-chloroacetanilide, is efficiently diformylated giving its acrylamide derivative (10) merely by heating for 1 h at 75 °C, although cyclisation was still inefficient. These results suggest that the beneficial effects of a sealed tube were mainly to do with keeping in the HCl of reaction rather than reversing the formamidine formation. At milder temperatures, addition of HCl is unnecessary since it is retained in solution.

We next examined a range of acetanilides under these mild formylating conditions (Table 5) it being first established that 2—2.5 mol equiv. of DMF was adequate for efficient diformylation rather than 3 mol equiv. as used earlier. The chloroquinolinecarbaldehydes (8) were readily obtained by filtration on pouring the reaction mixture into ice-water. The other products only appeared on basification of the filtrate and were separated by trituration of the material with light petroleum, in which the formamidines were very soluble while the diformylated products were not.

These are undoubtedly the best general conditions for formation of the chloroquinolinecarbaldehydes. Yields of quinolines were particularly good with a $+M$ substituent in the *meta*-position and once more the reaction was remarkable for its specificity, only one isomer being formed. It would appear that a combination of the mildness of the electrophilic conditions (*i.e.* the Reactivity–Selectivity Principle [11]) and the large steric

TABLE 5

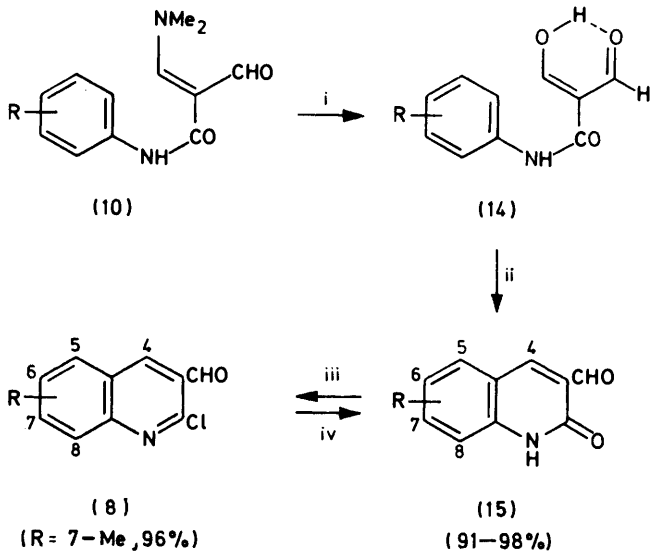
Reaction of acetanilides with DMF (2.5 mol equiv.) and $POCl_3$ (7 mol equiv.) in an open flask

$R{\cdot}C_6H_4NHAc$ R	*T*/°C	*t*/h	Products * Quinoline (8) R	(%)	Acrylamide (10) R	(%)	Formamidine (6) R	(%)
H	75	16.5	H	(68)		n.d.	H	11
2-Me	75	15.5	8-Me	(67)	2-Me	7	2-Me	13
3-Me	75	6	7-Me	(66)		n.d.		n.d.
4-Me	75	16	6-Me	(70)	4-Me	10	4-Me	6
2-OMe	75	15.5	8-OMe	(5)	2-OMe	7	2-OMe	14
3-OMe	75	4	7-OMe	(65)		n.d.		n.d.
4-OMe	75	16	6-OMe	(56)		n.d.	4-OMe	27
2-Cl	75	2	8-Cl	(0)	2-Cl	38	2-Cl	61
2-Cl	20	66	8-Cl	(0)	2-Cl	53	2-Cl	27
3-Cl	75	2	7-Cl	(25)	3-Cl	43	3-Cl	27
4-Cl	75	1.5	6-Cl	(2)	4-Cl	69		n.d.
4-Br	75	16.5	6-Br	(23)	4-Br	32	4-Br	45
$2\text{-}NO_2$	75	1.5	$8\text{-}NO_2$	(0)	$2\text{-}NO_2$	0	$2\text{-}NO_2$	95
$2\text{-}NO_2$	20	48	$8\text{-}NO_2$	(0)	$2\text{-}NO_2$	0	$2\text{-}NO_2$	95
$2\text{-}NO_2$	20	18	$8\text{-}NO_2$	(0)	$2\text{-}NO_2$	14		n.d.
$3\text{-}NO_2$	75	1.5	$7\text{-}NO_2$	(0)	$3\text{-}NO_2$	61	$3\text{-}NO_2$	28
$4\text{-}NO_2$	75	1.5	$6\text{-}NO_2$	(0)	$4\text{-}NO_2$	53	$4\text{-}NO_2$	45

* n.d. = not determined.

demand of the cyclising entity is the cause of the regiospecificity.

The mildness of the reaction conditions however also resulted in little or no quinoline formation even with mildly deactivating substituents such as halogen and no quinoline at all from the nitro-acetanilides. However, in both of these cases the diformylated acetanilides (10) were efficiently produced. These compounds were rapidly converted into the malondialdehydes (14) in very high yield by aqueous ethanolic alkali (Scheme 4).



SCHEME 4 *Reagents:* i, aq. EtOH, NaOH; ii, PPA (150 °C, 10 min); iii, $POCl_3$, heat; iv, aq. HCl, heat

Brief treatment of the malondialdehydes (14) with hot polyphosphoric acid (PPA) brought about efficient cyclisation to the quinolone aldehydes (15) (Table 6).

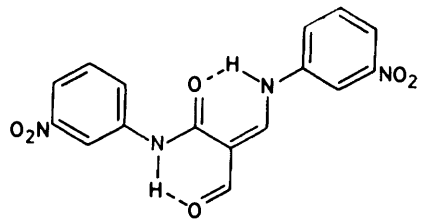
TABLE 6

Cyclisation of malondialdehydes (14) with PPA to 3-formyl-2-quinolones (15)

Malondialdehyde (14) R	Cyclisation conditions T/°C	t/mins	3-Formyl-2-quinolone (15) R	(%)
2-Cl	138	12	8-Cl	91
3-Cl	140—150	10	7-Cl	98
4-Cl	154—156	10	6-Cl	94
4-Br	140—150	10	6-Br	96

The 6-chloro-3-formylquinolone (15; R = 6-Cl) was identical to that obtained by hydrolysis of the corresponding chloroquinoline (Scheme 3). Furthermore, the reaction could be reversed by treating the quinolone briefly with hot phosphoryl chloride.

The diformylated *m*-nitroacetanilide (14; R = 3-NO_2) did not yield a quinolone with PPA but produced a dimer (16) in 84% yield which may superficially be considered to derive from interaction of the dialdehyde with *m*-nitroaniline produced by hydrolysis. The malondialdehyde imines (10) were generally inert to the action of PPA but surprisingly the *m*-nitro-derivative underwent deformylation to yield (17) (67%). It would seem likely that this product was formed by hydrolysis and recombination of the derived *m*-nitroaniline and β-dimethylaminoacrylaldehyde. Indeed, β-dimethylaminoacrylaldehyde was isolated as a by-product from the formylation of 4-nitroacetanilide.



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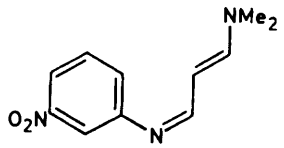
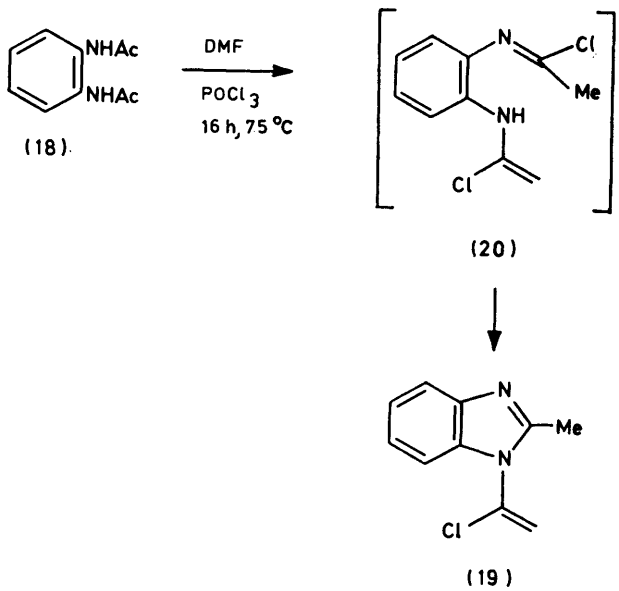
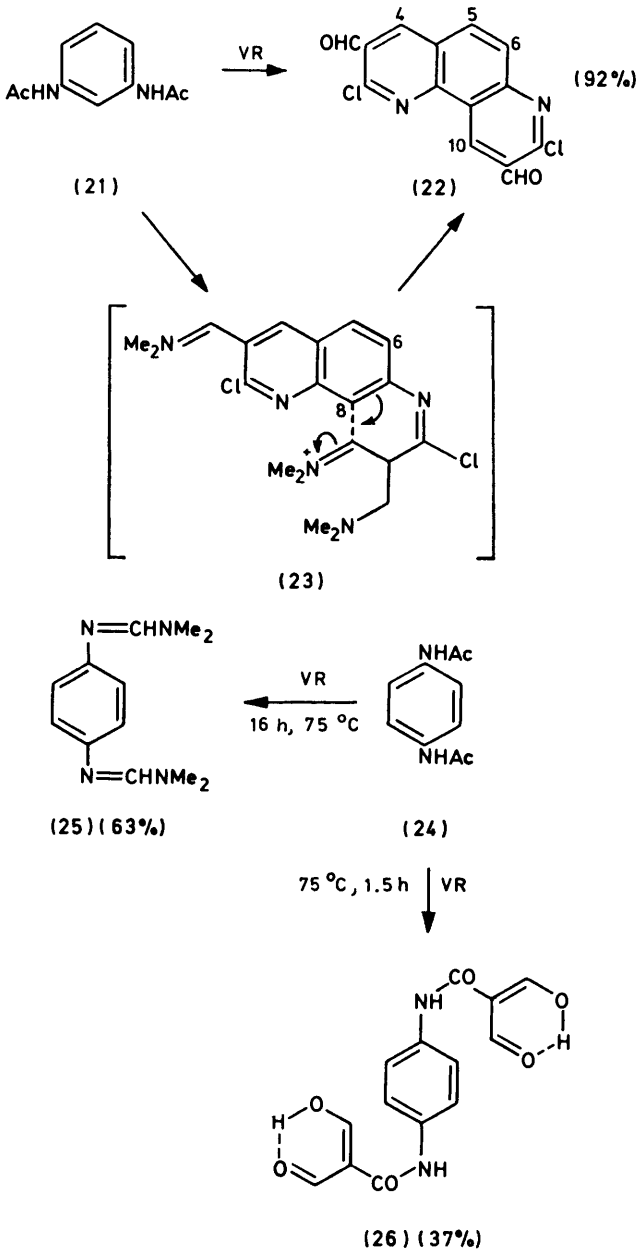


(17)

We finally turned our attention to the acetylated phenylenediamines. The *ortho*-system (18) yielded an oily solid on treatment with VR [DMF (6 mol equiv.) and $POCl_3$ (14 mol equiv.)] which showed only two components on t.l.c. On distillation under high vacuum the mixture transformed totally into one product,' an



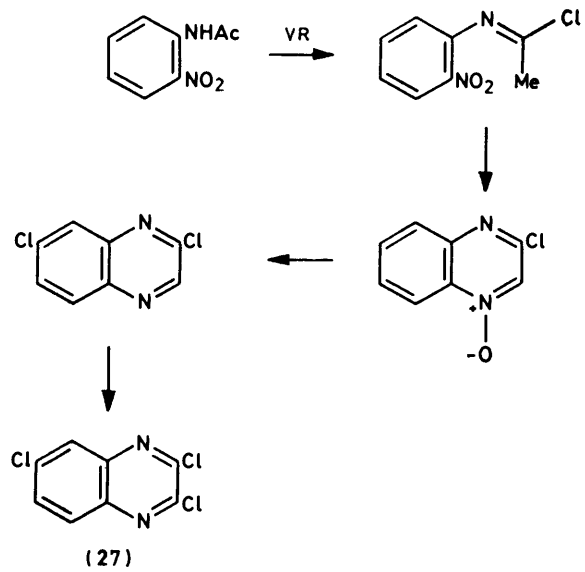
oil to which we assign the benzimidazole structure (19), isolated in 59% yield. It showed a typical benzimidazole chromophore in its u.v. spectrum (a sharp double absorption at 273 and 280 nm) and appropriate infrared [1 640 (C=C) and 760 cm^{-1} (*ortho*-disubstituted benzene



ring)], ^{1}H n.m.r. [δ(=CH_2) at 5.87 and 5.59, J 2 Hz, δ(CH_3) at 2.62], and mass spectra (M^+ 194/2 as well as $M - CH_3$, $M - Cl$, and $M - HCl$ peaks). It was probably formed by way of the enamine-imine (20) and the other initial product is likely to be (20) or a hydrolytic derivative therefrom.

Under the same conditions, the *meta*-isomer (21), in line with the greater reactivity of $+M$ *meta*-substituted acetanilides, efficiently cyclised twice giving regiospecifically in high yield the angular phenanthroline (22), as shown in particular by the *ortho*-coupled doublet for protons 9 and 10 in the ^{1}H n.m.r. spectrum.

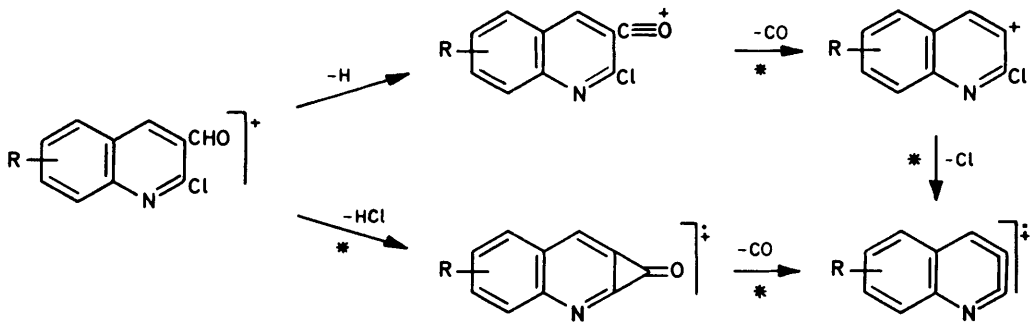
This result would seem to suggest that, in accord with



SCHEME 5

the known preferred reactivity of electrophiles for the 8- over the 6-position in quinolines, the intermediate (23) similarly selects this mode of cyclisation. Finally, the *para*-isomer (24), under the same conditions gave solely the bis-formamidine (25) while after a shorter reaction time, and appropriate work-up the bis-malondialdehyde (26) was isolated. However, attempted PPA-catalysed cyclisation of (26) gave only tar.

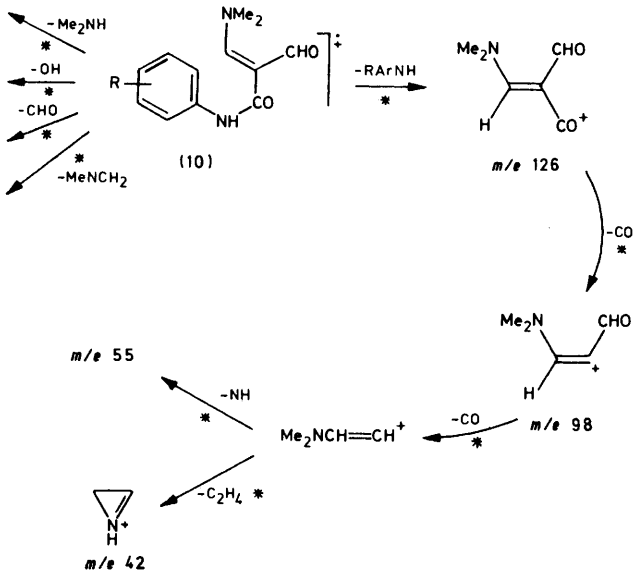
A curious by-product was noted during the formylation reactions of 2-nitroacetanilide. 2,3,6-Trichloroquinoxaline [12] (27) is formed in 4% yield, probably by way of a quinoxaline *N*-oxide [13] as outlined in Scheme 5. The origin of the third chlorine atom is, however, obscure.



SCHEME 6

The various types of products are readily characterised by their spectral properties. Thus the quinolines (8) and (15) in particular show a sharp, low-field singlet for H-4 in their n.m.r. spectra and generally give first-order spectra for their other aromatic protons [apart from the parent system (8; R = H) (see Table 8)]. The mass spectra of the chloroquinoline aldehydes (8) show a characteristic mode of fragmentation as depicted in Scheme 6.

The *N*-aryl-3-dimethylamino-2-formylacrylamides (10) show in their mass spectra, a strong molecular ion which loses OH, CHO, $CH_3N{=}CH_2$, Me_2NH, and R–ArNH all with appropriate metastable peaks. Also, loss of Me_2N is evident. The ion (*m/e* 126) further fragments as shown (Scheme 7) as supported by both metastable peaks



SCHEME 7

and accurate mass measurement.* Similarly, the *N*-aryl-2-formyl-3-hydroxyacrylamides (14) reveal losses of OH, CHO, and the complete side-chain yielding anilino radical-cations.

EXPERIMENTAL

I.r. spectra were recorded on a Perkin-Elmer 297 spectrometer, ^1H n.m.r. spectra on a Varian EM 360 (60 MHz) or Perkin-Elmer R32 (90 MHz) instrument, ^{13}C n.m.r. spectra on a Varian CFT20 (20 MHz) model, and mass spectra on AEI MS12 and AEI MS902S spectrometers. For u.v. spectra a Pye Unicam SP 800A machine was utilised. Petroleum refers to the fraction of b.p. 60–80 °C and light petroleum to that of b.p. 40—60 °C. Column chromatography was conducted with Laporte type H alumina and Type MFC silica (Hopkin and Williams). Thick-layer chromatography was carried out on 20 cm × 20 cm × 1 mm plates made with Merck type G silica. Phosphoryl chloride was distilled before use, b.p. 105—107 °C and dimethylformamide was distilled from phosphorus pentaoxide and stored over baked molecular sieves.

* The accurate mass measurements on $Me_2NCH{=}CHCHO$ confirmed the above assignments.

The acetanilides were all known compounds prepared by standard acetylation of the purchased anilines.

Action of Vilsmeier's Reagent on Acetanilides.—(i) *In refluxing phosphoryl chloride.* Dimethylformamide (9. 13 g, 9.6 ml, 0.125 mol) was cooled to 0 °C in a flask equipped with a drying tube and phosphoryl chloride (53.7 g, 32.2 ml, 0.35 mol) was added dropwise with stirring. To this solution was added the acetanilide (0.05 mol) and after 5 min the solution was heated under reflux for the appropriate time (3,4,5-trimethoxyacetanilide, 1.5 h; 3,4-dimethoxyacetanilide, 2 h; 3-methoxy- and 3-methylthio-acetanilide, 4 h). The reaction mixture was worked up as below.

(ii) *In a sealed tube.* To a 100 ml flask was added dimethylformamide (10.95 g, 11.6 ml, 0.15 mol) and the mixture was cooled in ice. Phosphoryl chloride (53.7 g, 32.3 ml, 0.35 mol) was added dropwise with stirring followed by the acetanilide (0.05 mol). The mixture was stirred at ambient temperature until a clear solution was formed. Any further catalyst was then added and the mixture was poured into a glass tube (O.D. 26 mm and of such a length as to give approximately 30 cm sealed tube) which was cooled in liquid nitrogen, evacuated to 0.1 mmHg, and sealed. After heating for the appropriate time in a preheated Carius furnace (see Tables 1, 2, and 3) the cooled tube was further cooled in liquid nitrogen and opened. Work-up was as below.

(iii) *In phosphoryl chloride solution at various temperatures in an open flask.* The reaction was conducted as in method (i) using a jacketed flask with a refluxing solvent in the jacket to give the appropriate temperature. Work-up was as follows.

The reaction mixture was poured into ice–water (300 ml) and stirred for 30 min at 0—10 °C. The chloroquinolinecarbaldehyde (8) was filtered off and washed with water (100 ml). The combined filtrate was made just alkaline (pH *ca.* 9) with aqueous sodium hydroxide (40%) with ice-cooling, and chloroform (200 ml) was added. The mixture was stirred for 30 min and then separated, and the aqueous phase was extracted further with chloroform (2 × 50 ml). The combined organic layer was dried ($MgSO_4$) and evaporated to give a brown oil which was treated further as below. The alkaline aqueous solution was re-acidified (pH *ca.* 2) using concentrated hydrochloric acid and the mixture was stirred with chloroform (100 ml) for 30 min. The layers were separated and the aqueous phase was further extracted with chloroform (2 × 50 ml) to give a small amount of a 3-hydroxyacrylamide (14) or tar.

Products from the Formylation of Acetanilides.—(a) *2-Chloro-3-formylquinolines* (8). The chloroquinolinecarbaldehydes (8) were washed well with water, dried, and recrystallised to give the products recorded in Tables 1, 2, 3, 4, and 5. The properties of these products are recorded in Tables 7 and 8.

(b) *Formamidines* (6). These products were isolated from the brown oil extracted from the alkaline mother-liquors generally by trituration with light petroleum, in which they were soluble. Removal of the solvent and distillation of the residue in a Kugelrohr apparatus gave the pure formamidine as recorded in Tables 2, 3, 5, 9, and 10.

(c) *N-Aryl-3-dimethylamino-2-formylacrylamides* (10). These products also came from the brown oil derived from the alkaline mother-liquors and were obtained as solids by trituration with light petroleum. Their formation and properties are recorded in Tables 3, 4, 5, 11, and 12 and in the Discussion.

TABLE 7

Properties of the 2-chloro-3-formylquinolines (8)

Compound (8) R	Recryst. solvent *	M.p./°C	Elemental analysis: Required (%) C	H	N	Formula	Found (%) C	H	N	$\nu_{max.}$(CO) †/ cm^{-1}
H	A	148—149	62.7	3.2	7.3	$C_{10}H_6ClNO$	62.75	3.3	7.4	1 690
6-Me	A	124—125	64.25	3.9	6.8	$C_{11}H_8ClNO$	64.5	4.1	6.8	1 685
7-Me	A	144.5—145.5	64.25	3.9	6.8	$C_{11}H_8ClNO$	64.4	3.8	6.7	1 690
8-Me	A	137—138	64.25	3.9	6.8	$C_{11}H_8ClNO$	64.4	4.0	6.7	1 680
6-OMe	A	145.5—146.5	59.6	3.6	6.3	$C_{11}H_8ClNO_2$	59.9	3.6	6.25	1 670
7-OMe	A	197—198	59.6	3.6	6.3	$C_{11}H_8ClNO_2$	59.8	3.6	6.1	1 690
8-OMe	A	191.5—192.5	59.6	3.6	6.3	$C_{11}H_8ClNO_2$	59.3	3.8	6.2	1 680
6-Br	B	188—189	44.4	1.9	5.2	$C_{10}H_5BrClNO$	44.3	1.9	5.05	1 680
6-Cl	B	190.5—191.5	53.1	2.2	6.2	$C_{10}H_5Cl_2NO$	53.15	2.2	6.2	1 680
7-Cl	B	158.5—159.5	53.1	2.2	6.2	$C_{10}H_5Cl_2NO$	53.2	2.3	6.15	1 680
7-SMe	A	195—196	55.6	3.4	5.9	$C_{11}H_8ClNOS$	55.3	3.5	6.2	1 680
6,7-(OMe)$_2$	A	215	57.3	4.0	5.6	$C_{12}H_{10}ClNO_3$	57.2	3.9	5.5	1 680
5,6,7-(OMe)$_3$	A	149—149.5	55.4	4.3	5.0	$C_{13}H_{12}ClNO_4$	55.5	4.4	4.9	1 690

* A = Ethyl acetate; B = acetonitrile. † As Nujol mulls.

TABLE 8

^{1}H N.m.r. spectra of the 2-chloro-3-formylquinolines (8) (δ)

Compound (8) R	Solvent *	H-4	H-5	H-6	H-7	H-8	CHO	Me	J/Hz
H	A †	8.83 (s)	7.6—			—8.3 (m)	10.35 (s)		
6-Me	B	8.68 (s)	7.82 (s)		7.70 (d)	7.86 (d)	10.44 (s)	2.55 (s)	$J_{7,8}$ 9
7-Me	B	8.71 (s)	7.95 (d)	7.49 (dd)		7.79 (s)	10.47 (s)	2.60 (s)	$J_{5,6}$ 9
8-Me	B	8.75 (s)	7.92 (dd)	7.55 (t)	7.75 (dd)		10.50 (s)	2.73 (s)	$J_{5,6} = J_{6,7} = 8$; $J_{5,7}$ 2
6-OMe	B	8.58 (s)	7.17 (d)		7.47 (dd)	7.91 (d)	10.50 (s)	3.94 (s)	$J_{7,8}$ 9; $J_{5,7}$ 3
7-OMe	A	8.72 (s)	8.03 (s)	7.27 (dd)		7.33 (s)	10.97 (s)	3.97 (s)	$J_{5,6}$ 9
8-OMe	C	8.70 (s)	7.55 (t)	7.25 (m)	7.55 (t)		10.57 (s)	4.10 (s)	
6-Br	B	8.68 (s)	8.18 (s)		7.95 (s)	7.95 (s)	10.55 (s)		
6-Cl	C	8.68 (s)	7.96 (s)		7.80 (dd)	8.03 (d)	10.55 (s)		$J_{7,8}$ 9; $J_{5,7}$ 2
7-Cl	B	8.73 (s)	7.95 (d)	7.58 (dd)		8.01 (s)	10.51 (s)		$J_{5,6}$ 9; $J_{6,8}$ 2
7-SMe	D	9.59 (s)	8.47 (d)	8.02 (d)		8.29 (s)	10.70 (s)	2.82 (s)	$J_{5,6}$ 9
6,7-(OMe)$_2$	C	8.84 (s)	7.07 (s)			7.30 (s)	10.42 (s)	4.00 (s)	
								4.02 (s)	
5,6,7-(OMe)$_3$	D	8.84 (s)				7.10 (s)	10.59 (s)	4.05 (s)	
								4.14 (s)	
								4.22 (s)	

* A = [$^2H_6$]DMSO; B = $CDCl_3$–[$^2H_6$]DMSO; C = $CDCl_3$; D = CF_3CO_2D. † At 100°.

TABLE 9

Properties of the formamidines (6)

Compound (6)	B.p./mmHg (m.p./°C)	Lit. b.p. or m.p.*	$\nu_{max.}$/cm^{-1} (neat): C=N	Others
H	140/0.05	140/18 [a]	1 635	2 910, 1 590, 1 090, 760, 695
2-Me	124—126/0.02	128—130/12 [b]	1 630	2 920, 1 590, 1 095, 755, 720
3-Me	124—126/0.02	78—79/0.05 [a]	1 630	2 910, 1 590, 1 570, 1 090, 770, 690
4-Me	140/0.01	103—105/0.5 [c]	1 630	2 910, 1 600, 1 510, 1 260, 1 095, 820
2-OMe	118/0.05	136/0.4 [d]	1 635	2 940, 1 585, 1 370, 1 240, 1 095, 745
3-OMe	150/0.2	164/12 [e]	1 640	2 930, 1 590, 770, 700
4-OMe	150/0.05	98/0.03 [a]	1 635	2 910, 1 500, 1 240, 1 100, 830
4-Br	106/0.01	173/14 [a]	1 630	2 900, 1 575, 1 480, 1 360, 1 095, 825
2-Cl	130/0.05	120—122/0.02 [f]	1 630	2 900, 1 580, 1 365, 1 095, 750
3-Cl	116—118/0.05	124/0.05 [a]	1 630	2 910, 1 575, 1 360, 1 090
4-Cl	95/0.01	101—108/0.06 [a]	1 630	2 900, 1 580, 1 480, 1 360, 1 095, 825
2,6-Cl_2	140/0.05	n.r.[f]	1 640	2 930, 1 390, 1 260, 770
2-NO_2	138—140/0.1	189/10 [g]	1 635	2 910, 1 590, 1 510, 1 370, 1 100, 745
3-NO_2	144/0.05	195/10 [g]	1 630	2 910, 1 600, 1 515, 1 345, 735
4-NO_2	(82—84)	86 [g]	1 635	1 570, 1 305, 1 095 (Nujol)

* n.r. = Not reported.

[a] D. Duerr, H. Aebi, and L. Ebner, U.S.P. 3,284,289/1967 (*Chem. Abstr.*, 1967, **66**, 28490). [b] E. B. Pedersen and S.-O. Lawesson, *Acta Chem. Scand., Ser. B*, 1974, **28**, 1045. [c] M. Seefelder, *Chem. Ber.*, 1966, **99**, 2678. [d] J. L. Neumeyer, *J. Pharm. Sci.*, 1964, **53**, 1539. [e] H. Bredereck, P. Effenberger, and H. Botsch, *Chem. Ber.*, 1964, **97**, 3397. [f] J. P. Marsh and L. Goodman, *Tetrahedron Lett.*, 1967, 683. [g] H. Bredereck, F. Effenberger, and A. Hofmann, *Angew. Chem. Int. Ed. Engl.*, 1963, **2**, 655.

TABLE 10

^{1}H N.m.r. spectra of the formamidines (6) in $CDCl_3$ (δ)

Compound (6) R	CH=N	Aromatic H's	Me_2N	CH_3
2-Me	7.35	6.6—7.2 (m)	2.94	2.25
3-Me	7.46	6.65—6.9 (m, 3 H), 7.0—7.25 (m, 1 H)	2.92	2.28
4-Me	7.50	6.80—7.15 (m)	2.98	2.30
2-OMe	7.49	6.7—7.0 (m)	2.97	3.80
3-OMe	7.48	6.45—6.65 (m, 3 H), 7.0—7.2 (m, 1 H)	2.90	3.71
4-OMe	7.45	6.83br	2.94	3.72
4-Br	7.42	6.80 (d, H-2 and H-6), 7.31 (d, H-3 and H-5)	2.95	
2-Cl	7.39	6.7—7.4 (m)	2.95	
3-Cl	7.43	6.7—7.25 (m)	2.93	
4-Cl	7.42	6.84 (d, H-2 and H-6), 7.16 (d, H-3 and H-5)	2.95	
2,6-Cl_2	7.13	6.71 (t, H-4), 7.26 (d, H-3 and H-5)	2.95	
2-NO_2	7.47	6.94 (t, H-4 and H-6), 7.32 (dt, H-5), 7.62 (dd, H-3)	2.95	
3-NO_2	7.59	7.2—7.5 (m, H-5 and H-6), 7.7—7.9 (m, H-2 and H-4)	3.05	
4-NO_2	7.60	6.95 (d, H-2 and H 6), 8.07 (d, H-3 and H-5)	3.05	

(d) 2,3,6-*Trichloroquinoxaline*. From 2-nitroacetanilide, on pouring the reaction mixture into ice–water, a pale brown solid precipitated (0.3 g, 4%) which recrystallised from toluene as fawn needles, m.p. 144.5—146 °C (lit.,[12] 143—144 °C) (Found: C, 41.2; H, 1.6; N, 11.9. Calc. for $C_8H_3Cl_3N_2$: C, 41.15; H, 1.3; N, 12.0%); $\nu_{max.}$ (Nujol) 1 590, 1 150, 1 000, 880, and 825 cm^{-1}; δ ($CDCl_3$) 7.73 (dd, H-7, $J_{7,8}$ 9, $J_{5,7}$ 2 Hz), 7.95 (d, H-8), and 8.00 (d, H-5); *m/e* 236 (35%), 234 (100), and 232 (100) (M^+); 199 (50) and 197 (70) (M − Cl); 164 (3) and 162 (9) (M − Cl_2); and 138 (13) and 136 (39) (M − Cl_2CN).

(e) 3-*Dimethylaminoacrylaldehyde*. From the final aqueous solution derived from 4-nitroacetanilide after removal of the formamidine was isolated a red oil (1.63 g) which was distilled (146—148 °C at 0.1 mmHg) to give a mixture of a solid and an oil. Addition of cold toluene (10 ml) precipitated a yellow solid (0.31 g, 5%), *p*-nitroaniline, m.p. 145—146 °C (lit.,[14] 147 °C). From the toluene was isolated as an oil (0.05 g), β-dimethylaminoacrylaldehyde; $\nu_{max.}$ (neat) 1 600 (CO), 1 400, 1 170, and 1 110 cm^{-1}; δ ($CDCl_3$) 2.97br (s, Me_2 N), 5.12 (dd, H-2), 7.04 (d, H-3), and 9.07 (d, CHO) ($J_{2,3}$ 13, $J_{1,2}$ 9 Hz); *m/e* 99 (93%, M^+, C_5H_9NO), 98 (67), 82 (71, C_5H_8N, M − OH), 70 (17, C_4H_8N, M − CHO), 55 (50, C_3H_7, M − CH_2NO), and 42 [100, C_2H_4N, M − (CH=CH–CHOH)]

Hydrolysis of the N-*Aryl*-3-*dimethylamino*-2-*formylacrylamides* (10).—The title product (0.2—5 g) in ethanol (50 ml) was treated with 20% aqueous sodium hydroxide (40 ml) and the mixture was boiled for 1 min. On cooling the mixture was poured onto ice (*ca.* 200 ml) and acidified. After 2 h the precipitate was filtered off, washed with water, and dried. Recrystallisation gave the *N*-aryl-2-formyl-3-hydroxyacrylamides (14) as recorded in Tables 13 and 14.

Hydrolysis of the N-*Aryl*-3-*dimethylamino*-2-*formylacryl amides* (10).—The title product (0.2—5 g) in ethanol (50 ml) was treated with 20% aqueous sodium hydroxide (40 ml) and the mixture was boiled for 1 min. On cooling the mixture was poured onto ice (*ca.* 200 ml) and acidified. After 2 h the precipitate was filtered off, washed with water, and dried. Recrystallisation gave the *N*-aryl-2-formyl-3-hydroxyacrylamides (14) as recorded in Tables 13 and 14.

Action of Polyphosphoric Acid on the Acrylamides (14).—

TABLE 11

Properties of the *N*-aryl-3-dimethylamino-3-formylacrylamides (10)

Compound (10) R	Recryst. solvent †	M.p./°C	Found (%) C	H	N	Formula	Required (%) C	H	N	$\nu_{max.}$/cm^{-1} CHO	C=C	Amide II
4-Me	A	143—144	66.5	6.8	11.8	$C_{13}H_{16}N_2O_2$	67.2	6.9	12.1	1 660	1 620	1 540
4-Br	A	128.5—129.5	48.4	4.4	9.5	$C_{12}H_{13}BrN_2O_2$	48.5	4.4	9.4	1 660	1 620	1 530
2-Cl	*	122								1 660	1 620	1 520
3-Cl	*	122								1 660	1 615	1 540
4-Cl	A	129—130	57.3	5.2	11.0	$C_{12}H_{13}ClN_2O_2$	57.0	5.2	11.1	1 660	1 615	1 520
3-NO_2	A	155—157	55.0	4.9	15.9	$C_{12}H_{13}N_3O_4$	54.75	5.0	16.0	1 660	1 620	1 530 ¶
4-NO_2	B	232—233 (decomp.)	55.0	5.0	16.1	$C_{12}H_{13}N_3O_4$	54.75	5.0	16.0	1 660	1 610	

* These compounds were not purified but hydrolysed directly to 3-hydroxy-2-formylacrylamides (14). † A = Toluene; B = ethanol. ¶ Also NO_2 absorption.

TABLE 12

^{1}H N.m.r. spectra of *N*-aryl-3-dimethylaminoacrylamides at normal probe temperature in $CDCl_3$

Compound (10) R	δ($CDCl_3$) Aromatic H	Me_2N	Others
4-Me	7.10 (d, H-3, H-5), 7.53 (d, H-2, H-6)	3.25	2.30 (s, Me)
4-Br	7.30—7.60 (q)	3.31	
2-Cl	6.8—7.5 (m, H-3, H-4, H-5), 8.45 (dd, H-6)	3.27	
3-Cl	6.9—7.5 (m, H-4, H-5, H-6), 7.84 (t, H-2)	3.29	
4 Cl	7.25 (d, H-3, H-5), 7.60 (d, H-2, H-6)	3.30	see text
3-NO_2	7.41 (t, H-5), 7.75—8.0 (m, H-4, H-6), 8.67 (t, H-2)	3.40	
4-NO_2 *	7.85 (d, H-2, H-6), 8.20 (d, H-3, H-5)	3.40	11.40 (s, NH), 9.29 (s, CHO)

* [$^2H_6$]DMSO instead of $CDCl_3$.

TABLE 13

Properties of the *N*-aryl-2-formyl-3-hydroxyacrylamides (14)

Compound (14) R	Recryst. solvent *	M.p./°C	Found (%) C	H	N	Formula	Required (%) C	H	N	$\nu_{max.}$/cm^{-1} OH	CO and C=C			Amide II
2-Me	A	92—93	64.30	5.4	7.0	$C_{11}H_{11}NO_3$	64.4	5.4	6.8	3 150	1 660	1 615	1 590	1 565
4-Me	A	81—82	64.7	5.45	7.3	$C_{11}H_{11}NO_3$	64.4	5.4	6.8	3 175	1 660	1 630	1 590	1 540
2,6-Me_2	B	99—101	65.75	6.1	6.2	$C_{12}H_{13}NO_3$	65.7	6.0	6.4	3 200	1 655	1 630		1 540
2-OMe	B	100—101	60.0	5.1	6.2	$C_{11}H_{11}NO_4$	59.7	5.0	6.3	3 200	1 670	1 620	1 590	
4-OMe	C	87—88	60.0	4.8	6.2	$C_{11}H_{11}NO_4$	59.7	5.0	6.3	3 150	1 655	1 620	1 590	1 545
4-Br	B	154—155	44.4	3.1	5.2	$C_{10}H_8BrNO_3$	44.5	3.0	5.2	3 175 3 125	1 665	1 630—1 600		1 550
2-Cl	A	104—105	53.3	3.6	6.5	$C_{10}H_8ClNO_2$	53.2	3.6	6.2	3 150	1 670	1 600		1 555
3-Cl	A	104—105	53.2	3.6	6.4	$C_{10}H_8ClNO_2$	53.2	3.6	6.2	3 090	1 660	1 610	1 590	1 550
4-Cl	B	134—135	53.45	3.6	6.3	$C_{10}H_8ClNO_2$	53.2	3.6	6.2	3 100	1 660	1 620	1 600	1 560
2-NO_2	B	120—121	50.9	3.55	11.9	$C_{10}H_8N_2O_5$	50.85	3.4	11.9	3 130	1 670	1 605	1 585	
3-NO_2	D	180 (decomp.)	51.1	3.7	11.6	$C_{10}H_8N_2O_5$	58.85	3.4	11.9	3 100	1 665	1 600		1 565

* A = Aqueous ethanol; B = ethanol; C = light petroleum–toluene; D = n-butanol.

TABLE 14

^{1}H N.m.r. spectra of *N*-aryl-2-formyl-3-hydroxyacrylamides

Compound (14) R	Solvent	Chemical shifts (δ) OH	NH	CHO	H-3	Aromatic	Me
2-Me	$CDCl_3$	15.8br	10.8br	9.26	8.30	7.0—7.4 (m, 3 H), 7.85—8.0 (m, H-6)	2.36
4-Me	$CDCl_3$	16.0br	10.8br	9.21	8.28	7.15 (d, H-3, H-5), 7.44 (d, H-2, H-6)	2.31
2,6-Me_2	$CDCl_3$	15—13br	10.35br	9.30	8.41	7.11 (s)	2.22
2-OMe	$CDCl_3$	16.0br	11.2br	9.20	8.21	6.8—7.2 (m, 3 H), 8.16br (H-6)	3.0
4-OMe	$CDCl_3$	16—25br	10.75br	9.20	8.29	6.87 (d, H-3, H-5), 7.46 (d, H-2, H-6)	3.79
4-Br	[$^2H_6$]DMSO	13.5br	10.7br	9.02	9.02	7.56 (s)	
2-Cl	$CDCl_3$	15.8—14.8	11.2br	9.30	8.21	7.0—7.5 (m, 3 H), 8.30 (dd, H-6)	
3-Cl	$CDCl_3$	15.5br	10.8br	9.23	8.20	7.0—7.5 (m, 3 H), 7.70 (t, H-2)	
4-Cl	[$^2H_6$]DMSO	13.65br	10.7br	9.00	9.00	7.37 (d, H-3, H-5), 7.67 (d, H-2, H-6)	
2-NO_2	$CDCl_3$	15.5—14.5	12.3br	9.33	8.20	7.30 (dt, H-4), 7.68 (dt, H-5), 8.17 (dd, H-6), 8.47 (dd, H-3)	
3-NO_2	[$^2H_6$]DMSO *	10.9br	10.9br	8.96	8.96	7.52 (t, H-5), 7.7—8.0 (m, H-4, H-6), 8.55 (t, H-2)	

* Spectrum run at 70 °C.

To the acrylamide (1.0 g) in a boiling tube was added polyphosphoric acid (15 g) and the mixture was heated with stirring as shown in Table 6. After cooling to 70—80 °C, ice (*ca.* 20 g) was added and the resulting solution was diluted to 100 ml. After 10 min the precipitate was filtered off, washed with water, and dried by suction to give the 3-formylquinolones shown in Table 6. Their properties are as follows: (a) 6-*chloro*-3-*formyl*-2-*quinolone* (15; R = 6-Cl), yellow needles, m.p. 357—358 °C (decomp.) (from acetic acid) (Found: C, 57.9; H, 3.1; N, 6.8. $C_{10}H_6ClNO_2$ requires C, 57,85; H, 2.9; N, 6.75%), $\nu_{max.}$ (Nujol) 3 150 (NH), 1 680 (CO), 1 550 (amide II), 890, and 815 cm^{-1}, $\nu_{max.}$ (hexachlorobutadiene) 3 200—2 500br (NH), δ ([$^2H_6$]DMSO at 100 °C) 11.90br (NH), 10.20 (s, CHO), 8.33 (s, H-4), 7.89 (d, H-5), 7.55 (dd, H-7), and 7.31 (d, H-8) ($J_{7,8}$ 9, $J_{5,7}$ 2 Hz); (b) 7-*chloro*-3-*formyl*-2-*quinolone* (15; R = 7-Cl), yellow needles, m.p. 338—340 °C (decomp.) (from acetic acid) (Found: C, 57.8; H, 3.1; N, 6.6. $C_{10}H_6ClNO_2$ requires C, 57.85; H, 2.9; N, 6.75%), $\nu_{max.}$ (Nujol) 1680 (CO), 1 610, 1 550 (amide II), and 1 210 cm^{-1}, δ ([$^2H_6$]DMSO at 90 °C) 10.12 (s, CHO), 8.33 (s, H-4), 7.81 (d, H-5), 7.31 (d, H-8), and 7.14 (dd, H-7) ($J_{5,6}$ 9, $J_{6,8}$ 2 Hz); 8-*chloro*-3-*formyl*-2-*quinolone* (15; R = 8-Cl), yellow crystals, m.p. 259 °C (decomp.) (from aqueous acetonitrile) (Found: C, 57.6; H, 2.9; N, 6.95. $C_{10}H_6ClNO_2$ requires C, 57.85; H, 2.91; N, 6.75%), $\nu_{max.}$ (Nujol) 3 160 (NH), 1 680 (CO) 1 585, and 1 200 cm^{-1}, δ ([$^2H_6$]DMSO at 90 °C) 10.18 (s, CHO), 8.38 (s, H-4), 7.78 (dd) and 7.66 (dd) (H-5 and H-7), and 7.14 (t, H-6) ($J_{5,6} \simeq J_{6,7} \simeq 8$ Hz); 6-*bromo*-3-*formyl*-2-*quinolone* (15; R = 6-Br), fawn crystals, m.p. 342—344 °C (decomp.) (from acetic acid) (Found: C, 47.4; H, 2.5; N, 5.7. $C_{10}H_6BrNO_2$ requires C, 47.65; H, 2.4; N, 5.6%), $\nu_{max.}$ (Nujol) 1 680 (CO), 1 540 (amide II), and 1 100 cm^{-1}, δ ([$^2H_6$]DMSO at 100 °C) 10.18 (s, CHO), 8.30 (s, H-4), 8.01 (d, H-5), 7.65 (dd, H-7), and 7.23 (d, H-8) ($J_{7,8}$ 9, $J_{5,7}$ 2 Hz).

2-*Formyl*-3-(3-*nitroanilino*)-N-(3-*nitrophenyl*)*acrylamide* (16). 2-Formyl-3-hydroxy-*N*-(3-nitrophenyl)acrylamide on heating at 140—150 °C for 10 min with polyphosphoric acid gave the title product (84%) as fawn *crystals* from aqueous dimethylformamide, m.p. 281—283 °C (decomp.) (Found: C, 53.9; H, 3.2; N, 15.75. $C_{16}H_{12}N_4O_6$ requires C, 53.0; H, 3.4; N, 15.7%), $\nu_{max.}$ (Nujol) 3 100br (NH), 1 660 (CO), 1 520 (amide II), 1 340, and 730 cm^{-1}, δ ([$^2H_6$]DMSO at 100 °C) 11.90br (OH), 11.15br (NH), 9.32 (s, H-3), 8.66 (t, 1 H), 8.35 (t, 1 H), and 7.4—8.1 (m, 7 H).

3-*Dimethylamino*-N-(3-*nitrophenyl*)*prop*-2-*en*-1-*imine* (17). When 3-dimethylamino-2-formyl-*N*-(3-nitrophenyl)acrylamide (10; R = 3-NO_2) was treated with polyphosphoric acid at 140 °C for 10 min, the title product was isolated (67%) and recrystallised from toluene–petroleum as red *needles*, m.p. 114—115 °C (Found. C, 60.3; H, 5.95; N, 19.2 $C_{11}H_{13}N_3O_2$ requires C, 60.3; H, 6.0; N, 19.2%), $\nu_{max.}$ (Nujol) 1 625, 1 505, 1 570, and 1 340 cm^{-1} (NO_2), δ ($CDCl_3$) 7.98 (d, H-2), 7.87 (m, 2 H), 7.40 (m, 2 H), 6.92 (d, H-4), 5.41 (q, H-3), and 2.98 (Me_2N), *m/e* 219 (M^+, 100%), 204 (M − Me, 15), 172 (M − HNO_2, 15), 158 (30), 157 (35), and 130 (30).

Action of Vilsmeier's Reagent on Acetylated Phenylenediamines.—(a) *On* NN'-*diacetyl-o-phenylenediamine.* The

acetylphenylenediamine (2.40 g, 0.0125 mol), dimethylformamide (5.48 g, 5.80 ml, 0.0375 mol), and phosphoryl chloride (26.9 g, 16.1 ml, 0.0875 mol) were allowed to react for 16 h at 75 °C according to the general method (iii) above. The mixture was poured into ice–water to give a clear solution, and basified. The oil which separated was extracted with ether and the extract was dried, evaporated, and distilled twice (Kugelrohr 124 °C at 0.2 mmHg and 90 °C at 0.01 mmHg) to give 1-(1-*chlorovinyl*)-2-*methylbenzimidazole* (19) (1.41 g, 59%) as a pale yellow oil (Found: C, 62.3; H, 4.8; N, 14.8. $C_{10}H_9ClN_2$ requires C, 62.35; H, 4.7; N, 14.5%), $\nu_{max.}$ (neat) 3 050 (=CH), 1 640 (C=N), 1 540, 1 450, 1 340, 1 280, 1 170, and 760 cm^{-1}, $\lambda_{max.}$ (MeOH) 273 and 280 nm, δ ($CDCl_3$) 7.70 (m, H-7), 7.2–7.5 (m, 3 H, aromatic), 5.87 (d, 1 H, olefinic, *J* 2 Hz), 5.59 (d, 1 H, olefinic), and 2.62 (s, me), *m/e* 194 (M^+, 22%), 192 (M^+, 65), 179/177 ($M - CH_3$, 1 and 3), 157 (M — Cl, 100), and 156 (M — HCl, 27).

(b) *On NN'-diacetyl*-m-*phenylenediamine*. Using double the quantities with the method as above, after 4 h heating under reflux the reaction mixture was poured into ice–water and neutralised with aqueous sodium hydroxide. The precipitate was filtered off, washed with water, and recrystallised from dioxan to give 2,8-*dichloro*-3,9-*diformyl*-1,5-*phenanthroline* (22) (7.0 g, 92%) as pale yellow platelets, m.p. 274 °C (decomp.) (Found: C, 54.6; H, 2.2; N, 9.2. $C_{14}H_6Cl_2N_2O_2$ requires C, 55.1; H, 2.0; N, 9.2%), $\nu_{max.}$ (Nujol) 1 680 cm^{-1} (CHO), δ ([$^2H_6$]DMSO) 8.12 (d) and 8.59 (d) (9-H and 10-H, *J* 9 Hz), 9.11 (s, 4-H and 8-H), and 10.46 (s, 2CHO), *m/e* 304/306/308 (M^+).

(c) NN'-*Diacetyl*-p-*phenylenediamine*. Using the same quantities and method as in (a) and the same reaction time and temperature, the reaction mixture was again poured into ice–water to give a clear solution. On making alkaline, an oil separated which solidified on standing and was filtered off. This solid was extracted (Soxhlet) with light petroleum for 24 h, when removal of the solvent gave 1,4-bis-*NN*-(dimethylaminomethyleneamino)benzene (25) (1.70 g, 63%) as yellow needles from cyclohexane, m.p. 119—120 °C (lit.,[15] 120.5—121.5 °C), $\nu_{max.}$ (Nujol) 1 620 (C=N), 1 360, 1 100, and 840 cm^{-1}, δ ($CDCl_3$) 7.51 (s, CH=N), 6.89 (s, aromatic), and 2.98 (s, Me_2N)

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REFERENCES

[1] Part 4, O. Meth-Cohn and B. Tarnowski, *Tetrahedron Lett.*, 1980, 3721. Preliminary publications: O. Meth-Cohn and B. Narine, *Tetrahedron Lett.*, 1978, 2045; O. Meth-Cohn, B. Narine, and B. Tarnowski, *ibid.*, 1979, 3111.

[2] M. C. Friedel, *Bull. Soc. Chim. Fr.*, 1896, **11**, 1028.

[3] O. Fischer, A. Muller, and A. Vilsmeier, *J. Prakt. Chem.*, 1925, **109**, 69.

[4] A. Vilsmeier and A. Haack, *Ber.*, 1927, **60***B*, 119.

[5] *E.g.* see K. E. Schulte and D. Bergenthal, *Arch. Pharm.* (*Weinheim, Ger.*), 1979, **312**, 265.

[6] For an excellent review see C. Jutz, *Adv. Org. Chem., Methods and Results*, 1976, **9**, 225.

[7] For some related quinoline syntheses see (*a*) H. Ulrich, 'The Chemistry of Imidoyl Halides,' Plenum Press, New York, 1968, p. 87 (dimerisation of chloroacetylanilides with phosphorus pentachloride); (*b*) H. Ahlbrecht and C. Vonderheid, *Chem. Ber.*, 1975, **108**, 2300 (conversion of *N*-methylacylanilides into 2,4-dichloroquinolinium salts with phosgene); (*c*) E. B. Pedersen, *Tetrahedron Lett.*, 1977, **33**, 217 (conversion of *ortho*-substituted acetanilides into 2,4-bis(dimethylamino)quinolines with hexamethylphosphoric triamide); (*d*) J. P. Chupp and S. Metz, *J. Heterocycl. Chem.*, 1979, **16**, 65 (conversion of *N*-substituted acetanilides into *N*-substituted-2-quinolones by Vilsmeier's reagent; this paper appeared after our preliminary publications).

[8] G. Ah-Kow, C. Paulmier, and P. Pastour, *Bull. Soc. Chim. Fr.*, 1976, 151; C. Paulmier and F. Outurquin, *J. Chem. Res.* (*S*), 1977, 318; (*M*), 1977, 3660; B. A. J. Clark, J. Parrick, and P. J. West, *J. Chem. Soc.* (*C*), 1970, 498; M. A. Kira, M. N. Aboul-Enein, and M. I. Karkor, *J. Heterocycl. Chem.*, 1970, **7**, 25.

[9] (*a*) Ref. 7*a*, p. 57; (*b*) H. Eilingsfeld, M. Seefelder, and H. Weidinger, *Angew. Chem.*, 1960, 836; (*c*) H. H. Bosshard and H. Zollinger, *Helv. Chim. Acta.*, 1959, **42**, 1659.

[10] J. von Braun and H. Silbermann, *Ber.*, 1930, **63**, 498.

[11] J. March, 'Advanced Organic Chemistry: Reactions, Mechanisms, and Structures,' McGraw-Hill, 2nd edn., 1977, p. 470.

[12] R. D. Haworth and S. Robinson, *J. Chem. Soc.*, 1948, 777.

[13] For related cyclisations of *o*-nitroaniline derivatives to quinoxaline *N*-oxides see A. R. Katritzky and J. M. Lagowski in 'Chemistry of Heterocyclic *N*-Oxides,' Academic Press, London, 1971, pp. 93 and 123. For the conversion of quinoxaline *N*-oxides into 2- and 6-chloroquinoxalines on treatment with phosphoryl chloride see G. W. H. Cheeseman and R. F. Cookson, in 'Condensed Pyrazines,' 'The Chemistry of Heterocyclic Compounds,' eds. A. Weissberger and E. C. Taylor, John Wiley and Sons, 1979, **35**, p. 43.

[14] F. J. Smith and E. Jones, 'A Scheme of Qualitative Organic Analysis,' Blackie and Sons Limited, London, 1949.

[15] H. Bredereck and K. Bredereck, *Chem. Ber.*, 1961, **94**, 2278.