Pyrolytic Elimination of Hydrogen Halide and Halogen from 2,3-Dihalogenoketones

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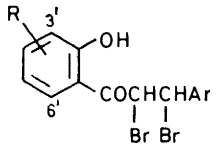
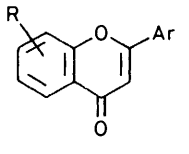
The thermal elimination of hydrogen chloride from 2′-hydroxychalcone dichlorides occurred in two stages, initially forming 3-chloroflavanones and then flavones; α-chloro-2′-hydroxychalcones, the likely intermediates in the formation of 3-chloroflavanones, also yielded the same products. The pyrolysis of 2′-hydroxychalcone dibromides resulted in debromination as well as dehydrobromination with the consequent appearance of brominated flavones among the products. The formation of 3-bromoflavanones was not observed but the isomeric (*E*)-α-bromo-2′-hydroxychalcones thermally isomerized to their (*Z*)-isomers and then underwent cyclization and dehydrobromination. The bromides were considerably more reactive than the dichlorides but, as a synthetic procedure, the pyrolysis of the dichlorides is cleaner and more productive.

THE thermal decomposition of alkyl halides is very complex and can involve a wide variety of competing processes. The effects of a large number of different substituents on the course of the reaction have been studied.[1] Of immediate interest is the work of Dakubu and Maccoll [1b] who observed that, in the pyrolyses of keto-halides, the carbonyl group in the α-position reduces the rate of elimination while in the β-position it slightly increases it. Reported here is the first systematic study of the thermal decomposition of 2,3-dihalogenoketones. The product distribution from the bulk pyrolysis of chalcone dihalides was observed. Most of the dihalides incorporated an *o*-hydroxy-substituent in an effort to trap intermediates. The thermal decomposition of such chalcone *dibromides* (1) was used by



(1)



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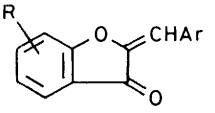
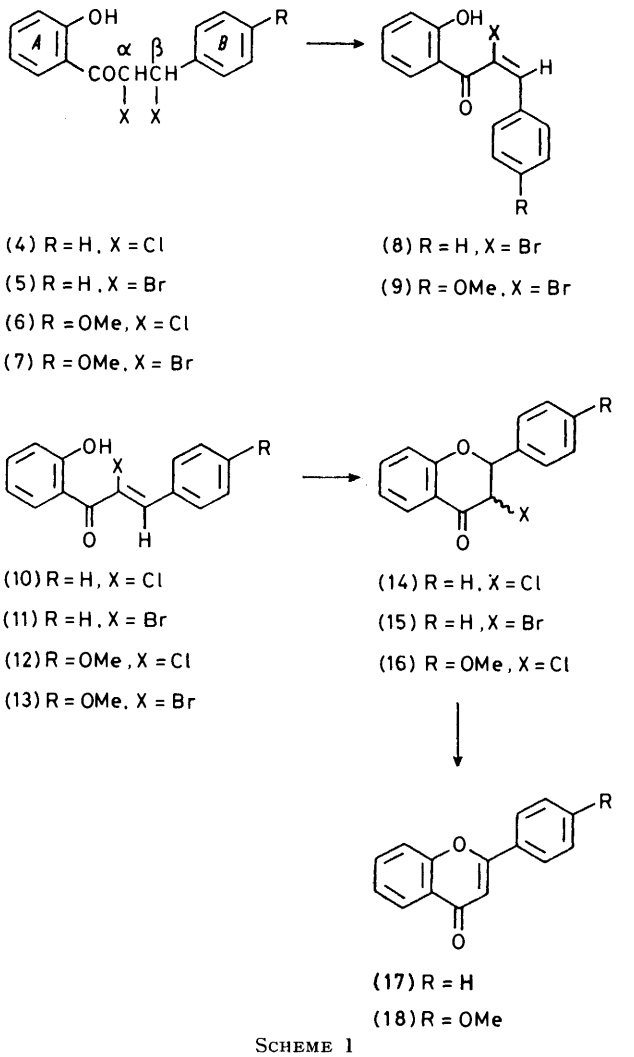


(3)

Wheeler and his co-workers [2a,b] as an authentic method of synthesizing flavones (2) at a time when the much-used alkaline cyclization [3] of these dibromides was considered to be unreliable; aurones (3) rather than flavones were often, unaccountably, isolated. Nothing has been recorded concerning the course of the reaction.

RESULTS AND DISCUSSION

The pyrolysis of chalcone dichlorides has not been previously reported. 2′-Hydroxychalcone dichloride (4) was now found (Scheme 1) to eliminate hydrogen chloride to give a mixture of *cis*- and *trans*-3-chloroflavanone (14) when heated at 200 °C. When heated for a slightly longer time at 210—220 °C, the dichloride (4) eliminated two molecules of hydrogen chloride and gave the flavone (17). The isolation of a 3-halogenoflavanone from the pyrolysis of a chalcone dihalide has not previously been observed even though it is the most likely intermediate



(4) R = H, X = Cl
(5) R = H, X = Br
(6) R = OMe, X = Cl
(7) R = OMe, X = Br
(8) R = H, X = Br
(9) R = OMe, X = Br
(10) R = H, X = Cl
(11) R = H, X = Br
(12) R = OMe, X = Cl
(13) R = OMe, X = Br
(14) R = H, X = Cl
(15) R = H, X = Br
(16) R = OMe, X = Cl
(17) R = H
(18) R = OMe

SCHEME 1

in the formation of flavones. 3-Chloroflavanone (14) probably arises from the isomerization of previously formed (*Z*)-α-chloro-2′-hydroxychalcone (10),[4a] which, although not isolated from the pyrolysis reaction, was

readily available from 2′-hydroxychalcone dichloride (4) by the action of potassium acetate in acetone at room temperature and which did isomerize thermally to a mixture of *cis*- and *trans*-3-chloroflavanone (14). (*Z*)-α-Chloro-2′-hydroxychalcone (10) also gave the flavone (17) when the pyrolysis time was increased. In accord with their proposed role of intermediate, the 3-chloroflavanone isomers (14) thermally eliminated hydrogen chloride and formed the flavone (17).

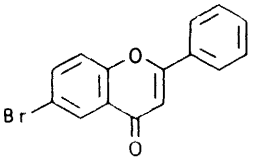
The corresponding chalcone dibromide, 2′-hydroxychalcone dibromide (5), was found to be considerably more unstable thermally. Its pyrolysis at 200 °C was complete in about one-tenth the time required for the dichloride (4). No 3-bromoflavanone intermediate (15) was observed, and yields of product were poor and complex. This was found to be typical of chalcone dibromides which, despite their preference by previous workers,[2] are inferior to chalcone dichlorides as substrates in this synthesis of flavones. Pyrolysis of 2′-hydroxychalcone dibromide (5) gave the previously isolated [2a] 6-bromoflavone (19) together with flavone (17), flavanone (20), and 2′-hydroxychalcone (21). The formation [2d] of the two last-mentioned products (20) and (21), isomers of each other, correlates with the formation of the brominated flavone (19) and indicates that bromine, as well as hydrogen bromide, is thermally eliminated from chalcone dibromides. The formation of 6-bromoflavone (19) suggests that nuclear halogenation of the phenolic A-ring may have occurred prior to cyclization as molecular bromination of flavone occurs [5] at the 3-position.

The elimination of one molecule of hydrogen bromide [4b] from 2′-hydroxychalcone dibromide (5) using potassium acetate in acetone gave (*E*)-α-bromo-2′-hydroxychalcone (8). The use of two molar equivalents of sodium acetate in dimethyl sulphoxide yielded the flavone (17). The chalcone dibromide (5) reacted with *ethanolic* potassium acetate to give (*E*)-α-bromo-2′-hydroxychalcone (8), *cis*- and *trans*-3-bromoflavanone (15), and the flavone (17).

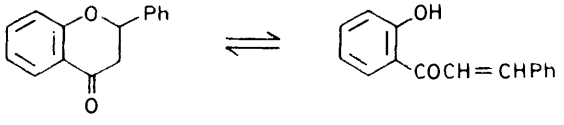
To test the assumption that the α-bromo-2′-hydroxychalcones (8) and (11), like their isomeric 3-bromoflavanones (15), are intermediates in the production of flavone, (*E*)-α-bromo-2′-hydroxychalcone (8) was heated at 200 °C. It readily isomerized to the (*Z*)-isomer (11) which, in turn, formed the flavone (17).

From the above class I chalcone dihalides,[2d] attention was turned to the pyrolysis of class 2A dihalides (A-ring substituted in the 6′-position). It was found necessary to employ the acetate (22) of 2′-hydroxy-4′,6′-dimethoxychalcone, as chlorination of the latter gave a mixture of variously chlorinated products. The chlorination of 2′-acetoxy-4′,6′-dimethoxychalcone (22) gave the nuclear and side-chain chlorinated product, 2′-acetoxy-3′-chloro-4′,6′-dimethoxychalcone dichloride (26). The orientation of the nuclear halogen was established by synthesizing the other possible isomer, 2′-acetoxy-5′-chloro-4′,6′-dimethoxychalcone dichloride (27) from authentic 5′-chloro-2′-hydroxy-4′,6′-dimethoxyacetophenone * by condensing the latter with benzaldehyde, acetylating the chalcone product (23), and dichlorinating this acetate. Chlorinating the intermediate 5′-chloro-2′-hydroxy-4′,6′-dimethoxychalcone (23) gave 3′,5′-dichloro-2′-hydroxy-4′,6′-dimethoxychalcone (24).

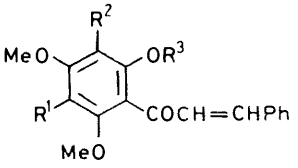
It was found impossible to hydrolyse (acid catalysis) 2′-acetoxy-3′-chloro-4′,6′-dimethoxychalcone dichloride (26) to obtain the required 2′-hydroxychalcone dichloride; the usual reagent, refluxing ethanolic hydrochloric acid, yielded (*Z*)-2′-acetoxy-α,3′-dichloro-4′,6′-dimethoxychalcone (29). As was to be expected, the hydrochloric acid was shown to be superfluous in this elimination of hydrogen chloride. The α-chlorochalcone



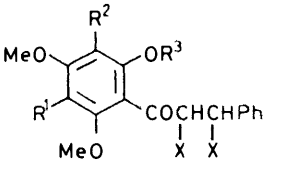
(19)



(20) (21)



(22) $R^1 = R^2 = H$, $R^3 = Ac$
(23) $R^1 = Cl$, $R^2 = R^3 = H$
(24) $R^1 = R^2 = Cl$, $R^3 = H$
(25) $R^1 = R^3 = H$, $R^2 = Br$



(26) $R^1 = H$, $R^2 = X = Cl$, $R^3 = Ac$
(27) $R^1 = X = Cl$, $R^2 = H$, $R^3 = Ac$
(28) $R^1 = R^2 = R^3 = H$, $X = Br$

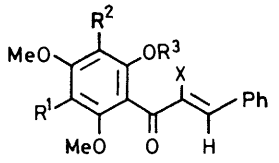
(29) was also prepared from the dichloride (26) by reaction with potassium acetate in acetone.

The pyrolysis of 2′-acetoxy-3′-chloro-4′,6′-dimethoxychalcone dichloride (26) at 200 °C gave (*Z*)-2′-acetoxy-α,3′-dichloro-4′,6′-dimethoxychalcone (29) and *cis*- and *trans*-3,8-dichloro-5,7-dimethoxyflavanone (32). Its pyrolysis at a slightly higher temperature and longer time gave 8-chloro-5-hydroxy-7-methoxyflavone (34); the presumed initial product, 8-chloro-5,7-dimethoxyflavone, was apparently demethylated by the eliminated hydrogen chloride, a phenomenon similar to that previously reported [2c] for chalcone dibromides. No reaction was observed when (*Z*)-2′-acetoxy-α,3′-dichloro-4′,6′-

* The chlorination of 2′-hydroxy-4′,6′-dimethoxyacetophenone in chloroform yields [6] 3′-chloro-2′-hydroxy-4′,6′-dimethoxyacetophenone as the minor and more insoluble product; the major product is 5′-chloro-2′-hydroxy-4′,6′-dimethoxyacetophenone. The structure of the 3′-chloroacetophenone has been proved [7a] in an alternative synthesis.

dimethoxychalcone (29), the putative intermediate in these reactions, was heated at 200 °C. However, the addition of hydrochloric acid immediately prior to heating resulted in the production of *cis*- and *trans*-3,8-dichloro-5,7-dimethoxyflavanone (32). It would appear that the hydrogen chloride eliminated from the chalcone dichloride in forming an α-chlorochalcone is vital for the subsequent deacetylation. Partial demethylation of polyalkoxy-flavones at the 5-position is common, unlike the similar demethylation of flavanones,[7b] and may be due to the intervention of the pyrone ring as shown formally (Scheme 2).

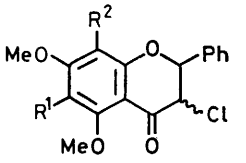
2′-Acetoxy-5′-chloro-4′,6′-dimethoxychalcone dichloride (27), like its isomer (26), was not deacetylated by ethanolic hydrochloric acid but neither did it eliminate hydrogen chloride under these conditions. The latter



(29) R^1 = H, R^2 = X = Cl, R^3 = Ac

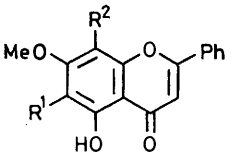
(30) R^1 = X = Cl, R^2 = H, R^3 = Ac

(31) R^1 = R^2 = R^3 = H, X = Br



(32) R^1 = H, R^2 = Cl

(33) R^1 = Cl, R^2 = H



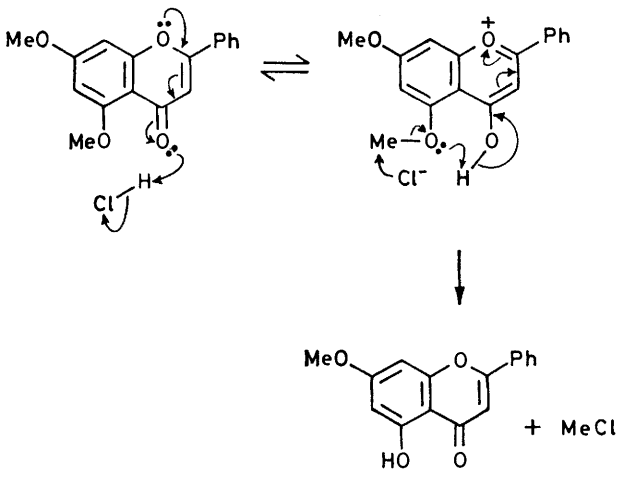
(34) R^1 = H, R^2 = Cl

(35) R^1 = Cl, R^2 = H

(36) R^1 = R^2 = H

reaction was carried out using potassium acetate in acetone and the product was (*Z*)-2′-acetoxy-α,5′-dichloro-4′,6′-dimethoxychalcone (30). Pyrolysis of the 5′-chlorochalcone dichloride (27) gave the α-chlorochalcone (30) and *cis*- and *trans*-3,6-dichloro-5,7-dimethoxyflavanone (33). When heated for a longer time it gave 6-chloro-5-hydroxy-7-methoxyflavone (35). Again, it is to be noted that, while the intermediate flavanone (33) was intact, the flavone product (35) was partially demethylated. Like its 3′-chloro-isomer (29), the thermolysis of (*Z*)-2′-acetoxy-α,5′-dichloro-4′,6′-dimethoxychalcone (30) required the addition of hydrochloric acid for reaction and gave a mixture of *cis*- and *trans*-3,6-dichloro-5,7-dimethoxyflavanone (33).

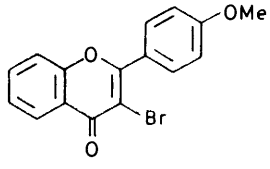
The bromides of class 2A, like their class 1 analogues, were thermally very reactive and gave yields of products that were poor and complex. The only product recovered from the pyrolysis of 2′-hydroxy-4′,6′-dimethoxychalcone dibromide (28) at 170 °C for 5 min was 3′-bromo-2′-hydroxy-4′,6′-dimethoxychalcone (25) which again shows the thermal debromination of 2,3-dibromoketones and nuclear halogenation. Pyrolysis of the chalcone dibromide (28) at 180 °C for 10 min gave, as the only product retrieved, the demethylated [2c] but non-nuclear brominated flavone, 5-hydroxy-7-methoxyflavone (36).



SCHEME 2

The same product (36) was obtained from the (*E*)-isomer of α-bromo-2′-hydroxy-4′,6′-dimethoxychalcone, while no usable conditions were found for the pyrolysis of the (*Z*)-isomer (31).

The pyrolysis (Scheme 1) of class 2B chalcone dichlorides (B-ring alkoxy-substituted in the *o*- or *p*-position) closely resembled that of class 1. 2′-Hydroxy-4-methoxychalcone dichloride (6) readily eliminated hydrogen chloride at 200 °C to give a mixture of *cis*- and *trans*-3-chloro-4′-methoxyflavanone (16). More pro-



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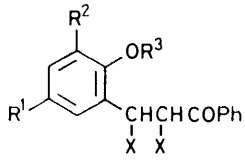
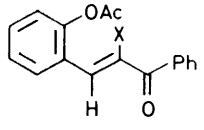


(38) R^1 = R^2 = H, R^3 = Ac, X = Cl

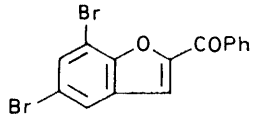
(39) R^1 = R^2 = X = Br, R^3 = H

(40) R^1 = R^2 = H, R^3 = Ac, X = Br



(41) X = Cl

(42) X = Br



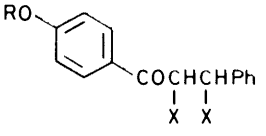
(43)

longed heating eliminated two molecules of hydrogen chloride and gave 4′-methoxyflavone (18). The reaction of the chalcone dichloride (6) with potassium acetate in acetone gave (*Z*)-α-chloro-2′-hydroxy-4-methoxy-

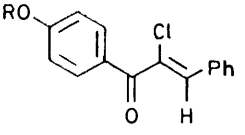
chalcone (12) which was thermally isomerized to *cis*- and *trans*-3-chloro-4′-methoxyflavanone (16) and, at a higher temperature to 4′-methoxyflavone (18). The 3-chloro-4′-methoxyflavanone isomers (16) thermally eliminated hydrogen chloride and formed 4′-methoxyflavone (18).

The analogous dibromide, 2′-hydroxy-4-methoxychalcone dibromide (7), underwent rapid pyrolysis at 150 °C to give 2′-hydroxy-4-methoxychalcone, 4′-methoxyflavone (18), and 3-bromo-4′-methoxyflavone (37). The first two of these products are the consequences of, respectively, the typical thermal debromination and dehydrobromination of 2,3-dibromoketones. The last-mentioned is a novel product and correlates with 6-bromoflavone (19) obtained in the pyrolysis of the class 1 dibromide (5) except that halogenation has here occurred *after* cyclization and in the position preferred [8] by molecular bromine. The elimination of one molecule of hydrogen bromide from 2′-hydroxy-4-methoxychalcone dibromide (7) gave both the (*E*)- and (*Z*)-isomers [(9) and (13)] of α-bromo-2′-hydroxy-4-methoxychalcone. The (*E*)-isomer (9) was thermally isomerized to the (*Z*)-isomer (13), which underwent pyrolysis to form 4′-methoxyflavone (18).

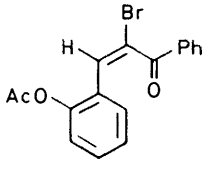
Class 3 chalcone dihalides (*o*-hydroxy-substituted in the B-ring) are characteristically cyclized by base [9] to



(44) R = H, X = Br
(45) R = H, X = Cl
(46) R = Ac, X = Cl



(47) R = H
(48) R = Ac



(49)

2-benzoylbenzofurans (*e.g.* 43); their pyrolysis has not been reported. To obtain a reasonably clean chlorination reaction, it was necessary to use an acetate. Chlorination of 2-acetoxychalcone gave 2-acetoxychalcone dichloride (38) which, surprisingly, could not be deacetylated in acid conditions. When pyrolysed at 200 °C, the dichloride (38) gave (*Z*)-2-acetoxy-α-chlorochalcone (41); no cyclized product was obtained. The (*Z*)-α-chlorochalcone (41) was also produced by the reaction of 2-acetoxychalcone dichloride (38) with potassium acetate and was isomerized by u.v. irradiation to its (*E*)-isomer.

Bromination of 2-hydroxychalcone gives [10] 3,5-dibromo-2-hydroxychalcone dibromide (39) but this could not be cleanly pyrolysed. When treated with potassium acetate in acetone, the chalcone dibromide (39) gave 2-benzoyl-5,7-dibromobenzofuran (43) rather than an α-bromochalcone. Bromination of 2-acetoxychalcone gives [9] 2-acetoxychalcone dibromide (40) and this, when pyrolysed at 150 °C, gave, as the only recoverable product, 2-acetoxychalcone. The reaction of this chalcone dibromide (40) with potassium acetate gave the (*Z*)-(42) and (*E*)-isomers of 2-acetoxy-α-bromochalcone.

TABLE 1

^{1}H N.m.r. data for new compounds

Compound	Chemical shifts (δ), coupling constants *J* in Hz
(4)	5.57 (s, α-H, β-H), 7.12—7.98 (m, Ar), 11.80 (s, OH)
(6)	3.88 (s, OMe), 5.60 (s, α-H, β-H), 6.93—8.07 (m, Ar), 11.87 (s, OH)
(8)	6.70—7.91 (m, Ar, β-H), 11.72 (s, OH)
(9)	3.72 (s, OMe), 6.67—8.02 (m, β-H, Ar), 11.77 (s, OH)
(10)	6.81—8.02 (m, Ar, β-H), 11.39 (s, OH)
(11)	6.84—8.04 (m, Ar, β-H), 11.48 (s, OH)
(12)	3.91 (s, OMe), 6.85—8.02 (m, Ar), 11.29 (s, OH)
(13)	3.89 (s, OMe), 6.87—8.11 (m, β-H, Ar), 11.39 (s, OH)
(14)	*cis*-Isomer: 4.50 (d, *J* 2, 3-H), 5.67 (d, 2-H), 7.02—8.20 (m, Ar). *trans*-Isomer: 4.94 (d, *J* 11, 3-H), 5.46 (d, 2-H), 7.02—8.20 (m, Ar)
(16)	*cis*-Isomer: 3.90 (s, OMe), 4.46 (d, *J* 2, 3-H), 5.65 (d, 2-H), 6.95—8.20 (m, Ar). *trans*-Isomer: 3.90 (s, OMe), 4.95 (d, *J* 11, 3-H), 5.43 (d, 2-H), 6.95—8.20 (m, Ar)
(24)	3.89 (s, 4′-OMe), 4.06 (s, 6′-OMe), 7.36—7.87 (m, Ph), 8.03 (s, α-H, β-H), 13.63 (s, OH)
(26)	2.38 (s, OAc), 4.01 (s, 4′- and 6′-OMe), 5.47 (s, α- and β-H), 6.53 (s, 5′-H), 7.51 (s, Ph)
(27)	2.37 (s, OAc), 4.03 (s, 4′-OMe), 4.05 (s, 6′-OMe), 5.43 (d, *J* 11, β-H), 5.56 (d, α-H), 6.72 (s, 3′-H), 7.54 (s, Ph)
(29)	2.23 (s, OAc), 3.86 (s, 4′-OMe), 4.02 (s, 6′-OMe), 6.57 (s, 5′-H), 7.28—8.06 (m, β-H, Ph)
(30)	2.17 (s, OAc), 3.91 (s, 4′-OMe), 3.97 (s, 6′-OMe), 6.71 (s, 3′-H), 7.27—8.08 (m, β-H, Ph)
(32)	*cis*-Isomer: 4.00 (s, 7-OMe), 4.06 (s, 5-OMe), 4.46 (d, *J* 2, 3-H), 5.83 (d, 2-H), 6.32 (s, 6-H), 7.40—7.79 (m, Ph). *trans*-Isomer: 4.00 (s, 7-OMe), 4.06 (s, 5-OMe), 4.83 (d, *J* 8, 3-H), 5.66 (d, 2-H), 6.29 (s, 6-H), 7.40—7.79 (m, Ph)
(33)	*cis*-Isomer: 3.98 (s, 7-OMe), 4.01 (s, 5-OMe), 4.42 (d, *J* 2, 3-H), 5.76 (d, 2-H), 6.63 (s, 8-H), 7.39—7.74 (m, Ph). *trans*-Isomer: 3.98 (s, 7-OMe), 4.01 (s, 5-OMe), 4.87 (d, *J* 10, 3-H), 5.49 (d, 2-H), 6.52 (s, 8-H), 7.39—7.74 (m, Ph)
(34)	4.04 (s, 7-OMe), 6.54 (s, 6-H), 6.80 (s, 3-H), 7.36—8.23 (m, Ph), 12.89 (s, OH)
(35)	4.04 (s, 7-OMe), 6.63 (s, 8-H), 6.74 (s, 3-H), 7.29—8.08 (m, Ph), 13.37 (s, OH)
(38)	2.40 (s, OAc), 5.77 (s, α- and β-H), 7.16—8.27 (m, Ar)
(41)	2.18 (s, OAc), 7.10—8.42 (m, β-H, Ar)
(42)	2.18 (s, OAc), 7.19—8.35 (m, β-H, Ar)
(44)	5.72 (d, *J* 11, β-H), 6.16 (d, α-H), 7.06 (d, *J* 9,3′- and 5′-H), 7.31—7.84 (m, Ph), 8.16 (d, 2′- and 6′-H), 9.32 (s, OH)
(46)	2.37 (s, OAc), 5.50 (s, α- and β-H), 7.19—8.29 (m, Ar)
(48)	2.36 (s, OAc), 7.24—8.07 (m, β-H, Ar)
(49)	2.34 (s, OAc), 6.78—8.06 (m, β-H, Ar)

An attempt to compare the pyrolyses of the above four classes of *o*-hydroxylated chalcone dihalides with that of similar but non-*o*-hydroxylated dihalides failed. The conditions for pyrolysing, at all cleanly, 4′-hydroxychalcone dibromide (44) and dichloride (45) were not found; even the dichloride produced a complex mixture of many products. Bromination of 4′-hydroxychalcone gave 4′-hydroxychalcone dibromide (44). The chalcone had to be acetylated, however, before chlorination, when

TABLE 2

Halogenation of chalcones

Halogen	Solvent	Substrate	Product	M.p. (°C) (Crystallization solvent)
Cl_2 (4.5 g)	CCl_4 (190 ml)	2′-Hydroxychalcone (21) (6.7 g)	2′-*Hydroxychalcone dichloride* (4) (2.0 g)	152—154 (EtOH)
Cl_2 (1.43 g)	CCl_4 (430 ml)	2′-Acetoxy-4′,6′-dimethoxychalcone (22) (6.0 g)	2′-*Acetoxy*-3′-*chloro*-4′,6′-*dimethoxychalcone dichloride* (26) (5.3 g)	180—182 (EtOH–H_2O)
Cl_2 (0.13 g)	CCl_4 (30 ml)	2′-Acetoxy-5′-chloro-4′,6′-dimethoxychalcone (0.5 g)	2′-*Acetoxy*-5′-*chloro*-4′,6′-*dimethoxychalcone dichloride* (27) (0.38 g)	145—146 (EtOH–H_2O)
Cl_2 (0.1 g)	CCl_4 (40 ml)	5′-Chloro-2′-hydroxy-4′,6′-dimethoxychalcone [6] (23) (0.5 g)	3′ 5′-*Dichloro*-2′-*hydroxy*-4′,6′-*dimethoxychalcone* (24) (0.234 g)	109—111 (EtOH–H_2O)
Cl_2 (1.6 g)	CCl_4 (170 ml)	2′-Hydroxy-4-methoxychalcone (5 g)	2′-*Hydroxy*-4-*methoxychalcone dichloride* (6) (2.7 g)	142—144 (benzene)
Cl_2 (1.9 g)	CCl_4 (130 ml)	2-Acetoxychalcone (5 g)	2-*Acetoxychalcone dichloride* (38) (4.54 g)	107—109 [light petroleum (b.p. 40—60°C)–diethyl ether]
Cl_2 (0.14 g)	CCl_4 (20 ml)	4′-Acetoxychalcone (0.5 g)	4′-*Acetoxychalcone dichloride* (46) (0.36 g)	126—128 (EtOH–H_2O)
Br_2 (2.0 g)	AcOH (55 ml)	4′-Hydroxychalcone (2.2 g)	4′-*Hydroxychalcone dibromide* (44) (2.35 g)	175—176 (EtOH–H_2O)

4′-acetoxychalcone gave 4′-acetoxychalcone dichloride (46); hydrolysis of the latter with ethanolic hydrochloric acid gave 4′-hydroxychalcone dichloride (45). (*Z*)-α-Chloro-4′-hydroxychalcone (47), obtained by dehydrochlorinating 4′-acetoxychalcone dichloride (46) with potassium acetate and hydrolysing the resulting (*Z*)-4′-acetoxy-α-chlorochalcone (48), was prepared in an unsuccessful attempt to detect this compound by t.l.c. or n.m.r. spectroscopy among the pyrolysis products of 4′-hydroxychalcone dichloride (45).

TABLE 3

Dehydrohalogenation of chalcone halides

Substrate	Solvent	Reagent	Product	M.p. (°C)
2′-Hydroxychalcone dichloride (4) (0.4 g)	Me_2CO (25 ml)	KOAc (0.14 g)	(Z)-α-*chloro*-2′-*hydroxychalcone* (10) (0.202 g)	oil
2′-Hydroxychalcone dibromide (5) (0.39 g)	Me_2CO (35 ml)	KOAc (0.15 g)	(E)-α-*bromo*-2′-*hydroxychalcone* (8) (0.182 g)	oil
2′-Hydroxychalcone dibromide (5) (0.1 g)	Me_2SO (5 ml)	NaOAc (40 mg)	Flavone (17) (52 mg)	96—97
2′-Hydroxychalcone dibromide (5) (0.975 g)	EtOH (150 ml)	KOAc (0.375 g)	(*E*)-α-bromo-2′-hydroxychalcone (8) (0.164 g)	oil
			cis- and *trans*-3-bromoflavanone [a] (15) (0.232 g)	oil
			flavone (17) (59 mg)	95—96
2′-Acetoxy-3′-chloro-4′,6′-dimethoxychalcone dichloride (26) (4 g)	EtOH (500 ml) H_2O (200 ml)	HCl-H_2O (10%; 100 ml) [b]	(Z)-2′-*acetoxy*-α,3′-*dichloro*-4′,6′-*dimethoxychalcone* (29) (2.4 g)	164—165 (EtOH–$CHCl_3$)
2′-Acetoxy-3′-chloro-4′,6′-dimethoxychalcone dichloride (26) (0.3 g)	Me_2CO (20 ml) H_2O (1 ml)	KOAc (0.22 g)	(*Z*)-2′-acetoxy-α,3′-dichloro-4′,6′-dimethoxychalcone (29) (0.23 g)	164 (EtOH–$CHCl_3$)
2′-Acetoxy-5′-chloro-4′,6′-dimethoxychalcone dichloride (27) (0.3 g)	Me_2CO (20 ml) H_2O (1 ml)	KOAc (0.105 g)	(Z)-2′-*acetoxy*-α,5′-*dichloro*-4′,6′-*dimethoxychalcone* (30) (0.234 g)	149—151 (EtOH–$CHCl_3$)
2′-Hydroxy-4-methoxychalcone dichloride (6) (0.5 g)	Me_2CO (25 ml)	KOAc (0.16 g)	(Z)-α-*chloro*-2′-*hydroxy*-4-*methoxychalcone* (12) (0.275 g)	102—104 (EtOH–H_2O)
2′-Hydroxy-4-methoxychalcone dibromide (7) (1.0 g)	Me_2CO (50 ml)	KOAc (0.36 g)	(E)-α-*bromo*-2′-*hydroxy*-4-*methoxychalcone* (9) (0.478 g)	98—99 (EtOH–H_2O)
			(Z)-α-*bromo*-2′-*hydroxy*-4-*methoxychalcone* (13) (0.122 g)	113—114 (EtOH–H_2O)
2-Acetoxychalcone dichloride (38) (0.96 g)	Me_2CO (70 ml)	KOAc (0.4 g)	(Z)-2-*Acetoxy*-α-*chlorochalcone* (41) (0.73 g)	68—69 (EtOH–H_2O)
3,5-Dibromo-2-hydroxychalcone dibromide [16] (39) (0.54 g)	Me_2CO (40 ml) H_2O (2 ml) H_2O (2 ml)	KOAc (0.3 g)	2-Benzoyl-5,7-dibromobenzofuran [7b] (43) (84 mg)	166—167 (EtOH–H_2O)
2-Acetoxychalcone dibromide (40) (1.0 g)	Me_2CO (50 ml)	KOAc (0.5 g)	(E)-2-*Acetoxy*-α-*bromochalcone* (49) (0.208 g)	oil
			(Z)-2-*Acetoxy*-α-*bromochalcone* (42) (0.201 g)	81—82 (EtOH–H_2O)
4′-Acetoxychalcone dichloride (46) (2.5 g)	Me_2CO (50 ml)	KOAc (1.1 g)	(Z)-4′-*Acetoxy*-α-*chlorochalcone* (48) (1.34 g)	79—80 (EtOH–H_2O)

[a] From which the *cis*-isomer (B. G. Bolger, K. G. Marathe, E. M. Philbin, T. S. Wheeler, and C. P. Lillya, *Tetrahedron*, 1967, **23**, 341) (90 mg) crystallized, m.p. 106—108 °C (light petroleum, b.p. 60—80 °C). [b] Refluxed for 1.5 h with or without the hydrochloric acid. Water (200 ml) then added and heating continued for a further 12 h.

TABLE 4

Substrate	Reaction temperature (°C)	Reaction time	Product	M.p. (°C)
2′-Hydroxychalcone dichloride (4) (0.5 g)	200	1.5 h	Substrate (57 mg; 11%)	
			cis- and trans-3-*chloroflavanone* [a] (14) (0.28 g; 64%)	oil
			flavone (17) (27 mg; 7%)	94—95
2′-Hydroxychalcone dichloride (4) (0.5 g)	210—220	1.5 h	flavone (17) (0.337 g; 90%)	94—95
(*Z*)-α-Chloro-2′-hydroxychalcone (10) (90 mg)	200	1 h	substrate (trace)	
			cis- and *trans*-3-chloroflavanone [a] (14) (10 mg; 11%)	oil
			flavone (17) (45 mg; 58%)	93—95
(*Z*)-α-Chloro-2′-hydroxychalcone (10) (30 mg)	200	2 h	flavone (17) (13 mg; 50%)	94—95
cis- and *trans*-3-Chloroflavanone (14) (0.225 g)	200	3 h	flavone (17) (0.11 g; 57%)	94—95
2′-Hydroxychalcone dibromide (5) (0.3 g)	200	10 min	2′-hydroxychalcone (21) (10 mg; 6%)	86—88
			flavanone (20) (25 mg; 14%)	75—76
			6-bromoflavone [b] (19) (34 mg; 14%)	190—192
			flavone (17) (62 mg; 36%)	93—95
(*E*)-α-Bromo-2′-hydroxychalcone (8) (0.35 g)	200	2 min	substrate (0.19 g; 54%)	
			(*Z*)-α-bromo-2′-hydroxychalcone (11) (0.14 g; 40%)	oil
(*Z*)-α-Bromo-2′-hydroxychalcone (11) (0.148 g)	200	10 min	flavone (17) (54 mg; 50%)	96—97
2′-Acetoxy-3′-chloro-4′,6′-dimethoxychalcone dichloride (26) (0.3 g)	200	1 h	(*Z*)-2′-acetoxy-α,3′-dichloro-4′,6′-dimethoxychalcone (29) (0.129 g; 47%)	164
			cis- and trans-3,8-*dichloro*-5,7-*dimethoxyflavanone* [a] (32) (57 mg; 23%)	220—225 (EtOH–H_2O)
2′-Acetoxy-3′-chloro-4′,6′-dimethoxychalcone dichloride (26) (0.15 g)	205—210	1.5 h	8-*chloro*-5-*hydroxy*-7-*methoxyflavone* (34) (26 mg; 25%)	238—240 (EtOH–H_2O)
(*Z*)-2′-Acetoxy-α,3′-dichloro-4′,6′-dimethoxychalcone [c] (29) (0.27 g)	200	1.25 h	substrate (0.102 g; 38%)	
			cis- and *trans*-3,8-dichloro-5,7-dimethoxyflavanone [b] (32) (81 mg; 34%)	223—229
2′-Acetoxy-5′-chloro-4′,6′-dimethoxychalcone dichloride (27) (0.3 g)	200	1.5 h	cis- and trans-3,6-*dichloro*-5,7-*dimethoxyflavanone* [a,d] (33) (0.101 g; 41%)	134—136 (EtOH–H_2O)
			(*Z*)-2′-acetoxy-α,5′-dichloro-4′,6′-dimethoxychalcone (30) (0.118 g; 43%)	148
2′-Acetoxy-5′-chloro-4′,6′-dimethoxychalcone dichloride (27) (0.3 g)	200	2 h	6-*chloro*-5-*hydroxy*-7-*methoxyflavone* (35) (0.117 g; 56%)	215—216 (EtOH–H_2O)
(*Z*)-2′-Acetoxy-α,5′-dichloro-4′,6′-dimethoxychalcone [b] (30) (0.27 g)	200	1.5 h	*cis*- and *trans*-3,6-dichloro-5,7-dimethoxyflavanone (33) (0.111 g; 46%)	oil
			substrate (83 mg; 31%)	
2′-Hydroxy-4′,6′-dimethoxychalcone dibromide [11] (28) (0.3 g)	170	5 min	substrate (95 mg; 32%)	165—167
			3′-bromo-2′-hydroxy-4′,6′-dimethoxychalcone [6b] (25) (44 mg; 18%)	182
2′-Hydroxy-4′,6′-dimethoxychalcone dibromide (28) (0.3 g)	180	10 min	5-hydroxy-7-methoxyflavone [e] (36) (52 mg; 29%)	165
(*E*)-α-Bromo-2′-hydroxy-4′,6′-dimethoxychalcone [f] (0.2 g)	150	0.5 h	5-Hydroxy-7-methoxyflavone [e] (36) (81 mg; 55%)	165
2′-Hydroxy-4-methoxychalcone dichloride (6) (0.5 g)	200	20 min	substrate (47 mg; 9%)	
			cis- and trans-3-*chloro*-4′-*methoxyflavanone* [a] (16) (0.27 g; 61%)	>90 (EtOH)
			4′-methoxyflavone (18) (62 mg; 16%)	156—158
2′-Hydroxy-4-methoxychalcone dichloride (6) (0.5 g)	200	1 h	4′-methoxyflavone (18) (0.277 g; 71%)	156—158
(*Z*)-α-Chloro-2′-hydroxy-4-methoxychalcone (12) (0.1 g)	160	4 h	substrate (33 mg; 33%)	
			cis- and *trans*-3-chloro-4′-methoxyflavanone [a] (16) (36 mg; 36%)	oil
			4′-methoxyflavone (18) (6 mg; 7%)	154—155
(*Z*)-α-Chloro-2′-hydroxy-4-methoxychalcone (12) (0.1 g)	200	1.5 h	4′-methoxyflavone (18) (65 mg; 74%)	155—157
cis- and *trans*-3-Chloro-4′-methoxyflavanone (16) (0.18 g)	200	2 h	4′-methoxyflavone (18) (80 mg; 51%)	155—157
2′-Hydroxy-4-methoxychalcone dibromide (7) (0.3 g)	150	5 min	2′-hydroxy-4-methoxychalcone (23 mg; 12%)	92—93
			3-bromo-4′-methoxyflavone [8] (37) (15 mg; 6%)	144—145
			4′-methoxyflavone (18) (0.103 g; 56%)	157—158
(*E*)-α-Bromo-2′-hydroxy-4-methoxychalcone (9) (0.15 g)	150	30 min	substrate (29 mg; 19%)	
			(*Z*)-α-bromo-2′-hydroxy-4-methoxychalcone (13) (0.107 g; 71%)	113—115
(*Z*)-α-Bromo-2′-hydroxy-4-methoxychalcone (13) (70 mg)	150	50 min	4′-Methoxyflavone (18) (6 mg; 11%)	151—153
2-Acetoxychalcone dichloride (38) (0.35 g)	200	30 min	(*Z*)-2-acetoxy-α-chlorochalcone (41) (0.129 g; 41%)	66—67
2-Acetoxychalcone dibromide (40) (0.3 g)	150	10 min	2-acetoxychalcone (19 mg; 10%)	oil

[a] Inseparable mixture. [b] N. A. Bhagwat and T. S. Wheeler, *J. Chem. Soc.*, 1939, 94. [c] Plus five drops of hydrochloric acid. [d] This compound lost HCl too readily to be completely purified (it discolours overnight). The best elemental analysis obtained was as follows. Found: C, 59.2; H, 4.2; Cl, 18.6. $C_{17}H_{14}Cl_2O_4$ requires C, 57.8; H, 4.0; Cl, 20.1%. [e] L. Reichel and G. Proksch, *Annalen*, 1971, **745**, 59. [f] J. A. Donnelly and H. J. Doran, *Tetrahedron*, 1975, **31**, 1791.

EXPERIMENTAL

^{1}H N.m.r. spectra of all products were obtained at 60 MHz in $CDCl_3$ with $SiMe_4$ as internal reference. The details are given in Table 1. Hydroxy-signals were identified by deuteriation. M.p.s were taken with a Kofler hot-stage apparatus. Satisfactory analyses were obtained for new compounds and are deposited as Supplementary Publication No. SUP 22733 (3 pp.).* Mixtures were fractionated by preparative thin layer chromatography (p.l.c.) on silica gel; products are mentioned in order of decreasing R_F values.

General Procedure for Halogenation.—A solution (*ca.* 10%) of the halogen was added dropwise to a stirred solution of the substrate in the remainder of the solvent. After 3 h, the solvent was removed under reduced pressure. The residue was then crystallized. Details are given in Table 2.

General Procedure for Dehydrohalogenation.—A solution of the dihalide, containing potassium or sodium acetate, was stirred for 2—5 h, diluted with water and extracted with chloroform. The extract was evaporated to dryness and the residue was purified by t.l.c. Details are given in Table 3.

General Procedure for Pyrolysis.—The halides were pyrolysed in bulk at the stated temperatures; pyrolysis of bromides was carried out under N_2. The residues were purified by t.l.c. Details are given in Table 4.

A solution of 5′-chloro-2′-hydroxy-4′,6′-dimethoxychalcone [6] (23) (1.4 g) in acetic anhydride (8 ml) was heated with sodium acetate (1.4 g) on a steam-bath for 1 h and poured onto ice. The precipitate crystallized from aqueous ethanol as pale yellow needles of *2′-acetoxy-5′-chloro-4′,6′-dimethoxychalcone* (1.14 g), m.p. 104—105 °C; δ 2.21 (s, OAc), 3.89 (s, 4′-OMe), 3.99 (s, 6′-OMe), 6.68 (s, 3′-H), and 7.20—7.78 (m, Ph, α-H, β-H).

A solution of (*Z*)-2-acetoxy-α-chlorochalcone (41) (0.2 g) in n-pentane (250 ml) was irradiated with u.v. light for 24 h. The solvent was removed under reduced pressure and the residue was fractionated by t.l.c. to give (E)-2-*acetoxy-α-chlorochalcone* as an oil (93 mg); δ 2.38 (s, OAc) and 6.98—8.12 (m, β-H, Ar). Some substrate (60 mg) was also isolated.

* For details of the Supplementary Publications scheme, see *J.C.S. Perkin I*, 1979, Index issue.

A solution of 4′-acetoxychalcone dichloride (46) (0.31 g) in ethanol (25 ml), water (10 ml), and dilute hydrochloric acid (10%; 5 ml) was refluxed for 1.5 h and diluted with water (50 ml). The precipitate crystallized from methanol, giving *4′-hydroxychalcone dichloride* (45), m.p. 159—161 °C; δ 5.51 (d, *J* 11 Hz, β-H), 5.79 (d, α-H), 7.04 (d, *J* 9 Hz, 3′-H, 5′-H), 7.35—7.78 (m, Ph), 8.14 (d, 2′-H, 6′-H), and 9.31 (s, OH).

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