Tetrahedron. Vol 28, pp. 493 to 504 Pergamon Press 1972. Printed in Great Britain

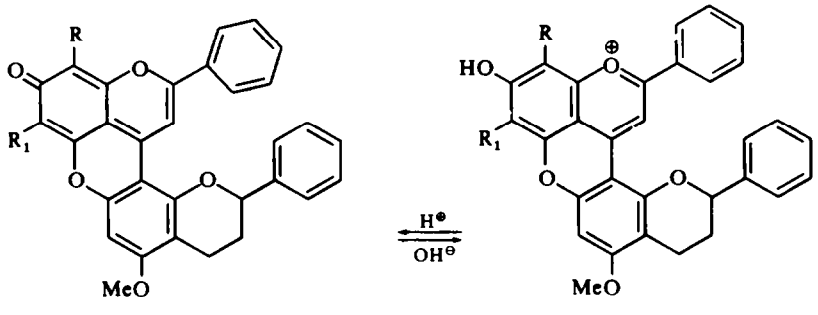
ANTHOCYANIDINS AND RELATED COMPOUNDS—XVI
THE DIMERIZATION OF FLAVYLIUM SALTS IN AQUEOUS SOLUTIONS

L. JURD
Western Regional Research Laboratory, Agricultural Research Service,
U.S. Department of Agriculture, Berkeley, California, 94710

(*Received in the USA* 13 *October* 1971; *Received in the UK for publication* 26 *October* 1971)

Abstract—7-Hydroxyflavylium salts dimerize in aqueous acetic acid solutions to form benzopyrylium salts substituted at position 4 with the corresponding dihydrochalcone nucleus. It is proposed that this dimerization involves initial condensation of the flavylium salt and its carbinol base to give a product which then undergoes a series of intermolecular hydride ion transfer reactions. It is also suggested that flavones are formed as by-products in these flavylium dimerization reactions.

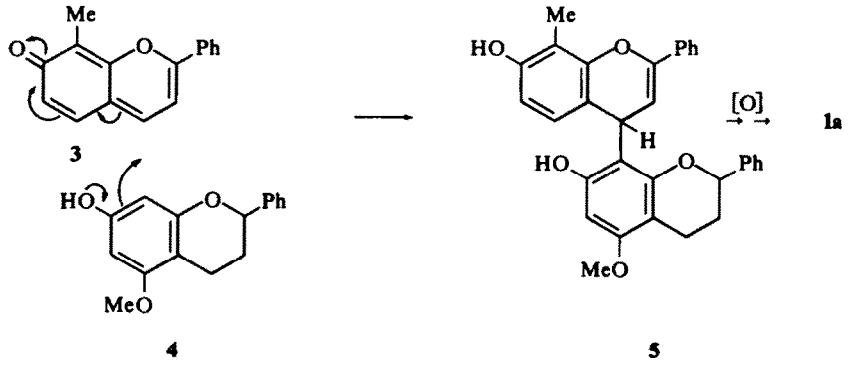
SINCE 1965[1–3] an increasing variety[4–8] of colorless bisflavanoids have been detected in plant extracts. Many of these compounds are formed as a result of flavan-4-ol or flavan-3,4-diol condensation reactions,[9] and contain two or more flavanoid nuclei linked by C—C or C—O bonds[10] from the 4-position of one nucleus. Dracorubin, a highly coloured anhydro base present in the resin of the palm, *Dracaena draco*, represents an unusual type of natural bisflavanoid. It has been[11] assigned structure **1a** or **1b**, and with acids forms orange-red dracorubylium salts (**2a** or **2b**). Dracorubin has not yet been synthesized,[12] although it has been suggested that dracorubin-type



1a; R = Me, R_1 = H
1b; R = H, R_1 = Me

2a; R = Me, R_1 = H
2b: R = H, R_1 = Me

compounds may be formed biosynthetically by oxidation of 5, 7-dihydroxyflavans,[13] or by oxidative condensations of 7-hydroxy-8 (or 6)-methylflavylium salts[14] or their anhydro bases, e.g., **3**, with phenolic flavans, e.g., **4**. The mechanistic feasibility of this proposal is supported by reports that model flavylium salts condense with



polyphenols,[15] catechin,[16] and other nucleophiles in aqueous media to yield, as initial products, 4-substituted flav-2-enes of type **5**.

In attempting to extend these condensation studies to the synthesis of dracorubin-type compounds, however, we have unexpectedly found that 7-hydroxy-8 (and 6)-methylflavylium salts undergo self-condensation in aqueous media to yield dimeric pigments, which are spectrally and visually similar to the monomeric flavylium salts. This recognition of facile flavylium self-condensation could be significant in two respects, viz. (1) it would suggest that similar dimers might occur naturally in plant extracts containing these or related flavylium salts, and (2) it has recently been

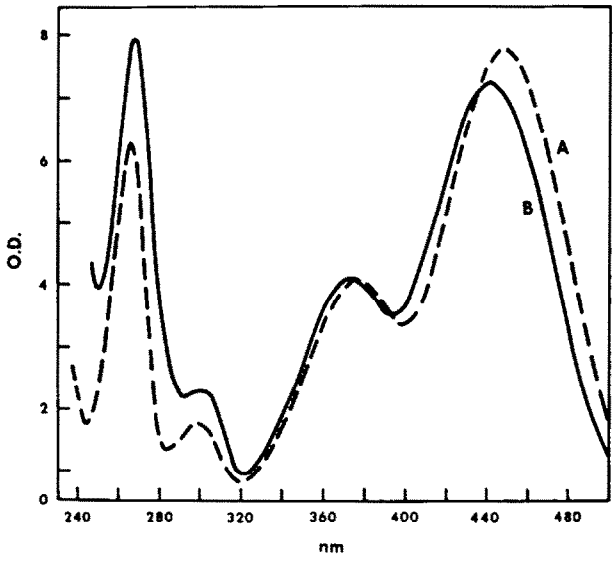


FIG 1. Spectrum in EtOH containing 0·5% HCl of (A) 7-hydroxy-8-methylflavylium chloride (6) (1·088) × 10^{-2} g/l.) and (B) its dimer (11) (2·108 × 10^{-2} g/l.)

established that on long standing in some aqueous media, e.g., as in the aging of red wines,[17] anthocyanins are slowly replaced by tannin-like red pigments, which retain the colour and spectral characteristics of the original monomeric anthocyanins.

The reaction sequence involved in anthocyanin polymerization is obscure. However, hydride ion transfer reactions, which appear to be involved in the flavylium self-condensation reaction under discussion, could provide a rational basis for further understanding of anthocyanin polymerization.

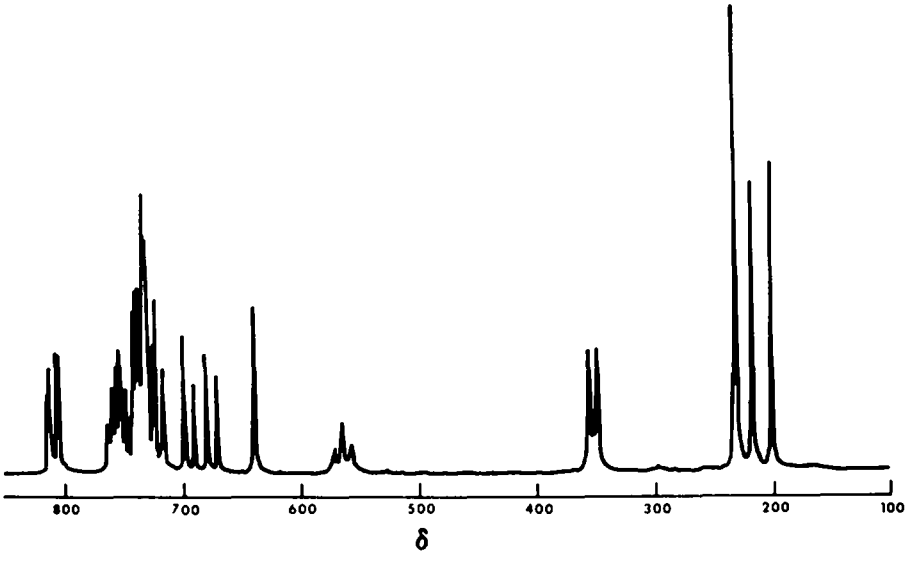
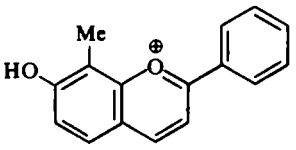


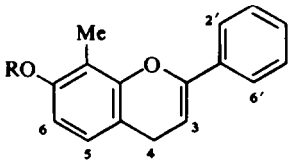
FIG 2. 100 MHz spectrum of 9 in $CDCl_3$: TMS as internal reference

Thus, solutions of 7-hydroxy-8-methylflavylium chloride (**6**) in aqueous AcOH at room temperature slowly deposit a highly coloured, crystalline product. About 60 to 80% conversion to the new product occurs in periods of 10 to 20 days. On paper chromatograms in aqueous HCl media the product has slightly lower R_f values than **6**, and it shows a dull, orange fluorescence under UV light in contrast to the bright, yellow fluorescence shown by **6**. Elemental analyses of the crystalline chloride and perchlorate of the product established its molecular formula as $C_{32}H_{27}O_5X$ (X=Cl or ClO_4). The visible and UV spectrum of the chloride (Fig. 1, B) is similar to that of the flavylium chloride **6** in ethanolic HCl solutions, except that the absorbance at its λ_{max} (443 nm) is only about one-half that of **6** for solutions of the same concentration (in g/l). On the basis of these data the reaction product contains the intact flavylium nucleus of **6**, substituted by a $C_{16}H_{13}O_3$ residue.

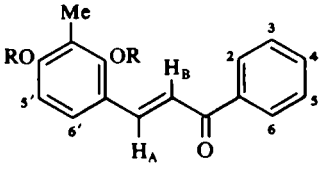
Treated with Ac_2O and a base catalyst the flavylium dimer yields a crystalline, cream-coloured diacetate, $C_{36}H_{30}O_7$. This diacetate has a λ_{max} at 331 nm, suggesting the presence of an unsaturated chromophoric grouping such as occurs in a chalcone. Furthermore, chromatograms of the diacetate instantly become bright yellow-orange on exposure to HCl vapors, a property which is typical of a flav-2-ene. Comparison of the 100 MHz NMR spectrum in $CDCl_3$ of this diacetate with the spectra of 7-acetoxy-8-methylflav-2-ene (**7b**) and trans 2′,4′-diacetoxy-3′-methylchalcone (**8b**) confirms the presence of both the flav-2-ene and the chalcone nuclei, and indicates structure **9** for the dimer acetylation product.



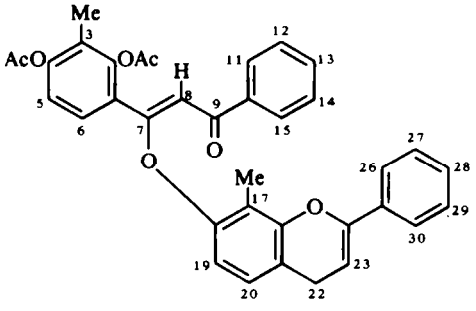
6



7a; R = H
7b; R = Ac



8a; R = H
8b; R = Ac

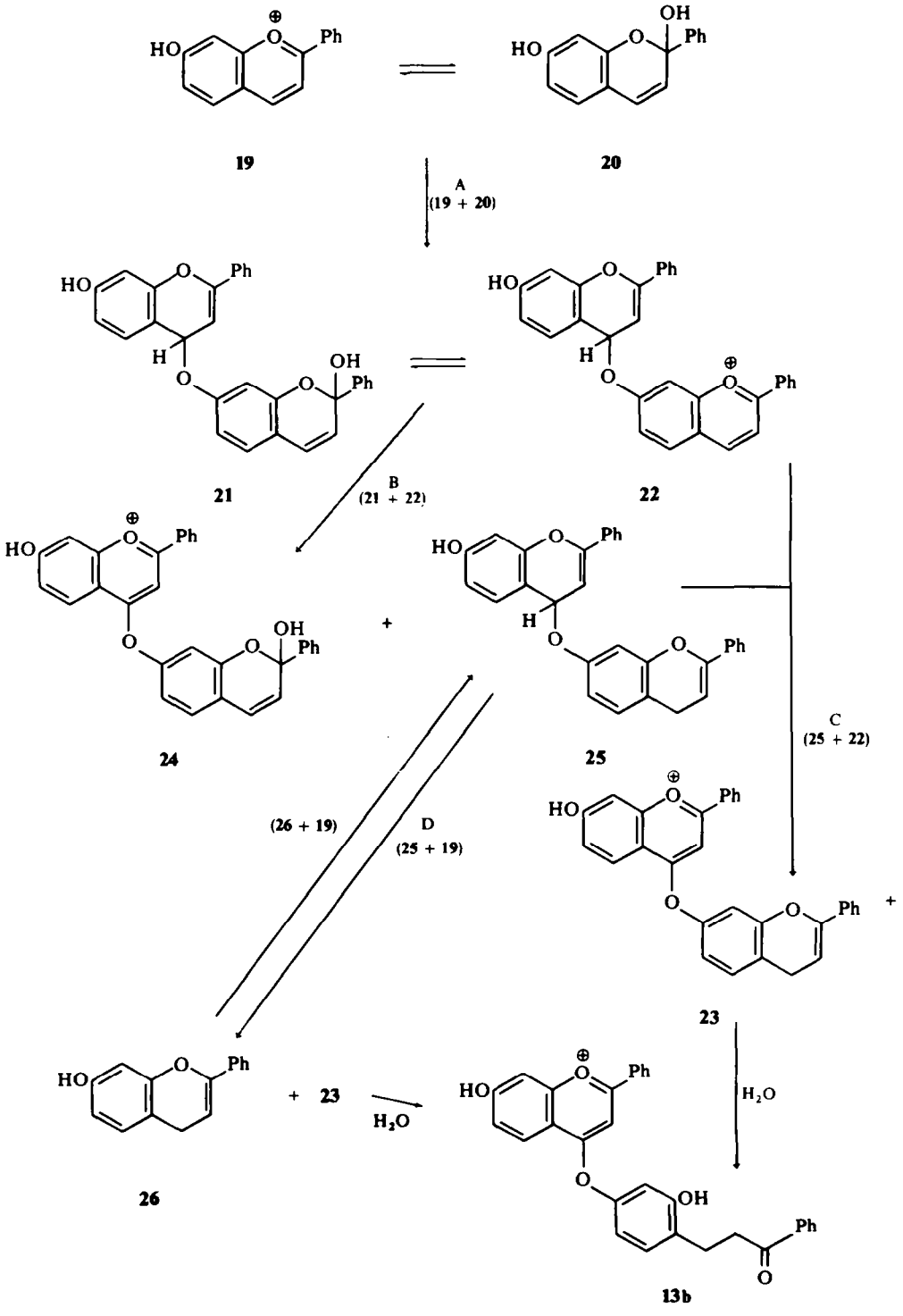


9

7-Acetoxy-8-methylflav-2-ene was prepared by acetylation of the phenolic flav-2-ene (**7a**) from $NaBH_4$ reduction of **6**. The 100 MHz NMR spectrum of **7b** in $CDCl_3$ shows the following proton assignments: benzylic methyl, 3H, δ2·16 (s); acetoxyl methyl, 3H, δ2·27 (s); C_4 methylene, 2H, δ3·49 (d, J = 4·0 Hz); C_3 methine proton, 1H, δ5·46 (t, J = 4·0 Hz). The aromatic protons at C_5 and C_6 appear as ortho-coupled doublets (J = 9·0 Hz) at δ6·65 and δ6·86, and the phenyl ring protons give a multiplet at δ7·18–δ7·70.

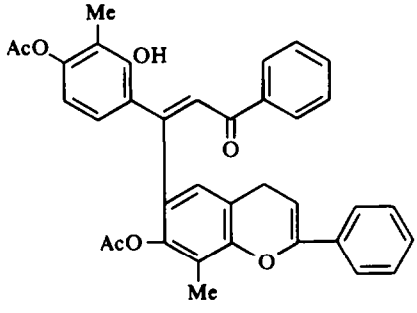
Trans 2′,4′-diacetoxy-3′-methylchalcone was prepared by acetylation of the phenolic chalcone (**8a**), formed by alkaline hydrolysis of **6**. The 100 MHz spectrum of **8b** in $CDCl_3$ shows the following proton assignments: benzylic methyl, 3H, δ2·00 (s); acetoxyl methyls, 3H, δ2·30 (s) and 3H, δ2·36 (s); the ethylenic H_B proton, δ7·44 (d, J = 16·0 Hz); the ethylenic H_A proton, δ7·77 (d, J = 16·0 Hz). The phenyl ring protons at C_2 and C_6, adjacent to the carbonyl group, appear downfield as a 2H multiplet at δ7·93–δ8·05, while the remaining phenyl ring protons appear as a multiplet at δ7·05–δ7·66. The aromatic protons at $C_{5'}$ and $C_{6'}$ give *ortho*-coupled doublets (J = 9·0 Hz) at δ7·02 and δ7·62, respectively.

In the 100 MHz spectrum of diacetate **9** the protons of the two acetoxyl methyl groups appear as 3H singlets at δ2·32 and δ2·34 (Fig 2). The benzylic methyl groups

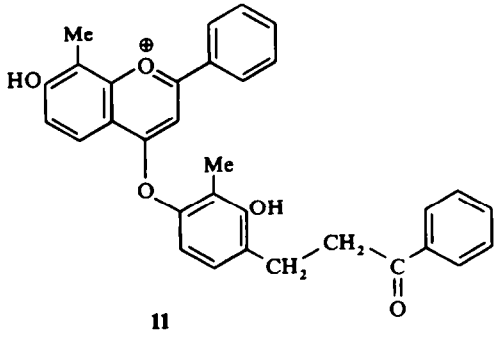

19
20
A
(19 + 20)
21
22
B
(21 + 22)
24
25
C
(25 + 22)
(26 + 19)
D
(25 + 19)
23
26
+ 23
H2O
H2O
13b

at C_3 and C_{17} appear as 3H singlets at δ2·02 and δ2·18, these chemical shifts being in close accord with the chemical shifts of the benzylic methyl protons in **8b** (δ2·00) and **7b** (δ2·16). The presence of the C_{22} methylene group and the C_{23} methine proton is confirmed by the 2H doublet at δ3·52 (J = 7·0 Hz) coupled to a 1H triplet at δ5·64 (J = 7·0 Hz). The larger coupling constant between the C_{22} and C_{23} protons, compared with the coupling constant between the C_3 and C_4 protons in **7b**, is probably due to steric stabilization of the flav-2-ene unit into one favoured conformation in the dimer acetate. The ethylenic proton at C_8 appears as a sharp, 1H singlet at δ6·39. The upfield shift of this proton, relative to the corresponding H_B proton in the chalcone **8b**, is a result of the expected shielding by the ethereal oxygen at C_7.

The NMR spectrum of the dimer acetate establishes the presence of 14 aromatic protons. Structures of type **10**, in which the chalcone and flavene nuclei are C—C linked and which might be anticipated on the basis of previous[15,16] flavylium salt-polyphenol condensation studies, contain only 13 aromatic protons, and, therefore, can be excluded. Additional evidence against structure of type **10** is provided by the pronounced upfield shift of the ethylenic proton at C_8, and by the fact that acetylation of the flavylium dimer gave only a diacetate,[22] rather than the triacetate which would be expected on the basis of formula **10**. Because of the multiplicity of signals



10



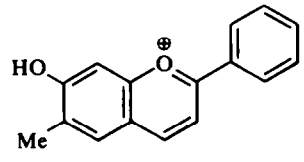
11

in the aromatic region of the spectrum of the dimer acetate their assignment to specific protons is, in general, not certain. However, in accord with structure **9**, the C_{11} and C_{15} protons adjacent to the carbonyl group appear downfield as a well-defined 2H multiplet at δ8·07–δ8·17. The splitting pattern of this 2H multiplet is

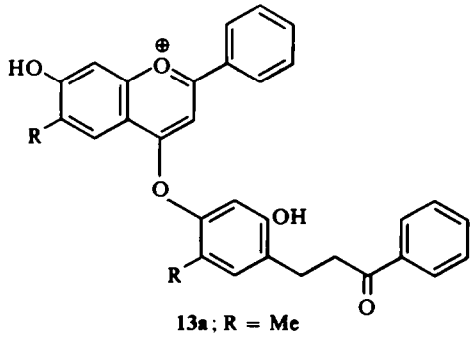
identical with that of the 2H multiplet given by the C_2 and C_6 protons of **8b**. The remaining 8 phenyl ring protons of the dimer acetate appear as a multiplet at δ7·15–δ7·66. Two doublets at δ6·76 (J = 9·0 Hz) and δ6·95 (J = 9·0 Hz) may be assigned to the protons at C_5 and C_{20}. The protons at C_6 and C_{19}, to which the C_5 and C_{20} protons are *ortho*-coupled, appear in the region δ7·15–δ7·66 and are obscured by the phenyl ring proton signals. Models indicate that the paramagnetic shift of the proton at C_{19}, as compared with the chemical shift of the corresponding C_5 proton in **7b**, is due to deshielding by the carbonyl group at C_9.

Acetylation of flavylium salts often yields acetates of the corresponding 2′-hydroxychalcones.[18] Furthermore, flav-2-enes are easily hydrolyzed in aqueous AcOH to dihydrochalcones.[16] On the basis of these two observations, the molecular formula and properties of the flavylium self-condensation product are accounted for by structure **11**. Formation of the diacetate **9** from **11** involves ring opening of the flavylium nucleus to form the acetylated chalcone unit, and ring closure by dehydration of the dihydrochalcone nucleus to form the flav-2-ene unit. The validity of this structural assignment is confirmed by determination of the NMR spectrum of the flavylium dimer in trifluoroacetic acid. The two methylene groups of the dihydrochalcone unit appear as coupled 2H triplets (J = 6·0 Hz) at δ3·24 and δ3·62. The benzylic methyls appear as 3H singlets at δ 2·08 and δ2·74, while the remaining 17 protons form a multiplet at δ6·96–δ8·12.

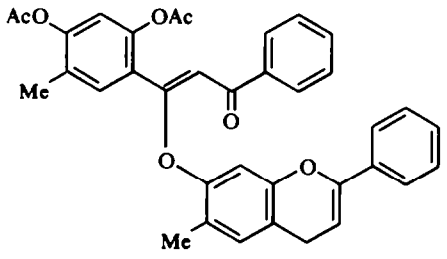
Like **6**, the isomeric 7-hydroxy-6-methylflavylium chloride **12** dimerizes in aqueous AcOH to yield the crystalline pigment **13a**. Structure of this product was confirmed by the appearance of the two methylene triplets at δ3·24 and δ3·63 in the NMR spectrum in TFA, and by acetylation to give the crystalline diacetate **14**. The 100 MHz spectrum of **14** in $CDCl_3$ showed the presence of the same structural features as in **9**. As expected, however, the two *ortho*-coupled protons at δ6·76 and δ6·95 in **9**, appear as *para*-coupled singlets at δ6·82 and δ6·95 in the spectrum of **14**. 7-Hydroxyflavylium chloride dimerizes very readily in dilute aqueous AcOH. Since



12



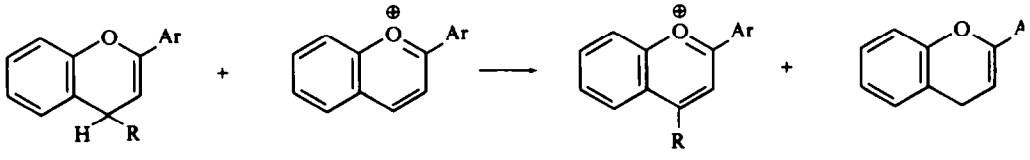
13a; R = Me
13b: R = H



14

the NMR spectrum of this product in TFA shows the present of two methylene groups, it is assigned the analogous structure **13b**. A crystalline acetate, however, could not be prepared from this dimer for structural verification.

The reaction sequence leading to flavylium dimerization can be rationalized on the basis of the established equilibrium reactions of flavylium salts in aqueous solutions and the known susceptibility of 4-substituted flav-2-enes to oxidation[16] by flavylium salts. The latter oxidation-reduction reaction occurs in aqueous acid media and involves intermolecular hydride ion transfer from the flav-2-ene to a flavylium nucleus, e.g., **15** + **16** → **17** + **18**.



15 16 17 18

In aqueous media at pH 2-pH 6, 7-hydroxyflavylium salts **19** form complex equilibrium mixtures with their corresponding anhydro bases, carbinol bases **20** and 2′-hydroxychalcones.[19] The flavylium dimerization process may be accounted for by initial nucleophilic attack of the 7-hydroxyl of the carbinol base **20** on the flavylium cation **19** or its anhydro base to give **21** ⇌ **22** (reaction A, Fig 3).

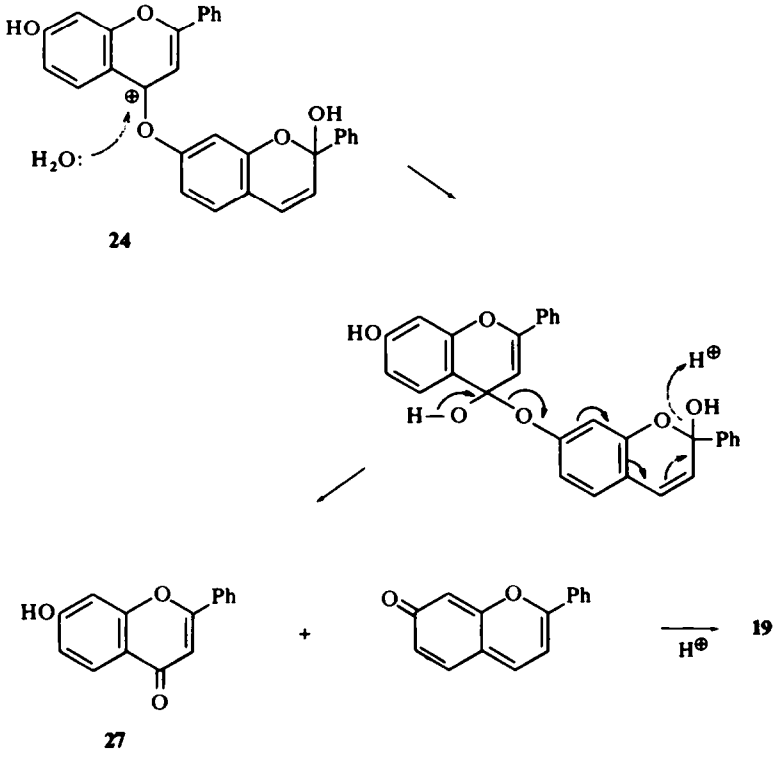
The cationic form **22** of the initial condensation product may then undergo an intramolecular hydride ion transfer to give **23**, which would give the isolated flavylium dimer **13b** on acid hydrolysis of the flav-2-ene ring. It is considered more probable, however, that the conversion of **21** or **22** into **23** is a multi-step process involving a series of intermolecular hydride ion shifts. The first of these involves hydride ion transfer from the 4- substituted flav-2-ene **21** to its cationic form **22** to yield **24** and **25** (reaction B).

Hydride ion transfer from **25** to a flavylium receptor then gives **23**, which is subsequently hydrolyzed to the flavylium dimer **13b**. The flavylium receptor may be the initial cationic condensation product **22** (reaction C), and/or the original monomeric flavylium salt **19** (reaction D). It will be noted that in reaction C **25** is regenerated from **22**, thereby allowing continual repetition of the reaction, at a rate independent of the rate of reaction B, until conversion to **23**, and subsequently **13b**, is complete.

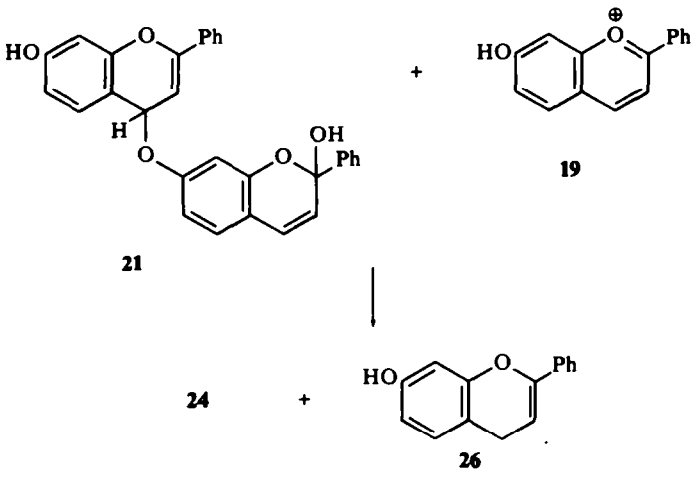
In reaction D with the flavylium salt **19** as receptor, hydride ion transfer from **25**

yields **23** and the monomeric flav-2-ene **26**. Reaction D is analogous to that which has been shown[16] to occur in flavylium-catechin condensations. The flav-2-ene **26** formed in this reaction would be expected to condense with a second molecule of flavylium salt **19** and thereby regenerate **25**. The net result of the reaction sequence D is repeated conversion of the flavylium salt **19** to the dimer **13b**.

It has previously been reported[20] that solutions of some flavylium salts yield small quantities of the corresponding flavones on standing. In accord with this, flavones have been isolated or detected chromatographically as minor products in the dimerization reactions under discussion, and also from aqueous AcOH and MeOH solutions of a number of other flavylium salts. The mechanism of flavone formation is obscure, although it is commonly believed to be due to aerial oxidation of the flavylium salts. It is now suggested, however, that flavones are by-products of the intermolecular hydride ion transfer reactions involved in flavylium dimerization. Thus compound **24**, which is formed in the slow reaction B (Fig 3), is not involved in the subsequent flavylium dimerization processes. Hydration of **24** in aqueous acid media would be expected to lead to its decomposition to the flavone **27** and flavylium salt **19**: The



flavone-precursor **24** may also be formed by a secondary reaction involving hydride ion transfer from the initial flavylium condensation product **21** to the flavylium salt **19**.



EXPERIMENTAL

7-Hydroxy-8-methylflavylium chloride (**6**). A solution of 2,4-dihydroxy-3-methylbenzaldehyde (12·0 g) and acetophenone (9·6 g) in EtOAc (50 ml) and EtOH (15 ml) was cooled in an ice-bath, saturated with HCl gas and kept for 24 hr at 0°. Ether (200 ml) was added and the orange crystals were collected (19·0 g). The crude flavylium salt (25 g) was purified by dissolving it in hot AcOH (150 ml) and H_2O (450 ml) (norite). The chloride crystallized on adding conc HCl (150 ml). Recrystallized from AcOH—10% aqueous HCl, *7-hydroxy-8-methylflavylium chloride* separated as orange needles, m.p. 244–245° (lit.[21] m.p. 127°); λ_{max} 448 (4·29), 376 (4·01), 299 (3·52), 267 (4·19) nm (Log E) ETOH–0·5% HCl), R_f 0·88 (H_2O–AcOH-conc. HCl, 80:40:5 V/V), 0·79 (H_2O–AcOH-conc. HCl, 80:20:5 V/V). (Found: C, 70·4; H, 4·83. Calc. for $C_{16}H_{13}O_2Cl$: C, 70·5; H, 4·80%).

The *perchlorate* of **6**, prepared by adding excess of 10% aqueous $HClO_4$ to a solution of the chloride in AcOH, crystallized from glacial AcOH as orange coloured plates, m.p. 238° (lit.[21] m.p. 187°). (Found: C, 57·2; H, 3·90. Calc. for $C_{16}H_{13}O_6$ Cl: 57·0; H, 3·89%).

Dimerization of 7-hydroxy-8-methylflavylium chloride. A solution of 7-hydroxy-8-methylflavylium chloride (5·0 g) in warm glacial AcOH (50 ml) and H_2O (100 ml) was kept at room temperature for two weeks. Highly coloured crystals separated. After addition of 10%HCl aq (50 ml) the product was collected and digested successively with MeOH (30 ml) and ether (100 ml). The orange-coloured, crystalline residue (3·7 g) was recrystallized from a large volume of MeOH containing two drops of conc. HCl. The *chloride* of the flavylium dimer (**11**) was thereby obtained as orange-coloured needles, m.p. 272–273°; λ_{max} 443 (4·26), 374 (4·02), 300 (3·76), 268 (4·30) nm (Log E) (EtOH–0·5% HCl), R_f 0·78 (water–AcOH-conc. HCl, 80:40:5 V/V), 0·57 (water–AcOH-conc. HCl, 80:20:5 V/V). (Found: C, 72·7; H, 5·21. Calc. for $C_{32}H_{27}O_5Cl$: C, 72·9; H, 5·17%).

The *perchlorate* of **11** was prepared by addition of excess 10% $HClO_4$aq to a solution of the chloride (0·5 g) in warm AcOH (10 ml). It crystallized from glacial AcOH as orange-coloured needles, m.p. 265°. (Found: C, 64·9; H, 4·58. Calc. for $C_{32}H_{27}O_9Cl$: C, 65·0; H, 4·61%).

Acetylation of flavylium dimer (**11**). A suspension of **11** chloride (0·50 g) in Ac_2O (2·5 ml) and pyridine (0·5 ml) was heated on a steam-bath for 10 min. Addition of water precipitated an oily acetate which crystallized on warming with MeOH. Recrystallized from acetone—MeOH the *diacetate* (**9**) separated as cream-coloured needles, m.p. 138° (0·40 g), λ_{max} 331, 276, 238 nm (EtOH). (Found: C, 75·2; H, 5·26; CH_3CO—, 22·3. Calc. for $C_{36}H_{30}O_7$: C, 75·2; H, 5·26; 3 CH_3CO—,* 22·5%). On silica acid TLC this acetate migrates as a single, blue-fluorescent species, R_f 0·93 (ether), 0·61 (ether–Skellysolve F, 2:1 V/V), 0·30 (EtOAc–Skellysolve F, 1:4 V/V). Hydrolysis of the acetate in AcOH–HCl aq regenerated **11** chloride.

7-Hydroxy-8-methylflav-2-ene (**7a**). $NaBH_4$ (2·0 g) was added rapidly to a cooled suspension of 7-hydroxy-8-methylflavylium chloride (4·0 g) in MeOH (20 ml). After 3 min 1% $NaHSO_3$ aq (100 ml) was added. The solid product crystallized from aqueous MeOH. *7-Hydroxy-8-methylflav-2-ene* separated as pink-coloured needles, m.p. 128° to a dark red liquid. (Found: C, 80·7; H, 5·98. Calc. for $C_{16}H_{14}O_2$: C, 80·6; H, 5·92%).

The *acetate* (**7b**) of the above product crystallized from MeOH as colourless needles, m.p. 103°. (Found: C, 77·0; H, 5·82; CH_3CO–, 15·2. Calc. for $C_{18}H_{16}O_3$: C, 77·1; H, 5·75; 1 CH_3CO–, 15·3%).

trans *2′,4′-Dihydroxy-3′-methylchalcone* (**8a**). A solution of 7-hydroxy-8- methyl-flavylium chloride (2·0 g) in MeOH (20 ml) and 5% of NaOH (40 ml) was warmed for 5 min, cooled, and acidified with glacial AcOH (10 ml). A red impurity in the solid product was removed by filtering a solution of the crude product in ether through silicic acid. Addition of excess of Skellysolve F to the filtrate precipitated the chalcone as compact yellow-brown crystals (1·75 g). Recrystallized from acetone–benzene trans-*2′,4′-dihydroxy-3′-methylchalcone* separated as glistening yellow plates, m.p. 156–159°.. (Found: C, 75·6; H, 5·57. Calc. for $C_{16}H_{14}O_3$: C, 75·6; H, 5·55%).

The *diacetate* (**8b**), prepared by acetylation of the chalcone with Ac_2O in pyridine, crystallized from MeOH as glistening, yellow needles, m.p. 122–123°. (Found: C, 71·1; H, 5·35: CH_3CO–, 25·6. Calc. for $C_{20}H_{18}O_5$: C, 71·0; H, 5·36; 2 CH_3CO–, 25·4%).

7-Hydroxy-6-methylflavylium chloride (**12**). A solution of 2,4-dihydroxy-5-methyl-benzaldehyde (6·0 g) and acetophenone (4·8 g) in EtOAc (30 ml) and EtOH (8·0 ml) was saturated with HCl gas and kept at 0° overnight. The solid product crystallized from AcOH–10% HCl aq to give *7-hydroxy-6-methylflavylium chloride* as yellow orange, soft needles, m.p. 167° (11·5 g), R_f 0·78 (H_2O–AcOH-conc. HCl, 80:20:5 V/V).

The *perchlorate* of **12** crystallized from glacial AcOH as yellow needles, m.p. 238°. (Found: C, 57·0; H, 3·95. Calc. for $C_{16}H_{13}O_6Cl$: C, 57·0; H, 3·89%).

Dimerization of 7-hydroxy-6-methylflavylium chloride. A solution of **12** chloride (2·0 g) in AcOH (10 ml) and H_2O (20 ml) was allowed to stand for 2 weeks at room temperature. After addition of 10% HCl aq (20 ml) the crystalline precipitate (1·04 g) was recrystallized from methanolic HCl to give the *chloride* of the dimer (**13a**) as orange-coloured needles, m.p. 280°, R_f 0·63 (H_2O–AcOH-conc. HCl, 80:20:5 V/V). (Found: C, 72·9; H, 5·24. Calc. for $C_{32}H_{27}O_5Cl$: C, 72·9; H, 5·17%).

The *perchlorate* of **13a** crystallized from AcOH–5% $HClO_4$ aq as yellow needles, m.p. 243–244°. (Found: C, 65·0; H, 4·63. Calc. for $C_{32}H_{27}O_9Cl$: C, 65·0; H, 4·61%).

Acetylation of the chloride of **13a** as previously described gave the *diacetate* (**14**) as cream-coloured needles EX acetone–MeOH, m.p. 161–162°. (Found: C, 75·0; H, 5·22; CH_3CO–, 22·7. Calc. for $C_{36}H_{30}O_7$: C, 75·2; H, 5·26; 3 CH_3CO–,* 22·5%). 100 MHz NMR spectrum in $CDCl_3$: 3H, δ2·15 (s); 3H, δ2·18 (s); 3H, δ2·31 (s); 3H, δ2·33 (s); 2H, δ3·54 (d, J = 7·0 Hz); 1H, δ5·65 (t, J = 7·0 Hz); 1H, δ6·42 (s); 1H, δ6·82 (s); 1H, δ6·95 (s); 10H, δ7·18–δ7·66 (m); 2H, δ8·04–δ8·17 (m).

Dimerization of 7-hydroxyflavylium chloride. A solution of 7-hydroxyflavylium chloride (5·0 g) in AcOH (25 ml) and H_2O (50 ml) was kept for 3 weeks at room temperature. 10% HCl aq (200 ml) was added, the crystalline solid was collected and digested with boiling EtOAc. The undissolved residue (4·3 g) was recrystallized from a large volume of methanolic HCl to give the *chloride* of **13b** as orange needles, m.p. 252°, R_f 0·71 (water–AcOH-conc. HCl, 80:20:5 V/V). (Found: C, 72·1; H, 4·75. Calc. for $C_{30}H_{23}O_5Cl$: C, 72·2; H, 4·65%).

REFERENCES

1 T. A. Geissman and H. F. K. Dittmar, *Phytochemistry* **4**, 359 (1965)
2 K. Weinges and K. Freudenberg, *Chem. Comm.* **11**, 220 (1965)
3 L. L. Creasy and T. Swain, *Nature* Lond. **208**, 151 (1965)
4 W. Mayer, L. Goll, E. M. Arndt, *Tetrahedron Letters* **4**, 429 (1966)
5 V. Krishnan and S. Rangaswami, *Ibid.* **26**, 2441 (1967)
6 A. G. Brown, U. B. Eyton, A. Holmes and W. D. Ollis, *Nature* Lond. **221**, 742 (1969)
7 A. J. Birch, C. J. Dahl and A. Pelter, *Tetrahedron Letters* **6**, 481 (1967); *Aust. J. Chem.* **22**, 423 (1969)
8 F. R. Volsteedt and D. G. Roux, *Tetrahedron Letters* **20**, 1647 (1971)
9 T. A. Geissman and N. Yoshimura, *Ibid.* **24**, 2669 (1966)
10 V. K. Bhatia, R. Madhav and T. R. Seshadri, *Current Sci.* **37** (20), 582 (1968)
11 A. Robertson, W. B. Whalley and J. Yates, *J. Chem. Soc.* 1876 (1950)
12 Ch. B. Rao and V. Venkateswarlu, *Tetrahedron* **20**, 551 (1964)
13 A. J. Birch and M. Salahuddin, *Tetrahedron Letters* **32**, 2211 (1964)
14 M. Blackburn, G. B. Sankey, A. Robertson and W. B. Whalley, *J. Chem. Soc.* 1573 (1957)

* Integration of the NMR spectrum of this acetate (**9**), as well as that (**14**) from the dimer (**13a**), shows unequivocally the presence of only two acetate groups in these acetates. The third acetate unit indicated by elemental analysis must arise from a nuclear decomposition during saponification

[15] L. Jurd and A. C. Waiss, *Tetrahedron* **21**, 1471 (1965)
[16] L. Jurd, *Ibid.* **23**, 1057 (1967)
[17] T. C. Somers, *Sonderdruck aus der zeitschrift "Vitis"*, 7, 303 (1968); F. M. Dean, *Naturally Occurring Oxygen Ring Compounds*, p. 446, Butterworths, London (1963)
[18] K. Freudenberg and K. Weinges, *Chem. Ber.* **590**, 140 (1954)
[19] L. Jurd, *J. Org. Chem.* **28**, 987 (1963); L. Jurd and T. A. Geissman, *Ibid.* **28**, 2394 (1963); C. F. Timberlake and P. Bridle, *J. Sci. Food Agr.* **18**, 473 (1966); K. A. Harper and B. V. Chandler, *Aust. J. Chem.* **20**, 731, 745 (1967)
[20] D. W. Hill and R. R. Melhuish, *J. Chem. Soc.* 1161 (1935)
[21] D. A. Collins, F. Haworth, K. Isarasena and A. Robertson, *J. Chem. Soc.* 1876 (1950)