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COMMENTS ON THE THERMAL AND MASS SPECTRAL FRAGMENTATION OF FLAVANONES AND BIFLAVANONES

B. Jackson, H.D. Locksley and F. Scheinmann
(Department of Chemistry, University of Salford)
and
W.A. Wolstenholme
(A.E.I. Ltd., Consultant Laboratory, Manchester)

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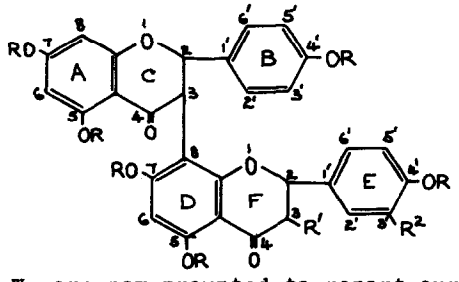
In a preliminary communication[1] on extractives from the heartwood of Garcinia buchananii Baker (Guttiferae) we reported the isolation of a new series of biflavanones, GB-1, (Ia); GB-1a, (Ib); and GB-2, (Ic). The structures* were assigned largely on the basis of ultraviolet, infrared, n.m.r., and mass spectral evidence and by degradation with alkali, which, in the case of GB-1, (Ia) and GB-1a, (Ib), gave phloroglucinol and p-hydroxybenzoic acid.

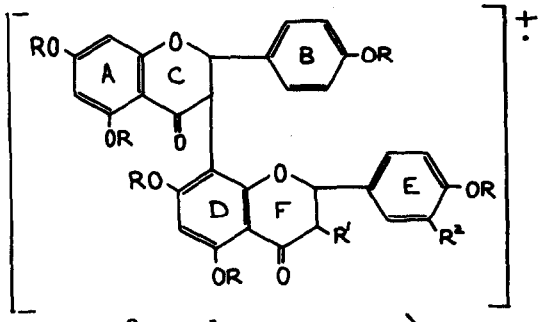


GB-1 (Ia: $R=R^2=H$, $R^1=OH$)
GB-1a (Ib: $R=R^1=R^2=H$)
GB-2 (Ic: $R=H$, $R^1=R^2=OH$)
(Id: $R=Me$, $R^1=OMe$, $R^2=H$)
(Ie: $R=Me$, $R^1=OH$, $R^2=H$)
(If: $R=Me$, $R^1=R^2=OMe$)

We are now prompted to report our results on the mass spectral** and thermal fragmentation of flavanones because a recent re-interpretation[2] of our work suggests that some of the mass spectral data(Scheme 1) on biflavanones demands further comment.

* These structures are presented with the reservation that the flavanone units may be alternatively 3,6-linked between rings C and D.

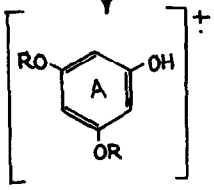
** All mass spectra were recorded on an A.E.I., MS9 double focusing spectrometer.



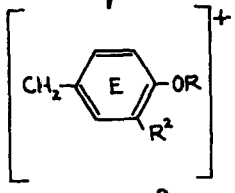
GB-1 (Ia: $R=R^2=H$, $R^1=OH$) m/e 558
GB-1a (Ib: $R=R^1=R^2=H$) m/e 542
GB-2 (Ic: $R=H$, $R^1=R^2=OH$) m/e 574
(Id: $R=Me$, $R^1=OMe$, $R^2=H$) m/e 656
(Ie: $R=Me$, $R^1=OH$, $R^2=H$) m/e 642

(Id) (IIb) (two retro Diels-Alder fragmentations)
(i) m^* = 345.4
(ii) m^* = 204.5

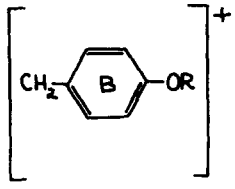
electron bombardment (?) and thermal decomposition



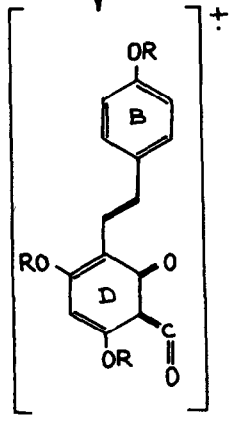
(Va: R=H) m/e 126
(Vb: R=Me) m/e 154



(IVa: $R=R^2=H$) m/e 107
(IVb: $R=Me$, $R^2=H$) m/e 121
(IVc: $R=H$, $R^2=OH$) m/e 123

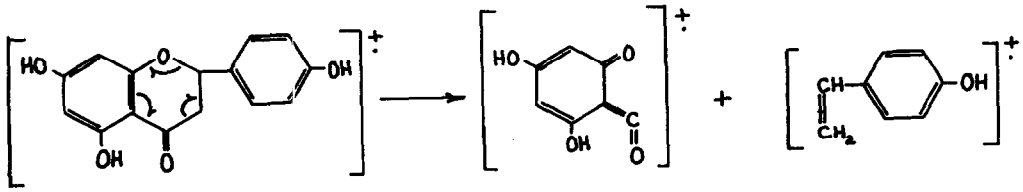


(IIIa: R=H) m/e 107
(IIIb: R=Me) m/e 121



(IIa: R=H) m/e 270
(IIb: R=Me) m/e 312

Scheme 1



(VIa)

Scheme 2

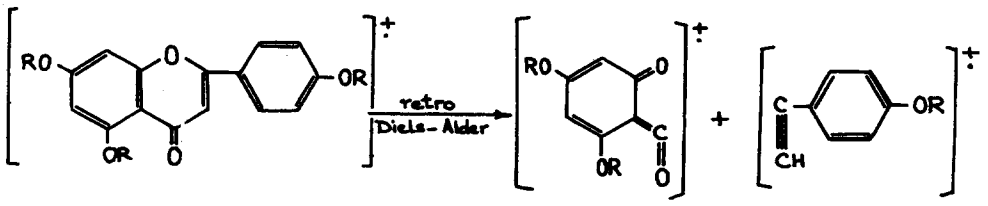
All the features we observed in the mass spectral fragmentation of biflavanones have analogies with similarly substituted monoflavanones. Thus, it has already been established[3] that the principal mode of fragmentation of flavanones occurs by way of the retro Diels-Alder reaction typified in Scheme 2 for naringenin (VIa).

This type of fragmentation also occurs readily with the biflavanones (Ia-c) and their ether derivatives (Id-e), and that two successive retro Diels-Alder fragmentations are involved is fully substantiated by the presence of metastable peaks associated with the two-stage breakdown of the heptamethyl ether of GB-1 (Id) to give finally the ion (IIb) at m/e 312 (Scheme 1). Thus, the implication by Pelter[2] that the fragment ions (IIa) at m/e 270 ($C_{15}H_{10}O_5$) or (IIb) at m/e 312 ($C_{18}H_{16}O_5$) are due to the formation of apigenin (VIIa) or its trimethyl ether (VIIb) is therefore completely unacceptable. Moreover, the fragmentation pattern below m/e 270 in the mass spectrum of GB-1 (Ia) bears no resemblance to that found in the mass spectrum of apigenin (VIIa) measured under identical instrumentation conditions. The mass spectrum of apigenin (VIIa) (Scheme 3) possesses prominent ions at m/e 152 and m/e 118 associated with a retro Diels-Alder fragmentation, and these important ions, amongst others, are entirely absent from the spectra of all the biflavanones (Ia-c).

The favourability of alternative fragmentation processes in flavanones appears to be dependent upon the presence of certain substituents. Thus the presence of an hydroxyl or a methoxyl group at the C-4 position of ring B (and in ring E of the biflavanones) facilitates the formation of p-hydroxybenzyl or p-methoxybenzyl fragments, respectively (or their equivalent tropilium ions), by enhanced resonance stabilisation of the resulting fragment ion. p-Hydroxy- or p-methoxybenzyl ions appear as peaks of significant intensity in the mass spectra of the biflavanones (Ia-c), naringenin (VIa), and those of their methyl ethers (e.g. (Id) and (VIb)), and with aromadendrin (VIc).

There is no difficulty in accounting for the formation of a p-hydroxy-

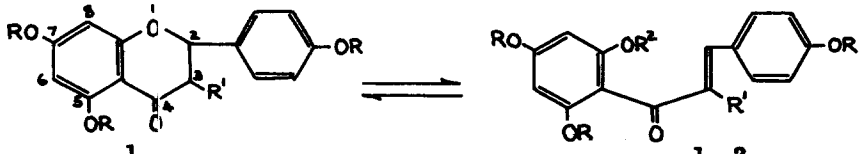
benzyl cation from aromadendrin (VIc), because tautomerism can give the benzyl ketone (VIII) which then fragments at the benzylic carbon atom.



(VIIa: R=H, m/e 270) (R=H, m/e 152) (R=H, m/e 118)
(VIIb: R=Me, m/e 312) (R=Me, m/e 180) (R=Me, m/e 132)

Scheme 3

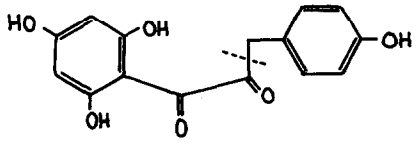
Electron bombardment of the chalcone trimethyl ether (IXb) - tautomeric with naringenin trimethyl ether (VIb) - yields the p-methoxybenzyl ion at m/e 121, and exchange of the remaining phenolic hydrogen atom with deuterium (by shaking a chloroform solution of the ether with deuterium oxide) gives fragment ions at both m/e 121 and m/e 122 with the same intensity ratio as the M^+ and $(M + 1)^+$ peaks. This shows that fragmentation involves the hydrogen of the phenolic group which, due to the equilibrium (VIb)$\rightleftharpoons$(IXb), can become located at C-3. Fragmentation of the chalcone tetramethyl ether (IXd) provides support for the migration of an hydrogen atom from C-3 (flavanone numbering), because the p-methoxybenzyl cation at m/e 121 is still observed, albeit at reduced intensity.



(VIa: $R=R^1=H$) (IXa: $R=R^1=R^2=H$)
(VIb: R=Me, $R^1=H$) (IXb: R=Me, $R^1=R^2=H$)
(VIc: R=H, $R^1=OH$) (IXc: $R=R^2=H$, $R^1=OH$)
(IXd: $R=R^2=Me$, $R^1=H$)

The formation of phloroglucinol (at m/e 126) from the biflavanones (Ia-c) or phloroglucinol dimethylether (at m/e 154) from the methyl ether derivatives (Id) and (Ie) of GB-1 (Ia) is probably of thermal origin. In fact phloroglucinol is so readily lost from GB-1 (Ia), GB-1a (Ib) and

GB-2 (Ic) that if the temperature of the ion chamber in the mass spectrometer much exceeds the minimum (~ 220°) for evaporation of the sample, there is difficulty in detecting the molecular ion. However, under all conditions, the base peak was due to phloroglucinol. The thermal instability of GB-1 (Ia) was verified: GB-1 (Ia) was heated in a tube at 280° and from the pyrolysis products phloroglucinol was isolated and characterised.



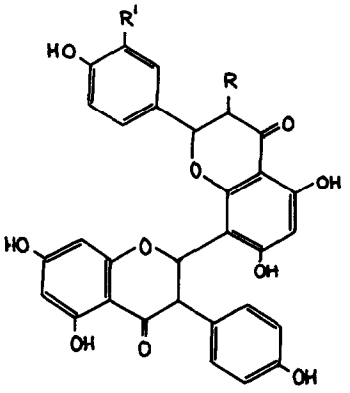
(VIII) - tautomeric with (VIc) and (IXc)

Owing to its increased volatility, the heptamethyl ether of GB-1 (Id) decomposes less readily in the mass spectrometer and thus the relative intensity of the phloroglucinol dimethyl ether peak at m/e 154 is reduced to one tenth that of the base peak at m/e 312 (IIb) (Scheme 1). Although the monoflavanone, naringenin (VIa), prefers to fragment by a retro Diels-Alder process on electron bombardment (see Scheme 2), experimental conditions can be contrived (ion chamber temperature ~ 320°)* to give phloroglucinol. Furthermore, mass spectral examination using the direct insertion probe shows that the product obtained by melting naringenin (VIa) in the atmosphere contains phloroglucinol. Phloroglucinol has also been isolated as a thermal degradation product of naringenin (VIa). Since even phloracetophenone decomposes thermally to give phloroglucinol, such degradations would appear to be a general property of acylphloroglucinols and their chalcones.

On the basis of an interesting biogenetic pathway, it has been suggested[2] that our experimental evidence is also consistent with the alternative structures (Xa-c) for GB-1, GB-1a and GB-2. In this context, it was reported[2] that "the only spectroscopic evidence that may have any

* We are indebted to Mr. Derek Hart of A.E.I. Ltd., Consultant Laboratory, Manchester, for this result.

bearing on the matter is the ion at m/e 121" (due to $[CH_2\text{-}C_6H_4\text{-}OMe]^+$) "in the mass spectrum of GB-1 heptamethyl ether. If this is assumed to arise from C-2 of a flavanone, then its presence or absence in GB-2 heptamethyl ether* might be indicative of the structure**". In fact this ether has never been prepared by us, but the mass spectrum of GB-2 (our structure Ic) itself may supply the answer (Fig. 1).



(Xa: R=OH, R^1=H)
(Xb: R=R^1=H)
(Xc: R=R^1=OH)

The spectrum clearly shows the presence of ions at m/e 107 and m/e 123 consistent with the elimination of fragments (IIIa) and (IVa) (Scheme 1)***. On this basis the structures (Ia-c) for GB-1, GB-1a and GB-2 are preferable to the alternatives (Xa-c). However, full details of the chemistry of the biflavanones will be published later.

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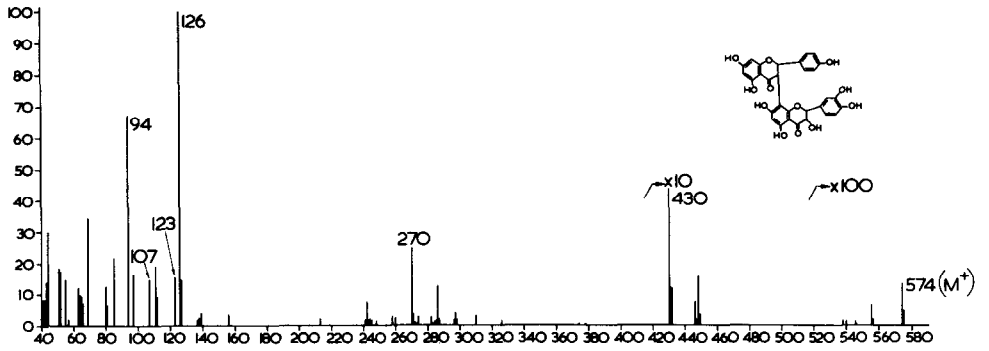
* In reference 2 our structure for GB-2 (Ic) was reproduced incorrectly and we assume also that "GB-2 heptamethyl ether" was intended to refer to the fully methylated derivative, which in fact would be GB-2 octamethyl ether (If).

** The Author[2] refers to structures (Ia-c) for the biflavanones.

*** Since it has been established that 4′-hydroxyflavanones lose a p-hydroxybenzyl fragment from C-2, it is perhaps significant that no peaks consistent with a 2,4,6-trihydroxybenzyl moiety from the alternative structures (Xa-c) appear in any of the biflavanone mass spectra.

Figure 1



The mass spectrum of GB-2 (Ic)
obtained on an A.E.I. MS 9 double focusing mass spectrometer

References

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4. N. Narasimhachari and T.R. Seshadri, Proc. Indian Acad. Sci., 27A, 223, (1948).