Anal. Calcd. for $C_{21}H_{24}N_4O_9$: C, 52.94; H, 5.08; N, 11.76. Found: C, 53.05; H, 5.13; N, 11.55.

The methiodide, m.p. 241–242°, formed in acetone–ether.

Acknowledgment.—We are indebted to Mr. Carl Gochman for excellent technical assistance and to Dr. G. H. Ellis and associates for analytical and optical data. We are grateful for the opportunity of acknowledging in this special issue many years of friendly and helpful connection with Professor Louis Frederick Fieser.

Organic Mass Spectrometry. I. Mass Spectra of Pteridine, Methylpteridines, and Hydroxypteridines*

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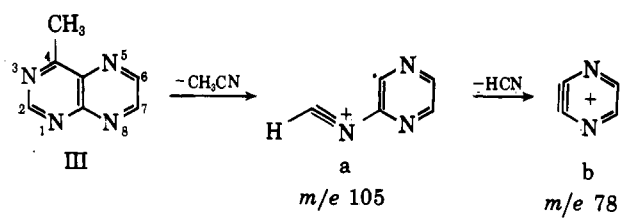
Mass spectra of pteridine, methylpteridines, and hydroxypteridines have been measured and the assignments have been made to the principal fragments by comparison with the spectra of some deuterium-labeled compounds.

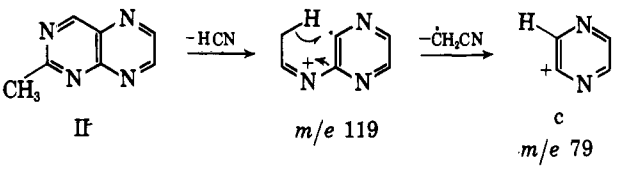
Compounds containing the pteridine nucleus are frequently found in nature.[2] However, structure determination of naturally occurring pteridines is usually limited by the small quantities of material available. Application of mass spectrometry to the structural problems of pteridine derivatives would, therefore, be highly desirable. In order to determine the principal fragmentation modes of the pteridine nucleus, the mass spectra of basic pteridine derivatives such as methyl- and hydroxypteridines as well as pteridine itself have been recorded.

Pteridine and Methylpteridines.—Mass spectra of pteridine, three methylpteridines, and a dimethylpteridine are given in Figure 1. These pteridines give a very intense molecular peak which is always the base peak. Their fragmentation patterns are not very complicated; the parent compound, pteridine (I), loses molecules of hydrogen cyanide successively, whereas an acetonitrile molecule is eliminated at some stage from the methyl derivatives II–V. However, since the pteridine molecule has four nitrogen atoms, each of which could be eliminated as hydrogen cyanide, the precise fragmentation processes cannot be determined without more extensive studies.

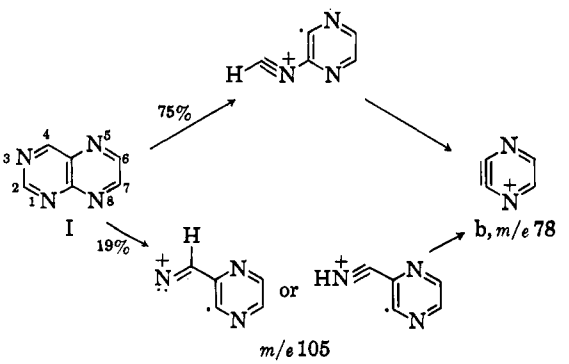
4-Methylpteridine (III) decomposes with the consecutive loss of molecules of acetonitrile and hydrogen cyanide and gives peaks at *m/e* 105 and 78. In this case the structure for the *m/e* 105 ion is limited to a and the fragment at *m/e* 78 must be the dehydropyrazine cation b, since no hydrogen cyanide is eliminated before an acetonitrile molecule is lost from the molecular ion (no peak at *m/e* 119).



2-Methylpteridine (II), however, eliminates hydrogen cyanide first to give an ion of *m/e* 119 which fragments in two ways: by the loss of acetonitrile (*m/e* 78) or by the elimination of a CH_2CN radical (*m/e* 79). The latter process can be explained by postulating a cyclic mechanism leading to the ion c.



That the C-4–N-3 part of the pteridine nucleus is eliminated most easily holds also in the fragmentation of pteridine itself. Thus, deuterium-labeling experiments show that 75% of the hydrogen cyanide which is first eliminated from pteridine comes from the C-4–N-3 part in the molecule and 19% from the C-2–N-1 part (Table I). The second molecule of hydrogen cyanide is abstracted mainly from the C-2–N-1 part and, thus, the peak at *m/e* 78 consists of mostly the dehydropyrazine cation b, but alternative pathways are also operating to a minor extent.



In the case of 7-methylpteridine (IV) the first step of the fragmentation is mainly loss of hydrogen cyanide. There are three CN groups, namely C-2–N-1, C-4–N-3, and C-6–N-5, each of which can give a molecule of hydrogen cyanide; the C-2–N-1 group, however, is not expected to be eliminated first by analogy with the behavior of pteridine. In order to determine which of the remaining CN groups is lost, the mass

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(2) For a recent review on pteridines, see W. Pfleiderer, *Angew. Chem., Intern. Ed. Engl.*, **3**, 114 (1964).

TABLE I

DEUTERIUM CONTENT[a]

Compd.	m/e 132 (P)	m/e 105	m/e 78
2-Deuteriopteridine	100	81	26
4-Deuteriopteridine	100	25	29

[a] Deuterium contents were calculated by the method described by K. Biemann ("Mass Spectrometry," McGraw-Hill Book Co., Inc., New York, N. Y., 1962, p. 223) and standardized with the deuterium content of the parent peak taken as 100%. Values are given in per cent.

spectrum of 4-deuterio-7-methylpteridine was examined; more than 95% of the original deuterium content was retained in the peaks at m/e 119 and 78 (Table II).

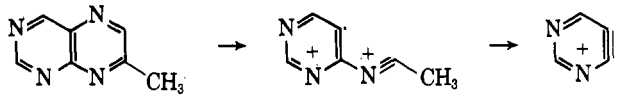
TABLE II

DEUTERIUM CONTENT[a]

Compd.	m/e 146 (P)	m/e 119	m/e 105	m/e 92	m/e 78
4-Deuterio-7-methylpteridine	100	95	94	54	98

[a] See footnote *a* in Table I.

This result suggests the following processes for the fragmentation of IV. Elimination of the C-6–N-5 group is facilitated by the electron-releasing effect of the C-7 methyl group which stabilizes a positive charge on the nitrogen of the C-7–N-8 group in the ion d.



IV d m/e 119 m/e 78

Similar behavior can be noted in the mass spectrum of 6,7-dimethylpteridine (V), although no evidence is obtained as to which acetonitrile moiety is eliminated first.

Hydroxypteridines.—In Figure 2 are shown the mass spectra of the four isomeric monohydroxypteridines and a dihydroxypteridine. The hydroxypteridines are considered to exist in the lactam form rather than the hydroxy form.[3] The base peak of these compounds is also the molecular ion (except 4-hydroxypteridine which shows an intense peak at m/e 44[4]).

There are two pathways for the fragmentation of the hydroxypteridines: one is the loss of hydrogen cyanide and the other is the elimination of carbon monoxide. 2-Hydroxypteridine (VI) loses only the elements of hydrogen cyanide to give an intense peak at m/e 121, whereas carbon monoxide is exclusively abstracted from the 6- and 7-hydroxy derivatives VIII and IX. 4-Hydroxypteridine (VII) eliminates either hydrogen cyanide or carbon monoxide from the molecular ion and gives peaks at m/e 121 and 120.

Loss of carbon monoxide from 6- and 7-hydroxypteridine (VIII and IX) would give the purine cation e or f, and, indeed, below m/e 120 the mass spectra of VIII and IX are very similar to that of purine XI

(3) D. J. Brown and S. F. Mason, *J. Chem. Soc.*, 3443 (1956).

(4) The possibility that the peak at m/e 44 is carbon dioxide from an air leak in the instrument is eliminated from a comparison of the spectra recorded in different runs. It could be a rearranged ion, $^{+}NH_2{=}C{=}O \leftrightarrow NH_2{-}C{\equiv}O^{+}$. That this peak is also appeared in the spectra of VIII and IX, but not in that of XI, is reasonable from their structures.

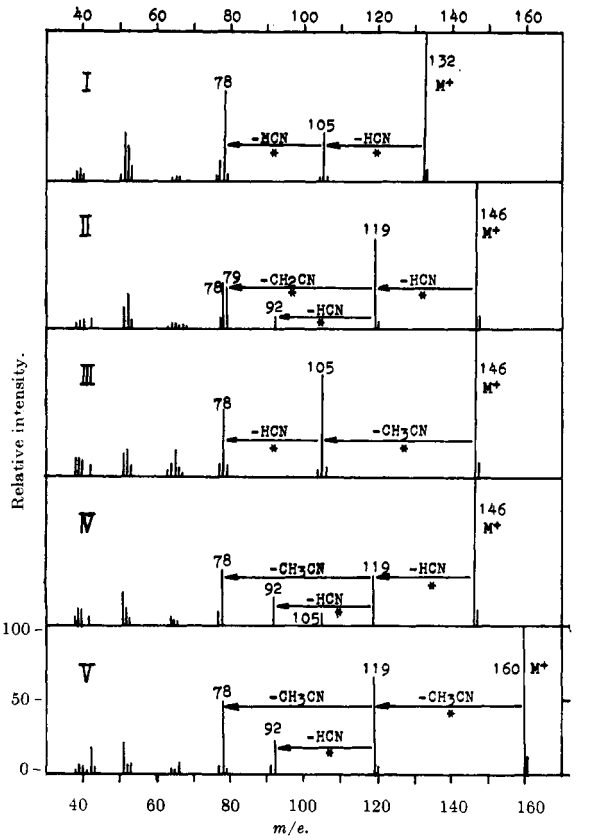
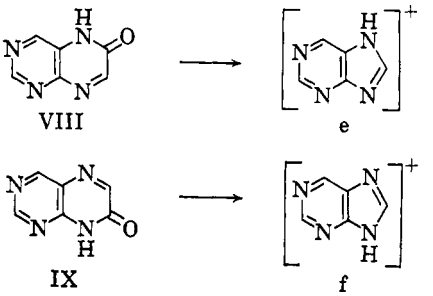


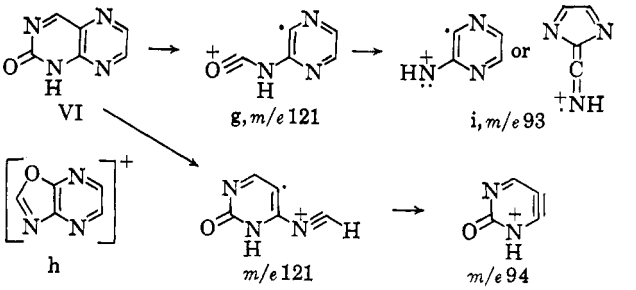
Figure 1.—Mass spectra of pteridine (I), 2-methylpteridine (II), 4-methylpteridine (III), 7-methylpteridine (IV), and 6,7-dimethylpteridine (V).

(Figure 3); successive loss of hydrogen cyanide takes place to give peaks at m/e 93 and 66[3]. Analysis of the mass spectrum of purine will be reported elsewhere.



VIII e IX f

In the mass spectrum of 2-hydroxypteridine (VI) the loss of carbon monoxide takes place in the second step. This indicates that the first step is the elimination of hydrogen cyanide, at least in part, from the C-4–N-3 group of VI. Whereas consecutive loss of molecules of hydrogen cyanide probably takes place at the pyrazine ring in VI.



VI g, m/e 121 i, m/e 93 h m/e 121 m/e 94

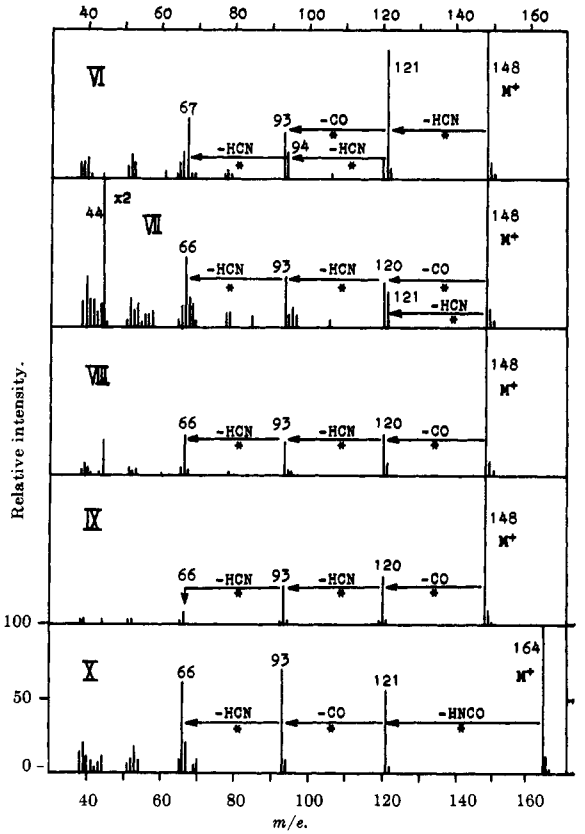


Figure 2.—Mass spectra of 2-hydroxypteridine (VI), 4-hydroxypteridine (VII), 6-hydroxypteridine (VIII), 7-hydroxypteridine (IX), and 2,4-dihydroxypteridine (X).

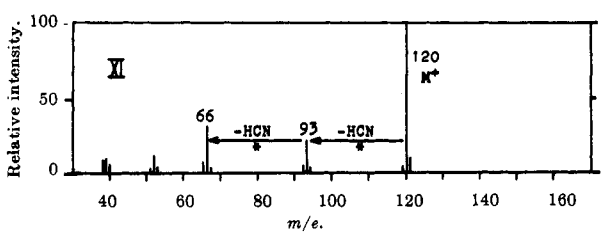
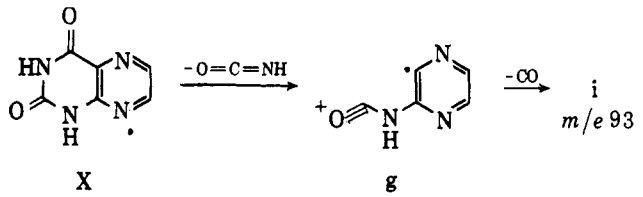


Figure 3.—Mass spectrum of purine (XI).

The rearrangement of the ion g to the ion h would be improbable since the structure of h can not account for the loss of carbon monoxide in the subsequent step.

Fragmentation patterns of 2,4-dihydroxypteridine (X) may be interpreted by analogy to the behavior of the 2-hydroxy derivative VI. Elimination of the fragment HNCO is followed by the loss of carbon monoxide to give the peak at *m/e* 93.



Most of the steps discussed above have been supported by the appropriate metastable peaks (indicated by asterisks in Figures 1 and 2).

Experimental

Materials.—Pteridine,[5] 2-methyl-, 4-methyl-, and 7-methylpteridine,[6] 6,7-dimethylpteridine,[6] 2- and 4-deuteriopteridine,[7] 2- and 4-hydroxypteridine,[5] 6- and 7-hydroxypteridine,[8] and 2,4-dihydroxypteridine[5] have been prepared by known methods. 4-Deuterio-7-methylpteridine was prepared from 4,5-diamino-6-deuteriopyrimidine[7] by the same method employed for the synthesis of 7-methylpteridine.[6] Deuterium content of the deuterio derivatives is about 35%.

Spectra.—The spectra were recorded using a Hitachi RMU-6C mass spectrometer equipped with an all-glass inlet system heated to 200°. The ionization energy was 80 e.v. and the ionizing current 80 μa.

Acknowledgment.—We are grateful for a grant from Toyo Rayon Company, Ltd., for the purchase of the spectrometer.

(5) A. Albert, D. J. Brown, and G. Cheeseman, *J. Chem. Soc.*, 474 (1951).
(6) A. Albert, D. J. Brown, and H. C. S. Wood, *ibid.*, 3832 (1954).
(7) S. Matsuura and T. Goto, *ibid.*, 623 (1965).
(8) A. Albert, D. J. Brown, and G. Cheeseman, *ibid.*, 1620 (1952).

Synthesis of Benzo[*a*]- and Naphtho[2,1-*a*]phenanthridizinium Salts*,[1]

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The synthesis of benzo[*a*]phenanthridizinium salts can be effected by cyclodehydration of quaternary salts derived from 1-phenylisoquinoline, even if no activating alkoxyl group is present. Similarly, 1-(2-naphthyl)isoquinoline is believed to yield naptho[2,1-*a*]phenanthridizinium salts.

In earlier work in this laboratory[2] it was shown that 1-phenyl-2-acetonylisoquinolinium salts (I, $R_2 = CH_3$; Z = O)[3] will not cyclize under conditions rather more drastic than used to effect the cyclization of 1-acetonyl-2-phenylpyridinium salts.[4] Subsequently,[5] it was found that introduction of a methoxyl group *para* to the position of expected cyclization, as in 1-(3-methoxyphenyl)-2-acetonyl-6,7-methylenedioxyisoquinolinium bromide made possible the preparation of a benzo[*a*]phenanthridizinium derivative.

It has now been found that the cyclization of unactivated systems, such as 1-phenyl-2-acetonylisoquinolinium bromide (I, $R_2 = CH_3$; Z = O), may be accomplished by heating them in polyphosphoric acid at 210–220°. Despite these vigorous conditions, little decomposition occurred and benzo[*a*]phenanthridizinium salts (II) were obtained, usually in good yields.

* To Professor Louis F. Fieser

(1) This research was supported by a grant (CA-05509) from the National Cancer Institute of the National Institutes of Health.

(2) C. K. Bradsher and L. E. Beavers, *J. Am. Chem. Soc.*, **78**, 2459 (1956).

(3) Throughout this paper all R groups not otherwise specified represent hydrogen.

(4) C. K. Bradsher and L. E. Beavers, *J. Am. Chem. Soc.*, **77**, 453 (1955).

(5) C. K. Bradsher and K. B. Moser, *J. Org. Chem.*, **24**, 592 (1959).