Mass spectrometry of *N*-[5,5-dimethyl-2(5*H*)-thienyliden]amines and *N*-(1-thiaspiro[4.5]dec-3-en-2-yliden)amines

Lyudmila V. Klyba,[a] Nina A. Nedolya,[a] Lambert Brandsma,[b] and Nataly I. Schlyakhtina[a]

[a] *A. E. Favorsky Irkutsk Institute of Chemistry, Siberian Branch of the Russian Academy of Sciences, RU-664033 Irkutsk, Russia. E-mail: klyba@irioch.irk.ru*
[b] *Julianalaan 273, NL-3722 GN Bilthoven, The Netherlands. E-mail: l.brandsma@wxs.nl*

Dedicated to Academician Michael G. Voronkov on the occasion of his 80th birthday
(received 28 Jun 01; accepted 27 Mar 02; published on the web 04 Apr 02)

Abstract
The fragmentation mechanisms of the title compounds upon impact with 12 and 60 eV have been studied using mass spectrometry. The molecular ions of the compounds undergo fragmentation involving both the ruptures of bonds and skeleton rearrangements followed by formation of odd-electron ions. The fragmentation pattern is considerably influenced by the nature of the 2- and 3-substituents in the dihydrothiophene ring.

Keywords: *N*-[5,5-Dimethyl-2(5*H*)-thienyliden]amines, *N*-(1-thiaspiro[4.5]dec-3-en-2-yliden)amines, mass spectra, electron impact, fragmentation, rearrangement

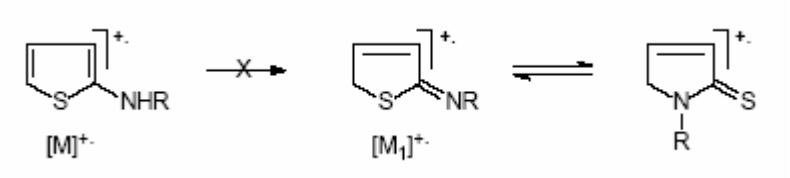
Introduction

Recently[1-3] we have initiated a theoretical and experimental study of the pathways and regularities of electron impact (EI) induced fragmentation of new series of pyrroles[4] and thiophenes,[5] which became accessible by our new approach for a number of heterocyclic systems based on interaction between metallated unsaturated compounds and heterocumulenes.[6,7]

Position and nature of ring substituents of 2-(thienyl)amines have been shown[1,2] to affect the preference of EI-MS-induced fragmentation pathways. Whereas the fragmentation of 3-methyl- and 5-methyl-2-(thienyl)amines starts mainly from the isomeric thiopyran form of the molecular ion,[2] the decomposition of derivatives containing an ethyl group in the position 3 (instead of a methyl group) occurs both by elimination of fragments from the substituents (3-Et and 2-NR^1R^2) and rupture of the thiophene ring. In the case of the 5-*tert*-butyl-substituted derivatives, the latter process (the decomposition of the heterocyclic system) is not observed.[2]

The similarity of fragmentation pathways induced by rupture of various heterocyclic bonds observed in the mass spectra of unsubstituted secondary and tertiary 2-(thienyl)amines,[1] allows

the essential conclusion that molecular ions $[M]^{+}$**.** of the latter fail to undergo isomerization to the form $[M_1]$+**.** of (*N*-[2(5*H*)-thienyliden]amines and/or 1,5-dihydro-2*H*-pyrrole-2-thiones) (Scheme 1).



Scheme 1

Nevertheless, for a complete understanding of the EI-induced fragmentation of sulfur-containing heterocycles, including the secondary 2-(thienyl)amines, it seemed relevant to examine the mass spectra of their tautomeric *N*-[2(5*H*)-thienyliden]amines, the more so that information of this kind is absent in the literature. Recently we convincingly proved the amino-imino tautomerism of *N*-monosubstituted (thienyl)amines.[8]

In the framework of our synthetic investigations[6] we developed a method for the synthesis of the hitherto unknown *N*-[5,5-dimethyl-2(5*H*)-thienyliden]-*N*-alkylamines (**1**–**3**) and *N*-(1-thiaspiro[4.5]dec-3-en-2-yliden)amines[9] (**4**, **5**) and studied their mass-spectral behavior. It should be emphasized that the presence of two substituents in the ring position *5* strictly fixes the imino-form of these compounds, thus ruling out the contribution of thiophene structures to the character and pathway of EI-induced molecular ion fragmentation.

Since in these compounds two different heteroatoms are present, it is evident that the pathway and character of the EI-induced fragmentation of their molecular ions can be determined by both the nitrogen and the sulfur atoms as ionization centers, analogous to the fragmentation mode of 2-(thienyl)amines.[1,2]

Results and Discussion

Table 1 lists the complete mass spectra of the (thienyliden)amines **1**–**3** obtained at 12 and 60 eV, relative abundance of the ion peaks and the fragmentations responsible for their genesis. General fragmentation patterns of the molecular ions $[M]^{+}$**.** of compounds **1**–**3** at 60 eV are depicted in Scheme 2.

Comparison of the fragmentation patterns of **1**–**3** with those of **4** and **5** show some quantitative and qualitative differences attributed to the nature of both the substituents at the 5-position of the ring and at the nitrogen atom. The 12 eV spectra of spirocyclic compounds **4** and **5** are much simpler and contain only molecular ion peaks [for **4**: *m/z* 181 (100%) and for **5**: *m/z* 243 (100%)]. Replacement of the spirocyclic unit at C-5 of the dihydrothiophene ring by two methyl groups (compounds **1**–**3**) considerably decreases the stability of the molecular ions and leads to their fragmentation already at 12 eV.

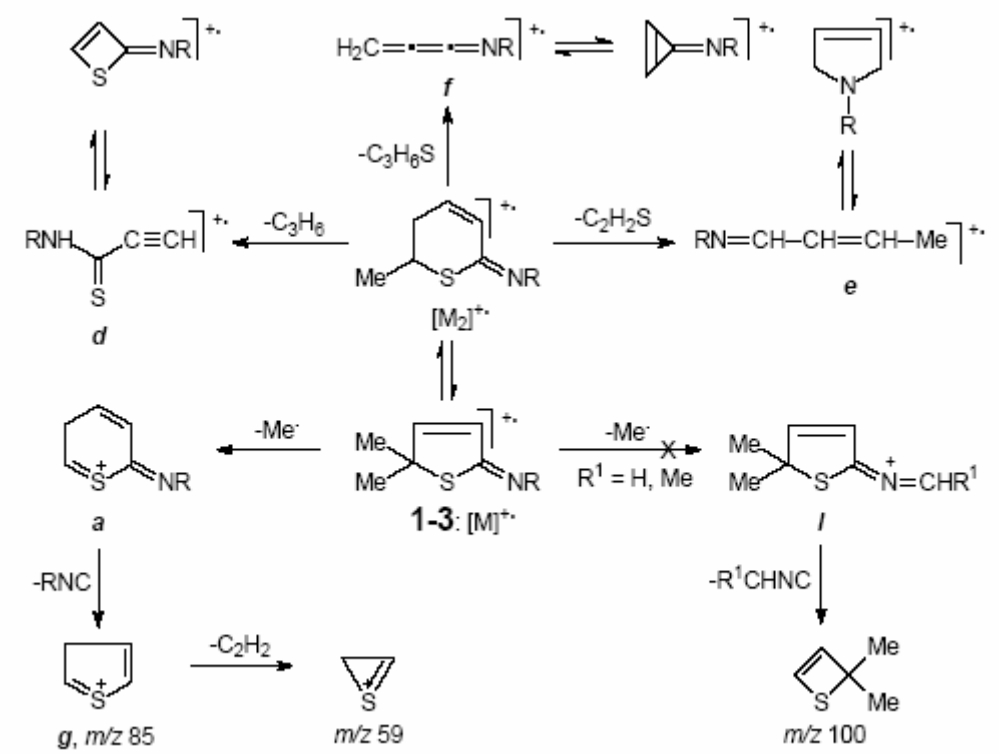
Table 1. The 12 and 60 eV mass spectra of compounds **1–3**

	Ions	*m/z* and relative intensities I (%)								
		1			**2**			**3**		
		m/z	$I_{12\ eV}$	$I_{60\ eV}$	*m/z*	$I_{12\ eV}$	$I_{60\ eV}$	*m/z*	$I_{12\ eV}$	$I_{60\ eV}$
	$[M]^+$.	141	100	85	155	100	67	169	75	34
a	$[M-Me]^+$	126	95	100	140	65	100	154	10	100
b	$[M-H]^+$	140	45	26	154	10	14	-		
c	$[M-SH]^+$	108	40	13	122	8	7	-		
d	$[M-C_3H_6]^+$.	99	10	22	113	3	16	127	10	27
e	$[M-C_2H_2S]^+$.	83	45	47	97	-	10	111	-	7
f	$[M-C_3H_6S]^+$	67	20	*	81	-	10	95	-	12
g	[***a*** –RNC]$^+$, *m/z* 85		5	14		-	14		-	6
h	$[M-NR]^+$, *m/z* 112		-	-		-	31		4	44
i	$[M-R]^+$, *m/z* 126		-	**		-	8		-	-
j	[***i*** –HCN]$^+$, *m/z* 99		-	***		-	13		-	-
k	[***c*** –RNC]$^+$, *m/z* 67		-	54		-	7		-	-
	m/z 68		-	-			9		-	7
	m/z 66			18			-			-
	m/z 59			9			6			3
	m/z 53			8			14			7
	m/z 45			7			1			3
	m/z 42			12			-			10
	m/z 41			19			10			24
	m/z 39			24			3			8?
	m/z 27			5			3			2?

* The peak at *m/z* 67 is a mixture of the ions ***f*** and ***k***. ** The peak at *m/z* 126 is a mixture of ions ***a*** and ***i***. *** The peak at *m/z* 99 is a mixture of ions ***d*** and ***j***.

In the 60 eV mass spectra of compounds **1**–**3** the molecular ion peaks are also present (Table 1), but their intensity is decreased by a factor 0.4 (from 85 to 34%) in going from **1** (with NMe substituent) to **3** (with N-*i*-Pr substituent), suggesting a lower stability of the molecular ion of **3**. Even at 12 eV (Table 1) the intensity of the molecular ion peak of **3** was 75% (lowest in the **1**–**5** series). This is consistent with the known fact that cleavage of the C–C and C–N bonds (elimination of fragments from alkyl substituents) in amine molecular ions occurs more easily with increasing length and branching of the alkyl substituent leading to the formation of stable ammonium ions10 thus destabilizing $[M]^+$.

The characteristic pathways of molecular ion fragmentation involve both bond cleavage followed by elimination of the methyl radical (ion ***a***) (for **1**–**3**), hydrogen atom (ion ***b***) and sulfanyl radical (ion ***c***) (for **1** and **2**), and skeleton rearrangements of the molecular ion, which are ascribed to the loss of C_3H_6 (ion ***d***), C_2H_2S (ion ***e***) and C_3H_6S (ion ***f***). The appearance of the peaks of ions ***d***-***f*** in the mass spectra seems to be caused by isomerization of molecular ions of **1**–**3** to *N*-(6-methyl-5,6-dihydro-2*H*-thiopyran-2-yliden)alkylamines $[M_2]^+$**.** followed by a fragmentation of the retro-diene reaction type.[11]

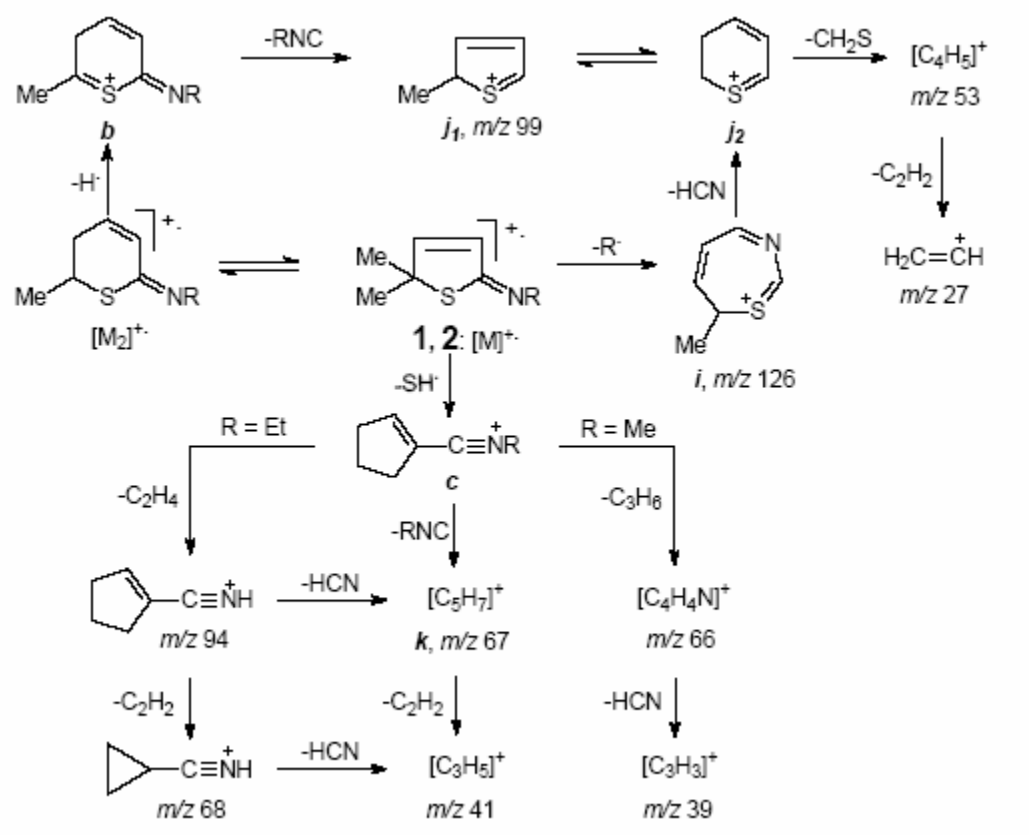


Scheme 2

It can be seen from Table 1 and Scheme 2 that the main fragmentation direction of compounds **1**–**3** caused by β-cleavage and elimination of methyl radical results in the formation of the $[M - Me]^+$ ions with peak intensities of 100% in all spectra. The structures of the molecules would suggest that loss of methyl could occur either from ring position C-5 and/or from the

substituent at the nitrogen atom (from NR). Examination of the mass spectra reveals that in contrast to 5-methyl-2-(thienyl)amines,[2] where the methyl radical is removed from the nitrogen atom with a positive charge localized on it, compounds **1**–**3** undergo cleavage leading to stabilized ions ***a***. This suggestion is based on the following arguments. First, loss of methyl from C-5 should be energetically more favorable because the resulting ions can be stabilized by ring expansion[10] to 2-(alkylimino)-2*H*,5*H*-thiopyranium ions (ion ***a***, Scheme 2); the presence of a lone electron pair at the sulfur atom accounts for resonance stabilization of ions ***a***. Second, in the mass spectrum of compound **4** being devoid of a methyl substituent in position C-5, the peak intensity of the ion $[M -Me]^+$ *m/z* 166 is less than 1%. Moreover, if the elimination of a methyl radical from NR (for R = Et or *i*-Pr) would be responsible for the formation of the ions $[M –Me]^+$ ***l*** type, the mass spectra is expected to show peaks caused by further fragmentation of ions ***l***. However, no peak of this type (ion *m/z* 100, for example) has been identified in the spectra of **2** and **3**.

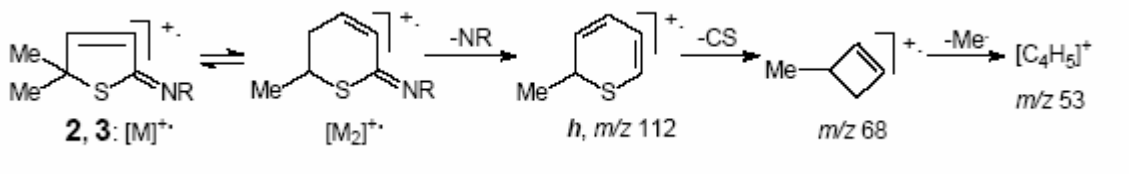
Furthermore, the fragmentation pathways of molecular ions depend upon the nature of the alkyl group at nitrogen. Although the mass spectra of compounds **1**–**3** are in general similar, the spectra of **1** and **2** display peaks absent in the mass spectrum of **3** (Table 1). General fragmentation pathways of **1** and **2** are shown in Scheme 3.



Scheme 3

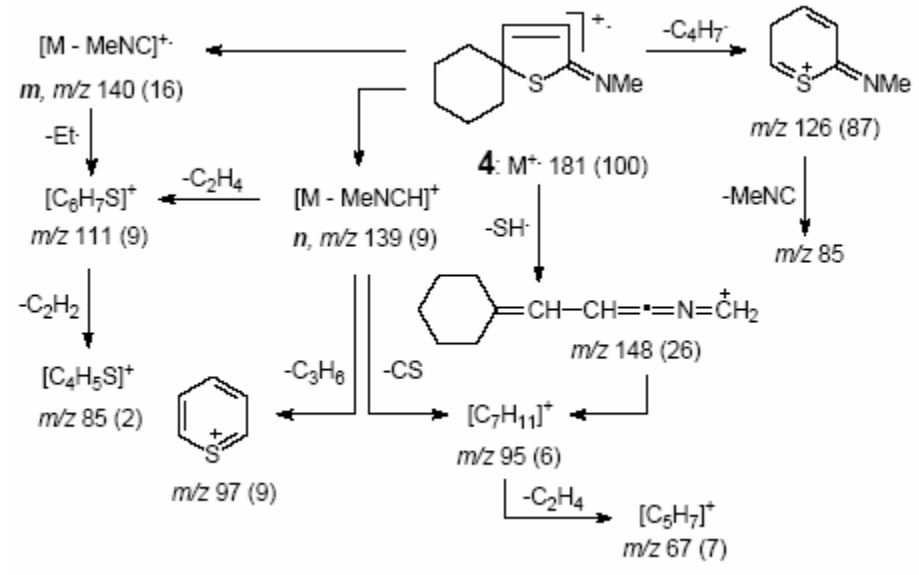
One of these peaks is ascribed to ion $[M - H]^+$ (***b***) with *m/z* 140 and 154 for **1** and **2**, respectively. The driving force of this fragmentation probably involves ring expansion to form the 6-methyl-2-(alkylimino)-2*H*,5*H*-thiopyranium-ion (***b***), which further rearranges either to 2-methyl-2*H*-thiophenium-ion (***j*$_1$**) or to the 2*H*,3*H*-thiopyranium-ion (***j*$_2$**) *m/z* 99. Another route of the molecular ion decomposition also leading to an ion with *m/z* 99 occurs by the subsequent loss of the N-substituent (as the radical R**.**) and of the HCN (from ion *m/z* 126). The last process suggests that the ion (***i***) *m/z* 126 has the structure of a 7-membered ring.

The loss of the sulfanyl radical from the molecular ion is the third fragmentation pattern not typical for compound **3** (ion ***c***, Scheme 3). Further fragmentation of ion ***c*** involves the loss both of RNC (ion ***k***) and of propene (*m/z* 66) or ethene (*m/z* 94) in the case of **1** and **2**, respectively.



Scheme 4

Scheme 4 shows the molecular ion fragmentation pathway characteristic of **2** and **3**, involving the formation of ion (***h***) *m/z* 112 with intensity 31 and 44%, respectively; for compound **3** this route is followed even at 12 eV (Table 1). It should be noted that homolytic cleavage of the bond between the nitrogen atom and the heterocyclic ring was not observed for unsubstituted 2-(thienyl)amines,[1] though it is typical for the decomposition of their 3-methyl- and 5-methyl-derivatives[2] leading to EI-induced expansion of the thiophene ring to thiopyran.



Scheme 5

Possible fragmentation pathways of compound **4** with *m/z* values and relative intensities of the resulting ions are presented in Scheme 5. Although the molecular ions of **4** and **5** are significantly more stable, than those of **1**-**3** (as indicated by the 100% intensity of these peaks and the absence of rearrangement ions ***d***, ***e*** and ***f***), the main fragmentation pathway of the molecular ions is common for all compounds under investigation (**1**-**5**). The most favorable fragmentation **4** and **5** also involves the loss of a radical from the substituent at ring position 5 with the formation of ions $[M - C_4H_7]^+$ with *m/z* 126 (87%) from **4** and *m/z* 188 (32%) from **5**. For **1**, **2**, **4** and **5**, there is other common ion $[M - SH]^+$ resulting from decomposition of the heterocyclic ring, but the intensity of these peaks is influenced by the nature of the N-substituent. Thus, replacement of the methyl group in **4** by phenyl in **5** leads to a decreased peak intensity of the ion $[M - SH]^+$: *m/z* 148 (26%) from **4** and *m/z* 211 (3%) from **5**.

The mass spectrum of **4** shows some peculiarities. The two channels characteristic of only molecular ion of **4** are induced by the elimination of MeNC and its protic radical [MeNCH.] giving rise to ions ***m*** (*m/z* 140) and ***n*** (*m/z* 139), respectively.

The mass spectrum of **5** is very simple and contains only five peaks: $[M]^+$**.**, aforementioned ions $[M - C_4H_7]^+$ and $[M - SH]^+$ as well as ions $[C_6H_5]^+$ *m/z* 77 (10%) and $[C_4H_3]^+$ *m/z* 51 (2%).

In conclusion, the molecular ions of **1**–**5** generated upon electron impact undergo fragmentation involving both rupture of bonds (ions ***a***–***c***) and skeleton rearrangements followed by the formation of odd-electron ions (***d***–***f***). The fragmentation pattern is considerably influenced by the nature of the 2- and 5-substituents in the dihydrothiophene ring.

Experimental Section

General Procedures. The synthesis of the compounds **1**–**5** has been described earlier.[9] Mass spectra were recorded on an LKB-2091 instrument at 12 and 60 eV. The accelerating voltage was 2.3 kV, and the ion source temperature was 250 °C. Samples were introduced into the ion source directly and *via* gas chromatographic inlet (SE-54, 30 m, 250 °C). The temperature was programmed from 70 to 250 °C at the rate of 10 °C·min^{-1}.

Acknowledgements

We thank the Russian Foundation for Basic Research for the financial support (Grant RFBR No. 01-03-32698).

References

1. Klyba, L. V.; Bochkarev, V. N.; Brandsma, L.; Tarasova, O. A.; Vvedensky, V. Yu.;

Nedolya, N. A.; Trofimov, B. A. *Russ. J. Gen. Chem*. (Engl. Transl. of *Zh. Obsh. Khim.*) **1999**, *69*, 1801.
2. Klyba, L. V.; Bochkarev, V. N.; Brandsma, L.; Tarasova, O. A.; Nedolya, N. A.; Trofimov, B. A. *Russ. Chem. Bull.* (Engl. Transl. of *Izv. Akad. Nauk, Ser. Khim.*) **2000**, *49*, 1548.
3. Klyba, L. V.; Bochkarev, V. N.; Brandsma, L.; Nedolya, N. A.; Trofimov, B. A. *Russ. J. Gen. Chem*. (Engl. Transl. of *Zh. Obsh. Khim.*) **1999**, *69*, 1805.
4. Nedolya, N. A.; Brandsma, L.; Verkruijsse, H. D.; Trofimov, B. A. *Tetrahedron Lett*. **1997**, *38*, 7247.
5. Tarasova, O. A.; Klyba, L. V.; Vvedensky, V. Yu.; Nedolya, N. A.; Trofimov, B. A.; Brandsma, L.; Verkruijsse, H. D. *Eur. J. Org. Chem*. **1998**, 253. (b) Tarasova, O. A.; Nedolya, N. A.; Vvedensky, V. Yu.; Brandsma, L.; Trofimov, B. A. *Tetrahedron Lett*. **1997**, *38*, 7241.
6. Nedolya, N. A. *Novel Chemistry Based on Isothiocyanates and Polar Organometallics.* Thesis Utrecht University, The Netherlands, 1999.
7. Brandsma, L.; Nedolya, N. A.; Tarasova, O. A.; Trofimov, B. A. *Chem. Heterocycl. Compd.* (New York. Engl. Transl. of *Khim. Geterotsikl. Soed.*) **2000**, *36*, 1241.
8. Brandsma, L.; Vvedensky, V. Yu.; Nedolya, N. A.; Tarasova, O. A.; Trofimov, B. A. *Tetrahedron Lett*. **1998**, *39*, 2433.
9. Nedolya, N. A.; Brandsma, L.; Schlyakhtina, N. I.; Lazarev, I. M.; Albanov, A. I.; Zinchenko, S. V.; Klyba, L. V. *ARKIVOC* **2001**, *2*, Part IX, 12, MV-226F.
10. Silverstein, R.M.; Bassler, G.C.; Morrill, T.C. *Spectrometric Identification of Organic Compounds*, John Wiley: New York-London-Sydney-Toronto, 1974.
11. Budzikevich, H.; Djerassi, C.; Williams, D. H. *Interpretation of Mass Spectra of Organic Compounds*, Holden-Day: San Francisco, 1964.