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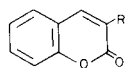
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The electron impact mass spectrometric fragmentation pathways for some 3-substituted derivatives of coumarin, benzo[*f*]coumarin, thieno[3,2-*f*]coumarin, thieno[2,3-*h*]coumarin and azacoumarin, *viz* nitriles, carboxamides, thiocarboxamides and esters were investigated. The initial cleavage of the pyrone ring is found to be largely dependent on the stability, under electron impact, of the attached functional group.

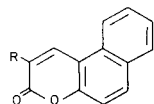
J. Heterocyclic Chem., **17**, 81 (1980).

Coumarins possess a wide range of biological activities (1) and several studies from the viewpoint of chemical taxonomy (2,3,4) have been made. We have recently described (5) a convenient method for the synthesis of coumarin thiocarboxamides. In the present paper we wish to report the mass spectral fragmentation patterns of these compounds and to compare them with those of the analogous carboxamides, nitriles and esters. For the compounds formulated in Fig. 1, the relative abundances of the ions

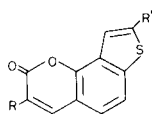
Figure 1



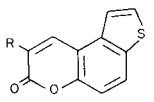
- I, R = CN
II, R = CONH₂
III, R = CSNH₂
IV, R = CO₂Et



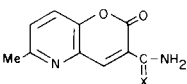
- V, R = CN
VI, R = CSNH₂



- VII, R = CN, R' = H
VIII, R = CN, R' = Br
IX, R = CONH₂, R' = H
X, R = CSNH₂, R' = Me
XI, R = CO₂Et, R' = H
XII, R = CO₂Et, R' = Me
XIII, R = CO₂Et, R' = Br

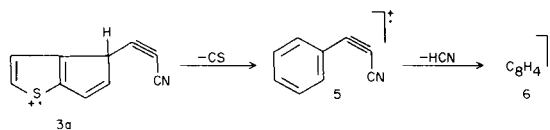
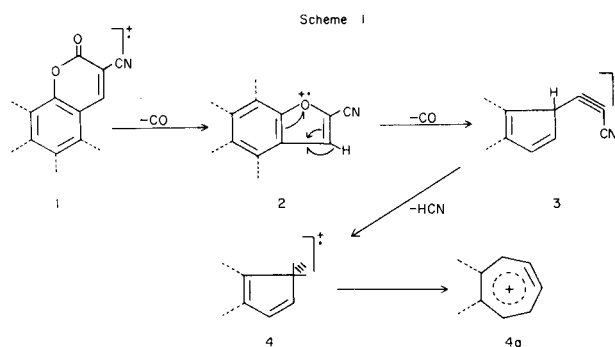


- XIV, R = CN
XV, R = CONH₂
XVI, R = CSNH₂
XVII, R = CO₂Et
XVIII, R = CO₂Me

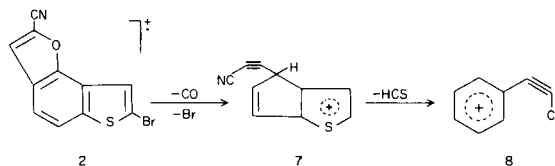


- XIX, X = O
XX, X = S

are shown in the Tables 1 to 4 and the proposed fragmentation patterns in Schemes 1 to 5. With few exceptions the latter have been justified by the existence of metastable ions and by comparison with the fragmentation patterns of known compounds.



Scheme 2



1. Coumarin-3-carbonitriles (I, V, VII, VIII, XIV).

The nitriles (Table 1) are relatively stable under electron impact. Their characteristic fragmentation pattern (Scheme 1) shows the loss of carbon monoxide leading to the furan carbonitrile **2** which in its turn loses another molecule of carbon monoxide to give the acetylenic ion **3** of varying intensity (14.5 to 47%). Both these transformations are corroborated by the presence of appropriate metastable ions.

Table 1

Relative Intensity data for the Nitriles (Figures in parentheses indicate the nature of the ions)

Compound							
I	m/e	172	171	144	143	115	114
	I%	11.7	100 (M ⁺)	8.5	81.3 (2)	47 (3)	14
	m/e	92	89	88	87	76	75
	I%	7	6.3	26.7 (4)	8	5.8	5.3
	m/e	72	63	62	61		
	I%	7.4	19.4	19.6	8.9		
V	m/e	222	221	220	194	193	165
	I%	16.5	100 (M ⁺)	17.3	7.8	53.1 (2)	17.6 (3)
	m/e	164	138	97	83		
	I%	20.3	10.5 (4)	11.3	12		
VII	m/e	228	227	199	171	170	127
	I%	14.4	100 (M ⁺)	42.5 (2)	14.7 (3)	11.4	18.8 (5)
	m/e	100					
	I%	6.2 (6)					
XIV	m/e	228	227	199	171	170	127
	I%	14.4	100 (M ⁺)	44.1 (2)	14.5 (3)	12.4	25.3 (5)
	m/e	100					
	I%	6.4 (6)					
VIII	m/e	308	307	306	305	279	277
	I%	15.4	100 (M ⁺) (a)	16.8	98.9 (M ⁺) (b)	38.2 (2) (a)	35.9 (2) (b)
	m/e	171	170	154	126	125	
	I%	5.4	41.1 (7)	7	4.6	16.8 (8)	

(a) For Br = 81. (b) For Br = 79.

Table 2

Relative Intensity data for the Carboxamides (Figures in parentheses indicate the nature of the ions)

Compound						
II	m/e	190	189	174	173	171
	I%	6.9	100 (M ⁺)	9.7	63.2 (10)	5.4 (11)
	m/e	161	146	145	143	118
	I%	3.7 (14)	10.2	15.7 (12)	4.5	10.2 (15)
	m/e	101	90	89	63	
	I%	9.6	11.6	24.1 (16)	15.5	
XV	m/e	246	245	244	230	229
	I%	15.5	100 (M ⁺)	25.1	5.3	37.7 (10)
	m/e	228	227	217	174	145
	I%	6.5	37 (11)	11.2 (14)	11 (15)	19.3 (16)
IX	m/e	246	245	244	230	229
	I%	15.2	100 (M ⁺)	11	6.3	44.2 (10)
	m/e	228	227	217	174	145
	I%	4.8	29 (11)	13.2 (14)	14.1 (15)	20.8 (16)
XIX	m/e	205	204	189	188	187
	I%	10.3	100 (M ⁺)	4.5	31.6 (10)	34.9
	m/e	186	160	133	132	131
	I%	10.5 (11)	4.7 (12)	14.4 (15)	6 (13)	10.7
	m/e	105	104	78	77	
	I%	11	14.4 (16)	8.2	5.9	

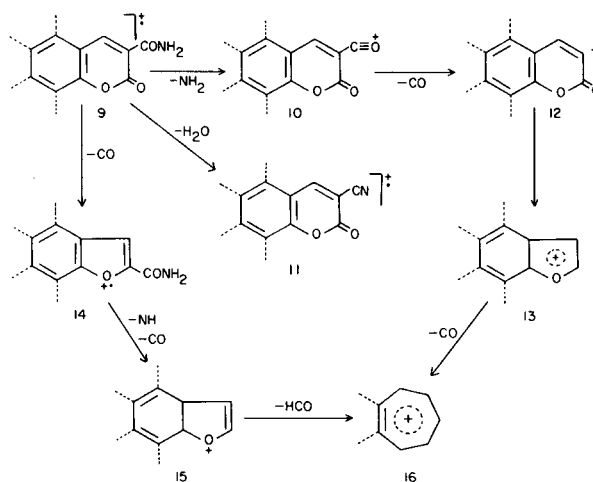
For the Compounds I and V, the ion **3** loses a molecule of hydrogen cyanide leading to **4** which probably undergoes rearrangement to the ionic species **4a** consisting of a seven membered ring. In the case of the thienocoumarins VII and XIV there is a cleavage of the thiophen ring accompanied by the loss of a CS fragment, before the loss of hydrogen cyanide, and this leads to the ions **5** and **6**. The bromoderivative VIII loses carbon monoxide and bromine at the same time from the ion **2** leading to the ion **7** (*m/e* 170) as shown in the Scheme 2. The ion **7** loses HCS in its turn to give **8**.

Contrary to what has been observed in other aromatic nitriles e.g. benzonitrile (**6**), the loss of hydrogen cyanide from the molecular ion of all the compounds, that we have investigated, appears to be of lesser importance. This probably reflects the less stable nature of the heterocycle under electron impact.

2. Coumarin-3-carboxamides (II, IX, XV, XIX).

In the carboxamides the fragmentation process is more complex. The characteristic behaviour of these four compounds involves a loss of mass 16: the corresponding peak has a relatively important intensity (32 to 63%). Most probably this signifies a loss of NH₂ either directly from the molecular ion **9** as in Scheme 3, or by losing NH and H in two successive steps as the analysis in Table 2 suggests. This initial fragmentation leads to the positive ion **10** which in turn loses carbon monoxide to give the ion **12**.

This last fragment, however, could not be properly characterized in the spectra of IX and XV.



Scheme 3 (c)

(c) For XIX replace -CH= by -N= in the 5-position of 9 and in equivalent positions throughout.

A second fragmentation pattern, resembling that of benzamide (**6**) proceeds through the loss of a water molecule from the molecular ion leading to the nitrile **11** which subsequently undergoes decomposition as in Scheme 1.

Table 3

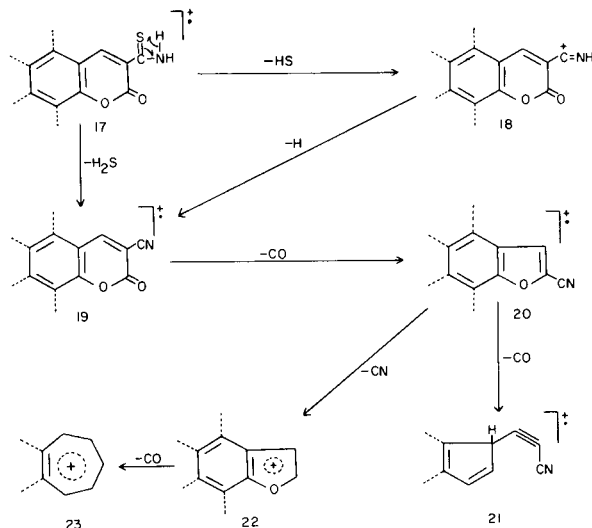
Relative Intensity data for the Thiocarboxamides (Figures in parentheses indicate the nature of the ions)

Compound	<i>m/e</i>	206	205	173	172	171	143	118
III	I%	14.2	52.4 (M*)	15.2	100 (18)	45.7 (19)	36.4 (20)	18.8
	<i>m/e</i>	115	89					
	I%	23.2 (21)	18.6 (23)					
	<i>m/e</i>	256	255	254	223	222	221	202
VI	I%	17.6	100 (M*)	22.7	20.6	97.1 (18)	29.1 (19)	7.3
	<i>m/e</i>	200	199	196	195	193	192	171
	I%	7.9	6	8.4	17.8	12.6 (20)	9.7	7.1
	<i>m/e</i>	167	166	165	140	139		
X	I%	15.7 (22)	5.8	4.8 (21)	16.8	29.4 (23)		
	<i>m/e</i>	276	275	243	242	241	213	212
	I%	15	93.5 (M*)	22	100 (18)	72 (19)	13 (20)	26
	<i>m/e</i>	188	187	159	69			
XVI	I%	13	11 (22)	6.5 (23)	13			
	<i>m/e</i>	262	261	229	228	227	199	173
	I%	10.5	74 (M*)	21	100 (18)	42 (19)	29 (20)	24 (22)
	<i>m/e</i>	171	145	127	69			
XX	I%	12 (21)	37 (23)	16	18.5			
	<i>m/e</i>	221	220	188	187	186	165	159
	I%	18.4	99.0 (M*)	9.7	100 (18)	92 (19)	8.3	37.7
	<i>m/e</i>	158	132	130	105	104	88	
	I%	9.1 (20)	7.5 (22)	8.2 (21)	7.9	8.3 (23)	11.7	

A third fragmentation pattern manifested by all the amides investigated and most particularly by coumarin-3-carboxamide consists of the loss of a molecule of carbon monoxide by the molecular ion, leading to the ion **14**. This then loses carbon monoxide and an NH moiety simultaneously, with migration of a hydrogen atom to the nucleus to give the furan **15**. The latter then loses a CHO radical in a manner typical of the furans. The resulting tropylium ion **16** could also be formed by decomposition of the positive ion **13**, but the participation of the latter in the different spectra is never very significant. The transitions $M^+ \rightarrow 10$, $10 \rightarrow 12$, $M^+ \rightarrow 11$, $M^+ \rightarrow 14$ and $15 \rightarrow 16$ have all been corroborated by the corresponding metastable peaks.

3. Coumarin-3-thiocarboxamides (III, VI, X, XVI, XX).

The fragmentation pattern of these thioamides is quite different (Table 3). Unlike their oxygen analogues, all have a most abundant peak in their spectra corresponding to the ion **18** (Scheme 4). This is formed by the loss of an HS radical from the molecular ion **17** which is facilitated by enothiolisation. The loss of a hydrogen atom from **18** leads



Scheme 4 (d)

(d) For XX replace -CH= by -N= in the 5- position of 17 and in equivalent positions throughout.

Table 4

Relative Intensity Data for the Esters (Figures in parentheses indicate the nature of the ions)

Compound IV	m/e	219	218	174	173	147	146	145
	I%	6.1	45.7 (M ⁺)	17.8 (27)	88.9 (25)	10.6	100 (28)	10.35 (26)
	m/e	118	101	90	89			
	I%	20.7 (29)	15.5	8.2	34.3 (30)			
XVII	m/e	275	274	230	229	218	203	202
	I%	15.5	100 (M ⁺)	13.3 (27)	57.3 (25)	22.4	14.5	95.6 (28)
	m/e	201	174	146	145			
	I%	4.4 (26)	27.4 (29)	7.5	38.6 (30)			
XI	m/e	275	274	230	229	218	203	202
	I%	15.3	100 (M ⁺)	10 (27)	46.5 (25)	7.9	8.9	17.4 (28)
	m/e	174	146	145				
	I%	18.2 (29)	4.7	39.1 (30)				
XII	m/e	289	288	256	244	243	229	216
	I%	21	100 (M ⁺)	9	10 (27)	65.4 (25)	10	43 (28)
	m/e	215	188	187	159	115	107	
	I%	9 (26)	25 (29)	15	30 (30)	12	11	
XIII	m/e	355	354	353	352	310	309	308
	I%	19.1	100 (M ⁺) (a)	18.1	98 (M ⁺) (b)	6.5 (27) (a)	34.7 (25) (a)	8.7 (27) (b)
	m/e	307	283	282	281	280	279	254
	I%	37.8 (25) (b)	6.6	50.3 (28) (a)	13.3 (26) (a)	55.9 (28) (b)	8.1 (26) (b)	14.6 (29) (a)
	m/e	252	225	223				
	I%	14.9 (29) (b)	12.5 (30) (a)	17 (30) (b)				
XVIII	m/e	261	260	232	229	203	202	201
	I%	14.7	100 (M ⁺)	14.3	58.2 (29)	5.6	35.7	20.6
	m/e	174	145					
	I%	9.0	31.8					

(a) For Br = 81. (b) For Br = 79.

to the nitrile **19** which also results from the loss of hydrogen sulphide from **17**. All these transitions have been authenticated by the presence of appropriate metastable peaks. The ion **19** then undergoes fragmentation like the other coumarin carbonitriles via **20** and **21** (Scheme 1) but with one difference. The resulting cyanofuran **20** also loses a CN radical to give the ionic furan **22**. This in turn leads to the ionic species **23** for which the corresponding peak is present in all the spectra.

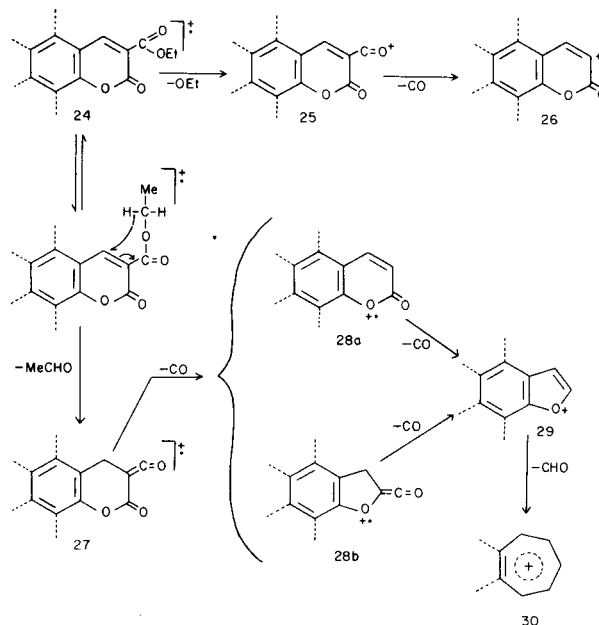
4. Alkyl Coumarin-3-carboxylates (IV, XI, XII, XIII, XVII, XVIII).

The alkyl esters undergo fragmentation by two principal pathways (Table 4). In the first the ethoxy group is lost in the well-known manner (7) as in Scheme 5, following the standard mechanism of electron impact induced fragmentation of the esters (8). This leads to the ion **25**, whose relative intensity is high in all cases. This then loses carbon monoxide to give the coumarin ion **26**. Although the latter could also be formed from the molecular ion by the loss of ethoxycarbonyl radical, we could not find any metastable ion to confirm this hypothesis.

The second route, shown in Scheme 5, which is of equal importance, involves a McLafferty rearrangement of **24** followed by the loss of ethanal leading to the ion **27**. The latter releases a molecule of carbon monoxide, apparently to give an ion of relatively high abundance (the base peak in the case of IV). It is difficult to establish the structure of this species; we propose two alternatives **28a** and **28b**, both of which may be present. Then loss of a molecule of carbon monoxide from **28a** and/or **28b** yields the furan **29**, which subsequently loses a formyl radical to give the familiar tropylium ion **30**.

The methyl ester XVIII also undergoes fragmentation by these two pathways. Loss of a methoxyl group from the molecular ion leads to the ion **25**, whilst loss of methanal leads to the radical ion **27**. However, there is also a peak of medium intensity (14.5%) at m/e 232 in the spectrum, which indicates the loss of a molecule of carbon monoxide from the molecular ion.

The loss of carbon monoxide from the molecular ion is thus observed in the cases of nitriles, carboxamides and methyl esters, but not with thiocarboxamides or ethyl esters. It is, therefore, conceivable that the fragmentation



Scheme 5

pattern of the coumarins investigated is largely dependent on the substituent present in the 3-position and not simply on the stability of the pyrone ring itself under electron impact. The difference between the decomposition paths of the esters XVIII and XVII may be attributed to the greater stability of the carbomethoxy compared to the carboxy function. Similarly, the difference between the fate under electron impact of the thiocarboxamides and those of the carboxamides and the nitriles is principally due to the facility with which the thioamides are known to lose sulphhydryl ions (9).

EXPERIMENTAL

The compounds have been prepared from the appropriate *ortho*-hydroxyaldehydes by base catalyzed Knoevenagel condensations (10). The aldehydes derived from benzo[*b*]thiophen, precursors of compounds VII to XIII (11) and XIV to XVIII (12), and the corresponding pyridine carbaldehyde required for compounds XIX and XX (13) are accessible by known methods. Others are commercially available. All the compounds investigated gave satisfactory elemental analyses. Some have been reported: III, VI and XVI (5), VII to XIII (14), I and II (15), IV (16) and V (17). The rest are described in Table 5.

The mass spectra were recorded in an AEI MS3074 instrument at an ionising potential of 70 eV. The samples were directly introduced into

Table 5

Compound	M.p. °C	Yield %	Formula	Calcd./Found		Calcd./Found		Calcd./Found	
				C%	H%	H%	N%	N%	
XIV	310	76	C ₁₂ H ₅ NO ₂ S	63.4	63.4	2.4	2.4	6.2	6.4
XV	289	59	C ₁₂ H ₇ NO ₂ S	58.8	58.6	2.9	3.2	5.7	5.3
XVII	144	47	C ₁₄ H ₁₀ O ₄ S	61.3	61.6	3.6	3.7	—	—
XVIII	177	44	C ₁₃ H ₈ O ₄ S	60.0	59.7	3.1	3.2	—	—
XIX	225	26	C ₁₀ H ₈ N ₂ O ₃	58.8	58.5	3.9	4.0	13.7	13.6
XX	202	24	C ₁₀ H ₈ N ₂ O ₂ S	54.5	54.3	3.6	3.6	12.7	12.8

the ionisation chamber through a heated inlet kept at 150 to 180°. Elemental compositions were obtained by the peak matching method.

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