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Mass Spectra of 3-Alkyl-4-cinnolinecarbonitriles

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Mass spectra (MS) of 3-alkyl-4-cinnolinecarbonitrile (I) were examined.

In MS of I, $(M-\cdot H)^+$ species are encountered only to a minor extent in the lower one in contrast with $(M-\cdot N_2H)^+$ species. In particular it is worth noting that $(M-\cdot H)^+$ species are not found in MS of 3-methyl- (Ib) and 3-ethyl-4-cinnolinecarbonitrile (Ic).

When the alkyl substituent at the 3-position of I such as methyl (Ib), ethyl (Ic), and propyl (Id), is not so bulky, the important fragmentation arises from the initial expulsion of $\cdot N_2H$ radical from M^+. In turn, when the alkyl substituent is bulkier than that of isopropyl, the importance of this process is not recognized as seen in MS of 3-isopropyl- (Ie) and 3-butyl-4-cinnolinecarbonitrile (If). Those facts mentioned above mean that the ring cleavage of I by the initial expulsion of $\cdot N_2H$ radical is dependent on the relative size of the alkyl substituent at the 3-position.

Keywords——cinnolinecarbonitriles; mass fragmentation; exact mass measurement; $\cdot N_2H$ expulsion; $(M-\cdot H)^+$ species

Except for the studies of the behavior of pyridinecarbonitriles,[2] pyrazinecarbonitriles,[3] 2-quinolinecarbonitriles,[4] 1-isoquinolinecarbonitriles,[4] and 4-pyrido[2,3-*d*]pyrimidinecarbonitrile[5] under electron impact, no systematic investigation of the characteristic cleavage of azine- or diazine-carbonitriles has been undertaken. Now we present the mass spectra (MS) of 3-alkyl-4-cinnolinecarbonitriles (I) as one of diazinecarbonitriles, and discuss their possible fragmentation patterns on the bases of the data of the exact mass measurement and the appropriate metastable peak, because any 3-deutroalkyl-4-cinnolinecarbonitriles could be hardly synthesized.

The nitriles (I) used in this study were as follows; 4-cinnolinecarbonitrile (Ia),[6] 3-methyl- (Ib),[7] 3-ethyl- (Ic),[7] 3-propyl- (Id),[7] 3-isopropyl- (Ie),[7] and 3-butyl-4-cinnolinecarbonitrile (If).[7] MS of I were shown in Table I. The observed metastable peaks were in Table II. The principal fragmentations were shown in Chart 1 to 6. The asterisk under the arrow in Chart denoted that an appropriate metastable peak has been observed in its MS. Each empirical formula of the principal ions was also given by its exact mass measurement as shown in Table III.

4-Cinnolinecarbonitrile (Ia)

The only important fragmentation in MS of Ia arises from the expulsion of nitrogen molecule from the molecular ion (M^+). Then the loss of hydrogen cyanide or acetylenecarbonitrile from the resulting radical ion **1** leads to the radical ion **2** or benzyne radical ion **3**, respectively. It has been well known that the initial expulsion of nitrogen molecule from M^+ was

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[1] Location: *2-2-1 Oshika, Shizuoka-shi.*
[2] G. Hvistendahl, K. Undheim, and J.H. Blanch, *Chem. Scr.*, **7**, 21 (1975).
[3] G. Holzmann, H.W. Rothkopf, R. Mueller, and D. Woehrle, *Org. Mass Spectrom.*, **10**, 97 (1975).
[4] *a*) A. Kubo, S. Sasaki, S. Yamada, I. Yokoe, A. Tatematsu, E. Hayashi, and H. Nakata, *Chem. Pharm. Bull.* (Tokyo), **15**, 1079 (1967); *b*) A. Kubo, S. Sasaki, S. Yamada, I. Yokoe, and C. Kaneko, *ibid.*, **16**, 1533 (1968).
[5] T. Higashino, M. Uchida, and E. Hayashi, *Chem. Pharm. Bull.* (Tokyo), **20**, 772 (1972).
[6] E. Hayashi, Y. Akahori, and T. Watanabe, *Yakugaku Zasshi*, **87**, 1115 (1967).
[7] E. Hayashi and T. Watanabe, *Yakugaku Zasshi*, **89**, 1092 (1969).

TABLE I. MS of I$^{a)}$

Ia	m/e	50	51	52	61	62	63	74	75	76	77	99	100	101	127	128	155	156	
	r.i.$^{b)}$	33	11	8	6	6	10	17	18	27	6	7	32	11	97	12	100	13	
Ib	m/e	50	51	61	62	63	64	74	75	76	87	88	89	99	100	113	114	115	139
	r.i.$^{b)}$	16	12	5	10	15	6	8	10	7	8	11	5	5	5	15	48	12	5
	m/e	140	141	169	170														
	r.i.$^{b)}$	100	15	66	9														
Ic	m/e	50	51	52	61	62	63	64	74	75	76	77	87	88	89	91	99	100	101
	r.i.$^{b)}$	16	16	6	5	9	16	6	10	12	12	10	7	7	5	27	10	11	5
	m/e	102	113	114	115	126	127	128	129	140	141	153	154	155	183	184			
	r.i.$^{b)}$	5	12	7	16	12	34	20	6	100	13	10	49	7	93	14			
Id	m/e	50	51	62	63	64	65	74	75	76	77	87	88	89	91	99	100	101	105
	r.i.$^{b)}$	14	13	8	18	6	5	9	11	10	7	8	9	6	5	7	10	5	10
	m/e	113	114	115	126	127	128	129	139	140	141	142	152	153	154	155	167	168	169
	r.i.$^{b)}$	23	19	12	7	51	13	10	6	71	42	10	5	11	46	8	7	24	8
	m/e	171	196	197	198														
	r.i.$^{b)}$	4	7	100	17														
Ie	m/e	50	51	62	63	64	74	75	76	77	87	88	89	100	101	102	103	114	115
	r.i.$^{b)}$	9	9	5	9	5	7	11	9	11	5	6	5	6	8	6	6	6	8
	m/e	126	127	128	140	141	144	152	153	154	157	167	169	170	182	183	196	197	198
	r.i.$^{b)}$	11	31	13	8	5	18	6	14	6	5	5	100	14	53	9	13	34	6
If	m/e	50	51	52	62	63	64	74	75	76	77	87	88	89	91	99	100	101	102
	r.i.$^{b)}$	12	13	5	7	16	5	7	10	9	9	7	8	5	8	7	9	5	5
	m/e	113	114	115	126	127	128	129	139	140	141	142	143	153	154	155	167	168	169
	r.i.$^{b)}$	18	23	15	10	43	16	5	6	49	47	10	5	13	47	10	11	37	20
	m/e	182	183	185	196	210	211	212											
	r.i.$^{b)}$	8	3	12	1	18	100	19											

a) All peaks are greater than 5% of the base peak, and the important peaks being less than 5% of the base peak are also shown.
b) The relative intensity is represented by percentage of the base peak.

TABLE II. Metastable Peaks (m)$^{a)}$ and Associated Transition (m_1—m_2)

Ia	$m_1 \to m_2$	155→127	127→100	127→ 76	100→ 75	76→ 50
	m	104.0(104.1)	79.0 (78.7)	45.3 (45.5)	56.0 (56.3)	33.0 (32.9)
Ib	$m_1 \to m_2$	169→141	169→140	140→114	140→113	114→ 88
	m	117.5(117.6)	115.8(116.0)	92.0$^{b)}$(92.8)	92.0$^{b)}$(91.2)	68.5 (67.9)
	$m_1 \to m_2$	88→ 62	75→ 51			
	m	43.7 (43.7)	34.5 (34.7)			
Ic	$m_1 \to m_2$	183→154	154→127	140→113	127→100	100→ 75
	m	129.0(129.6)	104.5(104.7)	91.5 (91.2)	78.5 (78.7)	56.0 (56.3)
Id	$m_1 \to m_2$	197→196	197→168	154→127	140→113	127→100
	m	195.0(195.0)	142.8(143.3)	104.7(104.7)	91.5 (91.2)	78.5 (78.7)
	$m_1 \to m_2$	113→ 88	100→ 75	88→ 63	75→ 51	
	m	68.0 (68.5)	56.0 (56.3)	45.0 (45.1)	35.0 (34.7)	
Ie	$m_1 \to m_2$	197→196	197→182	197→169	182→153	153→127
	m	195.0(195.0)	168.0(168.1)	144.5(145.0)	129.0(128.6)	105.0(105.4)
	$m_1 \to m_2$	140→113	127→100	100→ 75	88→ 63	
	m	91.0 (91.2)	78.0 (78.7)	56.0 (56.3)	46.0 (45.1)	
If	$m_1 \to m_2$	211→210	211→196	211→185	211→169	169→141
	m	209.0(209.0)	181.7(182.1)	163.0(162.2)	135.0(135.4)	118.0(117.6)
	$m_1 \to m_2$	154→127	141→114	140→113	127→100	113→ 88
	m	104.5(104.7)	91.5$^{b)}$(92.2)	91.5$^{b)}$(91.2)	78.0 (78.7)	69.0 (68.5)

a) Values in parentheses are theoretical maxima for m.
b) These m appear in overlapping.

Table III. Empirical Formulas of Principal Ions of I

I	m/e		Formula			m/e		Formula		
	Observed	Error[a]	C	H	N	Observed	Error[a]	C	H	N
Ia	155.0462	−2.0	9	5	3	127.0410	−1.2	9	5	1
	100.0285	−2.8	8	4	0	76.0319	0.6	6	4	0
Ib	169.0628	−1.2	10	7	3	140.0456	−4.3	10	6	1
	114.0433	−3.6	9	6	0	88.0278	−3.5	7	4	0
	76.0278	−3.5	6	4	0					
Ic	183.0766	−3.0	11	9	3	154.0656	−0.1	11	8	1
	140.0500	−0.1	10	6	1	127.0511	−3.6	10	7	0
Id	197.0914	−4.0	12	11	3	196.0831	−4.3	12	10	3
	169.0686	4.5	10	7	3	168.0788	−2.6	12	10	1
	155.0517	3.2	9	5	3	154.0627	−3.0	11	8	1
	140.0506	0.6	10	6	1	127.0439	1.7	9	5	1
	114.0434	−3.0	9	6	0					
Ie	197.0925	−2.8	12	11	3	196.0844	−3.1	12	10	3
	182.0704	−1.4	11	8	3	169.0629	−1.0	10	7	3
	153.0563	−1.4	11	7	1	140.0505	0.3	10	6	1
	127.0506	−4.1	10	7	0	114.0428	−4.1	9	6	0
If	211.1103	−0.7	13	13	3	185.1053	−2.1	12	13	2
	182.0736	1.7	11	8	3	169.0644	0.3	10	7	3
	168.0805	−0.8	12	10	1	154.0645	−1.2	11	8	1
	140.0487	−1.3	10	6	1	114.0419	−5.0	9	6	0

[a] Value is error from the theoretical value in millimass unit.

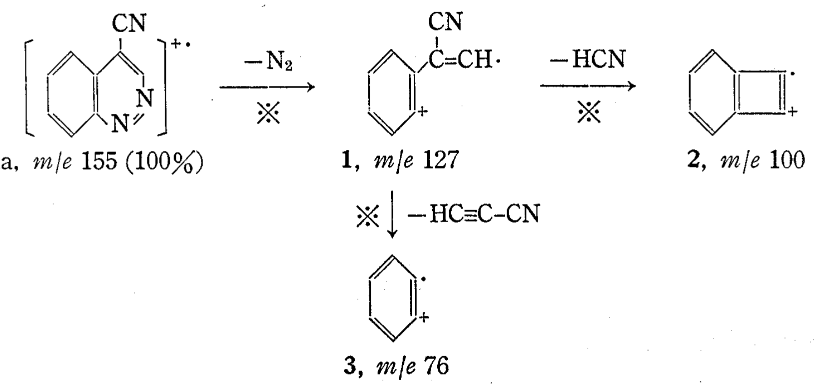

Chart 1

found in MS of heteroaromatic ring system containing adjacent nitrogen atoms such as phthalazine.[8]

3-Methyl-4-cinnolinecarbonitrile (Ib)

In MS of Ib the initial expulsion of nitrogen molecule is not recognized. The first is the expulsion of $\cdot N_2H$ radical from M^+. The cyano radical is then expelled from $(M-\cdot N_2H)^+$ ion (indenyl ion **4**, base peak) to form the radical ion **5**, as shown in Chart 2. The initial expulsion of $\cdot N_2H$ radical and the absence of $(M-\cdot H)^+$ species can be interpreted in the following way. Since nitrogen of the 1-position among adjacing nitrogen atoms probably acts as an acceptor of the hydrogen radical arising from β-cleavage of methyl group, Ib prefers to form Ib′ rather than $(M-\cdot H)^+$ ion such as a type of benzyl ion or diazotropylium ion (the ion **6** or **7**).

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[8] J.H. Bowie, R.G. Cooks, P.F. Donaghue, J.A. Halleday, and H.J. Rodda, *Aust. J. Chem.*, **20**, 2677 (1967).

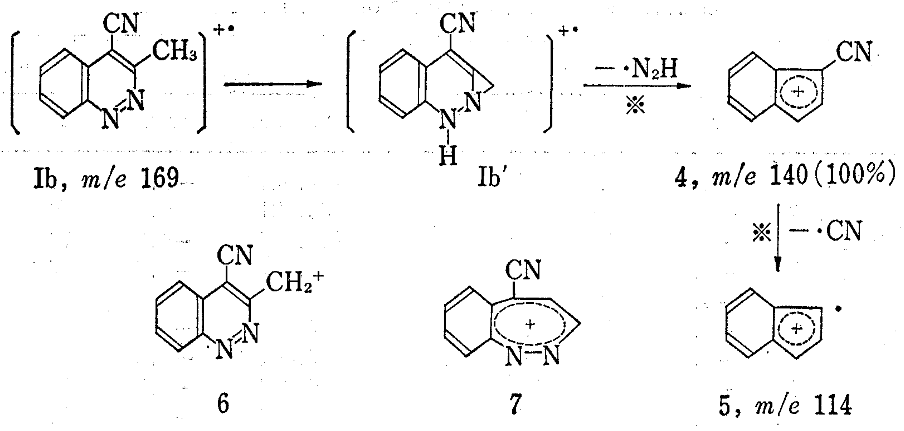

Chart 2

3-Ethyl-4-cinnolinecarbonitrile (Ic)

Since the initial expulsion of $\cdot N_2H$ radical from M^+ is found but no $(M-\cdot H)^+$ ion is found in MS of Ic, the rearrangement from Ic to Ic′ probably arises from the migration of the hydrogen radical with γ-cleavage of ethyl group. The fragmentation of the resulting ion **8** proceeds in two dissociation paths. One is the loss of carbene to form the ion **4**. Another is the elimination of hydrogen cyanide to give the ion **9**, as shown in Chart 3.

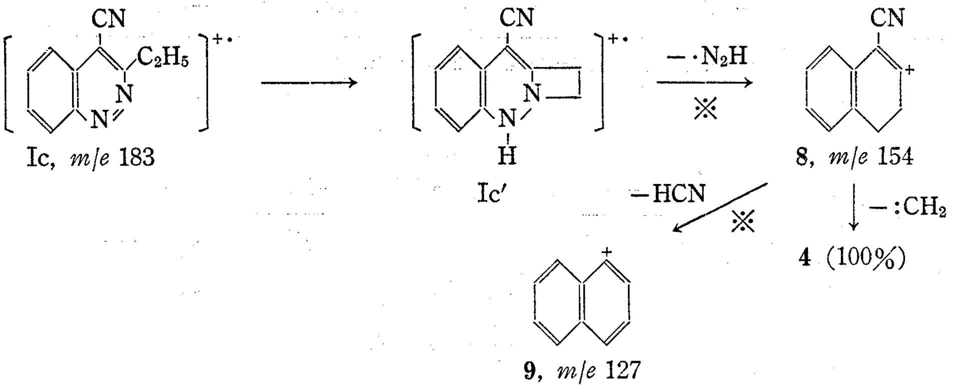

Chart 3

3-Propyl-4-cinnolinecarbonitrile (Id)

In MS of Id the main fragmentation arises from the initial expulsion of $\cdot N_2H$ radical, that is similar to Ic, to form the ion **10** which then leads to the ions **8** or **4** by the loss of carbene or ethylene. There are two dissociation bypaths, namely McLafferty rearrangement[9]

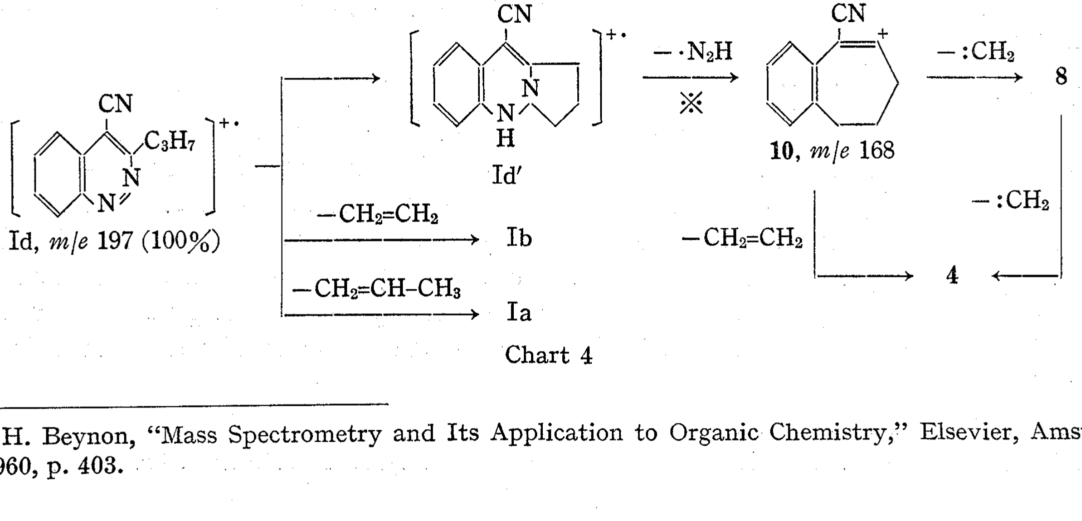

Chart 4

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[9] J.H. Beynon, "Mass Spectrometry and Its Application to Organic Chemistry," Elsevier, Amsterdam, 1960, p. 403.

and α-cleavage with the hydrogen radical rearrangement.[10a)] The former leads to Ib with the loss of ethylene, and the latter forms Ia with the loss of propene.

3-Isopropyl-4-cinnolinecarbonitrile (Ie)

The fragmentation of Ie is different from that of Ia to Id. Thus, the initial expulsion of nitrogen molecule or $\cdot N_2H$ radical from M^+ is not recognized in its MS. The main fragmentation is the initial loss of ethylene to form Ib (base peak).

The dissociation bypath is first the loss of methyl radical to form the ion **11** which is probably rearranged to the ion **12**. Then the expulsion of $\cdot N_2H$ radical from the ion **12** leads to the molecular ion of 1-naphthalenecarbonitrile (**13**).

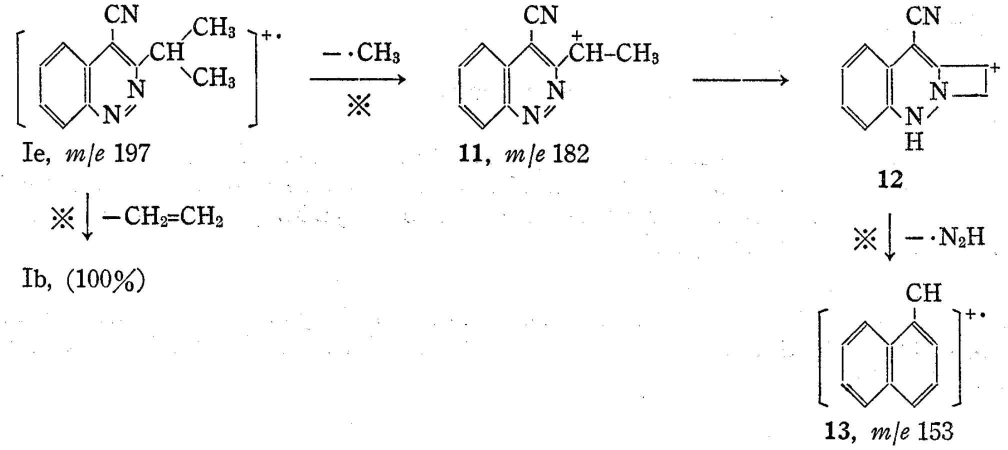

Chart 5

3-Butyl-4-cinnolinecarbonitrile (If)

Instead of the initial expulsion of nitrogen molecule or $\cdot N_2H$ radical, there are four dissociation paths involving the loss of diazomethyl radical, propene, cyano radical, and ethyl radical to form the ion **10**, Ib, **14**, and **15**, respectively, in MS of If. The ion **10** may originate from If′ isomerized by methyl radical rearrangement with δ-cleavage[10b)] of butyl group of If. Then the loss of carbene leads to the ion **8** which is also formed by the expulsion of nitrogen molecule from the ion **15**.

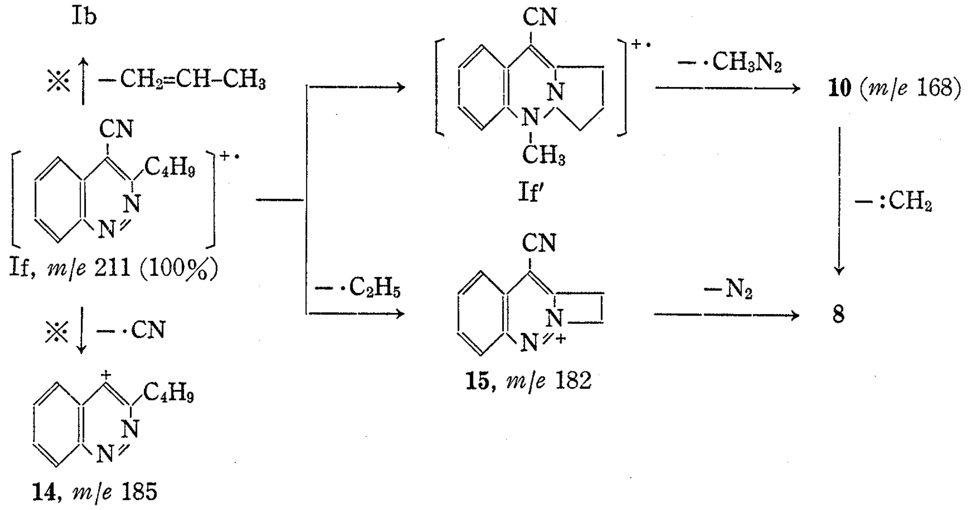

Chart 6

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10) *a*) H. Budzikiewicz, C. Djerassi, and D.H. Williams, "Mass Spectrometry of Organic Compounds," Holden-Day, Inc., San Francisco, 1967, p. 571; *b*) *Idem*, *ibid*., p. 575.

The following conclusion can be reached through the mass spectral data mentioned above. The loss of the hydrogen radical from M^+ is an important fragmentation in MS of nitrogen containing heteroaromatic ring system having the small alkyl substituent such as methyl or ethyl groups. But in MS of I, $(M-\cdot H)^+$ ion is encountered only to a minor extent in the lower one in contrast with $(M-\cdot N_2H)^+$ species. In particular it is worth noting that $(M-\cdot H)^+$ species are not found in MS of Ib and Ic as shown in Table I.

When the alkyl substituent at the 3-position of I such as methyl, ethyl, and propyl is not so bulky, the important fragmentation arises from the initial expulsion of $\cdot N_2H$ radical from M^+. In turn, when the alkyl substituent is bulkier than that isopropyl, the importance of this process is not recognized, as seen in MS of Ie and If. Those facts mean that the ring cleavage of I by the initial expulsion of $\cdot N_2H$ radical is dependent on the relative size of the alkyl substituent at the 3-position.

Experimental

MS were recorded on a Hitachi RMS-4 mass spectrometer. The ionization energy normally used was 75 eV. In order to simplify the complex spectra all samples were also recorded at the lower ionization energy (15 eV). The exact mass measurements were made on a JEOL JMS-01SG-2 mass spectrometer combined with JEC-6 spectrum computer.

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