

JMS Letters

Dear Sir,

Indistinguishable and Rich Unimolecular Dissociation Chemistry of Ionized *endo*- and *exo*-3-Substituted Camphor Isomers

The 2-ketotrimethyl-substituted terpene bicyclic ring system of camphor confers to its ionized form (**1**) a rich and somewhat complex dissociation chemistry that according to isotope labeling studies^{1,2} is dominated by the occurrence of several carbonium ion and free radical rearrangements. Little is known, however, about the dissociation chemistry of camphor derivatives. Most dissociation pathways for the simple camphor ion **1** can be rationalized by initial ionization at the carbonyl group, and therefore a considerable effect on dissociation chemistry is expected for substituents which are located adjacent to the carbonyl group or that could also drive ionization. Additionally, stereoelectronic effects³ may affect considerably the dissociation chemistry of *endo*- and *exo*-isomers of ring-substituted camphor derivatives since such effects have been observed to operate to great extents in some related ring-substituted compounds such as 5-chloro-2-norbornanone⁴ and 2-hydroxy-5-ketobornane.⁵ For instance, ionized *exo*-6-chloronorbornanone displays a much greater tendency to lose Cl[•] when compared with the corresponding *endo*-isomer most likely due to 'through-bond' orbital mixing that facilitates concerted C-1—C-2 ring opening and Cl[•] loss.⁴ Stereoelectronic effects, however, are not observed for the 5-chloro-substituted *endo*- and *exo*-isomers.

We have recently synthesized a series of *endo*- (**n**) and *exo*- (**x**) 3-substituted camphor derivatives (**1–10x,n**, **11** and **12**) and studied the influence of the substituents and of configuration effects on their ¹H and ¹³C NMR chemical shifts.^{6,7} We now report the 70 eV electron impact (EI) mass spectra of these derivatives. Although the nature of the 3-substituents confers a diverse and characteristic dissociation chemistry on these compounds, no stereoelectronic effects were observed for the

endo- and *exo*-isomers, hence they produce very similar 20–70 eV EI mass spectra.

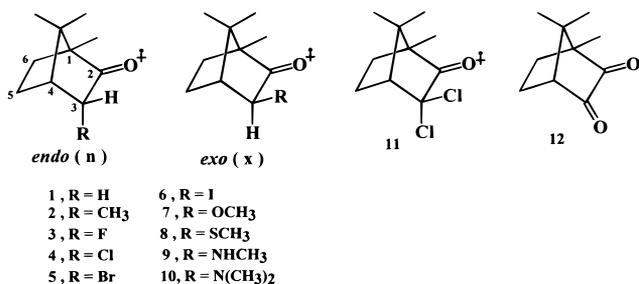


Table 1 presents the major peaks and relative abundances observed in the 70 eV EI mass spectrum of camphor (**1**) and several of its *endo*- and *exo*-3-substituted derivatives (**2–12**), and some representative cases are shown in Fig. 1. Nearly identical dissociation chemistry for the *endo*- and *exo*-isomers is observed, which therefore indicates negligible or no stereoelectronic effects. The lack of such effects is likely a consequence of facile ring opening by cleavage of the C-1—C-2 or C-2—C-3 bonds adjacent to the carbonyl group after ionization at either the C=O or 3-substituent. These ring-opening processes consequently lead to loss of the stereochemistry at the C-3 center. Very similar spectra (not shown) are also observed when employing 20 eV EI.

As observed in Fig. 1(a), the 3-methylcamphor ions **2** dissociate similarly to the simple camphor ion **1**,^{1,8} which indicates little effect of the 3-methyl group on the competition between the major dissociation channels. For some of the higher mass fragment ions, 14 u mass shifts [*m/z* 123 (109), 151 (137)] are observed as expected from the presence of the 3-methyl substituent. The 3-halo ions **3–6**, on the other hand, display distinct dissociation chemistry, as exemplified for **4n** in Fig. 1(b). The *m/z* 95 fragment, which is the major one for the camphor ion **1** (Table 1) and its 3-methyl analogs **2** [Fig. 1(a)], is very

Table 1. Major fragment ions in the 70 eV EI mass spectra of camphor and several of its 3-substituted derivatives^a

2-R	No.	<i>m/z</i> (relative abundance, %)
H	1	152 (28), 137 (5), 110 (14), 109 (32), 108 (41), 95 (100), 93 (18), 83 (29), 81 (74), 69 (44), 68 (20), 67 (33), 55 (44)
CH ₃	2n	166 (21), 151, (3), 123 (38), 110 (10), 109 (16), 108 (46), 95 (100), 83 (65), 81 (22), 69 (27), 67 (38), 55 (72)
F	3n,x^b	170 (24), 155 (3), 127, (22), 123 (12), 83 (100), 69, (31), 55 (59)
Cl	4n	186/188 (20/7), 151 (18), 143/145 (16/5), 123 (47), 83 (100), 69 (30), 55 (53)
Br	5n	230/232 (18/18), 151 (38), 123 (100), 95 (19), 83 (83), 81 (35), 69 (33), 67 (24), 55 (44)
Br	5x	230/232 (18/18), 151 (33), 123 (100), 95 (20), 83 (79), 81 (34), 69 (33), 67 (23), 55 (45)
I	6n	151 (46), 123 (100), 95 (18), 83 (62), 81 (43), 55 (46)
I	6x	151 (49), 123 (100), 95 (22), 83 (66), 81 (50), 55 (48)
OCH ₃	7n	182 (7), 154 (5), 139 (5), 122 (16), 83 (7), 71 (100), 55 (9)
OCH ₃	7x	182 (9), 154 (5), 139 (5), 122 (18), 83 (10), 71 (100), 55 (10)
SCH ₃	8n	198 (30), 170 (5), 155 (9), 123 (21), 122 (15), 87 (100), 55 (18)
SCH ₃	8x	198 (35), 170 (5), 155 (10), 123 (23), 122 (16), 87 (100), 55 (17)
NHCH ₃	9x	181 (1), 153 (9), 71 (4), 70 (100), 55 (2)
N(CH ₃) ₂	10x	195 (1), 167 (10), 84 (100), 55 (2)

^a Some spectra are shown in Fig. 1.

^b The mass spectrum for the *endo*-*exo* mixture.

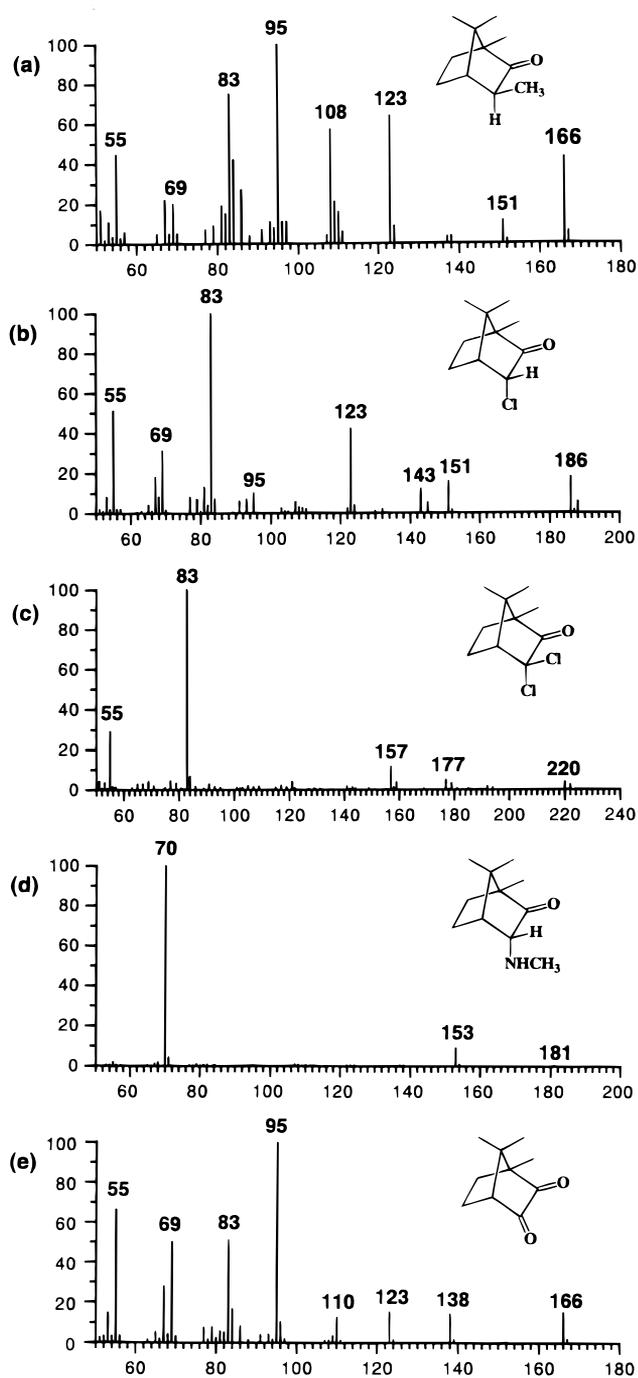
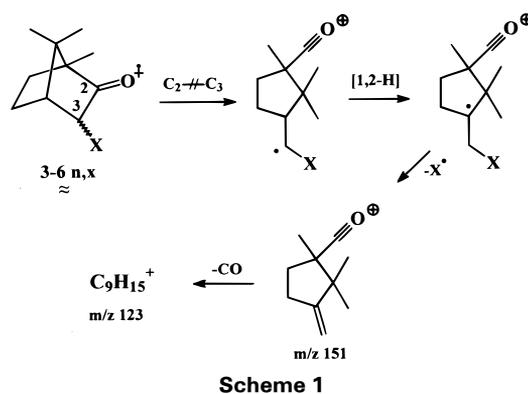


Figure 1. 70 eV EI mass spectra of some 3-substituted camphor derivatives.

minor for the 3-halo ions. On the other hand, the m/z 83 fragment is still a major ion. Additionally, loss of the halogen atom (m/z 151) followed most likely by loss of a neutral CO molecule (m/z 123) is also an important dissociation channel [high-resolution measurement on the m/z 123 ion (123.11708 u) indicates the $C_9H_{15}^+$ composition (Scheme 1) that corroborates CO loss and negates the alternative loss of a neutral molecule of ethylene (C_2H_4)]. It is interesting that the formation of the minor m/z 95 fragment has been proposed^{1,2} for 1 to be initiated by C-1—C-2 cleavage, whereas the dissociation process leading to m/z 83 was proposed to be initiated instead by C-2—C-3 cleavage. Additionally, initial cleavage of the

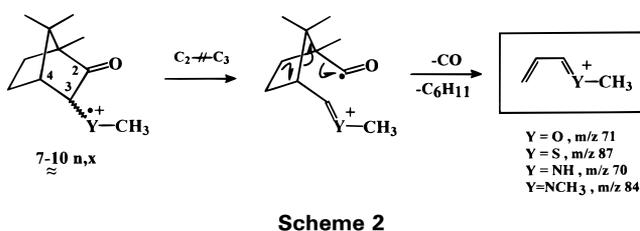


C-2—C-3 bond is also probably involved in the formation of the m/z 151 and 123 fragments (Scheme 1). C-2—C-3 cleavage appears therefore to dominate and to be greatly facilitated by the 3-halo substituents. Such a trend can therefore be rationalized as a consequence of the stabilizing effect of the 3-halo substituent on the radical site of the distonic ion formed upon C-2—C-3 cleavage (Scheme 1). It is also interesting that whereas the ratio of the relative abundances of the m/z 123 and 151 fragments remains approximately constant, the abundances of both of these ions with respect to the m/z 83 ion increase considerably on moving from 3 to 6, as represented in Fig. 2. This trend therefore reflects lower dissociation thresholds for the release of the halogen radicals (Scheme 1) proportioned by weaker C—X bonds⁹ in the order C—F (3) < C—Cl (4) < C—Br (5) < C—I (6). As a natural consequence of the more facile halogen atom loss, the competing process of $CH_3^·$ and CO loss is of medium importance for the 3-fluorocamphor ions 3 (m/z 127, 22%), and decreases sharply on moving to the heavier halogens, i.e. 4 (m/z 143, 16–13%), 5 (m/z 189, <1%), not being observed at all for the 3-iodocamphor ions 6.

The dissociation chemistry of the 3,3-dichlorocamphor ion 11 is very simple and characterized mainly by the great predominance of the m/z 83 fragment [Fig. 1(c)]. The greater radical-stabilizing effect in this case of two 2-Cl substituents that favors initial C-2—C-3 α -cleavage can again account for the even greater abundance of the m/z 83 ion.^{1,2} Such stabilization appears also to prevent a further [1,2-H] shift (Scheme 1) and Cl[·] loss (m/z 185) occurs to a very modest extent.

The 3-YCH₃ (Y = O, S, NH, NMe) substituted camphor ions 7–10 also display a very characteristic and simple dissociation chemistry, as exemplified for 9n in Fig. 1(d). A dissociation pathway that accounts for the formation of these fragments is shown in Scheme 2. Formation of ions with the $C_4H_7Y^+$ composition is confirmed by high-resolution measurements; for instance, a mass of 87.02652 u was found for the m/z 87 fragment of 8n whereas the calculated mass for $C_4H_7S^+$ is 87.02630 u. Note that such ions are also dominant fragments for several α -amino- and α -alkoxy-substituted cyclic ketones.⁸

The 3-ketocamphor ion, that is, ionized bornane-2,3-dione (12), similarly to the simple camphor ion 1, shows a rich dissociation chemistry dominated by the m/z 95, 83, 69 and 55 frag-



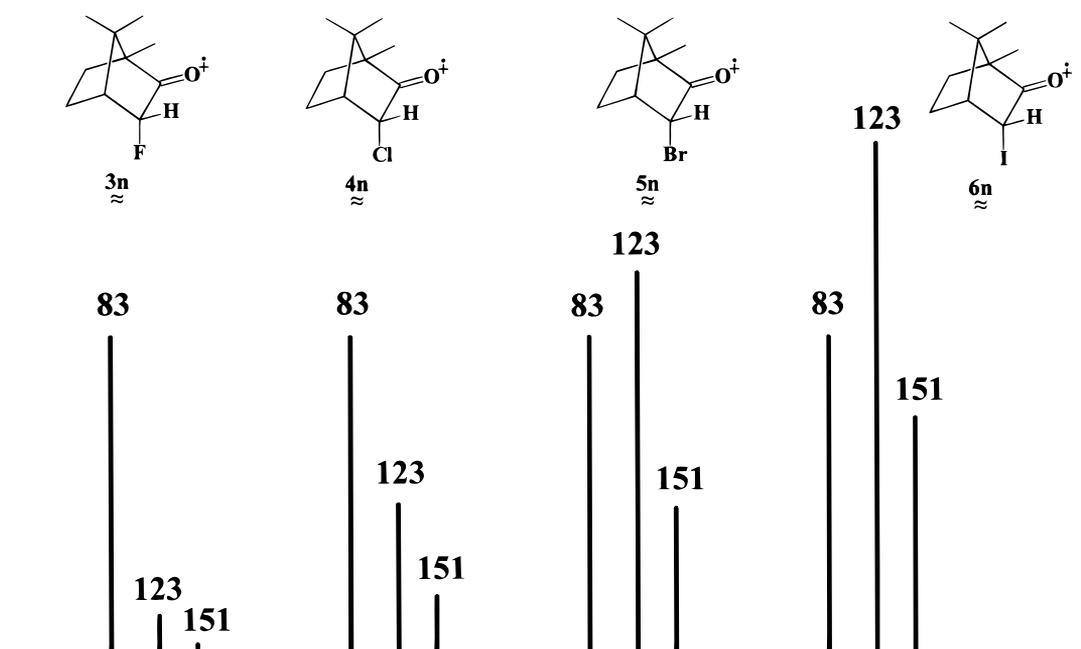


Figure 2. Relative abundances of the m/z 83, 123 and 151 fragments for the 3-halocamphor ions **3–6**. The increasing abundance of the m/z 151 ($X\cdot$ loss) and m/z 123 ($X\cdot$ plus CO loss) fragments is probably a consequence of lower dissociation thresholds for the release of the halogen radicals proportioned by weaker C–X bonds.

ments [Fig. 1(e)]. It appears that the main m/z 95 fragment is formed from **12** by two competitive routes that involve consecutive losses of either CO (m/z 138), $\text{CH}_3\cdot$ (m/z 123) and a second CO molecule (m/z 95), or CO (m/z 138), a second molecule of CO (m/z 110) and $\text{CH}_3\cdot$ (m/z 95).

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Yours

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