Strained Heterocyclic Systems. VII. The Mass Spectral Fragmentations of Dihydrocycloalka[*b*]quinolines and Quinoline *N*-Oxides (1).

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High resolution mass spectra of compounds **1-6** were investigated. The quinolines (**1-3**) all exhibit a prominent $(M-1)^+$ peak and subsequent loss of HCN. These processes are consistent with azatropylium ion intermediates. The *N*-oxides (**4-6**) all exhibit major peaks at $(M-16)^+$; the abundance of the latter is related to the geometry of the molecule. The four-membered ring compounds (**3** and **6**) give more complex spectra, which reflect the influence of the fused strained ring.

During the past decade, considerable attention has been directed toward establishing the fragmentation pathways of nitrogen heterocyclics (3-6) and the *N*-oxides of such systems (7-16) induced by electron impact. Frequently, these studies have included monoalkyl- and dialkylquinolines in which the side chains ranged from methyl to pentyl. None of the reports to date have treated cycloalkane derivatives.

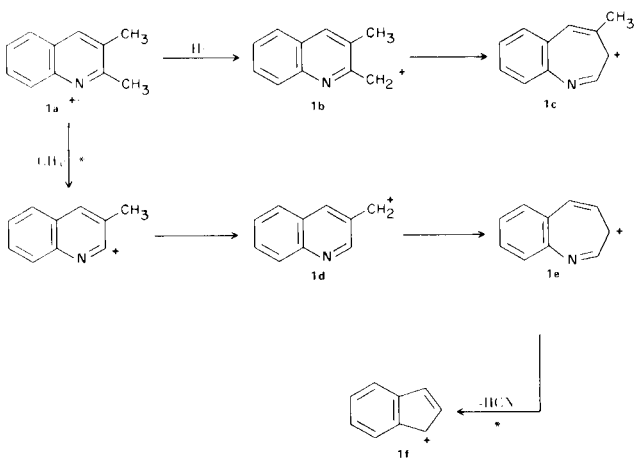
As a corollary to our interest in strained heterocyclic systems (17,18), we have prepared 2,3-dimethylquinoline (**1**), 2,3-dihydro-1*H*-cyclopenta[*b*]quinoline (**2**), 1,2-dihydrocyclobuta[*b*]quinoline (**3**), and their corresponding *N*-oxides (**4**, **5** and **6**, respectively) for mass spectrometric studies. The group of three *N*-oxides consistutes an interesting series for assessing the structural influences on the *ortho*-effect (8), by which the molecular ion loses a hydroxyl fragment. The spectra of the parent heterocyclics are of interest for two reasons. They serve as reference compounds for the *N*-oxides, since the latter are known to undergo deoxygenation (7). Also, the cycloalkane derivatives **2** and **3** comprise new systems for defining the scope of the ring expansion to azatropylium ions, a process known to occur with alkylquinolines (3,4).

The fragmentation patterns and established metastable transitions of the six compounds are summarized in Tables I-IV (19). 2,3-Dimethylquinoline (**1**) is included as a point of reference in considering novel features of the fragmentation patterns of the compounds whose structures include fused alicyclic rings. The fragmentation of **1** is

TABLE I

Major Fragments in the Mass Spectra of **1-3**

Species	Fragment Lost	Relative Intensities (%) **1**	**2**	**3**
M		100	100	100
M-1	H	39	87	68
M-2	H_2	2	25	4
M-15	CH_3	6	6	11
M-26	C_2H_2	6	2	6
M-27	C_2H_3	6	1	3
	HCN	0	0	7
M-28	C_2H_4	5	3	4
	CH_2N	3	1	8
M-29	C_2H_5	3	8	0
	CH_3N	3	0	0
M-40	C_3H_4	2	1	0.7
	C_2H_2N	0	0.5	9
M-41	C_3H_5	4	1	1
	C_2H_3N	3	2	8
M-42	C_3H_6	0	0.6	0.3
	C_2H_4N	20	2	5



dominated by propensity towards the azatropylium cation, which then loses HCN to yield an indenyl cation (20). Identification of the indicated metastable species, coupled with the assumption that the C and N in the HCN fragment are adjacent atoms, leads to the conclusion that **1b** is the correct structure for the benzyl-type cation, rather than the isomeric structure resulting from the loss of H from the 3-methyl. Similar reasoning leads to the depicted structures in the sequence to **1f**, where the 2-methyl is the initial loss rather than the 3-methyl. Furthermore, these fragmentations are consistent with reported fragmentation patterns for 2-methylquinoline (3,4) and 3-methylquinoline (3,21,22). Although there is a small abundance of the ion resulting from loss of CH_3CN from the molecular ion, no metastable transition was observed. For the ions of m/e 130, 129, 128, 117, and 116, resulting from loss of C_2H_3 or of HCN, it is noteworthy that loss of the hydrocarbon fragment consistently leads to the more abundant ion.

TABLE II

Major Fragments in the Mass Spectra of **4-6**

Species	Fragment Lost	Relative Intensities (%) 4	5	6
M		66	59	100
M-1	H	1	3	12
M-16	O	48	37	63
M-17	HO	100	100	45
M-18	H_2O	3	36	5
M-19	H_3O	6	6	0
M-28	CO	0	0	17
M-29	CHO	0	2	45
M-30	CH_2O	0	0	58
M-31	CH_3O	5	3	50
M-33	CH_5O	5	0	0
M-42	C_2H_2O	9	0	5
M-43	C_2H_3O	10	0	9
	CHNO	0	0	4
M-44	C_2H_4O	1	2	4
	CH_2NO	9	0	9
M-45	C_2H_5O	4	5	0
	CH_3NO	6	0	6
M-55	C_3H_3O	0	14	7
M-56	C_2H_2NO	0	0	44
M-57	C_3H_5O	10	0	0
	C_2H_3NO	0	0	26
M-58	C_2H_4NO	25	0	10

TABLE III

Metastable Transitions in the Mass Spectra of **1-3**

Compound	Transition	Relative Intensity (%) (a)
1	$157^+ \rightarrow 142^+ + CH_3\cdot$	1.3
	$157^+ \rightarrow 130^+ + C_2H_3\cdot$	0.6
	$157^+ \rightarrow 117^+ + C_3H_4$	0.2
	$156^+ \rightarrow 141^+ + CH_3\cdot$	0.07
	$156^+ \rightarrow 140^+ + CH_4$	0.06
	$156^+ \rightarrow 129^+ + HCN/C_2H_3\cdot$	1.6
	$155^+ \rightarrow 128^+ + HCN/C_2H_3\cdot$	0.5
	$154^+ \rightarrow 127^+ + HCN/C_2H_3\cdot$	0.1
	$142^+ \rightarrow 116^+ + C_2H_2$	0.3
	$142^+ \rightarrow 115^+ + HCN$	0.7
	$141^+ \rightarrow 114^+ + HCN$	0.05
	$140^+ \rightarrow 113^+ + HCN$	0.13
2	$168^+ \rightarrow 141^+ + HCN/C_2H_3\cdot$	0.2
	$167^+ \rightarrow 140^+ + HCN/C_2H_3\cdot$	0.1
	$166^+ \rightarrow 139^+ + HCN/C_2H_3\cdot$	0.1
	$156^+ \rightarrow 129^+ + HCN/C_2H_3\cdot$	0.04
	$155^+ \rightarrow 128^+ + HCN/C_2H_3\cdot$	0.1
	$154^+ \rightarrow 127^+ + HCN/C_2H_3\cdot$	0.2
	$143^+ \rightarrow 128^+ + CH_3\cdot$	0.04
	$143^+ \rightarrow 116^+ + HCN/C_2H_3\cdot$	0.03
	$142^+ \rightarrow 115^+ + HCN/C_2H_3\cdot$	0.3
	$141^+ \rightarrow 114^+ + HCN/C_2H_3\cdot$	0.2
	$140^+ \rightarrow 113^+ + HCN/C_2H_3\cdot$	0.01
3	$155^+ \rightarrow 140^+ + CH_3\cdot$	0.5
	$155^+ \rightarrow 129^+ + C_2H_2$	0.5
	$155^+ \rightarrow 128^+ + HCN/C_2H_3\cdot$	0.9
	$154^+ \rightarrow 127^+ + HCN/C_2H_3\cdot$	1.9
	$140^+ \rightarrow 113^+ + HCN/C_2H_3\cdot$	0.7
	$129^+ \rightarrow 102^+ + HCN/C_2H_3\cdot$	0.4
	$128^+ \rightarrow 101^+ + HCN/C_2H_3\cdot$	0.2
	$115^+ \rightarrow 89^+ + C_2H_2$	0.3

(a) The intensity (%) of the metastable ion precursor relative to the daughter fragment.

The cycloalkane derivatives **2** and **3** exhibit low resolution fragmentation patterns similar to that shown for **1**. The base peak for all three parent heterocyclic systems is the molecular ion, and the next most abundant species is the (M-1) ion. As might be expected, with the alicyclic ring structure present in **2**, the (M-2) ion is also abundant.

The structures of **2b** and **2c** are analogous to those inferred for **1b** and **1c**, and **2c** also was observed to lose C_2H_3 and HCN. Identical considerations apply to structures **2d** and **2e** but the loss of HCN is small compared to the loss of C_2H_3. With the exception of the $(M-C_2H_5)$ and $(M-C_2H_4N)$ ions, the competing fragmentations of C_2H_3 and HCN are comparable for **1** and **2**; *i.e.*, the loss of C_2H_3 is favored over the loss of HCN.

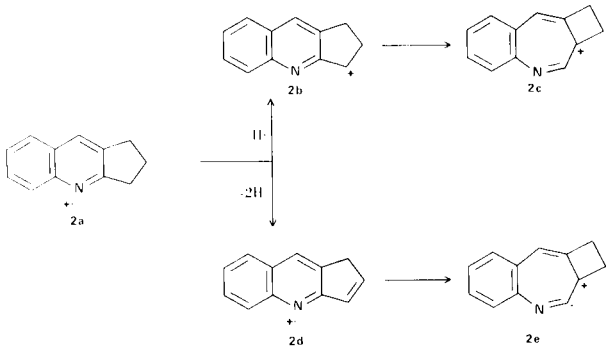


TABLE IV

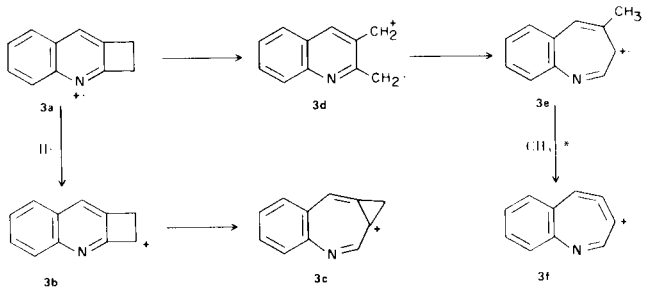
Metastable Transitions in the Mass Spectra of **4-6**

Compound	Transition	Relative Intensity (%) (a)
4	$173^+ \rightarrow 156^+ + OH\cdot$	3.0
	$172^+ \rightarrow 155^+ + OH\cdot$	0.8
	$157^+ \rightarrow 142^+ + CH_3\cdot$	0.4
	$157^+ \rightarrow 130^+ + C_2H_3\cdot$	0.6
	$156^+ \rightarrow 141^+ + CH_3\cdot/NH\cdot$	0.3
	$156^+ \rightarrow 140^+ + CH_4$	0.05
	$156^+ \rightarrow 129^+ + HCN/C_2H_3\cdot$	2.7
	$156^+ \rightarrow 116^+ + C_3H_4$	1.6
	$156^+ \rightarrow 115^+ + C_2H_3N$	0.8
	$156^+ \rightarrow 114^+ + C_2H_4N\cdot$	0.04
	$155^+ \rightarrow 128^+ + HCN/C_2H_3\cdot$	0.4
	$154^+ \rightarrow 127^+ + HCN/C_2H_3\cdot$	0.4
	$142^+ \rightarrow 116^+ + C_2H_2$	0.2
	$142^+ \rightarrow 115^+ + HCN$	1.2
	$141^+ \rightarrow 114^+ + HCN/C_2H_3\cdot$	0.2
5	$185^+ \rightarrow 168^+ + OH\cdot$	6.0
	$185^+ \rightarrow 130^+ + C_3H_3O\cdot$	0.3
	$184^+ \rightarrow 167^+ + OH\cdot$	0.3
	$184^+ \rightarrow 156^+ + CO$	0.08
	$184^+ \rightarrow 129^+ + C_3H_3O\cdot/C_2HNO\cdot$	0.02
	$183^+ \rightarrow 166^+ + OH\cdot$	0.1
	$182^+ \rightarrow 154^+ + CO$	0.02
	$169^+ \rightarrow 154^+ + CH_3\cdot$	0.04
	$168^+ \rightarrow 141^+ + HCN/C_2H_3\cdot$	0.02
	$167^+ \rightarrow 140^+ + HCN/C_2H_3\cdot$	0.12
	$166^+ \rightarrow 139^+ + HCN/C_2H_3\cdot$	0.24
	$157^+ \rightarrow 130^+ + C_2H_3\cdot$	0.07
	$156^+ \rightarrow 129^+ + HCN/C_2H_3\cdot$	0.08
	$155^+ \rightarrow 128^+ + HCN/C_2H_3\cdot$	0.12
	$154^+ \rightarrow 127^+ + HCN/C_2H_3\cdot$	0.22
	$153^+ \rightarrow 126^+ + HCN/C_2H_3\cdot$	0.7
	$143^+ \rightarrow 116^+ + C_2H_3\cdot$	0.06
	$142^+ \rightarrow 115^+ + HCN/C_2H_3\cdot$	0.2
	$141^+ \rightarrow 114^+ + HCN/C_2H_3\cdot$	0.17
	$140^+ \rightarrow 113^+ + HCN/C_2H_3\cdot$	0.2
	$130^+ \rightarrow 103^+ + HCN/C_2H_3\cdot$	0.3
	$129^+ \rightarrow 102^+ + HCN/C_2H_3\cdot$	0.1
	$128^+ \rightarrow 101^+ + HCN/C_2H_3\cdot$	0.2
6	$171^+ \rightarrow 154^+ + OH\cdot$	0.6
	$171^+ \rightarrow 143^+ + CO$	1.3
	$170^+ \rightarrow 153^+ + OH\cdot$	0.04
	$170^+ \rightarrow 142^+ + CO$	3.1
	$170^+ \rightarrow 141^+ + CHO\cdot$	1.7
	$169^+ \rightarrow 140^+ + CHO\cdot$	0.1
	$155^+ \rightarrow 140^+ + CH_3\cdot$	0.1
	$155^+ \rightarrow 129^+ + C_2H_2$	0.1
	$155^+ \rightarrow 128^+ + HCN/C_2H_3\cdot$	1.1
	$155^+ \rightarrow 115^+ + C_3H_4/C_2H_2N$	0.04
	$154^+ \rightarrow 127^+ + HCN/C_2H_3\cdot$	0.6
	$153^+ \rightarrow 126^+ + HCN$	0.3
	$144^+ \rightarrow 129^+ + CH_3\cdot$	0.1
	$143^+ \rightarrow 117^+ + C_2H_2$	0.2
	$142^+ \rightarrow 116^+ + C_2H_2$	0.8
	$142^+ \rightarrow 115^+ + HCN/C_2H_3\cdot$	3.1
	$141^+ \rightarrow 114^+ + HCN/C_2H_3\cdot$	3.7
	$140^+ \rightarrow 113^+ + HCN$	0.3
	$129^+ \rightarrow 102^+ + HCN/C_2H_3\cdot$	0.2
	$128^+ \rightarrow 101^+ + HCN/C_2H_3\cdot$	0.4

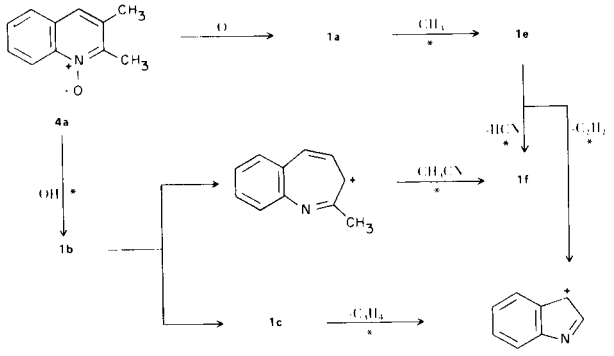
(a) The intensity (%) of the metastable ion precursor relative to the daughter fragment.

Although inspection of a low resolution scan of **3** suggests that the fragmentation pattern closely resembles **1** and **2**, there proves to be a marked change in the relative losses of HCN and C_2H_3. The loss of HCN is now favored over the loss of C_2H_3; indeed, this includes the loss of HCN from the molecular ion, an event which was trivial or nonexistent for **1** and **2**. Previous investigators (3) have speculated on whether or not ring expansion occurs in the M or the (M-1) species. Preferential loss of HCN over C_2H_3 in **3** is best accommodated by rearrangement of **3a** to an azatropylium ion (**3c**) prior to HCN expulsion. Further, although all three parent ions show a loss of CH_3 from the molecular ion, its relative intensity is actually enhanced in the spectrum of **3**. Both of these phenomena may be a result of the ring strain inherent in such a system (17,18). Thus, initial bond cleavage between C-1 and C-2 (relief of strain) would generate ion **3d** which, after ring expansion and hydrogen migration, can afford ion, **3e**. The structure of the latter species is consistent with the observed losses of CH_3 (**3f**) and HCN from the molecular ion. The principal fragmentation is still the loss of H from the molecular ion. The route to ion **3c** *via* **3b** is by analogy to the previous systems, since **3c** is known to lose HCN.

Of the three quinoline *N*-oxides **4-6**, the first two show the expected fragmentations. In addition to major

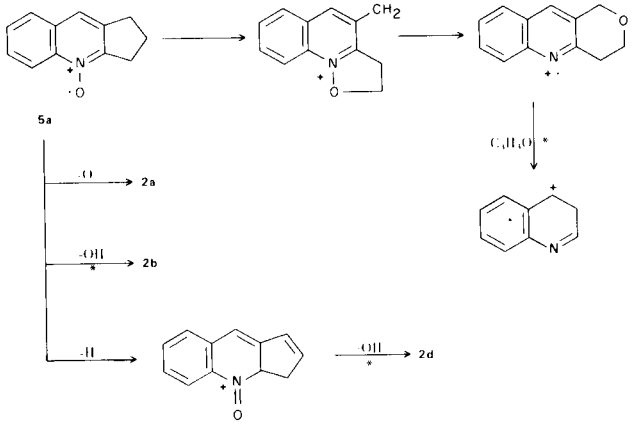


peaks at M and (M-16), both compounds have the base peak at (M-17). The deoxygenation of the molecular ion to (M-16) is characteristic of many aromatic *N*-oxides having no alkyl substituent at the α-position (7,8,11), although in some cases the base peak remains the molecular ion (9,10,12,14). It has recently been shown that the loss of oxygen is thermally induced and is not a result of electron impact (16,23). The subsequent fragmentations of the (M-16) species of **4** and **5** parallel the behavior of the molecular ions of **1** and **2**. For this reason many of the ions in the following two schemes are the same as those discussed above for the parent systems. However, the enhanced relative abundance of



several of those ions above the values found for the corresponding quinolines (**1** and **2**) indicates that their presence must also be due to electron impact fragmentations. Successive spectral scans clearly showed the enhancement of the (M-16) ion with time. Consequently, the spectra of **4-6** were obtained using the direct introduction probe of the CEC-21-110B with as short a time delay as was practicable.

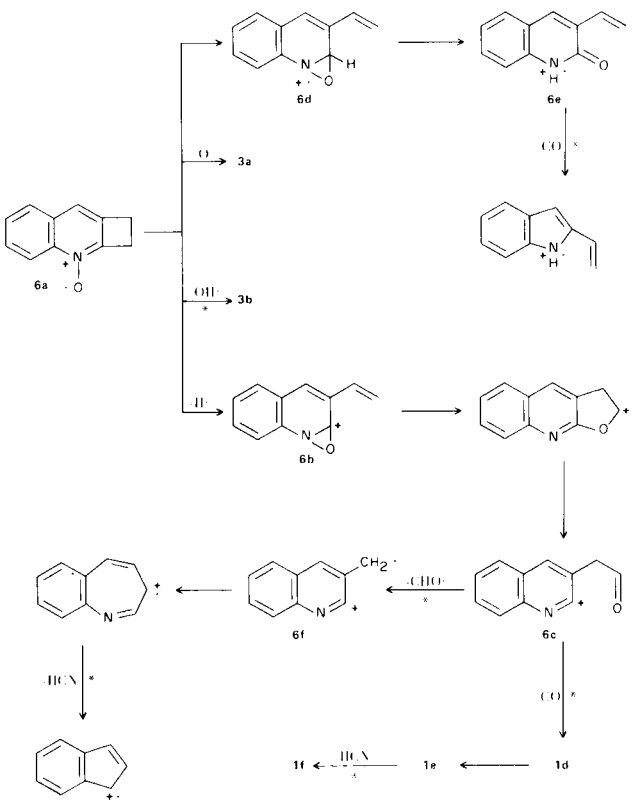
The base peaks at (M-17) for **4** and **5** are examples of the *ortho*-effect (8). The loss of OH is a concerted process, and the appropriate metastable transitions were observed for both **4** and **5**. Similar transitions have been detected for 2-methyl derivatives of pyridine (13), pyrazine (14), quinolines (12,16), and quinoxalines (10). The (M-17) species from **4** and **5** correspond to (M-1) species from the parent quinolines and the subsequent



fragmentations reflect those identifies.

The spectrum of **6** is quite complex; it is apparent that more principal pathways are involved than was the case with either **4** or **5**. The base peak of **6** is the molecular ion, and the (M-16) ion is the next most abundant. The latter species corresponds to M for **3** and the same fragmentations are observed (Chart I). The relative intensity of the (M-17) ion from **6** is significantly decreased, as might be expected from the unfavorable geometry of **6**, in which the hydrogen atoms of the α-methylene group required for a concerted elimination

CHART I



of OH are more distantly located than in **4** or **5**. That the (M-17) ion is produced *via* a one-step process was established by the appropriate metastable transition. This is in contrast with the situation for 2-alkylbenzimidazole *N*-oxides in which the (M-17) ion has been shown to arise from sequential losses of O and then H (10). The absence of an *ortho*-effect in the benzimidazole system was ascribed to the strain of the five-membered imidazole ring. The (M-17) species from **6** corresponds to (M-1) from **3** and the subsequent fragmentations have been discussed earlier.

The (M-1) ion from **6** proved to be an important intermediate. Metastable transitions were observed which established that **6b** was the precursor for losses of CO and CHO. Chart I diagrams these processes, along with the loss of CO from **6a**. The routes shown for these fragmentations are consistent with the photochemical rearrangements of quinoline *N*-oxides (11,24). The initial step is the formation of an oxaziridine intermediate (**6b** or **6d**). The isomerization of **6d** to **6e** has photochemical analogies (24). In the mass spectrum of quinoline *N*-oxide the isomerization to 2-quinolone was shown to be the result of electron impact rather than thermal induction (25). Kaneko and co-workers regard the presence of (M-CO) ions in such spectra as a criterion for the intermediacy of the corresponding oxaziridine structures (11). Loss of CO and CHO from **6c** give **1d** and **6f**, respectively, and both species undergo ring expansion and suffer loss of HCN. Normally, the predominance of the M minus OH process for 2-alkyl quinoline *N*-oxides precludes the M minus CO and M minus CHO fragmentations. This is indeed the case with **4** and **5**. It is a consequence of the four-membered ring in **6** that the pathways shown become operative.

EXPERIMENTAL

General.

Melting points, uncorrected, were obtained on a modified Hershberg apparatus with total-immersion Anschütz thermometers.

The preparation of compounds **1**, **3**, and **6** has been reported (18).

2,3-Dihydro-1*H*-cyclopenta[*b*]quinoline (**2**).

To a solution of cyclopentanone (3.0 g., 0.036 mole) and freshly-prepared *o*-aminobenzaldehyde (4.4 g., 0.036 mole) in 80 ml. of 95% ethanol was added 15 ml. of 33% aqueous potassium hydroxide solution. After 24 hours at room temperature the reaction mixture was filtered by gravity, and the filtrate was concentrated at reduced pressure on a rotary evaporator. A solution of the viscous residual oil in dichloromethane was washed with water, dried, filtered, and concentrated to give 3.4 g. of a bright yellow solid, m.p. 47-56°. The crude product was chromatographed on alumina (neutral, activity I) and eluded with chloroform to give 2.9 g. (48%) of white crystals, m.p. 58.8-59.8° [lit. (26) 59-60°].

2,3-Dimethylquinoline *N*-Oxide (**4**).

2,3-Dimethylquinoline (0.20 g., 1.3 mmoles) was oxidized by the procedure reported for **3** (18) to give 0.19 g. (86%) of crude product, m.p. 116.5-118.5°. Recrystallization from ligroin (b.p. 90-120°) and charcoal treatment afforded 0.1 g. of white crystals, m.p. 122.5-124.1° [lit. (27) 130-131°].

2,3-Dihydro-1*H*-cyclopenta[*b*]quinoline *N*-Oxide (**5**).

Compound **2** was oxidized by the same procedure to give 0.19 g. (86%) of crude product, m.p. 113-115° dec. Recrystallization from ligroin (b.p. 90-120°) afforded 0.09 g. (40%) of white crystals, m.p. 120.0-121.5° dec. [lit. (28) 111-113°].

Spectra.

Mass spectra were obtained with a CEC 21-110B mass spectrometer using the direct introduction probe and an ionizing voltage of 70 eV. Source temperatures for compounds **1-6** were 88°, 175°, 117°, 60°, 69°, and 85°, respectively. Exact mass measurements were made with a resolution exceeding 10,000; perfluorokerosene was used to provide reference mass. Metastable transitions were established by uniquely determining the precursor ions employing the ion accelerator decoupling technique (29).

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