Mass Spectrometry in Structural and Stereochemical Problems. CCXLI.[1] Investigation of the Electron Impact Induced Fragmentations of 1-Hepten-3-ol by Ion Cyclotron Resonance[2]

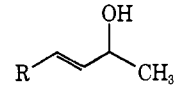
Barbara Grant[3] and Carl Djerassi*

Contribution from the Department of Chemistry, Stanford University, Stanford, California 94305. *Received November 24, 1973*

Abstract: Allylic alcohols show mass spectra which are very similar to those of the corresponding saturated ketones. In order to examine whether the former fragment by initial rearrangement to the isomeric ketones, the mechanism of electron impact induced decomposition of the allylic alcohol 1-hepten-3-ol (**2**) was investigated. Elucidation of the structure of the $C_4H_8O\cdot^+$ rearrangement ion (formally equivalent to the McLafferty rearrangement ion of the ketone 3-heptanone) generated from **2** was accomplished utilizing ion cyclotron resonance and metastable decomposition techniques. The results obtained indicate that ketonization of the molecular ion of the allylic alcohol does not provide a significant pathway for decomposition but rather that migration of the C-6 hydrogen occurs to the ionized olefinic bond. Those $C_4H_8O\cdot^+$ ions possessing sufficient internal energy to undergo further decomposition rearrange prior to decomposition and a hydrogen randomization process was suggested to accompany this rearrangement.

The striking similarity of the mass spectra of allylic alcohols to those of their corresponding saturated ketones and the fact that these alcohols upon electron bombardment yield fragment ions unobtainable by simple bond cleavages has been interpreted in terms of internal molecular rearrangement(s) prior to fragmentation. However, in contrast to the detailed studies of the mass spectral behavior of aliphatic ketones, the precise fragmentation processes for these structural isomers have received little attention to date.

Kraft and Spiteller in 1968[4] examined the mass spectra of alcohols of the general structure $RCH(OH)CH{=}CH_2$ and suggested that at high electron potential (70 eV) quantitative rearrangement of the molecular ion of the vinyl carbinol to the molecular ion of the ethyl ketone occurs before fragmentation. At lower electron potential (12 eV) the difference in intensity of the molecular ion for the allylic alcohol and the corresponding ketone coupled with the appearance of a fragment ion at $M - H_2O$ in the alcohol spectrum suggested that only partial ketonization had occurred. In a separate study, Willhalm and Thomas[5] reported that the mass spectra of allylic alcohols of general structure **1** and



1a, R = C_6H_5
b, R = CH_3

the corresponding saturated ketones were dominated by similar fragment ions but that metastable data suggested that these ions were generated *via* different routes. In addition, isotopic labeling experiments suggested that the decomposition of the allylic alcohols **1a** and **1b** occurred by a nonspecific double hydrogen transfer, excluding a simple ketonization process for these systems.[5]

Even a cursory analysis of the mass spectra of allylic alcohols shows that fragment ions exist whose formation cannot be explained simply by bond cleavage and thus some type of rearrangement process must be invoked. However, it is equally evident that a variety of pathways for internal molecular rearrangement are available to vinyl carbinols (including the ketonization process previously proposed[4]) but that existing data are not sufficient to distinguish among these processes. The present investigation was undertaken in an effort to offer further insight into the mass spectral behavior of this important class of organic compounds.

The mass spectrum[4] of the allylic alcohol 1-hepten-3-ol (**2a**) is shown in Figure 1. The fragment ion of particular pertinence was that of mass 72 ($M - C_3H_6$). This ion can be envisioned as resulting from a variety of fragmentation pathways all of which correspond to the McLafferty type rearrangement, involving migration of the secondary γ-hydrogen atom.[6] Three distinct paths are immediately apparent (Scheme I): (1) transfer of a γ hydrogen to the hydroxyl oxygen of the ionized unsaturated alcohol with concomitant β cleavage to produce the oxonium ion **3a**; (2) transfer of a γ-hydrogen atom to the ionized olefinic bond with β cleavage to give an ion radical of general structure **4a**;[7] (3) ketonization of the molecular ion of **2a** to the molecular ion of the isomeric ketone, 3-heptanone (**5a**), followed by a McLafferty rearrangement yielding the enolic ion **6a**. Information concerning the genesis of the mass 72 ion, and hence the mode of fragmentation of such vinyl carbinols, should be obtainable by employing ion cyclotron resonance (icr) techniques[8] developed in our laboratories for differentiating among ion structures of such types. The principles, instrumentation, applications, and other techniques con-

(1) For paper CCXL in this series, see R. R. Muccino and C. Djerassi, *J. Amer. Chem. Soc.*, **95**, 8726 (1973).

(2) Financial assistance from the National Institutes of Health (Grant No. AM 04257) is gratefully acknowledged.

(3) National Science Foundation Predoctoral Fellow, 1971–1974.

(4) M. Kraft and G. Spiteller, *Org. Mass Spectrom.*, **1**, 617 (1968).

(5) B. Willhalm and A. F. Thomas, *Org. Mass Spectrom.*, **1**, 627 (1968).

(6) (a) The α, β, or γ notation utilized herein is understood to be with respect to the hydroxyl functionality. (b) Isotopic labeling in this and earlier[4] studies verified that the reaction is a site-specific rearrangement involving only γ-hydrogen transfer.

(7) It should be noted that reference to this pathway as a McLafferty type rearrangement is not rigorously correct since a six-membered transition state may not necessarily be involved.

(8) J. Diekman, J. K. MacLeod, C. Djerassi, and J. D. Baldeschwieler, *J. Amer. Chem. Soc.*, **91**, 2069 (1969); G. Eadon, J. Diekman, and C. Djerassi, *ibid.*, **91**, 3987 (1969).

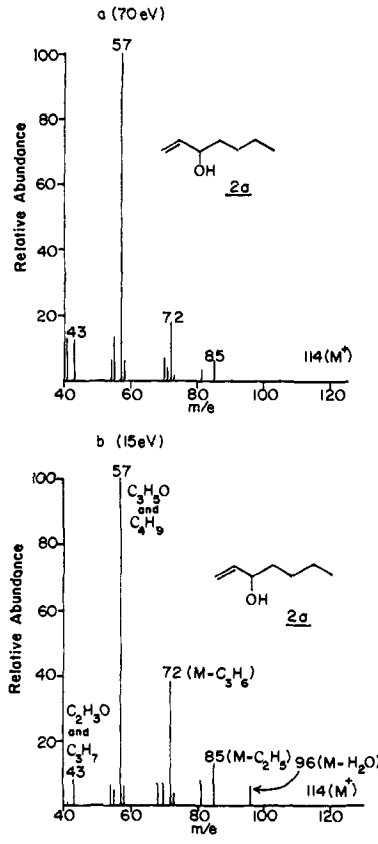


Figure 1. The mass spectrum of 1-hepten-3-ol (**2a**) determined at (a) 70 and (b) 15 eV.

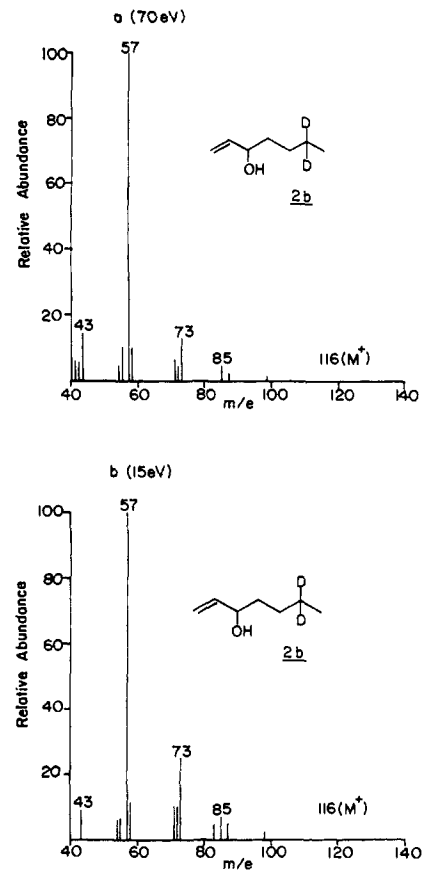
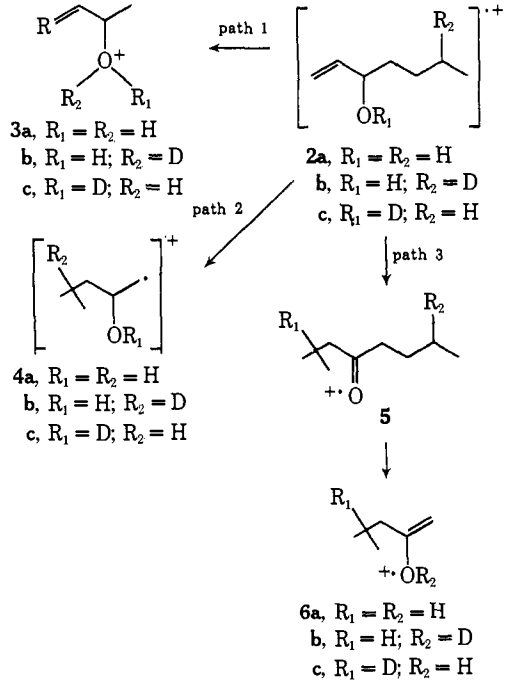


Figure 2. The mass spectrum of 1-hepten-3-ol-6,6-d_2 (**2b**) determined at (a) 70 and (b) 15 eV.

Scheme I



cerned with ion cyclotron resonance have been discussed previously[9] in considerable detail and will not be elaborated here. However, there are two features of ion cyclotron resonance that make it particularly suited for elucidating the structures of ions created upon electron impact. First, spectra may be recorded at sufficiently high operating pressures to observe gas phase ion–molecule reactions. Second, the pulsed double resonance technique[9] makes possible the verification of specific reactant/product relationships in all reaction sequences.

Results and Discussion

Ion Cyclotron Resonance. The ordinary mass spectrum of 1-hepten-3-ol-6,6-d_2 (**2b**) is shown in Figure 2. Because of the isotopic labeling at the γ position in this compound the fragment peak of interest has now shifted from mass 72 to 73. The three possible modes of fragmentation leading to this ion, as outlined above, are shown in Scheme I. Previous studies[8] of the ion–molecule reactions of ions similar to **4** and **6** have shown that the most prevalent gas phase reaction for this specie is transfer of the hydrogen atom bonded to oxygen to a neutral proton acceptor such as a ketone. These proton-transfer reactions are exceedingly convenient for this investigation since the three pathways outlined in Scheme I generate unique ions of mass 73 each of which has a different hydrogen/deuterium ratio on oxygen. If migration to the hydroxyl oxygen occurs *via* path 1, the resulting oxonium **3b** must have approximately equal amounts of hydrogen and deuterium bound to oxygen.[10] If deuterium migration occurs to the carbon of the olefinic bond (path 2), only hydrogen

(9) J. L. Beauchamp and J. Y. Armstrong, *Rev. Sci. Instrum.*, **40**, 123 (1969); J. D. Baldeschwieler, *Science*, **159**, 263 (1968); J. D. Baldeschwieler and S. Woodgate, *Accounts Chem. Res.*, **4**, 113 (1971).

(10) Although gas phase reactions of ionized species such as **3** have not been studied, it appears reasonable that any transfer reactions to a neutral acceptor should involve both protium and deuterium in approximately equal amounts barring significant isotope effects.

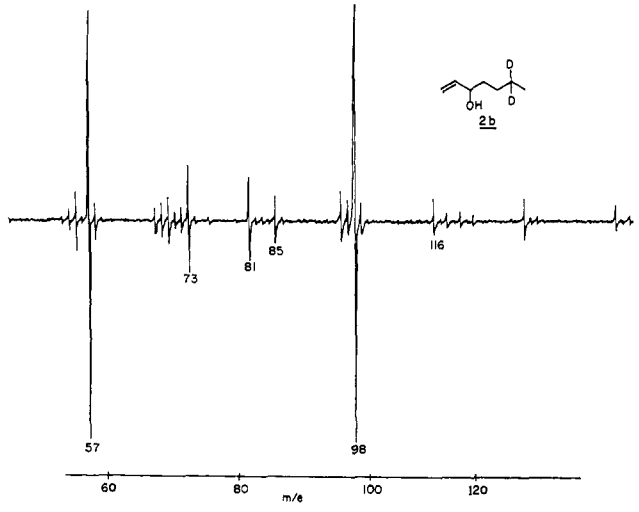


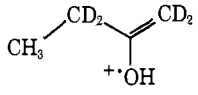
Figure 3. Ion cyclotron resonance spectrum of 1-hepten-3-ol-*6,6-d*$_2$ (**2b**), $\omega_1/2\pi$ = 153.5 kHz, 2 × 10^{-6} Torr, 20 eV.

will be attached to oxygen (**4b**) and available for transfer. Alternatively, if initial ketonization occurs followed by a McLafferty rearrangement (path 3), only deuterium will be bound to oxygen (**6b**) and thus transferable.

The ketone employed as proton acceptor for the double resonance experiments was in all cases 3-heptanone-*2,2,4,4-d*$_4$ (**7**). The McLafferty rearrange-

$CH_3CD_2COCD_2CH_2CH_2CH_3$

7



8, *m/e* 76

ment ion **8** of mass 76 arising from **7** is an excellent proton donor in the gas phase[8,11] and is located at a convenient mass/charge ratio for comparative studies with the mass 73 ion obtained from the parent alcohols **2**.

The single resonance spectrum of 1-hepten-3-ol-*6,6-d*$_2$ (**2b**) and the appropriate double resonance spectra of a mixture of **2b** and 3-heptanone-*2,2,4,4-d*$_4$ (**7**) are shown in Figures 3 and 4, respectively. Inspection of Figure 4 indicates a marked predominance of protium relative to deuterium transfer from the mass 73 ion, which strongly suggests that the ion arose by path 2 and possesses structure **4b**. In order to negate the possibility that this result merely reflects a large isotope effect, the analogous experiment was performed on the alcohol-*O-d* **2c**.

The possible structures of fragment ions derived from **2c** are summarized in Scheme I (**3c**, **4c**, and **6c**) and the appropriate double resonance spectra are shown in Figure 5. As indicated by these spectra deuterium transfer from the mass 73 ion occurs predominantly thus excluding the existence of a large isotope effect or the intervention of species such as **3c** and **6c** which would require partial or complete proton transfer.

The results from the double resonance experiments for **2b** and **2c** thus prove that in both cases fragmentation of the allylic alcohol occurs predominantly by path 2, *i.e., the γ hydrogen* (or deuterium) *migrates preferentially to carbon rather than oxygen.* Furthermore, it is apparent that at the electron energies employed for this investigation (20 eV), *ketonization* (path 3) *of the molecular ion is not occurring to a significant extent.*

(11) Pulsed double resonance studies performed on **7** indicated only very minor deuterium transfer from **8**.

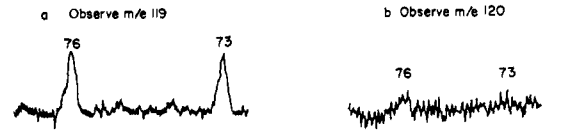


Figure 4. The pulsed double resonance spectra of the M + 1 (*m/e* 119) and the M + 2 (*m/e* 120) ions of 3-heptanone-*2,2,4,4-d*$_4$ (**7**) in the presence of 1-hepten-3-ol-*6,6-d*$_2$ (**2b**). Both spectra were recorded under identical conditions, the relative abundances of the mass 73 and 76 ions being approximately equal, with $\omega/2\pi$ = 153.5 kHz, 2.5 × 10^{-6} Torr, 0.1 V irradiating voltage and 20 eV ionizing voltage. Part a indicates protium donation from the mass 73 ion arising from **2b** and the mass 76 (**8**) from the ketone **7**. No significant deuterium donation from either ion was observed.

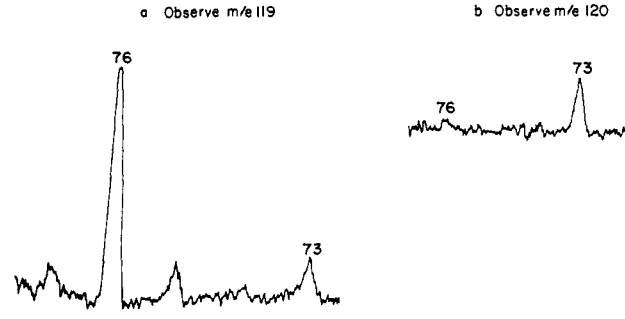
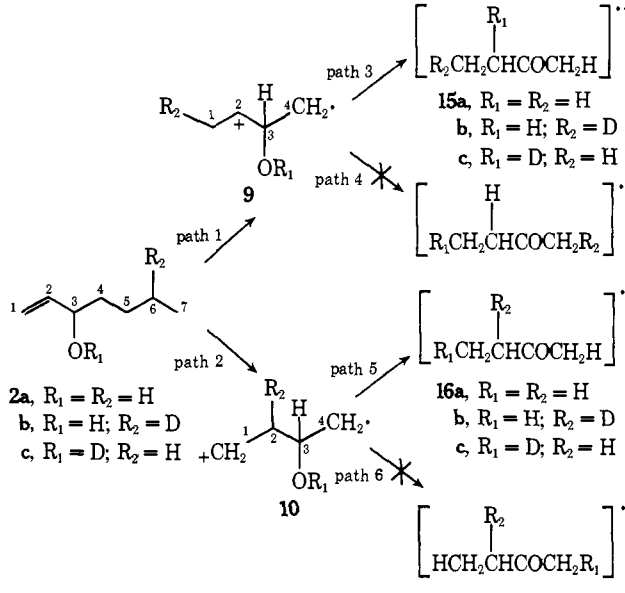


Figure 5. The pulsed double resonance spectra of the M + 1 (*m/e* 119) and M + 2 (*m/e* 120) ions of 3-heptanone-*2,2,4,4-d*$_4$ (**7**) in the presence of 1-hepten-3-ol-*O-d*$_1$ (**2c**). Conditions were as described in Figure 4. Parts a and b indicate protium transfer from the mass 76 ion (**8**) arising from **7** and deuterium donation from the mass 73 ion from **2c**.

The icr results having established path 2 as being the dominant mode of fragmentation of the parent alcohol **2**, it was of interest to determine more precisely, if possible, the nature of this hydrogen migration to carbon. Two distinct alternatives are available for the actual rearrangement step (Scheme II): (1) transfer of

Scheme II



the C-6 γ hydrogen (or deuterium) atom to the C-1

Table I. Defocusing and "DADI"[14] Results Corresponding to Decomposition of $C_4(H,D)_8O\cdot^+$ Ions in the First and Second Field Free Regions, Respectively[a]

Compd	Compd no.	Product ion abundance[b]					
		$C_3H_5O^+$	$C_3H_4DO^+$	$C_3H_3D_2O^+$	$C_2H_3O^+$	$C_2H_2DO^+$	$C_2HD_2O^+$
CH_2=CHCH(OH)-*n*-C_4H_9	**2a**	54			45		
CH_2=CHCH(OD)-*n*-C_4H_9	**2c**		52		47		
CH_2=CHCD(OH)-*n*-C_4H_9	**11**	5	52		36	5	
CH_2=CHCH(OH)$CD_2(CH_2)_2CH_3$	**12**	47	5	0.5	0.5	3	43
CH_2=CHCH(OH)$(CH_2)_2CD_2CH_3$	**2b**	1	57		42	1	
CH_2=CDCH(OH)-*n*-C_4H_9	**13**	3	60		34	2	
CD_2=CHCH(OH)-*n*-C_4H_9	**14**	0.5	3	56	47	2	0.5

[a] The abundance of the metastable ion is computed relative to the sum of the contribution of all daughter ions arising from the parent $C_4(H,D)_8O\cdot^+$ ion. [b] Loss of H_2O (and HDO in labeled substrates) is observed in 1–3% thus further differentiating this ion from those previously reported.[12]

terminal carbon of the olefinic bond *via* a seven-membered transition state producing an ion of structure **9** or (2) transfer of the C-6 γ hydrogen *via* a six-membered transition state to C-2 yielding ion **10**. A comprehensive investigation of the unimolecular decomposition reactions of the ion in question (**9** or **10**) was undertaken to attempt to distinguish between these two ion structures.

Metastable Peak Analysis. In a recent publication, McLafferty, *et al.*,[12] investigated the isomerization and decomposition reactions of $C_4H_8O\cdot^+$ ions by analysis of metastable and collision induced dissociation processes. In particular their investigation dealt with the isomeric enolic ions $C_2H_5C(OH)CH_2\cdot^+$ and $CH_3CHC(OH)CH_3\cdot^+$. This mode of analysis seemed well suited to the present mechanistic study; in addition, analysis of the distinct, yet isomeric, $C_4H_8O\cdot^+$ ion generated from **2** might offer an interesting comparison with the previously reported results.[12]

Data for the metastable decompositions of the $C_4(H,D)_8O\cdot^+$ ions pertinent to this investigation are given in Table I. These data represent analysis both by the defocusing technique[13] and the recently developed "Direct Analysis of the Daughter Ion" (DADI)[14,15] technique. Quantitative information cited is that obtained directly from the DADI results. The transitions observed using the defocusing technique in the first field free region (preelectrostatic analyzer) of a double focusing mass spectrometer and those transitions observed by the DADI technique which allows direct observation of daughter ions from decomposition of parent ions in the second field free region of a reversed geometry double focusing analyzer (preelectrostatic analyzer) were the same in all cases.

Before detailed analysis of the data shown in Table I is undertaken, it should be noted that the icr results presented above cannot necessarily be employed in conjunction with the decomposition data obtained for the $C_4(H,D)_8O\cdot^+$ ions. The possibility exists that the structure(s) of ions undergoing unimolecular decomposition and appearing as metastable transition in the mass spectrum may not be representative of the ion(s) comprising the majority of the $C_4(H,D)_8O\cdot^+$ peak. As has been noted previously,[16] the dependence of ion cyclotron spectra on the distribution of internal energy values, $P(E)$, of the precursor ions can result in dubious correlation to the structure of ions that undergo further unimolecular decay. However, comparison of the data shown in Table I with that reported by McLafferty, *et al.*,[12] indicates significant differences in the relative product ion abundances for analogous decompositions suggesting that in fact a distinct isomeric $C_4(H,D)_8O\cdot^+$ ion is encountered in the allylic alcohol system and ketonization is not a primary pathway of decay. This observation suggests that in fact ions **9** or **10** are viable structures for the ion in question.

The predominant products of the metastable decomposition of the mass 72 ion resulting from **2** are $C_3H_5O^+$ (72 − CH_3) and $C_2H_3O^+$ (72 − C_2H_5). Although loss of a methyl radical from the mass 72 ion through direct cleavage is consistent with an ion of structure **9**, it is not consistent with an ion of structure **10**. In addition, it can be seen that direct cleavage of an ethyl radical is not consistent with either **9** or **10**. These results indicate, therefore, that a rearrangement process must provide the major pathway of degradation. The nature of the decomposition products suggests a ketonization process, which would be in accord with the results reported by McLafferty[12] for the isomeric $C_4H_8O\cdot^+$ ions, $C_2H_5C(OH)CH_2\cdot^+$ and $CH_3CHC(OH)CH_3\cdot^+$. It is possible that the rearrangement to a ketonic species and the further decomposition of this ion are concomitant or that the subsequent decomposition of an intermediate ketonic ion is extremely facile. In any case, in future reference to this rearrangement process a ketonic structure will be assumed but the qualifying remarks given should be kept in mind.

The nature of the decomposition products (see Table I) of 1-hepten-3-ol-*O-d* (**2c**) suggests that rearrangement to the ketonic ion $CH_3COC_2H_4D\cdot^+$ (**15c** or **16c**, Scheme II) has occurred prior to fragmentation. This result requires that the ketonization process occur *via* a specific 1,2-hydrogen shift from C-3 to C-4 and 1,3- or 1,4-deuterium shift from oxygen to C-2 or C-1 depending on the site of initial γ-hydrogen transfer in the molecular ion (indicated as paths 3 and 5 in Scheme II). Rearrangement *via* the alternative hydrogen/deuterium shifts (paths 4 and 6) cannot be occurring since the $C_2H_2DO^+$ and $C_3H_5O^+$ ions are not products of the decomposition.

The principal decomposition products (see Table

(12) D. J. McAdoo, F. W. McLafferty, and T. E. Parks, *J. Amer. Chem. Soc.*, **94**, 1601 (1972).

(13) J. H. Beynon, *Anal. Chem.*, **42**, 97A (1970).

(14) K. H. Mauer, C. Brunee, G. Kappus, K. Habfast, U. Schroder, and P. Schulze, 19th Conference on Mass Spectrometry, Atlanta, 1971, Paper K-9.

(15) This technique is the same as that termed mass analyzed ion kinetic energy spectroscopy (MIKES); see J. H. Beynon, R. G. Cooks, J. W. Amy, W. E. Baitinger, and T. Y. Ridley, *Anal. Chem.*, **45** (12), 1023A (1973), and references cited therein.

(16) J. L. Beauchamp and R. C. Dunbar, *J. Amer. Chem. Soc.*, **92**, 1477 (1970); J. L. Occolowitz, *ibid.*, **91**, 5202 (1969); A. N. H. Yeo and D. H. Williams, *ibid.*, **93**, 395 (1971).

I) of 1-hepten-3-ol-*3*-d_1 (**11**) are $C_2H_3O^+$ and $C_2H_4DO^+$. In light of the specific ketonization process suggested from the data for compound **2c** (outlined in Scheme II), it would appear that a hydrogen/deuterium scrambling involving those atoms directly bonded to carbons 1, 2 and 3 must occur sometime prior to decomposition of the $C_4H_7DO\cdot^+$ ion. This randomization process could occur (1) in the molecular ion of the allylic alcohol prior to any fragmentations or (2) in the $C_4H_7DO\cdot^+$ ion prior to ketonization and decomposition. Either process clearly would not be detected in **2c** in view of the absence of isotopic labeling at these positions. The presence of the minor decomposition products, $C_2H_2DO^+$ and $C_3H_5O^+$, for compound **11** but their absence in the *O-d* analog **2c** is consistent with a randomization process (1 or 2) as well as the specific ketonization outlined earlier (Scheme II). A hydrogen/deuterium scrambling process involving the molecular ion of the allylic alcohol seems somewhat unlikely since several steps in this process would generate ions structurally equivalent to the enolic ion of the corresponding saturated ketone and presumably lead to the ionized ketone itself. The alternative randomization process involving the $C_4H_7DO\cdot^+$ ion prior to ketonization is outlined in Scheme III. The results listed in

Scheme III

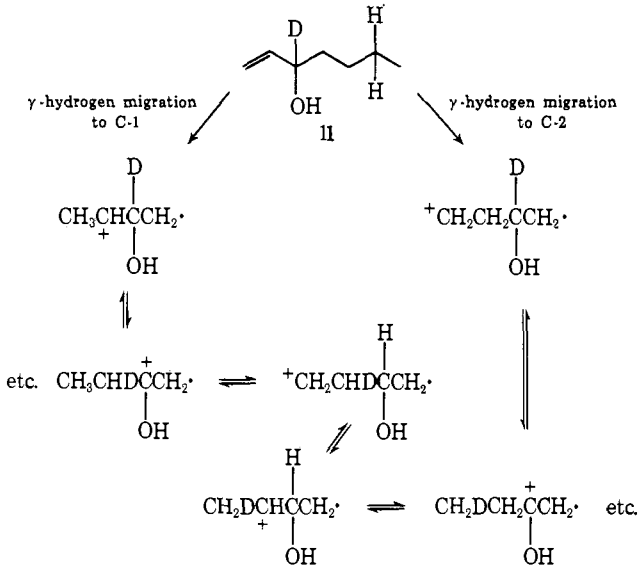


Table I for the metastable decompositions of the labeled compounds **2b**, **12**, **13**, and **14** all support this hydrogen/deuterium randomization process (Scheme III). Comparison of the relative abundance for the decomposition products of these compounds suggests that the scrambling process involves the vinyl carbon atoms 1 and 2 and the allylic carbon 3 to similar degrees. Data for compound **12** indicate that this scrambling process extends also to C-4 but to a minor extent.

Consider now the original mechanistic question posed, namely the nature of the transition state in the γ-hydrogen transfer to carbon. It is apparent that information as to whether γ-hydrogen transfer occurs to C-1 or C-2, yielding **9** and **10**, respectively, cannot be obtained since the rapid randomization process demonstrated by the metastable analysis (Table I) effectively equilibrates these two distinct ion structures, as indicated in Scheme III. It is interesting, however, that as nonspecific as this scrambling process appears to be the hydrogen (or deuterium) atom bound to oxygen is not involved in this process and migrates during the ketonization process specifically to the ethyl side chain while the hydrogen (or deuterium) atom at C-3 transfers to the methyl precursor.

Finally, the mechanistic data obtained in our study concerning the mode of fragmentation of the $C_4H_8O\cdot^+$ ion obtained from the allylic alcohol **2** present an interesting comparison to the results obtained by McLafferty[12] for isomeric $C_4H_8O\cdot^+$ ions in which stepwise rearrangement of individual hydrogen atoms generates the ketonic ion which subsequently decomposes. In conclusion, the present study demonstrates how far our ability to detect ion structures and their intimate mode of formation has progressed in recent years and how useful, as well as complementary, the techniques of ion cyclotron resonance spectrometry and metastable peak analysis can be.

Experimental Section

The basic ion cyclotron resonance spectrometer used in this study was the Varian V-5900 spectrometer. Conventional mass spectra as well as metastable defocusing data were obtained by Mr. R. Ross on an MS-9 double focusing mass spectrometer. Nmr spectra were recorded on a Varian T-60 model spectrometer with $CDCl_3$ as solvent. The 1-hepten-3-ol and 1-heptyn-3-ol utilized were purchased from Farchan Research Laboratories (Willoughby, Ohio). All final products were purified by preparative glpc on an Aerograph Gas Chromatograph using a 10 ft × 1/4 in. 15% Carbowax M on Chromosorb W column operated at 120°. Isotopic purities were determined in all cases from the mass spectrum.

1-Hepten-3-ol-*6,6*-d_2 (2b). Acetic acid was reduced with lithium aluminum deuteride in dry diglyme.[17] The resulting ethanol-*1,1*-d_2 was converted to the corresponding bromide by the procedure of Wiley, *et al.*[18] Formation of the Grignard reagent and condensation with dry CO_2 yielded propionic-*2,2*-d_2 acid. Reduction with lithium aluminum hydride,[17] bromination,[18] and homologation by condensation with diethyl malonate, followed by hydrolysis and decarboxylation,[19] gave pentanoic-*4,4*-d_2 acid. This was reduced to pentanol-*4,4*-d_2[20] and condensed with vinyllithium to give 1-hepten-3-ol-*6,6*-d_2 (98% d_2).

3-Heptanone-*2,2,4,4*-d_4 (7). Repeated exchange of the parent ketone in refluxing D_2O and THF (2:1) containing a catalytic amount of Na_2CO_3 gave the d_4 ketone in 97% isotopic purity.

1-Hepten-3-ol-*3*-d_1 (11). Low-temperature (0°) condensation of pentanoic acid with vinyllithium[21] gave the unsaturated ketone 1-hepten-3-one. Reduction with LAD in ether at 0° for 3 min yielded the labeled alcohol **11**. This structure was confirmed by the nmr spectrum which lacked an absorption at δ 4.13 which corresponded in the unlabeled compound **2a** to the proton at C-3. The preparations of 1-hepten-3-ol-*2*-d_1 (**13**) and 1-hepten-3-ol-*1,1*-d_2 (**14**) have been described recently.[22]

(17) L. Friedman and A. T. Jurewicz, *J. Org. Chem.*, 33, 1254 (1968).
(18) G. A. Wiley, R. L. Hershkowitz, B. M. Remu, and B. C. Chung, *J. Amer. Chem. Soc.*, 86, 964 (1964).
(19) R. Adams and R. M. Kamm, "Organic Synthesis," Collect. Vol. I, Wiley, New York, N. Y., 1932, p 250; E. B. Vliet, L. S. Marvel, and C. M. Hscuh, "Organic Synthesis," Collect. Vol. II, Wiley, New York, N. Y., 1943, p 416.
(20) A. O. Bedenbaugh, J. H. Bedenbaugh, W. A. Bergin, and J. D. Adkins, *J. Amer. Chem. Soc.*, **92**, 5774 (1970).
(21) M. Jorgenson, "Organic Reactions," Vol. 18, W. G. Dauben, Ed., Wiley, New York, N. Y., 1970.
(22) B. Grant and C. Djerassi, *J. Org. Chem.*, in press.