It is assumed that $k_{-3}' > k_{-3}$, which is reasonable on both steric and energetic grounds, *i.e.*, the primary allylic C–H bond is stronger than the secondary C–H bond. Making this assumption and the steady-state approximation, the expression for the ratio of 1-bromohexane and 2-hexene formed at low conversion is

$$\frac{(1\text{-bromohexane})}{(2\text{-hexene})} = \frac{k_1k_2(\text{HBr})}{k_3(k_{-1} + k_2(\text{HBr}))} \quad (9)$$

At low HBr concentrations this expression simplifies to

$$\frac{(1\text{-bromohexane})}{(2\text{-hexene})} = \frac{k_1k_2(\text{HBr})}{k_3k_{-1}} \quad (10)$$

Similar expressions in a slightly different form were derived by Adam, Gosselain, and Goldfinger[8] for the ratio of addition to allylic substitution by halogens. Since the temperature dependence of k_1 and k_2 should be smaller than k_{-1} and k_3, 1-bromohexane formation relative to 2-hexene should increase with decreasing temperature. This formation was observed. Also since 2-hexene is the principal precursor of 2- and 3-bromohexanes, the formation of 2- and 3-bromohexanes should decrease with decreasing temperature, which is consistent with observed phenomena.[9]

Acknowledgments. The author wishes to thank F. M. Nelsen, Jr., and V. A. Campanile for capillary glpc analyses, and Dr. D. O. Geymer for dosimetry measurements. Also the author expresses appreciation for helpful discussions with F. F. Rust and Dr. C. D. Wagner.

(8) J. Adam, P. A. Gosselain, and P. Goldfinger, *Nature*, **171**, 704 (1953).

(9) Recent experiments using ionizing radiation as the source of radical initiation (L. H. Gale, unpublished results) demonstrate that lowering the reaction temperature for addition of HBr to neat 1-hexene to −13° yields a product with the composition: 97.0% 1-bromo-, 2.46% 2-bromo-, and 0.50% 3-bromohexane. The low yield of 3-bromohexane indicates that the double-bond migration is practically negligible at −13° and that the bulk of the 2-bromohexane arises from ionic addition to 1-hexene. Also increasing the HBr concentration at 5° decreases the combined yield of 2-bromo- and 3-bromohexanes which is consistent with the behavior predicted by expression 10.

The Mass Spectrometry of Sulfonylureas. I. Mechanisms for the Loss of Sulfur Dioxide

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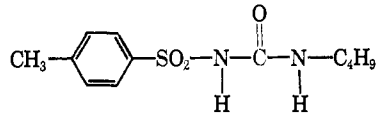
Contribution from the Biochemical Research Division, The Upjohn Company, Kalamazoo, Michigan 49001. *Received July 14, 1966*

Abstract: The unique loss of 64 mass units (sulfur dioxide) observed in the mass spectrum of tolbutamide,[1] the most energetically favored fragmentation, has been shown by deuterium labeling and high-resolution mass spectrometry to involve two rearrangement mechanisms. The contribution of each was assessed individually from the accurate mass measurements of the pertinent fragment ions. Some thermal decomposition of the sample was observed due to a high source temperature and/or high inlet system temperature.

The mass spectrum of tolbutamide (I)[1] shows a loss of 64 mass units from the molecular ion which is attributed to the loss of SO_2. We became interested



I

in the mechanism of this unique loss of the elements of SO_2 from the middle of this molecule. This paper reports studies to elucidate this mechanism.

Skeletal rearrangements upon electron impact involving the loss of SO_2 had been reported previously, but no mechanisms were given to explain such losses.[2,3] Since the beginning of our studies similar losses of SO_2 have been reported for aliphatic sulfur compounds[4] and alkyl and aryl sulfonylhydrazones.[5]

(1) The Upjohn Co. trademark for tolbutamide is Orinase.
(2) S. Meyerson, H. Drews, and E. K. Fields, *Anal. Chem.*, **36**, 1294 (1964).
(3) J. φ. Madsen, C. Nolde, S.-O. Lawesson, G. Schroll, J. H. Bowie, and D. H. Williams, *Tetrahedron Letters*, No. 49, 4377 (1965).
(4) A. Bhati, R. A. W. Johnstone, and B. J. Millard, *J. Chem. Soc.*, 358 (1966).
(5) R. G. Gillis and J. L. Occolowitz, *Tetrahedron Letters*, 1997 (1966).

Results and Discussion

The tolbutamide mass-spectral data are listed in Table I. The molecular ion was observed at *m/e* 270

Table I. Tolbutamide Mass Spectral Data

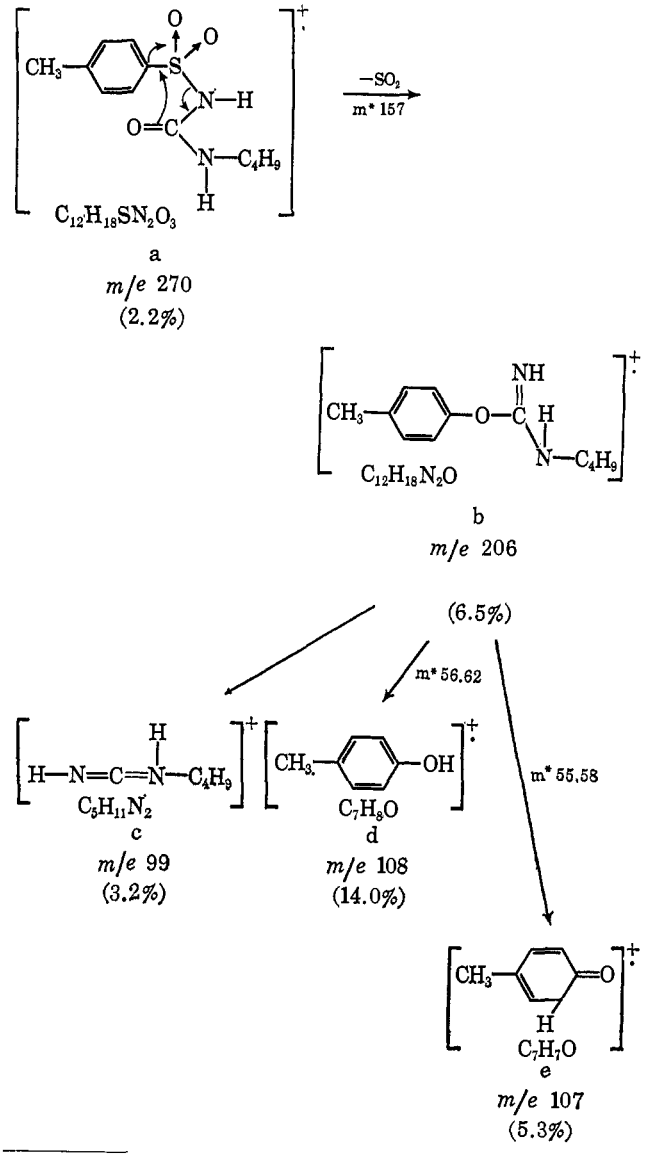
	% total ionization	
m/e	70 ev	19 ev
270	2.2	7.5
255	0.2	
241	0.3	
227	1.1	
215	0.4	
206	6.5	35.7
184	0.2	
171	0.6	0.5
163	0.3	
155	7.1	0.4
139	0.6	
115	2.0	1.5
108	14.0	19.4
107	5.3	11.5
99	3.2	3.3
91	15.4	0.1
73	3.2	3.1
72	2.3	0.5
65	4.6	
30	12.6	5.7

and at 70 ev the most intense peak was observed at *m/e* 91 (15.4% of total ionization). This peak can be represented as a $C_7H_7^+$ ion which decomposes further with the expulsion of an acetylene molecule to yield $C_5H_5^+$ (*m/e* 65; metastable at 46.4). An intense peak 64 mass units below the molecular ion at *m/e* 206 was also observed. The relative intensities of the *m/e* 206 and 208 peaks did not fit the known isotope ratio of sulfur.[6] Therefore, this 64-mass-unit loss must have included the sulfur atom and must have been due to the loss of the elements of SO_2.

The ease of the loss of SO_2 from tolbutamide under electron impact was vividly demonstrated in the 19 ev mass spectrum (listed in Table I). In this spectrum, the *m/e* 206 ion was the most intense peak (35.7% of total ionization) and the *m/e* 91 ion, the most intense peak of the 70 ev spectrum, was extremely weak (0.1% of total ionization). Therefore, the loss of SO_2 in the mass spectrum of tolbutamide is more energetically favored than the formation of the $C_7H_7^+$ ion, *m/e* 91.

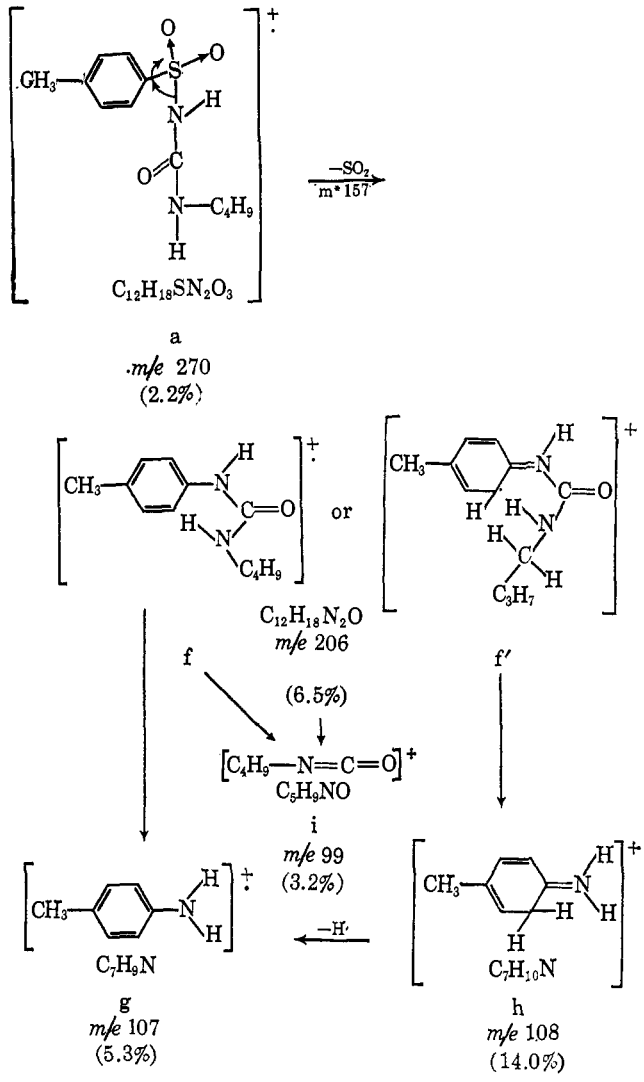
Considering the major peaks observed, the following two fragmentation schemes could apply.

Scheme I



(6) J. H. Beynon, "Mass Spectrometry and its Applications to Organic Chemistry," Elsevier Publishing Company, London, 1960.

Scheme II

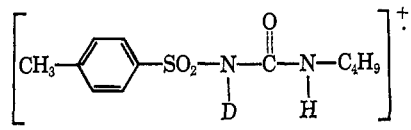


The schemes postulated an oxygen ion in a five-membered cyclic rearrangement or a nitrogen ion in a three-membered cyclic rearrangement. The ions b and f differed in the location of O and NH. These both have nominal mass 206, but they could be distinguished by labeling and/or high-resolution studies.

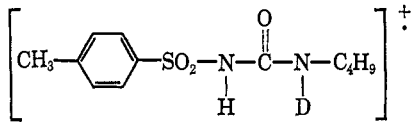
Previous nmr studies on tolbutamide had demonstrated that the amide hydrogens were readily exchangeable with deuterium. This labeled derivative offered the opportunity of determining which was the more logical fragmentation scheme.

The parent ions in the mass spectrum of the deuterated tolbutamide were observed at *m/e* 270, 271, and 272 with relative ratios of 8:40:52, respectively (ratios corrected for naturally occurring isotopes). Therefore, the three possible species were present, that is, 8% of the nondeuterated species (a), 40% of the monodeuterated species (j or k), and 52% of the dideuterated species (l). The nmr spectrum of the sample supported the presence of equal amounts of the compounds giving rise to ions j and k.

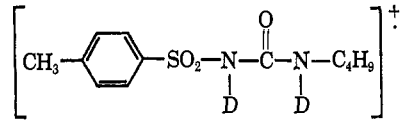
Additional peaks in the spectrum were observed at *m/e* 206, 207, 208, and 99, 100, and 101 in approximately the same ratio as that observed for the parent ions. Particularly significant is the *m/e* 99, 100, 101 triplet since ion i does not contain the labels but ion c does. If only Scheme II were operative, an ion at *m/e* 99



j



k



l

would have been observed with no *m/e* 100 and 101 ions. Therefore, it appeared from these results that the *m/e* 99 ion must be c and the fragmentation must take place by Scheme I. Minor participation of the second mechanism could not be excluded from these data due to the fact that all three species (j, k, and l) were present.

High-resolution mass spectrometry was required in this case to prove the mechanism for the loss of SO_2. The results of the high-resolution measurements of the *m/e* 99, 107, and 108 ions are listed in Table II.

Table II. High-Resolution Mass Measurements of Tolbutamide

m/e	Intensity ratio *a*	*b*	Resultant mass *a*	*b*	Composition (calcd mass)
98	1	Not measured	98.06080	...	C_5H_8NO (98.06058)
99	1	1	99.06613	99.07031	C_5H_9NO (99.06841)
99	0	7	...	99.09421	$C_5H_{11}N_2$ (99.09222)
107	1	3	107.04918	107.04939	C_7H_7O (107.04968)
107	2	10	107.07349	107.07321	C_7H_9N (107.07349)
108	12	16	108.05715	108.05671	C_7H_8O (108.05751)
108	1	1[c]	108.07609	108.07615	$C_6C^{13}H_9N$ (108.07717)

[a] Results obtained by Dr. D. A. Lightner, U. C. L. A., using an MS-9 instrument equipped with a direct insertion system (source temperature was 200–230°). [b] Results obtained by Mr. Robert Rhodes, Mellon Institute, Pittsburgh, Pa., using an MS-9 instrument with probe and a source temperature of 180–200°. [c] Ratios fit for this peak being the C^{13} isotope peak of C_7H_9N.

The *m/e* 108 ion is a doublet made up of C_7H_8O (ion d) and $C_6C^{13}H_9N$ with a relative ratio of about 16:1 showing that this ion is about 94% C_7H_8O. The per cent of total ionization value for the C_7H_8O portion of the *m/e* 108 ion is then equal to 94% of 14.0 (Table I) or 13.2%. Likewise, the *m/e* 107 ion is a doublet made up of C_7H_7O (ion e) and C_7H_9N (ion g) with a relative ratio of about 3:10. When the total ionization value of the *m/e* 107 ion is corrected in the same manner as described previously, the results show that C_7H_7O is 1.2% of the total ionization and C_7H_9N is 4.1%. These values can then be used to determine the relative contribution of each of the two proposed schemes as follows.

$$\frac{\text{Scheme I}}{\text{Scheme II}} = \frac{\%\text{ ion d} + \%\text{ ion e}}{\%\text{ ion g}} = \frac{13.2\% + 1.2\%}{4.1\%} = \frac{3.5}{1}$$

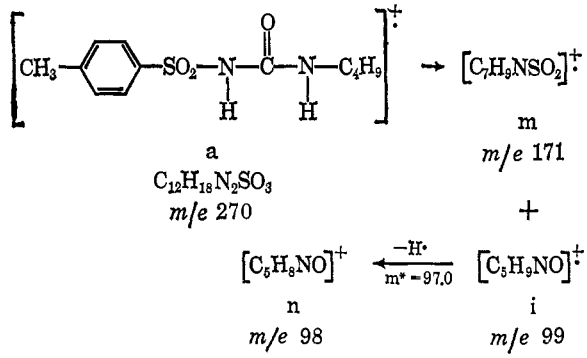
It is clear from these results that both schemes are operative with the loss of SO_2 by Scheme I being three to four times the loss of SO_2 by Scheme II. In addition, the ratios of the *m/e* 99, 100, and 101 peaks proved to be a poor criterion for determining the dominant fragmentation scheme because the smaller contribution of Scheme II did not significantly alter these ratios.

In obtaining the high-resolution mass measurements, the problem of the thermal decomposition of tolbutamide was encountered. This decomposition was not observed when the spectra were recorded at ~80° using the Atlas CH4 instrument equipped with the T04 direct inlet source. However, the mass spectrum of tolbutamide recorded at 150° and employing the high-temperature inlet system of the Atlas CH4 instrument (reservoir type with gold leak) did not show any loss of SO_2; it showed weak *m/e* 108 and 107 ions, and peaks at *m/e* 171, 99, and 98 (Table III). A metastable peak at *m/e* 97.0 showed that the *m/e* 98 peak resulted from the loss of a hydrogen atom from the *m/e* 99 ion which is consistent with the high-resolution data (Table II). These results suggest the following explanation for the thermal decomposition pathway.

Table III. Mass Spectral Data of Tolbutamide—High-Temperature Inlet

m/e	% total ionization	*m/e*	% total ionization
270	0.4	73	2.1
228	1.5	72	0.6
211	0.6	71	2.7
206	0.0	70	2.9
171	1.5	69	2.5
155	1.1	68	0.6
129	0.6	67	0.9
113	0.6	65	1.1
112	0.9	64	1.8
111	0.5	61	1.0
108	0.6	60	2.2
107	0.8	59	0.8
105	0.5	58	2.1
104	0.6	57	3.5
102	1.7	56	4.8
99	1.2	55	3.0
98	3.1	54	0.8
97	0.9	53	0.6
95	0.8	51	0.7
94	0.6	50	0.5
92	1.0	48	0.7
91	2.8	45	2.4
88	0.5	44	6.0
85	1.0	43	7.5
84	1.7	42	3.0
83	1.7	41	3.2
82	1.0	40	1.6
81	1.2	39	2.0
77	0.6	30	6.0

The *m/e* 98 peak was used as an indication of thermal decomposition. The high-resolution mass measurements at both temperatures showed some thermal decomposition so that the relative contributions of each



scheme were assessed from the *m/e* 107 and 108 peaks rather than from the *m/e* 99 peak.

Experimental Section

Mass Spectra. Low-resolution mass spectra were recorded using an Atlas CH4 instrument equipped with a TO4 direct inlet source and the high-temperature inlet system. High-resolution mass measurements were performed by peak matching using two MS-9 instruments employing the direct insertion system. Source temperatures on the two instruments were 180–200 and 200–230°.

Deuterated Tolbutamide. Sodium tolbutamide was dissolved in D_2O and concentrated by evaporation of solvent. Additional D_2O was added to bring the solution to the original volume and the solution was again concentrated. This process was repeated four times. The solution was then acidified with DCl and the deuterated tolbutamide was filtered, washed with D_2O, and dried overnight at 50° under high vacuum. The nmr spectrum of this material showed about equal absorptions assigned to both types of N–H groups in this molecule.

4,4,6-Trimethyl-1,3,2-dioxaborinane. A Stable Dialkoxyborane

William G. Woods and Philip L. Strong

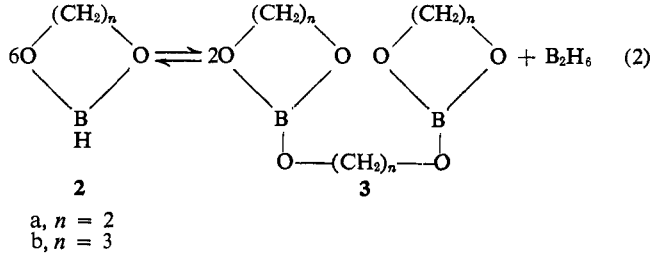
Contribution from the U. S. Borax Research Corporation, Anaheim, California.
Received June 20, 1966

Abstract: 4,4,6-Trimethyl-1,3,2-dioxaborinane (**5**) was prepared by reduction of the 2-chloro derivative (**4**) with sodium borohydride or lithium aluminum hydride, and from reaction of diborane and tris(2-methyl-2,4-pentanediol)biborate (**6**). Five-bond HCCOBH proton–proton coupling (J = 1.6 cps) was observed for **5**, but disappeared in the nmr spectrum of the 2-*d* compound. Hydroborations of cyclohexene, 1-octene, and allyl methyl sulfide with **5** gave the corresponding 2-alkyl compounds; **5** gave exclusively terminal addition with 1-alkenes and with 1-alkynes. The nmr spectra of the 1-alkene-1-boronates (**11** and **12**) from **5** with 1-hexyne and 1-heptyne constitute direct evidence for stereospecific *cis* addition in the hydroboration of acetylenes. A selective Raney nickel type hydrogenation catalyst was produced from nickel acetate and **5**. Reaction of **5** with dimethylamine gave the 2-dimethylamino derivative (**14**) and with ammonia gave the bis-2-amino compound (**13**); trimethylamine did not form a complex with **5**.

Interesting stability is exhibited by 2-vinyl-4,4,6-rimethyl-1,3,2-dioxaborinane with respect to other ethyleneboronates.[1] Evidence from our laboratories indicates unusual stability associated with other 2-substituted 4,4,6-trimethyl-1,3,2-dioxaborinanes.[2] Consequently, it was of interest to prepare 4,4,6-trimethyl-1,3,2-dioxaborinane (**5**), the parent member of this system. The instability of dimethoxyborane[3] (**1**), 1,3,2-dioxaborolane[4] (**2a**), and 1,3,2-dioxaborinane[5] (**2b**) toward disproportionation has been well documented (see eq 1 and 2). The extent to which **5** is stabilized toward disproportionation, therefore, was of prime concern.

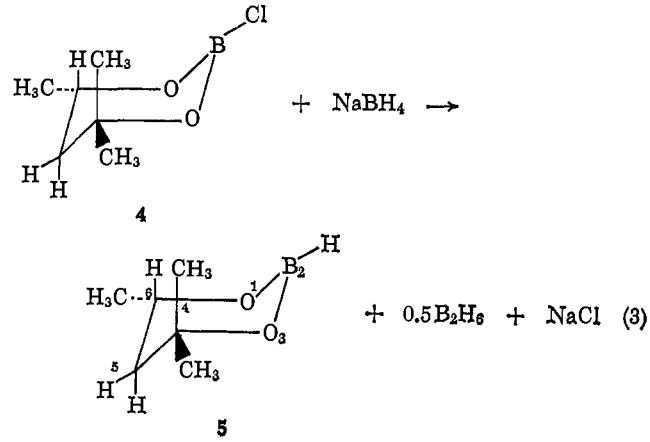
$$\underset{\mathbf{1}}{6(CH_3O)_2BH} \rightleftharpoons 4(CH_3O)_3B + B_2H_6 \qquad (1)$$

Synthesis. 4,4,6-Trimethyl-1,3,2-dioxaborinane (**5**) was prepared from 2-chloro-4,4,6-trimethyl-1,3,2-dioxaborinane (**4**) by reduction with sodium borohydride



(2)

in tetraglyme (eq 3). The yield based on **4** was near



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