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Notes

Selective Chemical Ionization Mass Spectrometry as an Aid in the Study of Thermally Labile Three-Membered Ring Sulfones

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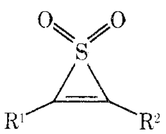
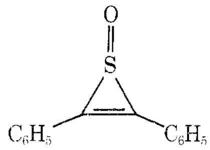
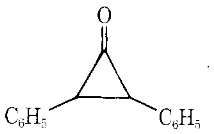
Recently a theoretically interesting group of compounds has been synthesized in which a sulfur has been incorporated in a three-membered ring.[1] The structures of these unusual compounds have been established by a combination of spectroscopic and chemical data. However, verification of the molecular weight of the sulfones **1a–1c** by mass spectrometry, employing the conventional electron impact (EI) ionization method, has been unsuccessful because of the absence or insignificant intensity of molecular ion peaks in their mass spectra. The base peak in the electron impact mass spectra of **1a–1c,** as well as the related compounds **2** and **3,** corresponds to the formation of the disubstituted acetylene ion [(R^1–C≡C–R^2)$\cdot^+$].



1a. $R^1 = R^2 = C_6H_5$
b, $R^1 = C_6H_5$, $R^2 = CH_3$
c, $R^1 = R^2 = CH_3$



2



3

No molecular ion peaks could be detected in the EI mass spectra of **1a** or **1b,** although very weak ones were observed in the mass spectra of the other compounds (see Table I).

Decomposition of the molecular ions in the EI spectra of **1–3** is particularly favorable because of the facile expulsion of the neutral species SO_2, SO, and CO, respectively. Indeed, in the sulfone case, considerable thermal decomposition may precede ionization as suggested by the fact that only the most volatile of the sulfones examined (**1c**) gave any evidence for a molecular ion. These sulfones generally undergo thermal fragmentation at approximately 100–125° at atmospheric pressure, and consequently we decided to investigate the mass spectrometry of these compounds under carefully controlled experimental conditions.

Table I
Relative Abundance of Molecular Ionic Species in the EI and CI Spectra of 1–3.

Compd	EI	CI CH_4	CI isobutane	CI NH_3	CI $NHMe_2$
1a				0.2,^{b} 2.9^c	23^d
1b				2,^{b} 21^c	42^d
1c	0.12^a	16^b	42^b	0.5,^{b} 86^c	70^d
2	0.25^a	26^b	49^b	24,^{b} 3^c	69^d
3	0.10^a	15^b	81^b	45,^{b} 9^c	75^d

^{a} Refers to %Σ of M$\cdot^+$. ^{b} Refers to %Σ of $(M + H)^+$ ion. ^{c} Refers to %Σ of $(M + NH_4)^-$ ion. ^{d} Refers to %Σ of $(M + NH_2Me_2)^+$ ion.

Results and Discussion

Lowering of the ionizing energy to ~10 eV in combination with lower ion source and inlet probe temperatures (<100°) failed to enhance significantly the relative abundance of the molecular ion in the EI spectra of **1–3**, and thus it became apparent that alternative ionization methods had to be considered. In view of the relatively lower energy processes involved in chemical ionization (CI) mass spectrometry,[2,3] we have explored the application of this technique as a means of determining the molecular weights of such unstable compounds. Chemical ionization spectra of **1–3** were obtained with various reagent gases and they are partially summarized in Table I. As a representative example, the complete EI and CI mass spectra of **1a** are compared in Figure 1. In all cases, the ion source temperature was kept at the lowest possible level required for sample vaporization to minimize possible thermal decomposition effects. The heat transmitted from the ion source of the CEC 21-110B mass spectrometer was sufficient for vaporization of the samples, and consequently no further heating of the solid inlet probe was necessary.

The methane CI spectra of **1a–1c** and **2** are dominated by the (R^1C≡CR^2 + H)$^+$ ion which carries approximately 55, 57, 60, and 26% of the total ion current in the case of **1a, 1b, 1c,** and **2**, respectively. As was the case with electron impact ionization, no molecular ion species were detected in the methane CI spectra of **1a** and **1b** at *m/e* values corresponding to $(M + H)^+$. The presence of the SO_2 function in the sulfones **1a–1c** is evident, however, from the intense *m/e* 65 peak corresponding to $(SO_2 + H)^+$, and which carries 22, 23, and 9% of the total ion current in **1a, 1b,** and

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1c, respectively. It is significant that distinct molecular ion species at *m/e* values corresponding to $(M + H)^+$ were observed in the methane CI mass spectra of both **1c** (16% Σ_{40}), **2** (26% Σ_{40}), and **3** (15% Σ_{40}). The higher thermal sta-

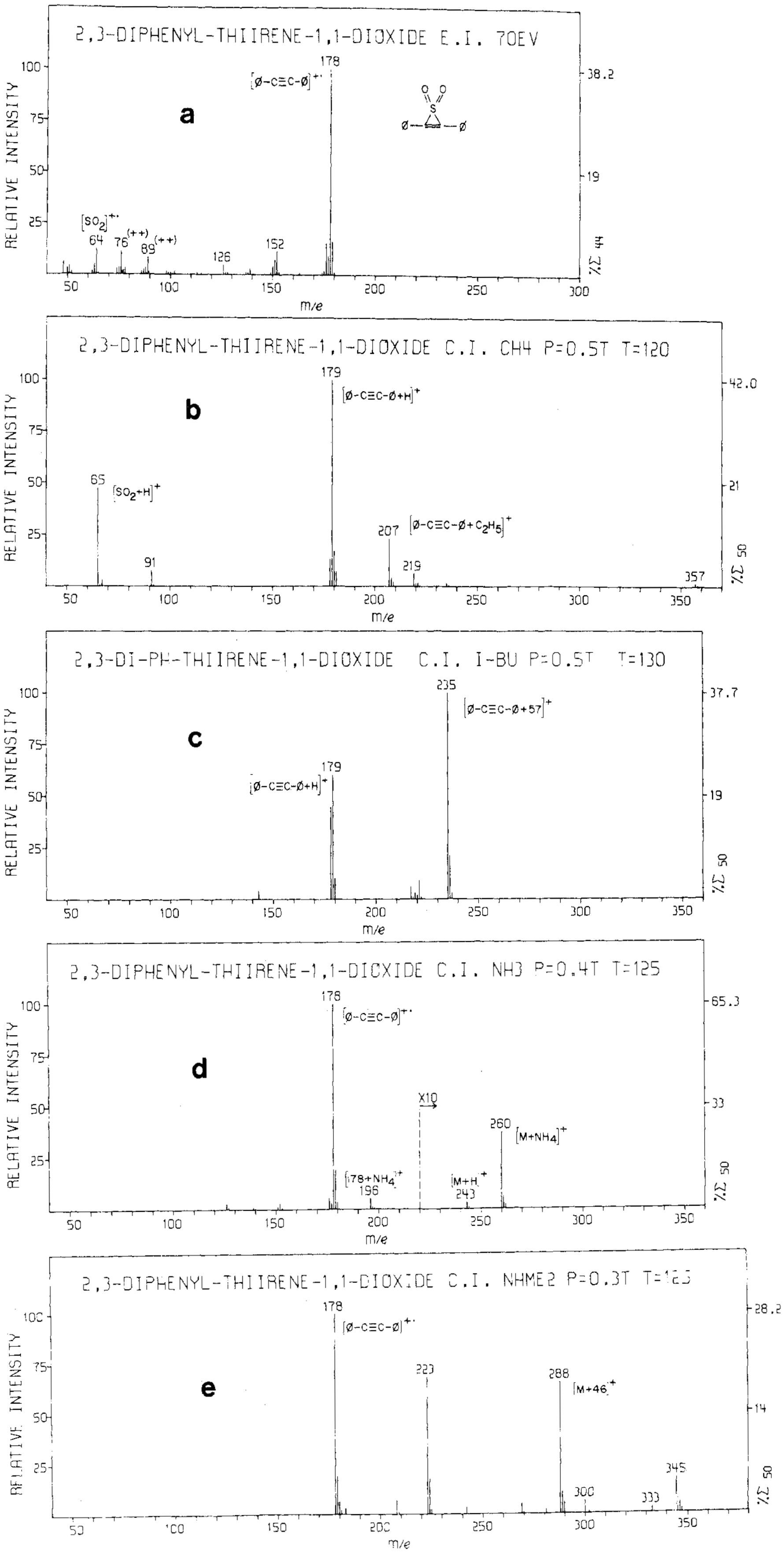


Figure 1. Mass spectra of 2,3-diphenylthiirene 1,1-dioxide: (a) Electron-impact spectrum (70 eV); (b) CI spectrum in methane; (c) CI spectrum in isobutane; (d) CI spectrum in ammonia; (e) CI spectrum in dimethylamine.

bility of the sulfoxide (**2**) over the sulfone (**1a**)[1] is further reflected in the comparison of the relative intensities of their ionic species at $M\cdot^+$ or $(M + H)^+$ (Table I). The EI spectrum of **2** exhibits a weak but discernible molecular ion peak while its methane CI spectrum shows an abundant $(M + H)^+$ ion (25% Σ_{40}). It might be noted that while the $(SO + H)^+$ ion was the predominant ionic species (35% Σ_{40}) in the spectrum of **2**, it was not possible to assess the contribution of $(CO + H)^+$ to the peak at *m/e* 29 in the spectrum of **3** because of the interfering reagent gas ion of the same nominal mass.

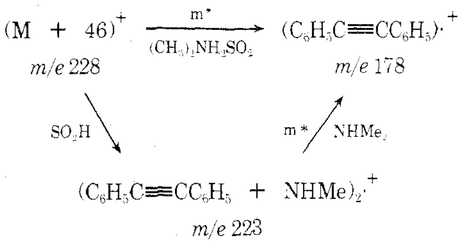
Assuming no thermal decompositions in the ion source or during sample vaporization, formation of $(R^1C{\equiv}CR^2 + H)^+$ and $(SO_2 + H)^+$ in the spectra of **1–2** occurs *via* elimination of SO_2 (SO in the case of **2**) respectively from $(M + H)^+$. In the absence of metastable transitions and because of the generally low thermal stability of thiirene dioxides, it is, of course, impossible to differentiate between thermal and ionic decompositions from the electron impact and methane CI spectra alone.

Proton transfer in isobutane reagent gas is accomplished by the *tert*-butyl carbonium ion and is accompanied by release of less energy than protonation in methane which is carried out by the highly acidic CH_5^+ ion.[4] Nevertheless, the CI spectra of compounds **1–3** in isobutane were similar to their methane counterparts, in that compounds **1a** and **1b** exhibited no $(M + H)^+$ or $(M + C_4H_9)^+$ adduct ions. The lower energy associated with this reaction is reflected in the increased relative intensity (Table I) of the $(M + H)^+$ peak in the spectra of **1c** (42% Σ_{40}), **2** (49% Σ_{40}), and **3** (81% Σ_{40}). On the other hand, in the case of **1a** or **1b** the amount of energy transferred during reaction with $C_4H_9^+$ is enough to cause complete decomposition of the initial molecular adducts formed. It is interesting to note that, as in the methane CI spectra, the adduct ion $[(R^1C{\equiv}CR^2 + H)^+]$ was also highly abundant in the isobutane CI spectra of **1–3** but, in addition, at the ion source temperatures employed, intense peaks were observed at $(R^1C{\equiv}CR^2 + 57)^+$, corresponding to formation of a dialkyl acetylene–$C_4H_9^+$ complex ion. The latter, of course, can be formed either by decomposition of the molecular adduct ion $(M + C_4H_9)^+$ and/or direct reaction of $C_4H_9^+$ with dialkyl acetylene produced by thermal decomposition of the sulfone.

The use of ammonia as a reagent gas in chemical ionization mass spectrometry was first demonstrated in the investigation of the mass spectra of nucleosides.[5] An enhancement in the abundance of the $(M + H)^+$ ions was noted as compared to CI in methane due to the lower acidity of the prevalent ammonium ion and the resulting lower exothermicity of the proton transfer reaction. In view of the above, we determined the mass spectra of compounds **1–3** in this system and, as indicated in Table I, there is a greatly enhanced abundance of the molecular ionic species. In the case of the sulfone **1a**, it is significant that although still weak, the molecular adduct ion peaks at $(M + H)^+$ and $(M + NH_4)^+$ are clearly detectable. The distinct preference for the formation of $(M + NH_4)^+$ rather than $(M + H)^+$ ions in the spectra of the sulfones **1a–1c** indicates a lower proton affinity for the sulfone function than for NH_3 under the experimental conditions. It should be noted that in an analogous fashion the ammonia CI spectrum of diphenyl sulfone ($C_6H_5SO_2C_6H_5$) showed a 100:1 abundance ratio of $(M + NH_4)^+$ to $(M + H)^+$ ions.

In a recent paper, Dzidic has suggested the use of alkylamine reagents for selective chemical ionization based on the relative proton affinities of the reagent gas and the sample.[6] In view of the apparent low proton affinity of the sulfone function, it was expected that no $(M + H)^+$ ions could be formed in the dimethylamine CI mass spectra of **1a–1c**, since $NHMe_2$ is a stronger base than NH_3.[6,7] Indeed, this was the case as indicated in Table I, but in the relatively low ion source temperatures required for mass spectrometry of the thiirene dioxides **1a–1c**, the conditions appear highly favorable for the formation of stable $(MNH_2Me_2)^+$ ion clusters. The greatly enhanced abundance of the molecular ion adducts in the mass spectra of the sulfones **1a** and **1b** provides unequivocal mass spectrometric evidence for the molecular weights of these compounds. Metastable defocusing experiments[8] confirmed that the decompositions *m/e* 288 → *m/e* 178 and *m/e* 223 → *m/e* 178 in the Me_2NH CI spectrum of **1a** are at least in part ionically induced and support the postulated fragmentation sequence (Scheme I). The relatively intense peak at *m/e* 345 in Figure 1e corresponds to $(M + 103)^+$. An ion of *m/e* 103 was always present in the spectrum of the reagent gas and is due to some undetermined impurity.

Scheme 1



The data presented above point out the usefulness of chemical ionization techniques for the mass spectrometric study of thermally unstable small ring unsaturated heterocyclic compounds. Selective chemical ionization by employment of different reagent gases can help enhance the relative abundance of molecular adduct ions and thus establish the molecular weight of the compounds investigated. Furthermore, since all chemical ionization mass spectra were obtained with the same instrument and at similar ion source temperature conditions, it is reasonable to assume that the observed decompositions to $(R^1C{\equiv}CR^2)\cdot^+$ or $(R^1C{\equiv}CR^2 + H)^+$ are not necessarily thermally, but at least in part ionically, induced.

Experimental Section

Electron impact ionization mass spectra were obtained with an LKB-9000 mass spectrometer, as well as a CEC 21-110B mass spectrometer operating in a low resolution mode. Samples were introduced into the ion source *via* the direct inlet probe and recorded at various ion source temperatures in the range 25–250°. The ionizing voltage unless otherwise specified was 70 eV. Chemical ionization mass spectra were obtained with a modified CEC 21-110B mass spectrometer,[9] at ion source temperatures ranging from 100–130°. Samples were introduced *via* the standard solid probe inlet provided with the instrument. The reagent gas pressures were 0.5 Torr for methane and isobutane, 0.4 Torr for ammonia, and 0.3 Torr for dimethylamine.

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Registry No.—**1a**, 5162-99-2; **1b**, 30503-83-4; **1c**, 30646-57-2; **2**, 31247-21-9; **3**, 52730-95-7.

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Thermally Labile Ketenimines from Triphenylphosphinalkylimines

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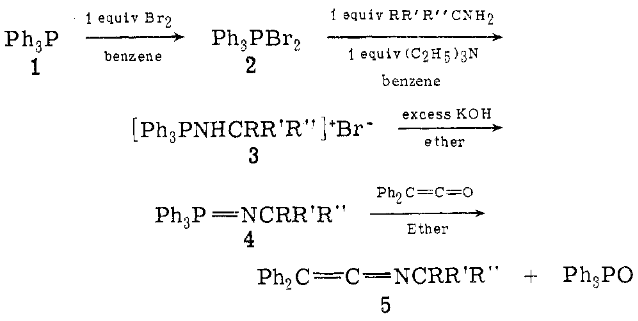
A recent study in our laboratory of a 1,3-nitrogen to carbon rearrangement (ketenimine → nitrile)[1] required routes to thermally labile and chiral ketenimines in which the asymmetric center was directly attached to the nitrogen. We wish to report our experience with the synthetic sequence shown in Scheme I. The key step is the reaction of diphenylketene with a triphenylphosphinalkylimine, first reported many years ago by Staudinger and Hauser.[2] We believe our present procedures offer some advantages over those previously described. Further, we demonstrate that optically active ketenimines can be prepared by this route with no measurable racemization at the asymmetric center directly attached to the nitrogen.

Scheme I



Nearly stoichiometric yields of the phosphonium bromides (**3**) were obtained by the addition of a primary amine and 1 equiv of triethylamine[3] to the *in situ* prepared triphenylphosphine dibromide (**2**). Deprotonation to the phosphinalkylimine (**4**) was readily accomplished by simply stirring **3** over excess potassium hydroxide in anhydrous ether for 20–40 hr. Previous workers used sodamide.[3] It is our experience that excellent yields are obtained by our procedure.

Slow addition of an ether solution of **4** at room temperature to an ether solution of diphenylketene under nitrogen gives diphenyl-*N*-(substituted)ketenimines in good to excellent yields. It is important to note that thermally labile ketenimines, which cannot be prepared by the more vigorous dehydration and dehydrohalogenation procedures[4] are easily prepared by Scheme I. Some difficulties encountered tered in separating the last traces of triphenylphosphine oxide from the ketenimine were overcome by chromatographing the product mixture over basic alumina.

By this reaction sequence, we have successfully prepared the diphenylketenimines having N-substituents of *tert*-butyl (**6**), benzyl (**7**), and 1-phenylethyl (**8**). The diphenyl-*N*-(diphenylmethyl)ketenimine (**9**) apparently also is formed *via* Scheme I, but is too labile toward rearrangement[1] at room temperature for isolation since 2,2,3,3-tetraphenylpropionitrile is recovered.

A synthetic sequence starting with (*S*)-(−)-1-phenylethylamine (α^{25}D −37.0°, neat) *via* (*S*)-(−)-triphenylphosphin-*N*-(1-phenylethyl)imine ($[\alpha]^{25}$D −62.4°, c = 14.4, CCl_4) yielded (*S*)-(−)-diphenyl-*N*-(1-phenylethyl)ketenimine ($[\alpha]^{25}$D 35.3°, c = 5.21, CCl_4). This synthetic sequence proceeds with complete retention of configuration since mild hydrolysis[5] of (*S*)-(−)-**8** gives a 95% yield of (*S*)-(−)-diphenyl-*N*-(1-phenylethyl)acetamide showing the same specific rotation as amide directly prepared from starting (*S*)-(−)-1-phenylethylamine and diphenylacetyl chloride ($[\alpha]^{25}$D −39.6°, c = 1.2, $CHCl_3$).

The scope of Scheme I is limited by (i) the thermal lability of the resulting ketenimines and (ii) the availability of reasonably stable ketenes. As a guide for point (i), we observed that the thermal thresholds for reaction of the diphenylketenimines in Table II are **6**, ~125°; **7**, ~70°; **8**, 50°; **9** $\gtrsim$ 25°. With regard to (ii), it should be possible to extend this synthesis to ketenimines derived from other ketenes if the self-reactions of the latter do not interfere.

Table I
Properties of the Alkylaminotriphenylphosphonium Bromides and Triphenylphosphinalkylimines

			$[Ph_3PNHCRR'R'']^+Br^-$ [a]			$Ph_3P{=}NCRR'R''$ [b]		
R	R'	R''	Mp, °C	Registry no.	Nmr (CD_3Cl, δ)	Mp, °C	Registry no.	Nmr (CCl_4, δ)
Ph	H	H	195–197	52826-42-3	4.33 (2 H) q, 7.2–8.1 (20 H) m, 2.03 (1 H) s	137–138	52826-45-6	4.43 (2 H) d,[c] 7.0–8.0 (20 H) m
Ph	CH_3	H	156–157[d] 116–117[e]	52826-43-4 52918-35-1	1.87 (3 H) q, 4.13 (1 H) m, 2.17 (1 H) s, 7.1–8.1 (20 H) m	67–68[d] oil[e]	52826-46-7 52882-00-5	1.43 (3 H) q,[f] 4.37 (1 H) m,[c] 7.0–8.0 (20 H) m
Ph	Ph	H	267–269	52826-44-5	2.10 (1 H) s, 5.07 (1 H) q, 7.1–8.1 (25 H) m	129–131	52826-47-8	5.33 (1 H) d,[c] 7.0–8.0 (25 H) m
CH_3	CH_3	CH_3	165–167	799-51-9	1.33 (9 H) s, 7.2–8.2 (15 H) m, 2.37 (1 H) s	146–147	13989-64-5	1.17 (9 H) d,[f] 7.0–8.0 (15 H) m

[a] All isolated yields are in excess of 95%. [b] All isolated yields are in excess of 75%. [c] J (P = N–CH–) ~20 Hz. [d] Racemic modification. [e] *S*-(−) compound. [f] J (P = N–C–CH_3) ~1 Hz.