Synthesis of Substituted 2-Pyridones via the Pummerer Cyclization−Deprotonation−Cycloaddition Cascade of Imidosulfoxides†

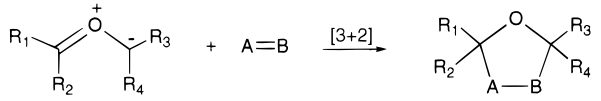
Albert Padwa,* Todd M. Heidelbaugh, and Jeffrey T. Kuethe

Department of Chemistry, Emory University, Atlanta, Georgia 30322

Received November 24, 1998

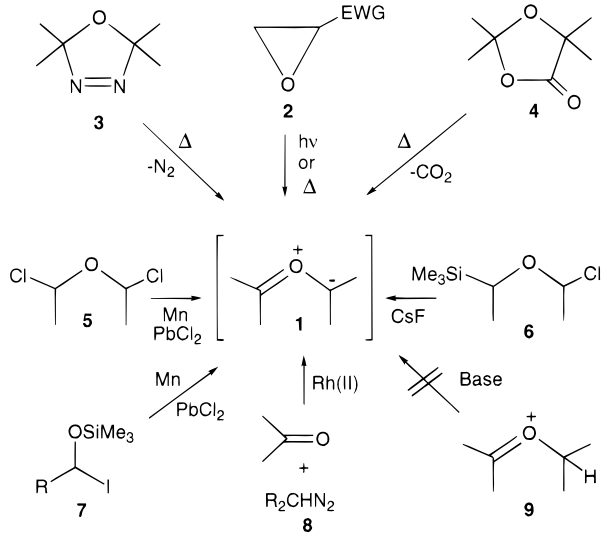
1-Ethanesulfinylacetylpiperidin-2-one was prepared from δ-valerolactam in two steps by heating with ethylsulfenylacetyl chloride followed by sodium periodate oxidation. Slow addition of the imidosulfoxide to a refluxing mixture of toluene, acetic anhydride (10 equiv), and *p*-toluenesulfonic acid (1 mol %) resulted in the formation of an isomünchnone dipole which underwent bimolecular trapping in good yield. The stereochemical assignment of the cycloadduct was made on the basis of X-ray crystallography and is the consequence of an e*ndo* cycloaddition with respect to the dipole. The regiochemistry of the cycloaddition is consistent with a HOMO-dipole controlled process. Several related imidosulfoxides containing a tethered alkenyl group were prepared and subjected to the Pummerer reaction conditions. The resulting mesoionic dipoles formed by the cyclization−deprotonation sequence undergo ready dipolar cycloaddition across the pendant olefin to afford intramolecular cycloadducts in high yield. Exposure of these cycloadducts to acetic anhydride in the presence of a trace of *p*-toluenesulfonic acid results in ring opening to give 5-acetoxy-substituted 2-pyridones. The lone pair of electrons on the amide nitrogen assists in opening the oxy bridge to generate a transient *N*-acyliminium ion, which subsequently loses a proton. In certain cases, the amide electron pair with the oxy bridge is partially twisted from an antiperiplanar arrangement and a competive ring cleavage also occurs to give 5-thioethyl-substituted 2-pyridones.

Due to their common occurrence in nature,[1] oxygen-containing heterocycles are frequent and important targets for synthesis either as final products or as useful synthetic intermediates. Of particular importance is the tetrahydrofuran ring[2] since this structural unit is found in many naturally occurring compounds.[3] Although the synthesis of tetrahydrofurans commonly proceeds via C−O bond formation,[3] the application of C−C bond forming reactions to construct this ring has also been used in recent years.[4] Conceptually, the 1,3-dipolar cycloaddition of carbonyl ylides with π-bonds represents an attractive strategy for the construction of tetrahydrofurans.[5]



Common methods for carbonyl ylide formation (Scheme 1) involve the thermolysis or photolysis of epoxides possessing electron-withdrawing substituents,[6−9] the thermal extrusion of nitrogen from 1,3,4-oxadiazolines,[10−12] and the loss of carbon dioxide from 1,3-dioxolan-4-ones.[13]

Scheme 1. Various Methods Utilized to Generate the Carbonyl Ylide Dipole



† This paper is dedicated to Henk van der Plas on the occasion of his 70th birthday, for his significant contributions to the field of heterocyclic chemistry.

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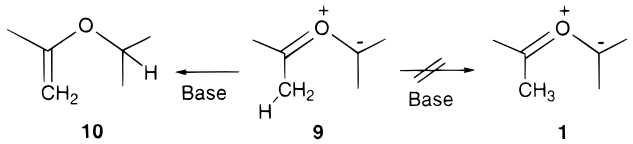
10.1021/jo982315r CCC: $18.00
Published on Web 03/03/1999

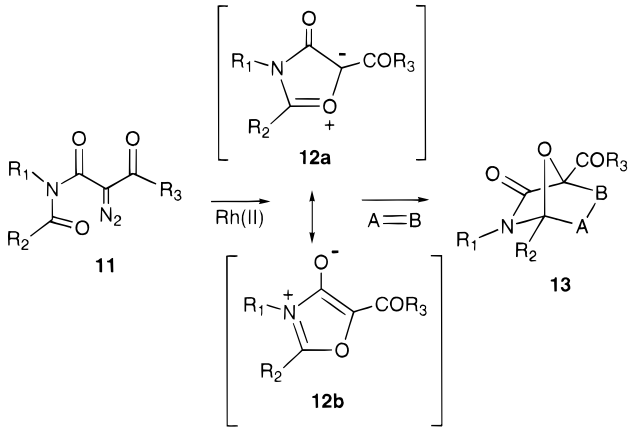
More recently, Hosomi and co-workers demonstrated that simple carbonyl ylides may be expediently produced by a silicon-based 1,3-elimination under mild and neutral conditions.[14] Nonstabilized carbonyl ylides were also generated by treating 1-iodoalkyl trialkylsilyl ethers with both SmI_2[15] and a manganese−$PbCl_2$−Me_3SiCl combination.[16]

The creation of carbonyl ylides from the reaction of diazo compounds with ketones in the presence of Rh(II) catalysts,[17,18] especially in intramolecular reactions,[19] has significantly broadened their applicability for natural product synthesis.[20−22] Subsequent studies have demonstrated that both carbonyl ylides as well as oxonium ylides, derived from the reaction of metallo carbenoids with carbonyl and ethereal oxygens, can be used as intermediates in a wide variety of subsequent transformations, including dipolar cycloadditions,[17−19] Steven's 1,2-shifts,[23,24] 2,3-sigmatropic rearrangements,[25,26] and simple β-eliminations.[27] While the generation of carbonyl ylides from diazo precursors is quite common, the base-induced deprotonation of an oxonium ion such as **9** as a method for dipole formation has largely been ignored. This is somewhat surprising since the removal of a proton from various onium salts is a well-recognized process that has been extensively used to form ammonium[28] and sulfonium ylides.[29] The absence of this method for carbonyl ylide formation is undoubtedly due to the inherent difficulty in forming the dipole by deprotonation. The problem stems from a competitive deprotonation at the β-site, which ultimately leads to a substituted enol ether (i.e., **10**) (Scheme 2).

Scheme 2



Scheme 3



In an attempt to clarify the factors that might influence carbonyl ylide formation by the deprotonation approach (i.e., **9** → **1**), we eventually were led to study the Pummerer reaction of imidosulfoxides.[30] Our interest in this particular reaction was stimulated by our continuing involvement with the cycloaddition chemistry of mesoionic compounds.[31] Mesoionic betaines are five-membered heterocyclic ring systems that cannot be represented by normal covalent structures and are best described as a hybrid of all possible forms.[32] The isomünchnone class of mesoionics can easily be generated from the Rh(II)-catalyzed reaction of α-diazo imides (Scheme 3).[33,34] The facility with which this mesoionic system was formed can be attributed to the dipolar aromatic resonance structure **12**, which helps stabilize the dipole.[33,34] Since isomünchnones contain a carbonyl ylide dipole within their framework, they are willing participants in 1,3-dipolar cycloaddition chemistry. α-Acyl thionium ions generated from α-acyl sulfoxides under Pummerer conditions are powerful electrophiles, reacting efficiently with a variety of nucleophilic species.[35−37] We reasoned that the initially formed thionium ion **15**

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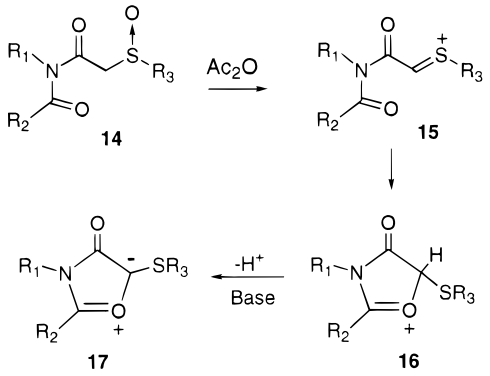
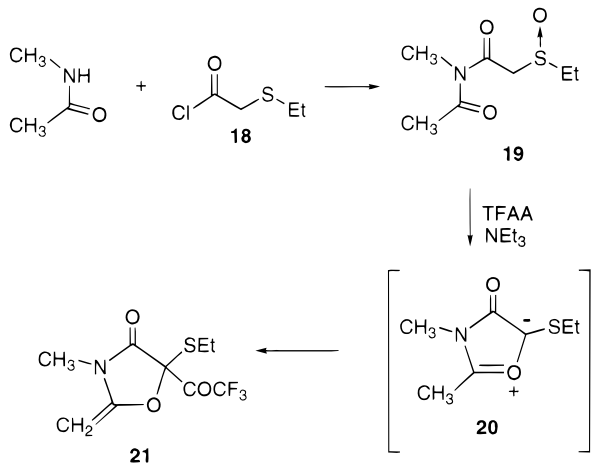
Scheme 4



Scheme 5

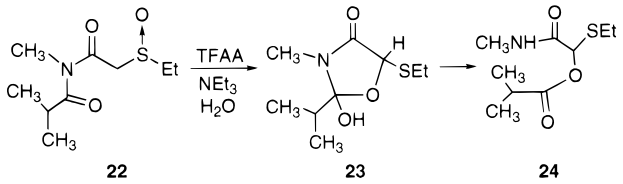


derived from imidosulfoxide **14** would rapidly cyclize with the neighboring imido group, and the resulting oxonium ion **16** should undergo ready deprotonation to produce the highly stabilized carbonyl ylide **17** (Scheme 4). Indeed, under the proper experimental conditions (vide infra), this tandem *Pummerer cyclization−deprotonation sequence* works extremely well and represents a highly efficient method for generating isomünchnone dipoles. In this paper, we report a full account of our efforts in this field.

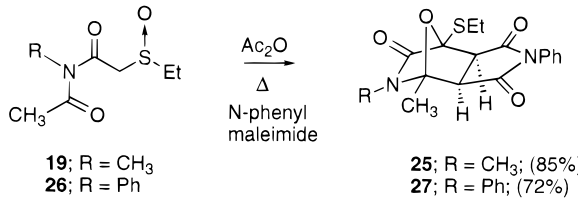
Results and Discussion

The required imidosulfoxides necessary for the *Pummerer-induced cyclization−deprotonation sequence* were easily obtained by heating the appropriate amide with (ethylsulfenyl)acetyl chloride (**18**)[38] followed by sodium periodate oxidation. The classical Pummerer reaction can be initiated by a variety of electrophilic reagents (Pummerer promoters).[35−37] Acetic anhydride is by far the most commonly used reagent and is often utilized as the solvent at reflux temperature or in combination with other solvents or cocatalysts. The more electrophilic trifluoroacetic anhydride (TFAA) has also been extensively employed since it allows the reaction to proceed under very mild conditions in the presence of basic (e.g., pyridine, triethylamine) or Lewis acid catalysts (e.g., $SnCl_4$). We opted to conduct our initial set of experiments using TFAA as the Pummerer promoter. The first system investigated involved the reaction of *N*-acetyl-2-ethanesulfinyl-*N*-methylacetamide (**19**) with excess TFAA at 0 °C in the presence of triethylamine. Even though this reaction was carried out in the presence of various trapping agents (i.e., DMAD, *N*-phenylmaleimide, methyl acrylate, etc.), no signs of an isomünchnone cycloadduct could be detected. The only product isolated corresponded to the trifluoroacetyl-substituted oxazolidone **21** (Scheme 5).

Apparently, the initially formed betaine is unstable to the reaction conditions and reacts further with excess TFAA followed by a subsequent deprotonation to give **21**. When the related isobutyramide **22** was treated under similar experimental conditions, the only product obtained (even with added dipolarophiles) corresponded to the ethylsulfenylmethyl carbamoyl ester **24**. This compound is formed by the addition of adventitious water to the isomünchnone dipole followed by ring opening of the transient hemiaminal **23**. When water was deliberately added to the reaction mixture, a high yield (88%) of **24** was isolated.



Our inability to isolate an isomünchnone cycloadduct from these TFAA-promoted reactions suggested that a modified triggering protocol had to be developed in order to trap the mesoionic betaine intermediate. After considerable experimentation with a variety of Pummerer promoters and cocatalysts, we found that dipole formation/trapping occurred in high yield when a mixture of toluene and acetic anhydride which also contained a catalytic quantity of *p*-toluenesulfonic acid (*p*-TSOH) was used.[39] These conditions, whereby the sulfoxide is slowly added to a refluxing mixture of toluene, acetic anhydride (10 equiv), *p*-TsOH (catalyst), and the appropriate dienophile (1.5 equiv), gave consistently the best results (>80% yields), for both the inter- and intramolecular cycloaddition reactions (vide infra). Thus, the reaction



of imidosulfoxide **19** under the above conditions with added *N*-phenylmaleimide led, after column chromatography, to cycloadduct **25** in 85% yield as a single diastereomer. Its spectroscopic properties support the stereochemical assignment of **25** as being the result of *endo* cycloaddition with respect to the dipole, and this

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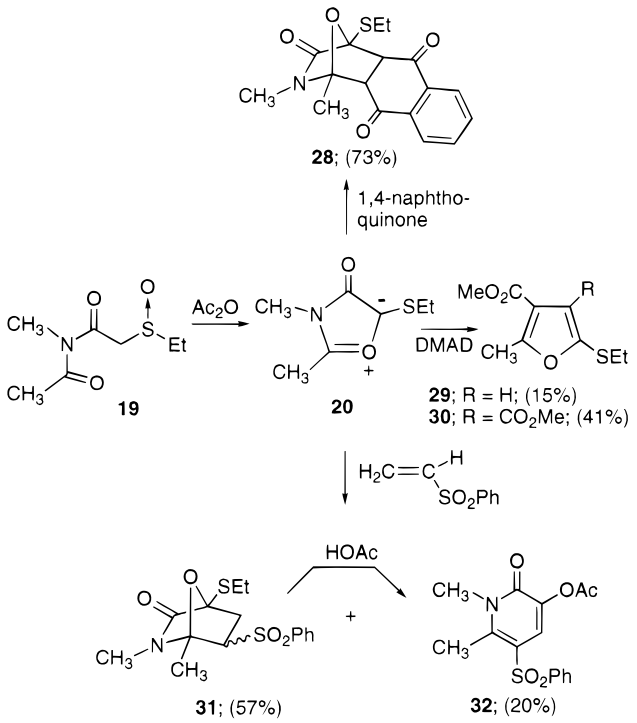
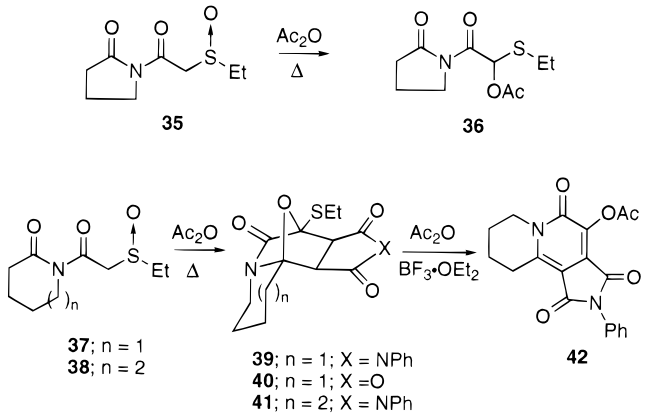
Scheme 6



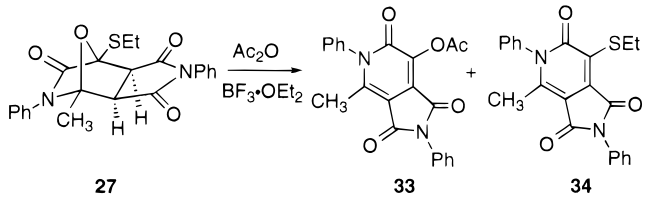
was confirmed by X-ray crystallography.[40] An analogous cycloaddition process occurred when the related phenylacetamide sulfoxide **26** (R = Ph) was used with *N*-phenylmaleimide as the trapping agent (i.e., **26** → **27** in 72% yield).

Several types of dipolarophiles were examined to establish the scope and generality of the process. The tandem *Pummerer-cyclization−deprotonation−cycloaddition* sequence using imidosulfoxide **19** proceeded smoothly with 1,4-naphthoquinone, dimethyl acetylenedicarboxylate, methyl propiolate, and phenyl vinyl sulfone (Scheme 6). In all cases the initially formed isomünchnone dipole was trapped by the added dipolarophile, and good yields of the expected dipolar cycloadduct were obtained. When acetylenic dipolarophiles were employed, the initially formed cycloadducts were not isolated, as they readily lost methyl isocyanate[41] to give α-thioethyl-substituted furans (i.e., **29** and **30**). When phenyl vinyl sulfone was used as the dipolarophile, a 2:1 mixture of the *exo* and *endo* isomers of the mesoionic cycloadduct **31** was isolated in addition to the acetoxy-substituted pyridone **32**. Compound **32** was shown to be derived from an acetic acid induced rearrangement of cycloadduct **31**. The regiochemistry of the cycloaddition is consistent with an FMO analysis of the reaction. MNDO calculations indicate that the dominant interaction of an isomünchnone dipole with an electron-deficient dipolarophile is between the HOMO-dipole LUMO-dipolarophile (type I).[42] This correlates with the exclusive formation of both cycloadduct **31** and furan **29**. The calculations indicate that the atomic coefficient at the C_3 carbon of the isomünchnone is larger than the C_5 carbon for the HOMO.[43] It is well-known that the C_β coefficient of the LUMO of an electron-deficient dipolarophile is larger than the C_α coefficient,[44] and consequently cycloadduct **31** (or furan **29**) is predicted to be the major regioisomer formed.

Scheme 7



During the course of our studies, we found that the isomünchnone cycloadducts underwent ready rearrangement to give 2-hydroxy pyridones when treated with a Lewis acid such as $BF_3{\cdot}OEt_2$. Typically, the ring-opened 2-hydroxy pyridones were converted to the corresponding acetoxy derivatives for characterization purposes. The major product is derived by oxybridge cleavage promoted by the nitrogen atom lone pair. In a typical example, treatment of cycloadduct **27** with $BF_3{\cdot}OEt_2$ at 80 °C afforded a 5:1 mixture of pyridones **33** and **34** (96% combined yield). Formation of pyridone **34** as the minor product (16%) is a consequence of oxybridge cleavage in the alternate direction.



To access synthetically more valuable targets, we focused our attention on the Pummerer-cycloaddition reaction of several cyclic imidosulfoxides. When the five-membered ring cyclic imide **35** was subjected to the Pummerer-deprotonation conditions, α-acetoxy sulfide **36** was the only product isolated from the reaction mixture. In this case, the initially generated thionium ion is reluctant to undergo cyclization with the adjacent carbonyl group, and instead, it reacts with an external nucleophile (i.e., AcO^-) to furnish the normal Pummerer product **36**. This behavior may be related to the ring strain present in the fused five-membered-ring mesoionic intermediate, which causes a significant suppression in the cyclization rate. In contrast to the five-membered-ring system, the six- (**37**) and seven- (**38**) membered imido-sulfoxides afforded good yields of cycloadducts **39**−**41** when treated with Ac_2O and *N*-phenylmaleimide (or maleic anhydride) (Scheme 7). Further treatment of **39** with $BF_3{\cdot}OEt_2$ followed by reaction with Ac_2O furnished pyridone **42** in 98% yield. The facility with which iso-

(40) The authors have deposited coordinates for structure **25** with the Cambridge Crystallographic Data Centre. The coordinates can be obtained, on request, from the Director, Cambridge Crystallographic Data Centre, 12 Union Road, Cambridge, CB2 1EZ, U.K.

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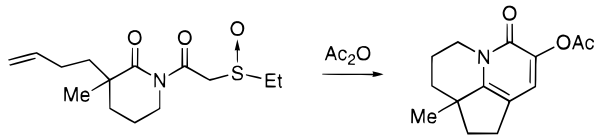
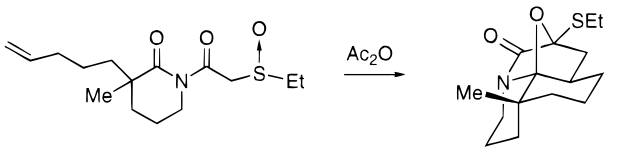
münchnone formation occurs with these larger ring lactams is undoubtedly associated with the faster rate of thionium ion cyclization with the adjacent carbonyl group. With these systems, intramolecular attack by the neighboring imido group onto the thionium ion is faster than the bimolecular reaction with an acetoxy anion. Ring strain is clearly not an issue in the cyclization of the six- and seven-membered lactams but is a significant factor with the five-membered-ring system.

The complexity of the resulting products could be significantly increased by generating isomünchnones where the peripheral substituents are part of a cyclic system. With this in mind, we decided to examine the Pummerer behavior of a series of cyclic imidosulfoxides containing tethered π-bonds. Treatment of the 3-butenyl-substituted imidosulfoxide **43** with excess acetic anhydride provided pyridone **44** in 85% yield as a crystalline solid. The formation of **44** is consistent with the sequence



43 **44**

of events proposed in Scheme 6. The critical steps involve (a) isomünchnone formation, (b) intramolecular dipolar cycloaddition, and (c) oxabicyclic ring cleavage. Interestingly, imidosulfoxide **45**, where the length of the alkenyl tether was increased by one methylene unit, was observed to undergo exclusive intramolecular cycloaddition across the isomünchnone dipole without further ring opening taking place under the reaction conditions. Thus, treatment of **45** with Ac_2O gave cycloadduct **46** as the only observable product in 73% yield. The assignment of

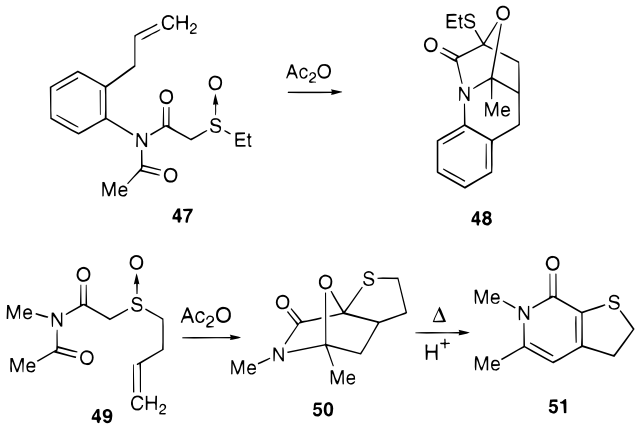


45 **46**

the stereochemistry of **46** was based on a comparison of its NMR signals with related substrates for which X-ray crystallographic data exist. The formation of the *endo*-cycloadduct with respect to the carbonyl ylide dipole is in full accord with molecular mechanics calculations which show a large ground-state energy difference between the two diastereomers. We assume that the transient cycloadduct derived from **43** undergoes an acid-assisted ring opening at a much faster rate than the homologous pentenyl adduct as a consequence of relief of ring strain. Cycloadduct **46** is sufficiently stable to the acidic conditions used to trigger the Pummerer reaction and can be isolated prior to rearrangement.

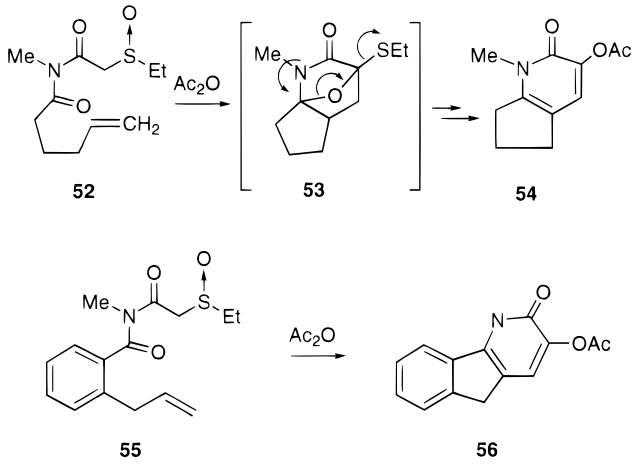
So that a cross section of additional information could be obtained in regard to the tandem *Pummerer cyclization−deprotonation−cycloaddition* protocol, a series of imidosulfoxides was needed representing a variety of different permutations. Ultimately, substrates **47**, **49**, **52**, and **55** were studied, as they contain a range of synthetically interesting and easily attainable functionality. High yields of an intramolecular cycloadduct were obtained upon treating imidosulfoxide **47** under the standard

Scheme 8



47 **48** **49** **50** **51**

Scheme 9

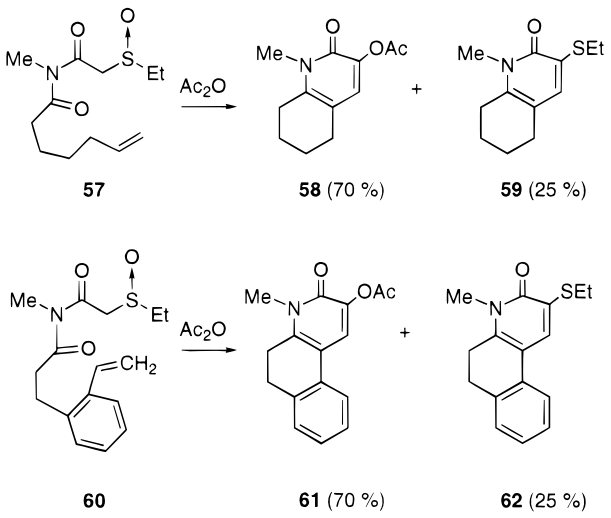


52 **53** **54** **55** **56**

Pummerer conditions. In this case, the oxabicyclic ring of **48** was quite stable toward ring opening and could be isolated in 83% yield (Scheme 8). In a related fashion, imidosulfoxide **49** produced primarily cycloadduct **50** (58%) together with lesser quantities of pyridone **51** (15%). This result demonstrates that a tethered alkene attached to the sulfoxide can also be used in these Pummerer-induced cycloadditions. Further heating of **50** in toluene with a trace of *p*-toluenesulfonic acid resulted in a dehydration producing pyridone **51** in quantitative yield.

Another substitution variant that was investigated corresponded to the placement of an alkenyl tether on the imido carbonyl group of an acyclic imide. Thus, treatment of imidosulfoxides **52** and **55** with acetic anhydride afforded the acetoxy-substituted pyridones **54** and **56**. In these cases, the initially formed cycloadduct (e.g., **53**) undergoes rapid ring opening of the oxybridge with ejection of the thioethyl group to furnish the pyridones in 78% and 70% yield, respectively (Scheme 9).

In a further investigation of the sequential *cyclization−deprotonation−cycloaddition* cascade, we also examined the Pummerer reaction of imidosulfoxides **57** and **60**. Interestingly, with these systems, significant quantities (ca. 25%) of the 5-thioethyl-substituted pyridone system (i.e., **59** and **62**) were isolated in addition to their acetoxy counterparts (i.e., **58** and **61** (70% yield)). One rationale that may account for why these two particular imidosulfoxides produce a mixture of pyridones in contrast to the other systems may be related to the stereoelectronic



factors associated with opening of the oxybridge of the initially formed cycloadduct. Acetoxy-substituted pyridones are formed when the amide lone pair of electrons and the oxy-bridge are antiperiplanar, as is typical for most 1,2-elimination reactions. Examination of molecular models suggests that cycloadduct **53** ($n = 1$) has the proper stereoelectronic alignment, and thus preferential cleavage of bond *b* occurs (Scheme 10). With the homologous cycloadduct **57** ($n = 2$), the geometry is slightly twisted away from an antiperiplanar arrangement. Consequently, participation of the lone pair of electrons from the sulfur atom can compete with the amido lone pair, thereby leading to thioethyl-substituted pyridones by bond *a* cleavage. A related explanation can be invoked to rationalize the mixture of pyridones obtained from imidosulfoxide **60**.

In conclusion, our studies have demonstrated that the Pummerer reaction of imidosulfoxides represents a highly efficient method for the synthesis of azapolycyclic ring systems. The subsequent ring cleavage reaction of the initially formed isomünchnone cycloadduct appears to be dependent upon stereoelectronic factors associated with the amide lone pair of electrons and the oxygen bridge. We are continuing to explore the scope and mechanistic details of these Pummerer-induced cycloaddition reactions and will report additional findings at a later date. Further utilization of this *cyclization−deprotonation−cycloaddition* sequence for the stereocontrolled synthesis of alkaloids is under current investigation.

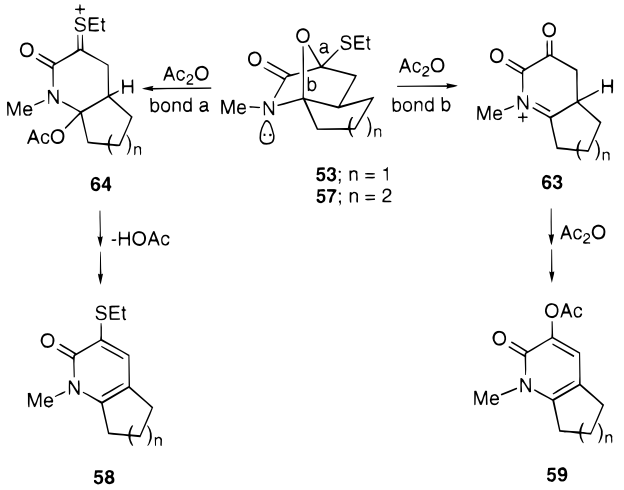
Experimental Section

Melting points are uncorrected. Mass spectra were determined at an ionizing voltage of 70 eV. Unless otherwise noted, all reactions were performed in flame-dried glassware under an atmosphere of dry argon. Solutions were evaporated under reduced pressure with a rotary evaporator, and the residue was chromatographed on a silica gel column using an ethyl acetate−hexane mixture as the eluent unless specified otherwise.

General Procedure for the Preparation of Imido Sulfoxides. A solution containing 10 mmol of the appropriate amide and 13 mmol of ethylsulfenylacetyl chloride (**18**)[38] in 100 mL of benzene was heated at reflux for 12 h. The reaction mixture was cooled, diluted with ether, and washed with 10% NaOH. The organic layer was dried over $MgSO_4$ and concentrated under reduced pressure. The residue was purified by flash silica gel chromatography.

To a solution of 5.5 mmol of sodium periodate in a 2:1 mixture of methanol−H_2O was added 5 mmol of the appropriate imido sulfide. The resulting mixture was stirred for 3 h at room temperature, diluted with water, extracted with chloroform, and dried over $MgSO_4$. The solvent was removed under reduced pressure, and the residue was subjected to silica gel chromatography to afford the pure imido sulfoxide.

Scheme 10



***N*-Acetyl-2-ethylsulfenyl-*N*-methylacetamide.** Following the general procedure, the reaction of 2.0 g (27 mmol) of *N*-methylacetamide with 4.9 g (36 mmol) of acid chloride **18** afforded 4.6 g (96%) of *N*-acetyl-2-ethylsulfenyl-*N*-methylacetamide as a colorless liquid: bp 110−112 °C; IR (neat) 2968, 1694, 1303, and 1139 cm^{-1}; ^1H NMR ($CDCl_3$, 300 MHz) δ 1.26 (t, 3H, $J = 7.4$ Hz), 2.41 (s, 3H), 2.61 (q, 2H, $J = 7.4$ Hz), 3.28 (s, 3H), and 3.72 (s, 2H); ^{13}C NMR ($CDCl_3$, 75 MHz) δ 13.9, 25.7, 25.8, 31.5, 37.1, 171.7, and 172.7. HRMS Calcd for $C_7H_{13}NO_2S$: 175.0667. Found: 175.0665.

***N*-Acetyl-2-ethanesulfinyl-*N*-methylacetamide (19).** The reaction of 2.3 g (13 mmol) of the above sulfide with 3.1 g (14 mmol) of sodium periodate gave 2.1 g (84%) of **19** as a clear oil: IR (neat) 2932, 1687, 1303, and 1047 cm^{-1}; ^1H NMR ($CDCl_3$, 300 MHz) δ 1.39 (m, 3H), 2.40 (s, 3H), 2.80−3.37 (m, 2H), 3.80 (s, 3H), 4.31 (d, 1H, $J = 4.8$ Hz), and 4.36 (d, 1H, $J = 4.8$ Hz); ^{13}C NMR ($CDCl_3$, 75 MHz) δ 6.5, 25.5, 32.0, 46.2, 60.5, 167.9, and 173.3. Anal. Calcd for $C_7H_{13}NO_3S$: C, 43.96; H, 6.86; N, 7.33. Found: C, 43.84; H, 6.73; N, 7.19.

5-Ethylsulfenyl-3-methyl-2-methylene-5-trifluoroacetyloxazolidin-4-one (21). To a solution containing 0.5 g (2.6 mmol) of acetamide **19** and 0.3 g (2.8 mmol) of triethylamine in 45 mL of CH_2Cl_2 at 0 °C was added dropwise 1.4 g (6.5 mmol) of trifluoroacetic anhydride. After stirring at room temperature for 0.5 h, the mixture was diluted with water, extracted with CH_2Cl_2, and dried over $MgSO_4$. The solvent was removed under reduced pressure, and the residue was chromatographed on silica gel to give 0.2 g (30%) of **21** as a colorless oil: IR (neat) 1766, 1694, 1581, 1452, and 1075 cm^{-1}; ^1H NMR ($CDCl_3$, 300 MHz) δ 1.36 (t, 3H, $J = 7.6$ Hz), 2.79 (q, 2H, $J = 7.6$ Hz), 3.18 (s, 3H), 5.30 (s, 1H), and 6.10 (s, 1H); ^{13}C NMR ($CDCl_3$, 75 MHz) δ 14.3, 25.0, 26.8, 75.5, 84.4, 116.1 (q, $J = 289$ Hz), 165.9, 167.6, and 175.6 (d, $J = 35$ Hz). HRMS Calcd for $C_9H_{10}F_3NO_3S$: 269.0333. Found: 269.0335.

***N*-Ethylsulfenylacetyl-*N*-methylisobutyramide.** Following the general procedure, treatment of 2.0 g (20 mmol) of the methyl amide of isobutyric acid with 3.6 g (26 mmol) of acid chloride **18** afforded 3.5 g (86%) of *N*-ethylsulfenylacetyl-*N*-methylisobutyramide as a colorless oil; IR (neat) 1689, 1297, and 1063 cm^{-1}, ^1H NMR ($CDCl_3$, 300 MHz) δ 1.20 (d, 6H, $J = 6.7$ Hz), 1.27 (t, 3H, $J = 7.4$ Hz), 2.62 (q, 2H, $J = 7.4$ Hz), 3.18 (m, 1H), 3.28 (s, 3H), and 3.74 (s, 2H); ^{13}C NMR ($CDCl_3$, 75 MHz) δ 14.3, 19.1, 26.2, 31.6, 34.4, 37.7, 172.7, and 180.4. HRMS Calcd for $C_9H_{17}NO_2S$: 203.0980. Found: 203.0982.

***N*-Ethanesulfinylacetyl-*N*-methylisobutyramide (22).** Treatment of 3.4 g (17 mmol) of the above sulfide with 3.9 g (19 mmol) of sodium periodate gave 3.0 g (80%) of **22** as a clear oil; IR (neat) 1689, 1305, and 1056 cm^{-1}; ^1H NMR ($CDCl_3$, 300

MHz) δ 1.21 (d, 6H, J = 6.7 Hz), 1.38 (t, 3H, J = 7.4 Hz), 2.88 (m, 2H), 3.06 (m, 1H), 3.31 (s, 3H), 4.12 (d, 1H, J = 14.7 Hz), and 4.34 (d, 1H, J = 14.7 Hz); ^{13}C NMR ($CDCl_3$, 75 MHz) δ 6.5, 18.8, 18.9, 31.3, 33.9, 46.1, 60.8, 168.3, and 180.3. Anal. Calcd for $C_9H_{17}NO_3S$: C, 49.29; H, 7.82; N, 6.39. Found: C, 49.15; H, 7.75; N, 6.27.

Isobutyric Acid Ethylsulfenylmethylcarbamoyl Methyl Ester (24). To a solution containing 0.6 g (2.7 mmol) of **22** and 0.3 g (3.0 mmol) of triethylamine in 45 mL of CH_2Cl_2 at 0 °C was added dropwise 1.4 g (6.7 mmol) of trifluoroacetic anhydride. After stirring for 1 h at room temperature, the mixture was diluted with water, extracted with CH_2Cl_2, and dried over $MgSO_4$. The solvent was removed under reduced pressure, and the residue was chromatographed on silica gel to give 0.5 g (88%) of **24** as a colorless oil; IR (neat) 1742, 1667, and 1139 cm^{-1}; ^{1}H NMR ($CDCl_3$, 300 MHz) δ 1.24 (d, 6H, J = 7.0 Hz), 1.29 (t, 3H, J = 7.3 Hz), 2.73 (m, 3H), 2.88 (d, 3H, J = 4.9 Hz), 6.19 (s, 1H), and 6.45 (brs, 1H); ^{13}C NMR ($CDCl_3$, 75 MHz) δ 14.8, 18.6, 18.8, 24.9, 26.4, 33.9, 75.9, 166.8, and 175.3. HRMS Calcd for $C_9H_{17}NO_3S$: 219.0929. Found: 219.0927.

1-Ethylsulfenyl-7,8-dimethyl-4-phenyl-10-oxa-4,8-diazatricyclo[5.2.1.0]decane-3,5,9-trione (25). To a refluxing solution of 1.8 g (18 mmol) of acetic anhydride, 0.4 g (2.3 mmol) of *N*-phenylmaleimide, and 2 mg of *p*-toluenesulfonic acid in 35 mL of toluene was added dropwise 0.34 g (1.8 mmol) of acetamide **19** in 2 mL of toluene. After heating at reflux for 1 h, the mixture was concentrated under reduced pressure, and the residue was subjected to silica gel chromatography to give 0.52 g (85%) of **25** as a white solid: mp 212−213 °C; IR (CCl_4) 1709, 1396, 1196, 1004, and 755 cm^{-1}; ^{1}H NMR ($CDCl_3$, 300 MHz) δ 1.27 (t, 3H, J = 7.4 Hz), 1.80 (s, 3H), 2.80 (q, 2H, J = 7.4 Hz), 2.82 (s, 3H), 3.27 (d, 1H, J = 6.8 Hz), 3.38 (d, 1H, J = 6.8 Hz), 7.25 (m, 2H), and 7.39 (m, 3H); ^{13}C NMR ($CDCl_3$, 75 MHz) δ 14.4, 15.1, 23.9, 25.6, 49.7, 53.1, 94.5, 94.9, 126.2, 128.7, 128.9, 131.1, 169.3, 170.6, and 171.9. Anal. Calcd for $C_{17}H_{18}N_2O_4S$: C, 58.95; H, 5.24; N, 8.09. Found: C, 59.09; H, 5.26; N, 8.03.

***N*-Acetyl-2-ethylsulfonyl-*N*-phenylacetamide.** Following the general procedure, treatment of 2.0 g (15 mmol) of *N*-phenylacetamide with 2.9 g (21 mmol) of acid chloride **18** gave 3.2 g (92%) of *N*-acetyl-2-ethylsulfonyl-*N*-phenylacetamide as a clear oil: IR (neat) 1702, 1595, and 1489 cm^{-1}; ^{1}H NMR ($CDCl_3$, 300 MHz) δ 1.22 (t, 3H, J = 7.1 Hz), 2.16 (s, 3H), 2.58 (q, 2H, J = 7.1 Hz), 3.59 (s, 2H), 7.15 (d, 2H, J = 6.3 Hz), and 7.40−7.42 (m, 3H); ^{13}C NMR ($CDCl_3$, 75 MHz) δ 14.1, 26.0, 26.3, 37.0, 128.5, 128.7, 129.5, 138.7, 171.9, and 172.5. Anal. Calcd for $C_{12}H_{15}NO_2S$: C, 60.73; H, 6.37; N, 5.90. Found: C, 60.79; H, 6.83; N, 5.84.

***N*-Acetyl-2-ethanesulfinyl-*N*-phenylacetamide (26).** The reaction of 3.2 g (13.6 mmol) of the above sulfide with 5.2 g (24 mmol) of sodium periodate afforded 2.6 g (80%) of **26** as a colorless oil: IR (neat) 1704, 1592, 1492, and 1362 cm^{-1}; ^{1}H NMR ($CDCl_3$, 300 MHz) δ 1.17 (t, 3H, J = 7.3 Hz), 1.96 (s, 3H), 2.61−2.80 (m, 2H), 3.95 (d, 1H, J = 14.8 Hz), 4.15 (d, 1H, J = 14.8 Hz), 7.01−7.10 (m, 2H), and 7.23−7.42 (m, 3H); ^{13}C NMR ($CDCl_3$, 75 MHz) δ 6.1, 25.9, 45.7, 59.3, 128.2, 128.8, 129.5, 137.6, 167.4, and 172.4. Anal. Calcd for $C_{12}H_{15}NO_3S$: C, 56.90; H, 5.97; N, 5.53. Found: C, 56.75; H, 5.81; N, 5.50.

1-Ethylsulfenyl-7-methyl-4,8-diphenyl-10-oxa-4,8-diazatricyclo[5.2.1.0]decane-3,5,9-trione (27). To a refluxing solution of 1.1 g (10 mmol) of acetic anhydride, 0.19 g (1.1 mmol) of *N*-phenylmaleimide, and 2 mg of *p*-toluenesulfonic acid in 20 mL of toluene was added dropwise 0.24 g (1.0 mmol) of **26** in 1 mL of toluene. After heating at reflux for 1.5 h, the reaction mixture was concentrated under reduced pressure, and the residue was purified by silica gel chromatography to give 0.32 g (72%) of **27** as a white solid: mp 203−204 °C; IR (neat) 1712, 1591, 1493, 1372, and 1191 cm^{-1}; ^{1}H NMR ($CDCl_3$, 300 MHz) δ 1.31 (t, 3H, J = 7.6 Hz) 1.84 (s, 3H), 2.87 (q, 2H, J = 7.5 Hz), 3.47 (d, 1H, J = 6.7 Hz), 3.70 (d, 1H, J = 6.9 Hz), and 7.17−7.47 (m, 10H); ^{13}C NMR ($CDCl_3$, 75 MHz) δ 14.4, 16.4, 24.0, 49.5, 54.7, 94.7, 96.5, 125.4, 126.2, 127.9, 128.8, 128.9, 129.5, 131.1, 133.6, 168.1, 170.5, and 171.8. Anal. Calcd for $C_{22}H_{20}N_2O_4S$: C, 64.69; H, 4.94; N, 6.86. Found: C, 64.88; H, 5.00; N, 6.73.

4-Ethylsulfenyl-4,10*a*-epoxy-1,2-dimethyl-1,4,4*a*,10*a*-tetrahydro-2*H*-benzo[*g*]isoquinoline-3,5,10-trione (28). To a refluxing solution of 2.5 g (25 mmol) of acetic anhydride, 0.5 g (3.2 mmol) of 1,4-naphthoquinone, and 2 mg of *p*-toluenesulfonic acid in 40 mL of toluene was added dropwise 0.47 g (2.4 mmol) of acetamide **19** in 2 mL of toluene. After heating at reflux for 1 h, the reaction mixture was concentrated under reduced pressure, and the residue was subjected to silica gel chromatography to furnish **28** (73%) as a white solid: mp 191−192 °C; IR (CCl_4) 1725, 1682, 1590, 1405, and 1259 cm^{-1}; ^{1}H NMR ($CDCl_3$, 300 MHz) δ 1.22 (t, 3H, J = 7.5 Hz), 1.64 (s, 3H), 2.75 (m, 2H), 2.90 (s, 3H), 3.38 (s, 2H), 7.78 (m, 2H), 7.97 (m, 1H), and 8.04 (m, 1H); ^{13}C NMR ($CDCl_3$, 75 MHz) δ 14.2, 16.4, 24.4, 25.7, 54.3, 57.6, 95.7, 96.3, 126.6, 127.3, 134.6, 135.0, 135.4, 136.5, 169.7, 191.2, and 192.8. Anal. Calcd for $C_{17}H_{17}NO_4S$: C, 61.62; H, 5.17; N, 4.23. Found: C, 61.63; H, 5.22; N, 4.19.

5-Ethylsulfenyl-2-methylfuran-3-carboxylic Acid Methyl Ester (29). To a refluxing solution of 3.0 g (30 mmol) of acetic anhydride, 0.35 g (4.2 mmol) of methyl propiolate, and 2 mg of *p*-toluenesulfonic acid in 40 mL of toluene was added dropwise 0.57 g (3.0 mmol) of acetamide **19** in 2 mL of toluene. After heating at reflux for 1 h, the reaction mixture was concentrated under reduced pressure, and the residue was subjected to silica gel chromatography to give 0.09 g (15%) of **29** as a pale yellow oil: IR (neat) 1716, 1595, 1438, 1218, and 1111 cm^{-1}; ^{1}H NMR ($CDCl_3$, 300 MHz) δ 1.26 (t, 3H, J = 7.4 Hz), 2.58 (s, 3H), 2.76 (q, 2H, J = 7.4 Hz), 3.82 (s, 3H), and 6.75 (s, 1H); ^{13}C NMR ($CDCl_3$, 75 MHz) δ 14.0, 14.9, 30.0, 51.3, 114.8, 117.8, 144.1, 161.9, and 163.8. Anal. Calcd for $C_9H_{12}O_3S$: C, 53.09; H, 6.05. Found: C, 52.94; H, 5.91.

2-Ethylsulfenyl-5-methylfuran-3,4-dicarboxylic Acid Dimethyl Ester (30). To a refluxing solution of 2.5 g (25 mmol) of acetic anhydride, 0.45 g (3.2 mmol) of dimethyl acetylenedicarboxylate (DMAD), and 2 mg of *p*-toluenesulfonic acid was added dropwise 0.47 g (2.5 mmol) of acetamide **19** in 2 mL of toluene. After heating at reflux for 1 h, the reaction mixture was concentrated under reduced pressure, and the residue was subjected to silica gel chromatography to give 0.26 g (41%) of **30** as a pale yellow oil: IR (neat) 1723, 1438, 1296, and 1211 cm^{-1}; ^{1}H NMR ($CDCl_3$, 300 MHz) δ 1.30 (t, 3H, J = 7.4 Hz), 2.53 (s, 3H), 2.95 (q, 2H, J = 7.4 Hz), 3.83 (s, 3H), and 3.86 (s, 3H); ^{13}C NMR ($CDCl_3$, 75 MHz) δ 13.1, 14.6, 27.9, 51.2, 51.5, 113.7, 119.9, 148.5, 159.0, 162.4, and 162.9. Anal. Calcd for $C_{11}H_{14}O_5S$: C, 51.15; H, 5.47. Found: C, 51.03; H, 5.42.

6-Benzenesulfonyl-4-ethylsulfenyl-1,2-dimethyl-7-oxa-2-azabicyclo[2.2.1]heptan-3-one (31). To a refluxing solution of 2.3 g (22 mmol) of acetic anhydride, 0.48 g (2.8 mmol) of phenyl vinyl sulfone, and 2 mg of *p*-toluenesulfonic acid in 35 mL of toluene was added dropwise 0.42 g (2.2 mmol) of acetamide **19** in 2 mL of toluene. After heating at reflux for 1 h, the reaction mixture was concentrated under reduced pressure, and the residue was subjected to silica gel chromatography. The first product (0.28 g (38%)) eluted from the column was the major diastereomer **31a** as a clear oil: IR (neat) 2939, 1723, 1396, 1310, and 1146 cm^{-1}; ^{1}H NMR ($CDCl_3$, 300 MHz) δ 1.25 (t, 3H, J = 7.5 Hz), 1.98 (s, 3H), 2.16 (dd, 1H, J = 12.7 and 9.7 Hz), 2.29 (dd, 1H, J = 12.7 and 4.9 Hz), 2.43 (dd, 1H, J = 9.7 and 4.9 Hz), 2.82 (m, 2H), 3.10 (s, 3H), 7.53 (m, 3H), and 7.87 (m, 2H); ^{13}C NMR ($CDCl_3$, 75 MHz) δ 14.9, 17.8, 23.9, 27.0, 35.4, 69.6, 93.1, 94.4, 127.7, 129.2, 129.5, 134.2, 139.6, and 169.2. Anal. Calcd for $C_{15}H_{19}NO_4S_2$: C, 52.77; H, 5.61; N, 4.11. Found: C, 52.62; H, 5.70; N, 4.08.

The second product isolated from the column contained 0.15 g (19%) of the minor diastereomer **31b**: IR (neat) 2950, 1720, 1396, 1316, and 1150 cm^{-1}; ^{1}H NMR ($CDCl_3$, 300 MHz) δ 1.28 (t, 3H, J = 7.4 Hz), 1.93 (dd, 1H, J = 13.0 and 8.4 Hz), 2.04 (s, 3H), 2.19 (dd, 1H, J = 13.0 and 5.0 Hz), 2.70 (m, 5H), 3.50 (dd, 1H, J = 13.0 and 5.0 Hz), 7.50 (m, 3H), and 7.81 (m, 2H); ^{13}C NMR ($CDCl_3$, 75 MHz) δ 14.7, 16.6, 23.9, 25.0, 36.0, 67.1, 92.0, 95.1, 128.2, 129.4, 134.1, 138.5, and 170.8. Anal. Calcd for $C_{15}H_{19}NO_4S_2$: C, 52.77; H, 5.61; N, 4.11. Found: C, 52.69; H, 5.78; N, 4.21.

The third product eluted from the column contained 0.13 g (20%) of 5-benzenesulfonyl-1,6-dimethyl-2-oxo-1,2-dihydropyridin-3-yl acetic acid ester (**32**) as a white solid: mp 167−168 °C; IR (CCl_4) 1773, 1673, 1303, and 1189 cm^{-1}; ^1H NMR ($CDCl_3$, 300 MHz) δ 2.33 (s, 3H), 2.57 (s, 3H), 3.53 (s, 3H), 7.57 (m, 3H), 7.83 (m, 2H), and 7.91 (s, 1H); ^{13}C NMR ($CDCl_3$, 75 MHz) δ 17.7, 20.3, 32.2, 117.5, 126.8, 127.3, 129.3, 133.3, 137.5, 141.5, 149.0, 157.6, and 168.0. Anal. Calcd for $C_{15}H_{15}NO_5S$: C, 56.07; H, 4.71; N, 4.36. Found: C, 56.06; H, 4.76; N, 4.36.

4-Methyl-1,3,6-trioxo-2,5-diphenyl-2,3,5,6-tetrahydro-1*H*-pyrrolo[3,4-*c*]pyridin-7-yl Acetic Acid Ester (33). To a stirred solution containing 0.19 g (0.5 mmol) of cycloadduct **27** in 20 mL of CH_2Cl_2 was added 0.3 g (2.4 mmol) of boron trifluoride etherate. The resulting mixture was heated at reflux for 4 h, quenched with water, and extracted with $CHCl_3$. The combined extracts were dried over $MgSO_4$ and concentrated under reduced pressure. The mixture was dissolved in 20 mL of benzene and 1.3 mL (9.6 mmol) of triethylamine, and 2.2 g (21 mmol) of acetic anhydride was added. The resulting mixture was heated at reflux for 45 min. The cooled mixture was diluted with brine and extracted with $CHCl_3$. The mixture was dried over $MgSO_4$ and concentrated under reduced pressure, and the residue was subjected to silica gel chromatography. The major product obtained from the column contained 0.14 g (80%) of **33** as a white solid: mp 279−281 °C; IR (neat) 1787, 1709, 1676, 1487, and 1149 cm^{-1}; ^1H NMR ($CDCl_3$, 300 MHz) δ 2.40 (s, 3H), 2.46 (s, 3H), and 7.20−7.68 (m, 10H); ^{13}C NMR ($CDCl_3$, 75 MHz) δ 16.9, 20.3, 126.5, 127.5, 128.6, 129.1, 129.9, 130.3, 131.2, 136.5, 148.6, 158.3, 159.6, 162.5, 164.8, 166.4, and 167.7. Anal. Calcd for $C_{22}H_{16}N_2O_5$: C, 68.02; H, 4.15; N, 7.22. Found: C, 67.96; H, 4.12; N, 7.08.

The minor product eluted from the column contained 0.03 g (16%) of 7-ethylsulfenyl-4-methyl-2,5-diphenyl-5*H*-pyrrolo[3,4-*c*]pyridine-1,3,6-trione (**34**) as a white solid: mp 254−255 °C; IR (neat) 1707, 1664, 1491, and 1379 cm^{-1}; ^1H NMR ($CDCl_3$, 300 MHz) δ 1.28 (t, 3H, J = 4.0 Hz), 2.42 (s, 3H), 3.36 (t, 2H, J = 5.9 Hz), and 7.17−7.60 (m, 10H); ^{13}C NMR ($CDCl_3$, 75 MHz) δ 15.4, 16.8, 27.4, 119.6, 125.5, 126.6, 127.6, 128.3, 129.0, 129.1, 129.7, 130.2, 134.6, 139.5, 147.7, 162.1, 165.0, and 169.4. Anal. Calcd for $C_{22}H_{18}N_2O_3S$: C, 67.67; H, 4.65; N, 7.18. Found: C, 67.54; H, 4.62; N, 7.05.

1-Ethylsulfenylacetylpyrrolidin-2-one. Following the general procedure, treatment of 1.3 g (15 mmol) of 2-pyrrolidinone with 2.7 g (20 mmol) of acid chloride **18** afforded 2.9 g (99%) of 1-ethylsulfenylacetylpyrrolidin-2-one as a colorless oil: IR (neat) 1734, 1682, and 1312 cm^{-1}; ^1H NMR ($CDCl_3$, 300 MHz) δ 1.27 (t, 3H, J = 7.6 Hz), 2.09 (q, 2H, J = 7.6 Hz), 2.62 (m, 4H), 3.83 (s, 2H), and 3.84 (m, 2H); ^{13}C NMR ($CDCl_3$, 75 MHz) δ 14.2, 16.9, 25.9, 33.3, 35.2, 45.4, 170.0, and 175.0. HRMS Calcd for $C_8H_{13}NO_2S$: 187.0667. Found: 187.0665.

1-Ethanesulfinylacetylpyrrolidin-2-one (35). The reaction of 2.8 g (15.3 mmol) of the above sulfide with 3.6 g (17 mmol) of sodium periodate gave 2.6 g (83%) of **35** as a colorless oil: IR (neat) 1735, 1682, 1327, and 1048 cm^{-1}; ^1H NMR ($CDCl_3$, 300 MHz) δ 1.38 (t, 3H, J = 7.4 Hz), 2.10 (m, 2H), 2.65 (t, 2H, J = 8.1 Hz), 2.91 (m, 2H), 3.87 (t, 2H, J = 7.2 Hz), 4.23 (d, 1H, J = 14.0 Hz), and 4.41 (d, 1H, J = 14.0 Hz); ^{13}C NMR ($CDCl_3$, 75 MHz) δ 6.4, 16.9, 33.0, 45.2, 46.2, 57.6, 165.1, and 175.6. Anal. Calcd for $C_8H_{13}NO_3S$: C, 47.28; H, 6.45; N, 6.90. Found: C, 47.19; H, 6.39; N, 6.87.

1-Ethylsulfenyl-2-oxo-2-(2-oxo-pyrrolidin-1-yl)ethyl Acetic Acid Ester (36). To a refluxing solution of 2.2 g (22 mmol) of acetic anhydride and 2 mg of *p*-toluenesulfonic acid in 15 mL of toluene was added dropwise 0.44 g (2.2 mmol) of pyrrolidinone **35** in 2 mL of toluene. After heating at reflux for 1 h, the reaction mixture was concentrated under reduced pressure, and the residue was subjected to silica gel chromatography to give 0.4 g (73%) of **36** as a colorless oil: IR (neat) 1742, 1697, 1357, and 1214 cm^{-1}; ^1H NMR (CDCl, 300 MHz) δ 1.28 (t, 3H, J = 7.5 Hz), 2.11 (m, 2H), 2.17 (s, 3H), 2.70 (m, 3H), 3.85 (m, 3H), and 7.01 (s, 1H); ^{13}H NMR ($CDCl_3$, 75 MHz) δ 14.5, 17.2, 20.5, 24.1, 33.2, 45.4, 74.9, 166.5, 170.2, and 174.7. Anal. Calcd for $C_{10}H_{15}NO_4S$: C, 48.97; H, 6.17; N, 5.71. Found: C, 48.82; H, 6.15; N, 5.68.

1-Ethanesulfinylacetylpiperidin-2-one (37). Following the general procedure, the reaction of 3.0 g (30 mmol) of δ-valerolactam with 5.5 g (39 mmol) of acid chloride **18** afforded 5.9 g (97%) of 1-ethylsulfenylacetylpiperidin-2-one as a colorless liquid: bp 145−147 °C (0.7 mm); IR (neat) 2954, 1687, 1381, 1289, and 1154 cm^{-1}; ^1H NMR ($CDCl_3$, 300 MHz) δ 1.26 (t, 3H, J = 7.4 Hz), 1.86 (m, 4H), 2.59 (m, 4H), 3.76 (m, 2H), and 3.89 (s, 2H); ^{13}C NMR ($CDCl_3$, 75 MHz) δ 14.2, 19.9, 22.0, 25.9, 34.4, 38.5, 44.0, 172.6, and 172.9.

Treatment of 6.4 g (32 mmol) of the above sulfide with 7.5 g (35 mmol) of sodium periodate gave 6.1 g (88%) of **37** as a colorless oil: IR (neat) 1680, 1296, 1154, and 1047 cm^{-1}; ^1H NMR ($CDCl_3$, 300 MHz) δ 1.38 (t, 3H, J = 7.5 Hz), 1.88 (m, 4H), 2.58 (m, 2H), 2.88 (m, 2H), 3.79 (m, 2H), 4.19 (d, 1H, J = 14.9 Hz), and 4.42 (d, 1H, J = 14.9 Hz); ^{13}C NMR ($CDCl_3$, 75 MHz) δ 6.5, 20.0, 22.0, 34.5, 44.3, 46.1, 61.3, 168.2, and 173.6. Anal. Calcd for $C_9H_{15}NO_3S$: C, 49.75; H, 6.96; N, 6.45. Found: C, 49.61; H, 6.85; N, 6.61.

4-Ethylsulfenyl-4-10*a*-epoxy-2,3,3*a*,4,7,8,9,10,10*a*,10*b*-decahydro-1,3,5-trioxo-2-phenyl-1*H*-pyrrolo[3,4-*a*]-4*H*-quinolizine (39). To a refluxing solution of 2.4 g (24 mmol) of acetic anhydride, 0.53 g (3.1 mmol) of *N*-phenylmaleimide, and 2 mg of *p*-toluenesulfonic acid in 35 mL of toluene was added dropwise 0.52 g (2.4 mmol) of imide **37** in 2 mL of toluene. After heating at reflux for 1 h, the reaction mixture was concentrated under reduced pressure, and the residue was subjected to silica gel chromatography to give 0.66 g (75%) of **39** as a white solid: mp 222−223 °C; IR (CCl_4) 2947, 2868, 1701, 1381, and 1182 cm^{-1}; ^1H NMR ($CDCl_3$, 300 MHz) δ 1.30 (t, 3H, J = 7.5 Hz), 1.64 (m, 2H), 1.88 (m, 2H), 2.06 (m, 1H), 2.58 (d, 1H, J = 13.0 Hz), 2.81 (m, 3H), 3.30 (d, 1H, J = 6.8 Hz), 3.55 (d, 1H, J = 6.8 Hz), 3.89 (d, 1H, J = 13.0 Hz), 7.27 (m, 2H), and 7.38 (m, 3H); ^{13}C NMR ($CDCl_3$, 75 MHz) δ 14.6, 20.2, 23.0, 24.2, 25.8, 39.7, 49.6, 50.7, 93.8, 94.7, 126.3, 128.8, 129.0, 131.3, 168.9, 170.6, and 172.0. Anal. Calcd for $C_{19}H_{20}N_2O_4S$: C, 61.27; H, 5.42; N, 7.53. Found: C, 60.99; H, 5.37; N, 7.46.

4-Ethylsulfenyl-4-10*a*-epoxy-2,3,3*a*,4,7,8,9,10,10*a*,10*b*-decahydro-1,3,5-trioxo-2-oxo-4*H*-quinolizine (40). To a refluxing solution of 2.1 g (21 mmol) of acetic anhydride, 0.27 g (2.6 mmol) of maleic anhydride, and 2 mg of *p*-toluenesulfonic acid in 35 mL of toluene was added dropwise 0.45 g (2.1 mmol) of imide **37** in 2 mL of toluene. After heating at reflux for 1 h, the reaction mixture was concentrated under reduced pressure, and the residue was taken up in 50 mL of chloroform, washed with a saturated $NaCO_3$ solution, and dried over $MgSO_4$. The solvent was removed under reduced pressure, and the product was filtered through a short plug of florsil to give 0.43 g (69%) of **40** as a light yellow oil: IR (CCl_4) 1865, 1780, 1730, and 1082 cm^{-1}; ^1H NMR ($CDCl_3$, 300 MHz) δ 1.30 (t, 3H, J = 7.5 Hz), 1.63 (m, 2H), 1.99 (m, 2H), 2.14 (m, 1H), 2.52 (d, 1H, J = 12.8 Hz), 2.79 (m, 3H), 3.51 (d, 1H, J = 7.1 Hz), 3.77 (d, 1H, J = 7.1 Hz), and 3.86 (m, 1H); ^{13}C NMR ($CDCl_3$, 75 MHz) δ 14.7, 20.0, 22.8, 24.4, 25.6, 39.9, 51.0, 52.2, 94.3, 95.0, 165.7, 167.0, and 168.1; HRMS Calcd for $C_{13}H_{15}NO_5S$: 297.0671. Found: 297.0670.

1-Ethylsulfenylacetylazepan-2-one. Following the general procedure, treatment of 1.0 g (8.8 mmol) of ϵ-caprolactam with 1.6 g (12 mmol) of acid chloride **18** gave 1.9 g (99%) of 1-ethylsulfenylacetylazepan-2-one as a clear oil: IR (neat) 1687, 1381, 1267, and 1147 cm^{-1}; ^1H NMR ($CDCl_3$, 300 MHz) δ 1.26 (t, 3H, J = 7.3 Hz), 1.75 (m, 6H), 2.58 (q, 2H, J = 7.3 Hz), 2.74 (m, 2H), 3.88 (s, 2H), and 3.91 (m, 2H); ^{13}C NMR ($CDCl_3$, 75 MHz) δ 14.3, 23.2, 26.0, 28.2, 29.0, 38.0, 39.5, 43.4, 172.1, and 177.4. Anal. Calcd for $C_{10}H_{17}NO_2S$: C, 55.79; H, 7.97; N, 6.51. Found: C, 55.65; H, 7.91; N, 6.47.

1-Ethylsulfinylacetylazepan-2-one (38). The reaction of 1.9 g (8.6 mmol) of the above sulfide with 2.0 g (9.5 mmol) of sodium periodate gave 1.9 g (94%) of **38** as a colorless oil: IR (neat) 1694, 1680, 1381, 1147, and 1047 cm^{-1}; ^1H NMR ($CDCl_3$, 300 MHz) δ 1.38 (t, 3H, J = 7.6 Hz), 1.77 (m, 6H), 2.76 (m, 2H), 2.89 (m, 2H), 3.95 (m, 2H), 4.16 (d, 1H, J = 14.7 Hz), and 4.42 (d, 1H, J = 14.7 Hz); ^{13}C NMR ($CDCl_3$, 75 MHz) δ 6.3, 23.1, 28.1, 28.7, 39.0, 43.2, 45.9, 60.7, 167.3, and 177.7. Anal.

Calcd for $C_{10}H_{17}NO_3S$: C, 51.93; H, 7.41; N, 6.06. Found: C, 51.82; H, 7.41; N, 5.87.

4-Ethanesulfenyl-4,11*a*-epoxy-1,2,2*a*,4,5,7,8,9,10,11,11*a*,-11*b*-dodecahydro-1,3,5-trioxo-2-phenyl-1*H*-pyrrolo[3,5-*a*]-pyrido[1,2-*a*]azepine (41). To a refluxing solution of 3.6 g (35 mmol) of acetic anhydride, 0.85 g of *N*-phenylmaleimide, and 2 mg of *p*-toluenesulfonic acid in 35 mL of toluene was added dropwise 0.81 g (3.5 mmol) of azepan-2-one **38** in 2 mL of toluene. After heating at reflux for 1 h, the reaction mixture was concentrated under reduced pressure, and the residue was subjected to silica gel chromatography to give 1.1 g (79%) of **41** as a 1:1 mixture of diastereomers, which were easily separated by silica gel chromatography.

One of the diastereomers (**41a**) exhibited the following spectral properties: mp 164−165 °C; IR (CCl_4) 1723, 1417, 1381, and 1182 cm^{-1}; ^1H NMR ($CDCl_3$, 300 MHz) δ 1.25 (m, 2H), 1.33 (t, 3H, J = 7.5 Hz), 1.59 (m, 1H), 1.78 (m, 3H), 2.41 (m, 2H), 2.60 (m, 1H), 2.92 (m, 2H), 3.64 (q, 2H, J = 7.5 Hz), 4.00 (d, 1H, J = 13.8 Hz), 7.09 (d, 2H, J = 6.5 Hz), and 7.38 (m, 3H); ^{13}C NMR ($CDCl_3$, 75 MHz) δ 14.9, 23.2, 24.1, 29.6, 30.7, 32.7, 41.2, 51.2, 55.1, 94.8, 97.2, 126.4, 128.7, 129.0, 130.9, 166.4, 170.2, and 171.0. Anal. Calcd for $C_{20}H_{22}N_2O_4S$: C, 62.16; H, 5.74; N, 7.25. Found: C, 62.25; H, 5.73; N, 7.26.

The second diastereomer (**41b**) exhibited the following spectral properties: mp 198−199 °C; IR (CCl_4) 1716, 1388, 1196, and 748 cm^{-1}; ^1H NMR ($CDCl_3$, 300 MHz) δ 1.29 (t, 3H, J = 7.6 Hz), 1.40 (m, 2H), 1.63 (m, 1H), 1.95 (m, 3H), 2.25 (m, 1H), 2.41 (m, 1H), 2.85 (m, 3H), 3.36 (q, 2H, J = 7.6 Hz), 3.93 (d, 1H, J = 14.0 Hz), 7.26 (d, 2H, J = 8.0 Hz), and 7.43 (m, 3H); ^{13}C NMR ($CDCl_3$, 75 MHz) δ 14.7, 23.0, 24.0, 29.9, 30.2, 31.2, 40.4, 49.6, 54.6, 94.4, 97.9, 126.2, 128.7, 128.9, 131.2, 168.1, 170.7, and 171.8. Anal. Calcd for $C_{20}H_{22}N_2O_4S$: C, 62.16; H, 5.74; N, 7.25. Found: C, 61.95; H, 5.71; 7.14.

1,3,5-Trioxo-2-phenyl-1,2,3,5,7,8,9,10-octahydropyrrolo-[3,4-*a*]quinolizin-4-yl Acetic Acid Ester (42). To a stirred solution containing 0.53 g (1.4 mmol) of cycloadduct **39** in 35 mL of CH_2Cl_2 was added 0.9 g (6.4 mmol) of boron trifluoride etherate. The resulting mixture was stirred at room temperature for 3 h, quenched with water, and extracted with CH_2Cl_2. The combined organic extracts were dried over $MgSO_4$ and concentrated under reduced pressure. The crude residue was dissolved in 35 mL of benzene, and 0.72 g (7 mmol) of acetic anhydride was added. The resulting mixture was heated at reflux for 1 h, concentrated under reduced pressure, and subjected to silica gel chromatography to give 0.49 g (98%) of **42** as a bright yellow solid: mp 198−199 °C; IR (CCl_4) 1780, 1719, 1667, and 1365 cm^{-1}; ^1H NMR ($CDCl_3$, 300 MHz) δ 1.92 (m, 2H), 2.03 (m, 2H), 2.42 (s, 3H), 3.39 (m, 2H), 4.04 (m, 2H), 7.37 (m, 3H), and 7.45 (m, 2H); ^{13}C NMR ($CDCl_3$, 75 MHz) δ 17.2, 20.3, 21.6, 25.4, 43.9, 102.3, 126.4, 127.1, 128.3, 128.9, 131.1, 132.9, 149.5, 159.1, 162.6, 164.6, and 167.8. Anal. Calcd for $C_{19}H_{16}N_2O_5$: C, 64.77; H, 4.58; N, 7.95. Found: C, 64.74; H, 4.59; N, 7.87.

1-Ethylsulfenylacetyl-3-methyl-3-buten-3-enylpiperidin-2-one. Following the general procedure, treatment of 1.0 g (6 mmol) of 3-buten-3-enyl-3-methylpiperidin-2-one[46] with 1.1 g (8 mmol) of acid chloride **18** gave 1.6 g (96%) of 1-ethylsulfenylacetyl-3-methyl-3-buten-3-enylpiperidin-2-one as a pale yellow oil: IR (neat) 1680, 1388, 1289, and 1139 cm^{-1}; ^1H NMR ($CDCl_3$, 300 MHz) δ 1.25 (t, 3H, J = 7.4 Hz), 1.27 (s, 3H), 1.64 (m, 2H), 1.86 (m, 4H), 2.07 (m, 2H), 2.59 (q, 2H, J = 7.4 Hz), 3.70 (m, 1H), 3.85 (s, 2H), 3.87 (m, 1H), 5.00 (m, 2H), and 5.79 (m, 1H); ^{13}C NMR ($CDCl_3$, 75 MHz) δ 14.4, 19.4, 25.8, 26.4, 28.4, 33.0, 38.5, 39.1, 44.5, 45.9, 114.7, 138.0, 173.8, and 179.1. HRMS Calcd for $C_{14}H_{23}NO_2S$: 269.1449. Found: 269.1446.

1-Ethanesulfinylacetyl-3-methyl-3-buten-3-enylpiperidin-2-one (43). Treatment of 1.5 g (5.4 mmol) of the above sulfide with 1.3 g (6 mmol) of sodium periodate afforded 1.4 g (88%) of **43** as an inseparable mixture of diastereomers; IR (neat) 1687, 1388, 1296, 1146, and 1047 cm^{-1}; ^1H NMR ($CDCl_3$, 300 MHz) δ 1.27 (s, 3H), 1.38 (t, 3H, J = 7.5 Hz), 1.65 (m, 2H), 1.88 (m, 4H), 2.05 (m, 2H), 2.88 (m, 2H), 3.67 (m, 1H), 3.86 (m, 1H), 4.11 (m, 1H), 4.36 (m, 1H), 5.00 (m, 2H), and 5.79 (m, 1H); ^{13}C NMR ($CDCl_3$, 75 MHz) δ 6.4, 18.9, 19.0, 25.5, 25.8, 28.2, 32.4, 38.6, 38.8, 44.3, 45.7, 46.1, 46.2, 61.4, 114.8, 114.9, 137.6, 137.7, 168.8, and 179.5. Anal. Calcd for $C_{14}H_{23}NO_3S$: C, 58.92; H, 8.13; N, 4.91. Found: C, 58.76; H, 8.05; N, 4.90.

8*a*-Methyl-5-oxo-1,2,6,7,8,8*a*-hexahydro-5*H*-5*a*-azaacenaphthylen-4-yl Acetic Acid Ester (44). To a refluxing solution of 1.8 g (18 mmol) of acetic anhydride and 2 mg of *p*-toluenesulfonic acid in 40 mL of toluene was added 0.5 g (1.8 mmol) of piperidinone **43** in 2 mL of toluene. After heating for 1 h at reflux, the reaction mixture was concentrated under reduced pressure, and the residue was subjected to silica gel chromatography. The major product isolated from the column (80%) was identified as pyridone **44**: mp 81−82 °C; IR (CCl_4) 1766, 1659, 1602, 1552, and 1196 cm^{-1}; ^1H NMR ($CDCl_3$, 300 MHz) δ 1.78 (s, 3H), 1.54 (dt, 1H, J = 12.0 and 5.0 Hz), 1.92 (m, 2H), 2.11 (m, 3H), 2.32 (s, 3H), 2.53 (dd, 1H, J = 14.9 and 8.3 Hz), 2.83 (m, 1H), 3.88 (m, 1H), 4.04 (m, 1H), and 7.10 (s, 1H); ^{13}C NMR ($CDCl_3$, 75 MHz) δ 19.2, 20.7, 23.2, 26.8, 32.2, 41.1, 41.4, 42.3, 113.8, 127.2, 138.4, 150.8, 157.4, and 169.0. Anal. Calcd for $C_{14}H_{17}NO_3$: C, 68.00; H, 6.93; N, 5.66. Found: C, 67.99; H, 6.89; N, 5.67.

1-Ethylsulfenylacetyl-3-methyl-3-pent-4-enylpiperidin-2-one. Following the general procedure, the reaction of 0.8 g (4.4 mmol) of 4-pent-4-enyl-3-methylpiperidin-2-one[46] with 0.8 g (5.7 mmol) of acid chloride **18** gave 1.2 g (94%) of 1-ethylsulfenylacetyl-3-methyl-3-pent-4-enylpiperidin-2-one as a clear oil: IR (neat) 1680, 1381, 1296, and 1139 cm^{-1}; ^1H NMR ($CDCl_3$, 300 MHz) δ 1.25 (t, 3H, J = 7.4 Hz), 1.29−1.63 (m, 9H), 1.80 (m, 3H), 2.05 (m, 2H), 2.59 (q, 2H, J = 7.4 Hz), 3.70 (m, 1H), 3.85 (s, 2H), 4.99 (m, 2H), and 5.79 (m, 1H); ^{13}C NMR ($CDCl_3$, 75 MHz) δ 14.4, 19.4, 23.3, 25.7, 26.3, 33.0, 33.9, 38.5, 39.4, 44.6, 45.8, 114.8, 138.2, 173.8, and 179.3. HRMS Calcd for $C_{15}H_{25}NO_2S$: 283.1606. Found: 283.1600.

1-Ethanesulfinylacetyl-3-methyl-3-pent-4-enylpiperidin-2-one (45). The reaction of 1.1 g (3.8 mmol) of the above sulfide with 0.9 g (4.2 mmol) of sodium periodate afforded 0.82 g (73%) of **45** as an inseparable mixture of diastereomers: IR (neat) 1687, 1296, 1146, and 1047 cm^{-1}; ^1H NMR ($CDCl_3$, 300 MHz) δ 1.25 (s, 3H), 1.28−1.67 (m, 8H), 1.85 (m, 3H), 2.10 (m, 2H), 2.87 (m, 2H), 3.63 (m, 1H), 3.84 (m, 1H), 4.11 (m, 1H), 4.35 (m, 1H), 5.00 (m, 2H), and 5.78 (m, 1H); ^{13}C NMR ($CDCl_3$, 75 MHz) δ 6.51, 19.0, 19.1, 23.2, 23.3, 25.5, 25.8, 32.6, 32.7, 33.8, 33.9, 39.1, 39.2, 44.5, 45.7, 45.8, 46.1, 46.2, 61.5, 114.9, 115.0, 137.9, 138.0, 168.9, 179.8, and 179.9. Anal. Calcd for $C_{15}H_{25}NO_3S$: C, 60.17; H, 8.42; N, 4.68. Found: C, 60.04; H, 8.35; N, 4.51.

Cycloadduct 46. To a refluxing solution of 1.5 g (15 mmol) of acetic anhydride and 2 mg of *p*-toluenesulfonic acid in 40 mL of toluene was added dropwise 0.44 g (1.5 mmol) of imidosulfoxide **45** in 2 mL of toluene. After heating at reflux for 1 h, the reaction mixture was concentrated under reduced pressure, and the residue was chromatographed on silica gel to give 0.3 g (73%) of cycloadduct **46** as a colorless solid: mp 80−81 °C; IR (CCl_4) 1719, 1444, and 1395 cm^{-1}; ^1H NMR ($CDCl_3$, 300 MHz) δ 1.11 (s, 3H), 1.31 (m, 5H), 1.48 (m, 4H), 1.66 (m, 2H), 1.93 (m, 4H), 2.14 (m, 1H), 2.70 (m, 2H), 2.90 (m, 1H), and 3.79 (m, 1H); ^{13}C NMR ($CDCl_3$, 75 MHz) δ 15.1, 19.0, 19.9, 22.4, 24.3, 32.1, 32.2, 33.1, 36.7, 38.3, 38.8, 40.0, 92.6, 95.6, and 171.6. Anal. Calcd for $C_{15}H_{23}NO_2S$: C, 64.02; H, 8.24; N, 4.98. Found: C, 64.07; H, 8.23; N, 4.88.

***N*-Acetyl-*N*-(2-allylphenyl)-2-ethylsulfenylacetamide.** Following the general procedure, treatment of 0.45 g (2.6 mmol) of *N*-(2-allylphenyl)acetamide[47] with 0.47 g (3.4 mmol) of acid chloride **18** gave 0.5 g (70%) of *N*-acetyl-*N*-(2-allylphenyl)-2-ethylsulfenylacetamide as a pale yellow oil: IR (neat) 1713, 1490, 1367, and 1253 cm^{-1}; ^1H NMR ($CDCl_3$, 300

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(46) Hertzog, D. L.; Nadler, W. R.; Zhang, Z. J.; Padwa, A. *Tetrahedron Lett.* **1992**, *33*, 7159.

(47) Padwa, A.; Austin, D. J.; Price, A. T. *Tetrahedron Lett.* **1994**, *35*, 7159.

MHz) δ 1.26 (t, 3H, J = 7.4 Hz), 2.16 (s, 3H), 2.62 (q, 2H, J = 7.4 Hz), 3.27 (d, 2H, J = 6.6 Hz), 3.60 (d, 1H, J = 14.2 Hz), 3.67 (d, 1H, J = 14.2 Hz), 5.13 (m, 2H), 5.85 (m, 1H), 7.12 (d, 1H, J = 7.4 Hz), and 7.34 (m, 3H); ^{13}C NMR ($CDCl_3$, 75 MHz) δ 14.2, 26.2, 26.6, 35.4, 37.4, 117.2, 127.8, 129.1, 129.4, 130.6, 135.2, 137.4, 137.9, 171.8, and 172.7. HRMS Calcd for $C_{15}H_{19}NO_2S$: 277.1136. Found: 277.1134.

***N*-Acetyl-*N*-(2-allylphenyl)-2-ethanesulfinylacetamide (47).** The reaction of 0.45 g (1.6 mmol) of the above sulfide with 0.38 g (1.8 mmol) of sodium periodate gave 0.4 g (84%) of acetamide **47** as a clear oil: IR (neat) 1713, 1367, 1258, and 1020 cm^{-1}; ^{1}H NMR ($CDCl_3$, 300 MHz) δ 1.36 (t, 3H, J = 7.4 Hz), 2.11 (s, 3H), 2.88 (m, 2H), 3.29 (m, 2H), 4.08 (m, 1H), 4.28 (m, 1H), 5.12 (m, 2H), 5.83 (m, 1H), 7.12 (m, 1H), and 7.36 (m, 3H); ^{13}C NMR ($CDCl_3$, 75 MHz) δ 6.4, 26.2, 35.6, 46.3, 59.8, 117.2, 127.9, 128.9, 129.6, 130.7, 134.8, 136.6, 137.5, 167.5, and 172.8. Anal. Calcd for $C_{15}H_{19}NO_3S$: C, 61.41; H, 6.53; N, 4.78. Found: C, 61.29; H, 6.44; N, 4.61.

3-Ethylsulfenyl-12-oxa-2-oxo-11-phenyl-3,4,5,6-tetrahydro-2*H*-1,5-methanobenzo[*b*]azocine (48). To a refluxing solution of 0.6 g (6 mmol) of acetic anhydride and 2 mg of *p*-toluenesulfonic acid in 35 mL of toluene was added 0.2 g (0.6 mmol) of amide **47** in 2 mL of toluene. After heating for 1 h at reflux, the reaction mixture was concentrated under reduced pressure, and the residue was subjected to silica gel chromatography to give 0.15 g (83%) of azocine **48** as a colorless solid: mp 129−130 °C; IR (CCl_4) 2933, 1751, 1490, 1390, 1312, and 1062 cm^{-1}; ^{1}H NMR ($CDCl_3$, 300 MHz) δ 1.36 (t, 3H, J = 7.5 Hz), 1.52 (d, 1H, J = 4.4 Hz), 1.56 (s, 3H), 2.45 (dd, 1H, J = 13.0 and 10.4 Hz), 2.73 (m, 1H), 2.92 (m, 3H), 3.16 (dd, 1H, J = 18.7 and 8.0 Hz), 7.23 (m, 4H); ^{13}C NMR ($CDCl_3$, 75 MHz) δ 15.2, 17.2, 24.3, 28.1, 40.9, 41.6, 92.6, 92.8, 126.2, 127.0, 128.8, 137.4, and 175.6. Anal. Calcd for $C_{15}H_{17}NO_2S$: C, 65.43; H, 6.22; N, 5.09. Found: C, 65.32; H, 6.27; N, 5.10.

***N*-[(But-3-enylsulfenyl)acetyl]-*N*-methylacetamide.** To a stirred solution of 5.0 g (47 mmol) of methyl thioglycolate in 100 mL of benzene was added 7.9 g (52 mmol) of DBU followed by 7.0 g (52 mmol) of 4-bromo-1-butene. The resulting mixture was stirred for 12 h at room temperature, diluted with water, extracted with ether, and dried over $MgSO_4$. Removal of the solvent under reduced pressure gave (but-3-enylsulfenyl)acetic acid methyl ester as a colorless liquid, which was used in the next step without further purification: IR (neat) 1738, 1436, 1279, and 1133 cm^{-1}; ^{1}H NMR ($CDCl_3$, 300 MHz) δ 2.36 (m, 2H), 2.71 (m, 2H), 3.25 (s, 3H), 5.08 (m, 2H), and 5.82 (m, 1H); ^{13}C NMR ($CDCl_3$, 75 MHz) δ 31.9, 33.1, 33.3, 52.3, 116.2, 128.2, 136.1, and 170.9.

To a suspension of 2.0 g (15 mmol) of potassium trimethylsilanolate in 150 mL of ether was added 2.1 g (13 mmol) of the above ester. After stirring at room temperature for 3 h, the mixture was diluted with water, washed with ether, and acidified with a 10% HCl solution. The aqueous layer was extracted with ether, dried over $MgSO_4$, and concentrated under reduced pressure to give 1.68 g (89%) of (but-3-enylsulfenyl)acetic acid, which was used in the next step without further purification: IR (neat) 1709, 1425, and 1297 cm^{-1}; ^{1}H NMR ($CDCl_3$, 300 MHz) δ 2.35 (m, 2H), 2.71 (m, 2H, 3.24 (s, 2H), 5.05 (m, 2H), 5.79 (m, 1H), and 11.36 (brs, 1H); ^{13}C NMR ($CDCl_3$, 75 MHz) δ 32.0, 33.1, 33.4, 116.4, 136.0, and 177.0.

To a solution of 1.4 g (9.4 mmol) of the above acid was added 9.4 mL of a 2 M solution of oxalyl chloride followed by 1 drop of DMF. The solution was stirred for 2 h at room temperature and was then concentrated under reduced pressure. The crude acid chloride was taken up in 75 mL of toluene, and 0.53 g (7.2 mmol) of *N*-methyl acetamide was added. The resulting mixture was heated at reflux for 12 h, washed with a 10% NaOH solution, and dried over $MgSO_4$. The solvent was removed under reduced pressure, and the residue was chromatographed on silica gel to give 1.1 g (75%) of *N*-[(but-3-enylsulfenyl)acetyl]-*N*-methylacetamide as a light yellow oil: IR (neat) 1694, 1369, 1310, and 1139 cm^{-1}; ^{1}H NMR ($CDCl_3$, 300 MHz) δ 2.36 (m, 2H), 2.41 (s, 3H), 2.67 (m, 2H), 3.27 (s, 3H), 3.72 (s, 2H), 5.07 (m, 2H), and 5.81 (m, 1H); ^{13}C NMR ($CDCl_3$, 75 MHz) δ 26.2, 31.4, 31.9, 33.3, 37.9, 116.1, 136.2, 172.0, and 173.0. HRMS Calcd for $C_9H_{15}NO_2S$: 201.0823. Found: 201.0822.

***N*-[(But-3-enylsulfinyl)acetyl]-*N*-methylacetamide (49).** The reaction of 1.0 g (5.0 mmol) of the above sulfide with 1.2 g (5.5 mmol) of sodium periodate afforded 0.83 g (77%) of **49** as a clear oil: IR (neat) 1693, 1371, 1311, and 1034 cm^{-1}; ^{1}H NMR ($CDCl_3$, 300 MHz) δ 2.39 (s, 3H), 2.58 (m, 2H), 2.94 (m, 2H), 3.28 (s, 3H), 4.19 (d, 1H, J = 14.9 Hz), 4.38 (d, 1H, J = 14.9 Hz), 5.16 (m, 2H), and 5.87 (m, 1H); ^{13}C NMR ($CDCl_3$, 75 MHz) δ 25.4, 26.3, 31.9, 51.7, 61.2, 117.0, 134.5, 167.7, and 173.2. Anal. Calcd for $C_9H_{15}NO_3S$: C, 49.75; H, 6.96; N, 6.45. Found: C, 49.52; H, 6.74; N, 6.33.

7,8-Dimethyl-10-oxa-2-thia-8-azatricyclo[5.2.1.0^{1,5}]decan-9-one (50). To a refluxing solution of 2.4 g (24 mmol) of acetic anhydride and 2 mg of *p*-toluenesulfonic acid in 40 mL of toluene was added 0.5 g (2.4 mmol) of amide **49** in 2 mL of toluene. After heating at reflux for 30 min, the reaction mixture was concentrated under reduced pressure, and the residue was subjected to silica gel chromatography. The major product isolated (58%) was a colorless oil whose structure was assigned cycloadduct **50**: IR (neat) 1724, 1398, and 1002 cm^{-1}; ^{1}H NMR ($CDCl_3$, 300 MHz) δ 1.68 (s, 3H), 1.70 (m, 1H), 1.84 (m, 1H), 2.07 (dd, 1H, J = 12.0 and 7.5 Hz), 2.45 (m, 2H), 2.80 (s, 3H), and 3.27 (m, 2H); ^{13}C NMR ($CDCl_3$, 75 MHz) δ 17.9, 25.4, 34.4, 37.0, 39.8, 52.2, 96.7, 104.0, and 171.7. Anal. Calcd for $C_9H_{13}NO_2S$: C, 54.25; H, 6.58; N, 7.83. Found: C, 54.13; H, 6.54; N, 7.72.

5,6-Dimethyl-2,3-dihydro-6*H*-thieno[2,3-*c*]pyridin-7-one (51). The minor fraction (15%) from the above column chromatography was identified as pyridone **51**: mp 131−132 °C; IR (CCl_4) 1650, 1566, and 1426 cm^{-1}; ^{1}H NMR ($CDCl_3$, 300 MHz) δ 2.32 (s, 3H), 3.21 (m, 2H), 3.30 (m, 2H), 3.52 (s, 3H), and 6.05 (s, 1H); ^{13}C NMR ($CDCl_3$, 75 MHz) δ 20.6, 30.9, 31.5, 37.4, 104.2, 128.0, 142.0, 147.1, and 158.6. Anal. Calcd for $C_9H_{11}NOS$: C, 59.64; H, 6.12; N, 7.73. Found: C, 59.65; H, 6.10; N, 7.74. This same compound was obtained in quantitative yield by heating a sample of cycloadduct **50** in toluene at 110 °C for 1 h.

2-Ethylsulfenyl-*N*-hex-5-enyl-*N*-methylacetamide. Following the general procedure, the reaction of 2.0 g (16 mmol) of hex-5-enoic acid methylamide with 2.9 g (21 mmol) of acid chloride **18** gave 2.9 g (80%) of 2-ethylsulfenyl-*N*-hex-5-enyl-*N*-methylacetamide as a clear oil: IR (neat) 1695, 1350, 1140, and 971 cm^{-1}; ^{1}H NMR ($CDCl_3$, 300 MHz) δ 1.27 (t, 3H, J = 7.3 Hz), 1.79 (m, 2H), 2.13 (m, 2H), 2.63 (m, 4H), 3.25 (s, 3H), 3.74 (s, 2H), 5.03 (m, 2H), and 5.80 (m, 1H); ^{13}C NMR ($CDCl_3$, 75 MHz) δ 14.3, 23.4, 26.1, 31.4, 32.8, 36.7, 37.7, 115.3, 137.7, 172.2, and 175.6. HRMS Calcd for $C_{11}H_{19}NO_2S$: 229.1136. Found: 229.1135.

2-Ethanesulfinyl-*N*-hex-5-enyl-*N*-methylacetamide (52). Treatment of 0.9 g (3.9 mmol) of the above sulfide with 0.9 g (4.3 mmol) of sodium periodate afforded 0.72 g (75%) of **52** as a colorless oil: IR (neat) 1687, 1374, 1303, and 1047 cm^{-1}; ^{1}H NMR ($CDCl_3$, 300 MHz) δ 1.39 (m, 3H), 1.79 (m, 2H), 2.13 (m, 2H), 2.62 (m, 2H), 2.79−2.95 (m, 2H), 3.27 (s, 3H), 4.16 (m, 1H), 4.34 (m, 1H), 5.05 (m, 2H), and 5.80 (m, 1H); ^{13}C NMR ($CDCl_3$, 75 MHz) δ 6.4, 23.0, 31.1, 32.5, 35.9, 46.0, 60.7, 115.4, 137.3, 167.8, and 175.7. Anal. Calcd for $C_{11}H_{19}NO_3S$: C, 53.95; H, 7.81; N, 5.71. Found: C, 53.72; H, 7.59; N, 5.65.

1-Methyl-2-oxo-2,5,6,7-tetrahydro-1*H*-pyridin-3-yl Acetic Acid Ester (54). To a refluxing solution of 1.8 g (18 mmol) of acetic anhydride and 2 mg of *p*-toluenesulfonic acid in 40 mL of toluene was added dropwise 0.44 g (1.8 mmol) of acetamide **52** in 2 mL of toluene. After heating at reflux for 1 h, the reaction mixture was concentrated under reduced pressure, and the residue was subjected to silica gel chromatography to give 0.29 g (78%) of pyridone **54**: mp 122−123 °C; IR (CCl_4) 1766, 1659, 1602, and 1196 cm^{-1}; ^{1}H NMR ($CDCl_3$, 300 MHz) δ 2.16 (m, 2H), 2.32 (s, 3H), 2.79 (t, 2H, J = 7.5 Hz), 2.90 (t, 2H, J = 7.5 Hz), 3.52 (s, 3H), and 7.09 (s, 1H); ^{13}C NMR ($CDCl_3$, 75 MHz) δ 20.6, 22.4, 30.4, 32.0, 32.9, 116.5, 126.9, 138.8, 146.8, 157.7, and 169.1. Anal. Calcd for $C_{11}H_{13}NO_3$: C, 63.76; H, 6.32; N, 6.76. Found: C, 63.82; H, 6.33; N, 6.73.

2-Allyl-*N*-ethylsulfenylacetyl-*N*-methylbenzamide. Following the general procedure, treatment of 1.1 g (6 mmol) of 2-allyl-*N*-methylbenzamide[48] with 1.1 g (7.8 mmol) of acid chloride **18** afforded 1.2 g (72%) of 2-allyl-*N*-ethylsulfenylacetyl-*N*-methylbenzamide as a colorless oil: IR (neat) 1687, 1417, and 1310 cm^{-1}; ^{1}H NMR ($CDCl_3$, 300 MHz) δ 1.28 (t, 3H, J = 7.4 Hz), 2.62 (q, 2H, J = 7.4 Hz), 3.06 (s, 3H), 3.49 (d, 2H, J = 6.5 Hz), 3.83 (s, 2H), 5.07 (m, 2H), 5.92 (m, 1H), and 7.35 (m, 4H); ^{13}C NMR ($CDCl_3$, 75 MHz) δ 14.3, 26.3, 34.0, 37.1, 37.5, 116.7, 126.4, 130.5, 135.3, 136.0, 137.6, 173.0, and 173.2. HRMS Calcd for $C_{15}H_{19}NO_2S$: 277.1136. Found: 277.1140.

2-Allyl-*N*-ethanesulfinylacetyl-*N*-methylbenzamide (55). The reaction of 1.1 g (3.8 mmol) of the above sulfide with 0.9 g (4 mmol) of sodium periodate gave 1.0 g (92%) of benzamide **55** as a clear oil: IR (neat) 1687, 1310, and 1047 cm^{-1}; ^{1}H NMR ($CDCl_3$, 300 MHz) δ 1.40 (t, 3H, J = 7.4 Hz), 2.94 (m, 2H), 3.07 (s, 3H), 3.47 (d, 2H, J = 6.6 Hz), 4.16 (d, 1H, J = 14.5 Hz), 4.45 (d, 1H, J = 14.5 Hz), 5.06 (m, 2H), 5.90 (m, 1H), and 7.37 (m, 4H); ^{13}C NMR ($CDCl_3$, 75 MHz) δ 6.6, 34.2, 37.2, 46.4, 60.1, 117.0, 126.6, 130.8, 131.0, 134.4, 135.9, 137.8, 168.3, and 173.8. Anal. Calcd for $C_{15}H_{19}NO_3S$: C, 61.41; H, 6.53; N, 4.78. Found: C, 61.35; H, 6.51; N, 4.66.

1-Methyl-2-oxo-2,5-dihydro-1*H*-indeno[1,2-*b*]pyridin-3-yl Acetic Acid Ester (56). To a refluxing solution of 1.4 g (14 mmol) of acetic anhydride and 2 mg of *p*-toluenesulfonic acid in 40 mL of toluene was added dropwise 0.4 g (1.4 mmol) of benzamide **55** in 2 mL of toluene. After heating for 1 h at reflux, the solvent was removed under reduced pressure, and the residue was chromatographed on silica gel to give 0.24 g (70%) of **56** as a white solid: mp 149−150 °C; IR (CCl_4) 1769, 1649, 1536, and 1197 cm^{-1}; ^{1}H NMR ($CDCl_3$, 300 MHz) δ 2.37 (s, 3H), 3.69 (s, 2H), 4.08 (s, 3H), 7.36 (m, 3H), 7.58 (d, 1H, J = 6.4 Hz), and 7.92 (d, 1H, J = 7.9 Hz); ^{13}C NMR ($CDCl_3$, 75 MHz) δ 20.7, 32.5, 34.9, 118.9, 121.9, 125.4, 126.6, 127.2, 127.6, 136.6, 138.8, 144.2, 144.8, 157.8, and 169.0. Anal. Calcd for $C_{15}H_{13}NO_3S$: C, 70.58; H, 5.13; N, 5.49. Found: C, 70.69; H, 5.19; N, 5.31.

***N*-Methyl-2-ethylsulfenyl-*N*-hept-6-enoylacetamide.** Following the general procedure, the reaction of 1.0 g (7.4 mmol) of hept-6-enoic acid methylamide with 1.4 g (9.8 mmol) of acid chloride **18** gave 1.2 g (66%) of *N*-methyl-2-ethylsulfenyl-*N*-hept-6-enoylacetamide as a clear oil: IR (neat) 1695, 1292, and 1086 cm^{-1}; ^{1}H NMR ($CDCl_3$, 300 MHz) δ 1.27 (t, 3H, J = 7.2 Hz), 1.46 (m, 2H), 1.68 (m, 2H), 2.09 (m, 2H), 2.63 (m, 4H), 3.25 (s, 3H), 3.73 (s, 2H), 5.00 (m, 2H), and 5.82 (m, 1H); ^{13}C NMR ($CDCl_3$, 75 MHz) δ 14.3, 23.9, 26.1, 28.2, 31.4, 33.4, 37.5, 37.8, 114.6, 138.3, 172.2, and 175.7. HRMS Calcd for $C_{12}H_{21}NO_2S$: 243.1293. Found: 243.1302.

***N*-Methyl-2-ethanesulfinyl-*N*-hept-6-enoylacetamide (57).** The reaction of 1.0 g (4.2 mmol) of the above sulfide with 1.0 g (4.7 mmol) of sodium periodate afforded 1.1 g (99%) of **57** as a colorless oil: IR (neat) 1694, 1456, 1305, and 1048 cm^{-1}; ^{1}H NMR ($CDCl_3$, 300 MHz) δ 1.43 (m, 5H), 1.69 (m, 2H), 2.11 (m, 2H), 2.69 (m, 2H), 2.90 (m, 2H), 3.28 (s, 3H), 4.16 (d, 1H, J = 14.8 Hz), 4.36 (d, 1H, J = 14.8 Hz), 5.01 (m, 2H), and 5.81 (m, 1H); ^{13}C NMR ($CDCl_3$, 300 MHz) δ 6.3, 23.4, 27.8, 31.1, 33.1, 36.6, 45.9, 60.6, 114.6, 137.9, 167.8, and 175.7. Anal. Calcd for $C_{12}H_{21}NO_3S$: C, 55.57; H, 8.17; N, 5.40. Found: C, 55.49; H, 8.08; N, 5.43.

1-Methyl-2-oxo-1,2,5,6,7,8-hexahydroquinolin-3-yl Acetic Acid Ester (58). To a refluxing solution of 1.9 g (19 mmol) of acetic anhydride and 2 mg of *p*-toluenesulfonic acid in 40 mL of toluene was added dropwise 0.49 g (1.9 mmol) of acetamide **57** in 2 mL of toluene. After heating at reflux for 1 h, the reaction mixture was concentrated under reduced pressure, and the residue was chromatographed on silica gel. The major fraction isolated from the column contained 0.31 g (70%) of pyridone **58** as a white solid: mp 118−119 °C; IR (CCl_4) 1763, 1664, 1613, 1560, and 1200 cm^{-1}; ^{1}H NMR ($CDCl_3$, 300 MHz) δ 1.71 (m, 2H), 1.85 (m, 2H), 2.31 (s, 3H), 2.51 (m, 2H), 2.60 (m, 2H), 3.52 (s, 3H), and 6.92 (s, 1H); ^{13}C NMR ($CDCl_3$, 75 MHz) δ 20.4, 21.4, 22.1, 27.0, 27.2, 30.4, 112.8, 130.5, 138.0, 140.7, 157.5, and 168.8. Anal. Calcd for $C_{12}H_{15}NO_3$: C, 65.14; H, 6.83; N, 6.33. Found: C, 65.50; H, 6.87; N, 6.34.

1-Methyl-3-ethylsulfenyl-5,6,7,8-tetrahydro-1*H*-quinolin-2-one (59). The minor product obtained from the above column chromatography contained 0.09 g (25%) of quinolin-2-one **59**: mp 98−99 °C; IR (CCl_4) 1638, 1583, 1420, and 1213 cm^{-1}; ^{1}H NMR ($CDCl_3$, 300 MHz) δ 1.32 (t, 3H, J = 7.3 Hz), 1.71 (m, 2H), 1.83 (m, 2H), 2.52 (m, 2H), 2.61 (m, 2H), 2.86 (q, 2H, J = 7.3 Hz), 3.52 (s, 3H), and 6.95 (s, 1H); ^{13}C NMR ($CDCl_3$, 75 MHz) δ 13.6, 21.7, 22.3, 25.0, 27.0, 27.5, 30.6, 114.6, 125.9, 135.0, 139.5, and 160.8. Anal. Calcd for $C_{12}H_{17}NOS$: C, 64.54; H, 7.67; N, 6.27. Found: C, 64.31; H, 7.55; N, 6.10.

***N*-Ethylsulfenylacetyl-*N*-methyl-3-(2-vinylphenyl)propionamide.** Following the general procedure, the reaction of 1.1 g (5.8 mmol) of *N*-methyl-3-(2-vinylphenyl)propionamide[49] with 1.1 g (7.6 mmol) of acid chloride **18** afforded 1.5 g (90%) of *N*-ethyl-sulfenylacetyl-*N*-methyl-3-(2-vinylphenyl)propionamide as a clear oil: IR (neat) 1693, 1372, 1288, and 1085 cm^{-1}; ^{1}H NMR ($CDCl_3$, 300 MHz) δ 1.26 (t, 3H, J = 7.4 Hz), 2.60 (q, 2H, J = 7.4 Hz), 2.93 (m, 2H), 3.05 (m, 2H), 3.20 (s, 3H), 3.71 (s, 2H), 5.32 (d, 1H, J = 11.0 Hz), 5.66 (d, 1H, J = 17.3 Hz), 6.98 (dd, 1H, J = 17.3 and 11.0 Hz), 7.22 (m, 3H), and 7.48 (m, 1H); ^{13}C NMR ($CDCl_3$, 75 MHz) δ 14.2, 26.1, 28.1, 31.3, 37.6, 38.8, 116.0, 125.9, 126.7, 127.9, 129.4, 134.0, 136.4, 137.7, 172.0, and 174.9. HRMS Calcd for $C_{16}H_{21}NO_2S$: 291.1293. Found: 291.1301.

***N*-Ethanesulfinylacetyl-*N*-methyl-3-(2-vinylphenyl)-propionamide (60).** The reaction of 1.5 g (5.2 mmol) of the above sulfide with 1.2 g (5.7 mmol) of sodium periodate gave 1.6 g (99%) of **60** as a colorless oil: IR (neat) 1686, 1302, and 1043 cm^{-1}; ^{1}H NMR ($CDCl_3$, 300 MHz) δ 1.36 (t, 3H, J = 7.4 Hz), 2.88 (m, 4H), 3.03 (m, 2H), 3.17 (s, 3H), 4.13 (d, 1H, J = 14.9 Hz), 4.31 (d, 1H, J = 14.9 Hz), 5.34 (d, 1H, J = 11.0 Hz), 5.67 (d, 1H, J = 17.3 Hz), 6.96 (dd, 1H, J = 17.3 and 11.0 Hz), 7.20 (m, 3H), and 7.48 (m, 1H); ^{13}C NMR ($CDCl_3$, 75 MHz) δ 6.3, 27.6, 30.9, 37.8, 45.9, 60.4, 116.1, 125.8, 126.7, 127.7, 129.2, 133.7, 136.2, 137.0, 167.7, and 174.8. Anal. Calcd for $C_{16}H_{21}NO_3S$: C, 62.52; H, 6.89; N, 4.56. Found: C, 62.44; H, 6.72; N, 4.50.

4-Methyl-3-oxo-3,4,5,6-tetrahydrobenzo[*f*]quinolin-2-yl Acetic Acid Ester (61). To a refluxing solution of 5.2 g (51 mmol) of acetic anhydride and 2 mg of *p*-toluenesulfonic acid in 75 mL of toluene was added dropwise 1.6 g (5.1 mmol) of propionamide **60** in 2 mL of toluene. After heating at reflux for 1 h, the reaction mixture was concentrated under reduced pressure, and the residue was chromatographed on silica gel. The major product (70%) isolated from the column was identified as quinolin-2-yl acetic acid ester **61**: mp 172−173 °C; IR (CCl_4) 1770, 1651, 1616, and 1204 cm^{-1}; ^{1}H NMR ($CDCl_3$, 300 MHz) δ 2.33 (s, 3H), 2.81 (m, 4H), 3.56 (s, 3H), 7.17 (m, 3H), 7.30 (d, 1H, J = 7.6 Hz), and 7.56 (s, 1H); ^{13}C NMR ($CDCl_3$, 75 MHz) δ 20.3, 25.0, 27.2, 31.1, 111.9, 121.5, 124.9, 126.4, 126.9, 127.3, 131.3, 132.2, 138.8, 142.7, 157.0, and 168.4. Anal. Calcd for $C_{16}H_{15}NO_3$: C, 71.36; H, 5.61; N, 5.20. Found: C, 71.30; H, 5.65; N, 5.15.

2-Ethylsulfenyl-4-methyl-5,6-dihydro-4*H*-benzo[*f*]quinolin-3-one (62). The minor product (25%) obtained from the above column chromatography was a colorless solid whose structure was assigned as 2-ethylsulfenyl-4-methyl-5,6-dihydro-4*H*-benzo[*f*]quinolin-3-one (**62**): mp 171−172 °C; IR (CCl_4) 1633, 1586, 1534, and 1420 cm^{-1}; ^{1}H NMR ($CDCl_3$, 300 MHz) δ 1.33 (t, 3H, J = 7.4 Hz), 2.91 (m, 6H), 3.62 (s, 3H), 7.23 (m, 3H), 7.44 (d, 1H, J = 7.7 Hz), and 7.61 (s, 1H); ^{13}C NMR ($CDCl_3$, 75 MHz) δ 13.5, 25.1, 25.2, 27.7, 31.5, 113.7, 121.6, 126.4, 127.0, 127.1, 127.6, 129.9, 132.1, 132.6, 141.9, and 160.4. Anal. Calcd for $C_{16}H_{17}NOS$: C, 70.82; H, 6.31; N, 5.16. Found: C, 70.62; H, 6.30; N, 5.15.

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Acknowledgment. We gratefully acknowledge the National Cancer Institute for generous support of this work. Use of high-field NMR spectrometers used in these studies was made possible through equipment grants from the NIH and NSF. We also thank Scott M. Sheehan for determining the X-ray crystal structure of compound **25**.

Supporting Information Available: ^{1}H NMR and ^{13}C NMR spectra for new compounds lacking analyses together with an ORTEP drawing for structure **25**. This material is available free of charge via the Internet at http://pubs.acs.org.

JO982315R