added, and the product extracted into chloroform. The extract was dried, the solvent evaporated, and the residue distilled *in vacuo* to give 18.8 g of a colorless liquid: bp 55° (16 mm); n^{28}D 1.6081; ir (film) 3100, 3080, 1450, 1300, 1100, 870 cm^{-1}; nmr (CCl_4) 7.47 (d, J = 3.8 Hz, 1, H_5), 6.66 (d, J = 3.8 Hz, 1, H_4). H_5 was further split into another doublet of doublets with J = 40 Hz (^{77}Se coupling).

4-Methyl-1,2,3-selenadiazole-5-carboxylic Acid Ethyl Ester (2, R = CH_3; R' = CO_2Et).—To a mixture of 18.8 g (0.1 mol) of ethylacetoacetate semicarbazone in 200 ml of glacial acetic acid was added gradually 11.1 g (0.1 mol) of powdered selenium dioxide and heated gently on water bath for 3 hr. The mixture was filtered, the filtrate was diluted with water and extracted with chloroform, and the chloroform evaporated. The residue was steam distilled to give 17.7 g of an oil which on treatment with petroluem ether crystallized as pale yellow crystals: mp 39–41°; ir (KBr) 1725, 1310, 1090, 760 cm^{-1}; nmr (CCl_4) 4.31 (q, 2, OCH_2), 2.91 (s, 3, CH_3), 1.32 (t, 3, OCH_2CH_3).

Hydrolysis of 4-Methyl-1,2,3-selenadiazole-5-carboxylic Acid Ethyl Ester (2, R = CH_3; R' = CO_2Et).—To a refluxing solution of 1.88 g (0.01 mol) of 4-methyl-1,2,3-selenadiazole-5-carboxylic acid ethyl ester in 15 ml of 95% ethyl alcohol was added dropwise a solution of 0.4 g (0.01 mol) of sodium hydroxide in 5 ml of water. The refluxing was continued for 30 min. After cooling the solution was diluted with water and extracted with chloroform. The aqueous layer was acidified with hydrochloric acid and the resulting crystalline solid separated and recrystallized from chloroform to afford 1.2 g (75%) of 4-methyl-1,2,3-selenadiazole-5-carboxylic acid (2, R = CH_3; R' = CO_2H): mp 194–195°; ir (KBr) 1695, 1500, 1430, 1190, 870, 730 cm^{-1}.

Reesterification of 4-Methyl-1,2,3-selenadiazole-5-carboxylic Acid (2, R = CH_3; R' = COOH).—A mixture of 1.0 g (0.0052 mol) of the acid and 2 ml of thionyl chloride was refluxed for 30 min, excess thionyl chloride was removed under reduced pressure, and to the residue 10 ml of ethanol was added and refluxed for 10 min. On evaporation of the excess alcohol and crystallization of the residue from petroleum ether, 0.4 g of a pale yellow solid was obtained, mp and mmp (with authentic sample) (see Table I), 38–40°.

Pyrolysis of 4-Methyl-1,2,3-selenadiazole-5-carboxylic Acid Ethyl Ester.—A mixture of the selenadiazole, 1.0 g (0.0052 mol), and 5.0 g of acid-washed sand was gradually heated to 160° and kept at that temperature for 10 min. On distillation under reduced pressure, 0.42 g (82 %) of a colorless oil was obtained, bp 160–161°, n^{20}D 1.4289, identified by comparison with authentic material to be tetronic acid ethyl ester.

Cycloaddition of a 1,4 Dipole with Alkyl Ketones. A Novel Synthesis of 1,3,4-Tetrahydrooxadiazines

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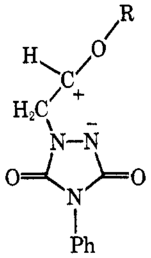
The intermediate 1,4 dipole from the spontaneous reaction of 4-phenyl-1,2,4-triazoline-3,5-dione with vinyl ethers was observed to react readily with weakly dipolarophilic alkyl ketones to form a new 1,3,4-tetrahydrooxadiazine ring structure. The characterization of these new compounds is described. The reactivity of the 1,4-dipolar intermediate was found to be sensitive to substituent effects.

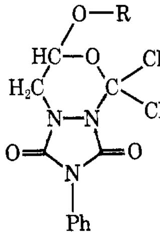
1,4-Dipolar cycloaddition reactions have been the topic of a recent review[1] and have received attention in other reviews on dipolar cycloaddition reactions.[2] Many different reactive dipolarophiles have been utilized to react with the various 1,4 dipoles studied, *i.e.*, isocyanates, acetylene dicarboxylate esters, and ketenes among many others. However, to the best of our knowledge the only case reported of a ketone performing this function is in the reactions of perhaloacetones with cyanamides to form 1,3,5-oxadiazines.[3]

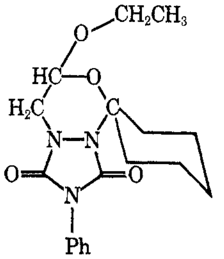
4-Phenyl-1,2,4-triazoline-3,5-dione (PhTD) has been shown to be a strong dienophile in 4 + 2 cycloaddition reactions[4] and recently has been shown to participate in a 2 + 2 cycloaddition reaction with indene in which a 1,4-dipolar intermediate was trapped with water.[5]

We wish to report a novel cycloaddition reaction using alkyl ketones as the dipolarophile with the 1,4 dipole (I) from PhTD and vinyl ethers.

When PhTD and ethyl vinyl ether (EVE) are mixed in a 1:1 molar ratio in acetone at room temperature two products are observed. 3-Oxa-2,2-dimethyl-4-ethoxy-8-phenyl-1,6,8-triazabicyclo[4.3.0]nona-7,9-dione (IIa), a new 1,3,4-tetrahydrooxadiazine ring structure, is formed in 42% yield along with a 1:1 alternating copolymer which we have reported elsewhere.[6]


I


IIa, R = CH_2CH_3
b, R = $CH_2CH(CH_3)_2$
c, R = $CH{=}CH_2$


III

Structure IIa was assigned on the basis of the following data. The infrared spectrum (KBr) showed strong absorbances at 2980–2880 (saturated CH), 1770 and 1710 cm^{-1} (double carbonyl), and gave strong bands in the 1200–1000 cm^{-1} region due to the acetal linkage. A 60-MHz proton nmr spectrum ($CDCl_3$) gave a triplet at δ 1.25 (3 H), two equivalent singlets at δ 1.70 and 1.85 (3 H each) assigned to the nonequivalent methyl group protons from the incorporated acetone, a multiplet at δ 3.73 (4 H) from the two sets of methylene protons, a quartet at δ 5.02 (1 H) assigned to the single proton on the acetal carbon, and a multiplet at δ 7.40 (5 H) originating from the aromatic protons.

Substituting isobutyl vinyl ether for ethyl vinyl ether

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[2] (a) R. Gompper, *Angew. Chem., Int. Ed. Engl.*, **8**, 312 (1969); (b) R. M. Acheson, *Advan. Heterocycl. Chem.*, **1**, 125 (1963).

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[4] R. C. Cookson, S. S. H. Gilani, and I. D. R. Stevens, *J. Chem. Soc. C*, 1905 (1967).

[5] E. K. von Gustorf, D. V. White, B. Kim, D. Hess, and J. Leitish, *J. Org. Chem.*, **35**, 1155 (1970).

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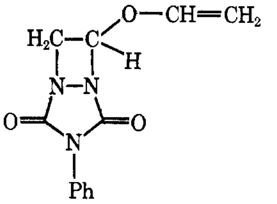
resulted in formation of 3-oxa-2,2-dimethyl-4-isobutoxy-8-phenyl-1,6,8-triazabicyclo[4.3.0]nona-7,9-dione (IIb) in 47% yield. The ir spectrum was practically identical with that of compound IIa, with only minor differences noted in the CH stretching frequencies and in the fingerprint region of the spectrum. The 60-MHz proton nmr spectrum ($CDCl_3$) for IIb was similar to that of IIa except that a doublet for the methyl groups of the isobutyl group was present, δ 0.95 (6 H), and the multiplet due to the methylene protons was less complex because of the isobutyl group.

Changing the ketone solvent from acetone to cyclohexanone resulted in formation of 3-oxa-2-spirocyclohexyl-4-ethoxy-8-phenyl-1,6,8-triazabicyclo[4.3.0]nona-7,9-dione (III) in 12% yield. Apparently the low yield resulted from the more complicated procedure for product isolation. The infrared spectrum appeared practically identical with those of IIa and IIb. The 60-MHz nmr spectrum differed from that of IIa in that the nonequivalent methyl absorbances at δ 1.70 and 1.85 were replaced by a broad multiplet absorbance from δ 1.50–2.80 (10 H) from the cyclohexyl protons.

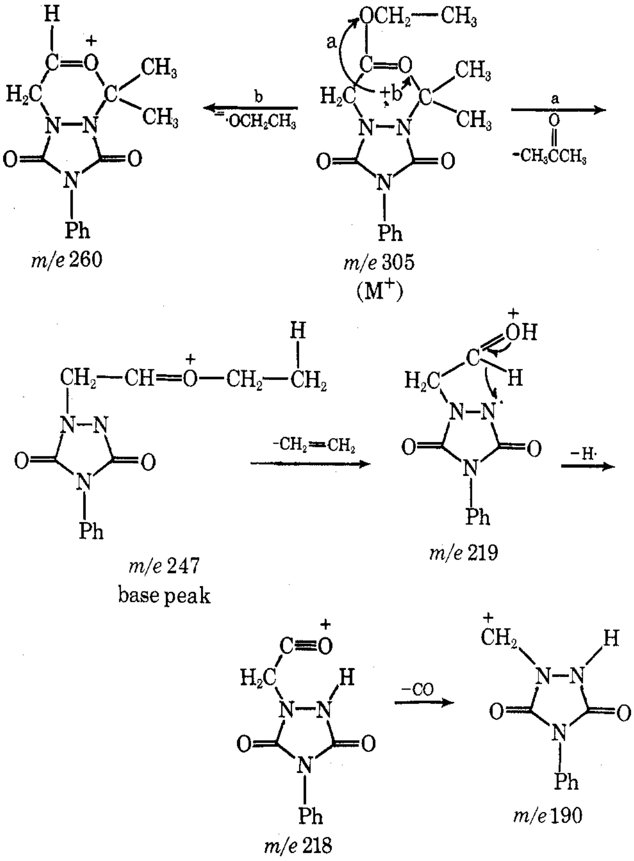
Divinyl ether, PhTD, and acetone resulted in a small amount of the tetrahydrooxadiazine (IIc) and a trace of the 1,2-diazetidine, 3-phenyl-6-vinyloxy-1,3,5-triazabicyclo[3.2.0]hepta-2,4-dione (IV). Both were identified from their nmr spectra, with the oxadiazine spectrum resembling IIa, IIb, and III. The nmr spectrum of the 1,2-diazetidine was identical with that of an authentic sample prepared by the reaction of PhTD and divinyl ether in methylene chloride at room temperature. The 60-MHz proton nmr spectrum ($CDCl_3$) of IV gave a multiplet centered at δ 4.50 (4 H) assigned to the methylene ring protons and the terminal vinyl protons, a triplet at δ 5.81 (1 H) assigned to the single hydrogen next to the vinyloxy substituent, a quartet centered at δ 6.50 (1 H) from the vinyl proton, and a singlet at 7.48 (5 H) from the aromatic hydrogens. These assignments are consistent with the nmr data from other 1,2-diazetidine structure determinations.[5] The ir spectrum (KBr) gave important absorbances at 1795, 1730 and 1710 (carbonyl) and 1645 and 1625 cm^{-1} (vinyl ether chromophore). The mass spectrum gave the correct parent peak at m/e 245.



IV

The new 1,3,4-tetrahydrooxadiazine ring structures possess a unique acetal linkage with one ether linkage in the ring and the other outside of it. The structure in this respect is similar to glucosides. Strong corroborative evidence for these structures is offered by the mass spectral fragmentation patterns, which are very similar to known acetal fragmentations.[7] Scheme I shows the fragmentation pattern for IIa. Although not normally seen in acetal fragmentations,[7] the molecular ion appears at m/e 305 (1%). This ion then is believed to fragment by two pathways, a and b.

SCHEME I



Pathway a involves loss of acetone to form m/e 247, the base ion. This is followed by the loss of ethylene to m/e 219 (8%), which then appears to rearrange and lose a hydrogen atom to m/e 218 (22%). Ion m/e 190 (59%) subsequently follows by loss of carbon monoxide. Pathway b involves loss of the ethoxy radical to form ion m/e 260 (7%), a general cracking course for both acetals[7] and glucosides.[8] Both IIb and III gave similar ions resulting from the same double fragmentation pathway. A summary of experimental results is given in Table I.

TABLE I

Vinyl ether	Ketone	Yield, %	Mp, °C
$CH_2=CHOCH_2CH_3$	Acetone	42	149–151
$CH_2=CHOCH_2CH_3$	Cyclohexanone	12[a]	170–171
$CH=CHOCH_2CH(CH_3)_2$	Acetone	47	125–126
$CH_2=CHOCH=CH_2$	Acetone	Trace[b]	

[a] Yield lower possibly because of difficulty in work-up. [b] Identified from nmr. Also some 1,2-diazetidine formed.

From these results it appears that the reactivity of the 1,4 dipole is quite sensitive to stabilization of its positive center. The high yields of oxadiazine when the carbonium ion stabilizing substituents, ethoxy and isobutoxy, are present and the low yield with vinyloxy probably means that the intermediate has more pronounced dipolar character when its positive center is

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(7) H. Budzikiewicz, C. Djerassi, and D. H. Williams, "Mass Spectrometry of Organic Compounds," Holden-Day, San Francisco, Calif., 1967, Chapter 6.

(8) R. I. Reed, W. K. Reid, and J. M. Wilson in *Advan. Mass Spectrom.*, **2**, 420 (1962).

stabilized and hence can add across the weak dipolarophilic alkyl ketones. In agreement with the above suggestion is the PhTD–indene[5] reaction in which no oxadiazine was reported even though the reaction was performed in acetone.

Experimental Section

Infrared spectra were recorded with a Beckman IR-8 using potassium bromide disks. Proton nmr spectra were obtained by use of a Varian A-60 spectrometer. Mass spectral data were obtained using a Hitachi Perkin–Elmer RMU mass spectrometer.

All melting points are uncorrected and were taken in a Thomas–Hoover capillary melting point apparatus. Reagent grade acetone and cyclohexanone were dried over molecular sieves for at least 24 hr prior to use. Divinyl ether, ethyl vinyl ether, and isobutyl vinyl ether were obtained from commercial sources and distilled prior to use. Elemental analyses were performed by Atlantic Microlab, Inc., Atlanta, Ga.

4-Phenyl-1,2,4-triazoline-3,5-dione (PhTD).—4-Phenylurazole was prepared from 4-phenyl-1-ethoxycarbonyl semicarbazide by cyclization with 4 *M* KOH according to Zinner and Deucker.[9] The resulting urazole was smoothly oxidized to PhTD by the method of Stickler and Pirkle[10] with gaseous dinitrogen tetroxide in methylene chloride at 0°. The PhTD was purified by sublimation (0.3 Torr, 70°) and the resulting crystalline red solid was stored under refrigeration in the absence of light.

3-Oxa-2,2-dimethyl-4-ethoxy-8-phenyl-1,6,8-triazabicyclo-[4.3.0]nona-7,9-dione (IIa).—PhTD (0.500 g, 0.0028 mol) was placed into a 50-ml erlenmeyer flask equipped with a magnetic stirring bar and a rubber serum cap. Using a syringe, acetone (15 ml) was introduced and a deep red solution resulted. Ethyl vinyl ether (0.199 g, 0.0028 mol), dissolved in 10 ml of acetone, was added in like manner. After 0.5 hr the dark red color had faded to a slight pink tinged solution. The acetone was then removed on a rotary evaporator at ambient temperature. The solid product was dissolved in CH_2Cl_2 (15 ml) and then precipitated by slowly dropping into 300 ml of hexane. The white, polymeric solid was removed by filtration and the resulting yellow filtrate was carefully evaporated to dryness on a rotary evaporator. The light yellow, crystalline product (0.361 g, 42% yield) was recrystallized from absolute ethanol: mp 149–151°; ir (KBr) (prominent absorbances) no NH, 2980–2880 (m, saturated CH), 1770 and 1710 (s, double C═O), 1600 (w), 740 (m) and 650 (m) (aromatic), 1170 (m), 1150 (m), 1130 (m), and 1030 (m) (acetal ether linkages); nmr ($CDCl_3$) δ 1.25 (t, 3), 1.70 (s, 3), 1.85 (s, 3), 3.73 (m, 4), 5.02 (q, 1), and 7.40 (m, 5); mass spectrum (70 eV) *m/e* (rel intensity) 305 (M^+, 4), 260 (7), 248 (17), 247 (100), 219 (8), 218 (22), 205 (7), 191 (13), 190 (59), 177 (2), 174 (2), 159 (4), 149 (2), 148 (4), 128 (4), 120 (18), 119 (27), 99 (11), 81 (10), 77 (7), 72 (26), and 71 (24). *Anal.* Calcd for $C_{15}H_{19}N_3O_4$: C, 59.00; H, 6.24; N, 13.79. Found: C, 59.03; H, 6.33; N, 13.79.

3-Oxa-2,2-dimethyl-4-isobutoxy-8-phenyl-1,6,8-triazabicyclo-[4.3.0]nona-7,9-dione (IIb).—The experimental procedure followed was identical with that for IIa with isobutyl vinyl ether used in place of ethyl vinyl ether. The recrystallized light yellow product (47% yield) had the following characteristics: mp 125–126°; ir (KBr) (prominent absorbances) no NH, 2980–2880 (m, saturated CH), 1770 and 1710 (s, double C═O), 1600 (w), 740 (w), and 650 (m) (aromatic), 1170 (m), 1130 (s), 1090 (m), 1035 (s), and 1015 (m) (acetal ether linkages); nmr ($CDCl_3$) δ 0.95 (d, 6), 1.70 (s, 3), 1.85 (s, 3), 3.50 (m, 4), 5.00 (q, 1) and 7.42 (m, 5); mass spectrum (70 eV) *m/e* (rel intensity) 333 (M^+, 1), 276 (4), 275 (20), 261 (1), 260 (7), 219 (6), 218 (30), 191 (30), (100), 177 (1), 162 (1), 149 (1), 148 (1), 141 (1), 135 (2), 134 (1), 120 (15), 119 (22), 100 (2), 91 (8), 84 (5), 77 (5), 71 (18), 59 (24), 58 (3), 57 (30), and 56 (29). *Anal.* Calcd for $C_{17}H_{23}N_3O_4$: C, 61.30; H, 6.90; N, 12.61. Found: C, 61.49; H, 6.98; N, 12.47.

3-Oxa-2-spirocyclohexyl-4-ethoxy-8-phenyl-1,6,8-triazabicyclo-[4.3.0]nona-7,9-dione (III).—The experimental procedure followed was identical with that for IIa with a change in the work-up due to the high boiling point of cyclohexanone. The cyclohexanone was removed by vacuum distillation at 60°. The oily residue was dissolved in CH_2Cl_2 and added slowly to hexane as before. The gummy polymeric material formed was filtered and the filtrate was evaporated to obtain a white solid which was readily purified by recrystallization from absolute ethanol (12% yield, probably much higher but lost in the work-up). The white, needlelike crystalline solid exhibited the following characteristics: mp 170–171°; ir (KBr) (prominent absorbances) no NH, 2980–2860 (m, saturated CH), 1775 and 1715 (s, double, C═O), 1600 (w), 740 (m), and 685 (m) (aromatic), 1170 (m), 1150 (m), 1135 (s), 1070 (m), and 1020 (m) (acetal ether linkages); nmr ($CDCl_3$) δ 1.25 (t, 3), 1.50–2.80 (broad m, 11), 3.70 (m, 4), 5.10 (q, 1), and 7.40 (m, 5); mass spectrum (70 eV) *m/e* (rel intensity) 345 (M^+, 2), 300 (3), 248 (18), 247 (100), 219 (11), 218 (21), 214 (3), 205 (8), 191 (12), 190 (37), 177 (3), 162 (1), 149 (1), 148 (4), 135 (2), 128 (5), 121 (2), 120 (21), 119 (29), 99 (15), 91 (10), 81 (14), 77 (7), 71 (26), and 56 (16). *Anal.* Calcd for $C_{18}H_{23}N_3O_4$: C, 62.60; H, 6.67; N, 12.17. Found: C, 62.73; H, 6.76; N, 12.32.

3-Phenyl-6-vinyloxy-1,3,5-triazabicyclo[3.2.0]hepta-2,4-dione (IV).—Divinyl ether and PhTD were allowed to react according to the procedure followed in the previous reactions with the exception that methylene chloride was used in place of acetone as the reaction solvent. The reaction mixture was precipitated into 300 ml of hexane and the resulting solid (copolymer and IV) was removed by filtration. The filtrate was concentrated slightly *via* the water aspirator and then was placed into an ice–water bath. A white solid crystallized out and filtration of this solid yielded 0.15 g of pure IV: mp 128–129°; ir (KBr) (prominent absorbances) no NH, 1795 (m), 1730 (s), and 1710 (s) (C═O), 1645 (m), 1625 (m), 945 (m), and 810 (w) (vinyl ether), 1600 (w), 740 (m), and 685 (m) (aromatic); nmr ($CDCl_3$) δ 4.50 (m, 4), 5.81 (t, 1), 6.50 (q, 1), and 7.48 (s, 5); mass spectrum (70 eV) *m/e* (rel intensity) 246 (10), 245 (M^+, 69), 216 (3), 203 (6), 202 (9), 177 (8), 176 (9), 170 (3), 160 (3), 155 (8), 149 (17), 148 (6), 147 (12), 141 (16), 120 (22), 119 (100), 97 (5), 91 (23), 84 (5), 83 (14), 77 (8), 70 (44), 64 (4), and 57 (9). *Anal.* Calcd for $C_{12}H_{11}N_3O_3$: C, 58.80; H, 4.50; N, 17.20. Found: C, 58.88; H, 4.61; N, 17.24.

Registry No.—IIa, 30883-00-2; IIb, 30883-01-3; III, 30883-02-4; IV, 30883-03-5.

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[10] J. C. Stickler and W. H. Pirkle, *J. Org. Chem.*, **31**, 3444 (1966).