tion about the C–N bond. The other component of the expected doublet could be obscured by the δ 2.80 singlet. Identical results were observed with highly purified **3c** obtained from the reaction of **1c** with **2b**.

Anal. Calcd for $C_5H_8N_4O_3$: C, 34.9; H, 4.7; N, 32.6. Found: C, 35.1; H, 4.8; N, 32.7.

In a separate experiment, 10 g of the azo compound afforded 6.1 g of chloroform-soluble oil and 2.2 g of crude 4-methylurazole, mp 210–220°. A 0.50-g portion of the oil was distilled at 140° (0.1 mm) in a Kügelrohr distillation apparatus to give 0.23 g of colorless distillate which partially crystallized on standing. NMR and TLC established the material to be 1,3-dimethylurea: NMR δ 2.50 (d, J = 4 Hz), 5.8 (broad, NH). Several minor impurity peaks (<10%) were noted between δ 2.9 and 3.4. The extrapolated yield of distilled 1,3-dimethylurea from this experiment is 47%.

Decomposition of 0.25 g (1.7 mmol) of the azo compound at 180° in a flask connected to a gas buret gave 0.61 mmol (36%) of a mixture of CO and N_2. The mixture was determined to consist of 80% N_2 and 20% CO by comparison of peak heights in the high-resolution mass spectrum.

The presence of methyl isocyanate was detected in the gaseous products by carrying out the thermolysis of 1.0 g of **1c** in small portions and leading the effluent gases into a solution of 1.5 g of aniline in benzene. The benzene was evaporated and the residue was treated with 10 ml of 6 N HCl. The acid solution was extracted with chloroform. Evaporation of the chloroform gave a gummy residue that separated into two components with TLC. These components had the same R_f values as 1-methyl-3-phenylurea and trimethyl isocyanurate.

The complex mass spectrum of the thermolysis products (70 eV, 200°) included the following significant peaks: m/e (rel intensity, assignment) 198 (5, $7^{\cdot+}$), 115 (14, $4^{\cdot+}$), 88 (5, $CH_3NHCONH\text{-}CH_3^{\cdot+}$), 57 (50, $CH_3NCO^{\cdot+}$), 31 (5, $CH_3NH_2^{\cdot+}$), 30 (10), 28 (100).

Thermolysis of *N,N'*-Dimethyldiazenedicarboxamide (1c) in *o*-Dichlorobenzene. The azo compound (15 g) was suspended in 300 ml of *o*-dichlorobenzene and the suspension was stirred and heated under reflux for 1.5 hr. Filtration of the hot suspension afforded 6.1 g (41%) of crude *N,N'*-dimethyl-1,2-hydrazinedicarboxamide (**5a**), mp 227–232°. Identity was established by comparison of the ir spectrum and R_f values (TLC) with data from an authentic sample, mp 256° (lit.[7] mp 260°).

The cooled dichlorobenzene filtrate afforded a solid that was suspended in 30 ml of boiling ethanol. Filtration of the hot suspension gave 0.63 g (6%) of 3,7-dimethyl-2,4,6,8-tetraoxo-1,3,5,7-tetraazabicyclo[3.3.0]octane (**6**), mp 300–303°. Recrystallization from aqueous *N,N*-dimethylformamide gave white crystals: mp 303–304°; ir (KBr) 1760 cm^{-1}; mass spectrum m/e 198 (molecular ion); NMR (DMSO-d_6) δ 2.88 (s).

Anal. Calcd for $C_6H_6N_4O_4$: C, 36.4; H, 3.1; N, 28.3. Found: C, 36.5; H, 3.0; N, 28.5.

The cooled ethanol filtrate deposited 0.51 g (6%) of crude 1-methylcarbamoyl-4-methylurazole (**3c**), mp 176–182°. After recrystallization from ethanol, white crystals, mp 196–198°, were obtained. Identity was established by comparison of the ir spectrum with that of an authentic sample.

In a separate experiment, 3.0 g of the azo compound was decomposed as described above, giving 1.43 g of solid material which was insoluble in *o*-dichlorobenzene. The filtrate was evaporated in vacuo to give 0.42 g of an oil which partially crystallized on standing. The NMR spectrum of this material revealed it to be a complex mixture with 1,3-dimethylurea as the major component.

Decomposition of 0.50 g (35 mmol) as described above resulted in the evolution of 11 mmol (31%) of water-insoluble gases.

Preparation of 1-Methylcarbamoyl-4-methylurazole (3c). A solution containing 2.15 g (0.019 mol) of **2b**[5] and 2.74 g (0.019 mol) of **1c** in 100 ml of *o*-dichlorobenzene was heated and stirred under reflux for 2 hr. After decantation of the hot solution from a small amount of tarry material the cooled solution deposited 1.78 g (54%) of crude product (mp 164–185°) which on recrystallization from ethanol afforded 0.82 g of white crystals, mp 200–203°. An additional recrystallization raised the melting point to 204–206°. The NMR spectrum of the product was identical with that of the material isolated from the thermolysis of **1c**.

When heated at 230° for 12 hr, **3c** evolved methyl isocyanate and was quantitatively converted to 4-methylurazole, mp 225–228°.

Thermal Decomposition of 4-Methyl-3*H*-1,2,4-triazole-3,5(4*H*)-dione (2b). The triazoline[5] (0.5 g) was suspended in 5 ml of *o*-dichlorobenzene and heated under reflux with stirring for 2 hr. The solution was decanted from tarry material and allowed to evaporate. A yellow powder (0.2 g), mp 240–260°, was obtained which was identified as **6** from its NMR and ir spectra (no impurity peaks were noted in the NMR spectrum).

Thermolysis of *N,N'*-Dimethyldiazenedicarboxamide (1c) in Dimethyl Sulfoxide. A solution of 2.0 g of **1c** in 30 ml of dimethyl sulfoxide was heated at 120° for 22 hr. The solvent was removed in vacuo and the dark residue was treated with 10 ml of chloroform. Filtration yielded 0.55 g (36%) of crude 4-methylurazole (identified by ir and TLC), mp 195–203°. The filtrate deposited 60 mg of unidentified material, mp 225–228°. Evaporation of the chloroform gave a dark oil.

Thermolysis of *N,N'*-Diethyldiazenedicarboxamide (1b) in *o*-Dichlorobenzene. The azo compound[12] (1.5 g) was suspended in 30 ml of *o*-dichlorobenzene and heated under reflux with stirring for 1 hr. Stirring was continued at room temperature overnight. Filtration afforded 0.8 g of crude *N,N'*-diethylhydrazinedicarboxamide (**5b**), mp 230–235°. Identity was established by comparison of the ir spectrum with that obtained from an authentic sample,[13] mp 247–249°. Evaporation of the filtrate gave an uncharacterized oil.

Acknowledgment. We thank the donors of the Petroleum Research Fund, administered by the American Chemical Society, and the Research Foundation of State University of New York for support of this project. We are indebted to Professors Martin S. Gibson and Albert Padwa for providing the mass spectra. We also wish to acknowledge the cordial cooperation of Drs. J. E. Herweh and R. M. Fantazier in providing preprints of their diazenedicarboxamide results and valuable discussions.

Registry No.—**1b**, 18880-19-8; **1c**, 18880-14-3; **2b**, 13274-43-6; **3b**, 16050-65-0; **3c**, 55029-97-5; **5a**, 2937-76-0; **5b**, 2937-75-9; **6**, 55029-98-6; 1,3-dimethylurea, 96-31-1; 1-methyl-3-phenylurea, 1007-36-9; trimethyl isocyanurate, 827-16-7.

References and Notes

(1) Taken in part from S. B. Kaldor, M.S. Thesis, State University of New York College of Arts and Science at Geneseo, 1973.
(2) (a) R. F. Smith, T. C. Rosenthal, P. T. Hussong, and P. B. Buri, *Tetrahedron Lett.*, 4007 (1970); (b) S. Wawzonek, T. H. Plaisance, and D. P. Boaz, *Tetrahedron*, **28**, 3669 (1972).
(3) J. C. Bevington and A. Wabid, *Polymer*, **4**, 129 (1963).
(4) J. E. Herweh and R. M. Fantazier, *J. Org. Chem.*, **39**, 786 (1974). These authors have also investigated the photolytic decomposition of **1a**.[12]
(5) J. C. Stickler and W. H. Pirkle, *J. Org. Chem.*, **31**, 3445 (1966).
(6) R. Stolle, *Ber.*, **45**, 273 (1912). These reactions may involve the addition of thermally produced CONRCO radicals to the N=N bond of the triazoline.
(7) F. Arndt, L. Loewe, and A. Tarklan-Akon, *Rev. Fac. Sci. Univ. Istanbul*, **13A**, 127 (1948); *Chem. Abstr.*, **42**, 8190 (1948). We obtained a quantitative yield of **3b** by heating **5a** at 245–250° for 1.5 hr.
(8) C. M. Kraebel and S. M. Davis, *J. Org. Chem.*, **34**, 2226 (1969).
(9) Triazoline **2a** is extremely labile and decomposes to nitrogen, carbon monoxide, and isocyanic acid.[4] Thermal decomposition of **2c** to phenyl isocyanate, nitrogen, and carbon monoxide has been proposed[2b] to account for the products resulting from the thermolysis of *N,N'*-diphenyldiazenedicarboxamide.
(10) R. S. Gohlke and F. W. McLafferty, *Anal. Chem.*, **34**, 1281 (1962).
(11) K. E. Cooper and E. H. Ingold, *J. Chem. Soc.*, 1894 (1929).
(12) R. M. Fantazier and J. E. Herweh, *J. Am. Chem. Soc.*, **96**, 1187 (1974).
(13) R. Stolle, *Ber.*, **43**, 2470 (1910).

Nucleosides. XVII. Benzylation–Debenzylation Studies on Nucleosides

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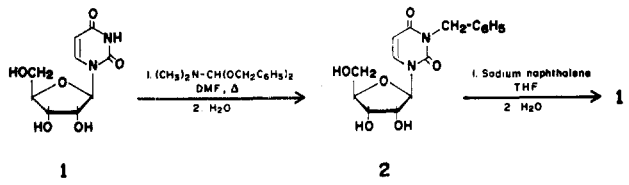
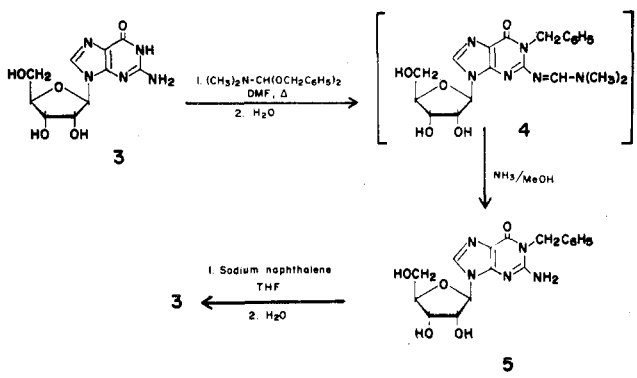
The present study was prompted by an internal need to develop a facile blocking–deblocking sequence of the –CONH– moiety in uridine (**1**) and guanosine (**3**) so that the corresponding (blocked) intermediates would be amenable to purification via anion exchange chromatography.

Scheme I



Scheme II



To this end, benzylation–debenzylation procedures were reexamined.

The benzylation of 1 with benzyl bromide and sodium hydride in either DMSO or DMF leads in low yield to a mixture of N^3-benzyluridine (2) and N^3-2′-*O*-dibenzyluridine,[1] although the latter can be hydrogenolyzed to 2. By contrast, 2 itself is resistant to hydrogenolysis in the presence of either Pd/C or $Pd/BaSO_4$.[1]

In the purine series, the monobenzylation of inosine can be accomplished with benzyl chloride in DMF containing sodium bicarbonate to give N^1-benzylinosine in 50% yield.[2] Only partial catalytic hydrogenolysis has been effected.[2]

The use of *N,N*-dimethylformamide acetals as alkylating agents of the acidic amide group of heterocyclic bases[3-6] and as esterifying agents for carboxylic acids[7,8] has been well documented. In cases of the neopentyl acetal, which is too hindered sterically to serve as an alkylating agent, intramolecular cyclization[9] and decarboxylative elimination of uronic acids[8,10] are observed.

It was found that uridine (1) is quantitatively converted into 2 by heating with *N,N*-dimethylformamide dibenzyl acetal in DMF for 3 hr at 80°, as indicated by TLC and paper chromatography; crystallization from THF gave an 85% yield of 2 (Scheme I).

Guanosine (3), treated under nearly identical conditions, gave the *N*-dimethylaminomethylene derivative 4 [uv λ_{max} (water) 315 nm] which was readily converted into N^1-benzylguanosine (5) by action of methanolic ammonia. The deblocked derivative 5 was chromatographically homogeneous, and crystallization from water gave N^1-benzylguanosine (5) in 76% yield (Scheme II). This product was assigned structure 5 on the basis of a comparison of its uv data at several pH values with the uv data of other alkyl (N^1-, N^7-, and O^6-) guanosine derivatives[11] together with the known alkylating properties of *N,N*-dimethylformamide acetals.

It is of interest to note that while uridine and inosine are readily N-methylated with *N,N*-dimethylformamide dimethyl acetal in DMF, guanosine (3) is not.[12] The fact that guanosine, by contrast, is readily benzylated can be explained by the increased reactivity of the dibenzyl acetal relative to that of the dimethyl derivative.

Sodium naphthalene has been used for the reductive cleavage of toluenesulfonates to regenerate the corresponding alcohols,[13] and more recently for the reduction of syn and anti oxime benzoates while maintaining the stereochemistry of the oxime.[14] We have found that sodium naphthalene in THF readily reduces both N^3-benzyluridine and N^1-benzylguanosine in good yield to give the parent compounds 1 and 3. Debenzylation of 2 was accomplished by treatment with an excess of sodium naphthalene in THF for 3 hr to give 1 in 84% yield after crystallization from water–methanol (Scheme II), and N^1-benzylguanosine (5) was similarly converted to guanosine in 76% yield (Scheme II).

N^3-Benzyluridine (2) and N^1-benzylguanosine (5) could readily be eluted from a Dekker column (Dowex-1, OH^-) by 50% methanol–water and 70% methanol–water, respectively, contrary to the behavior of uridine and guanosine,[15] indicating the absence of acidic protons (–CONH–) on the base and thus supporting the structural assignments of 2 and 5. Uridine and guanosine derivatives that are modified in the sugar moiety should readily be separable via this high-yielding benzylation–debenzylation procedure.

Experimental Section

General Methods. Evaporations were carried out in a Buchi rotary evaporator in vacuo. Melting points were determined on a Thomas-Hoover Unimelt capillary melting point apparatus and are uncorrected. Microanalyses were performed by M-H-W Laboratories, Garden City, Mich. Thin layer chromatography (TLC) in chloroform–methanol (9:1) was performed on 6 × 2 cm, precoated, silica gel F-254 aluminum foils (Merck, Darmstadt, Germany). Paper chromatograms were run by the descending method in isopropyl alcohol–ammonium hydroxide–water (7:1:2). Paper electrophoresis was conducted on a Savant electrophoresis flat plate using 0.02 *M* disodium hydrogen phosphate (pH 7.5) as a buffer on Whatman No. 1 paper at 40 V/cm for 1 hr. Uv-absorbing compounds were detected using a Mineralight lamp. Optical rotations were determined with a Perkin-Elmer Model 141 polarimeter. Uv spectra were measured on a Cary Model 11 spectrophotometer. *N,N*-Dimethylformamide was dried with Linde molecular sieves, 4A. *N,N*-Dimethylformamide dibenzyl acetal was a product of Fluka, Switzerland.

Sodium Naphthalene. Sodium chips (0.9 g, 40 mmol) and naphthalene (5.24 g, 41 mmol) were placed in a flask under a nitrogen atmosphere, and dry THF (100 ml) was added with a syringe. The mixture, which began to turn green immediately indicating the presence of the radical anion, was magnetically stirred (glass-covered stir bar) for 12 hr to ensure complete dissolution of the sodium. The solution was stored under a nitrogen atmosphere and was assumed to have a concentration of 0.35 *M*. Aliquots were removed under nitrogen by syringe and added to the reaction mixtures under nitrogen.

N^3-Benzyluridine (2). Uridine (1, 1.0 g, 4.1 mmol) was coevaporated with DMF (2 × 10 ml) to remove traces of water, and DMF (30 ml) and *N,N*-dimethylformamide dibenzyl acetal (5.2 ml, 20 mmol) were added. The reaction mixture was heated at 80° for 3 hr and evaporated, and the resulting syrup was kept in water (20 ml) for 1 hr at room temperature to destroy any 2′,3′-orthoamide formed. The aqueous solution was evaporated and the semisolid was crystallized from THF: yield 1.2 g (85%); mp 172–173° (lit.[1] mp 175.5–176.5); $[\alpha]^{25}D$ +20° (*c* 0.5, water); λ_{max} (pH 1) 263 nm (ϵ 8300), λ_{min} 235 nm (ϵ 2700); λ_{max} (pH 11) 263 nm (ϵ 7300), λ_{min} 234 nm (ϵ 2400); NMR (DMSO-d_6 + D_2O) δ 3.47 (m), 3.83 (m, 2, H-3′,4′), 4.98 (s, 2, $CH_2C_6H_5$), 5.72 (m, 2, H-1′ + H-5), 7.14 (broad s, 5, $CH_2C_6H_5$), 7.78 (d, 1, H-6, $J_{5,6}$ = 8 Hz). The compound was homogeneous by TLC, paper chromatography, and paper electrophoresis.

N^1-Benzylguanosine (5). Guanosine (3, 1.0 g, 3.5 mmol) was evaporated with DMF (2 × 10 ml) to remove traces of water, and DMF (25 ml) and *N,N*-dimethylformamide dibenzyl acetal (4.7 ml, 18 mmol) were added. The reaction mixture was heated for 5 hr at 80° and then evaporated to a pale yellow syrup. This syrup was taken up in water (50 ml) and kept for 1 hr at room temperature to destroy any 2′,3′-orthoamide formed; the aqueous solution was evaporated to give a yellow syrup whose uv spectrum showed a strong absorption at 315 nm, indicating that the *N*-dimethylaminomethylene derivative 4 had been formed. The syrup was kept in MeOH–NH_3 (saturated at 0°) for 24 hr at ambient temperature, after which time the peak at 315 nm disappeared completely. The

solution was evaporated to dryness and crystallized from water to give 0.99 g (76%) of **5**: mp 149–150°; $[\alpha]^{25}D$ −36° (*c* 0.5, water); λ_{max} (pH 1) 258 nm (ε 12,000); λ_{min} 231 nm (ε 3700), 280 s (7100); λ_{max} (pH 11) 256 nm (ε 14,000), λ_{min} 229 nm (ε 4200), 280 s (7900); NMR (DMSO-d_6 + D_2O) δ 3.5–4.4 (broad m), 5.18 (s, 2, $CH_2C_6H_5$), 5.68 (d, 1, H-1′, $J_{1',2'}$ = 6.0 Hz), 7.18 (broad s, 5, $CH_2C_6H_5$), 7.89 (s, 1, H-8). The compound was homogeneous by TLC, paper chromatography, and paper electrophoresis.

Anal. Calcd for $C_{17}H_{19}N_5O_5$: C, 54.68; H, 5.13; N, 18.76. Found: C, 54.37; H, 5.34; N, 18.34.

Debenzylation of N^3-Benzyluridine (2). Sodium naphthalene in dioxane (7.7 ml, 2.7 mmol) was added to **2** (100 mg, 0.30 mmol) in dioxane (20 ml) under nitrogen, and the mixture was stirred for 3 hr, after which time TLC indicated complete disappearance of **2**. The solution was left open to the atmosphere until the green color disappeared and then evaporated to dryness. The solid was washed with diethyl ether (3 × 10 ml) to remove the naphthalene and then taken up in water and treated with Amberlite IR 120 (H^+) to remove the sodium ions. The resin was removed by filtration and washed with water (10 ml), and the combined filtrates were evaporated to a solid that was recrystallized from water–methanol to give **2** (78 mg, 84%) which was identical in all respects with uridine.

Debenzylation of N^1-Benzylguanosine (5). The debenzylation of **5** (50 mg, 0.13 mmol) in THF (20 ml) with sodium naphthalene in THF (3.3 ml, 1.2 mmol) was carried out as described for N^3-benzyluridine (**2**) except that sodium ions were removed with Dowex 50 (pyridinium), yield 28 mg (76%).

Ion-Exchange Chromatography. Samples of N^3-benzyluridine (**2**, 5 mg) and N^1-benzylguanosine (**5**, 5 mg) were applied to analytical ion-exchange (Dowex 1, OH^-) columns as described by Dekker.[15] N^3-Benzyluridine was readily eluted in 50% methanol–water and N^1-benzylguanosine in 70% methanol–water.

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Registry No.—**1**, 58-96-8; **2**, 14985-34-3; **3**, 118-00-3; **4**, 55043-74-8; **5**, 55043-75-9; *N,N*-dimethylformamide dibenzyl acetal, 2016-04-8.

References and Notes

(1) N. Imura, T. Tsuruo, and T. Ukita, *Chem. Pharm. Bull.*, **16**, 1105 (1968).
(2) E. Shaw, *J. Am. Chem. Soc.*, **80**, 3899 (1958).
(3) J. Žemlička, *Collect. Czech. Chem. Commun.*, **28**, 1060 (1963).
(4) A. Holý, S. Chládek, and J. Žemlička, *Collect. Czech. Chem. Commun.*, **34**, 253 (1969).
(5) J. Žemlička, *Collect. Czech. Chem. Commun.*, **35**, 3572 (1970).
(6) A. Holý, R. Bald, and N. D. Hong, *Collect. Czech. Chem. Commun.*, **36**, 2658 (1971).
(7) H. Brechbühler, H. Büchi, E. Hatz, J. Schreiber, and A. Eschenmoser, *Helv. Chim. Acta*, **48**, 1746 (1965).
(8) J. Žemlička, R. Gasser, J. V. Freisler, and J. P. Horwitz, *J. Am. Chem. Soc.*, **94**, 3213 (1972).
(9) J. Žemlička, *Collect. Czech. Chem. Commun.*, **33**, 3796 (1968).
(10) K. D. Philips, J. Žemlička, and J. P. Horwitz, *Carbohydr. Res.*, **30**, 281 (1973).
(11) P. B. Farmer, A. B. Foster, M. Jarman, and M. J. Tisdale, *Biochem. J.*, **135**, 203 (1973).
(12) J. Žemlička and A. Holý, *Collect. Czech. Chem. Commun.*, **32**, 3159 (1967).
(13) W. D. Closson, P. Wriede, and S. Bank, *J. Am. Chem. Soc.*, **88**, 1581 (1966).
(14) J. C. Philips and C. Perianayagam, personal communication.
(15) C. A. Dekker, *J. Am. Chem. Soc.*, **87**, 4027 (1965).

Photochemical Reaction of α,β-Epoxy Esters in Protic Solvent

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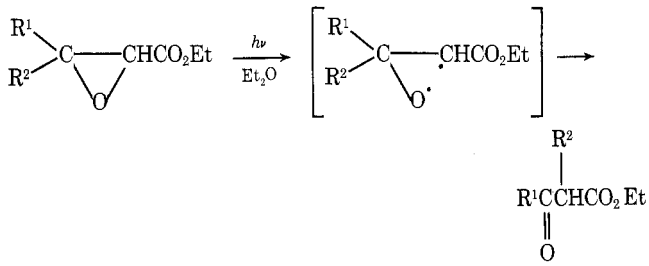
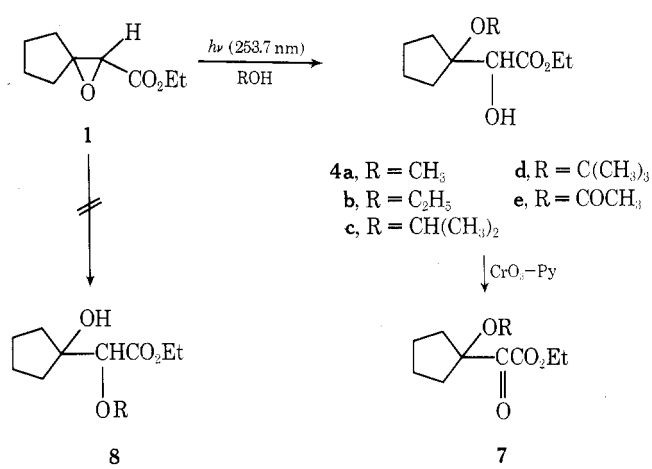
It was previously reported that α,β-epoxy esters with simple alkyl substituents were rearranged to the corresponding β-keto esters when they were irradiated in an aprotic solvent such as diethyl ether and carbon tetrachloride.[1] These transformations have been also reported in various types of α,β-epoxy ketones, and the mechanism involved may well be a homolytic fission of α carbon–oxygen bond followed by a transfer of β-alkyl substituent.[2] The present investigation was undertaken to determine whether homolytic fission of the epoxy ring would preferentially occur even when irradiated in a protic solvent.



Irradiation of ethyl 1-oxaspiro[2,4]heptane-2-carboxylate (**1**) in methanol with 253.7-nm light produced α-hydroxy ester **4a** in a 67% yield. The structure of **4a** was determined by NMR spectroscopy and an oxidation reaction. The NMR spectrum of **4a** in DMSO-d_6 exhibits a doublet at δ 5.47 (J = 5.8 Hz) attributable to the hydroxyl proton, which indicates the presence of a secondary hydroxyl group.[3] Oxidation with chromium trioxide–pyridine complex yielded α-keto ester **7a**. Acid-catalyzed thermal reaction of **1** in methanol produced **4a** and ethyl 2-hydroxy-2-(1-cyclopentenyl)acetate. From these results it is concluded that the alternative product (**8**) is not produced in this reaction. Dark reaction of **1** in methanol for 15 days was confirmed not to provide a detectable amount of **4a**. Irradiation of **1** with a high-pressure mercury vapor lamp produced only a small amount of **4a** because of the secondary photolytic decomposition of the product.



Irradiation of **1** in several protic solvents produced the corresponding α-hydroxy esters (**4a–e**). These results are summarized in Table I. Dark reaction in acetic acid under the same conditions produced a 75% yield of **4e** in a 31% conversion. The lower yield of **4e** in the photochemical reaction is due to the fast photolytic decomposition of the product. On the other hand, the lower yields of **4c** and **4d**[4] are probably due to the weak nucleophilicities of 2-propanol and 2-methyl-2-propanol, because the acid-catalyzed thermal reactions in both solvents produced low yields of **4c** and **4d**.

Ethyl 1-oxaspiro[2,5]octane-2-carboxylate (**2**) and ethyl 3-methyl-3-ethyl glycidate (**3**) also produced the corresponding α-hydroxy-β-methoxy esters **5a** (26%) and **6a** (34%) in 66 and 96% conversions, respectively, when irra-