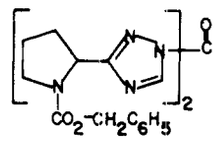
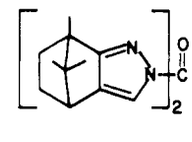


VII



VIII

Acknowledgments. We thank Professor C. S. Foote for his encouragement, advice, and aid in the determination of $^1O_2$. Financial support was provided by the National Science Foundation.

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A Convenient Photosynthesis of Aziridinopyrrolo[1,2-*a*]benz[*f*]indoloquinone and Heterocyclic Quinones as Model Compounds of Mitomycins by a One-Pot Reaction

Summary: The photochemical reactions of 3-chloro-2-bis-(ethoxycarbonyl)methyl-1,4-naphthoquinone with various secondary amines provide a convenient, one-pot, preparative route to the title compounds (4) in good yields.

Sir: Recently we reported an example of a novel type of photoinduced intramolecular cyclization in various solvents using amino-1,4-naphthoquinones possessing an active methylene group at the 2 position to form indoloquinones.[1] In this communication we wish to describe a novel route to aziridinopyrrolo[1,2-*a*]benz[*f*]indoloquinone, a model compound of mitomycins, and related compounds by a one-pot reaction utilizing this procedure.

A solution of aminoquinones (**2a–e**)[2] prepared from the reaction of 3-chloro-2-bis(ethoxycarbonyl)methyl-1,4-naphthoquinone (**1**)[3] with various amines (pyrrolidine, piperidine, morpholine, hexamethylenimine, and diethylamine) in ethanol was irradiated with a high-pressure mercury arc lamp through Pyrex glass in a stream of nitrogen for 1–2 h (Scheme I). After allowing the irradiated solution of **2a–e** to stand for more than 24 h at room temperature followed by evaporation of the solvent, ring-closed quinones (**4a–e**) were obtained in high yields. In the case of **2e**, **5e**[4] was isolated as a minor product along with **4e**.The results are summarized in Table I. The structural assignments for **4a–f** were based on their analytical and spectral properties, which were in good agreement with their formulations. Their ^1H NMR spectra revealed the presence of a bridgehead methine proton at 4.50–5.00 ppm instead of an active methine.

We have also extended this photocyclization reaction to a simple synthesis of an aziridine-containing pyrroloindoloquinone ring system. A similar photoreaction[5] using 6-(4-bromophenyl)-3,6-diazabicyclo[3.1.0]hexane[6] as an amine gave aziridinopyrrolo[1,2-*a*]benz[*f*]indoloquinone (**4f**) in 63% yield, mp 189–191 °C (from ethanol). The stereochemistry of this compound was determined by ^1H NMR analysis. The

Scheme I

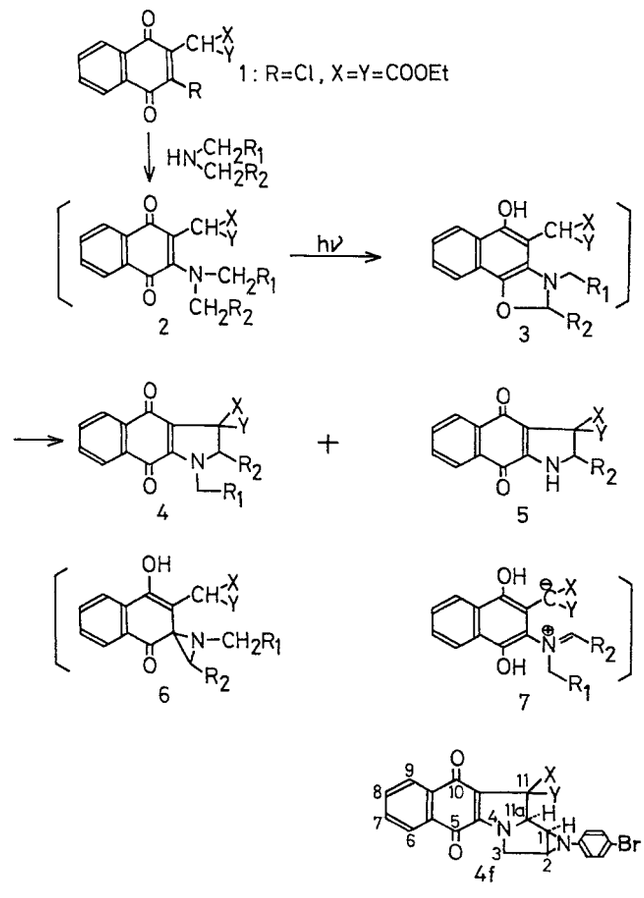
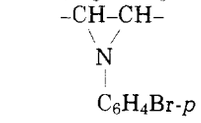


Table I. Photoproducts from Active Methylene-Containing Amino-1,4-naphthoquinones by a One-Pot Reaction

Substrate	R_1 R_2	Product	Mp, °C	Yield, %	NMR bridgehead CH, ppm	Mass (*m/e*), M^+
2a	$-(CH_2)_2-$	**4a**	158	70	4.80 (d, d)	383
b	$-(CH_2)_3-$	**b**	158	73	5.00 (d, d)	397
c	$-CH_2OCH_2-$	**c**	133	75	4.60 (d, d)	399
d	$-(CH_2)_4-$	**d**	137–139	78	4.50 (d, d)	411
e	CH_3 CH_3	**e**	oil	55	4.78 (q)	385
f		**f**	189–191	63	5.01 (d)	550

results from a 100-MHz NMR spectrum of **4f** in $CDCl_3$, together with those from a double irradiation experiment, permitted assignment of all of the proton signals and the determination of proton–proton coupling constants. The C-3 methylene protons at 4.52 and 3.56 ppm couple with the C-2 methine proton at 2.90 ppm unequally. In addition, the dihedral angle of H–C(2)–C(3)–H is 90°, since the vicinal coupling constants $J_{2,3} \simeq 0$, consistent with the molecular geometry[7] for the solid phase indicated by x-ray analysis for the *N*-brosyl derivative of mitomycin A and $J_{2,3} = 2.5$ Hz.[8] On the other hand, the C(11a) methine proton at 5.01 ppm has a coupling of 2.5 Hz with the C(1) methine proton at 3.24 ppm. Therefore, the stereochemistry of the C(1) and C(11a) methine protons were assigned as a cis configuration, the same as that of mitomycin. The observed value of $J_{1,2} = 4.5$ Hz is also consistent with the cis coupled aziridine ring proton.[9] It is noteworthy that this photocyclization appears to be stereoselective, giving only one diastereomer.

Several reactions involving abstractions of hydrogen from the side chains of quinone have been reviewed previously.[10] The interest in the photochemistry of these and related systems has continued. To date, only a few examples of such photoreactions[11] were reported on quinones bearing certain secondary amino substituents. The photochemical formation of the ring-closed quinones presumably involves intramolecular hydrogen abstraction by the excited quinones as the first step. Subsequently the biradical[12] could lead to benzoxazoline (**3**)[13] via spiroaziridine species **6**[14] by hydrogen transfer, ring closure, and aromatization. In polar solvents, under conditions which might be expected to favor a zwitterion intermediate (**7**) (**3** ⇌ **7**), **7** undergoes the intramolecular nucleophilic attack to give ring-closed quinones followed by oxidation. In an attempt to trap the intermediate (**3**) in the photoreaction, **2f** was photolyzed in ethanol at low temperature (0–5 °C), giving unstable aziridinonaphthoxazoline (**3e**)[4] as a sole product. After allowing the solution of **3e** to stand in ethanol for a long time at room temperature, **4f** was obtained in a good yield. As shown in Table I, yields in the ring-closed quinone series increase with increasing size of the amino-containing ring. These facts may be rationalized by the ease of proton transfer from the methylene of the amino group, which would be held close to the quinone carbonyl in the excited state.

We believe that this photoinduced reaction of amino-substituted quinone may be of great utility in the simple synthesis of heterocyclic quinones in comparison to the Nenitzescu reaction.[15] The consecutive reactions (amino substitution, photolysis, and ring conversion) described above could also be carried out continuously as a one-pot reaction. For the purpose of the total synthesis of mitomycins,[16] the implication of the one-pot reaction in the photolysis of aminotoluquinones is being studied and will be reported elsewhere.

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