Nitrosamine Photolysis as a Synthetic Method: The Addition of Aminium Radicals to Unsaturated Carbon – Carbon Bonds

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Acid complexed nitrosamines decompose from their lowest singlet excited state to give aminium radicals and nitric oxide radical transients. Aminium radicals initiate addition to various unsaturated groups to give 1-amino-2-nitroso compounds under an inert atmosphere, or 1-amino-2-nitrates under oxygen. In this report, photoaddition of nitrosamines to olefins, acetylenes and fused aromatic hydrocarbons, and the subsequent transformations of the intermediates are described. Aminium radical initiated intramolecular cyclization to prepare tetracyclic aza compounds is also described. While photoaddition of nitrosamines to 4-propenylanisole or 3-butenol was efficient, that to 3-butenyl benzoates under oxidative conditions was only fair, obviously due to the presence of a benzene

ring. The oxidative photoaddition to 3-butenyl halide was followed by spontaneous cyclization to an azaspiro compound. The photoaddition to phenyl-substituted acetylenes gave β -nitroso enamines which hydrolyzed to diketomonoximes under neutral conditions but decomposed extensively under acidic conditions. Certain fused aromatic hydrocarbons acted as singlet sensitizers as well as substrates to induce similar addition giving amino nitroso adducts. These adducts took different courses of conversion dependent on reaction conditions, and on steric and electronic factors.

Some years ago¹⁻³ we discovered that *N*-nitrosodialkylamines add efficiently across a carbon – carbon double bond under photolysis in acidic solution but not in neutral solution. That is, these nitrosamines are photolabile only in acidic solution.¹

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Scheme 1.

In the ensuing investigation, we established that the aminium radicals are the reactive intermediates involved in this photoaddition^{4,5} and that they are generated from the lowest singlet excited state of acid-complexed nitrosamines,⁶ and that the photoaddition occurs by a stepwise radical addition.^{4,5} The reaction pattern is summarized in Scheme 1. Photoaddition carried out under nitrogen gives α -amino oximes *via* the nitroso intermediate.^{4,5} However, under oxygen the photoaddition is cleanly diverted to the formation of α -amino nitrates presumably *via* the peroxyxynitrite intermediates.⁷⁻¹⁰ In a series of publications, the efficiency and applicability of the oxidative and non-oxidative photoaddition to olefins in preparations of various oximes, aminonitrates and amino alcohols have been described.⁴ We now report the photoaddition of *N*-nitrosodimethylamine (NND) and *N*-nitrosopiperidine (NNP) to various unsaturated compounds, and certain accompanying complications.

RESULTS AND DISCUSSION

(1) *Photoaddition to olefins.* In analogy to previously reported photoadditions of nitrosamines to olefins,¹⁻³ photoaddition of NND to 4-propenylanisole (*1*) in acidic solution under nitrogen gave *syn*-1-(*p*-methoxyphenyl)-2-*N,N*-dimethylaminopropan-1-one oxime (*2s*), the corresponding *anti*-isomer (*2a*) and 1-(*p*-methoxyphenyl)-1-*N,N*-dimethylaminopropan-2-one oxime (*3*) in 68, 11 and 3% isolated yields, respectively. The structures of these oximes were determined from their elemental analysis as well as spectroscopic data as given in the Experimental section. The *syn-anti* configuration of *2s* and *2a* were decided by the NMR quartets for the methine

protons at 3.55 and 3.27 ppm according to the correlation of α -proton signals of oximes proposed previously.¹¹ The minor oxime *3* exhibited a methyl singlet at 1.38 ppm because of a methyl ketoxime structure. In agreement with the aminium radical initiated addition to the conjugated double bond¹² the attack occurs predominantly at the β -carbon of *1* to yield the more stabilized benzyl radical intermediate leading to oximes *2s* and *2a*. Regioselectivity is not complete, however, yielding a small amount of *3*.

The oxidative photoaddition of NNP was demonstrated using 3-butenol and 3-butenyl esters as substrates. The photolysis was carried out in the presence of one of the 3-butenyl derivatives *4a-4h* under constant oxygen purging. These photoadditions yielded the amino nitrates *5* and the amino alcohols *6* in nearly a 1:1 ratio. Only in the case of the addition to 3-butenol, *5a* and *6a* were separated by taking advantage of their solubility difference. In the photoaddition to *4b-4g*, the crude products were reduced with lithium aluminum hydride to *6a* or by catalytic hydrogenation to give the corresponding amino alcohols *6*. The presence of the nitrates *5* and alcohols *6* in each crude product could be recognized from the NMR quintet signal for the methine protons and pertinent IR absorptions at 1630, 1280 and 865 cm^{-1} for a nitrate group^{7,8} and 3440 and 1045 cm^{-1} for a hydroxyl group in addition to the typical absorptions for other functionalities. The ratios of *5:6* could be estimated from the NMR triplet of the C-4 protons. In contrast to the good yields of the photoadducts from *4a* and *4b*, the yields from benzoates *4c, 4d* and *4e* were low and that from tosylate *4f* was nil. The cause of the yield variation merits further investigation.

The percent yields of amino alcohols *6* were surprisingly high in comparison to the cases of the

	X	%yields of 5 and 6
4a	OH	72
4b	OCOCH ₃	80
4c	OCOC ₆ H ₄ CH ₃ (<i>p</i>)	26
4d	OCOC ₆ H ₄ OCH ₃ (<i>p</i>)	32
4e	OCOC ₆ H ₄ CN(<i>p</i>)	33
4f	OSO ₂ C ₆ H ₄ CH ₃ (<i>p</i>)	0

oxidative photoaddition to simple olefins where amino nitrates were always obtained as the major product.^{7,8} Undoubtedly, the ester groups at the C-4 position intervene in an intramolecular displacement, probably at the peroxyxynitric stage, to give solvolysis products.

Oxidative photoaddition of NNP to 3-butenyl chloride and bromide in the presence of perchloric acid proceeded smoothly to give the perchlorate of 2-nitrato-5-azoniaspiro[4,5]decane (8) in 38 and 46%, respectively, which was isolated by continuous extraction with methylene chloride. No doubt the azaspiro compound 8 was derived from the expected nitrate ester 7, the primary photoaddition product, by cyclization. The hydroxy compound corresponding to 8 was also formed but could not be isolated. The structure 8 was confirmed by analysis and NMR decoupling experiments which unraveled the coupling patterns of the C-1, C-2 and C-4 protons; the details of the decoupling results are described in the thesis presented by Pillay.¹³

(2) *Photoaddition to acetylenes.* Photolysis of NNP in the presence of diphenylacetylene¹⁴ under nitrogen also proceeded rapidly to give benzil monoxime (9) in 61% yield. Similar photolysis in the presence of phenylacetylene gave phenylglyoxal

ketoimine 10 in 65% yield only when the photolysis was carried out at dry ice-methanol temperature and the photolysate was neutralized with sodium carbonate immediately after the photolysis. Similar photolysis without these precautions yielded ketoimine 10 in 27% yield in addition to 2,2'-dimethoxyacetophenone (11, 22%), 2-methoxy-2-piperidinoacetophenone oxime (12, 24%) and phenylglyoxal dioxime (13, 9%). These phenylglyoxal derivatives were most likely formed by acid-catalyzed addition of methanol, substitution and/or transoximation from the primary photoadduct 14, a β -nitroso enamine.

Both ketoimines 9 and 10 were derived from hydrolysis of the primary photoadduct, the β -nitroso enamine 14, that occurred readily under neutral or slightly basic conditions. As the intermediate 14 contained a β -nitroso enamine, a chromophore which would certainly absorb in the 300–350 nm region, a light filter with cutoff at 320–340 nm was used in order to minimize the secondary photodecomposition of 14. Indeed, when a Pyrex filter was used, the yields of ketoimines 9 and 10 were much lower and many minor products were obtained.

Compound 10 exhibited interesting tautomerization behavior between phenylglyoxal ketoimine 10 and the dimer of 1-nitroso-2-hydroxystyrene (10a). A chloroform solution of the compound exhibited a strong carbonyl absorption at 1700 cm⁻¹ indicating the existence of ketoimine form 10. Evaporation of

chloroform left an oil which crystallized to give **10**, m.p. 48.5–50.0, IR absorption in Nujol at 1705 cm^{-1} . The crystals gradually transformed at room temperature to another crystal, m.p. 113–115°C, showing IR absorption at 1210 (s) and 1590 (m) cm^{-1} indicating the presence of the *trans*-dimeric structure **10a**. Dissolution of **10a** in various organic solvents caused tautomerization to give **10** as shown by its NMR and IR spectra. Sublimation of **10a** gave **10** and slow crystallization of **10** from chloroform gave **10a**.

Other alkylacetylenes, such as 1-hexyne, were also used as substrate in the photoaddition but gave no products that could be extracted with a variety of solvents. While water soluble products were formed, attempts to isolate them have not been successful.

(3) *Sensitized photoaddition to aromatic hydrocarbons.* Photolysis of NNP in the presence of benzene, toluene, anisole and benzonitrile in acidic solution causes a rapid decomposition of the nitrosamine but gives no addition product to the benzene derivatives. Careful analysis shows that piperidine is the only isolable product. The reason for the lack of addition may be that the attack of the aminium radical on the π -system of the benzene rings requires a higher activation energy than those required in other processes, *e.g.*, the hydrogen abstraction from methanol. Fused aromatic hydrocarbons would provide sites of a less delocalized double bond and higher electron densities; such double bonds could be attacked by aminium radicals to cause photoaddition. Fused aromatic hydrocarbons generally absorb light strongly in the 300–400 nm region^{15,16} and it is impractical to design a photoreaction in which nitrosamines (absorption maximum at 345 nm) are excited in the primary photoexcitation. It also occurred to us that since most of these aromatic hydrocarbons possess substantial fluorescence quantum yields¹⁵ and reasonably long singlet lifetimes,¹⁶ it might be possible to use certain aromatic hydrocarbons as singlet sensitizers as well as substrates to carry out the photoaddition. NND (and other nitrosamines) has the lowest excited singlet state at about 75 kcal/mol and the lowest triplet state energy of 59 kcal/mol;⁶ a classical sensitization mechanism by energy transfer from the singlet state of these hydrocarbons is thus possible.

Our conclusion that nitrosamines photolytically dissociate from their lowest singlet state was further supported by the failure of benzophenone¹⁶ ($\tau_s < 10^{-12}$ s, $\phi_F = 0$, $\phi_{ISC} = 1.00$), an excellent

triplet sensitizer, to sensitize the photodecomposition of NNP in acid solution. Anthracene sensitized photolysis of NNP in acidic ethanol under helium gave 9-piperidinoanthrone oxime¹⁷ (**16**) in a 70% yield and a small amount of 9-ethoxyanthrone oxime (**18**) in addition to trace amounts of unidentified compounds. The photolysis solution contained a low concentration of NNP (0.014 M) so that more than 95% of the incident light was absorbed by anthracene. It was obvious that the oxime **16** was a tautomeric product of the primary photoadduct **15**. The oxime **18** was a secondary photolysis product since under similar photolysis conditions oxime **16** was slowly converted to **18**. The photoconversion could be explained by the elimination of piperidinium ion followed by the addition of ethanol to 9-nitrosoanthracene (**17**). The assigned structures for **16** and **18** were supported by analysis and spectroscopic data. When a similar sensitized photoreaction was repeated in the presence of cyclohexene or *cis*-4-methyl-2-pentene, only trace amounts of the addition products to olefins^{1,2} were obtained but **16** was isolated as the major product. Nitrosamines are known to form loose collision complexes with aromatic π -electron systems in solution.¹⁸ Such complexes conceivably

facilitate the sensitization process as well as the addition to anthracene. The process may be represented by the mechanism (1), where *A* is anthracene having ¹⁶ $E_s = 76.3$ kcal/mol, $\phi_f = 0.27$ and $\tau_s = 5$ ns.

Sensitized photoaddition of NNP to 1,4-dimethylantracene (19) in acidic methanol gave 1,4-dimethyl-9-piperidino-10-methoxy-9,10-dihydroanthracene (20, 48%) and a trace of 2,4-dimethyl-9-piperidino-10-hydroxy-9,10-dihydroanthracene (21). The stereochemistry of these two compounds was not determined. It is simplest to assume that these products arise from the nucleophilic substitution of the nitroso group in the primary photoadduct (*i.e.* the 1,4-dimethyl analogue of 15) by methanol or water. The intermediate C-nitroso compound would be difficult to tautomerize to the corresponding oxime because of the steric crowding from the methyl group at the *peri*-position. The steric hindrance of the dimethyl group is also reflected by the low yields of the products. In these photoreactions, the dimers¹⁹ of the anthracenes were also formed. The photoaddition of nitrosamines to 1,3-dimethylantracene and 1,2-benzanthracene also gave the corresponding products in low yields; these results and experiments are described in the thesis presented by C. J. Colon.²⁰

Sensitized photoaddition of NNP to pyrene (22), $E_s = 79$ kcal/mol, $\tau_s = 450$ ns, $\phi_f = 0.58$ ¹⁶ in acidic

methanol solution proceeded rapidly to give blackish solution and could not be carried to completion. It gave 4-piperidinopyrene 23 in 52% yield together with some recovered pyrene from the neutral extract. While the spectroscopic data could not indicate the complete structure, the substitution at C-4 was deduced on the basis that the π bond at C-4,5 is localized more than others for ozone addition and is probably just as susceptible to an electrophilic radical attack. Obviously 23 was formed from the C-nitroso intermediate, the primary adduct corresponding to 15, by elimination of HNO. Mechanistically the elimination could occur either by acid catalysis or sensitized photolysis. The driving force for the elimination may be ascribed to the tendency to achieve extended conjugation. Interestingly, sensitized photoaddition of NNP to phenanthrene gave only a trace amount of a piperidinophenanthrene and was not pursued further.

Acenaphthene is not exactly a fused aromatic but it structurally resembles these compounds. As it possesses no absorption > 320 nm, irradiation of a mixture with nitrosamines is more likely to cause direct excitation of the nitrosamines. Photoaddition of NND to acenaphthene (24) in acidic methanol under nitrogen gave 2-dimethylamino-acenaphth-1-one oxime (27, 51%) in addition to large amounts of the dimer of acenaphthene²² and acenaphthoquinone (28). The oxime fraction consisted of *anti* and *syn* isomers in a 7:3 ratio and only *anti*-25 was isolated in the pure state. The stereochemistry was deduced from the chemical shifts of the methine and methyl protons in the NMR spectra.¹¹ The *anti*-oxime exhibited the singlets at 5.22 and 2.14 ppm while the *syn*-oxime showed the corresponding signals at 5.43 and 2.42 ppm. The copious yield of acenaphtho-

quinone 28 was surprising and indicated that oxidizing species were formed during photolysis.

(4) *Intramolecular photoaddition.* We have demonstrated that a $\Delta^{4,5}$ -alkenylaminium radical generated from the corresponding nitrosamine efficiently cyclizes exclusively to form a five-membered pyrrolidine intermediate, that is, the aminium radical center intramolecularly attacks the C-4 of the olefin exclusively.²³⁻²⁵ It was also shown that such a C-radical intermediate can be scavenged by oxygen to form a nitrate ester and by bromotrichloromethane to form a bromo compound as the final product.²⁵ Applications of this process for synthesis of azapolycyclic oximes, nitrates and bromides have been reported.^{24,25} The synthesis of a tetracyclic aza compound is described here.

The tricyclic nitrosamine 31 was prepared from readily available *endo*-norbornene-*cis*-5,6-dicarboxylic anhydride (29) by a four-step operation as described in the Experimental section. Photolysis of 31 in acidic methanol under oxygen was expected to give, by the oxidative intramolecular aminium radical addition, the nitrate ester which was reduced by LAH to give a good yield of tetracyclic amino alcohol 32; this compound was oxidized to the corresponding ketone 34. When a similar photolysis of nitrosamine 31 was carried out in the presence of bromotrichloromethane, the tetracyclic amine bromide 33 was isolated in 46% yield. The structures of these tetracyclic aza compounds were decided from analysis and spectral data. The configuration of the OH and Br groups in 32 and 33 was determined from the NMR coupling pattern of the geminal proton, H_e, which was shown not to be, or only weakly, coupled to the adjacent proton H_a and to be coupled by a long range spin-spin

interaction with H_c; the information was gained by extensive decoupling experiments with the aid of an Europium shift reagent. The details and spectra were described in the thesis written by R. L. Lockhart.²⁶

CONCLUSION

The examples described above demonstrate that photoexcited nitrosamines are a good source of aminium radicals and react readily with various unsaturated systems to give 1-amino-2-nitroso compounds or 2-aminonitrates depending on the presence or absence of oxygen. These C-nitroso compounds exhibit some interesting chemistry and may reveal even more unexpected behavior when the nitroso group is in conjugation with other functional groups. The photoaddition is a valuable general method for synthesis of C-nitroso compounds; their preparation as well as their chemistry have not been investigated extensively. Unfortunately, *nitrosamines are carcinogens*²⁷ and, thus, utmost precaution is required for their handling.

Aminium radicals can be generated by thermal or photolytic decomposition of chloramines in highly acidic media, *e.g.*, 2 M H₂SO₄ or higher in acetic acid.²⁸ Nitrosamine photolysis is a much milder method for aminium radical generation and a more amenable method for the investigation of aminium radical reactivity. Because of propensity to attack a π -bond over hydrogen abstraction from alkyl or allyl groups, aminium radicals are potentially useful reactive intermediates in synthesis.²⁹

EXPERIMENTAL

General conditions. Unless specified otherwise the following conditions were used. Infrared spectra were recorded with a Perkin-Elmer 457 spectrophotometer using liquid films or Nujol mulls. Ultraviolet spectra were taken with either a Cary 14 or a Unicam SP8000 spectrophotometer. Nuclear magnetic resonance spectra were recorded on a Varian A-56/60 or an XL-100 in CCl₄ or CDCl₃ with Me₄Si as the internal standard. The chemical shifts of NMR were reported in δ -value (ppm) from Me₄Si and coupling constants in Hertz (Hz). The decoupling experiments were performed with the XL-100 spectrometer. Mass spectra were recorded with a Hitachi Perkin-Elmer RMU-6E mass spectrometer. High resolution mass spectra were

performed at the University of British Columbia, Mass Spectrometric Services. Elemental analyses were carried out by Mr. M. K. Yang using a Perkin-Elmer 240 microanalyzer. Gas chromatographic analyses were performed on a Varian 1200 flame analytical machine using a Varian Aerograph Model 20 recorder equipped with a Model 224 disc chart integrator.

Photoaddition of nitrosamines to olefins. 1. 4-Propenylanisole (1). A solution of NND (1.24 g, 17 mmol), **1** (3.05 g, 21 mmol) and concentrated hydrochloric acid (1.5 ml, 18 mmol) in methanol (350 ml) was irradiated in an ice bath with a Rayonet lamp (350 nm) for 5 h and 40 min. The photolysate was evaporated to dryness. Water (50 ml) was added and the aqueous solution was extracted with ether (3 × 25 ml). The combined ethereal solution was dried (MgSO_4) and evaporated to give the recovered **1** (0.63 g). The aqueous solution was adjusted with a saturated solution of sodium carbonate to pH 10, and extracted with methylene chloride (3 × 25 ml). The combined methylene chloride solution was evaporated to give a solid (2.97 g) which was taken up in benzene and chromatographed on neutral alumina to give the following compounds in the order of elution.

(i) A solid (2.55 g, 68%) which was recrystallized from a benzene–cyclohexane mixture and was sublimed at 85°C/0.1 mmHg to give *syn*-1-(*p*-methoxyphenyl)-2-*N,N*-dimethylaminopropan-1-one-oxime (**2s**): m.p. 93–94.5°C; IR 1605, 1520, 1030, 954, 926 and 855 cm^{-1} ; NMR δ 1.42 (d, $J=7$ Hz, 3H), 2.37 (s, 6H), 2.55 (q, $J=7$ Hz, 1H), 3.78 (s, 2H) and 7.17 (AB q, $\Delta\nu=44$, $J=9$ Hz, 4H); m/e (%) 222 (M^+ , 25), 205(20), 189(9), 176(6), 163(6), 147(71), 133(71), 115(16), 103(40), 90(36), 78(27) and 72(100); Calc. for $\text{C}_{12}\text{H}_{18}\text{N}_2\text{O}_2$: C, 65.84; H, 8.16; N, 12.60. Found: C, 65.06; H, 8.27; N, 12.46.

(ii) A solid (0.42 g, 11%) which was recrystallized from a benzene–cyclohexane mixture and sublimed at 90°C/0.1 mmHg to give *anti*-1-(*p*-methoxyphenyl)-2-*N,N*-dimethylaminopropan-1-one-oxime (**2a**): m.p. 112.5–114°C; IR 3300, 1620, 1525, 1260, 1182, 1038, 942 and 830 cm^{-1} ; NMR δ 1.18 (d, $J=7$ Hz, 3H), 2.24 (s, 6H), 3.37 (q, $J=7$ Hz, 1H), 3.77 (s, 3H) and 7.15 (AB q, $\Delta\nu=35$, $J=9$ Hz, 4H); m/e (%) 222 (M^+ , 4), 205(100), 189(14), 179(14), 176(24), 163(11), 147(8), 133(72), 118(10), 103(27), 90(30), 78(14) and 72(50).

(iii) An oil (100 mg) which was distilled at 85°C/0.1 mm to give a colorless oil which was tentatively assigned as 1-(*p*-methoxyphenyl)-1-*N,N*-dimethylaminopropan-2-one oxime (**3**): IR 2940, 2870, 2830, 2780, 1675, 1600, 1510, 1455, 1260, 1235, 1170, 1100, 1030, 930 and 845 cm^{-1} ; NMR δ 1.38 (s, 3H), 2.28 (s, 6H), 3.70 (s, 3H) and 7.15 (AB q, 4H); m/e (%) 222 (M^+ , <1), 205(3), 176(2), 151(60), 148(100), 121(5), 107(5), 92(8), 77(15) and 72(10); Calc. for

$\text{C}_{12}\text{H}_{18}\text{N}_2\text{O}_2$: C, 64.84; H, 8.16; 12.60; Found: C, 64.95; H, 8.08; N, 12.67.

2. 3-Butenol. A solution of NNP (2.736 g, 0.024 mol), 3-butenol (**4a**, 1.44 g, 0.02 mol) and perchloric acid (70%, 4 ml) in methanol (320 ml) was irradiated (200 watt Hanovia lamp) through a Nonex filter under oxygen at 0°C. After 1.5 h, the absorption at 350 nm disappeared completely and a colourless solution was obtained. The photolysate was concentrated under reduced pressure at 10°C and was diluted with water to ca. 100 ml and extracted with ether (4 × 50 ml) to give an oil (66 mg) which contained unreacted 3-butenol as shown by IR and NMR analysis. The aqueous acidic solution was cooled to 5°C, basified with saturated sodium carbonate solution (pH 9.5) and extracted with methylene chloride (5 × 50 ml). The methylene chloride extract was worked up in the usual manner to afford 3-nitrato-4-piperidinobutanol (**5a**) as an oil (2.209 g, 51%): IR 3370 (m), 2800 (m), 1625 (s), 1225 (s), 1055 (m), 865 (m) and 855 cm^{-1} ; NMR δ 5.22 (q, $J=6.0$ Hz, 1H), 5.15 (bs, D_2O exch., 1H), 3.71 (t, $J=5.5$ Hz, 2H), 2.58 (d, $J=6.0$ Hz, 2H), 2.45 (m, 4H), 1.97 (q, $J=6.0$ Hz, 2H) and 1.5 (m, 6H).

Continuous extraction of the basic solution with methylene chloride gave 4-piperidino-1,3-butanediol (**6a**) as an oil (710 mg, 21%): IR 3370 (s), 2800 (m), 1975 (s), 1050 (s) and 1040 (s) cm^{-1} ; NMR δ 4.62 (s, D_2O exch., 2H), 3.87 (q, $J=6.5$ Hz, 1H), 3.72 (t, $J=6.0$ Hz, 2H), 2.47 (m, 4H), 2.40 (d, $J=6.5$ Hz, 2H), 1.68 (q, $J=6.0$ Hz, 2H) and 1.53 (m, 6H); $m.s. m/e$ (%) 174 (M^+ , 7), 128(30), 99(37), 98(100), 84(27), 55(28), 42(25) and 41(31).

Reduction of the aminonitrate **5a** (2.2 g) with LAH (1.9 g, 0.05 mol) in ether (150 ml) for 24 h followed by the usual work-up afforded diol **6a** (1.824 g). Treatment of diol **6a** (173 mg) with *p*-nitrobenzoyl chloride (186 mg) in dry THF (2 ml) gave a solid which was recrystallized from 2-propanol to give the hydrochloride of 3-hydroxy-4-piperidinobutyl-*p*-nitrobenzoate (216 mg, 60%): m.p. 192–193°C (d); IR 3260 (s), 1720 (s), 1525 (s), 1350 (s), 1340 (s), 1285 (s) and 720 (s) cm^{-1} ; NMR δ 1.95 (m, 8H), 3.9–2.7 (m, 6H), 4.3 (m, 1H), 4.57 (t, $J=6.5$ Hz, 2H) and 8.3 (m, 4H); Calc. for $\text{C}_{16}\text{H}_{23}\text{N}_2\text{O}_5\text{Cl}$: C, 53.56; H, 6.46; N, 7.82. Found: C, 53.86; H, 6.28; N, 7.92.

3. 3-Butenyl esters 4b–4f. The butenyl esters **4b–4f** were prepared from 3-butenol with appropriate acyl halides. They were purified and characterized as described in the thesis.¹³

Similar oxidative photoaddition of NNP to the butenyl esters **4b–4f** were carried out and worked up as described above. The neutral fraction contained the starting butenyl esters as shown by GC co-injection and IR spectra. The basic fraction was examined by IR and NMR spectroscopy to estimate the ratio of **5** to **6**. They are described below.

(i) *4b*: The crude basic fraction (80%) contained 3-nitrato-4-piperidinobutyl acetate (*5b*) and 3-hydroxy-4-piperidinobutyl acetate (*6b*) in the approximate ratio 1:1 as shown by the intensities of the triplets at 4.23 and 4.18 ppm: IR 3440(m), 1740(s), 1630(s), 1280(s), 1240(s), 1045(s), 895(s), 865(s) and 855(s) cm^{-1} ; NMR δ 5.27 (qi, $J = 6.0$ Hz), 4.77 (bs, D_2O exch.), 4.23 (t, $J = 6.5$ Hz), 4.18 (t, $J = 6.5$ Hz), 4.18 (t, $J = 6.5$ Hz), 3.72 (qi, $J = 5.5$ Hz), 2.47(m), 2.04(s) and 1.52(m). Reduction of the crude fraction (5.6 g) with LAH in ether gave diol *6a* (3.938 g) in an overall yield of 80%.

(ii) *4c*: The basic fraction (26%) contained 3-nitrato-4-piperidinobutyl-*p*-methylbenzoate *5c* and 3-hydroxy-4-piperidinobutyl-*p*-methylbenzoate *6c* in a 1:1 ratio as shown by the intensities of the NMR triplets at 4.49 and 4.43 ppm: IR 3420(m), 1720(s), 1630(s), 1278(s), 1180(s), 1108(s), 860(s) and 758(s) cm^{-1} ; NMR δ 1.51(m), 2.42(s), 2.5(m), 5.37 (qi, $J = 6.5$ Hz), 4.49 (t, $J = 6.5$ Hz), 4.43 (t, $J = 6.0$ Hz), 3.67 (s, D_2O exch.), 3.8(m), 7.24 and 7.92 (A_2B_2 , $J = 8.0$ Hz, $\Delta\nu = 41$ Hz).

This mixture was hydrogenated in methanol (50 ml) in the presence of platinum oxide (125 mg) to afford *6c* as an oil (934 mg); IR 3400(s), 1715(s), 1280(s), 1180(m), 1105(s) and 755(s) cm^{-1} ; NMR δ 1.53(m), 1.85 (q, $J = 6.5$ Hz, 2H), 2.42 (s, 3H), 2.40 (m, 6H), 3.90 (qi, $J = 6.5$ Hz, 1H), 4.50 (t, $J = 6.5$ Hz, 2H), 4.95 (m, D_2O exch., 1H), 7.23 and 7.93 (A_2B_2 , $J = 8.5$ Hz, $\Delta\nu = 42$ Hz, 4H). The hydrochloride of *6c* was recrystallized from 2-propanal and was analyzed; m.p. 184–185 °C.

(iii) *4d*: The basic fraction (32%) contained 3-nitrato-4-piperidinobutyl-*p*-methoxybenzoate (*5d*) and 3-hydroxy-4-piperidinobutyl-*p*-methoxybenzoate (*6d*) in the approximate ratio 1:1 as indicated by the intensities of the NMR signals at 4.47 and 4.42 ppm: IR 3420(m), 1703(s), 1630(s), 1608(s), 1280(s), 1260(s), 1173(s), 1100(s), 1033(s), 853(s) and 733(s) cm^{-1} ; NMR δ 1.5(m), 2.46(m), 3.86(s), 4.42 (t, $J = 6.0$ Hz), 4.47 (t, $J = 6.5$), 5.37 (qi, $J = 6.5$ Hz), 4.12 (s, D_2O exch.), 3.76(m), 6.92 and 7.99 (A_2B_2 , $J = 9.0$ Hz). This mixture was hydrogenated in methanol (50 ml) in the presence of platinum oxide (125 mg) to give *6d* as an oil (1.12 g): IR 3400(s), 1710(s), 1605(s), 1280(s), 1260(s), 1170(s), 1100(s), 1030(m) and 770(m) cm^{-1} ; NMR δ 1.54(m), 1.84 (q, $J = 6.5$ Hz, 2H), 2.4(m), 3.87 (s, 3H), 3.79 (m, 1H), 4.48 (t, $J = 6.5$ Hz, 2H), 4.66 (m, 1H), 6.92 and 8.00 (A_2B_2 , $J = 9.0$ Hz, 4H). The hydrochloride of *6d* (m.p. 159–160 °C) was recrystallized from 2-propanol and was analyzed.

(iv) *4e*: The basic fraction (33%) consisted of 3-nitrato-4-piperidinobutyl-*p*-cyanobenzoate (*5e*) and 3-hydroxy-4-piperidinobutyl-*p*-cyanobenzoate (*6e*) in a 1:1 ratio as judged from the intensities of the NMR signals at 4.55 and 4.51 ppm: IR 3400(m), 2230(m), 1725(s), 1628(s), 1275(s), 1105(s), 1120(s),

860(s), 768(s) and 690(s) cm^{-1} ; NMR δ 8.13 and 7.75 (A_2B_2 , $J = 8.0$ Hz, $\Delta\nu = 23$ Hz), 5.35 (qi, $J = 6.0$ Hz), 4.55 (t, $J = 6.5$ Hz), 4.51 (t, $J = 6.0$ Hz), 3.97(m), 3.98 (bs, D_2O exch.), 2.45(m) and 1.5(m). Part of the crude basic mixture was reduced with LAH in ether to give diol *6a*.

(v) *4f*: The neutral fraction contained the unreacted *4f* (95%) and the basic fraction gave some piperidine and dipiperidylmethane.

4. 3-Butenyl chloride (*4g*) and bromide (*4h*). A methanol solution (320 ml) of NNP (2.74 g, 0.024 mol), 3-butenyl chloride (1.81 g, 0.02 mol) and perchloric acid (70%, 3.5 ml) was photolyzed under oxygen as described before. After irradiation (1.5 h), the colourless photolysate was worked up in the usual manner to give a neutral (62 mg) and basic (520 mg) fraction; the latter contained predominantly piperidine and dipiperidylmethane. The aqueous solution was re-extracted continuously with methylene chloride for several days to give a solid (2.263 g, 38%) which was recrystallized from methanol to give the perchlorate of 2-nitrato-5-azoniaspiro[4,5]decane (*8*): m.p. 134.5–135.5 °C; IR 3040(w), 1643(s), 1303(s), 1293(s), 1275(s), 1095(s), 870(s), 860(s) and 625(s) cm^{-1} ; NMR (acetone- d_6) δ 5.96 (m, H-2), 4.23 (2H, m, H-1, $J = 14.5$ and 3.5 Hz), 3.98 (2H, m, H-4, $J = 15$, 7 and 4 Hz), 3.71 (4H, m), 2.82 (2H, m, H-3, $J = 16$, 7 and 4 Hz) and 2.3–1.6 (6H, m). Calc. for $\text{C}_9\text{H}_{17}\text{N}_2\text{O}_7\text{Cl}$: C, 35.95; H, 5.70; N, 9.31. Found: C, 36.01; H, 5.84; N, 9.31. A similar photolysis of NNP in the presence of 3-butenyl bromide gave 46% of *8*.

Photoaddition of NNP to Acetylenes. 1. Diphenylacetylene. A solution of NNP (7.72 g, 68 mmol), diphenylacetylene (4.66 g, 26 mmol) and concentrated hydrochloric acid (5.8 ml, 69 mmol) in methanol (200 ml) was irradiated in an ice bath with a Hanovia lamp (450 W) through a filter solution (cut off at 350 nm) for 2 h. The photolysate was evaporated to dryness. Water (50 ml) was added and the aqueous solution was extracted with ether (3 $\times$ 25 ml). The ethereal solution was evaporated to give an oil (4.37 g) which contained *N*-nitrosopiperidine (0.22 g) and a solid (4.15 g, 61%). The solid was recrystallized from benzene to give benzil monoxime (*9*): m.p. 136–138 °C; (lit. 137 °C);³⁰ IR 3340, 3060, 1640, 1600, 1375, 1310, 1215, 1010, 930, 875 and 695 cm^{-1} ; m/e (%) 225 (M^+ , 7), 122(18), 105(100), 103(56) and 77(56).

2. Phenylacetylene. A solution of NNP (7.87 g, 69 mmol), phenylacetylene (8.37 g, 82 mmol) and concentrated hydrochloric acid (6 ml, 72 mmol) in methanol (300 ml) was irradiated in a dry ice–methanol bath with a Hanovia lamp (450 W) through a Uranium glass filter for 15 h. While the absorption at 340 nm decreased gradually, new peaks at 305, 280 and 276 nm increased. The photolysate was rendered basic with solid sodium

carbonate (8 g) immediately on termination of the irradiation. The precipitate was filtered off and the filtrate was evaporated to dryness. An aqueous solution of the residue was worked up in the usual manner to give a basic and a residue fraction. The basic fraction was chromatographed on a silicic acid column to give NNP (2.58 g), a yellow liquid (49 mg), the oily major product (4.53 g) and an unknown solid mixture (300 mg). The major oil was distilled at 95 °C/0.1 mmHg to give crystalline phenylglyoxal ketoxime (10): m.p. 48.5–50 °C; IR (CHCl₃) 3240, 3060, 3030, 2840, 1700, 1590, 1440, 1370, 1280, 1050, 990, 960 and 685 cm⁻¹; NMR δ 7.47 (s, 5H) and 9.80 (s, 1H); *m/e* (%) 149.0520 (calc. for C₈H₇NO₂: 149.0478, 20), 119(53), 103(45), 91(24) and 77(100); Calc. for C₈H₇NO₂: C, 64.42; H, 4.73; N, 9.39. Found: C, 64.29; H, 4.77; N, 9.05. The bis-phenylhydrazone was recrystallized once from dilute ethanol solution, and twice from a mixture of benzene and light petroleum to give a crystalline solid: m.p. 147–149 °C (lit. 152 °C);³⁰ IR 3300, 3180, 1590, 1540, 1490, 1370, 1265, 1245, 1160, 1070, 1010, 950, 750 and 685 cm⁻¹; *m/e* (%) 314 (M⁺, 100), 222(75), 209(36), 195(12), 116(12), 104(24), 83(80) and 77(50).

The neat oil resulting from chromatography crystallized on standing overnight. The crystals partially dissolved on heating in chloroform, leaving a solid nitroso dimer of 1-nitroso-2-hydroxystyrene (10a) which was filtered: m.p. 113–115 °C; IR 3230, 3060, 1590, 1310, 1280, 1210, 1130, 1055, 990, 960 and 700 cm⁻¹; NMR (DMSO-*d*₆) δ 7.47 (s, 5H), and 9.80 (s, 1H); *m/e* (%) 149 (1/2M⁺, 46), 119(98), 103(37), 91(15) and 77(100); Calc. for C₁₆H₁₄N₂O₄: C, 64.42; H, 4.73; N, 9.39. Found: C, 64.07; H, 4.92; N, 9.12. The dimer 10a was dissolved in chloroform on prolonged heating and the chloroform solution was evaporated to give 10 as shown by the IR absorption at 1700 cm⁻¹ and the NMR signal at 9.80 ppm. The dimer 10a was sublimed at 110 °C/0.1 mmHg to give an oil 10 which crystallized (m.p. 48–50 °C) and showed the typical IR and NMR spectra.

Separately, a similar photoreaction was carried out with an ice bath, and the acidic photolysate was evaporated. The residue was worked up to give acidic and basic fractions. From the acidic fraction (2.81 g), NNP (390 mg), the acetophenone 11 (1.40 g, 22%), ketoxime 10 (1.2 g mg, 27%) and dioxime 13 (540 mg, 9%) were obtained by chromatography on a silicic acid column. Chromatography of the basic fraction gave oxime 12 (2.0 g, 24%) and four unknown minor compounds. The detail of chromatography and characterization of these compounds are described in the thesis presented by D. W. L. Chang.³¹

Photoaddition of Nitrosamines to Fused Aromatic Compounds. 1. Anthracene. NNP (2.3 g, 0.02 mol), concentrated hydrochloric acid (2 ml, 0.024 mol) in

ethanol (1.4 l) exhibited an optical density of 1.40 at 350 nm. Anthracene (5.4 g, 0.03 mol) was added and vigorously stirred for 1/2 h. The supernatant liquid exhibited optical density of 0.34 at 350 nm with 1/100 dilution. The heterogeneous solution was irradiated for 14 h with a Rayonet RPR 3500 Å lamp. The photolysate was concentrated to 60 ml and diluted with water. The precipitated anthracene and its dimer¹⁹ (2.8 g) were filtered. The acidic aqueous layer was extracted with CH₂Cl₂ (50 ml × 3). The CH₂Cl₂ extract was washed with water, dried (MgSO₄) and evaporated to give a resin (1.5 g) which was chromatographed on silicic acid (40 g) to give anthracene (76 mg), NNP (500 mg) and a solid (360 mg). The solid was sublimed to give 9-ethoxyanthrone oxime (18, 360 mg): m.p. 155–158 °C; IR 3400, 1680, 1320, 1295, 1000, 980, 950, 800, 780, 715, 693 cm⁻¹; NMR δ 8.5 (m, 1H), 7.95 (m, 1H), 7.47 (m, 6H), 5.40 (s, 1H), 3.56 (q, 2H, *J* = 7 Hz), 1.24 (t, 3H, *J* = 7 Hz); m.s. (15 eV) *m/e* (%) 253(89), 208(100).

The aqueous layer was made basic with a sodium carbonate solution to give a white precipitate (3.3 g) which was recrystallized from 2-propanol to give 16: m.p. 182–184 °C (decomposition with gas evolution); IR 3300, 2400, 1500, 1325, 1193, 1165, 1144, 1118, 1098, 1072, 1060, 1038, 1000, 978, 962, 953, 940, 930, 894, 878, 850, 782, 758, 740, 719, 660 cm⁻¹; NMR (pyridine-*d*₅) δ 9.1 (m, 1H), 8.2 (m, 1H), 7.5 (m, 6H), 4.82 (s, 1H), 2.46 (m, 4H), 1.25 (m, 6H); Calc. for C₁₉H₂₀N₂O: C, 78.05; H, 6.90; n, 9.58. Found: C, 77.73; H, 7.00; N, 9.49.

The oxime 16 (100 mg), concentrated hydrochloric acid (0.2 ml) and anthracene (200 mg) in ethanol (100 ml) were irradiated under nitrogen as above. The crude neutral fraction, after removal of anthracene and its dimer, was chromatographed to give oxime 18 (6 mg).

2. 1,4-Dimethylantracene. NNP (3.05 g, 0.03 mol) concentrated hydrochloric acid (17.5 ml) and 1,4-dimethylantracene (1,4-DMA, 3.24 g, 0.014 mol) were dissolved in methanol (400 ml). The solution was irradiated under nitrogen with a 200 watt Hanovia lamp for 6 h. The deposited crystals were filtered to give the 1,4-DMA dimer (335 mg): m.p. 242–250 °C; IR 1160, 1030, 938, 807, 760, 750, and 660 cm⁻¹; NMR δ 6.84 (m, 8H), 6.44 (s, 4H), 4.73 (s, 4H), 2.26 (s, 12H). The filtrate was worked up in the usual manner to give the syrupy neutral (5.3 g) and the basic fraction (930 mg). This crude neutral resin (1.0 g) was chromatographed on silicic acid (50 g). Elution with CHCl₃ gave NNP (100 mg). Elution with CHCl₃ containing up to 5% methanol gave the hydrochloride of 20 (400 mg); IR 3450, 2490, 1600, 1500, 1250, 900, 820, 750 cm⁻¹; NMR δ 8.25 (m, 2H), 7.48 (m, 4H), 6.63 (s, 1H), 5.50 (s, 1H), 3.56 (s, 3H), 3.44 (b, 4H), 2.69 (s, 3H), 2.52 (s, 3H), 1.70 (m, 6H). One of these fractions (153 mg) was treated with a saturated

K₂CO₃ solution to give 20.

The basic syrup was treated with 2-propanol to give crystals (155 mg) which were recrystallized 4 times and sublimed (115 °C, 0.2 mm Hg) to afford an analytical sample of 1,4-dimethyl-9-piperidino-10-methoxy-9,10-dihydroanthracene (20); m.p. 145–146 °C; IR 1612, 1585, 1078, 935, 825, 810, 760, 740 cm⁻¹; NMR δ 7.40 (s, 4H), 7.13 (s, 2H), 5.23 (s, 1H), 4.30 (s, 1H), 3.48 (s, 3H), 3–2 (m, 4H), 2.52 (s, 3H), 2.48 (s, 3H), 1.4 (m, 6H); Calc. for C₂₂H₂₇NO; C, 82.84; H, 8.41; N, 4.36. Found C, 82.16; H, 8.34; N, 4.51. The mother liquor was evaporated to dryness (384 mg) and chromatographed on alumina (40 g) to give 20 (90 mg) and a solid (30 mg). The solid was crystallized from methanol to give 1,4-dimethyl-9-piperidino-10-hydroxy-9,10-dihydroanthracene (21); m.p. 206–207 °C; IR 3300, 1600, 1500, 1108, 1070, 1039, 980, 970, 950, 828, 820, 750 cm⁻¹; NMR δ 7.24 (m, 4H), 7.00 (s, 2H), 6.62 (s, 1H), 4.37 (s, 1H), 2.50 (s, 3H), 2.40 (s, 3H), 2.5 (m, 4H), 1.4 (m, 6H); m.s. (1.7 kV) *m/e* (%) 307(81), 224(100), 204(80); M⁺ Calc. for C₂₁H₂₅NO; 307.1936. Found 307.1932.

3. *Pyrene*. A heterogeneous solution of NNP (2.3 g, 0.02 mol), concentrated hydrochloric acid (2 ml, 0.024 mol) and pyrene (2.1 g, 10.01 mol) in methanol (300 ml) was irradiated under nitrogen with a 450 W Hanovia lamp for 3 h. At this time the solution had turned black. The photolysate was evaporated to 100 ml and filtered to give crystals of pyrene (502 mg); m.p. 110–118 °C. The photolysate was worked up in the usual manner to give neutral (2.53 g) and the basic (58 mg) fractions. The neutral oil (1.5 g) was chromatographed on alumina (45 g) to give a solid (700 mg), NNP (100 mg) and unidentified mixtures (200 mg). The solid was recrystallized 3 times from benzene-2-propanol to give 4-piperidinopyrene 23; m.p. 90–91 °C; IR 1600, 1590, 1513, 1226, 840 cm⁻¹; NMR δ 8.00 (m, 9H); 3.1 (m, 4H), 1.75 (m, 6H); Calc. for C₂₁H₁₉N; C, 88.38; H, 6.71; N, 4.91. Found: C, 88.00; H, 6.82; N, 5.00. Compound 23 dissolved in CHCl₃ turned a brown-purple color after some days.

4. *Acenaphthene*. A solution of the NND (3.70 g, 0.05 mol) concentrated hydrochloric acid (7.5 ml, 0.09 mol) and acenaphthene (9.10 g, 0.06 mol) in methanol (400 ml) was irradiated with a 200 watt Hanovia lamp for 8 h. The solution was then filtered to give crystals of acenaphthene dimer (603 mg); m.p. 227–228 °C, lit.²² 234 °C. The solution was evaporated to 40 ml and cooled to give crystals (800 mg, m.p. 230–235 °C dec) which were crystallized from 2-propanol three times to give acenaphthoquinone (28); m.p. 252–255 °C, lit.²² 261 °C; IR 1720, 1260 cm⁻¹.

The concentrated photolysate was worked up in the usual manner to give a neutral (3.7 g) and a basic (5.9 g) fraction. The neutral fraction contained acenaphthene and NND by IR and NMR spectral

analysis. The basic fraction was treated with benzene to afford crystals (1.05 g) which were recrystallized five times from benzene to afford an analytical sample of *anti*-2-dimethylaminoacenaphth-1-one oxime (27); m.p. 123–125 °C; IR 3100, 970, 930, 858, 850, 800, 785 cm⁻¹; NMR δ 11.0 (b, 1H, D₂O exch.), 8.4 (m, 1H), 7.7 (m, 5H), 5.22 (s, 1H), 2.14 (s, 6H).

The presence of *syn*-2-dimethylaminoacenaphth-1-one oxime (27) was indicated by the singlet signals at 5.43 and 2.42 ppm (the ratio of 1:6) in addition to the signals indicated above in the recovered material. The ratio of the *syn* to *anti* isomers was 3:7.

Preparation of N-nitroso-4-azatricyclo[5.2.1.0^{2,6}]dec-8-ene (31). *Endo*-Norbornene-*cis*-5,6-dicarboxylic anhydride (29) (50 g) was treated with concentrated NH₄OH (150 ml) to give the ammonium salt as a solid (45 g); m.p. >250 °C; IR 3460(s), 3200(s), 1710(m), 1660(s), 1628(s), 1412(s), 1290, 1270, 1232(s) and 730(s) cm⁻¹. This solid (23 g) was refluxed in acetic anhydride (12 ml) for 2 h to give *endo*-norbornene-*cis*-5,6-dicarboximide (19.75 g); m.p. 186–187 °C (lit. 185–186.5 °C);³² IR 3155, 3060(s), 1750, 1700(s), 1295(s), 1230(m), 1190, 1120, 992(s), 840, 738 and 640(s) cm⁻¹; NMR δ 8.50 (m, D₂O exch. 1H), 6.20 (m, 2H), 3.33 (m, 4H), 1.78 and 1.52 (AB q, *J* = 9 Hz, 2H).

The imide (16 g, 0.1 mol) was reduced with LAH (16 g, 0.41 mol) in dry THF (700 ml) to yield a semisolid (15.5 g). Recrystallization from ethyl acetate–light petroleum (30–60 °C) or vacuum sublimation (25 °C/0.05 mmHg) gave 4-azatricyclo[5.2.1.0^{2,6}]dec-8-ene (30); m.p. 59–60 °C; IR 3350 (s, br), 3050(w), 2720(w), 2460(w), 1625(m), 1512(s), 1255, 1230(m), 820, 752 and 720(m) cm⁻¹; NMR 6.22 (m, *W*_{1/2} = 4 Hz, 2H), 5.00 (s, D₂O exch., 2H), 2.89 (m, 8H), 1.55 and 1.40 (AB q, *J* = 8.5 Hz); m.s. *m/e* (%) 135(41), 134(10), 94(53), 69(41) and 68(100); Found: C, 48.8; H, 6.39; N, 6.02.

A crude amine 30 was treated with NOBF₄ to yield *N*-nitrosamine 31. An analytical sample was prepared by repeated sublimation (25 °C/0.5 mm): m.p. 73–73.5 °C; IR 3060(w), 1452(s), 1412(s), 1312(s), 1220, 842, 802, 770, 742(m) and 720(m) cm⁻¹; NMR δ 6.18 (m, 2H), 4.10 (m, H-5, 2H), 3.40 (m, H-3, 2H), 3.02 (m, 5H), 1.65 and 1.47 (AB q, *J* = 9 Hz); m.s. *m/e* (%) 164 (M⁺, 62), 134(29), 105(54), 79(71), 68(91), 67(54) and 66(100); UV (methanol) 348 nm (ϵ , 87); Calc. for C₉H₁₂N₂O; C, 65.83; H, 7.37; N, 17.06. Found: C, 65.80; H, 7.22; N, 17.11.

Photolysis of nitrosamine 31. 1. *Under oxygen*. A solution of nitrosamine 31 (2 g, 0.012 mol) and concentrated HCl (1.1 ml, 0.066 N) in methanol (200 ml) was photolyzed under oxygen for 2.75 h. The basic fraction was extracted into ether (4 × 50 ml) which was immediately dried and stirred overnight with LAH (2 g). The usual work-up gave a clear oil

(2.63 g) which showed one major spot at R_f 0.12 on TLC (silica gel, 10% methanol- CH_2Cl_2) and the NMR spectrum corresponded essentially to that of alcohol 32 with weak signals of unidentified products. The oil (100 mg) was purified by preparative TLC to give a semisolid (36 mg) which was recrystallized several times from ether to give tetracyclic amino alcohol 32: m.p. 150–153°C; IR 3200 (s, br), 1270(m), 1140, 1092(m), 1040(s), 1005(s), 960, 940, 902, 815 and 778(m) cm^{-1} ; NMR δ 5.08 (s, D_2O exch.), 4.30 (m, $W_{1/2}=4$ Hz, H_e), 3.59 (m, H_d), 3.25 (dd, $J=12$ and 2 Hz, H_a), 3.02 (m, 1H), 2.8–2.2 (unresolved, 7H), 1.65 and 1.60 (AB q, $\Delta\nu=38$, $J=10.5$ Hz, H_b and H_c) and 1.60 (m, 1H); m.s. m/e (%) 151 (M^+ , 45), 134(33), 122(55), 85(55), 80(50), 79(50), 68(44) and 57(100).

The picrate of 32 was recrystallized three times from ethanol–light petroleum: m.p. 245–255°C (decomp): Calc. for $\text{C}_{15}\text{H}_{16}\text{N}_4\text{O}_8$: C, 47.37; H, 4.24; N, 14.73. Found: C, 47.70; H, 4.47; N, 14.53.

Amino alcohol 32 (30 mg) in acetone (3 ml) was treated with $\text{CrO}_3-\text{H}_2\text{SO}_4$ at 0°C. The green solution was stirred for 10 min at which time the acetone was evaporated and the residue was basified with aqueous Na_2CO_3 . Extraction with CH_2Cl_2 gave crystalline ketone 34 (18 mg, 62%): m.p. 115–117°C; IR 1750(s), 1490(w), 1282, 1162, 990, 958(m), 820, 770 and 732(m) cm^{-1} ; NMR δ 3.2–2.5 (unresolved, 8H) and 1.55 (AB q, $\Delta\nu=24$, $J=11.5$ Hz, 2H); m.s. m/e (%) 149 (M^+ , 11), 121(100), 120(60), 100(54), 93(60), 80(48), 79(54) and 77(55).

2. In bromotrichloromethane. A solution of nitrosamine 31 (1 g, 0.006 mol) and concentrated HCl (0.52 ml) in methanol- CBrCl_3 (1:4, 120 ml) was photolyzed under nitrogen for 1.5 h. The blue solvent mixture was distilled under vacuum and the usual work-up gave a neutral extract (260 mg) and a basic extract (750 mg). The basic fraction (500 mg) was chromatographed on silica gel where elution with ethyl acetate gave bromoamine 33 (335 mg): IR 1505(w), 1300, 1280, 1260, 1228(m), 1180, 1130, 1055, 1008, 928(m), 880(s), 802, 770, 745(s), 730 and 678(m) cm^{-1} ; NMR 4.70 (m, $W_{1/2}=3.5$ Hz, H_e), 3.40 (m, $W_{1/2}=9$ Hz, H_a), 3.21 (dd, $J=12.5$ and 2.5 Hz, H_d), 2.7–2.2 (unresolved, 5H), 2.10 (m, 1H) and 1.60 (d, $J=10.5$ Hz, H_c); m.s. m/e (%) 215(1.5), 213 (M^+ , 1.5) and 134(100).

The picrate of 33 was recrystallized four times from ethanol to give yellow needles: m.p. 224–235°C with slow decomposition: Calc. for $\text{C}_{15}\text{H}_{15}\text{N}_4\text{O}_7\text{Br}$: C, 40.65; H, 3.41; N, 12.64. Found: C, 40.85; H, 3.31; N, 12.84.

Acknowledgements. This paper is submitted in honour of Professor Holger Erdtman on the occasion of his 80th birthday in appreciation of his contributions to organic chemistry. The financial support of this project given by the Natural Science

and Engineering Research Council of Canada is gratefully acknowledged. We thank Swan Chow for the technical drawings.

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Received February 25, 1982.