

24 hr. Evaporation below 30° resulted in 1.07 g. of *p*-toluenethiol in the distillate. The residue was dissolved in water and extracted with ether; the ether removed 0.5 g. more of the thiol. The aqueous layer then was shaken with ether²¹ while an iced aqueous solution of potassium hydroxide (9.5 g.) was added. The water layer was extracted thrice more with ether; each ether layer was backwashed rapidly with water and at once shaken with 5 ml. of 12 *N* hydrochloric acid in water. Finally, the combined ether extracts were washed with water; evaporation gave *p*-tolyl disulfide (1.15 g.). Upon partial evaporation of the acid extracts, crystallization occurred. Filtration separated 2-(*p*-tolylidithio)-ethylamine hydrochloride (VII) as colorless plates; yield 5.0 g., 75% (allowing for recovery of the thiol and *p*-tolyl disulfide; the actual conversion was 42%), m.p. 136–137°. Heating of the melt to 190° resulted in separation into two liquid layers.

Anal. Calcd. for C₉H₁₄ClNS₂: C, 45.84; H, 5.98; Cl, 15.04; S, 27.20; neut. equiv., 236. Found: C, 45.58; H, 6.20; Cl, 14.91; S, 27.08; neut. equiv., 232.

Evidence for Homogeneity of III.—By the usual procedure of multiple fractional extraction,¹¹ III (1.4982 g.) in water-saturated ether was extracted with six portions of ether-saturated water. Each aqueous phase was contacted in sequence with five ether layers. The first ether layer contained 1.3348 g., and the second, 0.1063 g. (total recovery, 96%). In view of the solubilities of I mentioned above, III therefore is very unlikely to be a mixture of I and *p*-tolyl disulfide such as could afford the excellent analysis for III.

In the m.p.-composition studies, five mixtures of I and *p*-tolyl disulfide (mole fraction, 0.2–0.8), all melted over broad ranges (42–49°) between the extremes of *ca.* 45° and 93° for the pure substances.

Disproportionation of Unsymmetrical Disulfides.—The symmetrical disulfides isolated were identified by their infrared spectra. The “% disproportionated” was calcd. as (100 × 2 × moles of either symmetrical disulfide isolated) / (moles of unsymmetrical disulfide used).

(a) Of 2-(*t*-Butylidithio)-ethylamine Hydrochloride (VI).—(1) A sintered glass funnel containing VI was heated at 104° for 17 hr. The product was washed with cold pentane and dried; recovery 99.9%. Heating was continued for 1.5 hr. at 150–160°; recovery 99.7%. The infrared spectrum in both instances was unchanged. At 210°, VI darkened and partially liquefied; clogging of the filter prevented the usual washing. When VI (0.2468 g.) was heated in a slow nitrogen

(21) If the aqueous solution is not shaken with solvent when alkali is added a high yield of *p*-tolyl disulfide and little or none of the disulfide VII result.

stream, no change was apparent in 10 min. at 190°, but at 205–210° after 1 hr. *t*-butyl disulfide (0.0836 g.) was trapped; % disproportionated, at least 77. (2) A solution of VI (0.3 g.) in water (9 ml.) heated in a sealed ampoule at 104° for 20 hr. and cooled showed no separation of insoluble material. (3) A solution of VI (0.1285 g.) in water (10 ml.) was irradiated in a silica cell 3–4 in. from a 250-watt mercury vapor lamp (General Electric Co., Uviarc UA-2). In 10 min., the clear solution clouded. After 45 min., extraction with ether and evaporation left 0.1244 g. of solid; % disproportionated,⁷ (assuming the loss in wt. represented *t*-butyl disulfide, the only ether-extractable product).

(b) Of 2-(*p*-Tolylidithio)-ethylamine Hydrochloride (VII).—(1) Solid VII (0.0907 g.) was unchanged (wt., appearance) after 2.75 hr. at 104° and gave only slight cloudiness upon dissolution in water, indicating negligible disproportionation. (2) A solution of VII (0.0874 g.) in water (10 ml.) was heated for 2.75 hr. (ampoule) at 104°. Ether extracted 0.0303 g. of *p*-tolyl disulfide; % disproportionated, 68 (the water layer gave 0.0560 g. of presumed mixture). (3) After 36 hr. of normal exposure to light at 25°, 0.0905 g. of VII in water (2 ml.) deposited 0.0214 g. of *p*-tolyl disulfide; % disproportionated, 46. When 0.0870 g. of VII in 10 ml. of water was irradiated with ultraviolet light as above, insoluble material quickly separated; after 45 min. 0.0447 g. of *p*-tolyl disulfide was extracted with ether; % disproportionated, 98 (the water layer contained 0.0426 g. of solid, largely 2-aminoethyl disulfide dihydrochloride from its infrared spectrum).

(c) Of 2-(*p*-Tolylidithio)-ethylamine.—A solution of the hydrochloride VII (0.2291 g.) in aqueous ethanol (32 ml., 1:1) neutralized to pH 10.5 with potassium hydroxide was kept at 25° for 90 minutes, acidified with dilute hydrochloric acid and extracted with ether. The ether extract afforded *p*-tolyl disulfide (0.0115 g.); % disproportionated, 10.

(d) Of 2-(*p*-Nitrophenylidithio)-1-acetamidoethane (IV).—Ultraviolet irradiation as above of 0.3 g. of IV in ethanol (10 ml.) for 80 min. at 0° resulted in no precipitate of *p*-nitrophenyl disulfide, even after the solution was seeded and chilled for 2 days in the dark. Since the solubility of *p*-nitrophenyl disulfide in ethanol proved to be *ca.* 0.02% at *ca.* 25°, evidently less than 1% disproportionation occurred.

(e) Of 2-(*p*-Tolylidithio)-1-acetamidoethane (III).—A solution of III (0.1252 g.) in 10 ml. of ether was irradiated as above for 45 min. The cloudy solution (initially clear) was seeded with I and chilled overnight. A deposit of 0.0065 g. of I resulted, m.p. 88°; % disproportionated, *ca.* 11 (the solubility of I in ether at 0°, while not determined quantitatively, is such as to preclude the possibility that any significant amount of I remained in solution).

[CONTRIBUTION FROM THE GORGAS LABORATORY, ROHM & HAAS CO., REDSTONE ARSENAL RESEARCH DIVISION, HUNTSVILLE, ALA.]

Small Ring Heterocyclic Nitrosoamines¹

BY CARL L. BUMGARDNER, KEITH S. MCCALLUM AND JEREMIAH P. FREEMAN

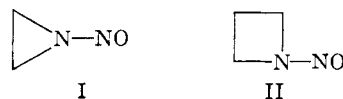
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N-Nitroso-3-nitrocarbazole, a mild nitrosating reagent, converts N-methylaniline to N-nitrosomethylaniline in benzene solution. This reagent reacts with aziridine under similar conditions to yield ethylene and nitrous oxide, products which may arise from decomposition of N-nitrosoaziridine (I). Previous observations concerning the stability of N-nitrosoazetidine (II) have been verified and the structure characterized by its n.m.r. spectrum. The effect of temperature on the n.m.r. spectrum of N-nitrosoazetidine is compared with that of N-nitrosodimethylamine, and the differences attributed to ring strain. Oxidation of N-nitrosoazetidine with peroxytrifluoroacetic acid gives N-nitroazetidine. Differences in the ultraviolet spectra of N-nitroazetidine and di-*n*-propylnitramine are rationalized in terms of ring strain.

Cyclic nitrosoamines, where a nitrogen atom is part of a small ring system, have received little attention. N-Nitrosoaziridine (I) has been postulated as an intermediate in solution but has not

(1) A portion of this work was presented at the 135th Meeting of the American Chemical Society, Boston, Mass., April, 1959. This work was carried out under Army Ordnance Contract DA-01-021-ORD-11878.

been isolated.² N-Nitrosoazetidine (II) has been

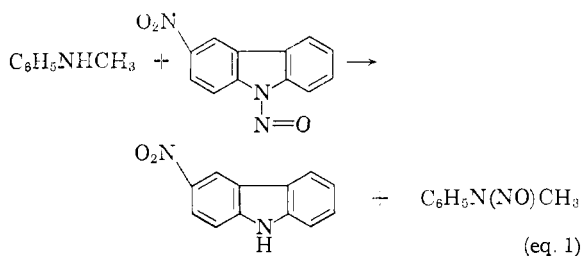


reported but has not been characterized com-

(2) H. Euler, *Chem. Zentr.*, **74**, **II**, 1165 (1903).

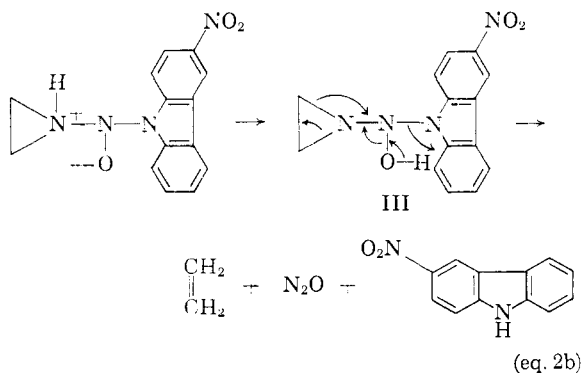
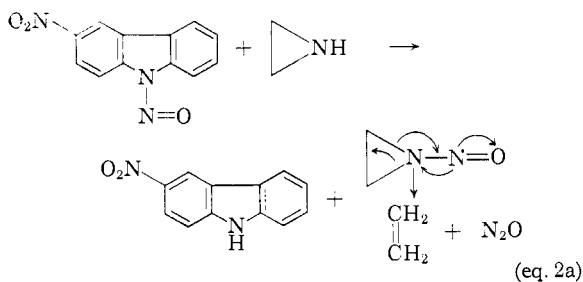
pletely.³ These structures contain two potentially reactive sites, the nitroso group and the ring, and so an investigation of their reactivity was undertaken.

Because aziridine polymerizes rapidly in acid solution,⁴ any successful attempt to obtain the nitroso derivative by direct nitrosation must be carried out in an acid-free environment. N-Nitroso-3-nitrocarbazole was found to be a suitable reagent for nitrosating secondary amines in an organic solvent. This reagent, for example, converts N-methylaniline in boiling benzene to N-nitrosomethylaniline (eq. 1).



3-Nitrocarbazole, the other product formed, largely precipitates during the reaction, which may be viewed as transnitrosation analogous to transesterification and transamination.⁵

When aziridine was treated with a benzene solution of the nitrosocarbazole in an attempt to isolate compound I, a reaction occurred from which 3-nitrocarbazole, ethylene and nitrous oxide were isolated. The reaction may proceed by collapse of the initially formed N-nitrosoaziridine (eq. 2a), or by concerted decomposition of intermediate III⁶ (eq. 2b).



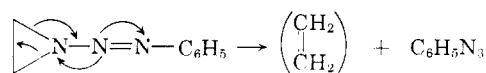
(3) C. C. Howard and W. Marckwald, *Ber.*, **32**, 2032 (1899).

(4) J. S. Fruton, in "Heterocyclic Compounds," Vol. I, ed. by R. C. Elderfield, John Wiley and Sons, Inc., New York, N. Y., 1950, p. 61.

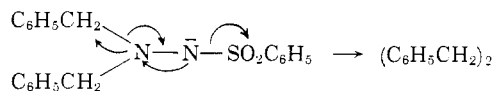
(5) D. J. Cram and G. S. Hammond, "Organic Chemistry," Mc-Graw-Hill Book Co., Inc., New York, N. Y., 1959, pp. 310, 318.

(6) We are indebted to one of the referees for this suggestion.

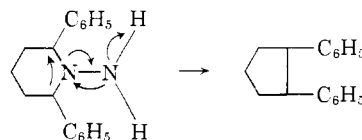
This transformation is reminiscent of the decomposition of 1-phenyl-3,3-dimethylenetriazene,⁷ the



coupling observed when 1,1-dibenzyl-2-benzene-sulfonylhydrazide is treated with base,⁸ and the ring



contraction observed when 1-amino-2,6-diphenylpiperidine is oxidized with mercuric oxide.⁹

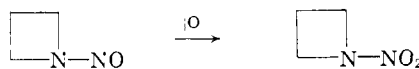


Since the results given in eq. 2 suggest that N-nitrosoaziridine is either never formed or is unstable under mild conditions, we investigated the claim of Howard and Marckwald³ that nitrosation of azetidine with sodium nitrite and acetic acid yields N-nitrosoazetidine, a stable, yellow oil boiling at 197°. Their observations have been verified and the structure confirmed by analysis of its n.m.r. spectrum (Fig. 1).

The proton resonance consists of three bands of equal areas centered at 89.1, 117.1 and 187.2 c.p.s. (higher field than benzene). The two bands at lower field are triplets and therefore arise from the protons in the 2- and 4-positions. These are not equivalent because the nitroso group is not rotating freely about the N-N bond. The high field band, due to the 3-position protons, is split into five members by the 2- and 4-position protons.

Although N-nitrosoazetidine is a stable compound, strain in the four-membered ring is evident from the effect of temperature on its n.m.r. spectrum (Fig. 2). When a sample is heated, the low field bands mentioned above decrease and a single band appears between them. This transition is complete at 130°. Since the number of protons in the two environments is equal, the rate of transition at 130° can be calculated.¹⁰ The rate found is about 93 transitions per second at 130° compared to 110 per second at 180° for N-nitrosodimethylamine, an acyclic example.¹¹ This comparison indicates less double bond character between the nitrogen atoms of the cyclic compound and reflects the additional strain introduced by a double bond exocyclic to a four-membered ring.

Oxidation of N-nitrosoazetidine with peroxytrifluoroacetic acid produced N-nitroazetidine, the first example of a small ring heterocyclic nitramine.



(7) C. S. Rondestvedt and S. J. Davis, *J. Org. Chem.*, **22**, 200 (1957).

(8) L. A. Carpino, *J. Am. Chem. Soc.*, **79**, 4427 (1957).

(9) C. G. Overberger, J. G. Lombardino and R. G. Hiskey, *ibid.*, **79**, 1510 (1957).

(10) H. S. Gutowsky and C. H. Holm, *J. Chem. Phys.*, **25**, 1228 (1956).

(11) C. E. Looney, W. D. Phillips and E. L. Reilly, *J. Am. Chem. Soc.*, **79**, 6136 (1957).

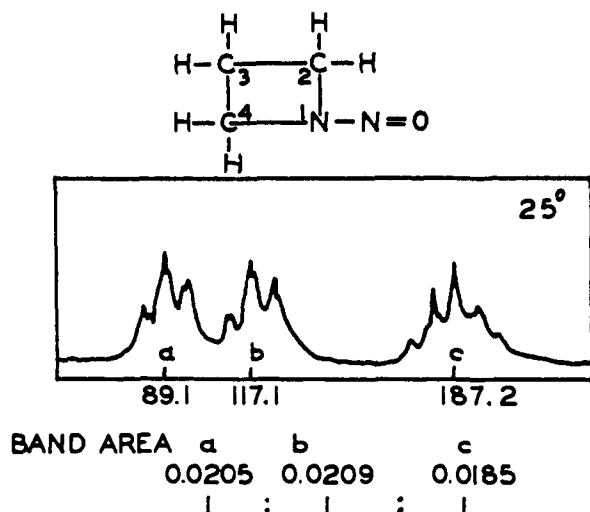
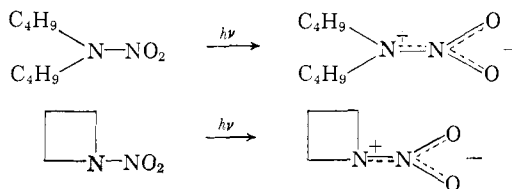


Fig. 1.—N.m.r. spectrum on N-nitrosoazetidene (II).

The nitramine was characterized by its n.m.r. and infrared spectra.

A comparison of the ultraviolet spectrum of N-nitrosoazetidene with that of an acyclic nitramine, di-*n*-propylnitramine,¹² indicates some resonance damping in the former. The open-chain derivative shows a maximum at 244 m μ , ϵ 6,500 (in methylene chloride); the heterocyclic derivative, however, has its maximum at 240 m μ , ϵ 4,400.



This shift may be associated with the strain imposed by increased N-N double bond character in the polar excited state of the small ring derivative and parallels the temperature dependence of the n.m.r. spectrum of N-nitrosoazetidene discussed above.

Experimental¹³

Reaction of N-Methylaniline with N-Nitroso-3-nitrocarbazole.—To a solution of 9.5 g. of N-nitroso-3-nitrocarbazole¹⁴ in 160 ml. of dry benzene was added 2.16 g. of N-methylaniline. The mixture was refluxed for 20 minutes and filtered, giving 4.0 g. of 3-nitrocarbazole, m.p. 211°.¹⁴ The filtrate, after being washed with 10% aqueous hydrochloric acid solution, yielded an additional 1.9 g. of 3-nitrocarbazole. The filtrate was washed again with 10% hydrochloric acid solution, then with 10% aqueous sodium hydroxide solution, and with water. Concentration under reduced pressure left a dark yellow oil and 0.6 g. of crude 3-

(12) W. D. Emmons, *J. Am. Chem. Soc.*, **76**, 3468 (1954).

(13) Melting points and boiling points are uncorrected. Infrared spectra were determined with a Perkin-Elmer model 21 spectrophotometer with a sodium chloride prism. Ultraviolet spectra were determined with a Beckman recording spectrophotometer, model DK-1. Mass spectra were determined with a C.E.C. Type 21-620 mass spectrometer.

(14) D. A. Shirley, "Preparation of Organic Intermediates," John Wiley and Sons, Inc., New York, N. Y., 1951, p. 218.

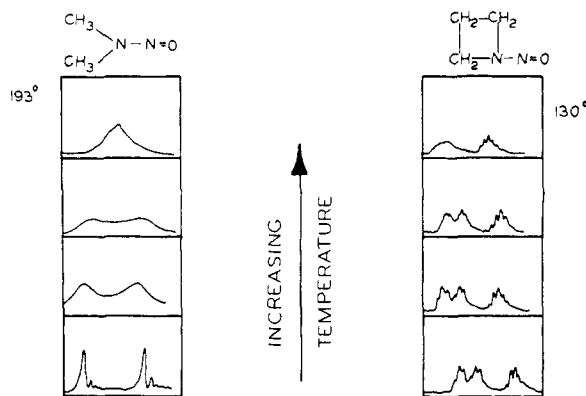


Fig. 2.—Effect of temperature on n.m.r. spectrum of N-nitrosoazetidene (II).

nitrocarbazole. The total yield of 3-nitrocarbazole was 6.5 g. (78%). Distillation of the yellow oil through a semi-micro column yielded 2.9 g. (55%) of N-nitrosomethylaniline, b.p. 83–86° (2 mm.),¹⁵ identified by its infrared spectrum.

Reaction of Aziridine with N-Nitroso-3-nitrocarbazole.—The reaction was carried out in a three-neck flask equipped with a stirrer and reflux condenser to the top of which was attached a gas trap. While nitrogen gas was passed through the system the gas trap was cooled in liquid nitrogen. To 12.0 g. of N-nitroso-3-nitrocarbazole in 175 ml. of dry benzene was added 22.0 g. of freshly distilled aziridine (Chemirad Corp.). The solution was heated to reflux temperature (67°) and stirred for 1 hr. The gaseous products trapped out by the liquid nitrogen were identified as ethylene and nitrous oxide by their infrared and mass spectra. A total of 1.03 l. (NTP) of gas was collected which consisted of 54 mole % of nitrous oxide and 46 mole % of ethylene according to mass spectral analysis. The yield of nitrous oxide was therefore 50%; that of ethylene 42%. The residue in the reaction flask was poured into water and the precipitate which formed was removed by filtration, giving 8.0 g. (75%) of 3-nitrocarbazole, m.p. 205–206°.¹⁴

N-Nitrosoazetidene (II) was prepared according to the directions given in ref. 3. A small amount of an impurity which showed a band in the infrared at 3300 cm.⁻¹ was removed by chromatography on silica gel. The nitrosoamine was eluted with methylene chloride and ether and distilled; b.p. 198–199° and 60° (3.5 mm.).

Anal. Calcd. for C₃H₆N₂O: C, 41.85; H, 7.02. Found: C, 41.90; H, 7.28.

Nuclear magnetic resonance spectra were obtained with a Varian Associates model V-4300-B high resolution spectrometer using a 40 Mc. probe. External benzene was employed as reference for neat liquid samples.

N-Nitrosoazetidene.—N-Nitrosoazetidene (1.2 g.) was oxidized by the procedure used by Emmons¹² to convert N-nitrosodimethylamine to N-nitro-dimethylamine. N-nitrosoazetidene (0.67 g.), b.p. 59° (1.5 mm.), was obtained in 47% yield.

Anal. Calcd. for C₃H₆N₂O₂: N, 27.5. Found: N, 27.1.

The infrared spectrum shows bands at 1250, 1340 and 1500 cm.⁻¹ (N-NO₂). The n.m.r. spectrum (25°) has signals at 103 and 191 c.p.s. (field higher than benzene) in the ratio of 2:1, respectively. The former signal is due to the four α -protons; the latter to the two β -protons.

Acknowledgments.—We wish to thank Mr. A. Kennedy for the mass spectral analyses and Mr. Charles Anerton for technical assistance.

(15) W. W. Hartman and L. J. Roll, "Organic Syntheses," Coll. Vol. II, ed. by A. H. Blatt, John Wiley and Sons, Inc., New York N. Y., 1957, p. 460.