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AZEPINE FORMATION FROM BENZENE AND CARBETHOXYNITRENE : A REACTION OF THE SINGLET NITRENE.

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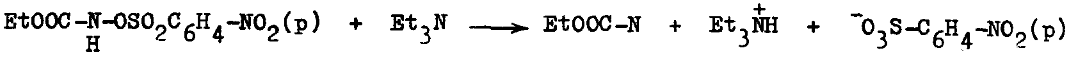
Carbethoxynitrene [1,2] (EtOOC-N), inserts into C-H bonds to form substituted urethans, adds to double bonds to give aziridines, and expands the benzene ring to form N-carbethoxyazepines [2,3,4]. Recently, we reported that both the singlet and the triplet carbethoxynitrene are involved in reactions in solution [5], and that only the singlet inserts into C-H bonds, while both singlet and triplet add to C=C double bonds [6], although with different stereochemistry [5]. Having demonstrated earlier [4] that it is indeed the carbethoxynitrene (and not its precursor, ethyl azidoformate) that forms the azepine from benzene [3], we now wish to report that it is only the singlet form of carbethoxynitrene which does so react.

When generated by base-induced decomposition of N(p-nitrobenzene)sulfonoxy-urethan, carbethoxynitrene is formed exclusively in the singlet state [7], but its conversion to the triplet ground state [8] competes with its intermolecular reactions. By employing low substrate concentrations, and thus slowing down bimolecular reactions, one can cause most of the nitrene to be converted to the triplet state [5,6,7]. Thus, C-H insertion becomes unimportant at low substrate concentrations, while addition to C=C double bonds still occurs in reasonably good yields -- e.g. a 35% yield of the aziridine from cyclohexene at 0.2 mole% concentration in dichloromethane [6].

We have studied reactions of carbethoxynitrene with equimolar mixtures of benzene with cyclohexane, and of benzene with cyclohexene, in dichloromethane as solvent. The nitrene was made by α-elimination :



$$\mathrm{EtOOC}-\underset{\mathrm{H}}{\mathrm{N}}-\mathrm{OSO_2C_6H_4}-\mathrm{NO_2(p)} + \mathrm{Et_3N} \longrightarrow \mathrm{EtOOC}-\mathrm{N} + \mathrm{Et_3}\overset{+}{\mathrm{N}}\mathrm{H} + {}^{-}\mathrm{O_3S}-\mathrm{C_6H_4}-\mathrm{NO_2(p)}$$

A one mole excess of triethylamine was employed, and the substrates were in at least 15-fold excess over the nitrene. The products were separated by gas chromatography on a fluorosilicone QF 6500 on Anachrom ABS column at 120°. Yields were measured by calibrating the gas chromatograph with weighed injections of standard solutions, and by injecting known aliquots of the reaction mixtures. Peak areas were determined planimetrically.

As shown in Table I, the ratio of the yields of N-carbethoxyazepine and cyclohexylurethan changes little when the concentration of benzene + cyclohexane decreases from 32 to 0.5 mole% each. The absolute yields, however, drop drastically. We conclude that the two products are produced by the same species. For benzene-cyclohexene mixtures, an entirely different result is obtained, as shown in Table II. The yield of azepine drops sharply with decreasing benzene concentration, but the yield of the aziridine (7-carbethoxy-7-azabicyclo 4.1.0 heptane) is still 16% at a concentration of 0.1 mole% of cyclohexene (and of benzene). The ration of the yields of azepine and aziridine approaches zero at low substrate concentrations, even though benzene and cyclohexene are present in equal concentrations in each run. We conclude that the two products are formed by different reactive intermediates. Taking into account our results with the 4-methylpent-2-enes, and with cylclohexene [5,6,7] the simplest way of accounting for our present observations is, to assume that only the singlet carbethoxynitrene converts benzene to N-carbethoxyazepine (just as only the singlet inserts into C-H bonds with any facility), while both singlet and triplet carbethoxynitrene add to the double bond in cyclohexene.

TABLE I

Reaction of carbethoxynitrene with benzene + cyclohexane :

concentration (mole%)		absolute yields (%)		ratio
benzene	cyclohexane	azepine (I)	urethan (II)	I/(I + II)
32	32	20	20	0.50
22.5	22.5	20	19	0.52
5	5	8.2	6.7	0.55
2.5	2.5	7.7	3.8	0.67
1	1	3.5	2.2	0.61
0.5	0.5	4	2	0.67

TABLE II

Reaction of carbethoxynitrene with benzene + cyclohexene :

concentration (mole%)		absolute yields (%)		ratio
benzene	cyclohexene	azepine (I)	aziridine (III)	I/(I + III)
32	32	28.8	56.4	0.34
5	5	29.3	57.3	0.34
0.5	0.5	4.5	33.8	0.045
0.1	0.1	trace	16.4	very small

Note : Absolute yields are based on nitrene precursor, so that the maximum theoretical yield is 100% for the sums of the yields of I + II, and I + III, respectively.

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8) We are indebted to Dr. E. Wasserman, of Bell Laboratories, for privately communicating to us, that he has obtained e.s.r. spectra of triplet carbethoxynitrene at very low temperatures.