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ELECTRON TRANSFER INITIATED PHOTOCYCLIZATIONS OF N-ALLYLPYRIDINIUM AND QUINOLINIUM SALTS

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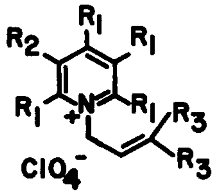
Results from study of the photochemistry of N-allylpyridinium and -quinolinium perchlorates demonstrate that intramolecular electron transfer occurs to generate cation diradical precursors of products containing the tetrahydroindolizidine moiety. Catalytic hydrogenation of the crude photolysates leads to production of perhydroindolizidines in synthetically useful yields

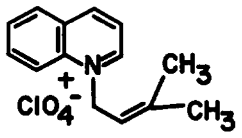
Our recent photochemical studies have focused on substances containing the iminium ion, $\gt C=\overset{+}{N}\lt$, grouping [2] These efforts have uncovered interesting excited state processes initiated by one electron transfer from π- and n-electron donors to the $\gt C=\overset{+}{N}\lt$ grouping. Pyridinium and related heteroaromatic cations which contain this chromophore should serve as interesting electron acceptors in excited state processes as evidenced by examples of alcohol photoadditions proceeding by electron transfer mechanisms.[3] Relevant electrochemical and photophysical data[4] suggested that electron rich olefins should serve as electron donors to singlet excited states of these heteroaromatic salts. Indeed, fluorescence quenching studies with quinolinium and isoquinolinium salts and olefins of varying oxidation potentials demonstrated a correlation between quenching rate constants and predicted[4] k_{et} values These findings stimulated an exploration of the photochemistry of the N-allylpyridinium and -quinolinium perchlorates 1-4.

Irradiation (flint) of a methanolic solution of 4[5] gave, after catalytic hydrogenation (PtO_2), neutralization and chromatographic separation (silica-gel), a mixture of 1,2,3,4-tetrahydroquinoline (23%) and the stereoisomeric (1 6·1) benzoindolizidines 5 (27%) (ϕ=0 004)[5]. The quinolinium salt 4 is converted to a mixture of tetrahydroquinoline (37%) and the diastereomeric carbinols 6 (21%) when irradiated in 25% aqueous-acetonitrile followed by the above described work-up The features of these indolizidine forming reactions are explained through the mechanism outlined in Scheme 1 Importantly hydrogenation of the crude photolysate must be conducted prior to neutralization owing to the instability of the neutral substance 10 (R_1, R_2=benzo) Quinoline, the precursor of the tetrahydro material, can be generated by one of a number of photofragmentation pathways[6] leading to the prenyl cation 8 (R_3=CH_3) Trapping of 8 occurs to yield $(CH_3)_2C(OCH_3)CH=CH_2$ and $(CH_3)_2C=CHCH_2OCH_3$ in a 1 1 4 ratio

Investigations with the pyridinium salts 1 and 2 provided additional information



1 (R_1=R_2=H; R_3=CH_3)
2 (R_1=R_2=R_3=H)
3 (R_1=H; R_2=CO_2CH_3; R_3=CH_3)



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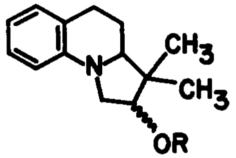


5 (R=CH_3)
6 (R=H)

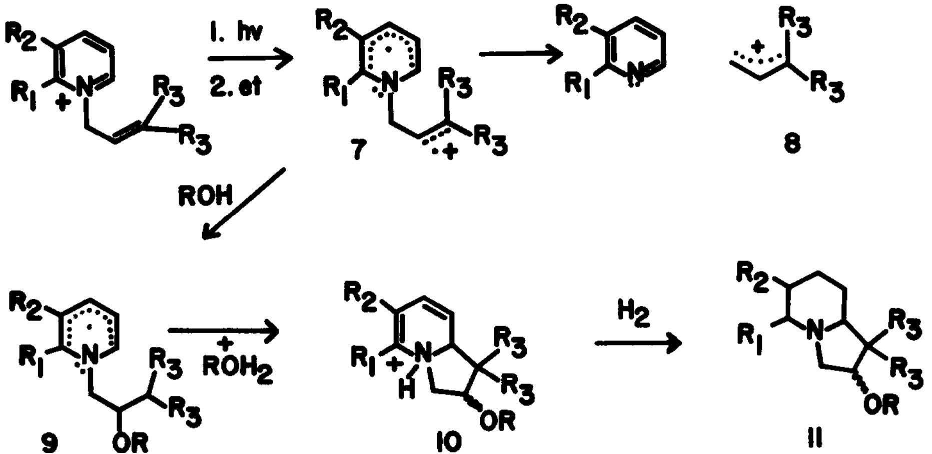
about the process. The N-prenyl salt **1** undergoes efficient (90% at 54% conversion, Ø=0.04)[7] photocyclization giving the stereoisomeric perhydroindolizidines **12** when irradiated in methanol followed by hydrogenation, neutralization, and molecular distillation. Interestingly, the hexahydroindolizidines **13** are isolated in similar yields when catalytic hydrogenation is not performed prior to neutralization and work-up of the crude photolysate. Production of **13** under these conditions suggests that an unusual process is involved in reduction of the initially formed tetrahydroindolizidine (**10**, R_1=R_2=H) or a protonated derivative. The mechanistic details of this process are currently being explored.

Additional data about the electron transfer nature of these reactions are provided by study of the N-allyl perchlorate **2**. Intramolecular electron transfer from the monosubstituted olefinic unit in **2** to the singlet pyridinium moiety should be inefficient (ΔG_{et}° ca. 0 kcal/mol) as compared to **1** (ΔG_{et}° ca. -24 kcal/mol).[4] Thus, the excited state reaction pathways followed by **2** might mimic those of N-alkyl analogs. Accordingly, irradiation of **2** (Corex) in methanol followed by basic work-up and molecular distillation yields (86%, Ø=0.0024) the aminocyclopentene **14**, characterized by x-ray crystallographic analysis of its dimethylammonium salt.[8]

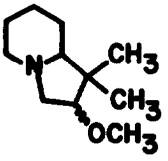
A route, analogous to one described earlier by Wilzbach and his co-workers[9], and not involving electron transfer via an acid catalyzed, stereocontrolled methanolysis of **16**, is responsible for this photoreaction. N-Methylpyridinium perchlorate produces (80%) **15** via **17** under similar conditions. Accordingly, **17** can be detected by glc analysis of the neutralized photolysate prior to it rapid (2h, dark) conversion to **16**.

The above observations suggest that indolizidine forming photocyclizations of N-allylheteroaromatic salts proceed by electron transfer mechanisms involving cyclization of the ultimate diradical **9**. These features were further explored by study of the methyl nicotinate derived salt **3**. Based upon spin density data[10] and borohydride reduction studies,[11] it is expected that diradical cyclization in this case should generate 6-carbomethoxytetrahydroindolizidines (**10**, R=H, R_2=CO_2CH_3) which should resist secondary reduction if prior protonation of the dihydropyridine moiety is required. Our observations support this conjecture. Irradiation (Corex) of **3** in methanol followed by basic work-up generates only trace quantities of materials arising by fragmentation pathways.[12] An unprotonated tetrahydroindolizidine formed under these work-up conditions would be unstable. In contrast, two stereoisomeric indolizidines **18** and **19**, are obtained in reasonable yields (28% and 25%)[13] when the crude photolysate

Scheme I.



is hydrogenated prior to neutralization. The structural assignments to these indolizidines are based on spectroscopic data. Chemical methods were employed to gain stereochemical information. Indolizidines 18 and 19 are epimerized (NaOCH$_3$, CH$_3$OH) to two different stereoisomers, 20 and 21, respectively. Thus, the photocyclization products must be epimeric at C-2 and have the thermodynamically less favored cis relationship at H-8a and H-6. The latter result is expected since hydrogenation of the dihydropyridine ring of 10 (R$_1$=H, R$_2$=CO$_2$CH$_3$) should occur from the least hindered α-face.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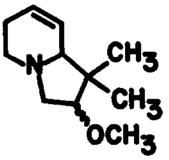
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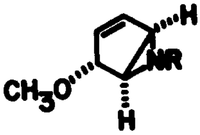
14 (R=CH$_2$CH=CH$_2$)

15 (R=CH$_3$)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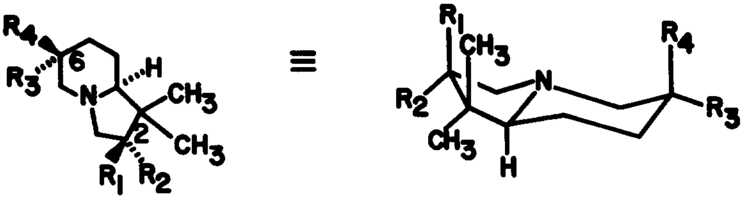
17



18 (R$_1$=OCH$_3$, R$_2$=H, R$_3$=H, R$_4$=CO$_2$CH$_3$)

19 (R$_1$=H, R$_2$=OCH$_3$, R$_3$=H, R$_4$=CO$_2$CH$_3$)

20 (R$_1$=OCH$_3$, R$_2$=H, R$_3$=CO$_2$CH$_3$, R$_4$=H)

21 (R$_1$=H, R$_2$=OCH$_3$, R$_3$=CO$_2$CH$_3$, R$_4$=H)

REFERENCES

1. The author to whom inquiries about this article should be sent at the University of Maryland.
2. (a) Mariano, P.S., Stavinoha, J.L., Swanson, R., J. Am. Chem. Soc., 1977, 99, 6781; (b) Mariano, P.S., Stavinoha, J.L., Pepe, G., Meyer, E.F., ibid, 1978, 100, 7114; (c)Stavinoha, J.L., Mariano, P.S., ibid, 1981, 103, 3136; (d) Mariano, P.S., Stavinoha, J.L., Leone, A.A., Swanson, R., ibid, 1981, 103, 3148; (e) Mariano, P.S., Leone, A.A., Tetrahedron Lett., 1980, 4581; (f) Stavinoha, J.L., Bay, E., Leone, A.A., Mariano, P.S., ibid., 1980, 3455 (g) Mariano, P.S., Stavinoha, J.L., Bay, E., Tetrahedron, 1981, 36, 0000.
3. (a) McCall, M.T., Whitten, D., J. Am. Chem. Soc., 1969, 91, 5681; (b) Ledwith, A., Catteau, J.P., Lablache-Combier, A., Tetrahedron, 1975, 31, 2255; (c) Whitten, D. in "The Photochemistry of Heterocyclic Compounds", ed Buchardt, O., Wiley, New York, 1976, Chap 8 for a review of this area of chemistry.
4. Rehm, D., Weller, A., Isr. J. Chem., 1970, 8, 259.
5. Preparative and spectroscopic details will be reported in our full paper on this subject. All new compounds gave satisfactory molecular compositions. Flint glass transmits light >300 nm. Basic work-up of crude photolysates involves treatment with aqueous Na_2CO_3 after concentration in order to liberate free amine products. Quantum yields are for product formation and are measured at <10% conversion.
6. Jaeger, D.A., J. Am. Chem. Soc., 1975, 97, 902; Cristol, S.J., Schloemer, G.C., ibid., 1972, 94, 5916; Cristol, S.J., Strom, R.M., ibid., 1979, 101, 5707; Laird, T., Williams, H., J. Chem. Soc. Chem. Commun., 1969, 561; Maycock, A.L., Berchtold, G.H., J. Org. Chem., 1970, 35, 2532.
7. The hexahydroindolizidine 13 is unstable under the photolytic reaction conditions although it does not absorb the incident light. Product yields begin to decrease after 50% conversion. Quantum yields were measured at <5% conversion.
8. The complete x-ray crystallographic analysis will be discussed elsewhere.
9. Kaplan, L., Pavlick, J.W., Wilzbach, K.E., J. Am. Chem. Soc., 1972, 94, 3283.
10. Dohrmann, J.K., Becker, R., J. Magn. Resonance, 1977, 27, 371.
11. Kinoshita, N., Hamana, M., Kawasaki, J., Chem. Pharm. Bull., 1962, 10, 753.
12. The isolation and mechanism for formation of methyl nicotinate and 6-isopropylnicotinate under these conditions will be discussed in our full paper.
13. Yields are based on 60% conversion and are low due to the fact that the dihydropyridine products strongly absorb incident light.
14. Support of this research by the National Science Foundation (CHE-80-90813) and National Institutes of Health (GM-27251) is gratefully acknowleged.

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