Evidence for Ionic Intermediates in Fluorination of Alkenes with N–F Type of Reagents

Marko Zupan,* Primož Škulj, and Stojan Stavber
Laboratory of Organic and Bioorganic Chemistry, Department of Chemistry and "J. Stefan" Institute, University of Ljubljana Aškerčeva 5, 1000 Ljubljana, Slovenia

(Received March 23, 1998; CL-980223)

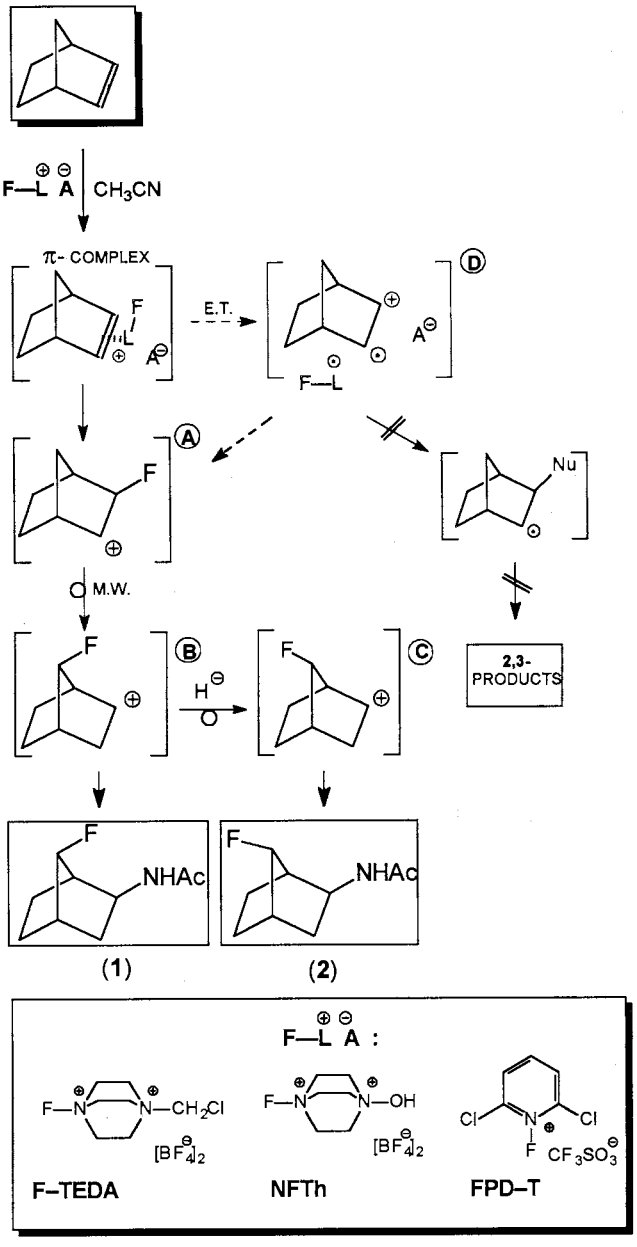
2-Exo-acetamido-7-syn-fluoro norbornane and 2-exo-acetamido-7-anti-fluoro norbornane were formed in the room temperature reaction of bicyclo[2.2.1]heptene in acetonitrile with N–F type reagents [1-chloromethyl-4-fluoro-1,4-diazoniabicyclo [2.2.2] octane bis(tetrafluoroborate) (F–TEDA), 1-fluoro-4-hydroxy-1,4-diazoniabicyclo[2.2.2]octane bis(tetrafluoroborate (NFTh) and 2,6-dichloro-1-fluoro pyridinium triphlate (FPD–T)]. Such Meerwein-Wagner rearrangement and hydride shift indicated the formation of fluoro carbonium ions.

The N–F class of reagents are easy to handle and commercially available, while their reactivity depends on their type,[1] which might be the R_1R_2NF type,[2] N-fluoro pyridinium and related salts[3] or $F\text{-}N^+R_1R_2R_3$ A^- type.[4] Fluoro functionalizations of alkenes with the N–F type of reagents were explained with ion radical formation,[2,3] while the low Hammet ρ value suggested the nonpolar nature of the rate-determining step.[5] On the other hand, laser flash photolysis studies demonstrated that ion radicals generated from alkenes are trapped by a nucleophile and the formation of radical intermediates was proven.[6] Bicyclo[2.2.1]heptene is an excellent model alkene enabling discrimination between radical and ionic intermediates.[7] The former intermediates are mainly transformed to 2,3-disubstituted products, while the latter intermediates usually undergo Meerwein-Wagner rearrangement and/or hydride shift and the formation of 2,5- and/or 2,7-disubstituted products are observed.

We now report the use of norbornene as a mechanistic tool to gain further insight into nature of the intermediates involved in the reactions of alkenes with N-F reagents. In a typical experiment we dissolved 1 mmol of norbornene in 5 ml of acetonitrile, 1.2 mmol of N–F reagent [F–TEDA, NFTh, FPD-T or N-fluoro bis(benzenesulphonamide) NFSi] was added and stirred at room temperature for 4 hours. NFSi did not react even at prolonged reaction times, whilst F–TEDA, NFTh and F–PDT gave crude reaction mixtures containing two products which were isolated by g.l.p.c. and characterized on the basis of their spectroscopic data.[8] The ratios between 2-exo-acetamido-7-syn-fluoro norbornane (**1**) and 2-exo-acetamido-7-anti-fluoro norbornane (**2**) are not much influenced by the structure of the N–F reagent (**1**: **2**; F–TEDA = 50:50, NFTh = 48:52, FPD–T = 55:45).

On the basis of the experimental results we suggest the mechanism presented in the Scheme. In the first step a π-complex is probably formed which could be tranformed to the β-fluoro carbonium ion (**A**), Meerwein-Wagner rearrangement gives ion (**B**), and reaction with acetonitrile results in the formation of (**1**). The rearranged fluoro carbonium ion (**B**) undergoes hydride shift forming ion (**C**) while reaction with acetonitrile gives (**2**). The absence of 2,3-disubstituted products diminishes the possibility of an electron transfer process; however conversion of the ion radical (**D**) to fluoro carbonium ion (**A**) cannot be completely excluded, because the situation in the proposed intimated pair (**D**) is not clear and not comparable

Scheme.



with laser-flash experiments, where ion radicals were transformed to radical intermediates.[6] The present results confirmed that the main intermediates in mild fluorinations of alkenes with N–F type of reagents have an ionic nature.

We are indebted to Dr. G. A. Shia, Allied Signal Chemicals, Buffalo, New York for free samples of NFTh and NFSi, and to Dr. K. Nukui, New Field Research Lab., Chichibu Onoda Cement Corp., Japan for FPD-T.

References

1 G. S. Lal, G. P. Pez, and R. G. Syvret, *Chem. Rev.*, **96**, 1737 (1996).

2 D. D. DesMarteau, Z. Q. Xu, and M. Witz, *J. Org. Chem.*, **57**, 629 (1992).

3 T. Umemoto, S. Fukami, G. Tomizawa, K. Harasawa, K. Kawada, and K. Tomita, *J. Am Chem. Soc.*, **112**, 8563 (1990).

4 R. E. Banks, S. N. Mohialdin-Khaffaf, G. S. Lal, I.; Sharif, and R. G. Syvret, *J. Chem. Soc., Chem. Commun.*, **1992**, 595; R. E. Banks, M. K. Besheesh, S. N. Mohialdin-Khaffaf, and I. Sharif, *J. Chem. Soc.; Perkin Trans. 1* **1996**, 2069; G. S. Lal, *J. Org. Chem.* **58**, 2791 (1993); S. Stavber, T. Sotler, and M. Zupan, *Tetrahedron Lett.*, **35**, 1105 (1994); S. Stavber, M. Zupan, A. J. Poss, and G. A. Shia, *Tetrahedron Lett.*, **36**, 6769 (1995).

5 S. Stavber, T. Sotler-Pečan, and M. Zupan, M. *Bull. Chem. Soc. Jpn.*, **69**, 169 (1996).

6 L. J. Johnston and N. P. Schepp, *J. Am. Chem. Soc.*, **115**, 6564 (1993); M. S. Workentin, N. P. Schepp, L. J. Johnston, and D. D. M. Wayner, *J. Am. Chem. Soc.*, **116**, 1141 (1994).

7 T. G. Traylor, *Acc. Chem. Res.*, **2**, 152 (1969); F. Freeman, *Chem. Rev.*, **75**, 439 (1975); R. S. Brown, *Acc. Chem. Res.*, **30**, 131 (1997).

8 Products were isolated by preparative g.l.c: 35% of 2-exo-acetamido-7-syn-fluoro norbornane (**1**), mp: 129°-131°C; δF=-207 ppm (ddd, J=58, 6, 6 Hz) δH_7=4,90 ppm (d) δH_2=3,73 ppm (m); MS: m/z=171, 109, 92, 86, 67; and 37% of 2-exo-acetamido-7-anti-fluoro norbornane (**2**), mp: 87°-88°C; δF=-201 ppm (dm, J=58 Hz) δH_7=4,90 ppm (d, $^2J_{FH}$=58Hz) δH_2=4,15 ppm (m); MS: m/z=171, 109, 92, 86, 67.