THE EFFECT OF THE TRIFLUOROMETHYL GROUP ON THE METHYLENECYCLOPROPANE REARRANGEMENT

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Summary: The CF_3 group, in conjunction with an electron donor group, can enhance the rate of the methylenecyclopropane rearrangement. This is attributed to captodative radical stabilization of the intermediate biradical.

Extensive studies have been carried out in which the potent electron withdrawing trifluoromethyl group is attached to a developing carbocationic center.¹ The effect of this important group on the stability of free radicals of type 1 has been investigated to a far lesser extent.² The σ_{α} value of Arnold³ indicated that CF₃ is slightly destabilizing relative to hydrogen when substituted on a benzyl radical. Our σ value, based on rearrangement rates of methylenecyclopropanes,⁴ indicates that CF₃ is slightly stabilizing relative to hydrogen while the Pasto's radical stabilization energies⁵ indicate that \cdot CH₂CF₃ is destabilized relative to the methyl radical. In light of these conflicting results, we have therefore carried out more extensive studies using our methylenecyclopropane rearrangement rates of 2. These studies were designed to evaluate the effect of CF₃ substituents (on the aromatic ring and directly attached to the radical center) on the stability of the biradical 3 (which is involved in the rearrangement of 2 to 4).



Thermal rearrangement rates of the methylenecyclopropanes 5-13 in C_6D_6 were measured by ¹H NMR spectroscopy.⁶ Shown below are rate comparisons of the p-H with the p-CF₃ analogs. The effect of the CF₃ group is not constant, but varies with the electronic character of the substituent. In the pair 5 and 6, the CF₃ group slows the rearrangement rate while in the remaining pairs, the CF₃ group enhances rate relative to the p-H analog. Based on these data, one cannot definitively classify p-CF₃ as radical stabilizing or destabilizing relative to hydrogen.



These data also suggest that a captodative effect⁷ can operate in the rearrangement of certain p- CF_3 substituted systems. The combination of the electron withdrawing p- CF_3 with an electron donor group imparts increased stability to the transition state leading to the biradical **3**. Using a valence bond notation, the intermediate **14** derives additional stabilization from forms such as **14c** and **14d** due to the anion stabilizing ability of CF_3 .⁸ While conjugating groups such as CN or COR have been suggested to be capable of captodative stabilization, this study suggests that the purely inductively electron withdrawing CF_3 group can also be involved in such free radical stabilization.



The m-CF₃ substituted system 13 also rearranges faster than the unsubstituted system 11, suggesting that the m-CF₃ substituted biradical intermediate also derives some additional stabilization. This finding is unusual in that electron withdrawing meta-substituents previously

have been found to slightly retard rates. The enhanced rate of 13 can also be attributed to a captodative effect as represented by 15. Spin delocalization to the para-position of the ring allows for conjugation of the methoxy non-bonding electron pair with the meta carbon as in 15b, a form which has increased importance due to the inductive effect of the CF₃ group.

Attention was next turned to systems where the CF₃ group is directly attached to the developing radical center. All of the α -CF₃ substituted systems rearrange faster⁹ than the α -H analogs but



rate enhancements due to CF_3 substitution, as before, are not constant. Interpretation of these data is complicated by the fact that steric factors are not constant in the α -CF₃ and α -H analogs. The α -CF₃ group is larger than α -H and probably enhances rate due to a steric factor. If one assumes that steric factors (and other ground state effects) remain constant in the α -CF₃ systems then rate effects due to radical stabilization or destabilization by CF₃ are not constant. Rate enhancements increase with the electron donating character of the para-substituent.

The rate data can be explained in terms of a captodative effect in systems containing electron donating groups. If one assumes that captodative stabilization cannot operate in biradicals derived from the p-CO₂Et system 17 and the p-SO₂CH₃ system 19, then the rate enhancements in these systems (a factor of about 3) is probably due to steric factors. In the other α -CF₃ systems, the combination of electron donor substituent with the CF₃ group leads to stabilization in the transition state and a rate enhancement which exceeds the steric enhancement factor of 3. Forms such as 27a and 27b illustrate this captodative effect.



Further analysis of rate data reveals that the electron withdrawing p-CO₂Et substituent in 16 enhances rate by a factor of 2.47 relative to the p-H analog 7. In the α -CF₃ analog 17 the p-CO₂Et substituent enhances rate to a smaller extent (a factor of 1.67) relative to the p-H analog 20. In the methylenecyclopropane 25, the electron donating p-NMe₂ substituent enhances rate by a factor of 10 relative to 7, but in the α -CF₃ analog 26, the p-NMe₂ substituent enhances rate by a factor of 10 relative to 7, but in the α -CF₃ analog 26, the p-NMe₂ substituent enhances rate by a larger factor of 18.9 relative to 20. *This suggests that the CF₃ group should not be classified as radical stabilizing or destabilizing in an absolute sense.* Instead, the CF₃ group enhances the radical stabilizing ability of electron donor groups such as OCH₃ and NMe₂ and decreases the radical stabilizing ability of electron withdrawing groups such as CO₂Et.

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References and Notes

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- 6. k for $5 = 2.35 \times 10^{-4} \text{ s}^{-1}$ at 40 °C. k for $7 = 5.57 \times 10^{-5} \text{ s}^{-1}$ at 80 °C. k for $9 = 3.78 \times 10^{-5} \text{ s}^{-1}$ at 60 °C. k for $11 = 1.12 \times 10^{-4} \text{ s}^{-1}$ at 22.8 °C.
- For a review of the captodative effect and leading references, see Viehe, H. G.; Janousek, Z.; Merényi, R. <u>Acc.</u> <u>Chem. Res.</u> 1985, 18, 148. For examples of the captodative effect in the methylenecyclopropane rearrangement, see (b) Creary, X.; Mehrsheikh-Mohammadi, M. E. <u>J. Org. Chem.</u> 1986, 51, 2664.
- For leading references, see Holtz, D. <u>Prog. Phys. Org. Chem.</u> 1971, 8, 1. See also Hine, J. in "Physical Organic Chemistry"; McGraw-Hill Book Company, Inc., New York, 1962, p 230.
- 9. 10^5 k (s⁻¹) for 16, 18, 7, 21, 23, and 25 in C₆D₆ at 60.0 °C are 1.25, 0.872, 0.505, 1.48, 1.13 and 5.08 respectively.

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