The facile loss of formic acid from an anion system in which the charged and reacting centres cannot interact
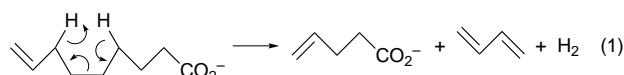
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Both the 3-[2-(2-formyloxy-1,3-[²H₆]propyl)]adamantane carboxyate anion and cation undergo loss of HCO_2D from the 3 substituent by processes which occur remote from and uninfluenced by the carboxylate charged centre.

It has been proposed that reactions which occur remote from and uninfluenced by the charged centre (charge-remote reactions) can occur following collisional activation of even electron organic anions in the gas phase.[1,2] In support of this, charge-remote loss of a radical from an $(M - H)^-$ ion is sometimes observed when the product formed is a stable radical anion.[3] The evidence in favour of the loss of (even electron) neutrals commonly occurring by charge-remote processes from even electron anions is not strong however.[4] One such process which has been substantiated is the Gross reaction:[1,2,5,6] the particular example shown in eqn. (1) is energetically unfavoura-

ble (calculations indicate that $\Delta H = +209$ kJ mol⁻¹ while the activation barrier is some 370 kJ mol⁻¹), and occurs following extensive hydrogen exchange along the carbon skeleton.[6] It appears that charge-remote reactions may occur when anion directed fragmentations are energetically unfavourable in comparison.

We have continued our search for charge-remote reactions utilising a system in which the anion site is unable to approach the reacting centre. Certain 1,3-disubstituted adamantanes fulfil this prerequisite, and we have chosen the carboxylate group as the anion site.

When cyclohexyl acetate is heated to 160 °C in solution, cyclohexene and acetic acid are formed in almost quantitative yield.[7] The reaction is slightly endothermic [$\Delta G = +18$ kJ mol⁻¹ (ref. 8)] and the barrier is calculated [at MP4 (SDTQ)/6-31G* level for the model system ethyl formate] to be near 220 kJ mol⁻¹.[9] We have synthesised **1**† as an anion model for this reaction. The two substituents in **1** can neither interact through bonds, nor approach through space. The parent $(M - H)^-$ ion fragments by exclusive loss of HCO_2D (Fig. 1): this charge-remote reaction (which shows similarities to both the McLafferty rearrangement of a radical cation, and the Norrish 2 rearrangement of a diradical) is summarised in eqn. (2).
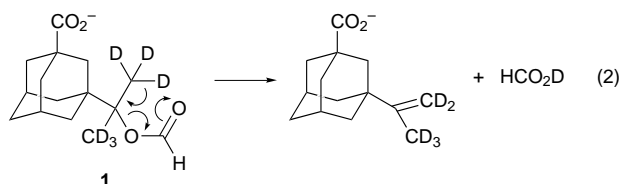
The neutrals formed following collisional activation of the unlabelled analogue corresponding to **1** have also been studied: the $^-N_fR^+$ spectrum (the compositive positive ion spectrum produced by ionisation of all neutrals formed following
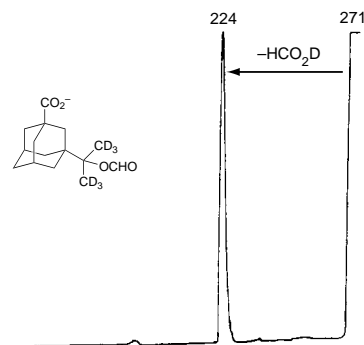
Fig. 1 Collisional activation mass analysed ion kinetic energy spectrum of **1**. VG ZAB 2HF mass spectrometer operating in negative chemical ionisation mode. The carboxylic acid precursor is deprotonated by HO⁻ (from H₂O), source pressure *ca.* 10⁻¹ Torr (1 Torr = 133.322 Pa), collision gas Ar (pressure 5×10^{-7} Torr), for full experimental details see ref. 6.

collisional activation of the parent negative ion)[5,6] of these shows a small peak on the side of the $CO_2^{·+}$ peak which corresponds to *m/z* 46 ($HCO_2H^{·+}$), establishing that formic acid is amongst the neutrals formed during fragmentation of unlabelled parent anion corresponding to **1**.

Finally, if this reaction is uninfluenced by the charged centre, then it should also operate for the cognate species containing a carboxylate cation centre, provided of course that there is no low energy positive ion fragmentation which occurs in preference to the charge-remote reaction. A carboxylate cation cannot be formed by conventional positive ion mass spectrometry, but it is accessible by charge reversal[11] of anion **1**. The charge reversal spectrum of **1** (Fig. 2) [a charge reversal spectrum is the positive ion spectrum resulting from the energised $(M - H)^+$ species formed following collision induced charge stripping of the $(M - H)^-$ ion] shows small peaks due to $(M - H)^+$, $[(M - H)^+ - CO_2]$ and $[(M - H)^+ - HCO_2D]$
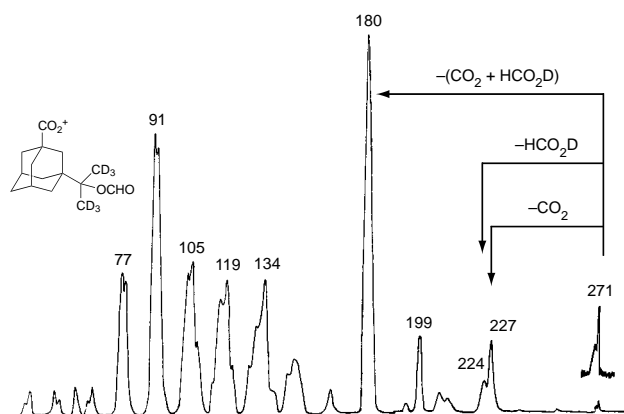
Fig. 2 Charge reversal (positive ion) mass spectrum of anion **1**. VG ZAB 2HF spectrometer. Experimental conditions as for Fig. 1 except that the voltage of the electric sector is reversed to allow the transmission of positive ions.

ions. The base peak is produced by the overall process $[(M - H)^+ - (CO_2 + HCO_2D)]$ but it is not known whether loss of HCO_2D in this instance occurs from the $(M - H)^+$ and/or the $[(M - H)^+ - CO_2]$ ions.

It is thus established experimentally that charge-remote loss of HCO_2D occurs from anion **1**, and also *via* the corresponding carboxylate cation.

Footnotes and References

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† Dimethyl-1,3-adamantane dicarboxylate was reacted with 2.1 mol equiv. of CD_3Li to form methyl 3-[2-(2-hydroxy-1,3-[$^2H_6$]propyl)]adamantane carboxylate, which was hydrolysed under base catalysed conditions to the corresponding carboxylic acid, which was formylated using acetic–formic anhydride[10] to yield 3-[2-(2-formyloxy-1,3-[$^2H_6$]propyl)]adamantane carboxylic acid (the neutral precursor of **1**) in 60% overall yield.

1 J. Adams and M. L. Gross, *J. Am. Chem. Soc.*, 1989, **111**, 435 and references therein; M. L. Gross, *Int. J. Mass Spectrom. Ion Process.*, 1992, **118/119**, 137.

2 J. Adams, *Mass Spectrom. Rev.*, 1990, **9**, 141.

3 P. C. H. Eichinger and J. H. Bowie, *Int. J. Mass Spectrom. Ion Process.*, 1991, **110**, 123.

4 V. H. Wysocki, M. H. Bier and R. G. Cooks, *Org. Mass Spectrom.*, 1988, **23**, 627; V. H. Wysocki, M. M. Ross, S. R. Horning and R. G. Cooks, *Rapid Commun. Mass Spectrom.*, 1988, **2**, 214; V. H. Wysocki and M. M. Ross, *Int. J. Mass Spectrom. Ion Process.*, 1991, **104**, 179.

5 M. M. Cordero and C. Wesdemiotis, *Anal. Chem.*, 1994, **66**, 861.

6 S. Dua, J. H. Bowie, B. A. Cerda, C. Wesdemiotis, M. J. Raftery, J. F. Kelly, M. S. Taylor, S. J. Blanksby and M. A. Buntine, *J. Chem. Soc., Perkin Trans. 2*, 1997, 695.

7 C. H. DePuy and R. W. King, *Chem. Rev.*, 1960, **60**, 431.

8 Data from G. Aylward and T. Findlay, *S. I. Chemical Data*, Wiley, New York, 3rd edn., 1994.

9 S. A. Boehm and P. N. Skauche, *Int. J. Quantum Chem.*, 1991, **40**, 491.

10 W. Stevens and A. Van, *Rec. Trav. Chim. Pays-Bas.*, 1964, **83**, 1287; 1294.

11 J. H. Bowie and T. Blumenthal, *J. Am. Chem. Soc.*, 1975, **97**, 2959; J. E. Szulejko, J. H. Bowie, I. Howe and J. H. Beynon, *Int. J. Mass Spectrom. Ion Phys.*, 1980, **13**, 76.