Chemically Induced Dynamic Polarisation of ^{19}F-Nuclei During Reactions at Chiral Centres; the Benzylic Insertion of Diphenylmethylene into Diastereoisomeric 1-Methylheptyl α-Fluorophenylacetates

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Summary Polarisation of ^{19}F-nuclei during the insertion of triplet diphenylmethylene into the benzylic C–H bond of individual, optically active, diastereoisomeric 1-methylheptyl α-fluorophenylacetates appears equally in both diastereoisomeric products, indicating that the radical pairs giving rise to CIDNP show no stereochemical preference in their combination.

Polarisation observed in n.m.r. spectra of products of radical reactions carried out in the high magnetic field of the spectrometer probe can be interpreted quantitatively using the radical-pair theory.[1] The currently favoured model for the radical pair regards the components as undergoing diffusion apart and re-encounter according to the theory of random walks during *ca.* 10^{-9} s.[2] During this period, evolution of singlet and triplet states of the radical pair can take place as a result of the Zeeman and hyperfine interactions of the odd electrons. Because of the nuclear-spin dependence of the hyperfine interaction and of the different chemical behaviour of singlet and triplet radical pairs on re-encounter, reaction products arise with non-Boltzmann distributions of nuclear-spin states. The success of the theory in predicting the appearance of polarised spectra is taken to justify the model used, and little direct experimental study of other aspects of the behaviour of these radical pairs has been undertaken. We describe here a preliminary investigation of stereochemistry.[3]

Decomposition of diphenyldiazomethane (1·0 M) in solution in racemic methyl α-fluorophenylacetate at 120° gave the product of insertion of the carbene into the benzylic C–H bond in *ca.* 15% yield. Polarisation of the ^{19}F- and ^{1}H-nuclei was observed in the product, $Ph_2CH{\cdot}CFPhCO_2Me$. For the ^{19}F-doublet, (466 Hz upfield from the solvent ^{19}F-doublet), a combination of net and multiplet polarisations A + E/A was observed and this is consistent with Kaptein's rules for reactions of triplet diphenylmethylene ($\Gamma_{NE} = \mu\epsilon\Delta g a_F = ++++ = + \equiv A$; $\Gamma_{ME} = \mu\epsilon a_F a_H J_{HF}\sigma = +++-+- = + \equiv E/A$). The polarised spectrum could be reproduced using a computer program kindly provided by Dr. J. A. den Hollander of the University of Leiden and adapted by Dr. D. A. R. Williams, using $a_F + 50$ G; $a_H - 8$ G; $g(Ph_2CH)$ 2·00250; $g(PhCFCO_2Me)$ 2·00425; $J_{HF} + 32$ Hz. The accumulated ^{19}F-spectrum of the depolarised product agreed in chemical shift and coupling constant with authentic material prepared from methyl α-fluorophenylacetate and diphenylmethyl bromide by treatment with sodium hydride.[4]

By esterifying racemic α-fluorophenylacetic acid with racemic n-octan-2-ol, a mixture of diastereoisomers results and two ^{19}F-doublets showing A + E/A polarisation could be observed when this reacted with diphenylmethylene at 135°. Resolution of the parent acid with (−)-ephedrine [(−)-isomer, $[\alpha]_D = -149°$ ($c = 1{\cdot}8$ in acetone); (+)-isomer, $[\alpha]_D = +136°$ ($c = 1{\cdot}5$ in acetone)] and esterification with (−)-n-octan-2-ol gave the individual diastereoisomers. When diphenyldiazomethane was decomposed in either of these esters, the same A + E/A pattern of polarisation was observed for *both* diastereoisomeric products. Indeed, the polarised spectra were essentially identical with that observed in the reaction with the racemic mixture of diastereoisomers. Some difficulty was experienced in assessing the relative intensity of the signals due to each diastereoisomeric product since, at the reaction temperature, the upfield line of one doublet has almost the same frequency as the downfield line of the other. However, within the experimental error, the polarised signals due to each product were of equal intensity at the time of maximum enhancement starting from either diastereoisomeric reactant.

Examination of the accumulated ^{19}F-n.m.r. spectrum of the products after completion of the reaction showed that the stereochemical outcome of the insertion was largely racemisation at the fluorine-bearing carbon atom, as expected in abstraction-recombination reactions of carbenes.[5] However, the depolarised spectra indicated a small excess (*ca.* 55 : 45) of one diastereoisomer which, from its chemical shift, we believe to be that formed with retention.

In the present experiments, the ^{19}F-polarisation clearly arises from combination of radical pairs which show no stereochemical preference. This behaviour is thus consistent with the diffusion model of CIDNP, in which combination of radical pairs to give polarised products occurs on re-encounter of the geminate pair after many diffusive displacements. The slight excess of retention in the overall reaction could arise either from a direct insertion pathway of the (singlet) carbene or by a true cage effect[6] in the geminate pair; neither process would lead to polarisation. Further work is in hand in an attempt to distinguish between these possibilities.

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[1] For reviews, see 'Chemically Induced Magnetic Polarisation,' eds. A. R. Lepley and G. L. Closs, Wiley-Interscience, New York, 1973; D. Bethell and M. R. Brinkman, *Adv. Phys. Org. Chem.*, 1973, **10**, 53.

[2] F. J. Adrian, *J. Chem. Phys.*, 1970, **53**, 3374; 1971, **54**, 3912.

[3] For a recent study of a rearrangement showing CIDNP using racemic diastereoisomers, see F. Gerhart and L. Wilde, *Tetrahedron Letters*, 1974, 475.

[4] R. Fraisse-Jullien and N. Thoi-Lai, *Bull. Soc. chim. France*, 1967, 3904.

[5] See, for example, W. Kirmse, 'Carbene Chemistry', Academic Press, New York and London, 2nd edn., 1971, p. 222; D. Bethell in 'Organic Reactive Intermediates,' ed. S. P. McManus, Academic Press, New York and London, 1973, ch. 2

[6] J. P. Lorand, *Progr. Inorg. Chem.*, 1972, **17**, 207.