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ELIMINATION REACTIONS. PART IV[1].

HEAVY ATOM ISOTOPE EFFECTS IN E1cB ELIMINATION REACTIONS

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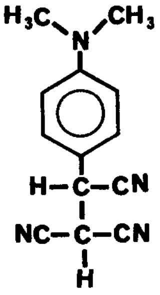
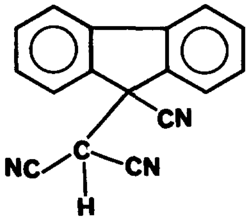
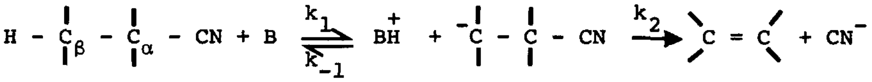
Although heavy-atom isotope effects have been widely used in mechanistic studies of substitution reactions, little work has been reported on their use in studies of elimination reactions[2]. In the latter, studies of these effects hold promise for the identification of the degree of bond extension (or bond breakage) in the rate determining step and thus for the investigation of reactions which lie close to the mechanistic borderlines between E1, or E1cB, and E2 reactions. We have been unable to find any examples of heavy atom isotope effects in E1cB eliminations and report here our preliminary studies of the ^{14}C leaving group effects in HCN elimination from the polycyanoethanes (I) and (II). Studies of the magnitude of such effects in E1cB eliminations, and the factors affecting them, are necessary prerequisites for their use in mechanistic interpretations.



I



II

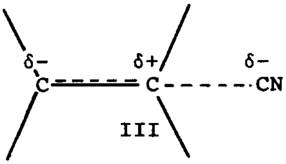


$$H-\overset{|}{\underset{|}{C}}_{\beta}-\overset{|}{\underset{|}{C}}_{\alpha}-CN+B\ \underset{k_{-1}}{\overset{k_1}{\rightleftharpoons}}\ \overset{+}{B}H+{}^{-}\overset{|}{\underset{|}{C}}-\overset{|}{\underset{|}{C}}-CN\xrightarrow{k_2}\,>C=C<\,+CN^{-}$$

Base catalyzed elimination of HCN from (I) and (II) occurs in methanol and methanol-water mixtures, both with and without added external base (e.g. methoxide ion, piperidine, etc.). The high acidity of the hydrogen attached to C_β enhances the probability of carbanion formation. The poor leaving group stabilizes the resulting carbanion and ElcB elimination results. The immediate exchange (in $CDCl_3$) of the acidic hydrogen with CD_3OD in (I) and (II) confirms the ease of carbanion formation, although this may, in some cases, be only a side reaction[3], and the rates of HCN elimination from both deuteriated and protiated substrates in CH_3OH are almost identical.

Labelling the leaving group (^{14}CN from $K^{14}CN$) showed that the second step (k_2) is slow and gave kinetic isotope effects as shown in the Table[4]. These values may be compared with those for decarboxylation of malonic acids (leading to the enol forms of the acetic acids) which show $^{12}C/^{14}C$ isotope effects of 1.064-1.088 for labelled carboxyl carbons[5,6]. Values for labelled leaving group carbon atoms generally lie in the range 1.02-1.08 for E2 eliminations. Although the labelled starting materials were obtained by $K^{14}CN$ addition to the product olefins, under the experimental conditions of the kinetic studies reactions could be followed to >90% completion. Thus no loss of product or build up of labelled substrate has occurred which would account for the high value for (II)[7]. (There is no evidence of any competing substitution). Although it is tempting to conclude that the values obtained reflect the degree of bond breakage in the rate determining step, and hence the extent of E2 character in this reaction, they probably indicate the effect of both geometry and substituents upon cyanide ion loss from C_α of the carbanions. The rigid geometry in (II) will make the transition state of the slow step more product-like than in (I) and the rehybridization energy will be higher. The stabilization of the potentially positive carbon in the transition state (e.g. III) should also be greater in (I) than in (II). Thus the transition state for (I) should be more reactant-like than that for (II) and a lower isotope effect may well result.

Some support for this interpretation is found in the rates of elimination in deuteriated solvent (Table). Assuming that there is no primary kinetic hydrogen isotope effect in these reactions,[8] the results reflect equilibrium isotope effects on k_1/k_{-1} and primarily solvent effects upon k_2. More product-like transition states, involving separation of charge, and requiring less solvation will be better stabilized by the deuteriated solvent[9], leading to inverse isotope effects upon k_2. Assuming an approximately equal isotope effect for the equilibrium ionization of both (I) and (II)[10], the lower overall value of k_H^H/k_D^D for (II) accords with this. Further studies of the effect of substituents upon the α carbon atom are necessary to confirm these suggestions.



III

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TABLE

Leaving group isotope effects and rate data for the elimination of HCN from (I) and (II) in methanol and methan [$^2H_1$]ol at 30°C.

Carbon isotope effects

I $k^{12}/k^{14} = 1.04 \pm 0.01$ II $k^{12}/k^{14} = 1.16 \pm 0.03$

First order rate constants x 10^5 (min^{-1})† ($k_{obs} = k_1k_2/k_{-1}$)

	CH_3OH	CH_3OD	k_H^H/k_D^D
I	97.7	34.3	
I-D*	92.2	32.5	2.8
II	8.78	6.82	
II-D*	8.34	7.18	1.2

† First order rate coefficients for (II) were obtained from the experimental zero order coefficients.

* Dicyanomethyl hydrogen atom replaced by deuterium.