

NUCLEOPHILIC PARTICIPATION OF HMPT IN THE BROMINATION OF ALKENES AND  
IN THE ACID-PROMOTED RING OPENING OF OXIRANES

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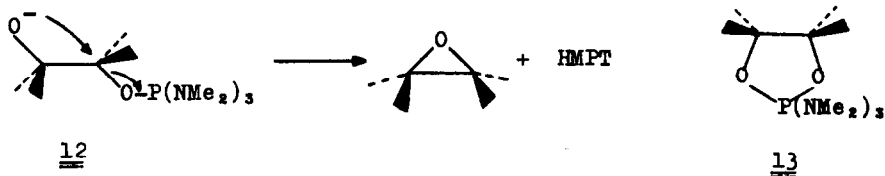
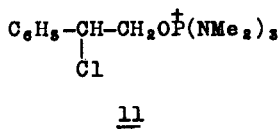
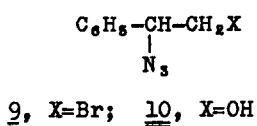
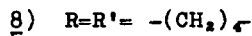
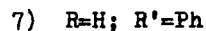
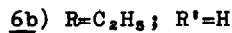
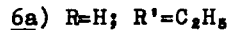
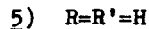
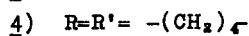
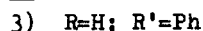
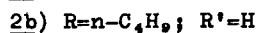
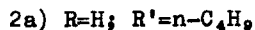
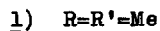
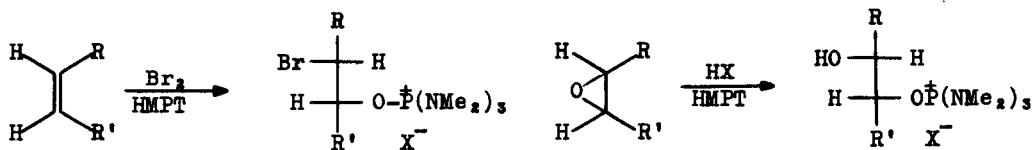
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Participation of basic solvents in the nucleophilic steps of electrophilic additions to alkenes and of acid-catalyzed ring openings of 1,2-epoxides, two closely related types of reactions, has been widely documented. In the case of anhydrous dipolar aprotic solvents this leads to the formation of intermediate cations, which in some cases (acetone<sup>1</sup>, acetonitrile<sup>1,2</sup>) are stabilized through formation of a covalent bond with an anion, in others (DMSO<sup>3</sup>, DMF<sup>1,4</sup>, pyridine-N-oxides<sup>5</sup>) are sufficiently stable as salts. The presence of these intermediate species has either been demonstrated through actual isolation, or inferred from indirect evidence.

We have now found that also hexamethylphosphoric triamide (HMPT) behaves in a similar way, producing particularly stable phosphonium salts. Thus, when a cold solution of cyclohexene (3 mmole) in HMPT (12 mmole) was treated with bromine (3 mmole), then diluted with ether a yellow semi-solid compound containing active bromine was obtained; solution in CHCl<sub>3</sub>, treatment with a little cyclohexene, and precipitation with ether gave the bromide 4 (X=Br), which was converted into the water insoluble tetraphenylborate salt. Analogous treatments converted cis-2-butene, 1-hexene, and styrene into salts 1, 2 and 3.

Addition of CF<sub>3</sub>COOH (40 mmole) to a solution of cyclohexene oxide (20 mmole) in HMPT (80 mmole), followed after 4 hr by dilution with ethyl ether and petroleum ether, gave an oil which was converted into the solid salt 8 (X=BPh<sub>4</sub>). Salts 5-7 were similarly obtained from the corresponding epoxides.

The structures of the salts 1-8, which evidently derive from a nucleophilic attack by the solvent on the intermediate bromonium (or bromocarbonium) and oxiranium ions, were attributed on the basis of elemental analyses and NMR



spectra. All the salts exhibit a doublet of 18 protons in agreement with the presence of 6 equivalent methyl groups coupled with P, with the expected  $^3J_{\text{HP}}$  of about 10 Hz<sup>6</sup>, and the other signals in the spectra agree with the proposed structures (Table I).

The bromides of 1-4 and the trifluoroacetates of 5-8 are easily soluble in water and their aqueous solutions do not undergo appreciable changes for several days at room temperature. The salts 1-4 are also quite stable in alkaline media: for instance 80% of the bromide of 4 was recovered unchanged after 2 hr from its solution in 2N NaOH.

On the other hand, the trifluoroacetates of 7 and 8 are quantitatively reconverted into the epoxides by treatment for 30 min. with 2N NaOH. The bromide of 3 and the trifluoroacetate of 7 react with NaN<sub>3</sub> in water to give respectively the azido derivatives 9<sup>7</sup> and 10<sup>8</sup>, free of the corresponding position isomers, thus proving the regiospecificity of the reactions of styrene and styrene oxide. In contrast the reactions of 1-hexene with bromine-HMPT and of 1-butene oxide

Table I NMR Spectra<sup>a</sup>

Compound <sup>b</sup>	m.p.	P[N(CH <sub>3</sub> ) <sub>2</sub> ] <sub>3</sub>	α-protons	Solvent
<u>1</u> , X=BPh <sub>4</sub>	147-149 <sup>o</sup>	2.63(d,10.5)	4.05 - 4.85 <sup>cd</sup> (m)	(CD <sub>3</sub> ) <sub>2</sub> SO
<u>1</u> , X=C10 <sub>4</sub>	156-157 <sup>o</sup>	2.92(d,10.5)	4.03 - 4.75 <sup>cd</sup> (m)	CDCl <sub>3</sub>
<u>2ab</u> , X=BPh <sub>4</sub>	113-115 <sup>o</sup>	2.65(d,10.5)	3.62 - 4.47 <sup>cd</sup> (m)	(CD <sub>3</sub> ) <sub>2</sub> SO
<u>2ab</u> , X=C10 <sub>4</sub>	67-71 <sup>o</sup>	2.90(d,10.5)	3.60 - 4.90 <sup>cd</sup> (m)	CDCl <sub>3</sub>
<u>3</u> , X=BPh <sub>4</sub>	116-118 <sup>o</sup>	2.21(d,10.5)	3.40 <sup>c</sup> (m, W <sub>1/2</sub> 12), 4.87 <sup>d</sup> (m, W <sub>1/2</sub> 19)	CDCl <sub>3</sub>
<u>4</u> , X=BPh <sub>4</sub>	140-142 <sup>o</sup>	2.68(d,10.4)	4.00 - 4.70 <sup>cd</sup> (m)	(CD <sub>3</sub> ) <sub>2</sub> SO
<u>5</u> , X=BPh <sub>4</sub>	152-153 <sup>o</sup>	2.65(d,10.2)	3.60 <sup>c</sup> (m, W <sub>1/2</sub> 12), 4.10 <sup>d</sup> (m, W <sub>1/2</sub> 16)	(CD <sub>3</sub> ) <sub>2</sub> SO
<u>6ab</u> , X=BPh <sub>4</sub>	123-126 <sup>o</sup>	2.66(d,10.5)	3.40 - 4.20 <sup>de</sup> (m)	(CD <sub>3</sub> ) <sub>2</sub> SO
<u>7</u> , X=BPh <sub>4</sub>	96-97 <sup>o</sup>	2.26(d,10.5)	3.35 <sup>c</sup> (m, W <sub>1/2</sub> 10), 4.75 <sup>d</sup> (m, W <sub>1/2</sub> 18)	CDCl <sub>3</sub>
<u>8</u> , X=BPh <sub>4</sub>	116-116.5 <sup>o</sup>	2.38(d,10.5)	2.90 - 3.90 <sup>de</sup> (m)	CDCl <sub>3</sub>

<sup>a</sup>Chemical shifts are expressed in p.p.m.(δ) from Me<sub>4</sub>Si as internal standard; multiplicity and coupling constants or half-band width (Hz) are given in parentheses. <sup>b</sup>Adequate analytical data were obtained for all compounds. <sup>c</sup>α to Br. <sup>d</sup>α to OP. <sup>e</sup>α to OH.

with CF<sub>3</sub>COOH-HMPT were less regiospecific, giving respectively mixtures of 2a and 2b and of 6a and 6b; the overlap of signals in the NMR spectra did not allow to establish the quantitative compositions of these mixtures.

Primary monofunctional phosphonium salts of the type R-CH<sub>2</sub>OP<sup>+</sup>(NMe<sub>2</sub>)<sub>3</sub>X<sup>-</sup> have recently been isolated in the form of hexafluorophosphates<sup>9</sup> or perchlorates<sup>6</sup> as intermediates in the conversion of alcohols into alkyl chlorides with CCl<sub>4</sub> and (Me<sub>2</sub>N)<sub>3</sub>P. The bifunctional derivatives obtained by us are more stable, probably because the inductive effect of the vicinal Br or OH strengthens the C-O bond and reduces the tendency to displacement by water or other nucleophiles. The possibility of charge delocalization towards the three N atoms accounts for the much higher stabilities of the ions 1-8 in comparison with the sulfoxonium and alkoxyimonium ions obtained in the analogous reactions with DMSO and DMF. It may also be mentioned that the position isomer of the chloro analogue of 3 (11) has recently been proposed (but not isolated) as an intermediate in the conversion of styrene oxide into 1,2-dichloro-1-phenylethane with (Me<sub>2</sub>N)<sub>3</sub>PCl<sub>2</sub><sup>10</sup>; in this case the phosphorus derivative would act as an electrophile.

The facile conversion of 7 and 8 into epoxides with bases is easily interpreted on the basis of an intramolecular displacement in an intermediate 12,

and provides confirmation for the relative stereochemistry of 8. Ramirez and co-workers<sup>11</sup> have postulated that intermediates of type 12 are involved in the transformation of aldehydes into epoxides with  $(Me_2N)_3P$ ; it has so far not been possible to establish if in our case 12 are in equilibrium with a 1,3,2-dioxaphospholane 13, which are the precursors of 12 in the reactions studied by Ramirez.

The new reactions described in this paper, beside indicating that great care must be exercised in the evaluation of reactions involving cationoid transition states if carried out in HMPT, may provide interesting intermediates for further synthetic elaboration through substitution of the phosphonium group with appropriate strong nucleophiles. This aspect is presently under investigation.

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