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The Effect of Onium Salt Additives on the Diels-Alder Reactions of a 1-Phenyl-1,2-dihydrophosphinine Oxide under Microwave Conditions

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*The microwave absorbing ability of toluene is increased in the presence of a slight amount (2–4 mg/3 mL) of quaternary ammonium or phosphonium salts. These additives somewhat accelerated the Diels-Alder reaction of 1-phenyl-1,2-dihydrophosphinine oxide **1** with N-phenylmaleimide and maleic acid anhydride to afford phosphabicyclo[2.2.2]octene derivatives.*

Keywords 1,2-Dihydrophosphinine oxide; Diels-Alder reaction; microwave; onium salt phosphabicyclo[2.2.2]octene

INTRODUCTION

Diels-Alder reactions form an important tool in the different fields of organic syntheses, hence also in the chemistry of phosphorus heterocycles. The 1,2-dihydrophosphinine oxides offered themselves as excellent dienes in cycloaddition reactions with different dienophiles, such as dimethyl acetylenedicarboxylate (DMAD), maleic acid derivatives and another unit of the 1,2-dihydrophosphinine oxide itself to afford the corresponding 2-phosphabicyclo[2.2.2]octene derivatives^{1–6}, which can be used in the fragmentation-related phosphorylation of alcohols, phenols or amines.⁷ The Diels-Alder reactions mentioned

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above were accomplished in boiling benzene or toluene and were found to be rather slow; in most cases the completion required more than one day. A recent study has shown that microwave irradiation was beneficial on the cycloaddition of 1,2-dihydrophosphinine oxides and DMAD or *N*-phenylmaleimide (NPMI).⁸

In this article we report the results of our studies, if the rate of the Diels-Alder reactions carried out under microwave irradiation can be increased in the presence of quaternary onium salts. In other examples, the presence of a quaternary leaving group in a benzyl derivative highly promoted the quaternization of phosphines under microwave conditions.⁹

RESULTS AND DISCUSSION

First, we investigated how toluene absorbs heat in the absence or presence of onium salts, like triethylbenzylammonium chloride (TEBAC), tetrabutylammonium bromide (TBAB) or ethyltriphenylphosphonium bromide (ETPPB). Figure 1 shows that the presence of 2 mg of the onium salts in 3 mL of toluene promoted the warming. Applying an irradiation of 20 W and depending on the nature of the additive, the temperature rose from 88°C to 95–100°C. The most

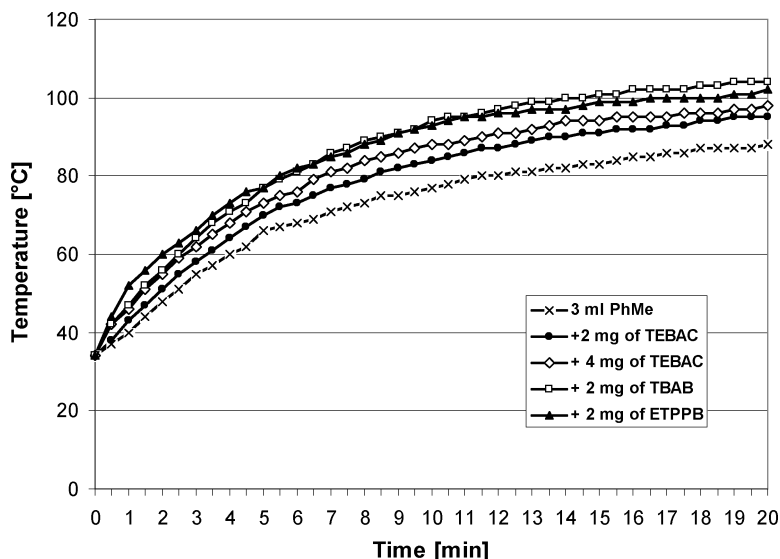


FIGURE 1 Heat uptake of toluene and toluene/onium salt mixtures measured at an irradiation of 20 W in a CEM Discover reactor.

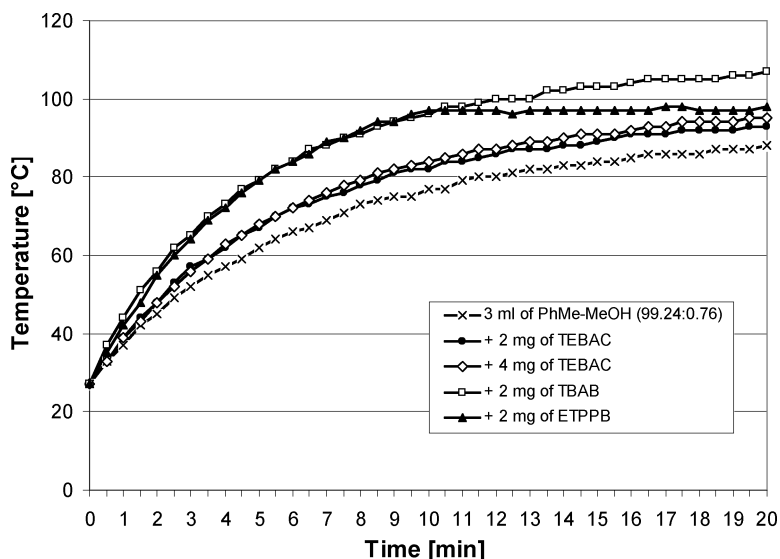
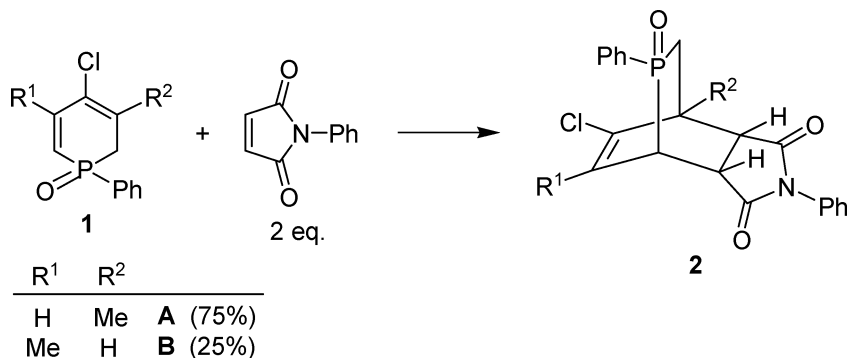


FIGURE 2 Heat uptake of 0.76% methanol in toluene and 0.76% methanol in toluene/onium salt mixtures measured at an irradiation of 20 W in a CEM Discover reactor.

efficient onium salt was TBAB and the quantity of the salt also had an impact on the warming. To ensure an entirely homogeneous medium, the above measurements were repeated in toluene containing 0.76% of methanol. As can be seen from Figure 2, the increases in the temperature were slightly higher.

In the next part of our work, the Diels-Alder reaction of 1,2-dihydrophosphinine oxide **1** and NPMI was studied at 100°C under

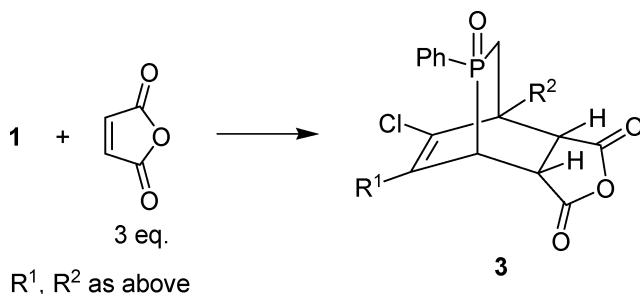


SCHEME 1

TABLE I Diels-Alder Reaction^a of 1,2-Dihydrophosphinine Oxide 1 with NPMI or MAA in the Absence or Presence of Onium Salts Under Different Conditions

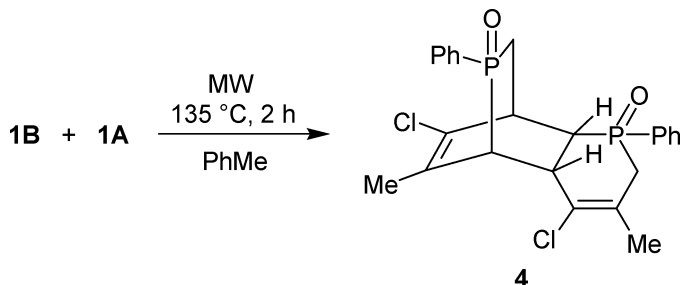
Reagent	Solvent	QX	Quantity of QX (mg)	Temperature (°C)	Way of heating Δ^b /MW	Reaction time (h)	Conversion ^{c,d} (%)	Entry
NPMI	PhMe	—	—	100	Δ	~2	~100	1
NPMI	PhMe	—	—	100	MW	0.5	60	2
NPMI	PhMe	TEBAC ^e	2	100	MW	0.5	66	3
NPMI	PhMe	TBAB ^e	2	100	MW	0.5	63	4
NPMI	PhMe	ETPPB ^e	2	100	MW	0.5	67	5
NPMI	PhMe	TEBAC ^e	4	100	MW	0.5	71	6
NPMI	0.76% MeOH in PhMe	—	—	100	MW	0.5	62	7
NPMI	0.76% MeOH in PhMe	TEBAC	2	100	MW	0.5	68	8
NPMI	0.76% MeOH in PhMe	TBAB	2	100	MW	0.5	70	9
NPMI	0.76% MeOH in PhMe	ETPPB	2	100	MW	0.5	69	10
NPMI	0.76% MeOH in PhMe	TEBAC	4	100	MW	0.5	73	11
MAA	PhMe	—	—	110	Δ	5	79	12
MAA	PhMe	—	—	125	MW	2	70	13
MAA	PhMe	TEBAC ^e	2	125	MW	2	72	14
MAA	PhMe	TEBAC ^e	4	125	MW	2	73	15
MAA	0.76% MeOH in PhMe	—	—	125	MW	2	72	16
MAA	0.76% MeOH in PhMe	TEBAC	2	125	MW	2	74	17

^aSee Experimental for general procedure; ^btraditional heating; ^cdetermined on the basis of relative ³¹P NMR intensities; ^dIn most cases from three independent experiments; and ^ewas not dissolved quantitatively.

**SCHEME 2**

microwave irradiation in toluene in the presence of onium salts (Scheme 1). Control experiments without any additives under traditional heating and using microwave irradiation were also performed. The results are summarized in Table I. It can be seen that microwave irradiation is more efficient than thermal heating (Table I, entries 1 and 2) and that the presence of onium salts has some beneficial effect on the proceeding of the cycloaddition, although it is more or less independent on the nature of the onium salt (Table I, entries 3–5). The use of twice as much of TEBAC somewhat helped (Table I, entry 6). It was observed that not all of the additive was dissolved in toluene; hence the above experiments were repeated in toluene containing a minimal quantity (0.76%) of methanol as a co-solvent (Table I, entry 7). It was found that the beneficial effects slightly increased in homogeneous solutions (Table I, entries 8–11), as compared to the heterogeneous cases (Table I, entries 3–6).

The Diels-Alder reaction of 1,2-dihydrophosphinine oxide **1** with maleic acid anhydride (MAA) (Scheme 2) was definitely slower than that with NPMI (Table I, entries 1 and 12, as well as entries 2 and 13). In the presence of TEBAC additive, these reactions were also found to have been somewhat accelerated, but the effect was not so significant

**SCHEME 3**

(Table I, entries 13–15). In homogeneous solutions the beneficial effect was only a little bit better (compare entries 13 and 16, as well as entries 14 and 17).

Almost all data listed in Table I represents the average of three independent experiments and can thus be regarded to be reliable.

The relatively slow dimerization reaction of dihydrophosphinine oxide **1** could not be really accelerated under microwave conditions. The cycloaddition of the double-bond isomers **1B** and **1A** to afford the phosphabicyclooctene oxide **4** (Scheme 3) slowed down after an irradiation of 1h producing subsequently only polymers.

To summarize our results, quaternary ammonium or phosphonium salt additives promoted the heat energy uptake of toluene under microwave irradiation. The Diels-Alder reactions of a 1,2-dihydrophosphinine oxide were somewhat accelerated under microwave irradiation in toluene containing a small amount of the onium salts. Possible utilization of the rate acceleration in the presence of onium salts in reluctant reactions is to be further explored.

EXPERIMENTAL

³¹P NMR spectra were recorded on a Bruker DRX-300 spectrometer at 121.5 MHz in CDCl₃ solutions. ³¹P Chemical shifts are referred to 85% H₃PO₄ as external standard. The starting 1,2-dihydrophosphinine oxide **1** was prepared as described earlier.^{10,11} The warming experiments and the Diels-Alder cycloadditions were carried out in a CEM Discover microwave reactor.

TABLE II ³¹P NMR Data for the 1,2-Dihydrophosphinine Oxide and Phosphabicyclo[2.2.2]Octene Oxides

										4		
	1A	1B		2A	2B		3A	3B		P ₁	P ₂	
δ _P lit	16.1	15.0	ref. ¹¹	37.3	37.1	ref. ⁴	42.7	42.3	ref. ⁵	37.5	28.6	ref. ⁶
δ _P measured	~15.6	~14.7		~36.9	~36.7		~42.1	~41.1		37.2	28.2	

General Procedure for the Microwave Initiated Diels-Alder Reactions

A mixture of 0.05 g (0.21 mmol) dihydrophosphinine oxide **1** (consisting of 75% of isomer **A** and 25% of isomer **B**), 0.072 g (0.42 mmol) of NPMI or 0.031 g (0.32 mmol) of MAA and 2 or 4 mg of the onium salt in 3 mL of the solvent (toluene or 0.76% methanol in toluene) was placed

in a standard glass vial (distributed along with CEM reactors), that was inserted in the CEM reactor and closed with a pressure controller. The mixture was irradiated at 20–15 W for 0.5–2 h. Then the content of the vial was evaporated and the residue thus obtained was purified by flash column chromatography (using 3% methanol in chloroform as the eluant and silica gel as the adsorbent). The oil thus obtained was analyzed by ^{31}P NMR spectroscopy.

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