

# Evidence for Equilibrium between *N*-Substituted 3-Phosphorylidenepyrrolidine-2,5-diones and *N*-Substituted Maleimides and Phosphines: Thermal Instability of the *N*-Substituted Phosphoranes

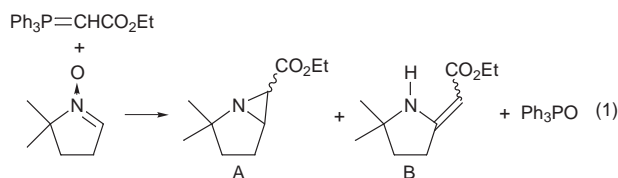
Mariola Koszytkowska-Stawińska and Wojciech Sas\*

Warsaw University of Technology, Faculty of Chemistry, ul. Noakowskiego 3, 00-664 Warszawa, Poland

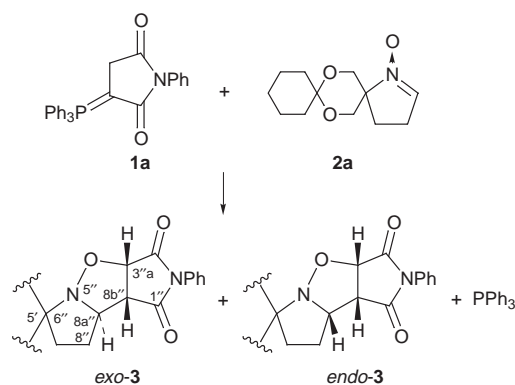
*J. Chem. Research (S)*,  
1999, 694–695  
*J. Chem. Research (M)*,  
1999, 2945–2952

The formation of *N*-substituted 3-phosphorylidenepyrrolidine-2,5-diones from *N*-substituted maleimides and phosphines is reversible and at elevated temperature the phosphoranes behave as a source of maleimide derivatives which give the corresponding cycloadducts with nitrones and 1,3-dienes; a consequence of this equilibrium is the thermal instability of the ylides.

Ethoxycarbonylmethylenetriphenylphosphorane reacts with 5,5-dimethyl-1-pyrroline 1-oxide in the presence of benzoic acid to give a mixture of the aziridine derivative **A** and the enaminic ester **B** in high yield [eqn. (1)].<sup>3</sup>



We undertook the examination of the reaction of 3-(phosphorylidene)pyrrolidine-2,5-dione derivatives **1**<sup>4</sup> with 7,14-dioxo-1-azadispiro[4.2.5.2]pentadec-1-ene 1-oxide **2a**<sup>5</sup> in the hope to obtain the corresponding analogues of **A** and **B**. However, the results of the studies were unexpected.



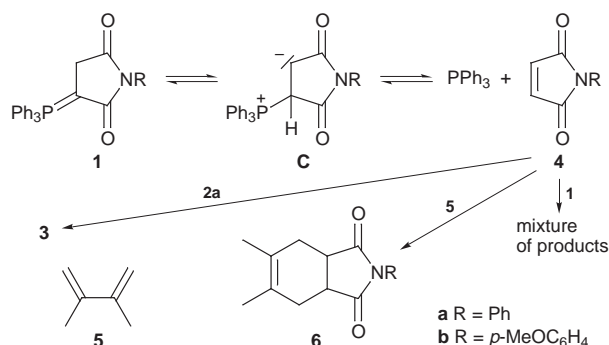
Scheme 1

We commenced our studies with an examination of the reaction of *N*-phenyl-3-(triethylphosphorylidene)pyrrolidine-2,5-dione **1a**<sup>4</sup> with nitron **2a**. This reaction proceeded surprisingly smoothly and after overnight heating in benzene at 85 °C the starting materials were not detected by TLC. However, to our surprise, a chromatographic separation of the reaction mixture afforded only triphenylphosphine and the [3 + 2]-cycloadduct **3** of *N*-phenylmaleimide with nitron **2a** in 83 and 87% yield, respectively (Scheme 1). The structure of **3** was assigned by comparison of its properties with a sample prepared from *N*-phenylmaleimide **4a** and **2a**.<sup>6</sup> Both reaction of **2a** with **1a** and of **4a** with **2a** afforded the same 84:16

*exo/endo* mixture. Under these conditions, the reaction of **1a** with **2b**, the 2-methyl derivative of **2a**, gave only a complex mixture.

The formation of **3** from **1a** and **2a** is best explained by the mechanism shown in Scheme 2. According to this, the formation of **1a** is reversible and at elevated temperature **1a** behaves as a 'source' of *N*-phenylmaleimide so that it is evident that the stereochemical outcomes of reactions of **1a** and **4a** with **2a** are identical. **1a** also reacted with 2,3-dimethylbuta-1,3-diene **5** in benzene at 85 °C for 18 h to afford the [4 + 2]-cycloadduct **6a** and triphenylphosphine in 76.6 and 82.3% yield, respectively.

Since the literature data reported that the ylide **1a**, formed *in situ*, catalyzes polymerization of *N*-phenylmaleimide *via* the nucleophilic addition of **1a** and/or **Ca** to **4a**,<sup>7</sup> we anticipated, that owing to the equilibrium shown in Scheme 2, phosphorane **1a** might decompose to the phosphine and a mixture of oligomers and/or polymers of **4a** and that this process is initiated by the reaction of **1a** with **4a**. Indeed, during heating of **1a** in benzene at 85 °C for 5 h, 47% of **1a** underwent decomposition to give the phosphine and a few unidentified products, probably oligomers and/or polymers of **4a**. The scale of decomposition was readily determined from the <sup>1</sup>H NMR spectrum of the reaction mixture by comparison of the intensity of the methylene signal of **1a** at  $\delta$  3.14 with the intensity of the aromatic absorption. The phosphine was isolated in 42% yield.



Scheme 2

The thermal instability of **1a** explains why the reaction of ketonitron **2b** with **1a** did not give any [2 + 3]-cycloadduct; our earlier studies revealed that **4a** reacted with **2b** much slowly than with **2a**,<sup>6</sup> thus in the case of the reaction of **1a** with ketonitron **2b** the decomposition of **1a**, *i.e.* the

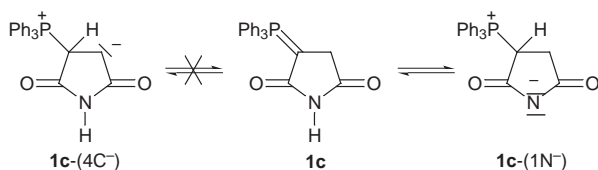
\*To receive any correspondence (e-mail: sas@cd.pw.edu.pl).

reaction of **4a** with **1a**, is much faster than the cycloaddition reaction of **4a** with **2b**. The absence of any Wittig adducts with ketones can similarly be explained.<sup>4</sup>

The influence of temperature and type of *N*-substituent on the stability of the ylides **1** as well as on their reaction with **5** were examined in DMSO solution at 60 and 85 °C and the composition of the resulting mixture analyzed by <sup>1</sup>H NMR spectroscopy. At 60 °C, 33% of **1a** decomposed after 5 h heating, while at 85 °C, 80% of **1a** decomposed after the same time. The reaction of **1a** and **1b** with **5** was not clean and some of **1** underwent decomposition (*ca.* 12–20%). The decomposition of **1a** was very slightly accelerated by addition of the acetic acid (Table 1, entry 4, see full text) whereas triethylamine did not affect the decomposition. Ylide **1b**, bearing a *p*-methoxyphenyl group on the nitrogen, reacted with the diene and decomposed more slowly than **1a**, but this effect was not dramatic.

Literature data suggest that *N*-alkyl derivatives **1** are also unstable; Barrett *et al.*<sup>8</sup> found that the reaction of *N*-triphenylmethyl-3-(triphenylphosphorylidene)pyrrolidine-2,5-dione with 2,3-*O*-isopropylidene-D-ribose had to be conducted at room temperature since at elevated temperature only decomposition took place. This outcome might be interpreted in terms of the aftermath of the equilibrium shown in Scheme 2 (R = trityl). By contrast, *N*-unsubstituted 3-(triphenylphosphorylidene)pyrrolidine-2,5-dione **1c** was quite stable and its reaction with the same protected ribose derivative could be carried out for 260 h at 65 °C in DME solution to give the required Wittig adduct in high yield.<sup>8</sup> Indeed, **1c** underwent neither decomposition nor reaction with the diene (Table 1, entries 8 and 9). Unfortunately, **1c**, although stable, did not react (72 h, DMSO, AcOH, 85 °C) with **2a**, either.

Based on the literature and our findings, we assume that the presence of a highly acidic imide proton is responsible for the stability of **1c**; thus owing to the evident difference in acidity between the *N*-H acid and the 4-(C-H) acid, the ylide **1c** is in equilibrium with the zwitterionic form **1c**-(1N<sup>-</sup>) but not **1c**-(4C<sup>-</sup>) (Scheme 3). The presence of the negative charge on the nitrogen in **1c**-(1N<sup>-</sup>) prevents the elimination of triphenylphosphine through an E<sub>1cb</sub> mechanism.



Scheme 3

Finally we examined the reactivity of PBu<sub>3</sub> derivatives of **1**. Heyda and Theodoropoulos have reported that the reaction of tributylphosphine with **4c** and **4a** afforded 3-(tributylphosphorylidene)pyrrolidine-2,5-dione and its *N*-phenyl analogue, respectively, but these ylides have never been fully characterized and the only proof of their existence has been formation of Wittig products.<sup>4</sup> Unfortunately our attempts to obtain 3-(tributylphosphorylidene)pyrrolidine-2,5-dione failed; maleimide reacted with tributylphosphine in acetic acid but no ylide was produced. Then we turned to *N*-phenyl-3-(tributylphosphorylidene)pyrrolidine-2,5-dione **1d**. The reaction of **4a** with tributylphosphine conducted in acetic acid at ambient temperature afforded crude **1d**, as a pale red oil, showing a <sup>1</sup>H NMR spectrum characteristic for the phosphoranes **1** (methylene doublet at  $\delta$  3.19) and giving 3-benzylidene-pyrrolidine-2,5-dione upon reaction with benzaldehyde in 61% yield. Since TLC showed that purification of **1d** would be difficult, we decided to use, as did Heyda and Theodoropoulos, crude product **1d**. Unfortunately **1d** did not react with the nitron **2a** at all: at room temperature no reaction was observed while at 40 °C only decomposition of **1d** took place. A similar outcome was obtained for the reaction of **1d** with the diene carried out at 85 °C with decomposition of **1d**. These results seem to indicate that **1d** is a better nucleophile than **1a**, therefore its reaction with **4a** (decomposition) is much faster than the reaction of **4a** with **2a** or **5**.

Techniques used: <sup>1</sup>H NMR, MS, IR

References: 9

Table 1: The influence of temperature and nature of *N*-substituent on stability of the phosphoranes **1** and their reaction with diene **5**

Received, 3rd June 1999; Accepted, 7th September 1999  
Paper E/9/04433G

#### References cited in this synopsis

- D. St. C. Black and V. C. Davis, *Aust. J. Chem.*, 1976, **29**, 1735.
- E. Hedaya and S. Theodoropoulos, *Tetrahedron*, 1968, **24**, 2241.
- M. Koszytkowska-Stawinska, W. Sas and A. Sowinska, *J. Chem. Res. (S)*, 1996, 162.
- M. Koszytkowska-Stawinska and W. Sas, *J. Chem. Res.* 1998, (S) 298; (M) 1356.
- P. Hodge, E. Khoshdel and A. A. Naim, *Polym. Commun.*, 1986, **27**, 322.
- A. G. M. Barrett, H. B. Broughton, S. V. Attwood and A. A. L. Gunatilaka, *J. Org. Chem.*, 1986, **51**, 495.