

David C. Holah, Alan N. Hughes and Daniel Kleemola

Department of Chemistry, Lakehead University, Thunder Bay, Ontario, Canada P7B 5E1

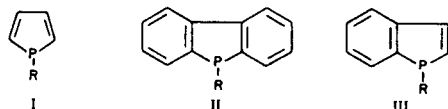
Received April 11, 1977

A new and possibly general route to the hitherto relatively inaccessible simple substituted phosphindoles, utilizing the extreme readiness of simple phosphole sulfides to undergo Diels-Alder dimerization, is described. The synthesis reported here is that of 3,6-dimethyl-1-phenylphosphindole sulfide which is prepared in good yield in two simple steps from the readily available 3-methyl-1-phenylphosphole.

*J. Heterocyclic Chem.*, 14, 705 (1977).

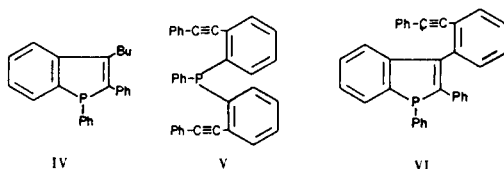
Sir:

Although phospholes (I) and dibenzophospholes (II) have been studied extensively over the past fifteen years (1-4), the related phosphindole (benzo[*b*]phosphole) system III has received very little attention. This does not reflect a lack of interest in the system but, rather, it is a consequence of the fact that simple derivatives of



phosphindole have been very difficult to synthesize. Thus, there are only six reports in the literature regarding the chemistry of phosphindoles.

The first of these (5) concerned the synthesis of the heavily substituted (and therefore non-typical) phosphindole IV by a route which, unfortunately, is not general for the phosphindole system. A route to the much simpler phosphindole III (R = Ph) and the corresponding oxide was later developed (6) but the synthesis, though ingenious,



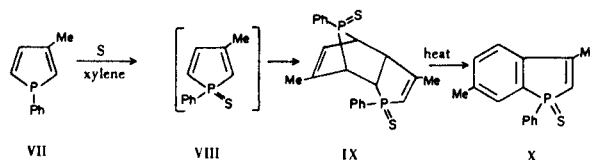
has several steps, involves expensive and not easily accessible reagents and apparently gives relatively low yields. The only other reported synthesis (7) of the phosphindole system is the unusual photocyclization of V to give the heavily substituted phosphindole VI.

The remaining three published reports concern the chemistry of the phosphindole IV with reference to ligand exchange and pyramidal inversion studies (8), reactions with dimethyl acetylenedicarboxylate (9) and ring expansion reactions (10). Crystallographic studies of VI and certain of its quaternary salts have also been made (11).

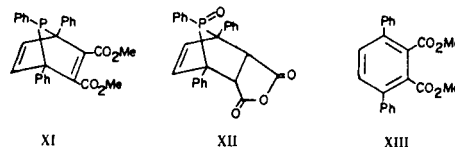
In connection with our studies of the inorganic donor character of phospholes (I) and dibenzophospholes (II) (discussed extensively in reference 3), it became necessary to extend these studies to phosphindoles and this, in turn, required the development of a more convenient, general

and higher-yield route to simple phosphindoles. We therefore wish to give a preliminary report here of a short and potentially general synthesis of the dimethylphosphindole sulfide X in 65% yield.

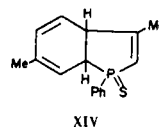
The synthesis follows the route outlined in the sequence VII → VIII → IX → X and was chosen for several reasons. First, simple phospholes are now very readily



accessible (12-15) and would be satisfactory starting materials for such a synthesis. Second, it is well known (12-14, 16-18) that simple phosphole oxides and sulfides of type VIII spontaneously dimerize to give structures of type IX in high yield. In this connection, it should be noted that an X-ray crystal structure determination of the dimer of 1-ethoxyphosphole oxide has confirmed (19) the structural type. Third, it is well known (20-24) that Diels-Alder adducts (such as XI and XII) of both phospholes (where drastic conditions are required for the Diels-Alder reaction) and phosphole oxides with dienophiles such as dimethyl acetylenedicarboxylate (20,22), maleic anhydride (21,22), acrylonitrile (22,23) and benzyne (24) readily, and sometimes spontaneously lose the bridging phosphorus-containing group on heating. The product is a 6-membered carbocyclic, usually aromatic, system such as XIII (derived from XI).



It therefore seemed likely that reduced-pressure pyrolysis of phosphole oxide or sulfide dimers of type IX should yield either dihydrophosphindole derivatives of type XIV



or, more probably in view of the severity of the conditions, phosphindole derivatives such as X. It should, however, be noted in passing that in earlier photochemical studies (25) of the similar dimer of 1-phenylphosphole oxide undertaken as an extension of studies of phospholene oxide pericyclic reactions, although the phosphorus-containing bridge was eliminated and could be trapped as a methanol adduct, no trace of the expected dihydrophosphindole was found. Sensitized irradiation led (25) to the formation of a complex cage structure. No such problems were encountered during the pyrolysis study and reduced pressure (*ca.* 1-2 Torr) distillation of the phosphole sulfide dimer IX (prepared by the method of Mathey (13) and chosen because, for trial experiments, it seemed the most convenient to prepare) gave the crude phosphindole sulfide X. Purification was effected by chromatography on neutral alumina using carbon tetrachloride as eluent to give X as a colorless glass in 65% yield. Microanalytical data were in good agreement with the proposed structure and confirmation of the structure was provided by spectroscopic data.

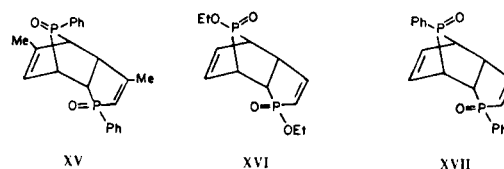
Thus, the mass spectrum showed the molecular weight to be 270 as expected and showed at  $(M+2)^+$  the isotopic peak characteristic (26) of compounds containing one sulfur atom. The molecular formula was confirmed by a precise mass determination for the molecular ion peak which showed a mass of  $m/e$  270.0629 ( $C_{16}H_{15}PS$  requires 270.0632). At very high gain, the mass spectrum showed what appeared to be small traces of an impurity of molecular weight 284.

The nmr spectrum in deuteriochloroform also supports the structure assigned since it shows eight aromatic protons as a broad, complex multiplet at  $\tau$  1.90-3.10, one olefinic proton as a doublet ( $J = 29$  Hz) centered on  $\tau$  3.86 and with each peak of the doublet broadened and apparently slightly split (*ca.* 1 Hz), three allylic or benzylic methyl protons as a sharp singlet at  $\tau$  7.57 and three allylic or benzylic methyl protons as a very closely spaced triplet ( $J = 1.5$  Hz) centered on  $\tau$  7.67. Spectra of different samples also showed traces of impurity peaks as a very complex multiplet in the range  $\tau$  7.6-9.0 with total integrations varying between one and two protons depending upon the sample. Repeated chromatographic treatments failed to remove this material completely but a substantial reduction in the already small amount of this impurity could be achieved.

The nmr spectrum is, therefore, in excellent agreement with the expected structure. For example  $^2J_{P-H}$  for the phosphorus-olefinic proton coupling in the five-membered ring of X measured as 29 Hz agrees very well with similar couplings observed (13) in 3,4-disubstituted phosphole sulfides and phospholium salts where values of 30-32 Hz have been obtained. Also, the location of the signal of the olefinic proton of X at  $\tau$  3.86 is almost identical with the

locations ( $\tau$  3.90-4.00) of the signals of similar protons in the spectra of 3,4-disubstituted phosphole sulfides (13). Furthermore, the fact that one of the methyl group signals appears as a distorted triplet ( $J = 1.5$  Hz) suggests that the signal is due to the methyl group on the five-membered ring of X and that  $^4J_{P-CH_3}$  and  $^4J_{HC=CCH_3}$  are approximately equal in magnitude. These couplings are entirely consistent with the proposed structure X since such couplings of very similar magnitude (1-2 Hz) have been observed for the structurally similar 3-methylphosphole sulfides (13). In this connection, it should again be noted that the peaks of the olefinic proton doublet are broadened and split by about 1 Hz.

There can, therefore, be little doubt that the product obtained by pyrolysis of the phosphole sulfide dimer IX is the phosphindole sulfide X. Clearly, this method is potentially general for the synthesis of a variety of phosphindole derivatives since other such systems related to IX (*e.g.*, XV, XVI, and XVII) are readily prepared (14,



17, 18) and should undergo thermal fragmentations similar to that of IX. Furthermore, similar dimeric phospholium salts are also known (27) and these might pyrolyze similarly. These possibilities and also the reduction of phosphindole sulfides to the corresponding phosphindoles are currently being explored and the results will form the basis of a more extensive publication.

Acknowledgement.

We thank the National Research Council of Canada for generous financial support of this work.

#### REFERENCES AND NOTES

- (1) A. N. Hughes and C. Srivanavit, *J. Heterocyclic Chem.*, **7**, 1 (1970).
- (2) F. G. Mann, "The Heterocyclic Derivatives of Phosphorus, Arsenic, Antimony and Bismuth", Wiley-Interscience, New York, N.Y., 1970.
- (3) D. G. Holah, A. N. Hughes and K. Wright, *Coord. Chem. Rev.*, **15**, 239 (1975).
- (4) A. N. Hughes and D. Kleemola, *J. Heterocyclic Chem.*, **13**, 1 (1976).
- (5) M. D. Rausch and L. P. Klemann, *J. Am. Chem. Soc.*, **89**, 5732 (1967).
- (6) T. H. Chan and L. T. L. Wong, *Can. J. Chem.*, **49**, 530 (1971).
- (7) W. Winter, *Tetrahedron Letters*, 3913 (1975).
- (8) W. Egan, R. Tang, G. Zon and K. Mislow, *J. Am. Chem. Soc.*, **93**, 6205 (1971).
- (9) A. N. Hughes, K. Amornraksa, S. Phisithkul and V. Reutrakul, *J. Heterocyclic Chem.*, **13**, 65 (1976).
- (10) A. N. Hughes, K. Amornraksa, S. Phisithkul and V.

- Reutrakul, *ibid.*, **13**, 937 (1976).
- (11) W. Winter, personal communication.
- (12) F. Mathey, *Compt. Rend.*, **269C**, 1066 (1969).
- (13) F. Mathey, R. Mankowski-Favelier and R. Maillet, *Bull. Soc. Chim. France*, 4433 (1970).
- (14) F. Mathey and R. Mankowski-Favelier, *Org. Magn. Reson.*, **4**, 171 (1972).
- (15) L. D. Quin, S. G. Borleske and J. F. Engel, *J. Org. Chem.*, **38**, 1858 (1973).
- (16) R. E. Donadio, *Dissertation Abstr.*, **20**, 495 (1959).
- (17) D. A. Usher and F. Westheimer, *J. Am. Chem. Soc.*, **86**, 4732 (1964).
- (18) G. Märkl and R. Potthast, *Tetrahedron Letters*, 1755 (1968).
- (19) Y. H. Chui and W. N. Lipscomb, *J. Am. Chem. Soc.*, **91**, 4150 (1969).
- (20) E. H. Braye and W. Hübel, *Chem. Ind. (London)*, 1250 (1959).
- (21) E. H. Braye, W. Hübel and I. Caplier, *J. Am. Chem. Soc.*, **83**, 4406 (1961).
- (22) I. G. M. Campbell, R. C. Cookson, M. B. Hocking and A. N. Hughes, *J. Chem. Soc.*, 2184 (1965).
- (23) R. C. Cookson, G. W. A. Fowles and D. K. Jenkins, *ibid.*, 6406 (1965).
- (24) U. Schmidt, I. Boie, C. Osterroht, R. Schroer and H. Grützmacher, *Chem. Ber.*, **101**, 1381 (1968); J. K. Stille, J. L. Eichelberger, J. Higgins, and M. E. Freeburger, *J. Am. Chem. Soc.*, **94**, 4761 (1972).
- (25) H. Tomioka, Y. Hirano and Y. Izawa, *Tetrahedron Letters*, 4477, (1974).
- (26) K. Biemann, "Mass Spectrometry", McGraw-Hill, New York, 1962, p. 59.
- (27) L. D. Quin, S. G. Borleske and J. F. Engel, *J. Org. Chem.*, **38**, 1954 (1973).