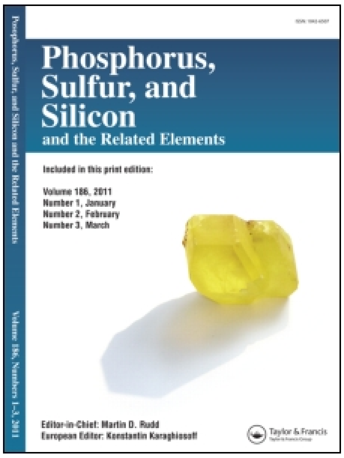


Phosphorus, Sulfur, and Silicon and the Related Elements
Publication details, including instructions for authors and subscription information:
http://www.informaworld.com/smpp/title~content=t713618290

DRY REACTION OF DIETHYL CYANOMETHYLPHOSPHONATE AND TETRAETHYL METHYLENEDIPHOSPHONATE WITH BENZALDEHYDE ON SOLID BASES

Messaoud Hachemi[a]; Monika Puciova-sebova[b]; Stefan Toma[b]; Didier Villemin[a]
[a] Ecole Nationale Supérieure d'Ingénieurs de Caen, I.S.M.R.A., Caen Cedex, France [b] Department of Organic Chemistry, Faculty of Natural Sciences, Comenius University, Bratislava, Slovakia

To cite this Article Hachemi, Messaoud , Puciova-sebova, Monika , Toma, Stefan and Villemin, Didier(1996) 'DRY REACTION OF DIETHYL CYANOMETHYLPHOSPHONATE AND TETRAETHYL METHYLENEDIPHOSPHONATE WITH BENZALDEHYDE ON SOLID BASES', Phosphorus, Sulfur, and Silicon and the Related Elements, 113: 1, 131 — 136

To link to this Article: DOI: 10.1080/10426509608046384

URL: http://dx.doi.org/10.1080/10426509608046384

Phosphorus, Sulfur, and Silicon, 1996, Vol. 113, pp. 131–136
Reprints available directly from the publisher
Photocopying permitted by license only

DRY REACTION OF DIETHYL CYANOMETHYLPHOSPHONATE AND TETRAETHYL METHYLENEDIPHOSPHONATE WITH BENZALDEHYDE ON SOLID BASES

MESSAOUD HACHEMI,† MONIKA PUCIOVA-SEBOVA,‡ STEFAN TOMA‡
and DIDIER VILLEMIN*·†
†Ecole Nationale Supérieure d'Ingénieurs de Caen, I.S.M.R.A., URA 480, F-14050 Caen Cedex France; ‡Department of Organic Chemistry, Faculty of Natural Sciences, Comenius University, SK 842-15 Bratislava, Slovakia

(Received January 3, 1996)

Competitive Horner and Knoevenagel reactions of benzaldehyde with diethyl cyanomethylphosphonate and tetraethyl methylenediphosphonate successively on different solid bases (oxide, fluoride and mixtures) without the use of solvent were investigated. Tetraethyl methylenediphosphonate with benzaldehyde with similar conditions gave only the product of Horner's reaction. Basicity of the solid and nature of the cation (mono or divalent) of the base seemed important to explain the ratio of products formed in the Horner/Knoevenagel reactions.

Key words: Phosphonate, Horner, Knoevenagel, solid bases, basicity.

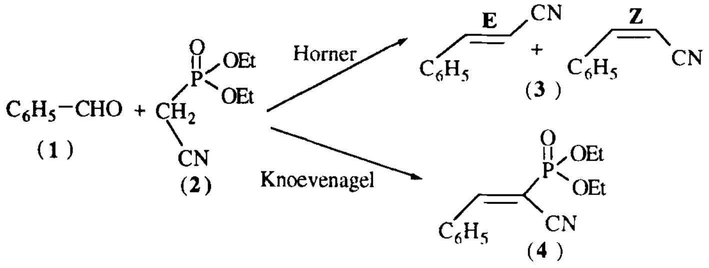
Reactions under heterogeneous conditions are generally more selective and easier to perform than in homogeneous solution. Horner's reactions are reported under heterogeneous conditions with different inorganic bases such as potassium carbonates,[1] potassium hydroxyde,[2] potassium fluoride,[3] alumina,[4] potassium fluoride on alumina,[5] barium oxide,[6] cesium carbonate,[7] magnesium and zinc oxides.[8]

The reaction of diethyl cyanomethylphosphonate (**2**) with benzaldehyde (**1**) leads to competitive reactions[5]: the product of Horner's reaction[9] (cyanoolefins) (**3**) or the product of Knoevenagel's reaction (cyanophosphono-olefin (**4**) was obtained according to the solid base used and the presence or the absence of a protic solvent, or Lewis acids (Scheme I). The stereochemistry of (**3**) in solution depends on the nature of the cation of the base.[10]

The dry reaction of tetraethyl methylenediphosphonate (**5**) with benzaldehyde in presence of solid bases and the competition between the Horner's and Knoevenagel's reactions was not studied until now. Horner's reaction of (**5**) was carried out under solid-liquid phase transfer conditions with potassium carbonate[1] whereas the product of the Knoevenagel's reaction was formed by condensation in the presence of titanium tetrachloride and N-methylmorpholine.[11]

The reaction of tetraethyl methylenediphosphonate (**5**) with poorly basic solids is of great interest because the compound possesses a methylene group (pKa/H_2O estimated $\simeq$ 17)[12] less acidic than that of diethyl cyanomethylphosphonate (**2**) (pKa/H_2O $\simeq$ 10)[13] and phosphono-olefins are materials of interest in synthesis.

We report herein successively the study of the reaction of diethyl cyanometh-



SCHEME I Competition between Horner's and Knoevenagel's reactions.

TABLE I
Dry reaction of diethyl cyanomethylphosphonate (**2**) with benzaldehyde (method A)

Solid catalyst	yield (**3**)/(**4**)	E/Z of (**4**)
Cs_2CO_3	100/0	100/0
CsF	95/5	95/5
CsF-Al_2O_3	100/0	60/40
MgF_2	0	0
CaF_2	0	0
BaF_2	0	0
CaO	69/31	66/33
$Ca(OH)_2$	100/0	78/22
KF-MgO	100/0	85/15
KF-CaO	100/0	81/19
KF-BaO	100/0	78/22
CsF-MgO	82/18	89/11
CsF-CaO	100/0	73/27
CsF-BaO	100/0	62/38
CsF-CaF_2	33/66	95/15
CsF-CaF_2*	0	0

* Heated at 250°C for 10h before reaction.

ylphosphonate (**2**) and tetraethyl methylenediphosphonate (**5**) with benzaldehyde (**1**) in the presence of different metal oxides and fluorides without solvent at room temperature or under microwave irradiation.[14] In the case of diethyl cyanomethylphosphonate (**2**) we have studied the reaction only with a limited number of cases which had not been described previously in the literature; the results are reported in Table I. Concerning the reaction of tetraethyl methylenediphosphonate (**5**) with benzaldehyde (**1**), the results are reported in Table II.

TABLE II

Dry reaction of tetraethylmethylene diphosphonate (**2b**) with benzaldehyde

Solid catalyst	Method	yield of (**6**)%	% of(**5**) recovered
$KF\text{-}Al_2O_3$	A	92	2
CaO	A	89	0
$Ca(OH)_2$	A	90	0
BaO	A	71	0
$CsF\text{-}Al_2O_3$	A	57	40
Cs_2CO_3	A	70	25
$CsF\text{-}Al_2O_3$	B	74	0
Cs_2CO_3	B	72	0
ZnO	A	0	91
K10	A	0	90*
silicalite	A	0	92
$ZnCl_2$	A	0	90
$Al(OiPr)_3$	A	33	60

A = Dry conditions, 24h, 20°C; B = Microwave, 4 mn
*PhCOOH was isolated also in quantitative yield

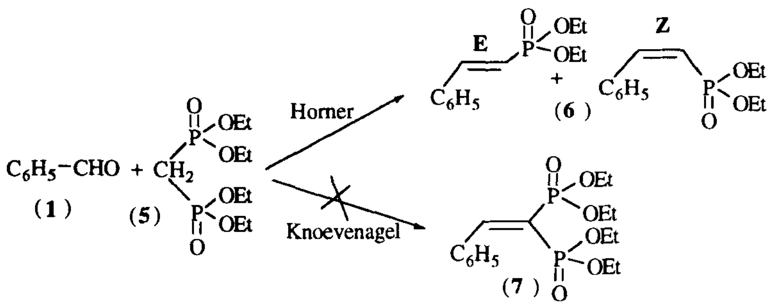
DISCUSSION OF THE RESULTS

Diethyl Cyanomethylphosphonate (**2**) *(Scheme I)*

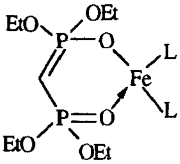
From the results reported in the literature and the results obtained (Table I), we can deduct that the ratio of products (**3**)/(**4**) of Horner's/Knoevenagel's reactions seems to depend on the basicity of solid. With an alkali oxide or fluoride the ratio (**3**)/(**4**) increases with basicity and decreases in the presence of a Lewis acid or a proton donor. Fluorides of metal group II (MgF_2, CaF_2, BaF_2), contrary to the alkali metal (group I) gave no Horner's or Knoevenagel's product. This result is in relation to the fact that metal fluorides of group II metals seems to have no acidobasic sites. The corresponding oxides (MgO, CaO, BaO) gave predominantly Horner's reaction and the calcium hydroxide appears more selective than calcium oxide. The mixtures of one alkali fluoride and one oxide gave Horner's reaction and the stereochemistry depend on the nature of the oxide for the same fluoride (KF or CsF). Magnesium oxide gave a better yield of the E-isomer. Recently Clark and Ando[15] have reported that the reactivity of the alkali metal fluorides KF and CsF as sources of nucleophilic fluorine is appreciably enhanced by the presence of calcium fluoride and in particular by the supported reagents $KF\text{-}CaF_2$ and $CsF\text{-}CaF_2$. $CsF\text{-}CaF_2$ gave principally Knoevenagel's reaction but when the solid is absolutely dry (previously preheated at 250°C for 10 h) no reaction takes place. The acidobasity of $CsF\text{-}CaF_2$ depends on the presence of water.

Tetraethyl Methylenediphosphonate (**5**) *(Scheme II)*

With tetraethyl methylenediphosphonate (**5**) no Knoevenagel's reaction was observed with acidic solids (ZnO, silicalite, $ZnCl_2$, montmorillonite K10) contrary to the results observed with diethyl cyanomethylphosphonate (**2**).



SCHEME II Reaction of tetraethyl methylenediphosphonate with benzaldehyde.



(8)

SCHEME III Complex of (5) with ferric ion.

With truly basic solids the product of Horner's reaction was formed; the best yield was obtained with KF on alumina and with calcium hydroxide. With cesium fluoride on alumina the yield increased when the reaction was performed under microwave irradiation or when the solid was preheated (110°, 16 h) before use. These results can be explained by the hygroscopicity of the cesium salts: water is able to shift the equilibrium in the deprotonation step to the left.

In the case of the reaction of tetraethyl methylenediphosphonate (**5**) with benzaldehyde (**1**) in presence of montmorillonite K10, we obtained benzoic acid when the reaction was performed in air atmosphere. Under an argon atmosphere, the yield of benzoic acid was poor. We think that ferric ions are always present in K10 and form a complex of type (**8**) in the presence of (**5**) which is the main catalyst. Ferric chloride with (**5**) catalysed the oxidation of benzaldehyde into benzoic acid in the presence of air.

We have recently reported the semi-quantitative determination of the relative basicity of oxides, fluorides and supported oxide-fluoride by a colourimetric method with organometallic complexes as indicators.[16] The fluorides of group II metals contrary to the fluorides of group I metals have no basic site. We observed a parallel between the basicity (strength, number of basic site) determined semi-quantitatively by the coloration of solids in the presence of the solution of Cu(tmen)(acac)NO_3 in nitrobenzene or propylene carbonate, and the Horner product formed in the reaction with (**2**) or better with (**5**).

EXPERIMENTAL

Proton spectra (PMR) and ^{13}C (CMR) recorded in ppm down-field from internal Me_4Si were recorded on a Brucker AC 250 instrument from a solution in ($CDCl_3$) of the product. Phosphorus NMR spectra (^{31}P NMR) in ppm down-field from external H_3PO_4, 85% were recorded on a Brucker WP 90 instrument. Microwave irradiations were carried out with a commercial microwave oven Toshiba ER 7620 at 2450 MHz.

An authentic sample of diethyl styrylphosphonate was prepared according to the literature.[17] Tetraethylstyryldiphosphonate was obtained by reaction of methylenediphosphonate with benzaldehyde in the presence of N-methylmorpholine and titanium tetrachloride.[11]

Cinnamonitrile (**3**): Pale yellow liquid, Bp 125 (0.1); ^{1}H NMR: E isomer 5.80 (d, J = 17 Hz, 1H) 7.30 (d, J = 17 Hz, 1H) 7.40 (m, 5H, H arom); Z isomer 5.40 (d, J = 12 Hz, 1H) 7.08 (d, J = 12 Hz, 1H) 7.40 (m, 5H, H arom); IR (film) 2210 cm^{-1} (ν CN).

E-Diethyl phosphonocinnanonitrile (**4**): Liquid, Bp 158 (0.4); ^{1}H NMR: 1.45 (t, 6H, CH_3) 4.25 (m, 4H, OCH_2) 7.50 (m, 5H, H arom) 8.05 (d, 1H, CHPh, J_{PH} = 20 Hz (P and H cis)); IR (film) 2210 cm^{-1} (ν CN).

Diethyl styrylphosphonate (**6**): Liquid, Bp 140 (0.4); ^{1}H NMR: 1.3 (t, 6H, J = 7 Hz, CH_3) 4.0 (2 dq, J = 7 Hz, J_{PH} = 8 Hz, CH_2O) 6.1 (dd, 1H, J_{PH} Htrans = 17 Hz) 7.2 (m, 5H, H arom) 7.3 (dd, 1H, J_{PH} Htrans = 17 Hz); ^{31}P (NMR): 19.15; ^{13}C (NMR): 16.42, 61.77, 114.44, 127.70, 128.89, 130.21, 135.03, 148.53.

Tetraethylstyryldiphosphonate (**7**): Liquid, ^{1}H NMR: 1.2 (2t, 12H, J = 7 Hz, CH_3) 4.0 (2 dq, J = 7 Hz, J_{PH} = 8 Hz, CH_2O) 7.5 (m, 5H, H arom) 8.1 (dd, 1H, J_{PH} isomer Z = 30 Hz, J_{PH} isomer E = 48 Hz); ^{31}P NMR: 11.74 (d, J_{PP} = 50 Hz) 17.16 (d, J_{PP} = 50 Hz); ^{13}C NMR: 16.43, 62.63, 128.15, 130.48, 161.36.

Method A

0.53 g of benzaldehyde (5 mmol), 0.815 g of diethylcyanophosphonate (5 mmol) or 1.44 g of tetraethyl methylenediphosphonate (5 mmol) were dissolved in 10 ml of dry dichloromethane and 3 g of solid catalyst was added. The solvent was evaporated under reduced pressure and the reaction mixture was allowed to stand at room temperature for 24 h. After addition of dichloromethane, the mineral salt was filtered off. The solvent was evaporated and product was purified by distillation using a Kugelrohr apparatus.

Method B

0.742 g of benzaldehyde (7 mmol) and 2.02 g tetraethyl methylenediphosphonate (5 mmol) were dissolved in dry dichloromethane (10 ml) and solid base was subsequently added. The solvent was evaporated under reduced pressure and the reaction mixture was irradiated in a microwave oven for 4 mn (250 W). The same work-up as in method A was used. The stereochemistry of the isomer of (**3**) was assigned by PMR analysis, the E isomer with a coupling constant of 17 Hz and Z isomer with a coupling constant of 12 Hz.

Preparation of Supported Fluorides

The support (oxide or fluoride) (240 mmol) was added to a solution of alkali fluoride (60 mmol) in distilled water. The mixture was evaporated with a rotary evaporator under vacuum and ethanol was added for terminating the elimination of water. The resultant solid was heated under vacuum at 120° for 24 h before use.

CONCLUSION

The results previously obtained with diethyl cyanomethylphosphonate (**2**) have been generalised. The competitive reactions under dry conditions allow the determination of the acidobasicity of the solids. We have noticed that the ratio of products of Horner's versus Knoevenagel's reactions increases with the basicity of the solid. Tetraethylmethylenediphosphonate (**5**) which is less acidic than (**2**) also allows a distinction between basic solids. The scale of basicity of oxides, fluorides and supported oxide-fluoride is similar to those obtained by the colourimetric method using organometallic complexes.

ACKNOWLEDGEMENTS

We thank Dr. A. Ben Alloum and P. Maniscalco for their preliminary experiments. We thank E. Esprimont for the determination with CAMEO of the pKa of (5) and Dr. Jonathan Miller for English correction. We also thank the firm Metalgeseleschaft AG for the generous gift of the cesium salts.

REFERENCES AND NOTES

1. J. Villieras, M. Rambaud and B. Kirschleger, *Phosphorus and Sulfur*, **14,** 385 (1983); J. Villieras and M. Rambaud, *Synthesis*, 924 (1982) and 300 (1983); J. Villieras, M. Rambaud and M. Graff, *Tetrahedron Lett.*, **26,** 53 (1985).
2. F. Texier-Boullet and A. Foucaud, *Synthesis*, 884 (1979); W. C. Still and C. Gennari, *Tetrahedron Lett.*, 4405 (1983).
3. F. Texier-Boullet and A. Foucaud, *Tetrahedron Lett.*, **21,** 2161 (1980).
4. F. Texier-Boullet and A. Foucaud, *Tetrahedron Lett.*, **23,** 4927 (1982).
5. Texier-Boullet, D. Villemin, M. Ricard, H. Moison and A. Foucaud, *Tetrahedron*, **41,** 1259 (1985); D. Villemin, *Chem. Ind.*, 166 (1985) and 69 (1986).
6. J. V. Sinesterra, Z. Mouloungui, M. Delmas and A. Gaset, *Synthesis*, 1097 (1985).
7. J. V. Sinesterra, J. Barrios, Z. Mouloungui, M. Delmas and A. Gaset, *Bull. Soc. Ch. Belge*, **100,** 257 (1991).
8. H. Moison, F. Texier-Boullet and A. Foucaud, *Tetrahedron*, **43,** 537 (1987).
9. J. I. G. Cardogan, "Organophosphorus Reagents in Organic Synthesis," Academic Press, London, New York, 1979; A. Johnson, "Ylid Chemistry," Academic Press, New York, 1966; W. S. Wadsworth, Jr., *Organic Reaction*, **25,** 73 (1978).
10. A. Radial and J. Seyden-Penne, *Tetrahedron Lett.*, 1733 (1974).
11. W. Lehnert, *Tetrahedron*, **30,** 301 (1974).
12. pKa estimated with CAMEO software (error ΔpKa ± 3): T. D. Salatin and W. L. Jorgensen, *J. Org. Chem.*, **45,** 2043 (1980).
13. The pKa of (2) was not available and was estimated by comparison with the pKa of diethyl phosphonoacetate (12.2) and the pKa of ethylcyanoacetate (9.0): M. A. Blanchette, W. Choy, J. T. Davis, A. P. Essenfeld, S. Masamune, W. Roush and T. Sakai, *Tetrahedron Lett.*, **25,** 2183 (1984); R. G. Pearson and R. L. Dillon, *J. Amer. Chem. Soc.*, **75,** 2439 (1953).
14. G. Bram, A. Loupy and D. Villemin, in "Solid Supports and Catalysts in Organic Synthesis," Chap. 12, pp. 302–326, K. Smith ed., Ellis Horwood and Prentice Hall, 1992.
15. J. H. Clark, A. J. Hyde and D. K. Smith, *J. Chem. Soc., Chem. Commun.*, 791 (1986); J. Ichihara, T. Matsuo, T. Hanafusa and T. Ando, *J. Chem. Soc., Chem. Commun.*, 793 (1986).
16. D. Villemin and M. Hachemi, *React. Kin. Cat. Lett.*, **53,** 147 (1994).
17. M. Rambaud, A. Vecchio and J. Villieras, *Synth. Commun.*, **14,** 833 (1984).