

Cyano-stabilized triphenylphosphonium ylids

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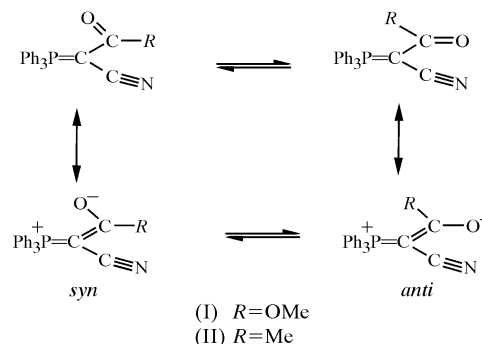
Crystalline cyano-stabilized triphenylphosphonium ylids with keto or ester groups give rise to an extended electronic delocalization. In methyl 2-cyano-2-(trimethylphosphonio)ethenoate, $\text{Ph}_3\text{P}=\text{C}(\text{CN})\text{CO}_2\text{CH}_3$ or $\text{C}_{22}\text{H}_{18}\text{NO}_2\text{P}$, (I), and 1-cyano-1-(trimethylphosphonio)prop-1-en-2-olate, $\text{Ph}_3\text{P}=\text{C}(\text{CN})\text{CO}-\text{CH}_3$ or $\text{C}_{22}\text{H}_{18}\text{NOP}$, (II), the carbonyl groups are oriented toward the cationoid P atom. Bond lengths and angles, torsion angles and $\text{P}\cdots\text{O}$ contact distances are consistent with a dominant coplanar conformation where the molecular structures are the result of a balance between intra- and intermolecular interactions. The main interactions presented by cyano-ester (I) and cyano-keto (II) are intramolecular interactions between the carbonyl O and the P atoms. In addition, both compounds show other less important intramolecular interactions between the carbonyl O and phenyl H atoms, which could contribute to form a preferred conformation in the crystal structure.

Comment

Electronic delocalization involving acyl keto and ester groups stabilizes phosphonium ylids and is maximized by their taking up planar conformations with favorable interactions between anionoid O atoms and cationoid phosphorus (Castañeda *et al.*, 2001; Castañeda, Recabarren *et al.*, 2003; Castañeda, Terraza *et al.*, 2003). However, in crystalline diethyl ester derivatives, interference involving the trigonal ester groups leads to a conformation where the acyl O atoms are *anti* to phosphorus, and the acyl groups are twisted out of the ylidic plane (Castañeda *et al.*, 2005, 2007). The linear cyano group is strongly electron withdrawing and should facilitate electronic delocalization in a planar ylidic unit (see scheme).

We therefore expected that the cyano group would favor cyano-keto or -ester compounds taking up conformations that

allow extensive electronic delocalization and interactions between phosphorus and an acyl O atom. The conformations should be similar in the solid and in solution, and we discuss here the geometries of the following ylids in the crystal



structure. Complete details of the geometries in solution will be given elsewhere. Crystalline methyl 2-cyano-2-(trimethylphosphonio)ethenoate, (I), and 1-cyano-1-(trimethylphosphonio)prop-1-en-2-olate, (II), have the molecular structures and selected geometric parameters shown in Figs. 1 and 2, and Tables 1 and 3, respectively. In both ylids, the configurations about the P atom are approximately tetrahedral, with phenyl groups forming a propeller-like arrangement. For (I) and (II), the bond angles $\text{C}31-\text{P}1-\text{C}11$, $\text{C}21-\text{P}1-\text{C}11$ and $\text{C}31-\text{P}1-\text{C}21$ are 107.42 (12), 107.44 (12) and 106.35 (12)°, and 108.17 (9), 105.79 (10) and 106.81 (9)°, respectively. The sums of the angles about the ylidic C1 atom for (I) and (II) are 359.9 and 360° respectively, consistent with sp^2 -hybridization in an almost trigonal-planar geometry. It is well known that stabilized ylids have a longer $\text{P}=\text{C}$ bond as a result of the electronic delocalization caused

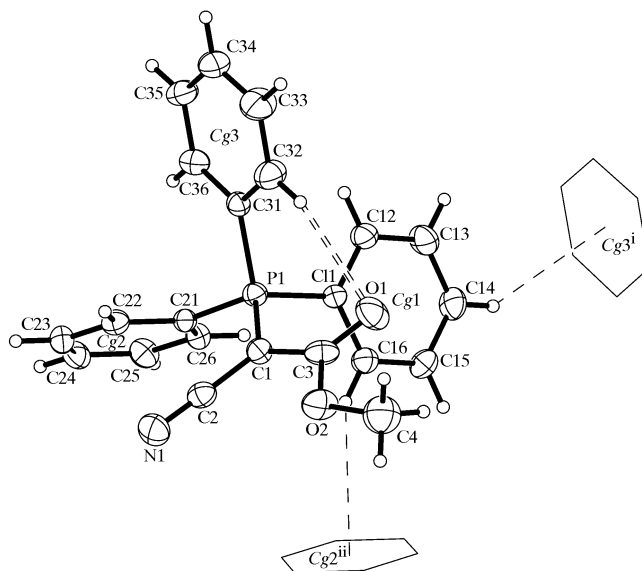


Figure 1
The molecular structure of (I), showing the numbering scheme used. The intramolecular hydrogen bond is shown as a double-dashed line and the intermolecular $\text{C}-\text{H}\cdots\pi$ contacts as single-dashed lines. Displacement ellipsoids are drawn at the 30% probability level. Symmetry codes are as given in Table 2.

by the stabilizing groups (Bachrach & Nitsche, 1994; Howells *et al.* 1973). In cyano-ester ylid (I) and cyano-keto ylid (II), the P1–C1 bond lengths are 1.730 (3) and 1.744 (2) Å, respectively. These values are between those reported for a P–C single bond (1.80–1.83 Å; Howells *et al.*, 1973) and P=C double bond (1.63–1.73 Å; Howells *et al.*, 1973) and they are considerably longer than the P=C bond in methylene-triphenylphosphorane, Ph₃P=CH₂ [1.661 (8) Å; Bart, 1969], where there is no opportunity for conjugation with other groups. Electronic delocalization toward the carbonyl groups shortens the C1–C3 and lengthens the C=O carbonyl bonds. In comparison with the normal value of 1.21 Å, the keto carbonyl bond is longer [1.239 (3) Å] than the ester carbonyl bond [1.212 (4) Å], as was reported by Castañeda *et al.* (2001, 2005) for keto-esters, diesters and diketo ylides. However, delocalization of the P=C bond toward the cyano group is small. Comparison of C≡N bond lengths for (I) [1.145 (4) Å] and (II) [1.150 (3) Å] with a normal value of 1.140 Å (Smith & March, 2001) could indicate that the CN group is mainly acting by inductive instead of resonance effects. Coplanarity between the ylidic, carbonyl and cyano units is established by their torsion angles (Tables 1 and 3). Ylids (I) and (II) present nearly coplanar systems with the carbonyl O atoms oriented *syn* to the P atoms, showing O1···P1 contact distances of 3.022 (2) and 2.928 (2) Å, respectively. These attractive intramolecular interactions between the acyl O atoms and the cationoid P atoms lead to *syn*-preferred conformations where the alkoxy or alkyl groups adopt an *anti* conformation to avoid repulsive steric interactions with the phenyl groups. There is

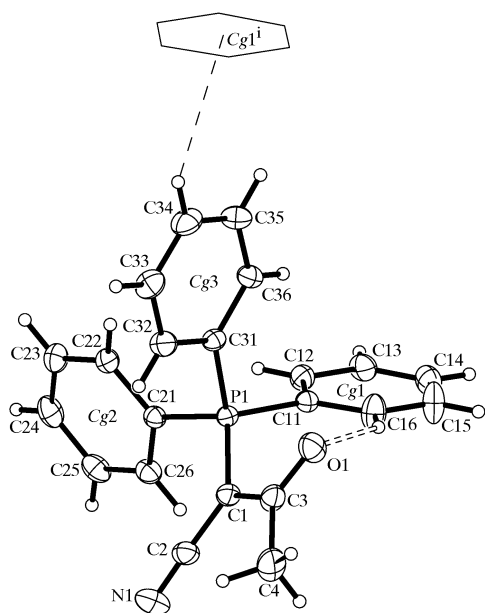


Figure 2
The molecular structure of (II), showing the numbering scheme used. The intramolecular hydrogen bond is shown as a double-dashed line and the intermolecular C–H··· π contact as a single-dashed line. Displacement ellipsoids are drawn at the 30% probability level. Symmetry codes are given in Table 4.

no evidence of a CH interaction involving alkoxy and phenyl groups (Castañeda, Terraza *et al.*, 2003). The structures of (I) and (II) have as a second intramolecular interaction C–H···O hydrogen bonds between phenyl donors and carbonyl acceptors (Tables 2 and 4). These types of non-classical interactions, despite being weak, could make a significant contribution to stabilizing conformations in the solid state. Several intermolecular interactions with phenyl groups acting as donors and acceptors are shown in Figs. 1 and 2. These interactions could affect favorably the observed molecular geometry and the packing conformations. The carbonyl IR stretching frequencies in KBr for (I) (1650 cm⁻¹) and (II) (1584 cm⁻¹) correlate with the crystallographic results, indicating an extensive electronic delocalization for the carbonyl groups.

Experimental

(Cyanomethylene)triphenylphosphorane was prepared according to a literature method (Trippet & Walker, 1959). Ylids (I) and (II) have been reported previously (Horner & Oediger, 1958; Kobayashi *et al.*, 2000). In this work, both (I) and (II) were synthesized by reaction of (cyanomethylene)triphenylphosphorane with methyl chloroformate or acetyl chloride under transylidation conditions. A general synthetic procedure was as follows: a solution of alkyl chloroformate (9.1 mmol) or acetyl chloride (9.1 mmol) in dry benzene (5 ml) was added slowly to (cyanomethylene)triphenylphosphorane (18.2 mmol) dissolved in dry benzene (50 ml) under an inert atmosphere. The stirred solution was maintained at room temperature for 6 h to allow a white solid to separate. After filtration of (cyanomethyl)-triphenylphosphonium chloride, the solvent was evaporated under reduced pressure to give the products, which were crystallized from ethanol. For (I): yield 75%, m.p. 485–486 K; ¹H NMR (CDCl₃): δ 3.64 (*s*, 3H), 7.5–7.8 (*m*, 15H); IR (KBr): 2179 (–CN), 1650 (CO) cm⁻¹. For (II): yield 65%, m.p. 478 K; ¹H NMR (CDCl₃): δ 2.38 (*s*, 3H), 7.5–7.7 (*m*, 15H); IR (KBr): 2172 (–CN), 1584 (CO) cm⁻¹.

Ylid (I)

Crystal data

C₂₂H₁₈NO₂P
M_r = 359.34
Monoclinic, P2₁/c
a = 9.9601 (14) Å
b = 9.0436 (13) Å
c = 20.708 (3) Å
 β = 94.659 (3)°
V = 1859.1 (5) Å³

Z = 4
D_x = 1.284 Mg m⁻³
Mo K α radiation
 μ = 0.16 mm⁻¹
T = 297 (2) K
Plate, colorless
0.30 × 0.24 × 0.10 mm

Data collection

Bruker SMART CCD
diffractometer
 φ and ω scans
14118 measured reflections

3659 independent reflections
2645 reflections with $I > 2\sigma(I)$
R_{int} = 0.052
 θ_{\max} = 26.0°

Refinement

Refinement on F²
R[F² > 2 σ (F²)] = 0.065
wR(F²) = 0.150
S = 1.07
3659 reflections
236 parameters
H-atom parameters constrained

$w = 1/[\sigma^2(F_o^2) + (0.0653P)^2 + 0.3502P]$
where $P = (F_o^2 + 2F_c^2)/3$
(Δ/σ)_{max} = 0.005
 $\Delta\rho_{\max}$ = 0.36 e Å⁻³
 $\Delta\rho_{\min}$ = -0.23 e Å⁻³

Table 1

Selected geometric parameters (Å, °) for (I).

P1—C1	1.730 (3)	C2—C1	1.407 (4)
O2—C3	1.350 (4)	C1—C3	1.427 (4)
O2—C4	1.432 (4)	O1—C3	1.212 (4)
C2—N1	1.145 (4)		
C3—O2—C4	117.0 (3)	C3—C1—P1	118.8 (2)
N1—C2—C1	179.2 (3)	O1—C3—O2	122.5 (3)
C2—C1—C3	120.8 (3)	O1—C3—C1	126.0 (3)
C2—C1—P1	120.3 (2)	O2—C3—C1	111.5 (3)
C4—O2—C3—O1	−4.1 (5)	P1—C1—C3—O1	4.4 (5)
C4—O2—C3—C1	175.0 (3)	C2—C1—C3—O2	7.5 (4)
C2—C1—C3—O1	−173.5 (3)		

Table 2

Non-bonding interactions and short contacts (Å, °) in (I).

Cg2 and Cg3 are the centroids of rings C21–C26 and C31–C36, respectively.

$D-H \cdots A$	$D-H$	$H \cdots A$	$D \cdots A$	$D-H \cdots A$
C32—H32 \cdots O1	0.93	2.51	3.294 (4)	142
C14—H14 \cdots Cg3 ⁱ	0.93	2.93	3.738 (3)	146
C16—H16 \cdots Cg2 ⁱⁱ	0.93	2.99	3.835 (3)	153
P1 \cdots O1	—	—	3.022 (2)	—

Symmetry codes: (i) $x, y - 1, z$; (ii) $-x + 1, y + \frac{1}{2}, -z + \frac{1}{2}$.**Ylid (II)***Crystal data*

C₂₂H₁₈NOP
 $M_r = 343.34$
 Monoclinic, $P2_1/c$
 $a = 10.1144$ (11) Å
 $b = 8.9938$ (10) Å
 $c = 19.968$ (2) Å
 $\beta = 91.744$ (2)°
 $V = 1815.6$ (3) Å³

$Z = 4$
 $D_x = 1.256$ Mg m^{−3}
 Mo $K\alpha$ radiation
 $\mu = 0.16$ mm^{−1}
 $T = 298$ (2) K
 Plate, colorless
 $0.42 \times 0.32 \times 0.14$ mm

Data collection

Bruker SMART CCD
 diffractometer
 φ and ω scans
 13496 measured reflections

3569 independent reflections
 2789 reflections with $I > 2\sigma(I)$
 $R_{\text{int}} = 0.038$
 $\theta_{\text{max}} = 26.0^\circ$

Refinement

Refinement on F^2
 $R[F^2 > 2\sigma(F^2)] = 0.054$
 $wR(F^2) = 0.143$
 $S = 1.03$
 3569 reflections
 227 parameters
 H-atom parameters constrained

$w = 1/[\sigma^2(F_o^2) + (0.0819P)^2 + 0.1374P]$
 where $P = (F_o^2 + 2F_c^2)/3$
 $(\Delta/\sigma)_{\text{max}} = 0.009$
 $\Delta\rho_{\text{max}} = 0.45$ e Å^{−3}
 $\Delta\rho_{\text{min}} = -0.27$ e Å^{−3}

H atoms were placed at idealized positions [C—H = 0.93 (aromatic) and 0.96 Å (methyl)] and allowed to ride on the corresponding host, with $U_{\text{iso}}(\text{H})$ values of $xU_{\text{eq}}(\text{C})$ [$x = 1.2$ (aromatic) and 1.5 (methyl)].

For both ylids, data collection: *SMART-NT* (Bruker, 2001); cell refinement: *SAINT-NT* (Bruker, 2001); data reduction: *SAINT-NT*; program(s) used to solve structure: *SHELXS97* (Sheldrick, 1997); program(s) used to refine structure: *SHELXL97* (Sheldrick, 1997); molecular graphics: *SHELXTL-NT* (Bruker, 2001); software used to prepare material for publication: *SHELXTL-NT* and *PLATON* (Spek, 2003).

Table 3

Selected geometric parameters (Å, °) for (II).

P1—C1	1.744 (2)	C1—C2	1.410 (3)
O1—C3	1.239 (3)	C1—C3	1.419 (3)
N1—C2	1.150 (3)	C3—C4	1.514 (3)
C2—C1—C3	121.8 (2)	O1—C3—C1	121.6 (2)
C2—C1—P1	120.27 (17)	O1—C3—C4	119.4 (2)
C3—C1—P1	117.95 (17)	C1—C3—C4	119.0 (2)
N1—C2—C1	178.4 (3)		
C2—C1—C3—O1	177.0 (2)	C2—C1—C3—C4	−3.3 (4)
P1—C1—C3—O1	−3.3 (3)		

Table 4

Non-bonding interactions and short contacts (Å, °) in (II).

Cg1 is the centroid of ring C11–C16.

$D-H \cdots A$	$D-H$	$H \cdots A$	$D \cdots A$	$D-H \cdots A$
C16—H16 \cdots O1	0.93	2.34	3.130 (3)	142
C34—H34 \cdots Cg1 ⁱ	0.93	2.91	3.703 (3)	144
P1 \cdots O1	—	—	2.928 (2)	—

Symmetry code: (i) $x, y + 1, z$.

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Supplementary data for this paper are available from the IUCr electronic archives (Reference: SQ3045). Services for accessing these data are described at the back of the journal.

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