β-Tosylhydrazono Phosphonates in Organic Synthesis. An Unambiguous Entry to Polysubstituted Pyrazoles

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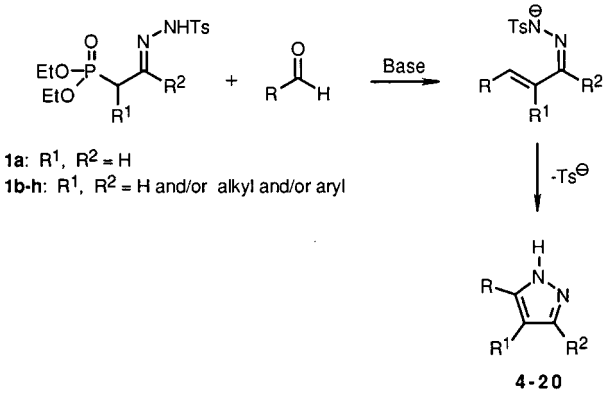
Abstract: β-Tosylhydrazono phosphonates are novel, bifunctional reagents which were used for a concise approach to a wide range of polysubstituted pyrazoles in a single operation from aromatic and aliphatic aldehydes.

Key words: β-tosylhydrazono phosphonate, aldehyde, α,β-unsaturated tosylhydrazone, pyrazole

While the relative inability of Nature in dealing with the N-N bond renders pyrazole containing natural products a real rarity, such heterocycles are indeed abundantly featured in agricultural, material and pharmaceutical chemicals. Among the many excellent methods available for pyrazoles synthesis, the condensation of hydrazine with 1,3-difunctional compounds or 1,3-dipolar cycloadditions to triple bond often emerge as the standard methods for their recognised versatility.[1] Although appealingly general, these procedures sometimes suffer from the need of multistep sequence to secure the starting material and the not so obvious regiocontrol of substitution in the final products. In the pursuit of synthetic efficiency, we have been exploring a new [1+4] approach which addresses the mentioned limits by combining aliphatic or aromatic aldehydes, as readily available C1 synthons, with novel β-tosylhydrazono phosphonates **1a-h** as the CCNN counterpart in a Horner-Emmons condensation / cyclative disproportionation fashion (Scheme 1).

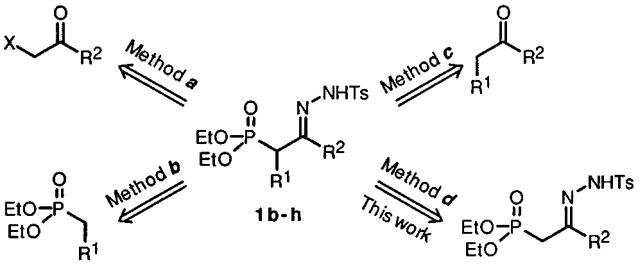


Scheme1

These features distinguish the present methodology from the important precedent of Beam and co-workers, who reported the [1+4] coupling of strongly basic dianions of ketone hydrazones with aromatic esters followed by acidic dehydration to pyrazole.[2]

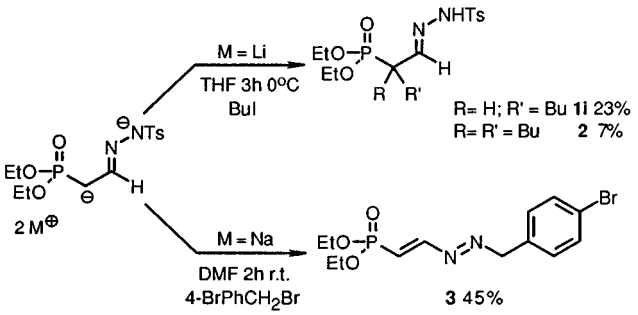
Diethoxyphosphorylacetaldehyde tosylhydrazone, **1a** (R^1, R^2 = H), the simplest member of the series, was recently employed for the one-pot synthesis of 3(5)-aryl, alkenyl and alkyl monosubstituted pyrazoles.[3] The generality, conciseness and wide functional groups compatibility (*e.g.* COOH, AcO, TBSO, NMe_2, $CH(OEt)_2$, OH) of the procedure, made it attractive enough to justify efforts to its extension to the convergent synthesis of polysubstituted pyrazoles from substituted β-tosylhydrazono phosphonates **1b-h** (R^1 and/or $R^2 \neq$ H) and aldehydes.

As indicated in Scheme 2, preparation of **1b-h** could be efficaciously approached on a substituent basis by exploiting one of the numerous procedures available[4] for the preparation of parent β-keto phosphonates:[5] primarily the Arbuzov reaction[6] (method *a*), the acylation of alkylphosphonate anion[7] (method *b*) or the methodologies based on the reaction of ketone enolates with electrophilic phosphorus reagents[8] (method *c*). Acidic condensation of the appropriate ketones with tosylhydrazide then gave the desired β-tosylhydrazono phosphonates **1b-h** as easily purified, highly crystalline, stable compounds (see Table 1).



Scheme 2

To further extend the flexibility of the synthesis, we surveyed the alkylation of β-tosylhydrazono phosphonates dianions, which could allow direct modification of β-tosylhydrazono phosphonates at the carbon next to phosphorous (method *d*). Reactive halides (*e.g.* 4-bromobenzylbromide) and lithium countercation were found to be essential for a clean transformation [*n*-BuLi 2.2 equiv, 15 min -50 to -70°C, then RX 2.8 equiv, 90 min, -78°C, THF]. On the other hand, unactivated primary iodide, *e.g.* *n*-BuI, reacted only partially, even at 0°C, providing low yields of mono- and dialkylated derivatives **1i** and **2** (23



Scheme 3

and 7% respectively), while sodium countercation and polar aprotic solvents (DMF) favoured dianion decomposition[9] over alkylation as demonstrated by the isolation of the vinylazobenzyl derivative **3** (Scheme 3).

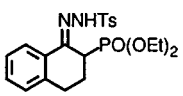
The substitution pattern influences the ease of deprotonation of β-tosylhydrazono phosphonates and the stability of the corresponding dianions. Thus, NaH [2 equiv, 0°C to r.t., THF] readily deprotonates α-unsubstituted phosphonates, **1a-c** (R^1 = H), giving thermally stable dianions. On the contrary, α-alkylation depresses both the acidity of the α-carbon and the stability of the dianions (see Table 1), probably by increasing steric hindrance and electronic density at the α position. In these cases, **1d-h** ($R^1 \neq$ H), stronger bases and/or lower temperatures ought to be used. Shapiro-like decomposition processes, which begin with the extrusion of *p*-tolylsulphinate, occurred fast at room temperature thus preventing complete consumption of the aldehyde in the subsequent Horner-Emmons condensation.

Although with non base-sensitive substrate trapping of *in situ* generated dianion [NaH 2 equiv, 50°C, THF] with aldehyde proved to be fruitful, in most cases, deprotonation of **1d-h**, was best accomplished with KH [2 equiv, 0°C to r.t., THF] or NaH/*n*-BuLi [1 equiv at 0°C then 1 equiv at -78°C or at 0°C, THF] (see Table 1).

Aldehyde was then added to the dianion solution and the temperature was adjusted to allow complete formation of α,β-unsaturated tosylhydrazone salts. While in some cases (aromatic aldehydes), eventual cyclization to pyrazole took place even at room temperature over long times, the cyclization process was greatly accelerated upon working at higher temperature and these conditions were routinely employed (see Table 2).

As apparent from the examples, the method is versatile, allowing for structural variations in both the aldehyde (see also ref. 3) and the phosphonate components. Substituents position on the heterocyclic nucleus is unambiguously determined by an *a priori* choice of the substitution pattern on the parent β-keto phosphonates, which is in turn easily predictable through a selection of the appropriate synthetic route. This can be especially useful for the synthesis of polyalkylsubstituted pyrazoles for which neither the hydrazine or dipolar approaches are expected to allow facile substitution regiocontrol. Moderate to low yields are sometimes observed in the synthesis of 3-alkyl-4-sub-

Table 1: Synthesis and Properties of β-Tosylhydrazono Phosphonates **1a-1h**

compnd	R^1	R^2	synthesis of phosphonates 1a-1h	yield(%)[a]	mp and solvent of crystallisation	deprotonation of phosphonates 1a-h[d]	decomposition (%) of phosphonates 1a-h dianion at r.t. after 30 and 90 min[e]
1a	H	H	$TsNHNH_2$, HCl 0.1M aq, 65°C 3h, ref. 3	85[b]	105-106°C HCl aq 0.1M	A, 0°C 0.5h	<2 and 5 ; Na salt
1b	H	CH_3	$TsNHNH_2$, HCl 0.1M aq, 65°C 1h	83[b]	120-121°C HCl aq 0.1M	A, 0°C 0.5h then 3h r.t.	4 and 6 ; Na salt 5 and 8 ; K salt
1c	H	C_6H_5	$TsNHNH_2$, AcOH, r.t. 4h	48[b]	87-90°C EtOH/iPr_2O	A, 30°C 2h or C	5 and 8 ; Na salt
1d	CH_3	H	alkylation of **1a** dianion, see text and experimental	80	122-123°C EtOAc/iPr_2O	A 50°C 0.5h[c] or B, r.t. 1h or C	20 and 27 ; K salt
1e	*p*-$BrC_6H_4CH_2$	H	alkylation of **1a** dianion, see text and experimental	65	171-173°C EtOAc/hexane	C	*f*
1f	C_6H_5	H	$TsNHNH_2$, HCl 0.1M in EtOH, reflux 4h	74[b]	159°C EtOH	B, r.t. 1h	22 and 30 ; K salt
1g	CH_3	CH_3	$TsNHNH_2$,AcOH, r.t. 3h	75[b]	132-134°C EtOAc/iPr_2O	B, r.t. 0.45h	<2 and 25 ; K salt
1h			$TsNHNH_2$ HCl 0.1M EtOH, reflux 4h	50[b]	131-133°C water/EtOH	D	*f*

[a]Isolated yield after crystallisation; [b]From the corresponding β-keto phosphonate; [c]Run in the presence of 4-bromobenzaldehyde; [d]A: NaH (2 equiv); B: KH (2 equiv); C: NaH (1 equiv), 0°C, 0.5h then *n*-BuLi (1 equiv) -78°C, 0.25h; D: NaH (1 equiv), 0°C, 0.5h then *n*-BuLi (1 equiv) 0°C, 0.25h; [e]As checked by monitoring the doublet for tolylsulphinate 2,6 protons at 7.52 ppm. [f]Overlapping signals in the region of interest

stituted pyrazoles (compounds **4**, **5**, **7**, **9**). In these cases, increase of steric hindrance at the α-position of β-tosylhydrazono phosphonates is expected to favour the formation of undesired (*Z*)-α,β-unsaturated tosylhydrazone at the expense of the (*E*) isomer required for the cyclization.[10] This is not especially a problem with aromatic aldehydes where the (*E*)/(*Z*) ratio is thermodynamically controlled, but causes serious yield decrease with aliphatic aldehydes for which the initial step of Horner-Emmons condensation in essentially irreversible.[11] On the contrary, substitution at the β-position (*i.e.* $R^2 \neq H$) is easily predicted to revert this trend and formation of pyrazoles proceeds in better yield with aromatic as well as aliphatic substrates (compounds **17**-**20**).

In conclusion, the use of β-tosylhydrazono phosphonates could be extended to the convergent synthesis of a wide array of polysubstituted pyrazoles.[12] Remarkably, heterocycle construction is possible in a single experimental operation, from readily accessible starting materials, under conditions which have been shown to respect a number of functional groups and with complete control of substituents position.

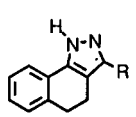
Experimental procedure for alkylation of diethoxyphosphoryl acetaldehyde tosylhydrazone (1a).

To a solution of **1a** (2.50g, 7.18 mmol) in dry THF (40 mL) at -50°C *n*-BuLi (1.6 M in hexane, 5 mL, 8.0 mmol) was added. The slightly yellow solution was cooled to -70°C and treated with *n*-BuLi (1.6 M in hexane, 5 ml, 8.0 mmol) to give an intensely yellow solution. After 15 min a solution of the electrophile (2.8 equiv) in dry THF (20 mL) was added and the stirring was continued for 90 min at -78°C. The reaction was then quenched with sat. aq. NH_4Cl and extracted with EtOAc. The solvent was removed under reduced pressure to give a crude product which was purified by crystallization (EtOAc/iPr_2O, 2.10 g of **1d**, 80%; hexane/EtOAc, 2.42 g of **1e,** 65%).

Typical procedure for pyrazoles formation.

A solution (or suspension) of β-tosylhydrazono phosphonates **1b-h** dianion in THF (0.1 M, 1.5 equiv) was generated as described in Table 1. The aldehyde in THF (0.7 M, 1.0 equiv) was added and the mixture was stirred at the indicated temperature until completion of the Horner-Emmons step (see Table 2, 1st step). The mixture was then refluxed for the time specified in Table 2 (2nd step) to allow

Table 2: Polysubstituted Pyrazoles **4-20** from Aldehydes RCHO and β-Tosylhydrazono Phosphonates **1b-h**

compnd	R	R^1	R^2	yield (%)[a]	β-tosylhydrazono phosphonate 1b-h[b]	rxn. conditions 1st / 2nd step[c]	selected spectroscopic data (^{1}H-NMR, 300 MHz; J in Hz)
4	$C_{17}H_{35}$	CH_3	H	47	**1d** (B)	40°C 0.5h / reflux 2h	MeOD: δ 0.91 (3H, t, J=8); 1.2-1.7 (30 H, m); 2.01 (3H, s); 2.59 (2H, t, J=8); 7.24 (1H, s).
5	$C_6H_5CH_2$	CH_3	H	26	**1d** (C)	0°C 0.5h / reflux 1h	MeOD: δ 1.92 (3H, s); 3.95 (2H, s); 7.20 (5H, m); 7.31 (1H, s).
6	*p*-BrC_6H_4	CH_3	H	88	**1d** (A)	*d* / reflux 1h	MeOD: δ 2.20 (3H, s); 7.48 (1H, s); 7.51 (2H, d, J=8.5); 7.58 (2H, d, J=8.5).
7	C_6H_{11}	C_6H_5	H	18	**1f** (B)	r.t. 1.5h / reflux 5h	MeOD: δ 1.20-1.95 (11H, m); 2.90 (1H, m); 7.30 (5H, m); 7.55 (1H, s).
8	*p*-BrC_6H_4	C_6H_5	H	50	**1f** (B)	r.t. 1.0h / reflux 2h	MeOD: δ 7.2-7.6 (9H, m); 7.75 (1H, s).
9	C_6H_{11}	*p*-$BrC_6H_4CH_2$	H	17	**1e** (C)	0°C 0.5h / reflux 2h	MeOD: δ 3.78 (2H, s); 7.10 (2H, d, J=8.5); 7.26 (1H, s); 7.41 (2H, d, J=8.5).
10	*p*-BrC_6H_4	*p*-$BrC_6H_4CH_2$	H	50	**1e** (C)	0°C 1.5h / reflux 1h	MeOD: δ 3.9 (2H, s); 7.03 (2H, d, J=8.5); 7.36 (2H, d, J=8.5); 7.39 (2H, d, J=8.5); 7.40 (1H, s); 7.51 (2H, d, J=8.5).
11	C_6H_{11}	H	CH_3	56	**1b** (A)	r.t. 1h / reflux 6h	CDCl3: δ 1.2-2.0 (10H, m); 2.29 (3H, s); 2.62 (1H, m); 5.86 (1H, s).
12	$C_6H_5CH_2$	H	CH_3	72	**1b** (A)	r.t. 1h / reflux 14h	MeOD: δ 2.21 (3H, s); 3.90 (2H, s); 5.79 (1H, s); 7.23 (5H, m).
13	*p*-BrC_6H_4	H	CH_3	77	**1b** (A)	r.t. 0.5h / reflux 3h	CDCl3: δ 2.32 (3H, s); 6.33 (1H, s); 7.51 (2H, d, J=8.5); 7.60 (2H, d, J=8.5).
14	C_6H_{11}	H	C_6H_5	74	**1c** (A)	r.t. 1h / reflux 1.5h	MeOD: δ 1.2-2.0.(10H, m); 2.65 (1H, m); 6.37 (1H, s); 7.2-7.8 (5H, m).
15	$C_6H_5CH_2$	H	C_6H_5	27	**1c** (C)	0°C 0.5h / reflux 3h	MeOD: δ 4.07 (2H, s); 6.39 (1H, s); 7.5 (10H, m).
16	*p*-BrC_6H_4	H	C_6H_5	71	**1c** (A)	40°C 0.5h / reflux 1h	MeOD: δ 7.07 (1H, s); 7.41 (3H, m); 7.52 (2H, d, J=8.5); 7.80 (3H, m).
17	C_6H_{11}	CH_3	CH_3	45	**1g** (B)	r.t. 1h / reflux 8h	MeOD: δ 1.20-1.90 (10H, m); 1.91 (3H, s); 2.13 (3H, s); 2.59 (1H, m).
18	*p*-BrC_6H_4	CH_3	CH_3	63	**1g** (B)	r.t. 1h / reflux 3.5h	MeOD: δ 2.10 (3H, s); 2.25 (3H, s); 7.50 (1H, d, J=8.5); 7.51 (1H, d, J=8.5).
19	C_6H_{11}			59	**1h** (D)	0°C 0.5h / reflux 1.5h	CDCl3: δ 1.20-2.00 (10H, m); 2.71 (1H, m); 2.77 (2H, t, J=7.5); 2.97 (2H, t, J=7.5); 7.2-7.8 (4H, m).
20	*p*-BrC_6H_4			76	**1h** (D)	0°C 0.5h / reflux 0.5h	CDCl3: δ 2.98 (4H, m); 7.20-7.70 (8H, m).

[a]Isolated yield after column chromatography; [b]In parentheses, reaction conditions for dianion formation (see Table 1 for A, B, C and D meaning); [c]1st and 2nd steps refer to the Horner-Emmons and cyclization step respectively. [d]Generation of phosphonate dianion in the presence of the aldehyde. Horner-Emmons condensation is complete under these conditions.

pyrazole formation. After quenching with 5% aq. NaH_2PO_4 and extraction with EtOAc, the residue was purified by chromatography on silica gel.

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(10) Only the (*E*)-isomer of β-monosubstituted α,β-unsaturated tosylhydrazones cyclize to pyrazole under the described conditions. See ref. 3.
(11) For a review of the effects of structural changes in the phosphoryl and carbonyl components on the (*E*)/(*Z*) ratio see *Organic Reactions* Vol. 25 Wadsworth W.S. pp 81-85.
All new compounds gave spectroscopic data and elemental analysis in agreement with the assigned structures. Spectral and fisical data for β-tosylhydrazono phosphonates **1b-h** follow:
Diethyl 2-oxopropylphosphonate tosylhydrazone (1b)
^{1}H-NMR (300 MHz, $CDCl_3$): δ 1.18 (6H, t, J = 7.0 Hz); 1.93 (3H, d, J_{HP} = 2.7 Hz); 2.43 (3H, s); 2.82 (2H, d, J_{HP} = 22.0 Hz); 3.95 (4H, m); 7.30 (2H, d, J = 7.5 Hz); 7.85 (2H, d, J = 7.5 Hz); 9.60 (1H, s) ^{13}C-NMR (75 MHz, $CDCl_3$): δ 16.2 (dq, J_{CP} = 5.3 Hz); 16.6 (q); 21.5 (q); 37.1 (dt, J_{CP} = 135.9 Hz); 62.2 (dt, J_{CP} = 7.5 Hz); 128.1 (d); 129.4 (d); 135.7 (s); 143.9 (s); 150.2 (d, J_{CP} = 9.4 Hz). Anal. Calcd for $C_{14}H_{23}N_2O_5PS$: C 46.40, H 6.35, N 7.73, S 8.83. Found 46.47, H 6.33, N 7.64, S 9.19.
Diethyl 2-oxo-2-phenylethylphosphonate tosylhydrazone (1c)
^{1}H-NMR (300 MHz, $CDCl_3$): δ 1.14 (6H, t, J = 7.0 Hz); 2.40 (3H, s); 3.34 (2H, d, J_{HP} = 22.9 Hz); 3.95 (4H, m); 7.28 (2H, d, J = 7.5 Hz); 7.35 (3H, m); 7.67 (2H, m); 7.95 (2H, d, J = 7.5 Hz); 10.1 (1H, s). ^{13}C-NMR (75 MHz, MeOD): δ 16.7 (dq, J_{CP} = 6.1 Hz); 21.8 (q); 28.3 (dt, J_{CP} = 135.1 Hz); 64.9 (dt, J_{CP} = 6.9 Hz); 128.1 (d); 129.7 (d); 129.6 (d); 130.9 (d); 131.3 (d); 137.5 (s); 138.1 (d,J_{CP} = 3.2 Hz); 145.9 (s); 149.0 (d, J_{CP} = 10.0 Hz). Anal. Calcd for $C_{19}H_{25}N_2O_5PS$: C 53.77, H 5.94, N 6.60, S 7.55. Found C 53.74, H 5.92, N 6.71, S 7.87.
Diethyl 1-formylethylphosphonate tosylhydrazone (1d)
^{1}H-NMR (300 MHz, MeOD): δ 1.24 (3H, t, J = 7.0 Hz); 1.25 (3H, t, J = 7.0 Hz); 1.28 (3H, dd, J_{HP} = 18.6 and J = 7.8 Hz); 2.42 (3H, s); 2.91 (1H, ddq, J_{HP} = 23.4 and J = 6.0 , 7.8 Hz); 3.97 (4H, m); 7.17 (1H, dd, J_{HP} = 4.0 and J = 6.0 Hz); 7.39 (2H, d, J = 7.5 Hz); 7.77 (2H, d, J = 7.5 Hz). ^{13}C-NMR (75 MHz, MeOD): δ 11.8 (dq, J_{CP} = 6.2 Hz); 17.0 (dq, J_{CP} = 5.7 Hz); 21.9 (q); 37.6 (dd, J_{CP} = 138.9 Hz); 64.3 (dt, J_{CP} = 6.8 Hz); 129.2 (d); 131.0 (d); 137.8 (s); 145.6 (s); 148.0 (dd, J_{CP} = 7.7 Hz). Anal. Calcd for $C_{14}H_{23}N_2O_5PS$: C 46.40, H 6.35, N 7.73, S 8.83. Found 46.21, H 6.38, N 7.68, S 8.81.
Diethyl 1-formyl-2-(4'-bromophenyl)ethylphosphonate tosyl hydrazone (1e)
^{1}H-NMR (300 MHz, MeOD): δ 1.24 (3H, t, J = 7.0 Hz); 1.25 (3H, t, J = 7.0 Hz); 2.48 (3H, s); 2.90-3.25 (3H, m); 4.03 (4H, m); 6.96 (2H, d, J = 7.8 Hz); 7.06 (1H, dd, J_{HP} = 3.7 and J = 6.5 Hz); 7.26 (2H, d, J = 7.8 Hz); 7.34 (2H, d, J = 7.5 Hz); 7.65 (2H, d, J = 7.5 Hz). ^{13}C-NMR (75 MHz, MeOD): δ 16.6 (dq, J_{CP} = 5.8 Hz); 21.7 (q); 32.5 (dt, J_{CP} = 3.9 Hz); 44.3 (dd, J_{CP} = 135.9 Hz); 64.2 (dt, J_{CP} = 7.1 Hz); 121.2 (s); 128.7 (d); 130.7 (d); 131.9 (d); 132.4 (d); 137.6 (s); 138.7 (d, J_{CP} = 15.5 Hz); 145.2 (s), 145.8 (dd, J_{CP} = 8.6 Hz). Anal. Calcd for $C_{20}H_{26}N_2O_5PSBr$: C 46.43, H 5.07, N 5.41, S 6.20, Br 15.44. Found C 46.75, H 5.06, N 5.47, S 6.23, Br 15.25.
Diethyl 1-formylbenzylphosphonate tosylhydrazone (**1f**)
^{1}H-NMR (300 MHz, MeOD): δ 1.07 (3H, t, J = 7.1 Hz); 1.16 (3H, t, J = 7.1 Hz); 2.42 (3H, s); 3.70-4.05 (4H, m); 4.15 (1H, dd, J_{HP} = 24.2 and J = 7.2 Hz); 7.30 (5H, m); 7.41 (1H, t, J_{HP} = 7.2 Hz); 7.36 (2H, d, J = 8.2 Hz); 7.75 (2H, d, J = 8.2 Hz). ^{13}C-NMR (75 MHz, MeOD): δ 16.4 (dq, J_{CP} = 5.8 Hz); 16.6 (dq, J_{CP} = 5.9 Hz); 21.5 (q); 49.7 (dt, J_{CP} = 137.8 Hz); 64.4 (dt, J_{CP} = 7.4 Hz); 64.5 (dt, J_{CP} = 7.6 Hz); 128.9 (s); 128.9 (d) 129. 8 (dd, J_{CP} = 2.3 Hz); 130.4 (dd, J_{CP} = 6.7 Hz); 130.7 (d); 134.1 (d, J_{CP} = 7.7 Hz); 137.4 (s); 145.3 (s); 146.6 (d, J_{CP} = 7.2 Hz). Anal. Calcd for $C_{19}H_{25}N_2O_5PS$: C 53.77, H 5.94, N 6.60, S 7.55. Found C 52.77, H 5.83, N 6.50, S 7.35.
Diethyl 1-methyl-2-oxopropylphosphonate tosylhydrazone (1g)
^{1}H-NMR (300 MHz, MeOD): δ 1.16 (3H, t, J = 7.0 Hz); 1.18 (3H, t, J = 7.0 Hz); 1.89 (3H, d, J_{HP} = 2.7 Hz); 2.43 (3H, s); 2.92 (3H, dq, J_{HP} = 21.0 Hz and J = 6.5 Hz); 3.93 (4H, m); 7.30 (2H, d, J = 7.5 Hz); 7.85 (2H, d, J = 7.5 Hz). ^{13}C-NMR (75 MHz, $CDCl_3$): δ 11.5 (dq, J_{CP} = 6.0 Hz); 15.0 (q); 15.56 (dq, J_{CP} = 2.4 Hz); 15.64 (dq, J_{CP} = 2.4 Hz); 20.4 (q); 41.4 (dt, J_{CP} = 136.4 Hz); 62.8 (dt, J_{CP} = 4.7 Hz); 62.9 (dt, J_{CP} = 4.5 Hz); 128.2 (d); 129.4 (d); 136.7 (s); 144.2 (s); 155.1 (d, J_{CP} = 7.3 Hz). Anal. Calcd for $C_{15}H_{25}N_2O_5PS$: C 47.86, H 6.69, N 7.44, S 8.50. Found C 47.55, H 6.81, N 7.47, S 8.39.
2-Diethoxyphosphoryl-1-oxo-1,2,3,4-tetrahydronaphtalene tosyl hydrazone (1h)
^{1}H-NMR (300 MHz, $CDCl_3$): δ 0.71 (3H, J = 7.1 Hz); 1.37 (3H, J = 7.1 Hz); 1.90-2.30 (2H, m); 2.41 (3H, s); 2.67 (1H, dt, J = 16.6, 4.4 Hz); 3.04 (1H, ddd, J = 16.6, 11.9, 4.7 Hz); 3.39 - 3.65 (2H, m); 3.68 (1H, ddd, J_{HP} = 24.3 Hz and J = 3.3, 5.8 Hz); 4.17 (2H, m); 7.08 (1H, d, J = 7.5 Hz); 7.16 (1H, t, J = 7.5 Hz); 7.25 (1H, t, J = 7.5 Hz); 7.31 (2H, d, J = 8.2 Hz); 7.92 (1H, d, J = 7.5 Hz); 7.98 (2H, d, J = 8.2 Hz); 10.38 (1H, s). ^{13}C-NMR (75 MHz, $CDCl_3$): δ 15.7 (dq, J_{CP} = 5.4 Hz); 16.3 (dq, J_{CP} = 5.8 Hz); 21.5 (q); 23.0 (dt, J_{CP} = 6.4 Hz); 26.2 (dt, J_{CP} = 4.0 Hz); 36.0 (dd, J_{CP} = 134.3 Hz); 62.7 (dt, J_{CP} = 6.8 Hz); 63.8 (dt, J_{CP} = 6.9 Hz); 125.5 (d), 126.5 (d), 128.3 (d), 128.4 (d), 129.2 (d), 129.8 (d); 131.0 (d, J_{CP} = 2.7 Hz);136.2 (s); 138.6 (d, J_{CP} = 1.6 Hz), 143.4 (s), 147.4 (d, J_{CP} = 7.5 Hz). Anal. Calcd for $C_{21}H_{27}N_2O_5PS$: C 55.99, H 6.09, N 6.22, S 7.12. Found C 55.99, H 6.00, N 6.21, S 7.15.