Electronic Supplementary Material (ESI) for RSC Advances.

Supporting Information

α-Alkylation of Ketimines using Visible Light Photoredox Catalysis

Allegra Franchino, Antonia Rinaldi and Darren J. Dixon

Chemistry Research Laboratory, Department of Chemistry, University of Oxford,
12 Mansfield Road, Oxford, OX1 3TA, United Kingdom

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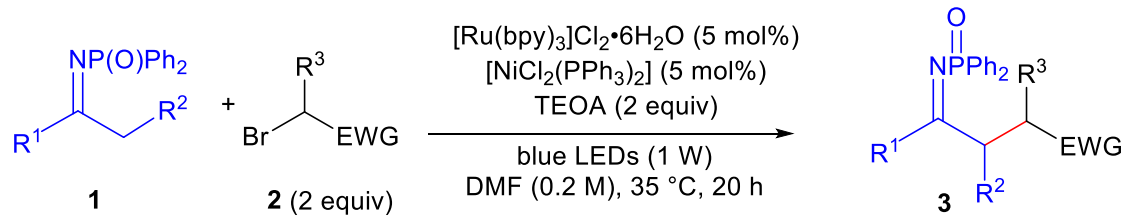
1. Supplementary tables

Table S1 Extended substrate scope



NMR yields for the ketimine tautomer:

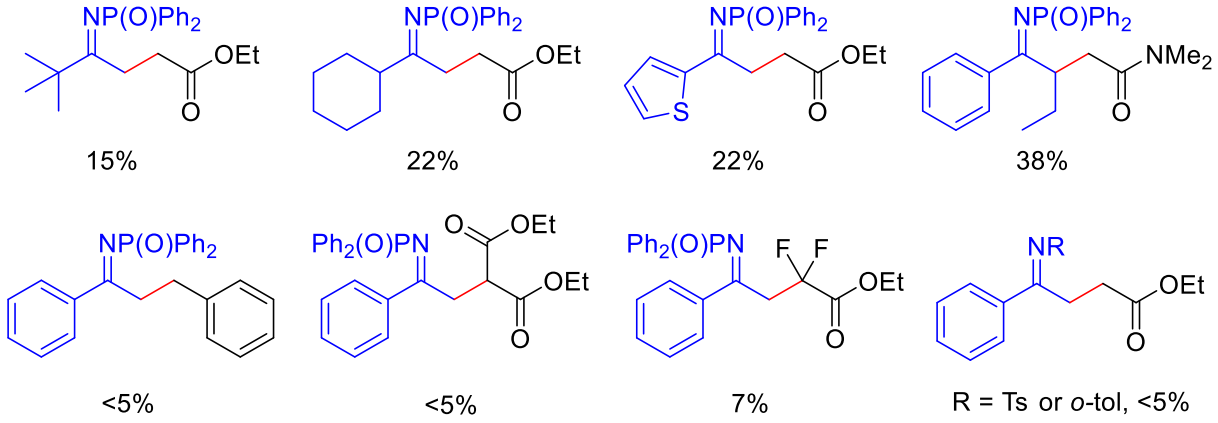
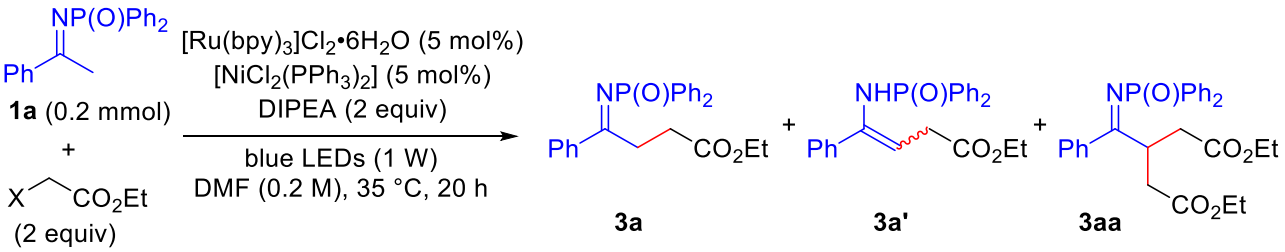


Table S2 Comparison betweeen ethyl iodo-, bromo- and chloroacetate

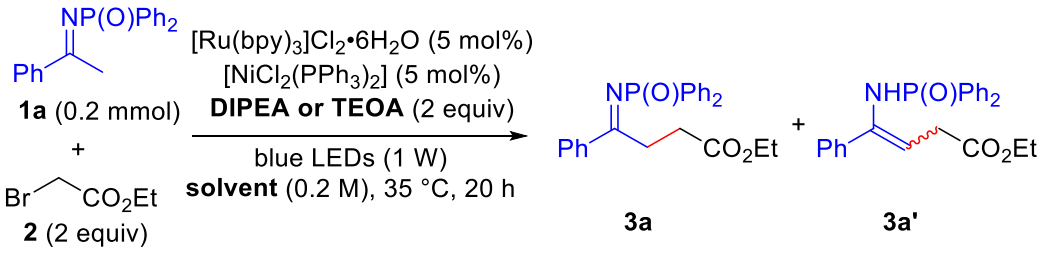


Entry	X	BDE CH_3-X (kcal/mol)[1]	unreacted **1a** (%)[a]	**3a** (%)[a]	**3a'** (%)[a]	**3aa** (%)[a]
1	Cl	83	83	12	5	0
2	Br	71	44	50	5	1
3	I	57	43	36	17	2

[a] Relative ratios were determined by ^{31}P NMR analysis of the reaction mixture after work-up. They are consistent with NMR yields calculated by ^{1}H NMR analysis of the reaction mixture after work-up using mesitylene (28 µL, 0.2 mmol, 1 equiv) as an internal standard.

When ethyl iodoacetate and ethyl chloroacetate were used instead of the ethyl bromoacetate, product **3a** was obtained with diminished NMR yield (Entries 1 and 3). In the case of ethyl chloroacetate, the low yield reflects a poor conversion, whereas the modest yield obtained using ethyl iodoacetate arises from the presence of enamine tautomers **3a'** and dialkylated product **3aa**. The poor reactivity of ethyl chloroacetate is likely related to the more negative reduction potential of this substrate as a consequence of the higher sp^3C–Cl bond dissociation energy (BDE). This observation supports a mechanism involving the formation of an α-carbonyl radical from the halocarbonyl precursor, presumably *via* mesolysis preceded by SET.

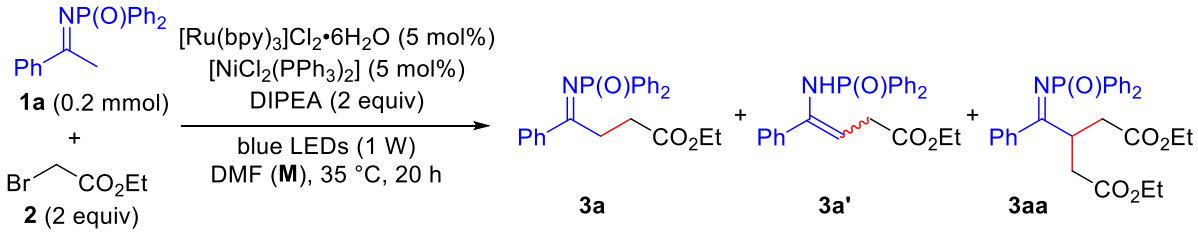
Table S3 Solvent screening



Entry	Solvent	**3a**[a,b] (%)	**3a'**[a,b] (%)	**3a**[a,c] (%)
1	CH_2Cl_2	11	0	29
2	Acetone	21	3	21
3	CH_3CN	34	0	49
4	MeOH	32	14	0
5	DMSO	34	23	25
6	DMF	50	5	28
7	^{i}PrOH	nd	nd	8
8	DMA	23[d]	<2	26
9	AcOEt	<5	<2	nd
10	benzene	<5	<2	nd
11[d]	dioxane	<5	<2	nd
12[d]	THF	<5	<2	nd

[a] NMR yield for the ketimine tautomer determined by ^{1}H NMR analysis of the reaction mixture after work-up using mesitylene (28 µL, 0.2 mmol, 1 equiv) as an internal standard. [b] DIPEA as a base. [c] TEOA as a base.

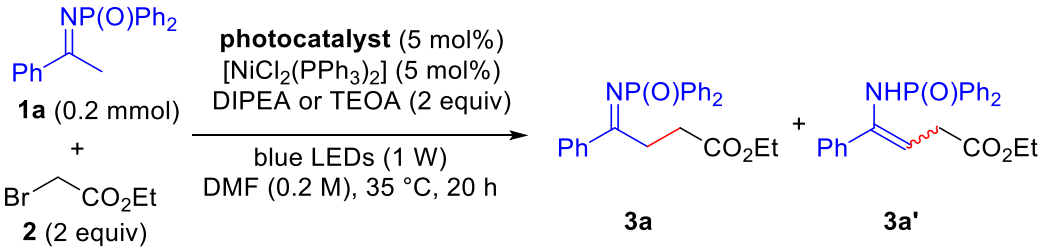
Table S4 Concentration screening



Entry	Concentration (M)	Conversion (%)	**3a** (%)	**3a'** (%)	**3aa** (%)
1	0.067	38	37	1	0
2	0.1	46	45	1	0
3	0.2	56	50	5	1
4	0.4	60	44	11	3
5[a]	0.2	15	11	4	0
6[b]	0.2	33	31	2	0

Conversion (consumption of ketimine **1a**) and NMR yields for **3a** and **3a'** determined respectively by ^{31}P and ^{1}H NMR analysis of the reaction mixture after work-up using mesitylene (28 µL, 0.2 mmol, 1 equiv) as an internal standard. [a] With 2 equivalents **1a** and 1 equivalent of **2**. [b] With 4 equivalents of **2**.

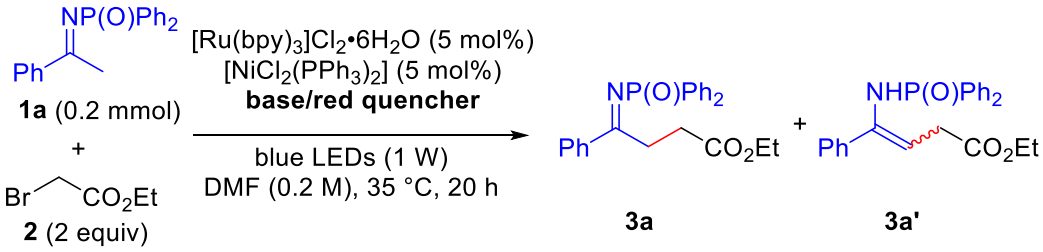
Table S5 Photocatalyst screening



Entry	Photocatalyst	**3a**[a,b] (%)	**3a**[a,c] (%)
1	$[Ru(bpy)_3]Cl_2 \cdot 6H_2O$	50, 43[d]	28
2	Eosin Y disodium form	41[d]	23
3	$[Ru(bpz)_3](PF_6)_2$	35[d]	19
4	$[Ir\{dF(CF_3)ppy\}_2(dtbbpy)]PF_6$	16[d]	15
5	$[Ir(ppy)_2(dtbbpy)]PF_6$	29[d]	40
6	$[Ru(phen)_3]Cl_2$	nd	36
7	Rose bengal disodium salt	nd	0
8	Rose bengal triethylammonium salt	nd	0
9	Fluorescein	nd	0

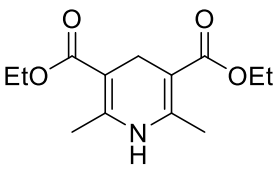
[a] NMR yield for the ketimine tautomer determined by ^1H NMR analysis of the reaction mixture after work-up using mesitylene (28 µL, 0.2 mmol, 1 equiv) as an internal standard. [b] DIPEA as a base. [c] TEOA as a base. [d] 0.1 M concentration.

Table S6 Base screening

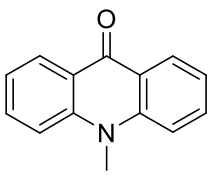


Entry	Base	Amount (equiv)	Conversion (%)	**3a** (%)	**3a'** (%)
1	DIPEA	2	56	50	5
2[a]	DIPEA	2	46	45	1
3[a]	DIPEA	1	31	31	0
4[a]	DIPEA	3	30	24	6
5	DIPEA + $NaHCO_3$	2 + 2	46	43	3
6	DIPEA + Na_2CO_3	2 + 2	34	33	1
7	DIPEA + Na_2HPO_4	2 + 2	49	31	15
8	DIPEA	2 + 2	72	45	14
9	$N(CH_2CH_2OH)_3$	2	95	28	21
10	$N(CH_2CH_2OCH_2CH_2OCH_3)_3$	2	71	42	22
11[a]	TEA	2	27	20	7
12[a]	$Ph_2N(p\text{-}OMeC_6H_4)$	2	<5	-	-
13[a]	2,6-lutidine	2	<5	-	-
14[a]	Na_2HPO_4	2	<5	-	-
15[a]	Acridinone	2	<5	-	-
16[a]	Hantzsch ester	2	100[b]	0	0

Conversion (consumption of ketimine **1a**) and NMR yields for **3a** and **3a'** determined respectively by ^{31}P and ^{1}H NMR analysis of the reaction mixture after work-up using mesitylene (28 µL, 0.2 mmol, 1 equiv) as an internal standard. [a] 0.1 M concentration of **1a**. [b] Decomposition observed.

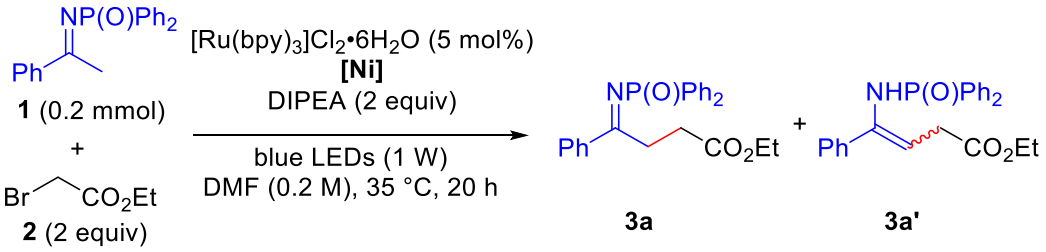


Hantzsch ester



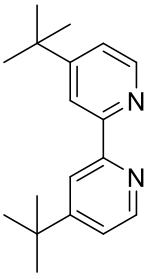
Acridinone

Table S7 Nickel complex screening

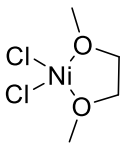


Entry	Nickel complex	Loading (mol %)	**3a** (%)
1	-	-	28[a]
2	$[NiCl_2(PPh_3)_2]$	5	50
3	$[NiCl_2(PPh_3)_2]$	10	36
4	$[NiCl_2(PPh_3)_2]$	50	25
5	$[NiCl_2(Ph_2PCH_2CH_2PPh_2)]$	5	26
6	$[NiCl_2(Ph_2PCH_2CH_2CH_2PPh_2)]$	5	37
7	$[NiCl_2(glyme)]$	5	42
8	$[NiCl_2(glyme)]$ + dtbbpy	5 + 5	36
9	$Ni(OAc)_2 \cdot 4H_2O$	5	45
10	$NiCl_2 \cdot 6H_2O$	5	22
11	$Ni(CF_3SO_3)_2$	5	39
12	$NiBr_2$	5	47
13	$[Ni(cod)_2]$ + PPh_3	5 + 5	36

NMR yield for **3aXX** determined by ^1H NMR analysis of the reaction mixture after work-up using mesitylene (28 µL, 0.2 mmol, 1 equiv) as an internal standard. [a] 10% of **3a'** was also formed.

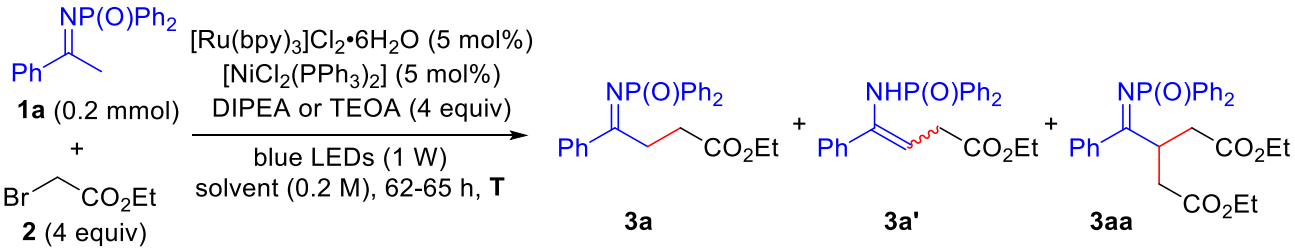


dtbbpy



$NiCl_2(glyme)$

Table S8 Temperature screening



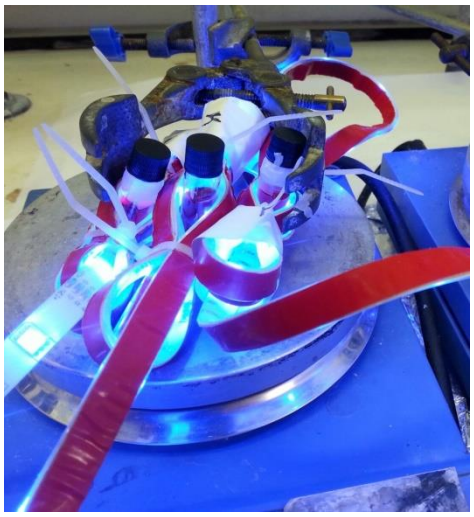
Entry	Solvent	Base	T (°C)	Conversion (%)[a]	**3a** (%)[a]	**3a'** (%)[a]	**3aa** (%)[a]
1	DMF	DIPEA[b]	11	42	38	4	0
2	DMF	DIPEA	11	56	**46**	7	0
3	DMF	TEOA[b]	11	86	37	29	20
5	DMF	TEOA	11	95	32	30	33
6	DMF	DIPEA[b]	21	63	**53**	3	0
7	DMF	DIPEA	21	47	30	12	0
8	DMF	TEOA[b]	21	65	23	18	7
9	DMF	TEOA	21	97	26	18	31
10	DMSO	DIPEA	11	43	36	6	1
11	frozen DMSO	DIPEA	11	45	<5, hydrolysis of **1a**		
12	DMSO	TEOA	11	42	21	13	2
13	DMSO	DIPEA	21	82	**65**	7	2
14	DMSO	TEOA	21	97	13	13	13

[a] Consumption of **1a** and NMR yield for the ketimine tautomer **3a** determined by ^{31}P and ^{1}H NMR analysis of the reaction mixture after work-up using mesitylene (28 µL, 0.2 mmol, 1 equiv) as an internal standard.
[b] With 2 equivalents of base and 2 equivalents of **2**.

When the reaction was performed at room temperature in the standard setup, the temperature measured inside the vial at the end of the reaction was appproximately 35 °C. In order to perform the reactions at lower temperature, the vials wrapped in the LED strip were stirred in a fridge either at 0 °C (resultiung in a 21 °C temperature inside the vial at the end of the reaction) or at 20 °C (corresponding to a 11 °C temperature inside the vial). Lower tempeatures decreased reactivity, hence prolonged reaction times and larger amounts of base and bromoacetate (4 equivalents) were required. When the reaction was run in DMSO at 21 °C for 65 hours with 4 equivalents of DIPEA and bromoacetate, the NMR yield for the desired product increased to 65% (entry 13). This result indicates that lower temperature can improve the product distribution (i.e. selectivity towards **3a**) and suggests that fine tailoring of the reaction conditions for each substrate may give better yields. However, because of safety and practicality issues (longer reaction time, larger excess of reagents) associated with this setup, the standard conditions (20 hours at 35 °C) were preferred for investigating the scope of the reaction.

2. Experimental procedures

2.1 General remarks



Reactions were performed with magnetic stirring under nitrogen, unless otherwise stated. Chemicals were obtained from commercial suppliers and used as received.

Photoredox reactions were run using Tingkam® waterproof strip with 150 RGB LEDs and 30 W output set on blue light at maximum intensity. Five LED lights (1 W total output) were wrapped around each vial on a stir plate (see picture), then the setup was covered with Al foil.

Bulk solutions were evaporated using a Büchi rotary evaporator under reduced pressure keeping the temperature below 30 °C. Solvents were commercially supplied or dried by filtration through activated alumina columns (powder ~150 mesh, pore size 58 Å, basic, Sigma-Aldrich) columns. Dry DMF was stored over 4 Å molecular sieves, previously activated by heating at 200 °C under vacuum for at least 12 h. Petrol ether (PE) refers to distilled light petroleum of fraction (30–40 °C).

Flash column chromatography (FCC) was carried out using Geduran® silica gel 60 (40–63μm) as stationary phase.[2] All reactions were followed by thin-layer chromatography (TLC) when practical, using Merck Kieselgel 60 F_{254} fluorescent treated silica. Visualisation was accomplished under UV light (λ_{max}= 254 nm) and by staining with aqueous potassium permanganate alkaline solution or vanillin staining dip (prepared by adding 2.5 mL of concentrated H_2SO_4 to a solution of 15 g of vanillin in 250 mL EtOH 95%).

NMR spectra were recorded on Bruker spectrometers operating at 300, 400 or 500 MHz (^{1}H resonance). Proton chemical shifts (δ) are given in parts per million (ppm) relative to tetramethylsilane (TMS) with the solvent resonance as internal standard:[3] $CDCl_3$, δ 7.26 ppm. ^{1}H NMR spectra are reported as follows: ppm (multiplicity, coupling constants, number of proton, assignment). The following abbreviations are used to describe spin multiplicity: s = singlet, d = doublet, t = triplet, q = quartet, quint = quintet, sext = sextet, sept = septet, m = multiplet, br = broad signal, app = apparent. Coupling constants (*J*) are given in Hertz (Hz) and are rounded to the nearest integer or half integer. ^{13}C, ^{19}F and ^{31}P NMR spectra were recorded with proton decoupling. Carbon chemical shifts are reported in ppm (δ) relative to TMS with the solvent resonance as internal standard:[2] $CDCl_3$, δ 77.16 ppm. Two-dimensional NMR spectroscopy experiments (COSY, HSQC and HMBC) were used where appropriate to assist in the assignment of signals in ^{1}H and ^{13}C spectra and data are not reported.

High resolution mass spectra (HRMS) were recorded by the University of Oxford mass spectrometry staff on a Bruker MicroTOF mass spectrometer equipped with an ESI source.

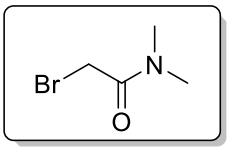
Infrared absorption spectra (IR) were recorded on a Bruker Tensor 27 FT-IR spectrometer from a thin film (the sample was dissolved in $CHCl_3$ and the solvent evaporated) on a diamond ATR module. Bands (ν_{max}) are reported in wavenumbers (cm^{-1}) and their intensity is indicated as strong (s), medium (m) or weak (w).

UV-visible spectra were recorded on Perkin-Elmer Lambda 20 spectrometer using 1 cm quartz cuvettes. Luminescence spectra were recorded on a Fluorescence Spectrophotometer Varian Cary Eclipse using 1 cm quartz cuvettes.
Melting points (m.p.) were recorded using a Reichert hot-stage microscope apparatus equipped with an analogic thermometer or a Leica Galen III hot-stage microscope apparatus with digital thermometer and are reported uncorrected.
Compound names are those generated by ACD LABS 12.0 software following the IUPAC nomenclature.

2.2 Synthesis of starting materials

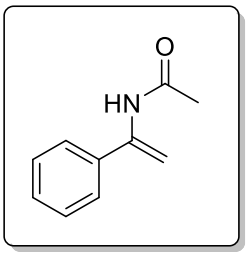
N-diphenylsphinoyl (*N*-DPP) ketimines **1a-1i** were prepared from the corresponding ketones via the oximes according to the literature.[4] The physical and spectroscopic data of ketimines **1a**,[5] **1b**,[5] **1c**,[6] **1d**,[6] **1e**,[5] **1f**,[6] **1g**, [5] **1h**[5] and **1i**[5] were in agreement with those reported. Low temperature ^{31}P NMR studies conducted by Shibasaki and co-workers established that *N*-DPP ketimines derived from aliphatic ketones exist in a very fast equilibrium between *E* and *Z* isomers.[7]

2-Bromo-*N*,*N*-dimethylacetamide



To a solution of 2-bromoacetyl bromide (1.7 mL, 20 mmol, 1 equiv) in CH_2Cl_2 (35 mL), dimethylammonium chloride (2.44 g, 30 mmol, 1.5 equiv) was added. The suspension was cooled to 0 °C and trimethylamine (4.88 mL, 35 mmol, 1.75 equiv) was added dropwise. The reaction was stirred overnight, allowing to warm up to room temperature, then filtered. The filtrate was evaporated and the crude was purified by flash column chromatography (Et_2O) to give the title compound as a yellow oil in 32% yield (1.04 g). Spectroscopic data match those given in the literature.[8]
^{1}H NMR ($CDCl_3$, 400 MHz): δ 3.92 (s, 2H, C$\underline{H}_2$), 3.10 (s, 3H, C$\underline{H}_3$), 2.99 (s, 3H, C$\underline{H}_3$).
^{13}C NMR ($CDCl_3$, 100 MHz): δ 166.8 ($\underline{C}$=O), 38.4 ($\underline{C}H_3$), 36.2 ($\underline{C}H_3$), 26.3 ($\underline{C}H_2$).

***N*-(1-Phenylethenyl)acetamide (7)**



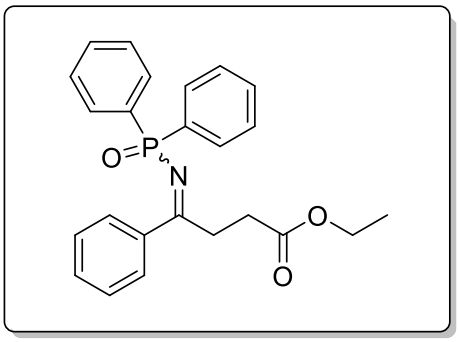
Prepared from the oxime according to a literature procedure.[9] To a solution of NaOAc (12.3 g, 150 mmol, 1.5 equiv) and $NH_2OH{\cdot}HCl$ (10.4 g, 150 mmol, 1.5 equiv) in EtOH/H_2O (1:1, 100 mL), acetophenone (11.7 mL, 100 mmol, 1.0 equiv) was added at room temperature, then the reaction mixture was refluxed overnight. EtOH was removed *in vacuo* and the aqueous solution was cooled to room temperature, then to 0 °C until precipitation of an off-white solid was observed. The solid was collected on Buchner. (*E*)-1-phenylethan-1-one oxime was obtained in 90% yield as an off-white solid (12.1 g).
To a solution of the oxime (5.0 g, 37 mmol, 1 equiv) in toluene (55 mL), Ac_2O (10.5 mL, 111 mmol, 3 equiv), AcOH (6.3 mL, 111 mmol, 3 equiv), Fe (4.3 g, 78 mmol, 2.1 equiv, Aldrich- 325 mesh) and a few drops of TMSCl were added. After stirring at 70 °C for 15 hours, the mixture was cooled to room temperature and filtered over Celite, washing with toluene (2 × 30 mL). The filtrate was washed

with 2 M NaOH (2 × 110 mL), dried over $MgSO_4$, filtered and evaporated under reduced pressure. The crude was purified by flash column chromatography (PE:AcOEt 8:2 to 6:4), affording compound **319** as an orange solid in 36% yield (2.15 g).
Characterisation data match those given in the literature.[10]
MP: 83–84 °C (lit: 89–90 °C).[10]
^{1}H NMR (400 MHz, $CDCl_3$): δ 8.29 (s, broad, NH), 7.37–7.27 (m, 5H, $C_{Ar}H$), 5.59 (s, 1H, N=CH), 5.04 (s, 1H, N=CH), 1.84 (s, 3H, CH_3).
LRMS (ESI, MeOH): calcd. for $C_{10}H_{11}NNaO^+$ $[M+Na]^+$ 184.1, found 184.2.

2.3 General procedure for the α-alkylation of ketimines

Ketimine **1** (0.2 mmol, 1 equiv), $[Ru(bpy)_3]Cl_2 \cdot H_2O$ (7.5 mg, 0.01 mmol, 0.05 equiv) and $[NiCl_2(PPh_3)_2]$ (6.5 mg, 0.01 mmol, 0.05 equiv) were put into an oven dried vial equipped with a magnetic stir bar and a pierceable cap. After 3 vacuum/Ar cycles, dry DMF (1 mL), then either DIPEA (70 µL, 0.4 mmol, 2 equiv) or triethanolamine (60 µL, 0.4 mmol, 2 equiv) and finally ehtyl bromoacetate (45 µL, 0.4 mmol, 2 equiv) were added under argon. The pierced cap was quickly replaced with a new one under a stream of inert gas and the vial wrapped with the blue LEDs strips, so that 5 LED lights (0.2 mW each, λ_{max} ~ 460 nm) were in contact with the vial. After stirring for 20 hours, the solution was diluted with 20 mL of Et_2O and washed with aqueous 5%$_{w/w}$ LiCl solution (3 × 10 mL). The organic phase was dried over Na_2SO_4, filtered and concentrated *in vacuo*. The crude product was analysed by ^{1}H and ^{31}P NMR, using mesitylene as internal standard (28 µL, 0.2 mmol, 1 equiv), then purified by flash column chromatography.
After chromatographic purification, spectra of the ketimine products show 0–56% enamine content depending on the nature of the product. Enamines are tautomeric forms of the ketimine products, therefore their presence is inherent to the nature of the products themselves, which partially tautomerise during FCC purification. NMR data are tabulated for the ketimine tautomers only, unless otherwise specified.
To aid the reader, (a) the ratio of ketimine:enamines for the purified products is provided below; (b) the enamine signals are highlighted with a pale blue shading in the ^{1}H NMR spectra; (c) ^{1}H NMR signals for the enamine tautomers are tabulated when the enamine content is higher than 30%.

2.4 Synthesis and characterisation of α-alkylated ketimines and derivatives



Ethyl-4-[(diphenylphosphoryl)imino]-4-phenylbutanoate (3a)

Prepared according to the general procedure using ketimine **1a** and ethyl bromoacetate as substrates, and DIPEA as a base. Purified by FCC (Et_2O to Et_2O/acetone 9:1) obtaining **3a** as a yellow oil in 45% yield (38.1 mg, ketimine:enamines ratio 90:10).

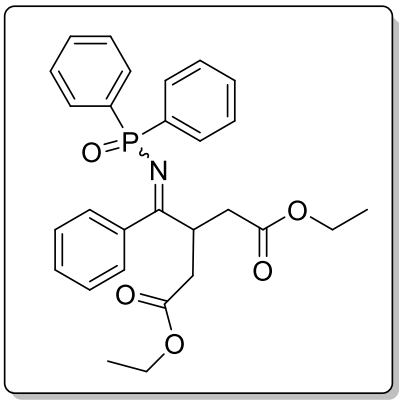
IR: 3058 (w), 2981 (w), 1731 (s, C=O), 1634 (s, C=N), 1438 (m), 1201 (s), 1121 (m), 1107 (m), 725 (s), 696 (s) cm^{-1}.

^{1}H NMR ($CDCl_3$, 400 MHz): δ 8.02–7.94 (m, 6H), 7.53 (tt, J = 7.5, 1.5 Hz, 1H, $C_{Ar}\underline{H}_{para}$), 7.48–7.40 (m, 8H), 4.04 (q, J = 7.0 Hz, 2H, $OC\underline{H}_2CH_3$), 3.65 (dt, $^4J_{HP}$ = 1.0 Hz, $^3J_{HH}$ = 8.0 Hz, 2H, $N{=}CC\underline{H}_2$), 2.67 (t, $^3J_{HH}$ = 8.0 Hz, 2H, $N{=}CCH_2C\underline{H}_2$), 1.17 (t, J = 7.0 Hz, 3H, $OCH_2C\underline{H}_3$).

^{13}C NMR ($CDCl_3$, 126 MHz): δ 184.0 (d, $^2J_{PC}$ = 8.0 Hz, $\underline{C}$=N), 172.0 ($\underline{C}$OOEt), 138.2 (d, $^3J_{PC}$ = 22.5 Hz, $N{=}C\underline{C}_{Ar}$), 134.7 (d, $^1J_{PC}$ = 131.0 Hz, $P\underline{C}_{Ar}$), 132.4 ($\underline{C}_{Ar}H_{para}$), 131.7 (d, $^3J_{PC}$ = 9.0 Hz, $\underline{C}_{Ar}H_{meta}$), 131.6 (d, $^4J_{PC}$ = 3.0 Hz, $\underline{C}_{Ar}H_{para}$), 128.8 ($\underline{C}_{Ar}H$), 128.6 (d, $^2J_{PC}$ = 12.5 Hz, $\underline{C}_{Ar}H_{ortho}$), 128.2 ($\underline{C}_{Ar}H$), 60.8 ($O\underline{C}H_2CH_3$), 32.6 ($\underline{C}H_2COOEt$), 31.5 (d, $^3J_{PC}$ = 13.0 Hz, $NC\underline{C}H_2$), 14.2 ($\underline{C}H_3$).

^{31}P NMR ($CDCl_3$, 162 MHz): δ 18.1.

HRMS (ESI+, MeOH): calcd for $C_{24}H_{25}O_3NP^+$ $[M+H]^+$ m/z 406.15666, found m/z 406.15668.



Diethyl-3-[(diphenylphosphoryl)imino](phenyl)methyl] pentanedioate (3aa)

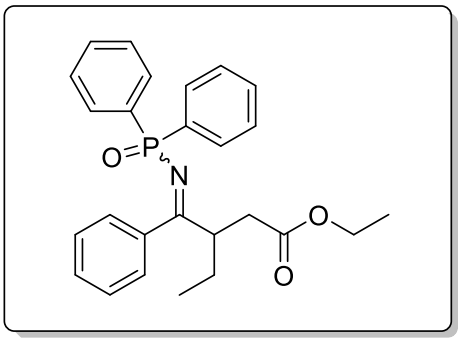
Obtained as a side product following the general procedure using ketimine **1a** and ethyl bromoacetate as substrates, and TEOA as a base. Purified by FCC (Et_2O to Et_2O/acetone 9:1) obtaining **3aa** as a yellow oil in 20% yield (19.7 mg).

IR: 2957 (w), 2924 (w), 2854 (w), 1731 (s, C=O), 1638 (m, C=N), 1438 (w), 1373 (w), 1203 (m), 1121 (w), 1107 (w), 1027 (w), 753 (w), 725 (m), 697 (m) cm^{-1}.

^{1}H NMR ($CDCl_3$, 500 MHz): δ 7.78 (ddd, J = 12.0, 8.5, 1.5 Hz, 4H, $C_{Ar}\underline{H}_{meta}$), 7.61 (d, J = 7.0 Hz, 2H, $C_{Ar}\underline{H}$), 7.48–7.30 (m, 9H, $C_{Ar}\underline{H}$), 4.02 (m, 1H, $NCC\underline{H}$), 3.92 (dq, J = 17.5, 7.0 Hz, 4H, $OC\underline{H}_2CH_3$), 2.97 (dd, J = 16.5, 7.5 Hz, 2H, $N{=}CCH(C\underline{H}_AH_B)_2$), 2.65 (dd, J = 16.5, 6.5 Hz, 2H, $N{=}CCH(CH_A\underline{H}_B)_2$), 1.11 (t, J = 7.0 Hz, 6H, $OCH_2C\underline{H}_3$).

^{13}C NMR ($CDCl_3$, 126 MHz): δ 189.2 (d, $^2J_{PC}$ = 10.0 Hz, $\underline{C}$=N), 171.7 ($\underline{C}$=O), 139.0 (d, $^3J_{PC}$ = 13.5 Hz, $N{=}C\underline{C}_{Ar}$), 134.3 (d, $^1J_{PC}$ = 130.5 Hz, $P\underline{C}_{Ar}$), 132.5 ($\underline{C}_{Ar}H_{para}$), 131.7 (d, $^3J_{PC}$ = 9.5 Hz, $\underline{C}_{Ar}H_{meta}$),

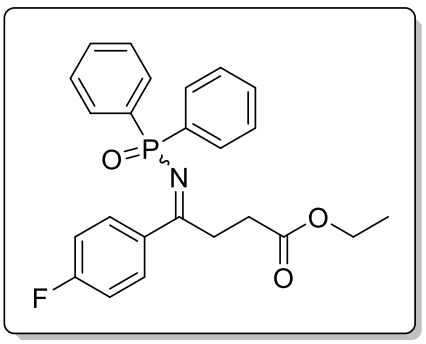
131.4 (d, $^{4}J_{PC}$ = 2.0 Hz, $\underline{C}_{Ar}H_{para}$), 130.9 ($\underline{C}_{Ar}H$), 128.2 (d, $^{2}J_{PC}$ = 12.0 Hz, $\underline{C}_{Ar}H_{ortho}$), 128.1 ($\underline{C}_{Ar}H$), 60.9 (O$\underline{C}H_2CH_3$), 43.2 (d, $^{3}J_{PC}$ = 17.5 Hz, NC$\underline{C}$H), 36.8 (CH$\underline{C}H_2$CO), 14.2 (OCH$_2\underline{C}H_3$).
^{31}P NMR ($CDCl_3$, 162 MHz): δ 16.7.
HRMS (ESI+, MeOH): calcd. for $C_{28}H_{30}O_5N_{23}NaP^+$ $[M+Na]^+$ m/z 514.17538, found m/z 514.17537.



Ethyl-3-[[(diphenylphosphoryl)imino](phenyl)methyl] pentanoate (3b)

Prepared according to the general procedure using ketimine **1b** and ethyl bromoacetate as substrates, and DIPEA as a base. Purified by FCC (Et_2O/PE 9:1) obtaining **3b** as a yellow oil in 36% yield (31.2 mg, ketimine:enamines ratio 75:13:12).

IR: 3058 (w), 2963 (w), 2929 (w), 1731 (s, C=O), 1640 (m, C=N), 1438 (m), 1182 (s), 1122 (m), 1029 (w), 724 (m), 697 (s) cm^{-1}.
^{1}H NMR ($CDCl_3$, 400 MHz): δ 7.92 (ddd, *J* = 12.0, 8.0, 1.5 Hz, 2H, $C_{Ar}\underline{H}_{meta}$), 7.69 (ddd, *J* = 12.0, 7.5, 1.0 Hz, 2H, $C_{Ar}\underline{H}_{meta}$), 7.58–7.55 (m, 2H, $C_{Ar}\underline{H}$), 7.45–7.28 (m, 9H, $C_{Ar}\underline{H}$), 3.94 (qd, *J* = 11.0, 7.0 Hz, 1H, OC$\underline{H}_A$H$_B$CH$_3$), 3.84 (qd, *J* = 11.0, 7.0 Hz, 1H, OCH$_A\underline{H}_B$CH$_3$), 3.59–3.52 (m, 1H, NCC$\underline{H}$), 3.21 (dd, *J* = 17.0, 10.0 Hz, 1H, C$\underline{H}_A$H$_B$CO), 2.63 (dd, *J* = 17.0, 4.5 Hz, 1H, CH$_A\underline{H}_B$CO), 1.84–1.72 (m, 1H, CHC$\underline{H}_A$H$_B$CH$_3$), 1.61–1.53 (m, 1H, CHCH$_A\underline{H}_B$CH$_3$), 1.09 (t, *J* = 7.0 Hz, 3H, OCH$_2$C$\underline{H}_3$), 0.79 (t, *J* = 7.5 Hz, 3H, CH CH$_2$C$\underline{H}_3$).
^{13}C NMR ($CDCl_3$, 100 MHz): δ 191.1 (d, $^{2}J_{PC}$ = 10.5 Hz, $\underline{C}$=N), 172.7 ($\underline{C}$=O), 140.1 (d, $^{3}J_{PC}$ = 14.5 Hz, N=C$\underline{C}_{Ar}$), 135.4 (d, $^{1}J_{PC}$ = 134.0 Hz, P$\underline{C}_{Ar}$), 134.2 (d, $^{1}J_{PC}$ = 133.5 Hz, P$\underline{C}_{Ar}$), 131.8 (d, $^{3}J_{PC}$ = 9.0 Hz, $\underline{C}_{Ar}H_{meta}$), 131.7 (d, $^{3}J_{PC}$ = 9.1 Hz, $\underline{C}_{Ar}H_{meta}$), 131.4 (d, $^{4}J_{PC}$ = 2.7 Hz, $\underline{C}_{Ar}H_{para}$), 131.1 (d, $^{4}J_{PC}$ = 2.8 Hz, $\underline{C}_{Ar}H_{para}$), 130.6 ($\underline{C}_{Ar}H_{para}$), 128.4 (d, $^{2}J_{PC}$ = 12.6 Hz, $\underline{C}_{Ar}H_{ortho}$), 128.2 (d, $^{2}J_{PC}$ = 12.6 Hz, $\underline{C}_{Ar}H_{ortho}$), 128.0 ($\underline{C}_{Ar}$), 127.9 ($\underline{C}_{Ar}$) 60.6 (O$\underline{C}H_2CH_3$), 48.8 (d, $^{3}J_{PC}$ = 16.6 Hz, NC$\underline{C}$H), 36.6 (CH$\underline{C}H_2$CO), 26.2 (CH$\underline{C}H_2CH_3$), 14.2 (OCH$_2\underline{C}H_3$), 11.6 (CHCH$_2\underline{C}H_3$).
^{31}P NMR ($CDCl_3$, 162 MHz): δ 16.0.
HRMS (ESI+, MeOH): calcd for $C_{26}H_{29}O_3NP^+$ $[M+H]^+$ m/z 434.18796, found m/z 434.18791.

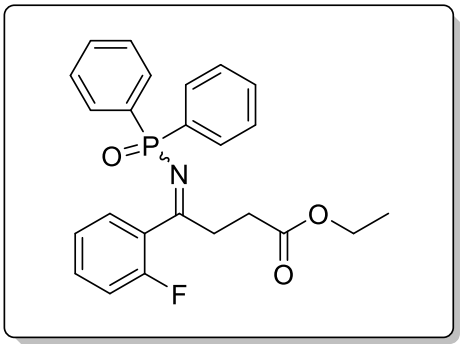


Ethyl-4-[(diphenylphosphoryl)imino]-4-(4-fluorophenyl) butanoate (3c)

Prepared according to the general procedure using ketimine **1c** and ethyl bromoacetate as substrates, and DIPEA as a base. Purified by FCC (Et_2O) obtaining **3c** as a yellow oil in 36% yield (30.5 mg, ketimine:enamines ratio 83:10:7).

IR: 3058 (w), 1731 (s, C=O), 1631 (s, C=N), 1588 (s), 1372 (m), 1235 (m), 1202 (s), 1156 (s), 1122 (m), 1106 (m), 725 (s), 696 (s) cm^{-1}.

^{1}H NMR ($CDCl_3$, 500 MHz): δ 8.03 (dd, $^{3}J_{ortho}$ = 9.0 Hz, $^{4}J_{HF}$ = 5.5 Hz, 2H, FCCHC$_{Ar}$H), 7.97–7.92 (m, 4H, C$_{Ar}$H$_{meta}$), 7.49–7.41 (m, 6H, C$_{Ar}$H$_{ortho}$ and C$_{Ar}$H$_{para}$), 7.16 (app t, $^{3}J_{HF}$ = $^{3}J_{ortho}$ = 8.5 Hz, 2H, FCC$_{Ar}$H), 4.05 (q, *J* = 7.0 Hz, 2H, OCH$_2$CH$_3$), 3.65 (dt, $^{4}J_{HP}$ = 1.0 Hz, $^{3}J_{HH}$ = 8.0 Hz, 2H, N=CCH$_2$), 2.68 (t, $^{3}J_{HH}$ = 8.0 Hz, 2H, N=CCH$_2$CH$_2$), 1.17 (t, *J* = 7.0 Hz, 3H, OCH$_2$CH$_3$).
^{13}C NMR ($CDCl_3$, 126 MHz): δ 182.6 (d, $^{2}J_{PC}$ = 7.5 Hz, CN), 172.0 (COOEt), 165.5 (d, $^{1}J_{CF}$ = 254.0 Hz, CF), 134.6 (d, $^{1}J_{PC}$ = 131.0 Hz, PC$_{Ar}$), 134.5 (dd, $^{3}J_{PC}$ = 22.5 Hz, $^{4}J_{CF}$ = 3.0 Hz, N=CC$_{Ar}$), 131.7 (d, $^{3}J_{PC}$ = 9.0 Hz, C$_{Ar}$H$_{meta}$), 131.6 (C$_{Ar}$H$_{para}$), 130.8 (d, $^{3}J_{CF}$ = 9.0 Hz, FCCHC$_{Ar}$H), 128.6 (d, $^{2}J_{PC}$ = 12.5 Hz, C$_{Ar}$H$_{ortho}$), 128.2 (C$_{Ar}$H), 115.9 (d, $^{2}J_{CF}$ = 22.0 Hz, FCC$_{Ar}$H), 60.9 (OCH$_2$), 32.5 (N=CCH$_2$CH$_2$), 31.0 (d, *J* = 12.5 Hz, N=CCH$_2$), 14.2 (OCH$_2$CH$_3$).
^{31}P NMR ($CDCl_3$, 162 MHz): δ 18.2.
^{19}F NMR ($CDCl_3$, 376 MHz): δ −106.6.
HRMS (ESI+, MeOH): calcd. for $C_{24}H_{24}O_3NFP^+$ $[M+H]^+$ m/z 424.14723, found m/z 424.14703.

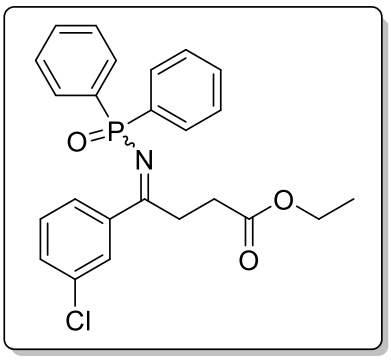


Ethyl-4-[(diphenylphosphoryl]imino]-4-(2-fluorophenyl)butanoate (3d)

Prepared according to the general procedure using ketimine **1d** and ethyl bromoacetate as substrates, and DIPEA as a base. Purified by FCC (Et_2O) obtaining **3d** as a yellow oil in 32% yield (27.1 mg, ketimine:enamines ratio 44:28:28).

IR: 3059 (w), 2981 (w), 1731 (s, C=O), 1649 (m, C=N), 1449 (m), 1204 (s), 1121 (s), 1107 (m), 755 (m), 725 (s), 697 (s) cm^{-1}.
^{1}H NMR ($CDCl_3$, 500 MHz, data for the ketimine tautomer): δ 7.97–7.92 (app ddt, *J* = 12.0, 7.0, 1.5 Hz, 2H, C$_{Ar}$H$_{meta}$), 7.47–7.33 (m, 8H, C$_{Ar}$H$_{ortho}$, C$_{Ar}$H$_{para}$ and C$_{Ar}$H), 7.18–7.14 (m, 2H, C$_{Ar}$H), 4.03 (q, *J* = 7.0 Hz, 2H, OCH$_2$CH$_3$), 3.40–3.37 (m, 2H, N=CCH$_2$), 2.76 (t, *J* = 7.0 Hz, 2H, N=CCH$_2$CH$_2$), 1.16 (t, *J* = 7.0 Hz, 3H, OCH$_2$CH$_3$).
Data for the enamine tautomer 1 (configuration not determined): δ 7.94 (ddd, *J* = 12.5, 8.5, 1.5 Hz, 4H, C$_{Ar}$H$_{meta}$), 7.53–7.29 (m, 8H, C$_{Ar}$H$_{ortho}$, C$_{Ar}$H$_{para}$ and C$_{ArF}$H), 7.13–7.01 (m, 1H, C$_{ArF}$H), 6.90 (td, *J* = 7.5, 1.2 Hz, 1H, C$_{ArF}$H), 5.58 (td, $^{3}J_{HH}$ = 7.5 Hz, $^{4}J_{PH}$ = 1.0 Hz, 1H, NHC=CH), 4.65 (d, $^{2}J_{PH}$ = 9.0 Hz, 1H, NH), 3.93 (q, *J* = 7.0 Hz, 2H, OCH$_2$CH$_3$), 2.75 (m, 2H, C=CHCH$_2$),1.10 (t, *J* = 7.0 Hz, 3H, OCH$_2$CH$_3$).
Data for the enamine tautomer 2 (configuration not determined): δ 7.78 (ddd, *J* = 12.0, 8.5, 1.5 Hz, 4H, C$_{Ar}$H$_{meta}$), 7.53–7.29 (m, 8H, C$_{Ar}$H$_{ortho}$, C$_{Ar}$H$_{para}$ and C$_{ArF}$H), 7.13–7.01 (m, 1H, C$_{ArF}$H), 6.76 (ddd, *J* = 10.5, 8.0, 1.0 Hz, 1H, C$_{ArF}$H), 5.91 (d, $^{2}J_{PH}$ = 7.5 Hz, 1H, NH), 5.23 (t, $^{3}J_{HH}$ = 7.5 Hz, 1H, NHC=CH), 4.14 (q, *J* = 7.0 Hz, 2H, OCH$_2$CH$_3$), 3.40–3.37 (m, 2H, C=CHCH$_2$), 1.24 (t, *J* = 7.0 Hz, 3H, OCH$_2$CH$_3$).
^{13}C NMR ($CDCl_3$, 126 MHz, data for the ketimine tautomer): δ 182.6 (d, $^{2}J_{PC}$ = 9.5 Hz, CN), 172.3 (COOEt), 159.3 (d, $^{1}J_{CF}$ = 250.0 Hz, CF), 134.1 (d, $^{1}J_{PC}$ = 130.5 Hz, PC$_{Ar}$), 132.3 (d, $^{3}J_{FC}$ = 9.0 Hz, C$_{ArF}$H), 131.7 (d, $^{3}J_{PC}$ = 9.0 Hz, C$_{Ar}$H$_{meta}$), 131.6 (d, $^{4}J_{PC}$ = 3.0 Hz, C$_{Ar}$H$_{para}$), 130.1 (d, $^{3}J_{CF}$ = 8.5 Hz, C$_{ArF}$H), 128.5 (d, $^{2}J_{PC}$ = 13.0 Hz, C$_{Ar}$H$_{ortho}$), 126.5 (dd, $^{2}J_{CF}$ = 13.0 Hz, $^{3}J_{PC}$ = 3.0 Hz, FCC$_{Ar}$), 124.2

(d, $^{4}J_{CF}$ = 3.0 Hz, $\underline{C}_{ArF}H$), 115.3 (d, $^{2}J_{CF}$ = 22.0 Hz, FC$\underline{C}_{Ar}H$), 60.9 (O$\underline{C}H_2$), 37.1 (d, $^{3}J_{PC}$ = 16.5 Hz, $^{4}J_{CF}$ = 3.5 Hz, N=C$\underline{C}H_2$), 30.9 (N=CCH$_2\underline{C}H_2$), 14.2 (OCH$_2\underline{C}H_3$).
^{31}P NMR ($CDCl_3$, 162 MHz): δ 17.7 (ketimine), 17.6 and 17.4 (enamine tautomers).
^{19}F NMR ($CDCl_3$, 376 MHz): δ −113.1 (ketimine), −131.0 and −113.9 (enamine tautomers).
HRMS (ESI, MeOH): calcd. for $C_{24}H_{24}O_3NFP^+$ $[M+H]^+$ 424.14723, found 424.14703.

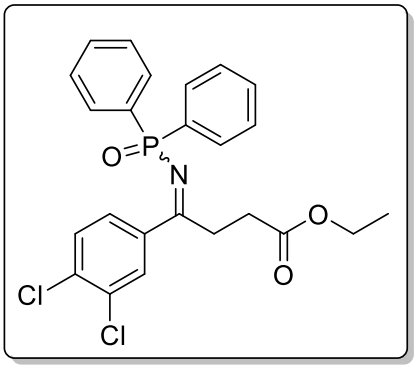


Ethyl-4-[(diphenylphosphoryl]imino]-4-(3-chlorophenyl) butanoate (3e)

Prepared according to the general procedure using ketimine **1e** and ethyl bromoacetate as substrates, and DIPEA as a base. Purified by FCC (Et_2O/PE 1:9 to Et_2O) obtaining **3e** as a yellow oil in 33% yield (29.0 mg, ketimine:enamines ratio 57:27:16).

IR: 3058 (w), 2980 (w), 1731 (s, C=O), 1632 (m, C=N), 1565 (w), 1438 (m), 1187 (s), 1180 (s) 1122 (m), 1106 (m), 725 (s), 695 (s) cm^{-1}.
^{1}H NMR ($CDCl_3$, 500 MHz, data for the ketimine tautomer): δ 7.92–7.96 (m, 4H, $C_{Ar}\underline{H}_{meta}$),7.50–7.30 (m, 10H, $C_{Ar}\underline{H}$), 4.05 (q, *J* = 7.0 Hz, 2H, O$\underline{C}H_2CH_3$), 3.60 (td, $^{3}J_{HH}$ = 8.0 Hz, $^{4}J_{HP}$ = 1.0 Hz, 2H, N=CC$\underline{H}_2$), 2.66 (t, *J* = 8.0 Hz, 2H, N=CCH$_2\underline{C}H_2$), 1.17 (t, *J*=7.0 Hz, 3H, OCH$_2\underline{C}H_3$).
Data for the enamine tautomers: δ 7.92–7.06 (m, 14H, $C_{Ar}\underline{H}$, both tautomers), 6.05 (d, $^{2}J_{PH}$ = 7.0 Hz, 1H, NH, major enamine), 5.52 (td, $^{3}J_{HH}$ = 8.0 Hz, $^{4}J_{PH}$ = 1.0 Hz, 1H, NHC=C$\underline{H}$, minor enamine), 5.24 (t, *J* = 7.5 Hz, 1H, NHC=C$\underline{H}$, major enamine), 4.67 (d, $^{2}J_{PH}$ = 9.0 Hz, 1H, N$\underline{H}$, minor enamine), 4.14 (q, *J* = 7.0 Hz, 2H, OC$\underline{H}_2$CH$_3$, major enamine), 3.97 (q, *J* = 7.0 Hz, 2H, OC$\underline{H}_2$CH$_3$, minor enamine), 3.55 (dd, $^{3}J_{HH}$ = 7.5 Hz, $^{5}J_{HP}$ = 1.0 Hz, 2H, C=CHC$\underline{H}_2$, major enamine), 2.80 (d, $^{3}J_{HH}$ = 8.0 Hz, C=CHC$\underline{H}_2$, minor enamine), 1.24 (t, *J* = 7.0 Hz, 3H, OCH$_2$C$\underline{H}_3$, major enamine), 1.13 (t, *J* = 7.0 Hz, 3H, OCH$_2$C$\underline{H}_3$, minor enamine).
^{13}C NMR ($CDCl_3$, 126 MHz): δ 182.6 (d, $^{2}J_{PC}$ = 8.0 Hz, $\underline{C}$=N), 171.8 ($\underline{C}$OOEt), 140.0 (d, $^{3}J_{PC}$ = 22.5 Hz, N=C$\underline{C}_{Ar}$), 134.9 ($\underline{C}$Cl), 134.2 (d, $^{1}J_{PC}$ = 131.0 Hz, P$\underline{C}_{Ar}$), 132.1 ($\underline{C}_{ArCl}H$), 131.6 (d, $^{3}J_{PC}$ = 9.0 Hz, $\underline{C}_{Ar}H_{meta}$), 131.6 (d, $^{4}J_{PC}$ = 3.0 Hz, $\underline{C}_{Ar}H_{para}$), 130.0 ($\underline{C}_{ArCl}H$), 128.8 ($\underline{C}_{Ar}H$), 128.6 (d, $^{2}J_{PC}$ = 12.5 Hz, $\underline{C}_{Ar}H_{ortho}$), 128.1 ($\underline{C}_{ArCl}H$), 126.1 ($\underline{C}_{ArCl}H$), 60.9 (O$\underline{C}H_2CH_3$), 32.3 ($\underline{C}H_2$COOEt), 31.6 (d, $^{3}J_{PC}$ = 12.5 Hz, NC$\underline{C}H_2$), 14.1 ($\underline{C}H_3$).
^{31}P NMR ($CDCl_3$, 162 MHz): δ 18.6.
HRMS (ESI+, MeOH): calcd. for $C_{24}H_{24}O_3N^{35}ClP^+$ $[M+H]^+$ m/z 440.11768, found m/z 440.11789.

Ethyl-4-(3,4-dichlorophenyl)-4-[(diphenylphosphoryl)imino] butanoate (3f)



Prepared according to the general procedure using ketimine **1f** and ethyl bromoacetate as substrates, and DIPEA as a base. Purified by FCC (Et_2O/PE 1:9 to Et_2O) obtaining **3f** as a yellow oil in 26% yield (24.7 mg, ketimine:enamines ratio 59:27:14).

IR: 1733 (s, C=O), 1640 (m, C=N), 1438 (m), 1208 (m), 1106 (m), 1029 (m), 726 (m), 696 (m) cm^{-1}

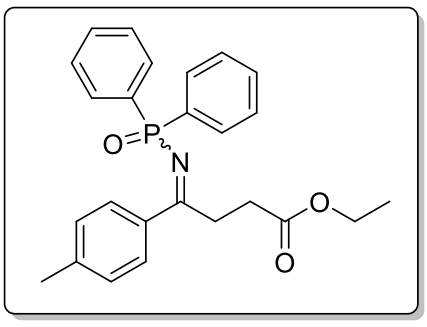
^{1}H NMR ($CDCl_3$, 400 MHz, data for the ketimine tautomer): δ 8.03 (d, $^3J_{meta}$ = 2.0 Hz, 1H, $C_{ArCl}\underline{H}$), 7.93 (ddd, J = 12.0, 8.0, 1.6 Hz, 4H, $C_{Ar}\underline{H}_{meta}$), 7.76 (m, 1H, $C_{ArCl}\underline{H}$), 7.50–7.36 (m, 7H, $C_{Ar}\underline{H}_{ortho}$, $C_{Ar}\underline{H}_{para}$ and $C_{ArCl}\underline{H}$), 4.05 (q, J = 7.0 Hz, 2H, $OC\underline{H}_2CH_3$), 3.58 (td, $^3J_{HH}$ = 8.0 Hz, $^4J_{HP}$ = 1.5 Hz, 2H, $N{=}CC\underline{H}_2$), 2.67 (t, J = 8.0 Hz, 2H, $N{=}CCH_2C\underline{H}_2$), 1.18 (t, J = 7.0 Hz, 3H, $OCH_2C\underline{H}_3$).

Data for the enamine tautomers: δ 8.06–6.98 (m, 13H, $C_{Ar}\underline{H}$, both tautomers), 6.13 (d, $^2J_{PH}$ = 7.0 Hz, 1H, NH, major enamine), 5.52 (td, $^3J_{HH}$ = 8.0 Hz, $^4J_{PH}$ = 1.0 Hz, 1H, $NHC{=}C\underline{H}$, minor enamine), 5.21 (t, J = 7.5 Hz, 1H, $NHC{=}C\underline{H}$, major enamine), 4.63 (d, $^2J_{PH}$ = 9.0 Hz, 1H, $N\underline{H}$, minor enamine), 4.15 (q, J = 7.0 Hz, 2H, $OC\underline{H}_2CH_3$, major enamine), 3.98 (q, J = 7.0 Hz, 2H, $OC\underline{H}_2CH_3$, minor enamine), 3.32 (dd, $^3J_{HH}$ = 7.5 Hz, $^5J_{HP}$ = 1.0 Hz, 2H, $C{=}CHC\underline{H}_2$, major enamine), 2.79 (d, $^3J_{HH}$ = 8.0 Hz, $C{=}CHC\underline{H}_2$, minor enamine), 1.25 (t, J = 7.0 Hz, 3H, $OCH_2C\underline{H}_3$, major enamine), 1.15 (t, J = 7.0 Hz, 3H, $OCH_2C\underline{H}_3$, minor enamine).

^{13}C NMR ($CDCl_3$, 126 MHz): δ 181.7 (d, $^2J_{PC}$ = 7.5 Hz, $\underline{C}{=}N$), 171.9 ($\underline{C}OOEt$), 138.4 (d, $^3J_{PC}$ = 23.0 Hz, $N{=}C\underline{C}_{Ar}$), 136.8 ($\underline{C}Cl$), 135.9 ($\underline{C}Cl$), 134.1 (d, $^1J_{PC}$ = 131.0 Hz, $P\underline{C}_{Ar}$), 131.7 (d, $^3J_{PC}$ = 9.0 Hz, $\underline{C}_{Ar}H_{meta}$), 132.2 (d, $^4J_{PC}$ = 3.5 Hz, $\underline{C}_{Ar}H_{para}$), 130.8 ($\underline{C}_{ArCl}H$), 130.1 ($\underline{C}_{ArCl}H$), 128.7 (d, $^2J_{PC}$ = 12.5 Hz, $\underline{C}_{Ar}H_{ortho}$), 127.4 ($\underline{C}_{ArCl}H$), 61.0 ($O\underline{C}H_2CH_3$), 31.7 (d, $^3J_{PC}$ = 12.5 Hz, $NC\underline{C}H_2$), 30.5 ($\underline{C}H_2CO_2Et$), 14.2 ($\underline{C}H_3$).

^{31}P NMR ($CDCl_3$, 162 MHz): δ 18.7

HRMS (ESI+, MeOH): calcd. for $C_{24}H_{23}O_3N^{35}Cl_2P^+$ $[M+H]^+$ m/z 474.07871, found m/z 474.07867.



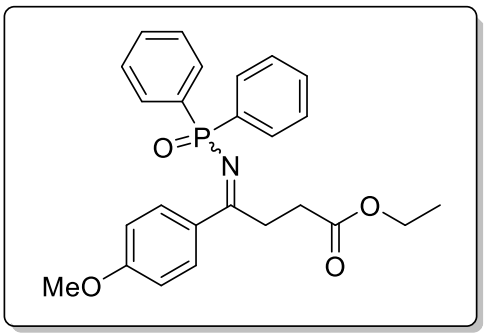
Ethyl-4-[(diphenylphosphoryl]imino]-4-(4-methylphenyl) butanoate (3g)

Prepared according to the general procedure using ketimine **1g** and ethyl bromoacetate as substrates, and DIPEA as a base. Purified by FCC (Et_2O) obtaining **3g** as a yellow oil in 36% yield (30.2 mg, ketimine:enamines ratio > 95:5).

IR: 2980 (w), 1731 (s, C=O), 1630 (s, C=N), 1603 (s), 1438 (m), 1202 (s), 1182 (s), 1121 (m), 1105 (m), 724 (s), 696 (s) cm^{-1}.

^{1}H NMR ($CDCl_3$, 500 MHz): δ 7.99 (ddd, J = 12.0, 8.0, 1.5 Hz, 4H, $C_{Ar}\underline{H}_{meta}$), 7.95 (d, J = 8.5 Hz, 2H, $C_{Ar}\underline{H}$), 7.49–7.42 (m, 6H, $C_{Ar}\underline{H}_{ortho}$ and $C_{Ar}\underline{H}_{para}$), 7.29 (d, J = 8.0 Hz, 2H, $C_{Ar}\underline{H}$), 4.07 (q, J = 7.0 Hz, 2H, $OC\underline{H}_2CH_3$), 3.65 (t, J = 8.0 Hz, 2H, $N{=}CC\underline{H}_2$), 2.68 (t, J = 8.0 Hz, 2H, $N{=}CCH_2C\underline{H}_2$), 2.44 (s, 3H, $C\underline{H}_3$), 1.20 (t, J = 7.0 Hz, 3H, $OCH_2C\underline{H}_3$).

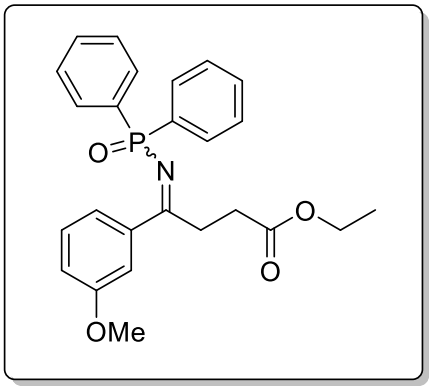
^{13}C NMR ($CDCl_3$, 126 MHz): δ 183.8 (d, $^{2}J_{PC}$ = 8.0 Hz, C=N), 172.2 (COOEt), 143.4 ($C_{Ar}CH_3$), 135.5 (d, $^{3}J_{PC}$ = 23.0 Hz, N=CC_{Ar}), 134.9 (d, $^{1}J_{PC}$ = 131.5 Hz, PC_{Ar}), 131.7 (d, $^{3}J_{PC}$ = 9.0 Hz, $C_{Ar}H_{meta}$), 131.5 (d, $^{4}J_{PC}$ = 3.0 Hz, $C_{Ar}H_{para}$), 129.6 ($C_{Ar}H$), 128.6 (d, $^{2}J_{PC}$ = 12.5 Hz, $C_{Ar}H_{ortho}$), 128.5 ($C_{Ar}H$), 60.9 (OCH_2CH_3), 32.7 (CH_2COOEt), 31.4 (d, $^{3}J_{PC}$ = 13.0 Hz, NCCH_2), 21.7 (CCH_3), 14.2 (OCH_2CH_3).
^{31}P NMR ($CDCl_3$, 162 MHz): δ 17.9.
HRMS (ESI+, MeOH): calcd. for $C_{25}H_{27}O_3NP^+$ $[M+H]^+$ m/z 420.17231, found m/z 420.17199.



Ethyl-4-[(diphenylphosphoryl]imino]-4-(4-methoxyphenyl)butanoate (3h)

Prepared according to the general procedure using ketimine **1h** and ethyl bromoacetate as substrates, and TEOA as a base. Purified by FCC (Et_2O) obtaining **3h** as a yellow oil in 35% yield (30.5 mg, ketimine:enamines ratio > 95:5).

IR: 2981 (w), 1731 (m, C=O), 1629 (m, C=N), 1596 (s), 1569 (m), 1438 (m), 1258 (m), 1201 (s), 1177 (s), 1121 (m), 1105 (m), 724 (m), 696 (m) cm^{-1}.
^{1}H NMR ($CDCl_3$, 500 MHz): δ 8.05 (d, J = 9.0 Hz, 2H, $C_{Ar}HCOCH_3$), 7.96 (ddd, J = 12.0, 8.0, 1.5 Hz, 4H, $C_{Ar}H_{meta}$), 7.49–7.42 (m, 6H, $C_{Ar}H_{ortho}$ and $C_{Ar}H_{para}$), 6.96 (d, J = 9.0 Hz, 2H, $C_{Ar}HCHCOCH_3$), 4.05 (q, J = 7.0 Hz, 2H, OCH_2CH_3), 3.87 (s, 3H, OCH_3), 3.62 (td, $^{3}J_{HH}$ = 8.0 Hz, $^{4}J_{PH}$ = 1.0 Hz, 2H, N=CCH_2), 2.66 (t, $^{3}J_{HH}$ = 8.0 Hz, 2H, N=CCH_2CH_2), 1.18 (t, J = 7.0 Hz, 3H, OCH_2CH_3).
^{13}C NMR ($CDCl_3$, 126 MHz): δ 182.7 (d, $^{2}J_{PC}$ = 7.5 Hz, C=N), 172.2 (COOEt), 163.4 ($C_{Ar}OCH_3$), 135.1 (d, $^{1}J_{PC}$ = 131.5 Hz, PC_{Ar}), 131.7 (d, $^{3}J_{PC}$ = 9.0 Hz, $C_{Ar}H_{meta}$), 131.4 (d, $^{4}J_{PC}$ = 3.0 Hz, $C_{Ar}H_{para}$), 130.8 (d, $^{3}J_{PC}$ = 25.5 Hz, N=CC_{Ar}), 130.6 ($C_{Ar}HCHCOCH_3$), 128.5 (d, $^{2}J_{PC}$ = 12.5 Hz, $C_{Ar}H_{ortho}$), 114.1 ($C_{Ar}HCOCH_3$), 60.9 (OCH_2CH_3), 55.7 (OCH_3), 32.9 (CH_2COOEt), 31.1 (d, $^{3}J_{PC}$ = 12.5 Hz, NCCH_2), 14.2 (OCH_2CH_3).
^{31}P NMR ($CDCl_3$, 162 MHz): δ 17.7.
HRMS (ESI+, MeOH): calcd. for $C_{25}H_{27}O_4NP^+$ $[M+H]^+$ m/z 436.16722, found m/z 436.16793.



Ethyl-4-[(diphenylphosphoryl]imino]-4-(3-methoxyphenyl) butanoate (3i)

Prepared according to the general procedure using ketimine **1i** and ethyl bromoacetate as substrates, and DIPEA as a base. Purified by FCC (Et_2O) obtaining **3i** as a yellow oil in 45% yield (39.2 mg, ketimine:enamines ratio 70:15:15).

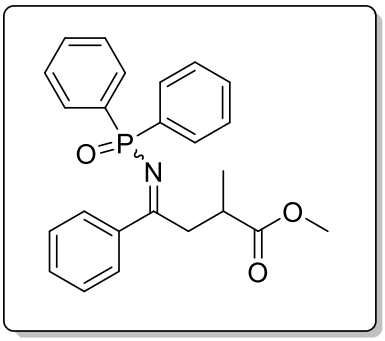
IR: 2981 (w), 1731 (s, C=O), 1631 (m, C=N), 1578 (m), 1437 (m), 1203 (s), 1121 (m), 1106 (m), 1045 (m), 725 (s), 697 (m) cm^{-1}.

^{1}H NMR ($CDCl_3$, 500 MHz): 7.96 (ddt, J = 12.0, 6.5, 1.5 Hz, 4H, $C_{Ar}\underline{H}_{meta}$), δ 7.55 (d, J = 2.0 Hz, 1H, $CC\underline{H}COCH_3$), 7.53 (d, J = 5.0 Hz, 1H, $CHC\underline{H}COCH_3$), 7.49–7.40 (m, 6H, $C_{Ar}\underline{H}_{ortho}$ and $C_{Ar}\underline{H}_{para}$), 7.37 (t, J = 8.0 Hz, 1H, $C\underline{H}CHCOCH_3$), 7.07 (dd, J = 8.0, 3.0 Hz, 1 H, $C\underline{H}CHCHCOCH_3$), 4.05 (q, J = 7.0 Hz, 2H, $OC\underline{H}_2CH_3$), 3.86 (s, 3H, $OC\underline{H}_3$), 3.62 (td, $^3J_{HH}$ = 8.0 Hz, $^4J_{PH}$ = 1.0 Hz, 2H, $N{=}CC\underline{H}_2$), 2.66 (t, J = 8.0 Hz, 2H, $N{=}CCH_2C\underline{H}_2$), 1.18 (t, J = 7.0 Hz, 3H, $OCH_2C\underline{H}_3$).

^{13}C NMR ($CDCl_3$, 126 MHz): δ 183.9 (d, $^2J_{PC}$ = 8.0 Hz, $\underline{C}$=N), 172.1 ($\underline{C}$OOEt), 159.9 ($\underline{C}_{Ar}OCH_3$), 139.7 (d, $^3J_{PC}$ = 22.5 Hz, $N{=}C\underline{C}_{Ar}$), 134.7 (d, $^1J_{PC}$ = 131.0 Hz, $P\underline{C}_{Ar}$), 131.7 (d, $^3J_{PC}$ = 9.0 Hz, $\underline{C}_{Ar}H_{meta}$), 131.6 (d, $^4J_{PC}$ = 3.0 Hz, $\underline{C}_{Ar}H_{para}$), 129.8 ($C\underline{H}CHCOCH_3$), 128.6 (d, $^2J_{PC}$ = 12.5 Hz, $\underline{C}_{Ar}H_{ortho}$), 120.8 ($CH\underline{C}HCOCH_3$), 118.0 ($C\underline{H}CHCHCOCH_3$), 113.8 ($C\underline{C}_{Ar}HCOCH_3$), 60.9 ($O\underline{C}H_2CH_3$), 55.7 ($O\underline{C}H_3$), 32.9 ($\underline{C}H_2COOEt$), 31.1 (d, $^3J_{PC}$ = 12.5 Hz, $NC\underline{C}H_2$), 14.2 ($OCH_2\underline{C}H_3$).

^{31}P NMR ($CDCl_3$, 162 MHz): δ 18.0.

HRMS (ESI+, MeOH): calcd. for $C_{25}H_{27}O_4NP^+$ $[M+H]^+$ m/z 436.16722, found m/z 436.16721.



Methyl-4-[(diphenylphosphoryl)imino]-2-methyl-4-phenyl butanoate (3j)

Prepared according to the general procedure using ketimine **1a** and methyl 2-bromopropionate as substrates, and DIPEA as a base. Purified by FCC (Et_2O) obtaining **3j** as a yellow oil in 45% yield (36.5 mg, ketimine:enamines ratio > 95:5).

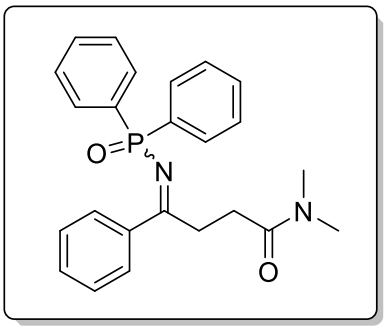
IR: 3057 (w), 2972 (w), 2951 (w), 1734 (m, C=O), 1632 (m, C=N), 1438 (m), 1280 (w), 1202 (s), 1120 (m), 1107 (m), 818 (w), 754 (w), 725 (m), 697 (m) cm^{-1}.

^{1}H NMR ($CDCl_3$, 400 MHz): δ 8.04–7.93 (m, 6H), 7.55–7.41 (m, 9H), 3.65 (app dt, J = 6.0 Hz, $^4J_{PH}$ = 1.5 Hz, 2H, $NCC\underline{H}_2$), 3.41 (s, 3H, $OC\underline{H}_3$), 2.98 (app sext, J = 7.5 Hz, 1H, $C\underline{H}CO$), 1.14 (d, J = 7.0 Hz, 3H, $C\underline{H}_3CHCO$).

^{13}C NMR ($CDCl_3$, 100 MHz): δ 183.5 (d, $^2J_{PC}$ = 8.0 Hz, $\underline{C}$=N), 175.5 ($\underline{C}$OOEt), 138.8 (d, $^3J_{PC}$ = 22.5 Hz, $N{=}C\underline{C}_{Ar}$), 135.1 (d, $^1J_{PC}$ = 131.0 Hz, $P\underline{C}_{Ar}$), 134.9 (d, $^1J_{PC}$ = 131.5 Hz, $P\underline{C}_{Ar}$), 132.3 ($\underline{C}_{Ar}H$), 131.8 (d, $^3J_{PC}$ = 9.0 Hz, $\underline{C}_{Ar}H_{meta}$), 131.5 (d, $^4J_{PC}$ = 2.5 Hz, $\underline{C}_{Ar}H_{para}$), 131.7 (d, $^3J_{PC}$ = 9.0 Hz, $\underline{C}_{Ar}H_{meta}$), 128.7 ($\underline{C}_{Ar}H$), 128.6 (d, $^2J_{PC}$ = 12.5 Hz, $\underline{C}_{Ar}H_{ortho}$), 128.5 (d, $^2J_{PC}$ = 12.5 Hz, $\underline{C}_{Ar}H_{ortho}$), 128.3 ($\underline{C}_{Ar}H$), 51.8 ($O\underline{C}H_3$), 39.3 (d, $^3J_{PC}$ = 12.0 Hz, $NC\underline{C}H_2$), 39.1 ($\underline{C}HCH_3$), 16.9 ($CH\underline{C}H_3$).

^{31}P NMR ($CDCl_3$, 162 MHz): δ 17.7.

HRMS (ESI+, MeOH): calcd. for $C_{24}H_{25}O_3NP^+$ $[M+H]^+$ m/z 406.15666, found m/z 406.15629.



4-[(diphenylphosphoryl)imino]-*N*,*N*-dimethyl-4-phenylbutanamide (3k)

Prepared according to the general procedure using ketimine **1a** and 2-bromo-*N*,*N*-dimethylacetamide as substrates, and TEOA as a base. Purified by FCC (AcOEt to AcOEt:MeOH 9:1) obtaining **3k** as a yellow oil in 35% yield (28.3 mg, ketimine:enamines ratio > 95:5).

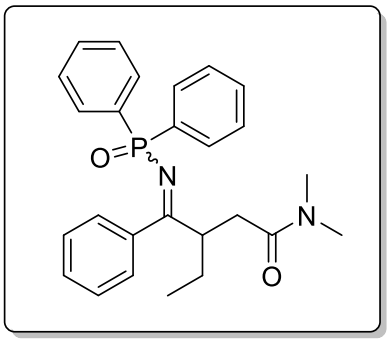
IR: 3436 (w), 3057 (w), 2980 (w), 1632 (s, C=N and C=O), 1438 (m), 1198 (m), 1107 (m), 725 (m), 695 (m) cm^{-1}.

^{1}H NMR ($CDCl_3$, 400 MHz): δ 8.13 (d, *J* = 7.0 Hz, 2H, $C_{Ar}\underline{H}$), 7.96 (ddt, *J* = 12.0, 8.0, 1.5 Hz, 4H, $C_{Ar}\underline{H}_{meta}$), 7.56–7.52 (m, 1H, $C_{Ar}\underline{H}$), 7.49–7.41 (m, 8H, $C_{Ar}\underline{H}$), 3.62 (t, *J* = 8.0 Hz, 2H, $NCC\underline{H}_2$), 2.94 (s, 3H, $NC\underline{H}_3$), 2.88 (s, 3H, $NC\underline{H}_3$), 2.71 (2H, t, *J* = 8.0 Hz, $NCCH_2C\underline{H}_2$).

^{13}C NMR ($CDCl_3$, 100 MHz): δ 185.2 (d, $^2J_{PC}$ = 7.5 Hz, $\underline{C}$=N), 171.2 ($\underline{C}$=O), 138.1 (d, $^3J_{PC}$ = 23.0 Hz, N=C$\underline{C}_{Ar}$), 134.9 (d, $^1J_{PC}$ = 131.0 Hz, P$\underline{C}_{Ar}$), 132.7 ($\underline{C}_{Ar}$H), 131.7 (d, $^3J_{PC}$ = 9.0 Hz, $\underline{C}_{Ar}H_{meta}$), 128.9 ($\underline{C}_{Ar}$H), 128.6 ($\underline{C}_{Ar}$H), 128.5 (d, $^2J_{PC}$ = 12.5 Hz, $\underline{C}_{Ar}H_{ortho}$), 37.4 ($N\underline{C}H_3$), 35.7 ($N\underline{C}H_3$), 32.1 ($\underline{C}H_2CO$), 32.1 (d, $^3J_{PC}$ = 12.5 Hz, $NC\underline{C}H_2$).

^{31}P NMR ($CDCl_3$, 162 MHz): δ 18.3.

HRMS (ESI+, MeOH): calcd for $C_{24}H_{26}O_2N_2P^+$ $[M+H]^+$ m/z 405.17264, found m/z 405.17178.



3-[[(diphenylphosphoryl)imino](phenyl)methyl]-*N*,*N*-dimethylpentanamide (3l)

Prepared according to the general procedure using ketimine **1b** and 2-bromo-*N*,*N*-dimethylacetamide as substrates, and TEOA as a base. Purified by FCC (AcOEt:PE 1:1 to AcOEt) obtaining **3l** as a yellow oil in 32% yield (27.7 mg, ketimine:enamines ratio > 95:5).

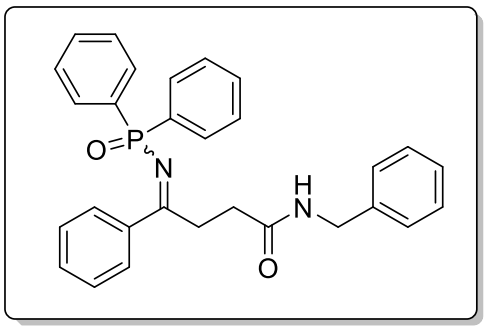
IR: 2962 (w), 2927 (w), 2873 (w), 1639 (s, C=N and C=O), 1438 (w), 1201 (m), 1121 (m), 851 (w), 724 (m), 698 (m) cm^{-1}.

^{1}H NMR ($CDCl_3$, 500 MHz): δ 8.05 (d, *J* = 7.5 Hz, 2H, $C_{Ph}\underline{H}_{ortho}$), 7.94 (d, *J* = 9.0 Hz, 2H, $C_{Ar}\underline{H}CNO_2$), 7.93–7.89 (m, 4H, $C_{Ar}\underline{H}_{meta}$), 7.60 (tt, *J* = 7.5, 2.5 Hz, 1H, $C_{Ph}\underline{H}_{para}$), 7.54 (t, *J* = 7.5 Hz, 2H, $C_{Ph}\underline{H}_{meta}$), 7.49–7.36 (m, 6H, $C_{Ar}\underline{H}_{ortho}$ and $C_{Ar}\underline{H}_{para}$), 7.32 (d, *J* = 9.0 Hz, 2H, $C_{Ar}\underline{H}CHCNO_2$), 3.81 (td, $^3J_{HH}$ = 8.0 Hz, $^4J_{PH}$ = 1.5 Hz, 2H, $NCC\underline{H}_2CH_2$), 3.04 (t, *J* = 8.0 Hz, 2H, $NCCH_2C\underline{H}_2$).

^{13}C NMR ($CDCl_3$, 126 MHz): δ 183.0 (d, $^2J_{PC}$ = 7.5 Hz, $\underline{C}$=N), 147.7 ($\underline{C}NO_2$), 138.2 (d, $^3J_{PC}$ = 23.5 Hz, N=C$\underline{C}_{Ar}$), 134.7 (d, $^1J_{PC}$ = 132.0 Hz, P$\underline{C}_{Ar}$), 132.8 ($\underline{C}_{Ph}H_{para}$), 131.6 (d, $^3J_{PC}$ = 9.0 Hz, $\underline{C}_{Ar}H_{meta}$), 129.7 ($\underline{C}_{Ar}HCHCNO_2$), 129.1 ($\underline{C}_{Ph}H_{meta}$), 128.6 (d, $^2J_{PC}$ = 12.5 Hz, $\underline{C}_{Ar}H_{ortho}$), 128.3 ($\underline{C}_{Ph}H_{ortho}$), 123.7 ($\underline{C}_{Ar}HCNO_2$), 36.6 (d, $^3J_{PC}$ = 12.0 Hz, $NC\underline{C}H_2$), 34.7 ($\underline{C}H_2CO$).

^{31}P NMR ($CDCl_3$, 162 MHz): δ 15.3.

HRMS (ESI+, MeOH): calcd. for $C_{26}H_{30}O_2N_2P^+$ $[M+H]^+$ m/z 433.20394, found m/z 433.20360.



_N_-benzyl-4-[(diphenylphosphoryl)imino]-4-phenylbutanamide (3m)

Prepared according to the general procedure using ketimine **1a** and 2-bromo-*N*-benzylacetamide as substrates, and TEOA as a base. Purified by FCC (CH_2Cl_2 to CH_2Cl_2:MeOH 95:5) obtaining **3m** as a yellow oil in 28% yield (26.1 mg, ketimine:enamines ratio > 95:5).

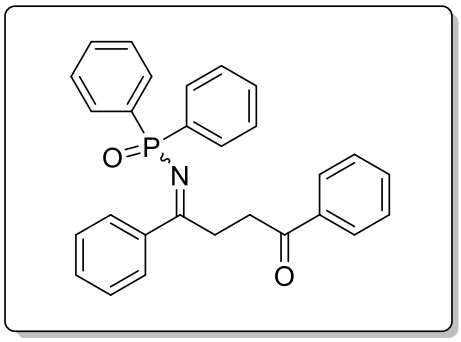
IR: 3061 (w), 2924 (w), 1657 (m, C=O), 1630 (m, C=N), 1574 (w), 1452 (m), 1311 (m), 1288 (w), 1186 (m), 1160 (m), 1122(w), 1106 (w), 1094 (w), 753 (w),726 (m), 692 (s) cm^{-1}.

^{1}H NMR ($CDCl_3$, 400 MHz): δ 8.12 (d, *J* = 7.0 Hz, 2H, $C_{Ar}\underline{H}$), 8.04 (t, *J* = 6.0 Hz, 1H, N$\underline{H}$), 7.92 (ddd, *J* = 12.0, 8.0, 1.5 Hz, 4H, $C_{Ar}\underline{H}_{meta}$), 7.63–7.38 (m, 10H, $C_{Ar}\underline{H}$), 7.32 (d, *J* = 5.0 Hz, 4H, $C_{Ar}\underline{H}$), 4.46 (d, *J* = 6.0 Hz, 2H, NC$\underline{H}_2$Ph), 3.61 (t, *J* = 8.5 Hz, 2H, NCC$\underline{H}_2$), 2.62 (t, *J* = 8.0 Hz, 2H, $NCCH_2C\underline{H}_2$).

^{13}C NMR ($CDCl_3$, 100 MHz): δ 184.5 (d, $^2J_{PC}$ = 8.0 Hz, $\underline{C}$=N), 171.8 ($\underline{C}$=O), 139.0 ($CH_2\underline{C}_{Ar}$), 137.8 (d, $^3J_{PC}$ = 23.0 Hz, N=C$\underline{C}_{Ar}$), 134.8 (d, $^1J_{PC}$ = 131.5 Hz, P$\underline{C}_{Ar}$), 133.2 ($\underline{C}_{Ar}$H), 131.9 (d, $^4J_{PC}$ = 3.0 Hz, $\underline{C}_{Ar}H_{para}$), 131.6 (d, $^3J_{PC}$ = 9.0 Hz, $\underline{C}_{Ar}H_{meta}$), 129.1 ($\underline{C}_{Ar}$H), 128.7 (d, $^2J_{PC}$ = 12.5 Hz, $\underline{C}_{Ar}H_{ortho}$), 128.6 ($\underline{C}_{Ar}$H), 128.5 ($\underline{C}_{Ar}$H), 127.8 ($\underline{C}_{Ar}$H), 127.2 ($\underline{C}_{Ar}$H), 43.5 (N$\underline{C}H_2$Ph), 36.7 ($\underline{C}H_2$CO), 33.6 (d, $^3J_{PC}$ = 13.0 Hz, NC$\underline{C}H_2$).

^{31}P NMR ($CDCl_3$, 162 MHz): δ 19.9.

HRMS (ESI+, MeOH): calcd for $C_{29}H_{28}O_2N_2P^+$ $[M+H]^+$ m/z 467.18829, found m/z 467.18865.



_N_-(4-oxo-1,4-diphenylbuylidene)-_P,P_-diphenylphosphinic amide (3n)

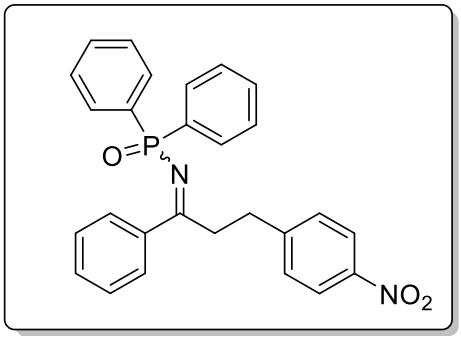
Prepared according to the general procedure using ketimine **1a** and 2-bromoacetophenone as substrates, and TEOA as a base. Purified by FCC (Et_2O:PE 8:2) obtaining **3n** as a yellow oil in 19% yield (16.6 mg, ketimine:enamines ratio > 95:5).

IR: 3057 (w), 2980 (w), 1686 (m, C=O), 1630 (m, C=N), 1594 (w), 1575 (w), 1450 (w), 1437 (m), 1282 (w), 1203 (s), 1121 (m), 1106 (m), 829 (w), 746 (m), 725 (s), 692 (s) cm^{-1}.

^{1}H NMR ($CDCl_3$, 400 MHz): δ 8.08 (d, *J* = 7.5 Hz, 2H, $C_{Ar}\underline{H}$), 7.97 (ddd, *J* = 12.0, 8.0, 2.0 Hz, 4H, $C_{Ar}\underline{H}_{meta}$), 7.90 (d, *J* = 7.0 Hz, 2H, $C_{Ar}\underline{H}$), 7.61–7.35 (m, 12H, $C_{Ar}\underline{H}$), 3.74 (t, *J* = 8.0 Hz, 2H, $NCC\underline{H}_2CH_2$), 3.37 (t, *J* = 8.0 Hz, 2H, $NCCH_2C\underline{H}_2$).

^{13}C NMR ($CDCl_3$, 100 MHz): δ 198.0 ($\underline{C}$=O), 185.3 (d, $^2J_{PC}$ = 7.5 Hz, $\underline{C}$=N), 138.3 (d, $^3J_{PC}$ = 22.5 Hz, N=C$\underline{C}_{Ar}$), 136.5 (CO$\underline{C}_{Ar}$), 134.8 (d, $^1J_{PC}$ = 130.5 Hz, P$\underline{C}_{Ar}$), 133.3 ($\underline{C}_{Ar}$H), 132.6 ($\underline{C}_{Ar}$H), 131.7 (d, $^3J_{PC}$ = 9.0 Hz, $\underline{C}_{Ar}H_{meta}$), 131.6 (d, $^4J_{PC}$ = 3.0 Hz, $\underline{C}_{Ar}H_{para}$), 128.9 ($\underline{C}_{Ar}$H), 128.7 ($\underline{C}_{Ar}$H), 128.6 (d, $^2J_{PC}$ = 12.5 Hz, $\underline{C}_{Ar}H_{ortho}$), 128.5 ($\underline{C}_{Ar}$H), 128.4 ($\underline{C}_{Ar}$H), 37.1 ($\underline{C}H_2$CO), 31.1 (d, $^3J_{PC}$ = 12.5 Hz, NC$\underline{C}H_2$).

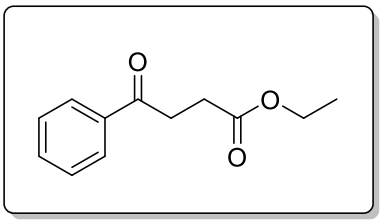
^{31}P NMR ($CDCl_3$, 162 MHz): δ 18.3.
HRMS (ESI+, MeOH): calcd. for $C_{28}H_{25}O_2NP^+$ $[M+H]^+$ m/z 438.16174, found m/z 438.16174.



N-[3-(4-nitrophenyl)-1-phenylpropylidene]-*P,P*-diphenylphosphinic amide (3o)

Prepared according to the general procedure using ketimine **1a** and 4-nitrobenzyl bromide as substrates, and TEOA as a base. Purified by FCC (pentane:AcOEt 1:1) obtaining **3o** as a yellow oil in 18% yield (16.3 mg, ketimine:enamines ratio > 95:5).

IR: 1630 (m, C=N), 1516 (m, $NO_{2\ asymmetric}$), 1344 (s, $NO_{2\ symmetric}$), 1201 (m), 1121 (w), 1106 (w), 724 (m), 694 (m) cm^{-1}.
^{1}H NMR ($CDCl_3$, 500 MHz): δ 8.05 (d, J = 7.5 Hz, 2H, $C_{Ph}\underline{H}_{ortho}$), 7.94 (d, J = 9.0 Hz, 2H, $C_{Ar}\underline{H}CNO_2$), 7.93–7.89 (m, 4H, $C_{Ar}\underline{H}_{meta}$), 7.60 (tt, J = 7.5, 2.5 Hz, 1H, $C_{Ph}\underline{H}_{para}$), 7.54 (t, J = 7.5 Hz, 2H, $C_{Ph}\underline{H}_{meta}$), 7.49–7.36 (m, 6H, $C_{Ar}\underline{H}_{ortho}$ and $C_{Ar}\underline{H}_{para}$), 7.32 (d, J = 9.0 Hz, 2H, $C_{Ar}\underline{H}CHCNO_2$), 3.81 (td, $^3J_{HH}$ = 8.0 Hz, $^4J_{PH}$ = 1.5 Hz, 2H, $NCC\underline{H}_2CH_2$), 3.04 (t, J = 8.0 Hz, 2H, $NCCH_2C\underline{H}_2$).
^{13}C NMR ($CDCl_3$, 126 MHz): δ 183.0 (d, $^2J_{PC}$ = 7.5 Hz, $\underline{C}$=N), 147.7 ($\underline{C}NO_2$), 138.2 (d, $^3J_{PC}$ = 23.5 Hz, N=C$\underline{C}_{Ar}$), 134.7 (d, $^1J_{PC}$ = 132.0 Hz, P$\underline{C}_{Ar}$), 132.8 ($\underline{C}_{Ph}H_{para}$), 131.6 (d, $^3J_{PC}$ = 9.0 Hz, $\underline{C}_{Ar}H_{meta}$), 129.7 ($\underline{C}_{Ar}HCHCNO_2$), 129.1 ($\underline{C}_{Ph}H_{meta}$), 128.6 (d, $^2J_{PC}$ = 12.5 Hz, $\underline{C}_{Ar}H_{ortho}$), 128.3 ($\underline{C}_{Ph}H_{ortho}$), 123.7 ($\underline{C}_{Ar}HCNO_2$), 36.6 (d, $^3J_{PC}$ = 12.0 Hz, NC$\underline{C}H_2$), 34.7 ($\underline{C}H_2CO$).
^{31}P NMR ($CDCl_3$, 162 MHz): δ 18.0.
HRMS (ESI+, MeOH): calcd. for $C_{27}H_{24}O_3N_2P^+$ $[M+H]^+$ m/z 455.15191, found m/z 455.15200.

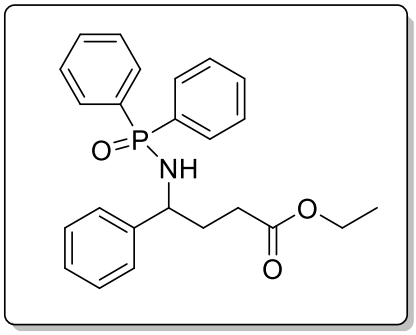


Ethyl 4-oxo-4-phenylbutanoate (4)

A biphasic solution of ketimine **3a** (40.5 mg, 0.10 mmol, 1 equiv) in 1 M HCl:CH_2Cl_2 1:1 (1.5 mL) was vigorously stirred at room temperature for 18 hours. The reaction mixture was diluted with water and CH_2Cl_2, phases were separated and the aqueous layer was extracted twice with CH_2Cl_2. Combined organic phases were dried over Na_2SO_4, filtered and evaporated. The crude product was purified by FCC (PE:Et_2O 8:2), obtaining the title compound **4** as a clear oil in 78% yield (16.1 mg). Data match those reported in the literature.[11]

IR: 2981 (w), 2919 (w), 1731 (s, EtOC=O), 1686 (s, PhC=O), 1597 (w), 1449 (m), 1217 (s), 1161 (s), 1030 (m), 749 (s), 691 (s) cm^{-1}.
^{1}H NMR ($CDCl_3$, 500 MHz): δ 7.99 (dd, J_{ortho} = 8.0 Hz, J_{meta} = 1.0 Hz, 2H, $C\underline{H}_{ortho}$), 7.56 (tt, J_{ortho} = 7.5 Hz, J_{meta} = 1.0 Hz, 1H, $C\underline{H}_{para}$), 7.47 (t, J_{ortho} = 8.0 Hz, 2H, $C\underline{H}_{meta}$), 4.16 (q, J = 7.5 Hz, 2H, $OC\underline{H}_2CH_3$), 3.32 (t, J = 7.0 Hz, 2H, $COC\underline{H}_2CH_2CO_2Et$), 2.76 (t, J = 7.0 Hz, 2H, $COCH_2C\underline{H}_2CO_2Et$), 1.27 (t, J = 7.5 Hz, 3H, $OCH_2C\underline{H}_3$).

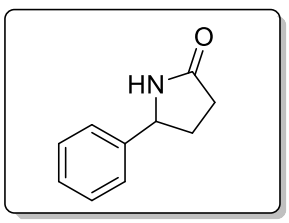
^{13}C NMR ($CDCl_3$, 126 MHz): δ ppm 198.1 (C=O), 172.9 (COOEt), 136.6 (C_{Ar}), 133.2 ($C_{Ar}H$), 128.6 ($C_{Ar}H$), 128.0 ($C_{Ar}H$), 60.7 (OCH_2CH_3), 33.4 ($COCH_2CH_2CO_2Et$), 28.3 ($COCH_2CH_2CO_2Et$), 14.2 (OCH_2CH_3).



Ethyl 4-((diphenylphosphoryl)amino)-4-phenylbutanoate (5)

To a stirred solution of ketimine **3a** (92.5 mg, 0.228 mmol, 1 equiv) in EtOH (6.5 mL) at −5 °C, sodium borohydride (9.4 mg, 0.247 mmol, 1.1 equiv) was added. The reaction mixture was stirred at −5 °C for 1 hour, then a further equivalent of sodium borohydride (9.4 mg, 0.247 mmol, 1.1 equiv) was added. After stirring at −5 °C for another hour, the reaction was quenched by sequential addition of water (10 mL) and saturated aqueous solution of $NaHCO_3$ (15 mL). The aqueous phase was extracted 3 times with CH_2Cl_2, then the collected organic phases were dried over Na_2SO_4, filtered and evaporated. The crude product was purified by FCC (Et_2O:acetone 95:5 to 70:30) affording the title compound **5** as an off-white solid in 82% yield (76.2 mg).

MP: 138–140 °C.
IR: 3191 (w), 3175 (w), 2923 (w), 1730 (s, C=O), 1457 (m), 1438 (m), 1186 (s), 1122 (m), 1110 (m), 747 (m), 724 (m), 698 (s) cm^{-1}.
^{1}H NMR ($CDCl_3$, 400 MHz): δ 7.75 (ddd, *J* = 12.0, 8.5, 1.5 Hz, 2H, $C_{Ar}H_{meta}$), 7.63 (ddd, *J* = 12.0, 7.5, 1.0 Hz, 2H, $C_{Ar}H_{meta}$), 7.42–7.28 (m, 4H, $C_{Ar}H$), 7.24–7.12 (m, 5H, $C_{Ar}H$), 7.10–7.05 (m, 2H, $C_{Ar}H$), 4.10 (m, 1H, NCH), 3.93 (q, *J* = 7.0 Hz, 2H, OCH_2CH_3), 3.54 (dd, *J* =10.0, 7.0 Hz, 1H, NH), 2.40–2.30 (m, 1H, $CH_2CH_AH_BCO$), 2.23–2.10 (m, 2H, $CH_AH_BCH_2CO$, $CH_2CH_AH_BCO$), 2.07–1.98 (m, 1H, $CH_AH_BCH_2CO$), 1.09 (t, *J* = 7.0 Hz, 3H, OCH_2CH_3).
^{13}C NMR ($CDCl_3$, 126 MHz): δ 173.5 (COOEt), 143.3 (d, $^{3}J_{PC}$ = 5.0 Hz, C_{Ar}), 133.2 (d, $^{1}J_{PC}$ = 128.0 Hz, PC_{Ar}), 132.7 (d, $^{3}J_{PC}$ = 10.0 Hz, $C_{Ar}H_{meta}$), 132.0 (d, $^{1}J_{PC}$ = 130.5 Hz, PC_{Ar}), 132.0 (d, $^{4}J_{PC}$ = 3.0 Hz, $C_{Ar}H_{para}$), 131.9 (d, $^{4}J_{PC}$ = 3.0 Hz, $C_{Ar}H_{para}$), 131.9 (d, $^{3}J_{PC}$ = 9.5 Hz, $C_{Ar}H_{meta}$), 128.8 ($C_{Ar}H$), 128.6 (d, $^{2}J_{PC}$ = 12.5 Hz, $C_{Ar}H_{ortho}$), 128.4 (d, $^{2}J_{PC}$ = 12.5 Hz, $C_{Ar}H_{ortho}$), 127.5 ($C_{Ar}H_{para}$), 126.5 ($C_{Ar}H$), 60.6 (OCH_2CH_3), 55.5 (NHCH), 34.5 (d, $^{3}J_{PC}$ = 4.0 Hz, $NCHCH_2$), 31.4 (CH_2CH_2CO), 14.3 (OCH_2CH_3).
^{31}P NMR ($CDCl_3$, 162 MHz): δ 22.7.
HRMS (ESI+, MeOH): calcd. for $C_{24}H_{27}O_3NP^+$ $[M+H]^+$ m/z 408.17231, found m/z 408.17212.



5-Phenylpyrrolidin-2-one (6)

To a solution of amino ester **5** (70.6 mg, 0.173 mmol, 1 equiv) in MeOH (1.7 mL), 37%$_{w/w}$ HCl (0.9 mL, ca 57 equiv) was added dropwise. The reaction mixture was stirred at room temperature for 5 hours, then water (5 mL) and powdered NaOH (485 mg, ca 70 equiv) were added. After stirring for 1 hour, the reaction mixture

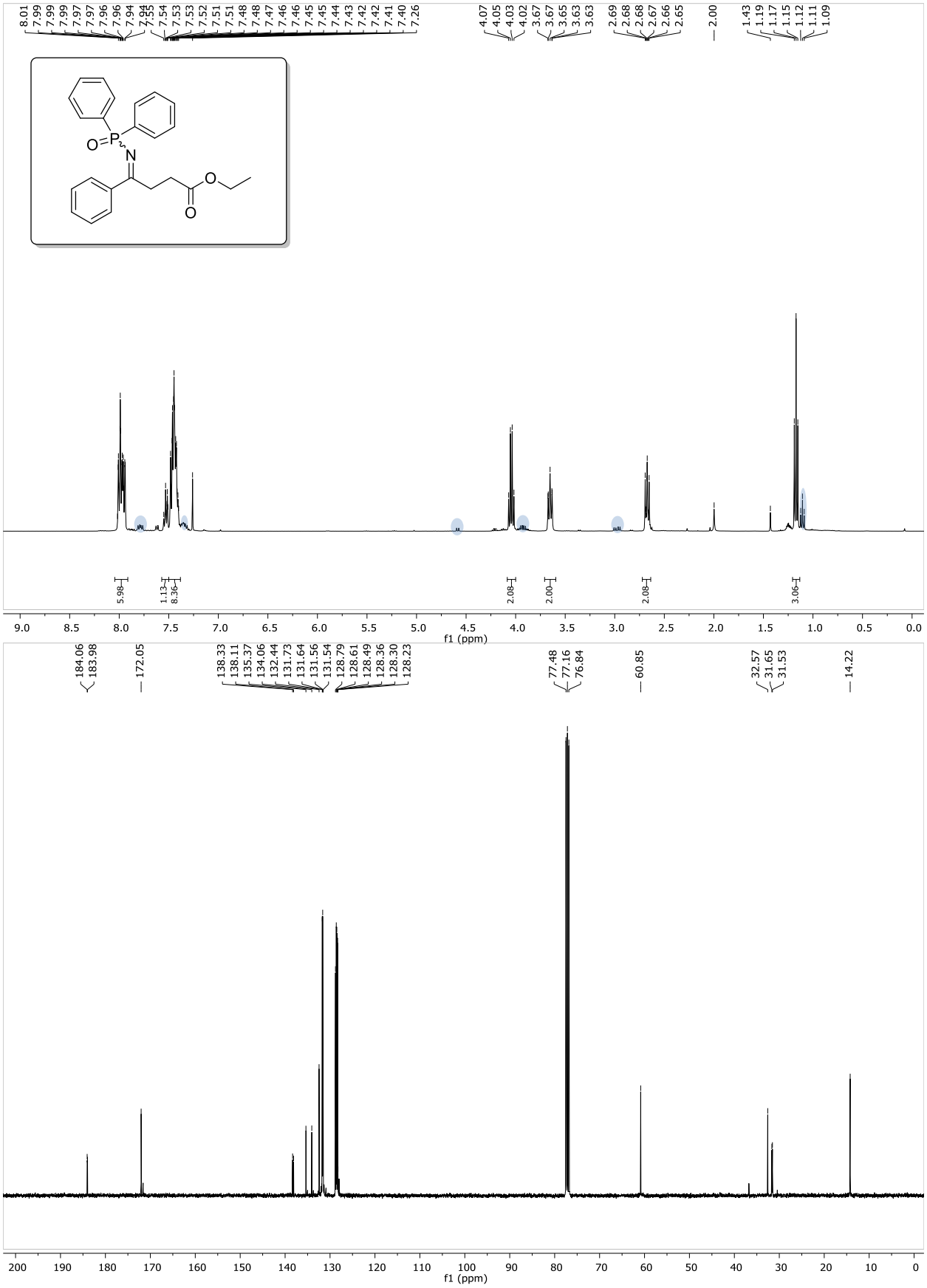
was extracted 4 times with CH_2Cl_2. The combined organic phases were dried over Na_2SO_4, filtered and evaporated. The crude product was purified by FCC (PE:AcOEt 1:9 to pure AcOEt) affording γ-lactam **6** as an off-white solid in 81% yield (22.7 mg). Data match those reported in the literature.[12]

RF (AcOEt): 0.26. **MP**: 106–108 °C (lit: 103.0–103.5 °C).[12]
^{1}H NMR ($CDCl_3$, 400 MHz): δ 7.40–7.34 (m, 2H, $C_{Ar}\underline{H}$), 7.32–7.28 (m, 3H, $C_{Ar}\underline{H}$), 6.19 (broad s, N$\underline{H}$), 4.75 (t, *J* = 7.1 Hz, 1H, NC$\underline{H}$), 2.63–2.52 (m, 1H, NCHC$\underline{H}_A$H$_B$CH$_2$CO), 2.50–2.36 (m, 2H, NCHCH$_2$C$\underline{H}_2$CO), 1.97 (dddd, *J* = 12.6, 9.2, 8.1, 6.6 Hz, 1H, NCHCH$_A\underline{H}_B$CH$_2$CO).
^{13}C NMR ($CDCl_3$, 126 MHz): δ 178.8 ($\underline{C}$O), 142.6 ($\underline{C}_{Ar}$), 129.0 ($\underline{C}_{Ar}$H), 127.9 ($\underline{C}_{Ar}$H), 125.7 ($\underline{C}_{Ar}$H), 58.2 (N$\underline{C}$H), 31.4 (NCH$\underline{C}$H$_2$), 30.4 ($\underline{C}$H$_2$CO).

3. ^{1}H and ^{13}C NMR spectra

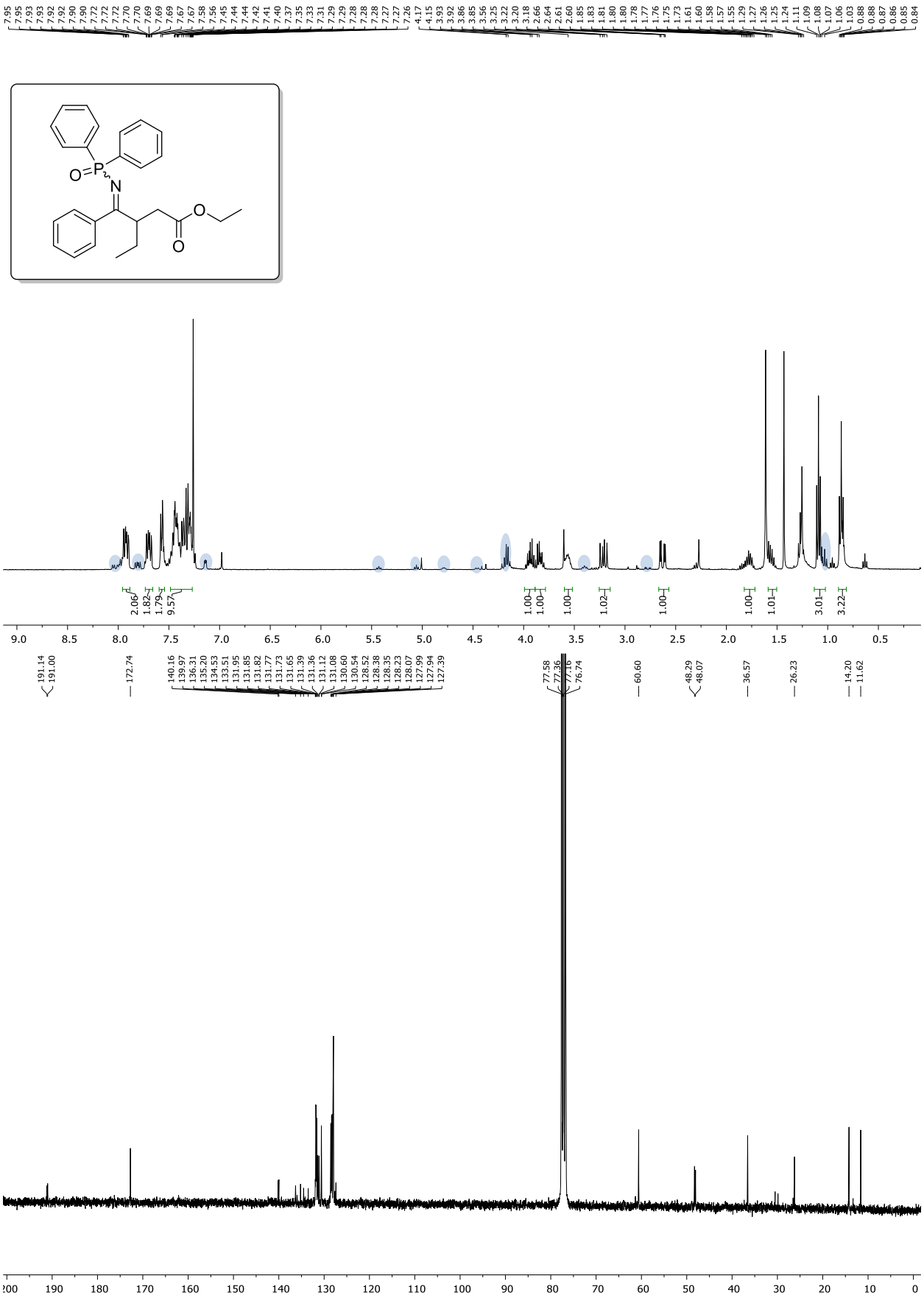
Ethyl-4-[(diphenylphosphoryl)imino]-4-phenylbutanoate (3a)

Ketimine:enamines ratio 90:10. Enamines signals highlighted with a pale blue shade.



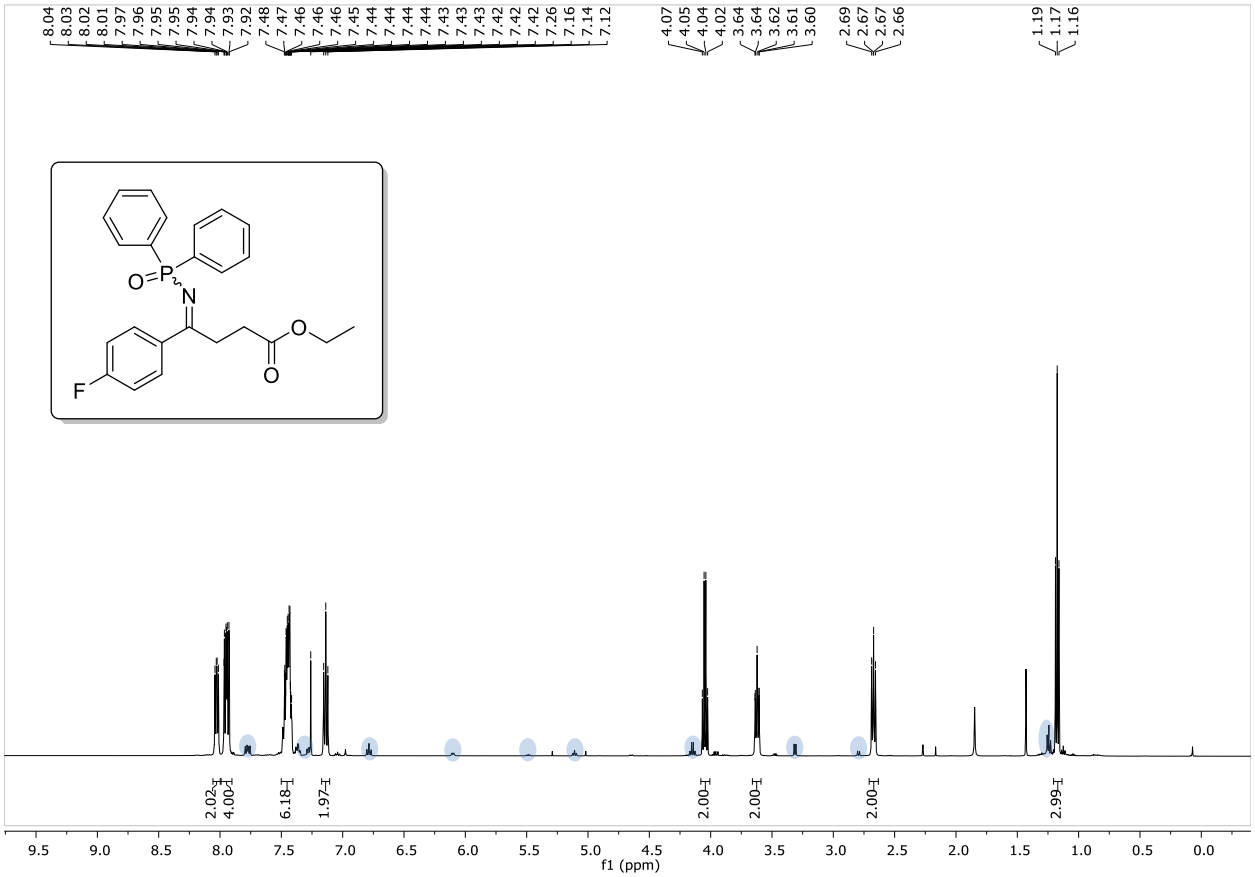
Ethyl-3-[[(diphenylphosphoryl)imino](phenyl)methyl]pentanoate (3b)

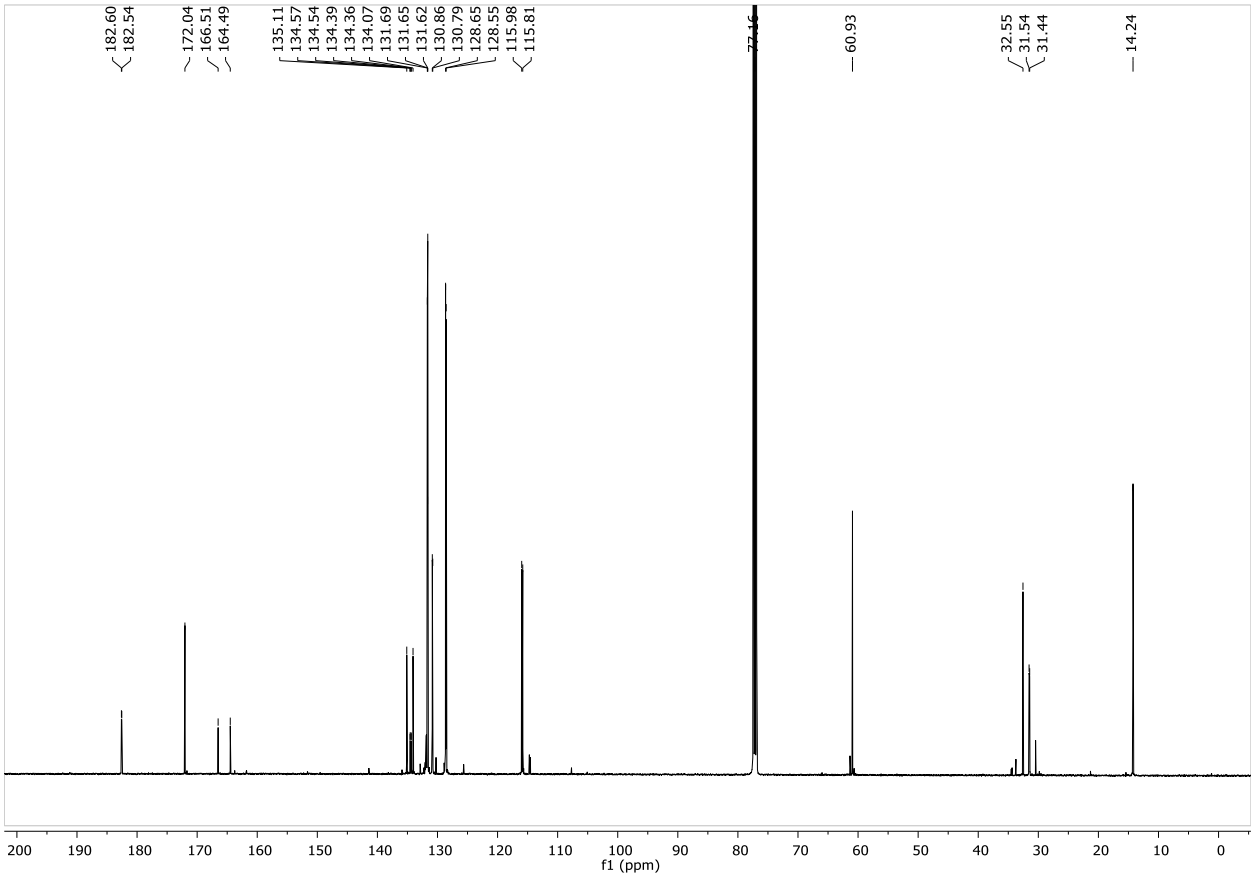
Ketimine:enamines ratio 75:13:12. Enamines signals highlighted with a pale blue shade.



Ethyl-4-[(diphenylphosphoryl)imino]-4-(4-fluorophenyl) butanoate (3c)

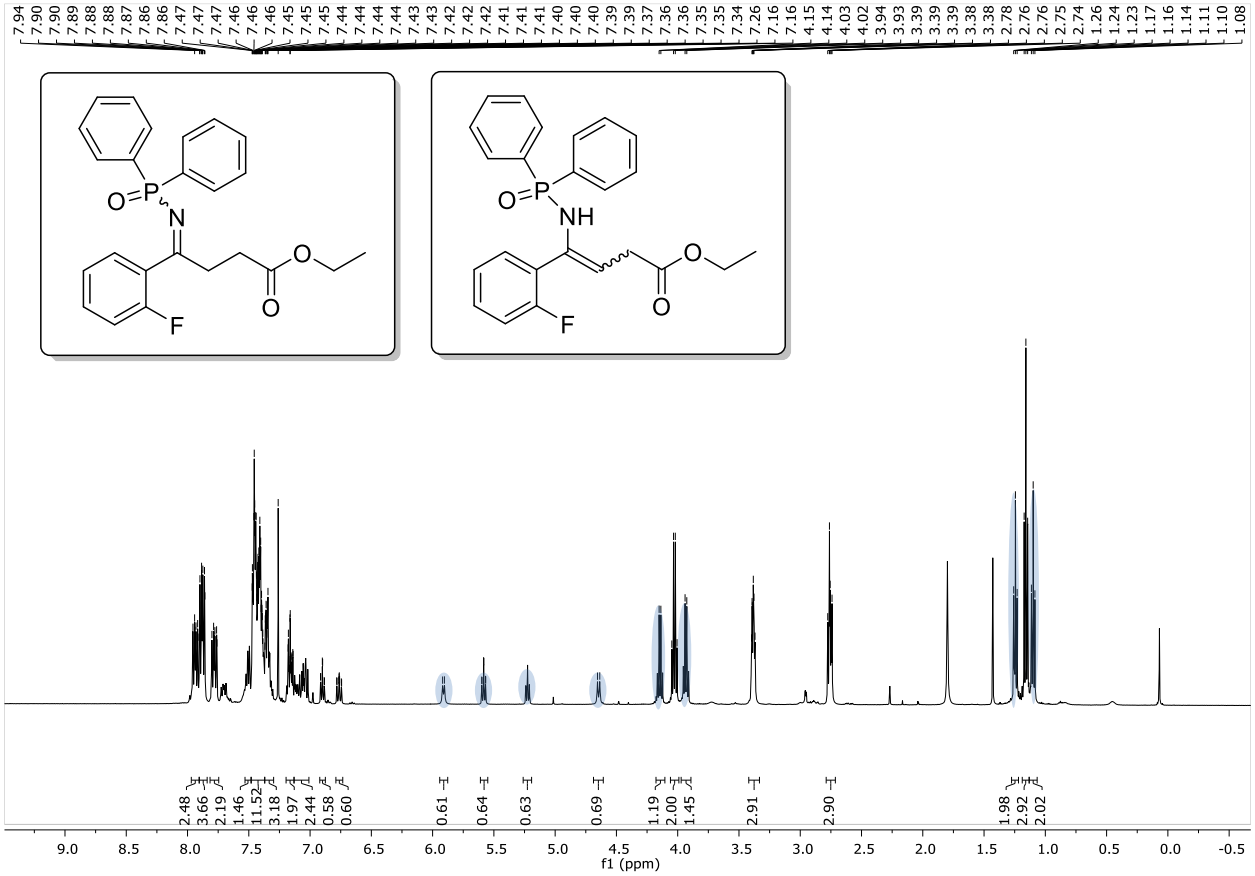
Ketimine:enamines ratio 83:10:7. Enamines signals highlighted with a pale blue shade.

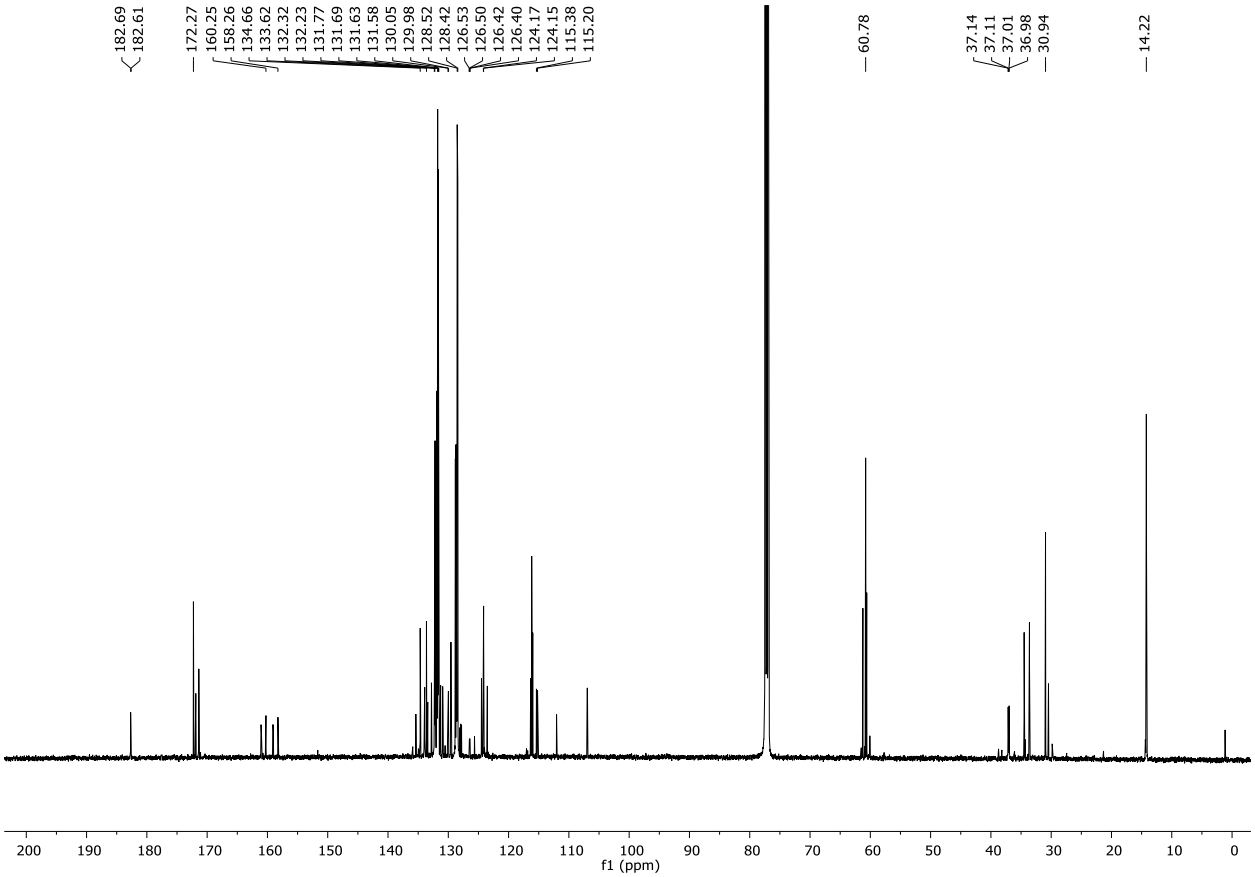




Ethyl-4-[(diphenylphosphoryl]imino]-4-(2-fluorophenyl)butanoate (3d)

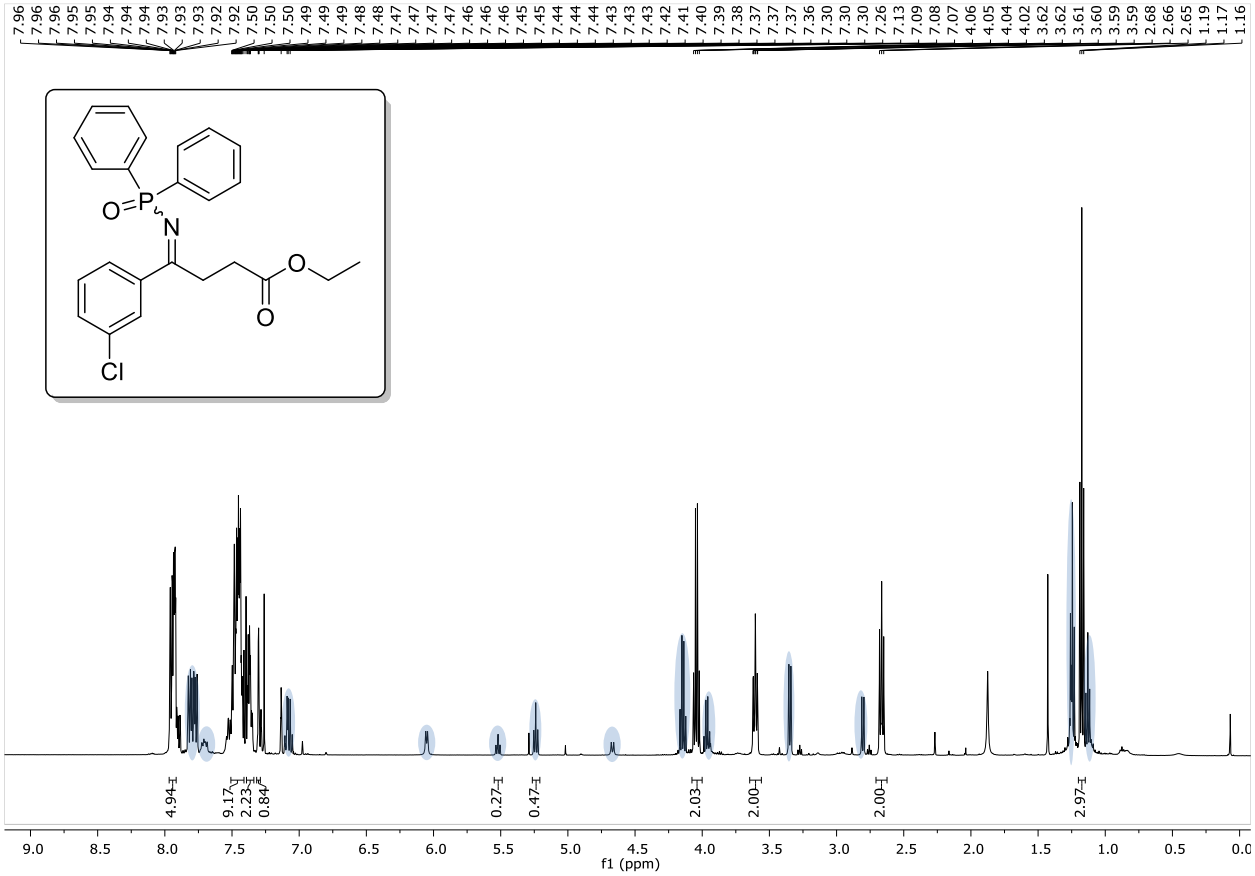
Ketimine:enamines ratio 44:28:28. Enamines signals highlighted with a pale blue shade.

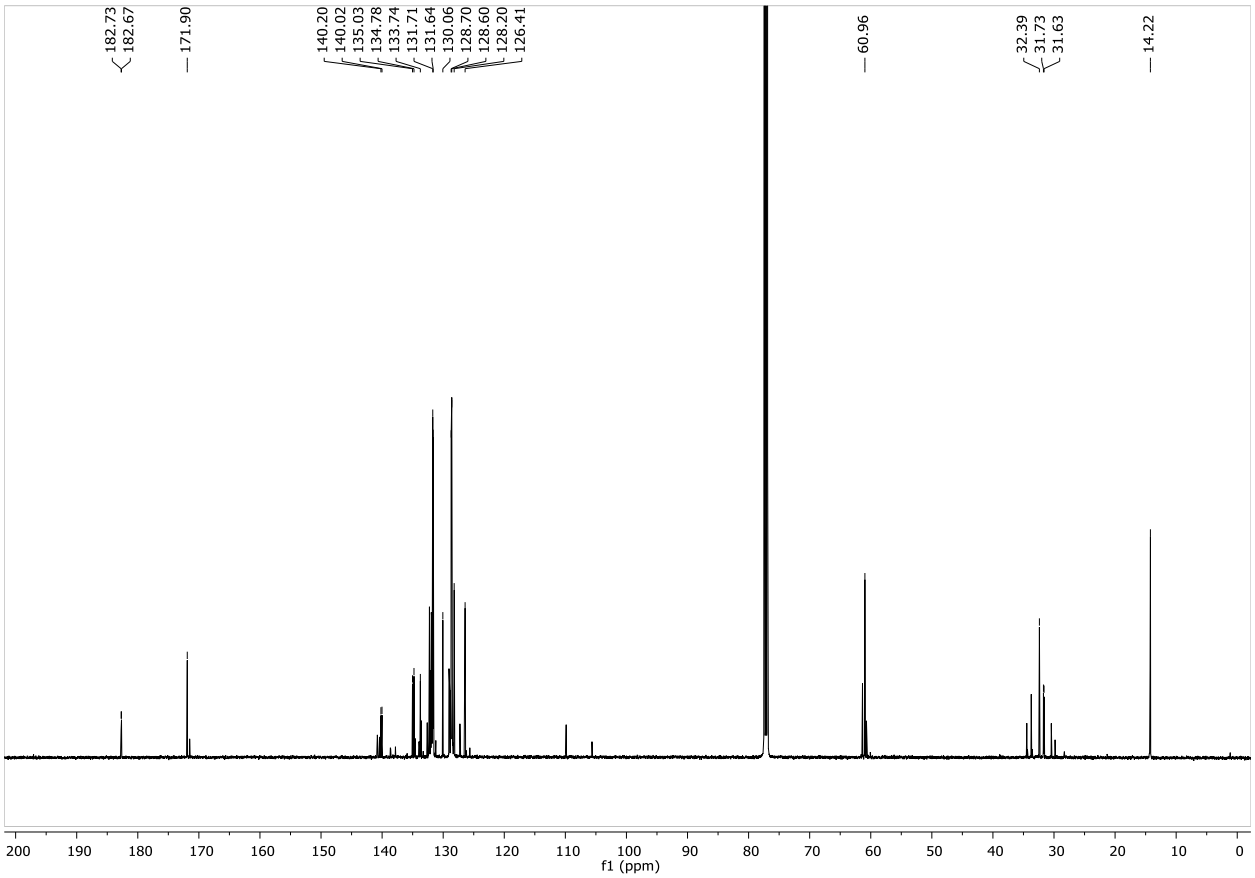




Ethyl-4-[(diphenylphosphoryl]imino]-4-(3-chlorophenyl) butanoate (3e)

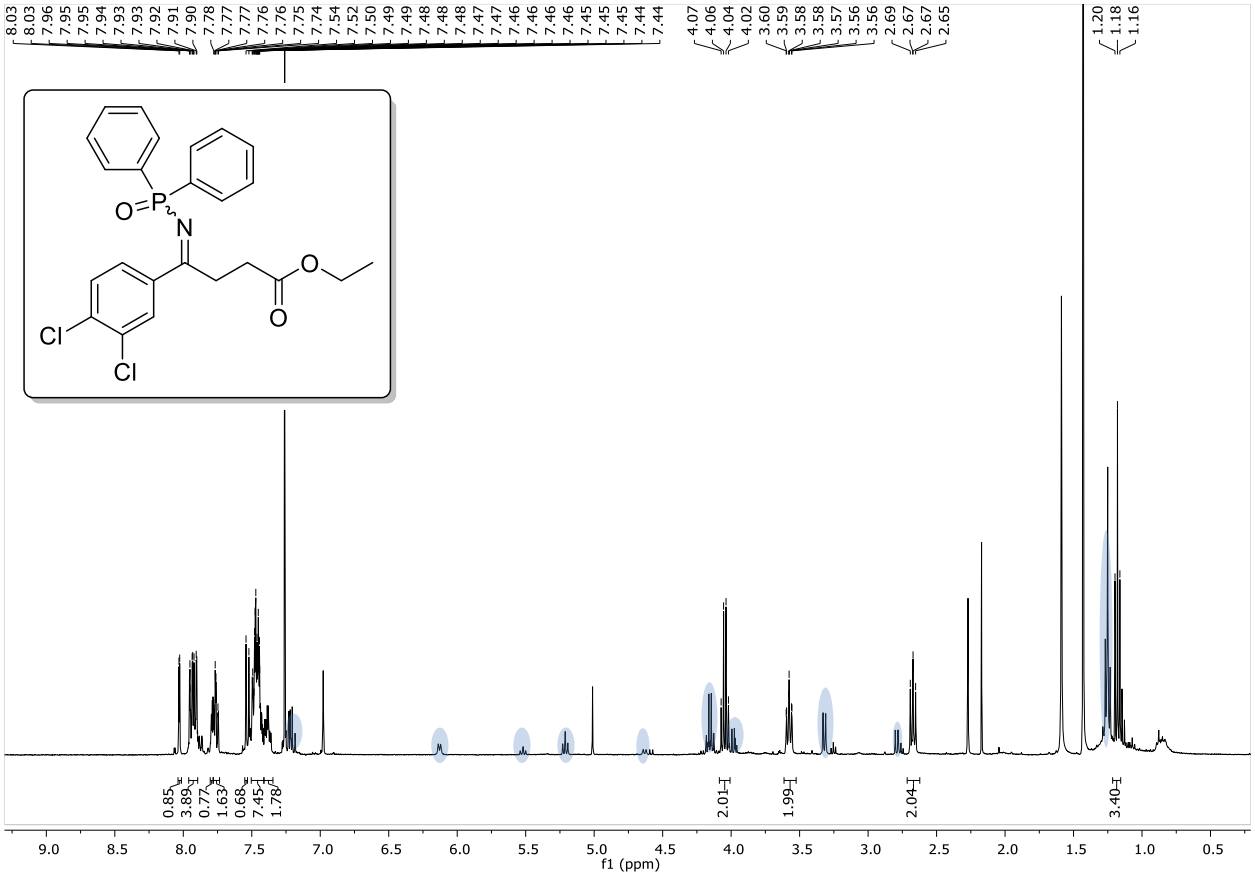
Ketimine:enamines ratio 57:27:16. Enamines signals highlighted with a pale blue shade.

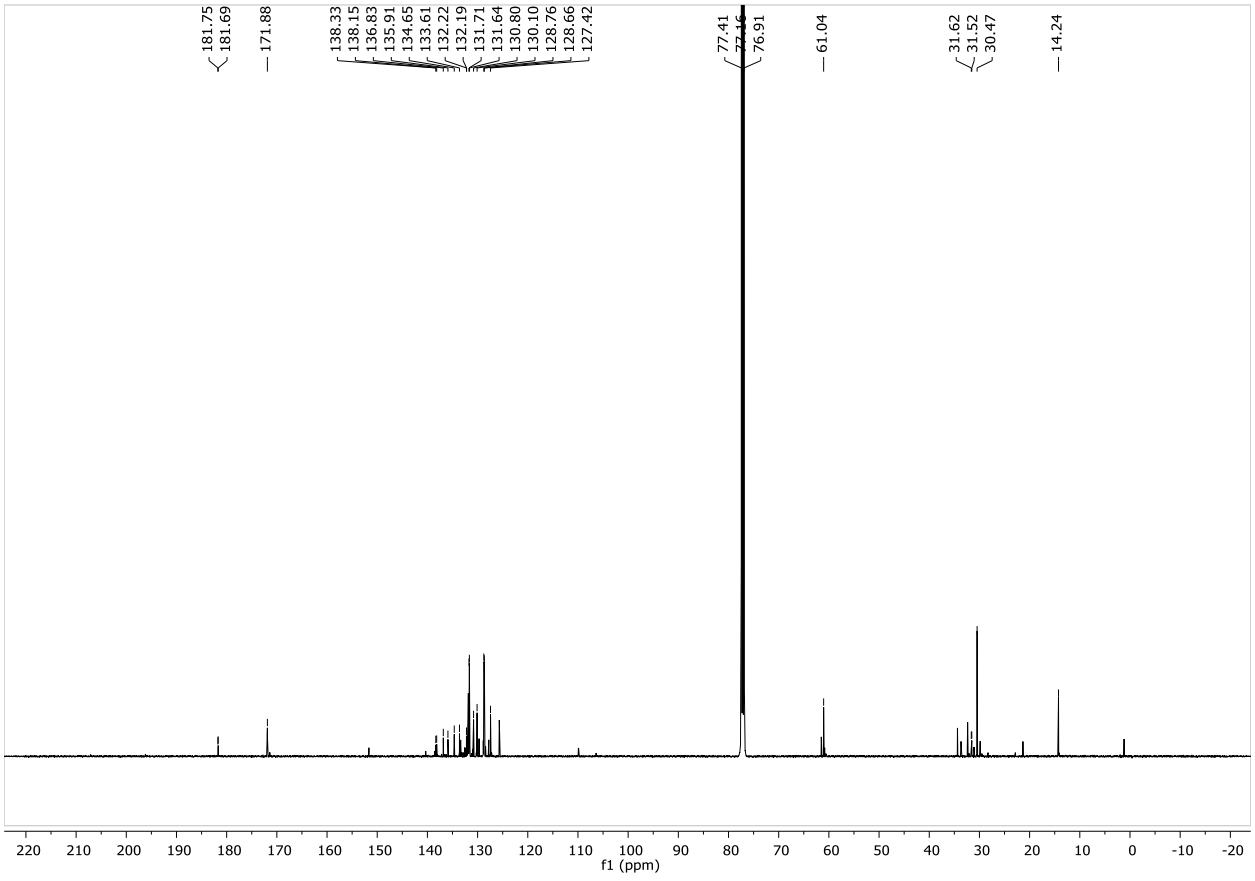




Ethyl-4-(3,4-dichlorophenyl)-4-[(diphenylphosphoryl)imino] butanoate (3f)

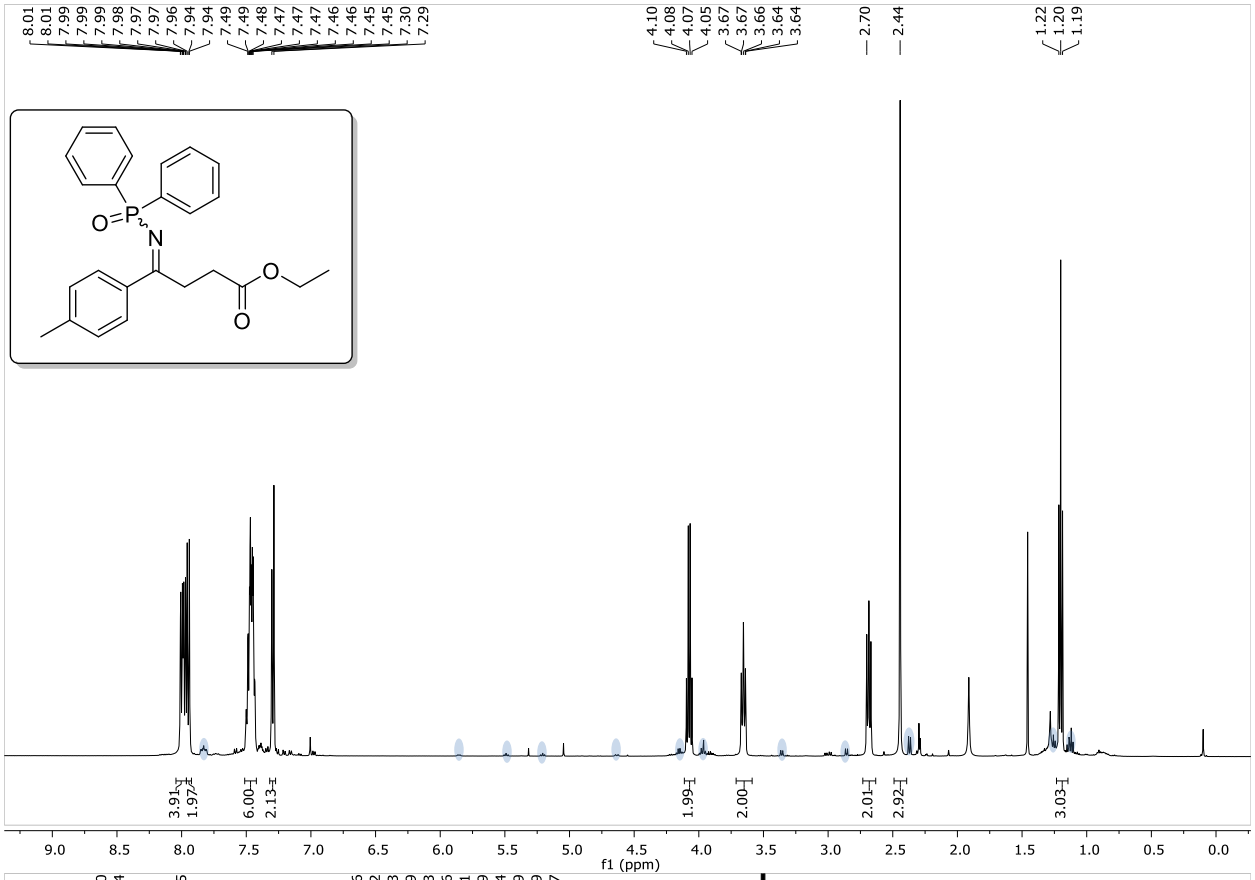
Ketimine:enamines ratio 59:27:14. Enamines signals highlighted with a pale blue shade.

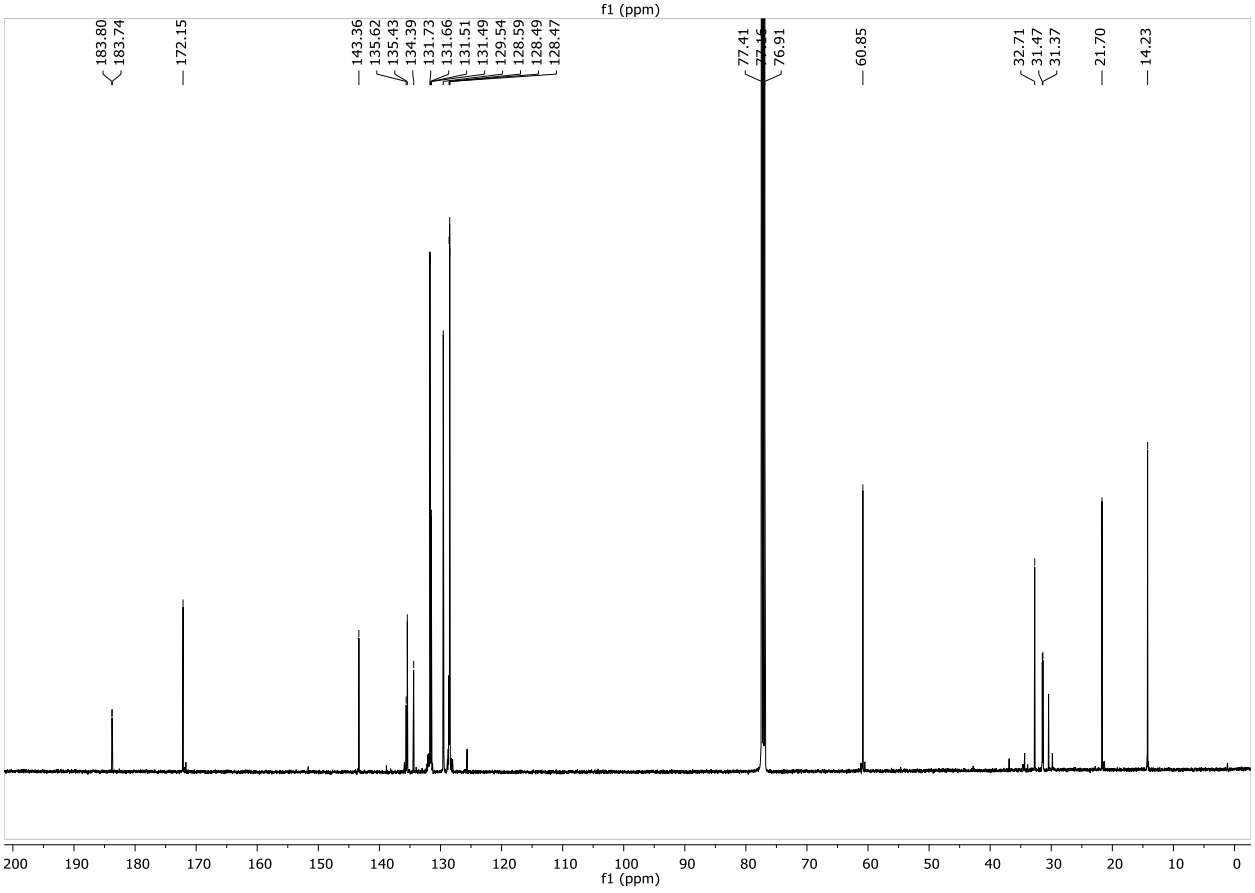




Ethyl-4-[(diphenylphosphoryl]imino]-4-(4-methylphenyl) butanoate (3g)

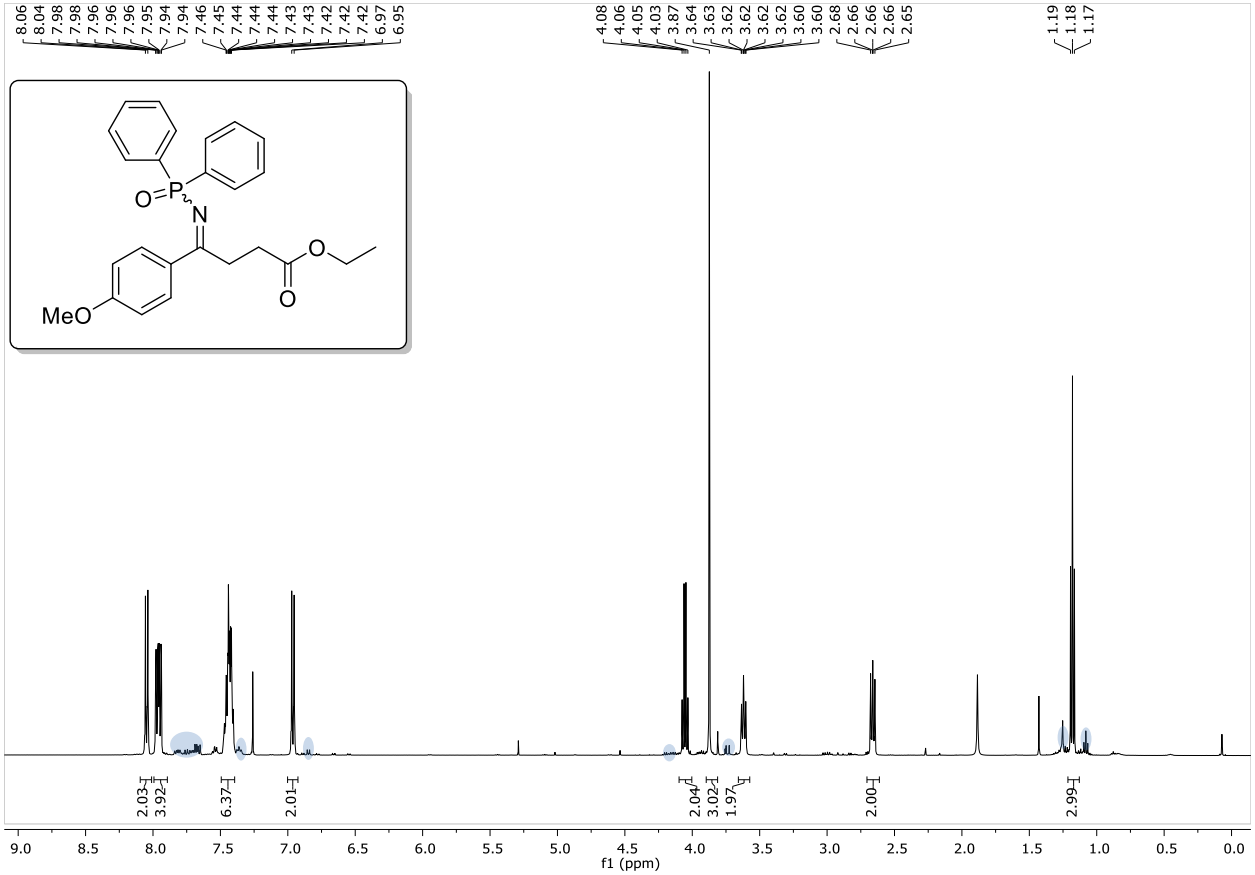
Ketimine:enamines ratio > 95:5. Enamines signals highlighted with a pale blue shade.

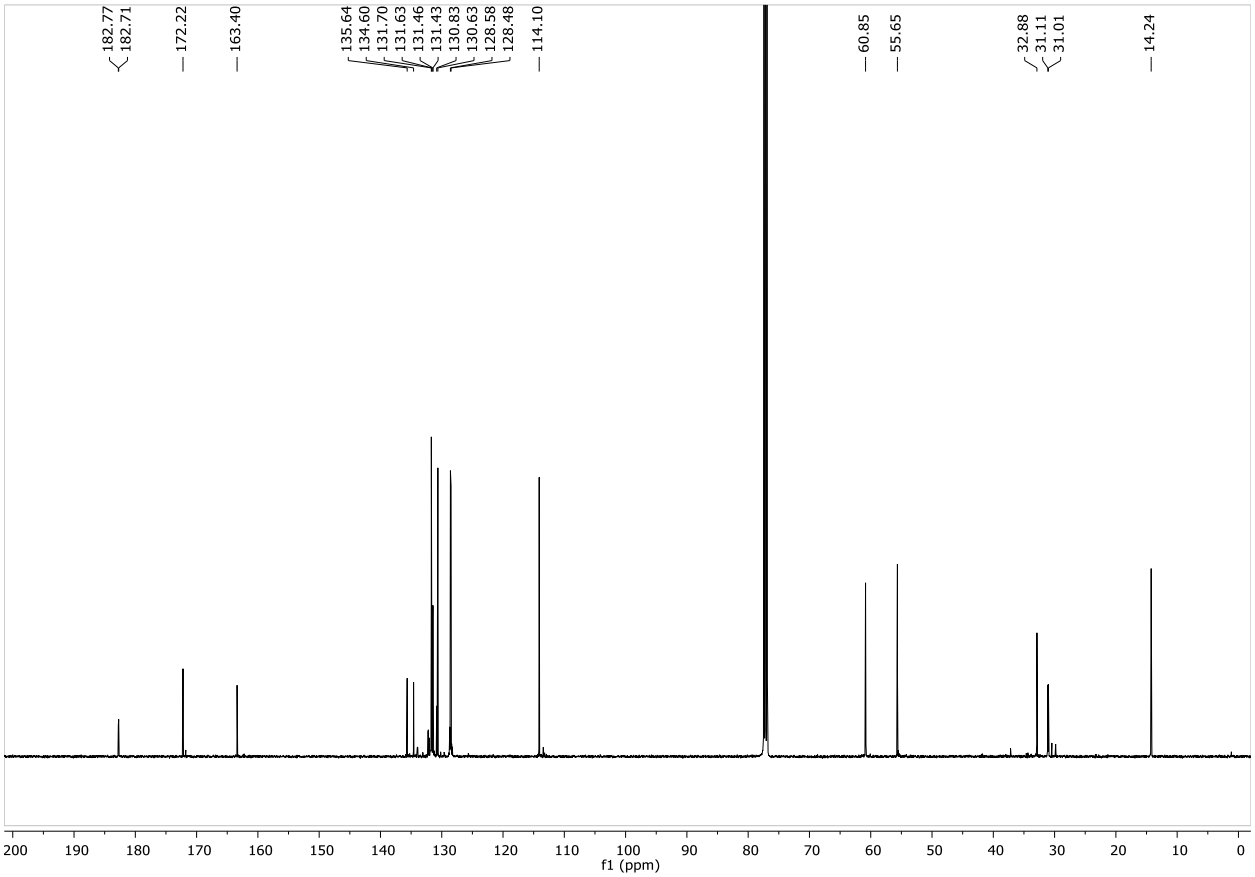




Ethyl-4-[(diphenylphosphoryl]imino]-4-(4-methoxyphenyl)butanoate (3h)

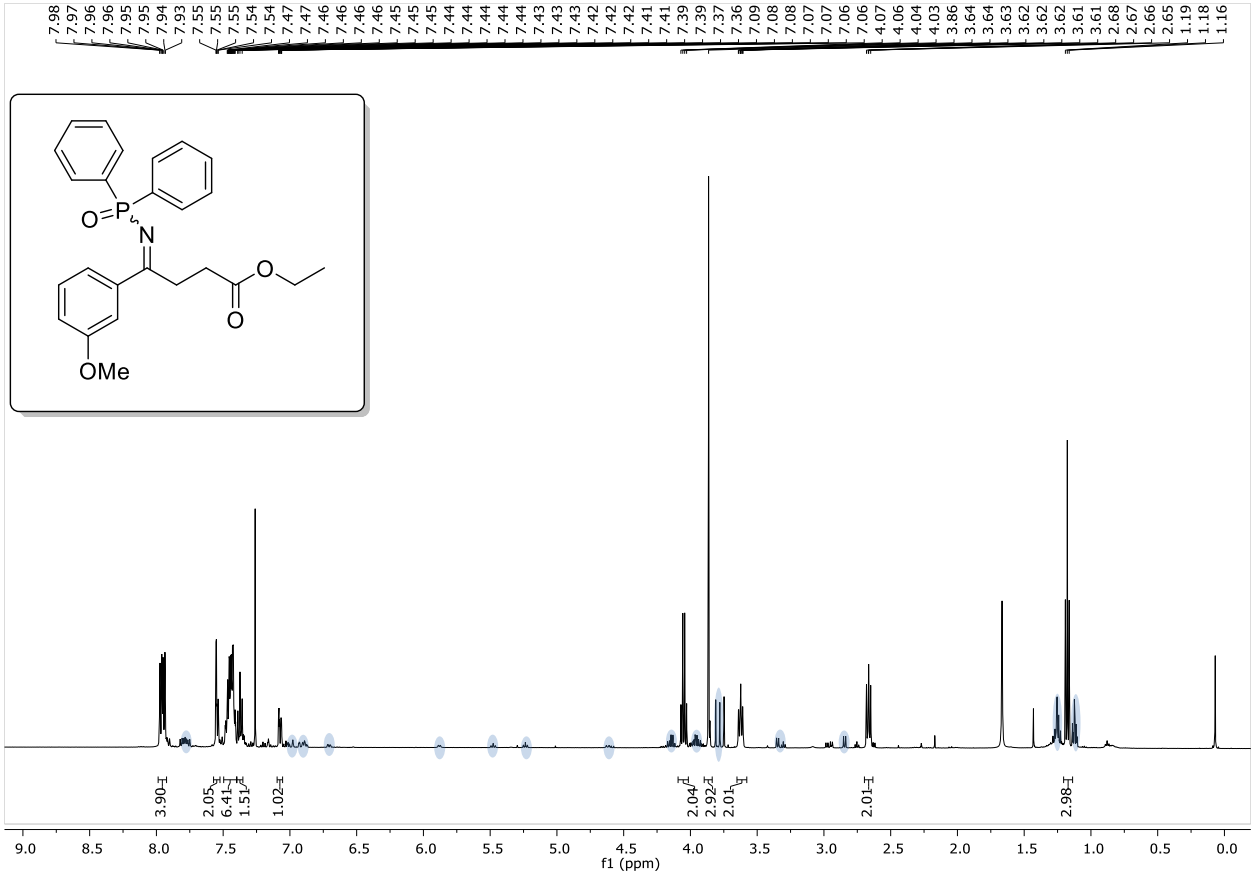
Ketimine:enamines ratio > 95:5. Enamines signals highlighted with a pale blue shade.

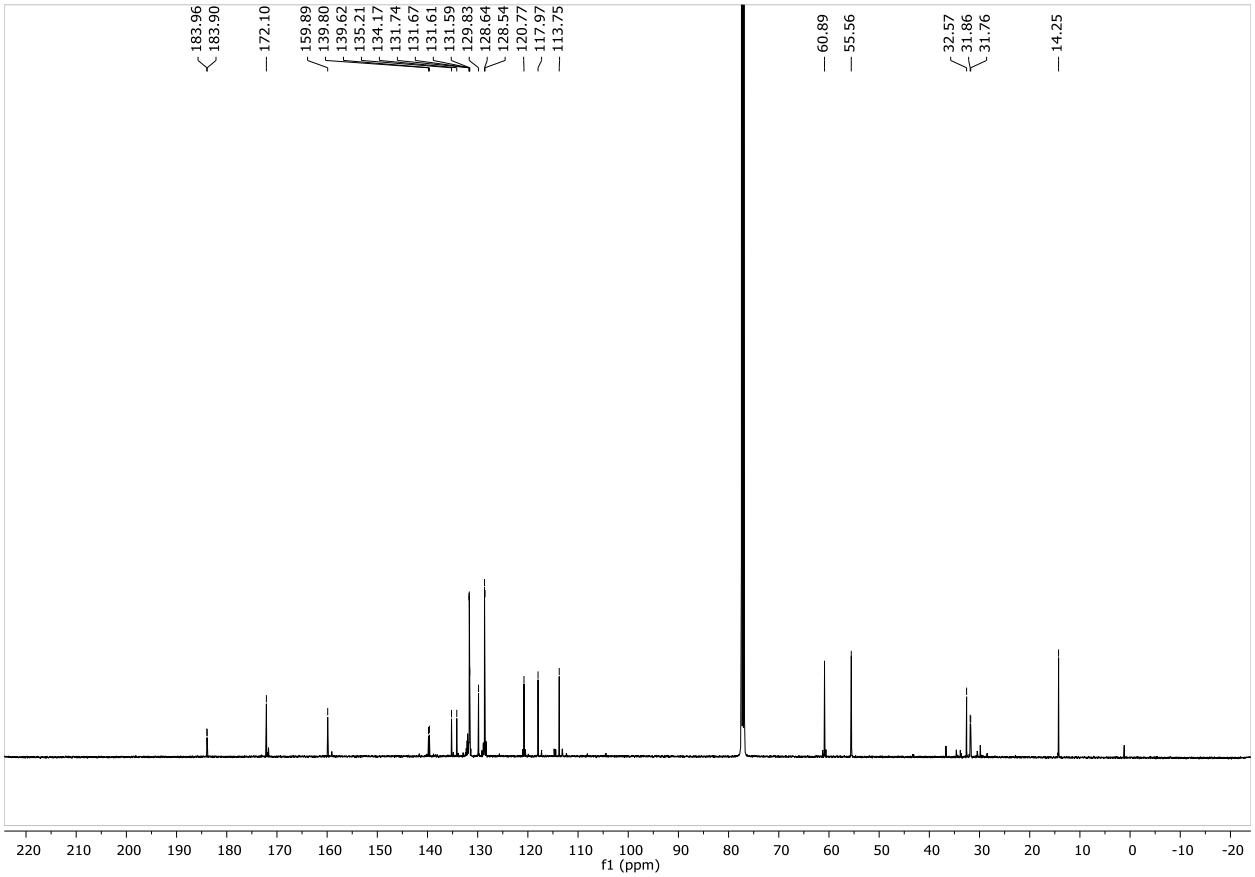




Ethyl-4-[(diphenylphosphoryl]imino]-4-(3-methoxyphenyl) butanoate (3i)

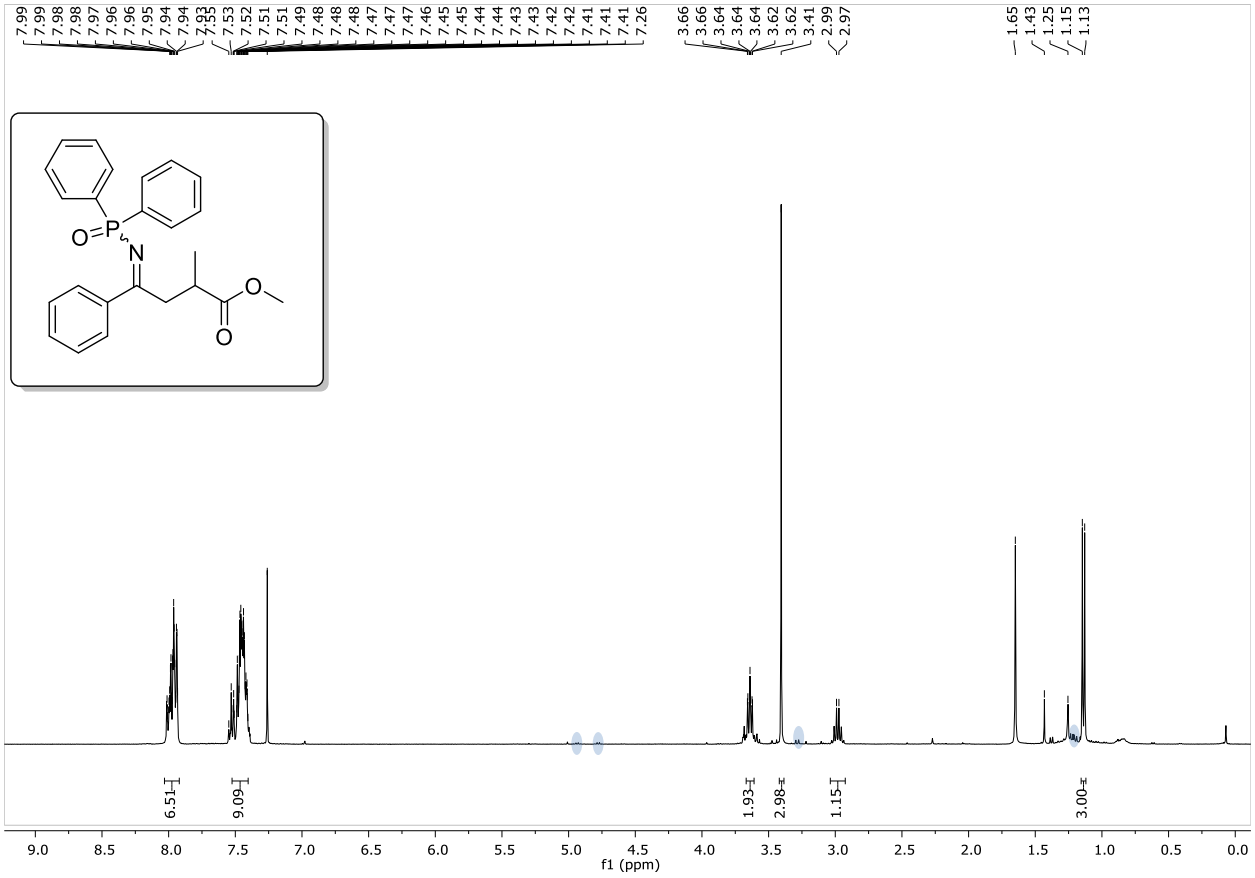
Ketimine:enamines ratio 70:15:15. Enamines signals highlighted with a pale blue shade.

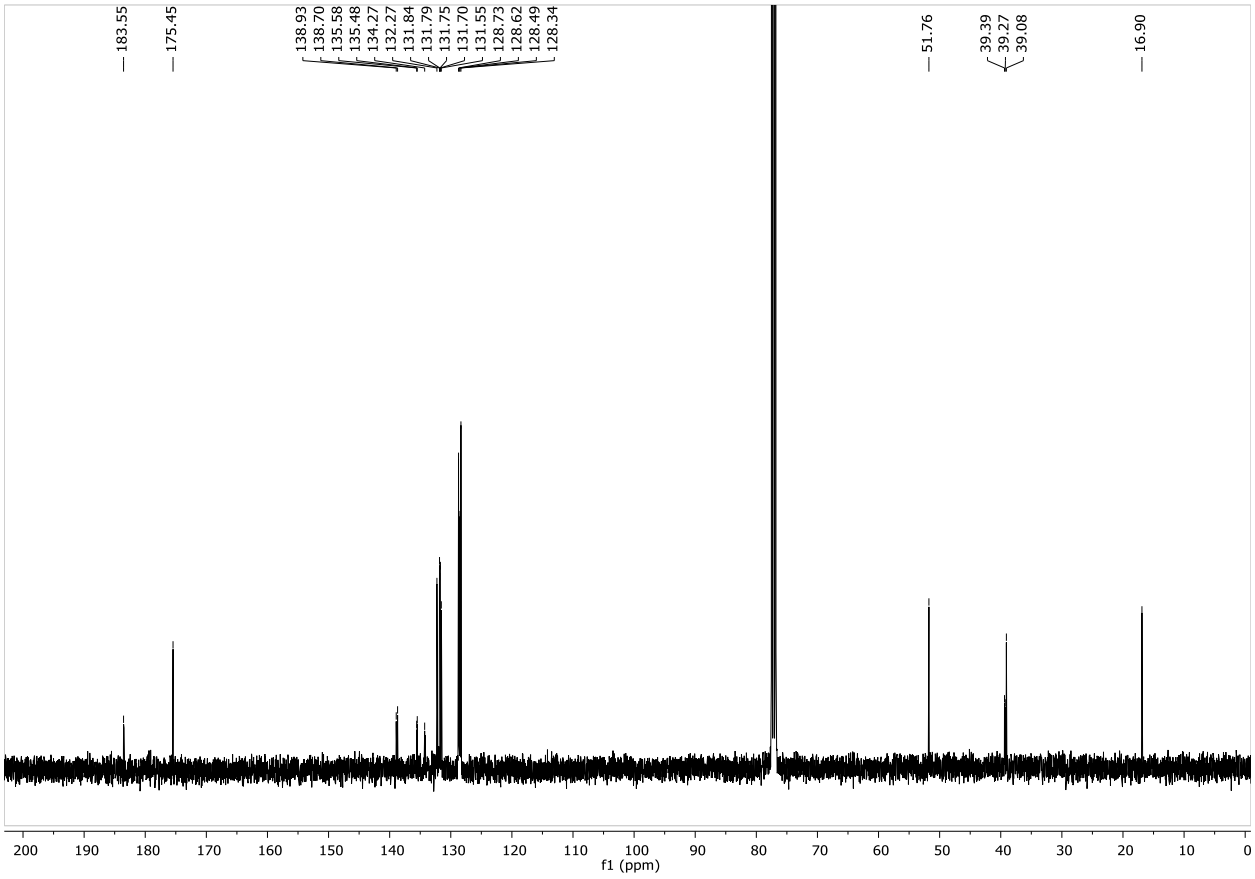




Methyl-4-[(diphenylphosphoryl)imino]-2-methyl-4-phenylbutanoate (3j)

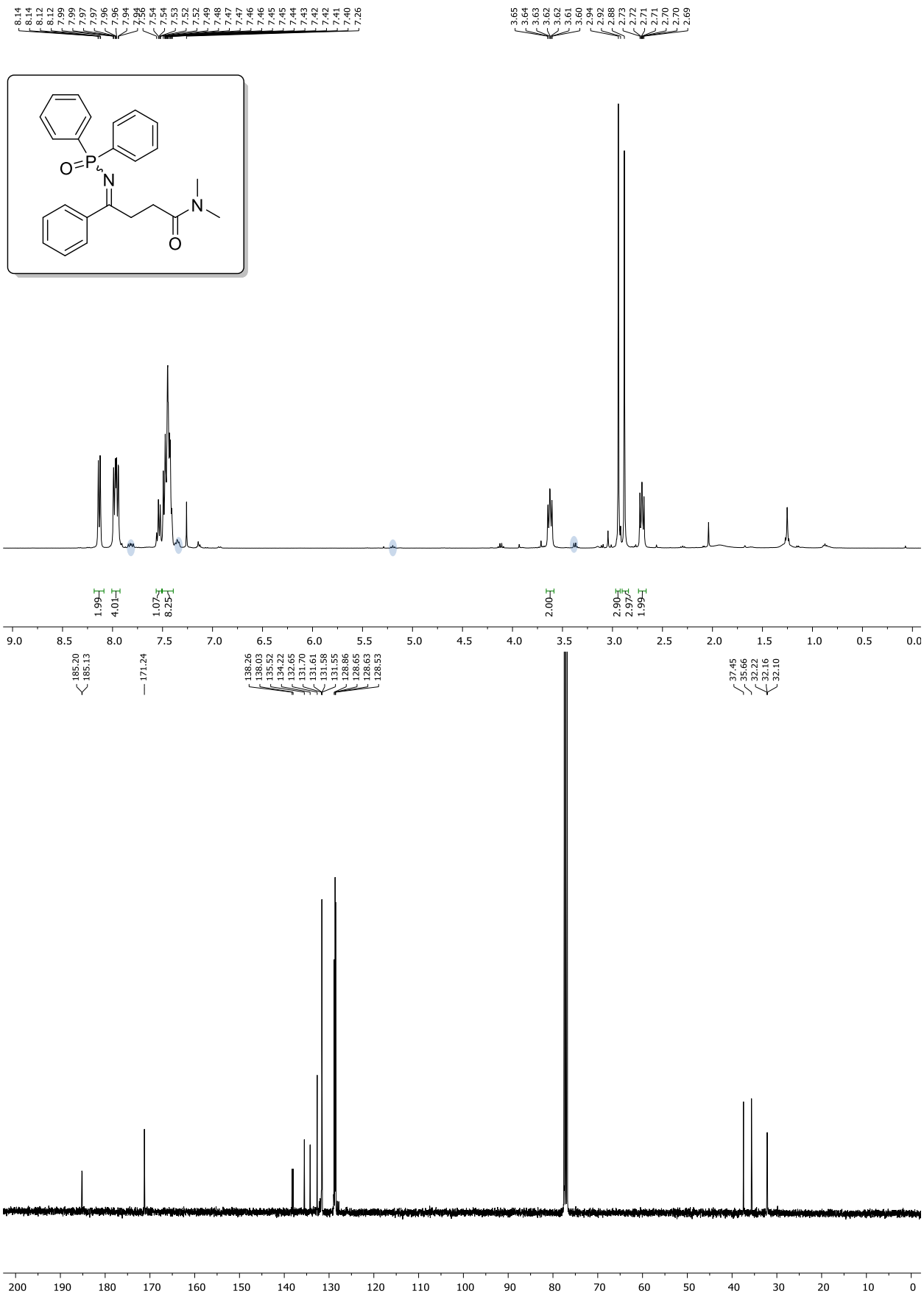
Ketimine:enamines ratio > 95:5. Enamines signals highlighted with a pale blue shade.





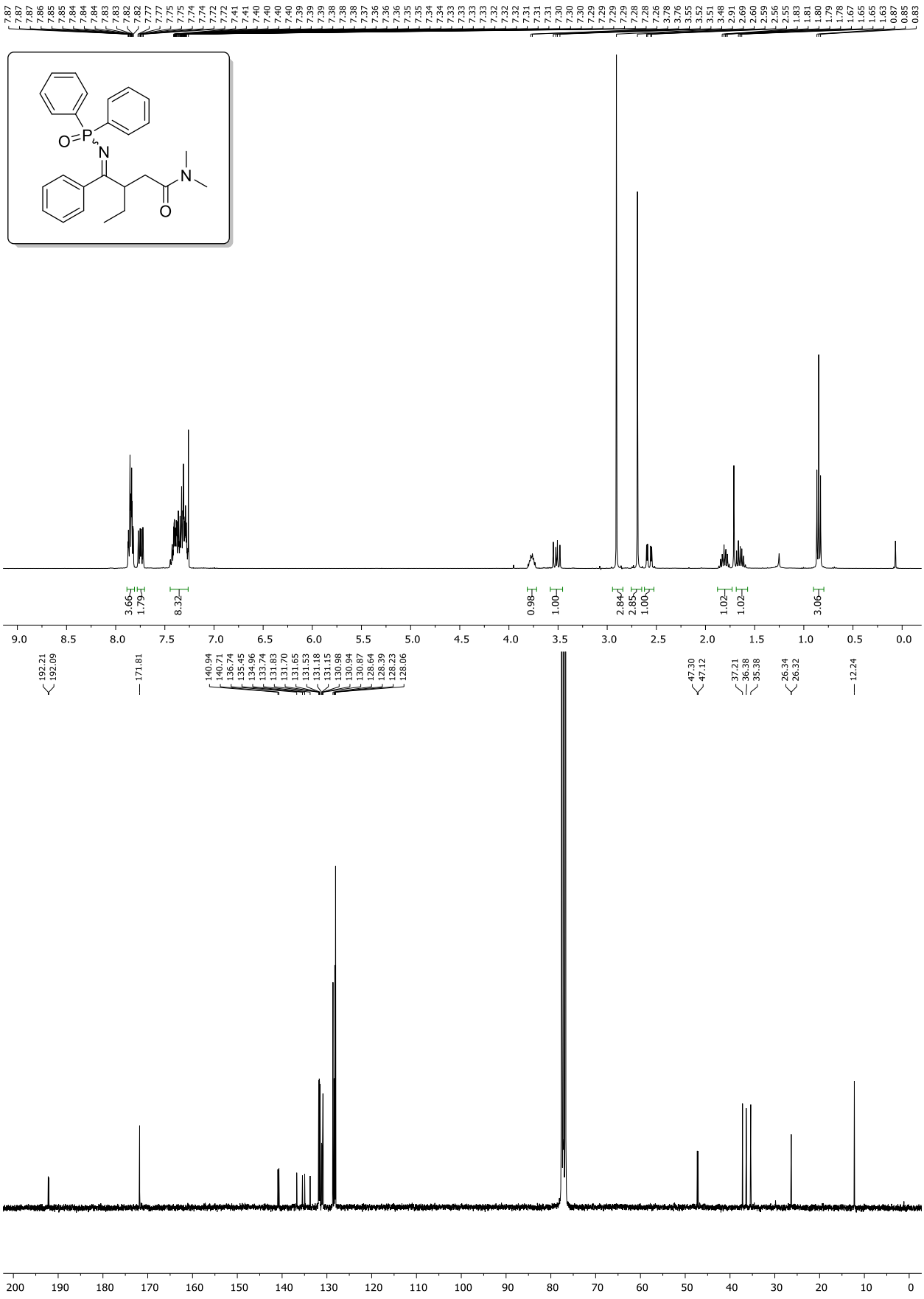
4-[(Diphenylphosphoryl)imino]-*N*,*N*-dimethyl-4-phenylbutanamide (3k)

Ketimine:enamines ratio > 95:5. Enamines signals highlighted with a pale blue shade.



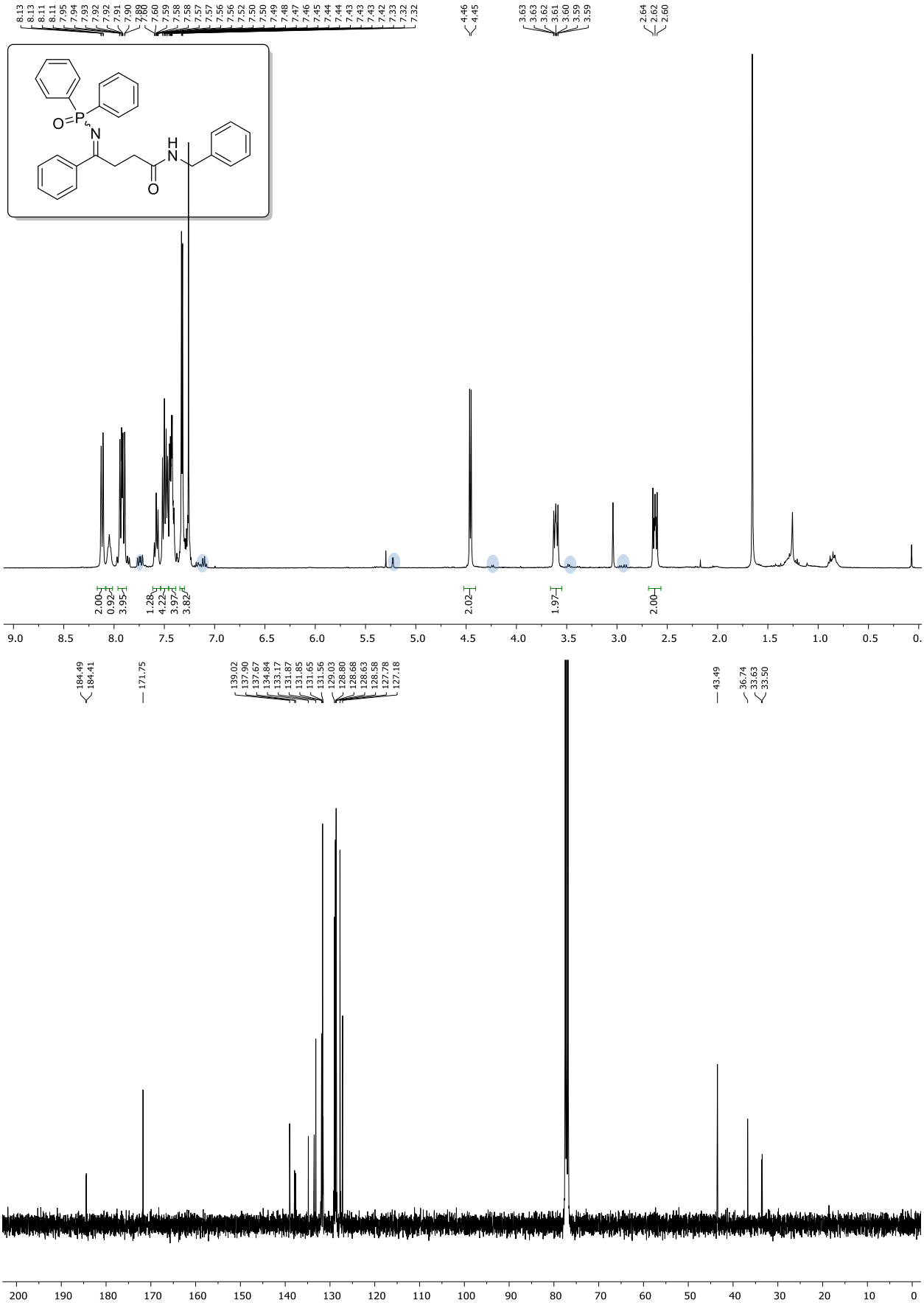
3-[[(Diphenylphosphoryl)imino](phenyl)methyl]-*N*,*N*-dimethylpentanamide (3l)

Ketimine:enamines ratio > 95:5.



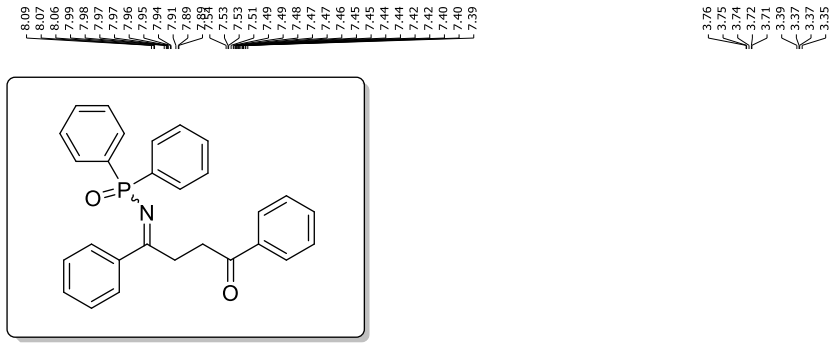
N-Benzyl-4-[(diphenylphosphoryl)imino]-4-phenylbutanamide (3m)

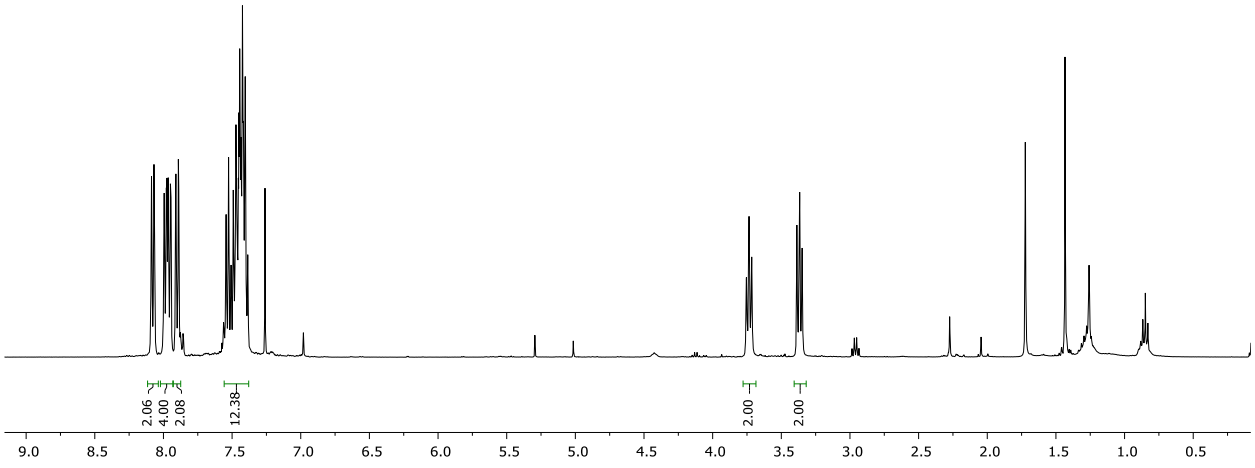
Ketimine:enamines ratio > 95:5. Enamines signals highlighted with a pale blue shade.

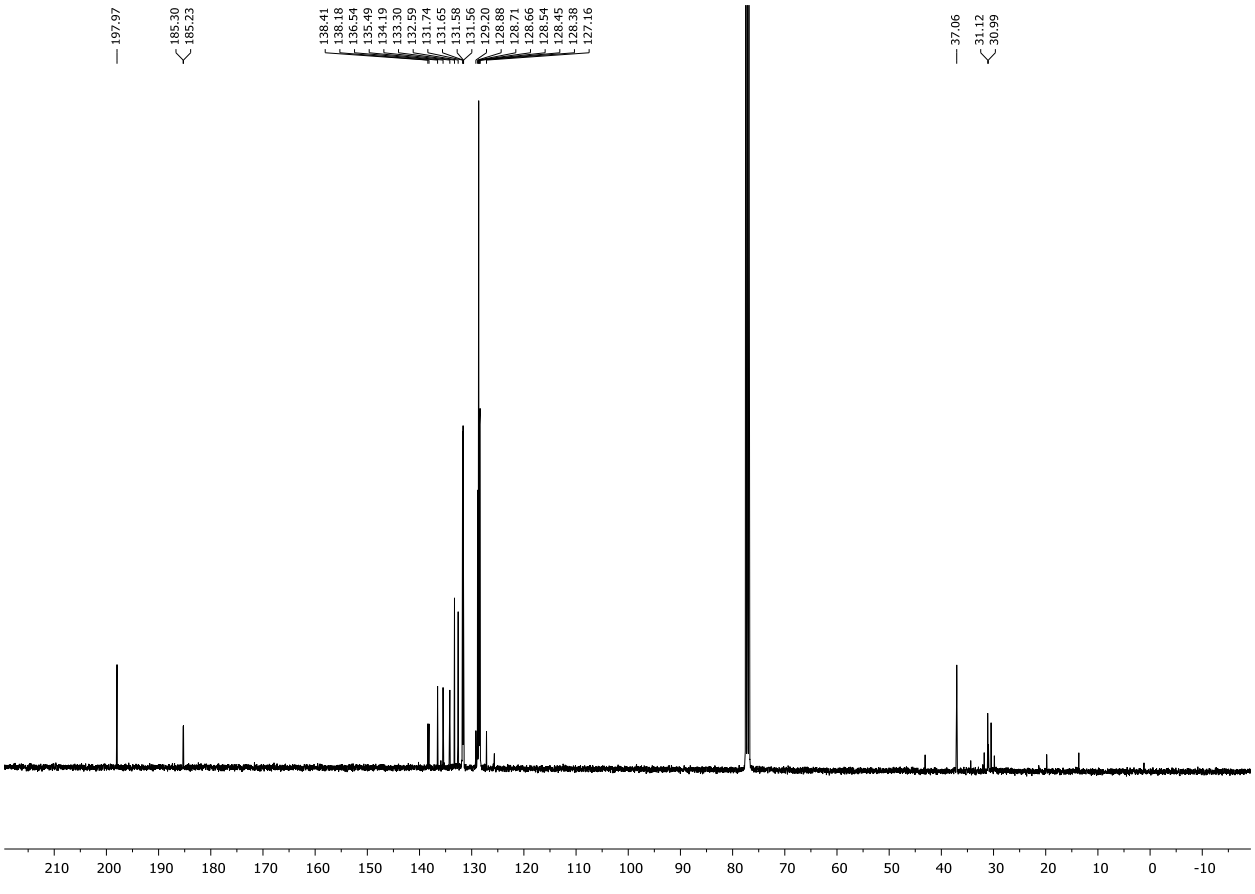


N-(4-Oxo-1,4-diphenylbuylidene)-*P*,*P*-diphenylphosphinic amide (3n)

Ketimine:enamines ratio > 95:5.

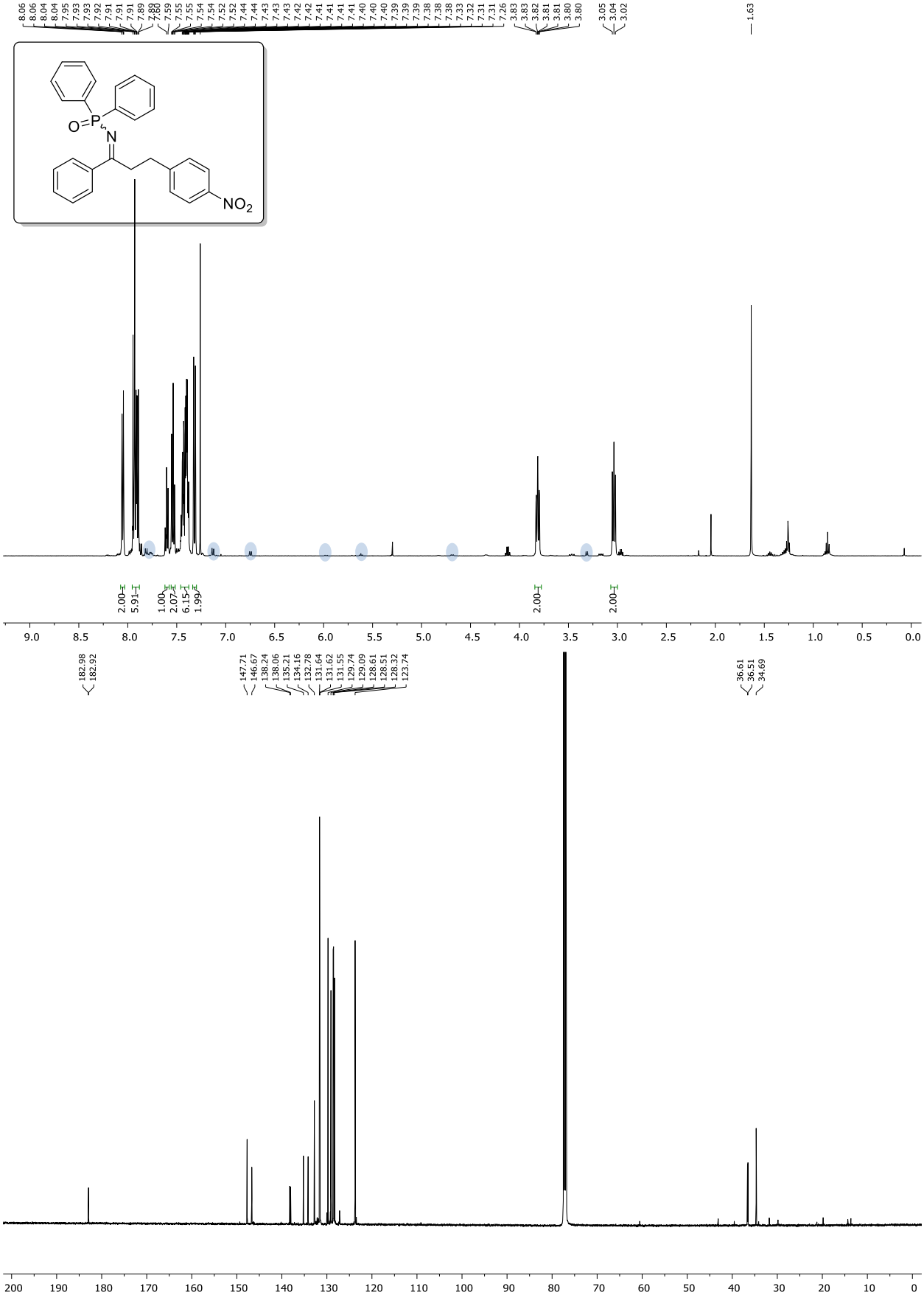




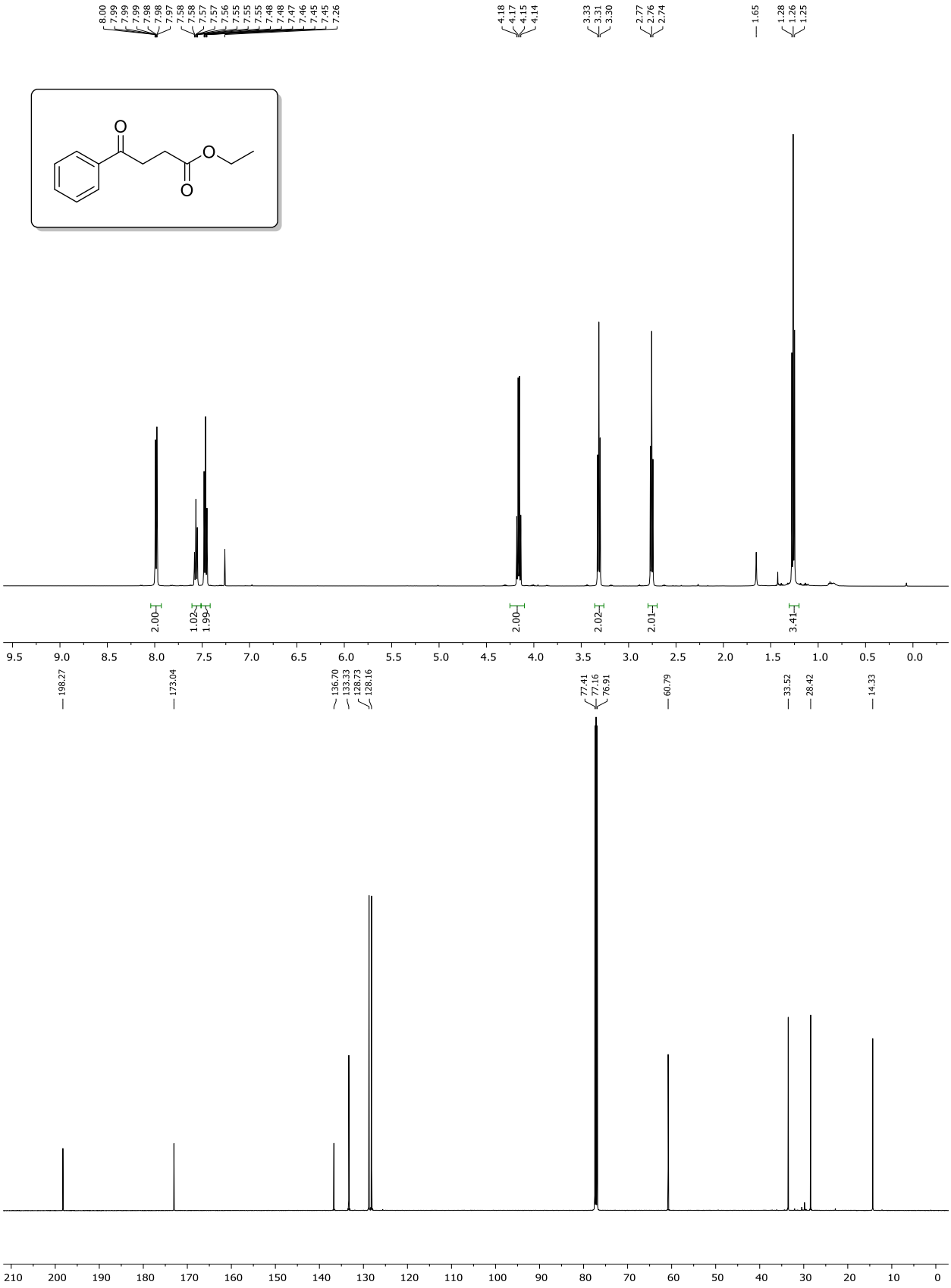


N-[3-(4-Nitrophenyl)-1-phenylpropylidene]-*P,P*-diphenylphosphinic amide (3o)

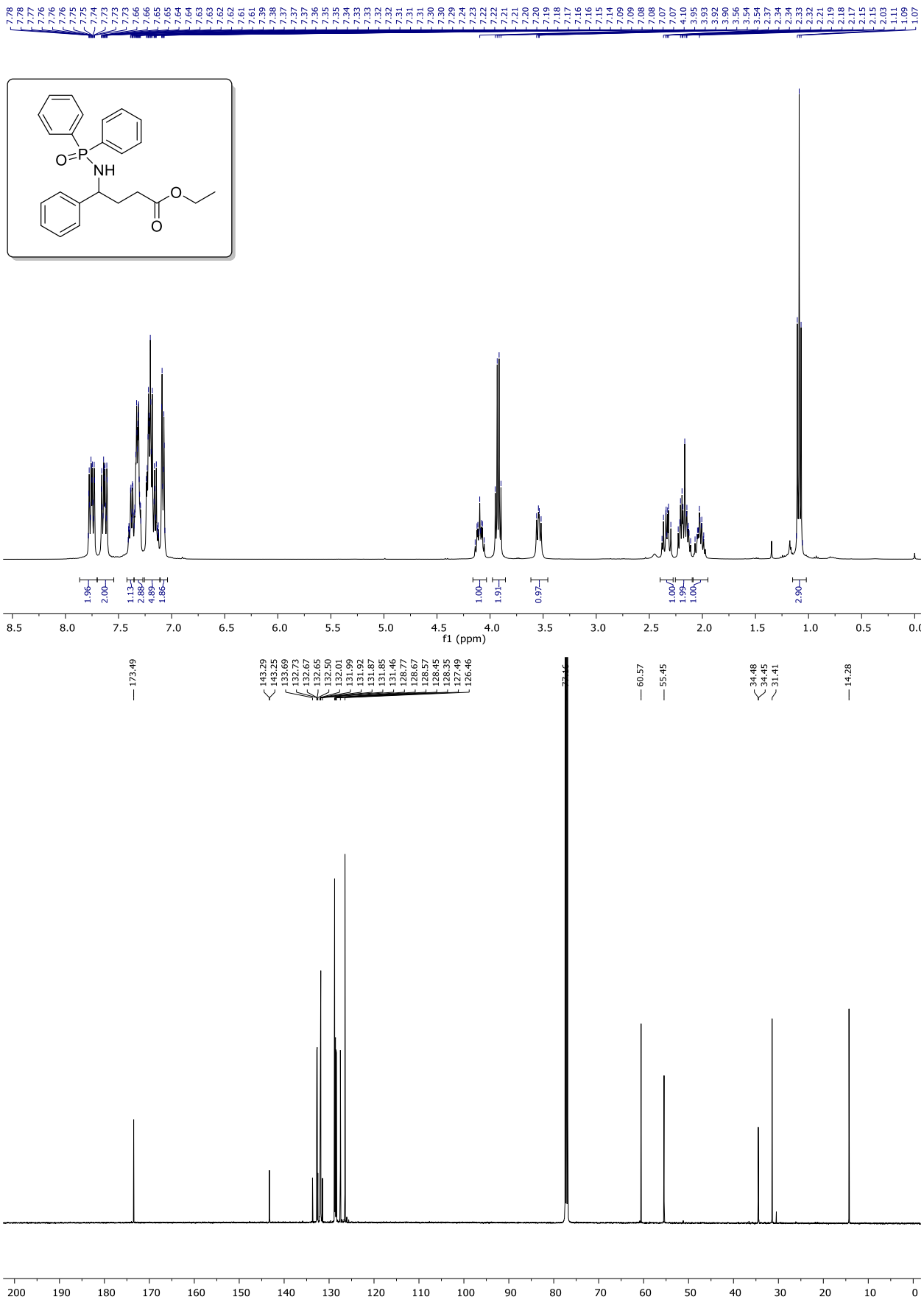
Ketimine:enamines ratio > 95:5. Enamines signals highlighted with a blue shade.



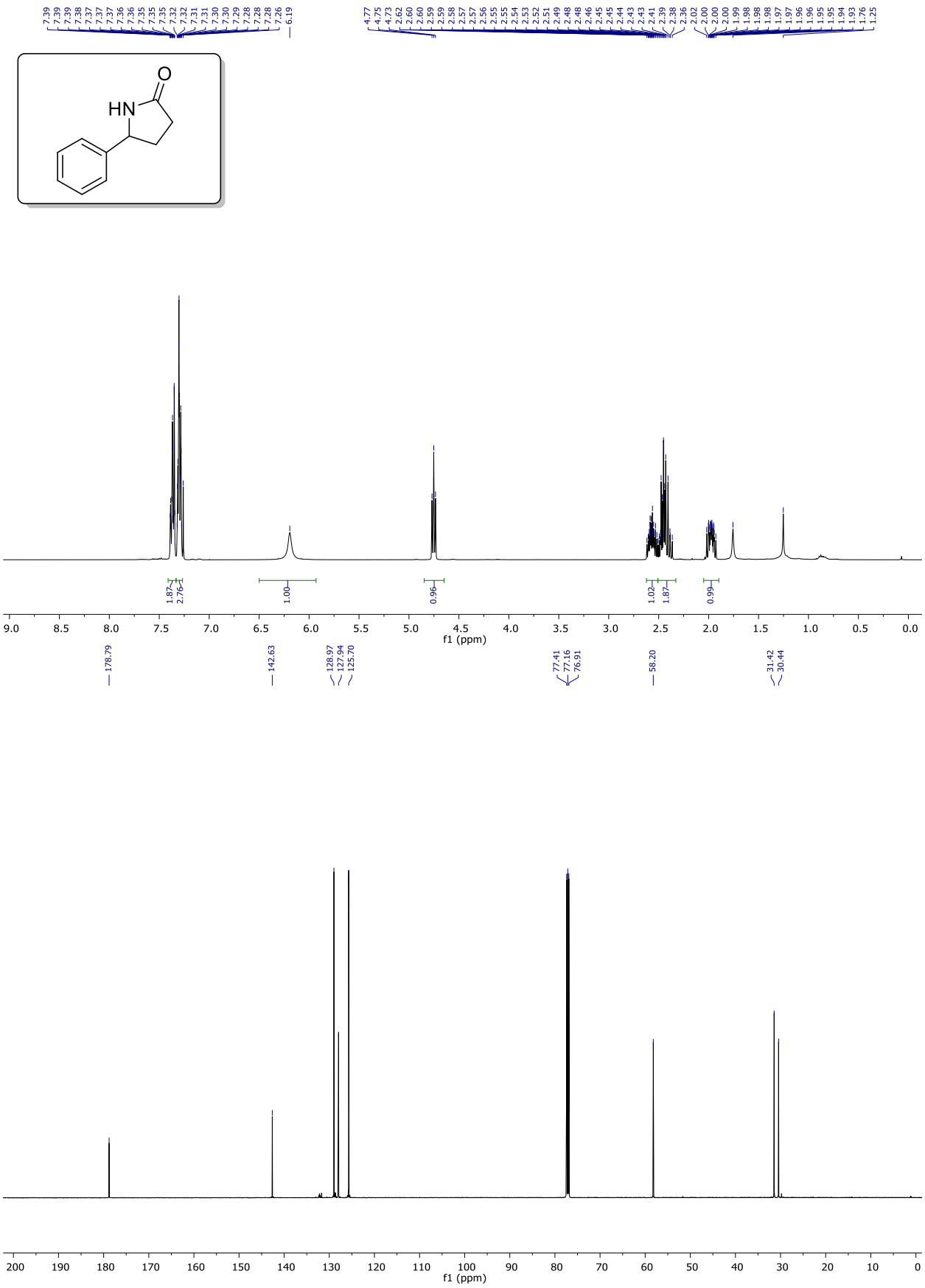
Ethyl 4-oxo-4-phenylbutanoate (4)



Ethyl 4-((diphenylphosphoryl)amino)-4-phenylbutanoate (5)



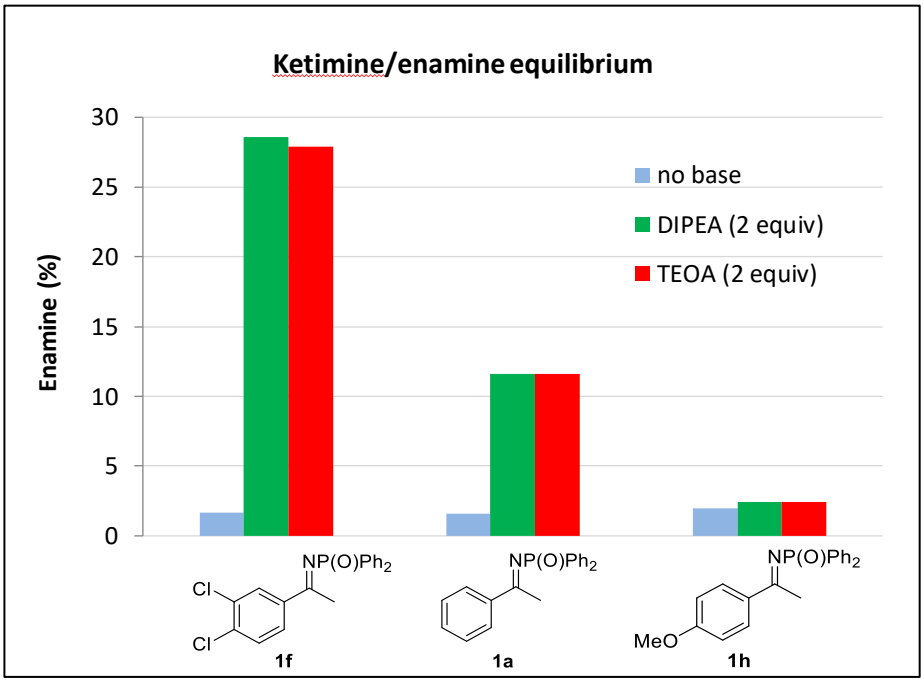
5-Phenylpyrrolidin-2-one (6)



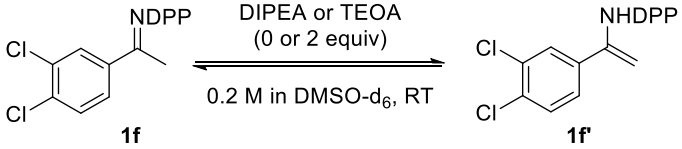
4. Mechanistic studies

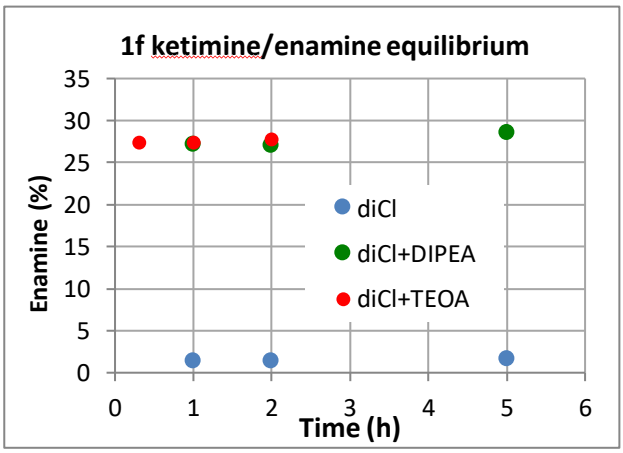
4.1 NMR studies on ketimine/enamine equilibrium

The ketimine/enamine equilibrium was studied by ^{1}H and ^{31}P NMR analysis of 0.2 M solutions of substrates **1a**, **1f** and **1h** in DMSO-d_6, with and without 2 equivalents of DIPEA and TEOA. DMSO-d_6 was chosen as a cheaper alternative to DMF-d_7, considering that the reaction profile is very similar (see Tables S3 and S7) in order to avoid peak overlap.



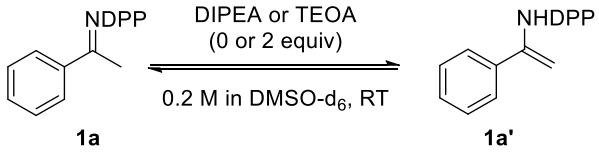
Percentage of enamine present in a 0.2 M solution of substrates **1a**, **1f** and **1h** in DMSO-d_6 after 5 hours, as determined by 1H and 31P NMR analysis.

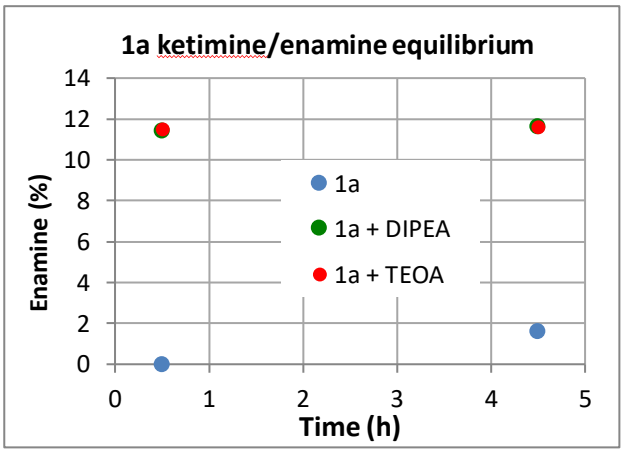




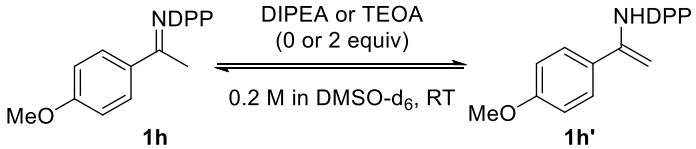
	1f	**1f** + DIPEA	**1f** + TEOA
time (h)	enamine (%)	enamine (%)	enamine (%)
0.3	nd	nd	27.5
1	1.5	27.2	27.5
2	1.5	27.1	27.9
5	1.7	28.6	nd
48	5.6	27.0	27.0[a]

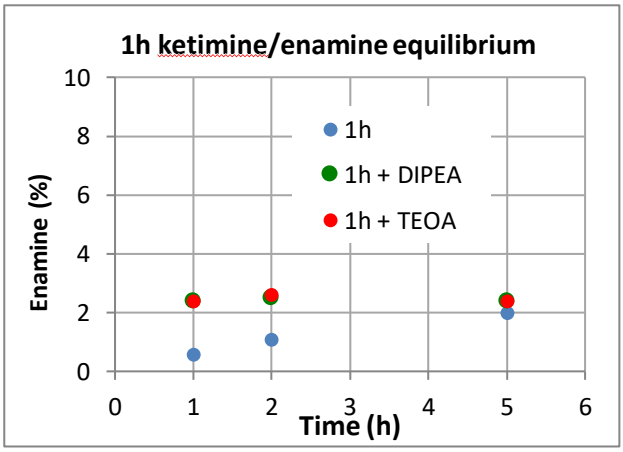
[a] With 5 mol% $[NiCl_2(PPh_3)_2]$.





	1a	**1a** + DIPEA	**1a** + TEOA
time (h)	enamine (%)	enamine (%)	enamine (%)
0.5	0	11.4	11.5
4.5	1.6	11.6	11.6





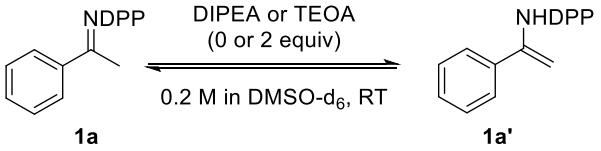
from	**1h**	**1h** + DIPEA	**1h** + TEOA
time (h)	enamine (%)	enamine (%)	enamine (%)
1	0.6	2.4	2.4
2	1.1	2.5	2.6
5	2.0	2.4	2.4
48	2.5	2.5	3.0, 3.5[a]

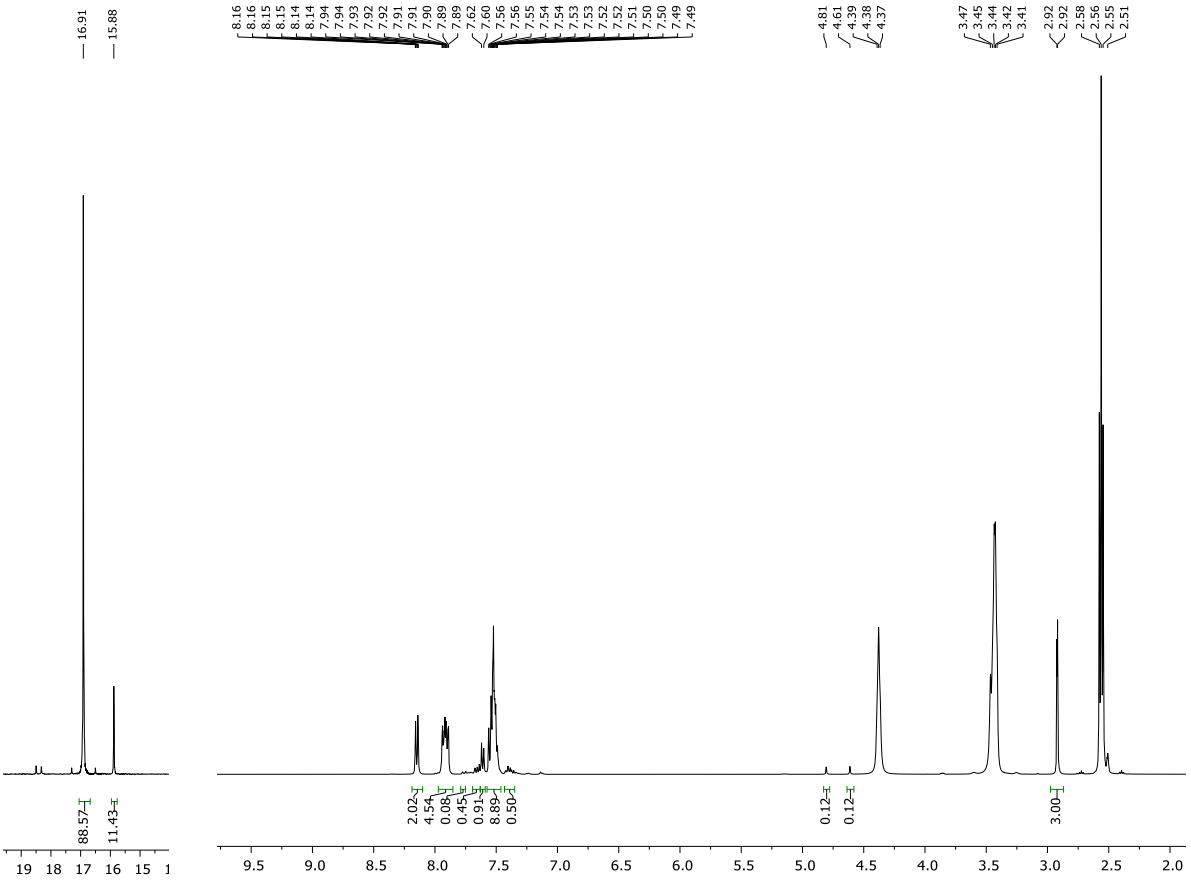
[a] With 5 mol% $[NiCl_2(PPh_3)_2]$.

No significant changes to the ketimine/enamine ratios were detected after one hour, or after the addition of 5 mol% $[NiCl_2(PPh_3)_2]$, indicating that the equilibrium position for the tautomerism is reached relatively quickly and it is not influenced by $[NiCl_2(PPh_3)_2]$. The ratio remained basically the same even after 48 h.

In all cases the bases promoted the formation of enamine, and no differences between DIPEA and TEOA emerged. The position of the equilibrium appears to be strongly dependent on the nature of the ketimine itself, with electron-poor ketimine **1f** more prone to tautomerisation than the electron-rich compound **1h** (~27% vs 2.5% enamine formed in the presence of base), and the model ketimine tautomerising up to 11.5% at the equilibrium. The extent of tautomerisation parallels reactivity in the present α-alkylation, thus suggesting that the reactive species is the enamine tautomer of the starting material.

Diagnostic NMR peaks

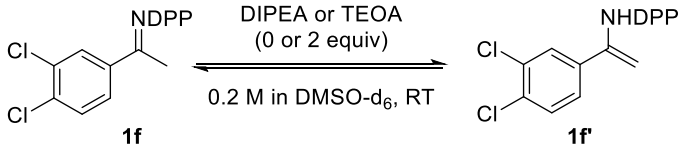




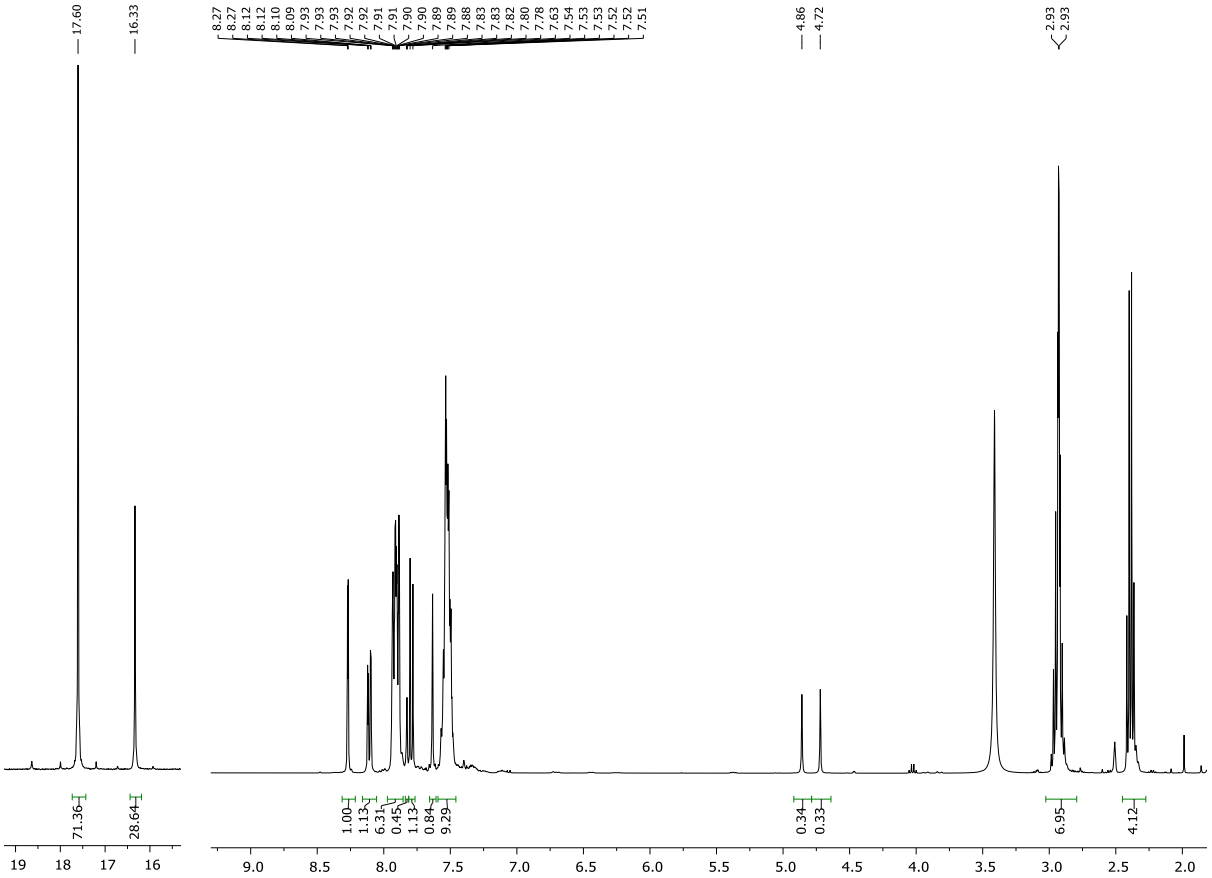
^{31}P NMR (DMSO-d_6, 162 MHz): δ 16.9 (**1a**), 15.9 (**1a'**).

^{1}H NMR (DMSO-d_6, 400 MHz): δ 4.91 (s, 1H, C=C$H_A$$\underline{H}_B$, **1a'**), 4.91 (s, 1H, C=C$\underline{H}_A$$H_B$, **1a'**), 2.92 (d, $^{4}J_{HP}$ = 2.0 Hz, 3H, C$\underline{H}_3$, **1a**).

Diagnostic NMR peaks



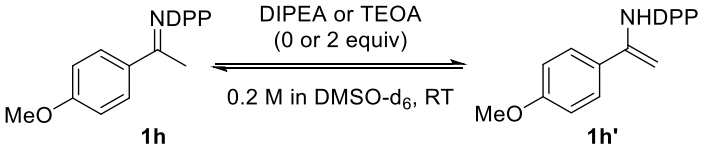
1f **1f'**

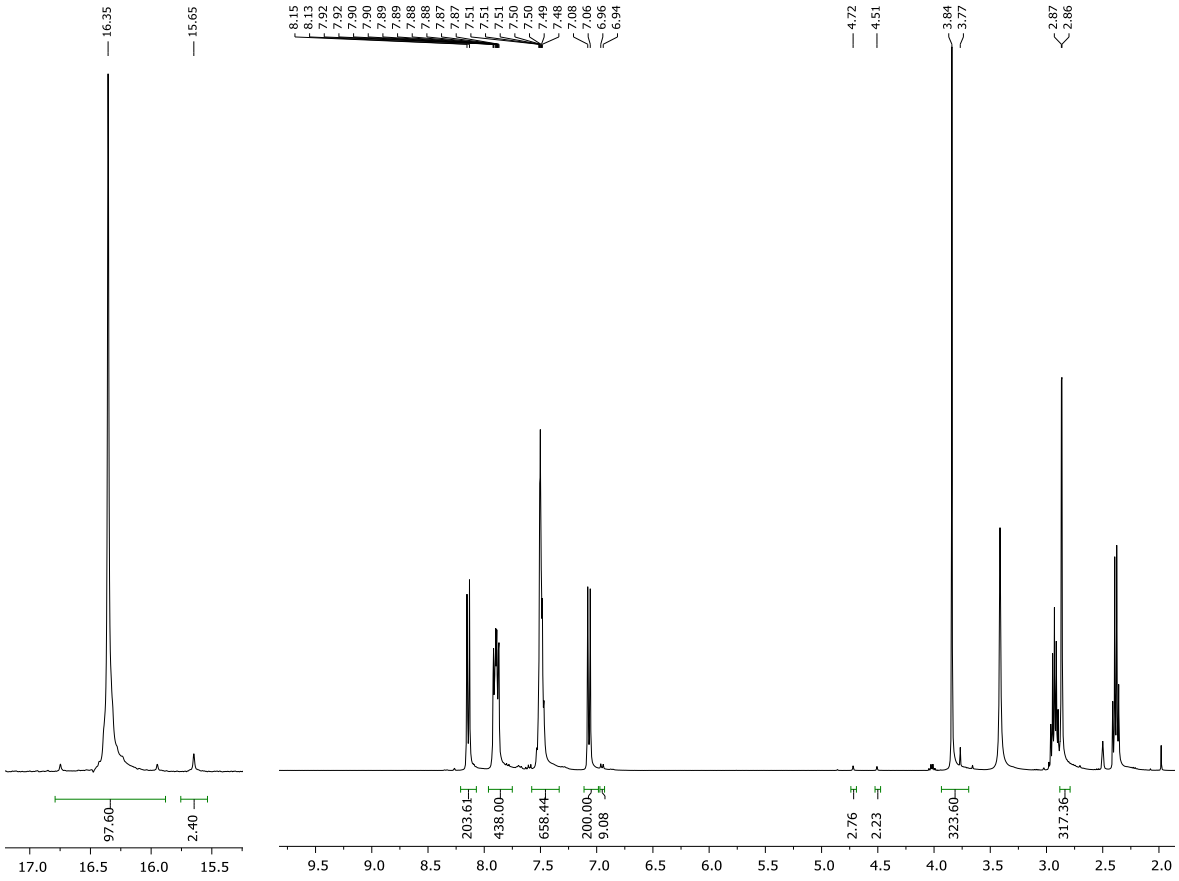


^{31}P NMR (DMSO-d_6, 162 MHz): δ 17.6 (**1f**), 16.3 (**1f'**).

^{1}H NMR (DMSO-d_6, 400 MHz): δ 8.27 (d, J = 2.0 Hz, 1H, N=CCC<u>H</u>CCl, **1f**), 4.86 (s, 1H, C=CH_A<u>H</u>$_B$, **1f'**), 4.72 (s, 1H, C=C<u>H</u>$_A$H$_B$, **1f'**), 2.93 (d, $^{4}J_{HP}$ = 2.0 Hz, 3H, C<u>H</u>$_3$, **1f**).

Diagnostic NMR peaks



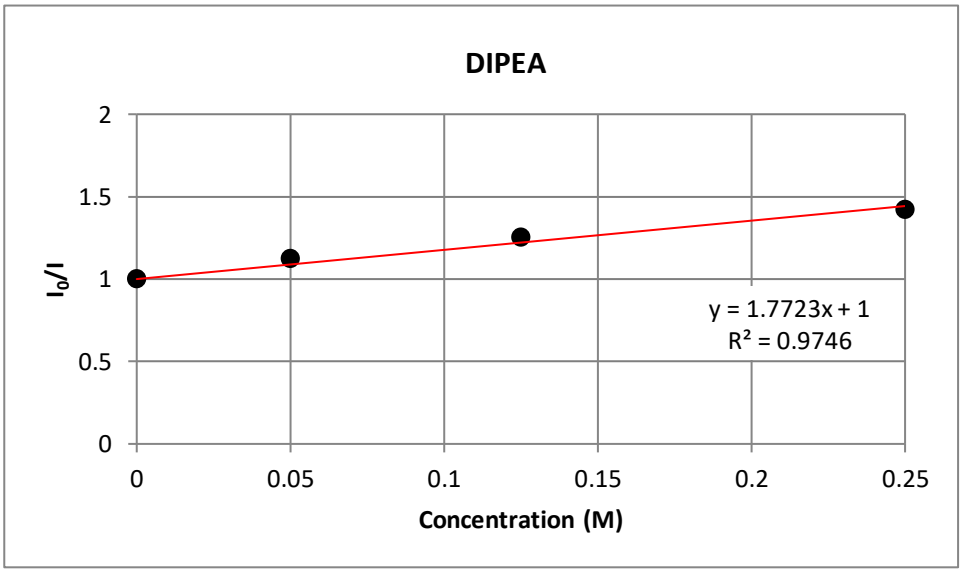


^{31}P NMR (DMSO-d$_6$, 162 MHz): δ 16.4 (**1h**), 15.7 (**1h'**).

^{1}H NMR (DMSO-d$_6$, 400 MHz): δ 7.07 (d, *J* = 9.0 Hz, 2H, C$_{Ar}$HCHCOCH$_3$, **1h**), 6.95 (d, *J* = 9.0 Hz, 2H, C$_{Ar}$HCHCOCH$_3$, **1h'**), 4.72 (s, 1H, C=CH$_A$H$_B$, **1h'**), 4.51 (s, 1H, C=CH$_A$H$_B$, **1h'**), 2.86 (d, $^{4}J_{HP}$ = 2.0 Hz, 3H, CH$_3$, **1h**).

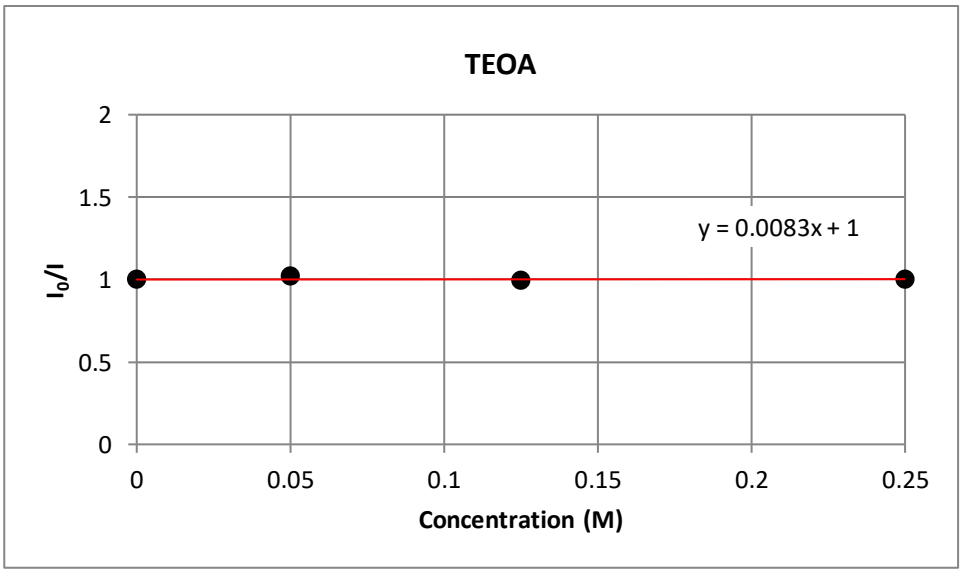
4.2 UV spectra and luminescence quenching studies

Luminescence experiments were performed to determine which species could be responsible for the quenching of the excited photocatalyst. Solutions (0.025–0.25 M in DMF) of DIPEA, TEOA, ethyl bromoacetate **2**, ketimine **1a,** ketimine **1f** and **1f** with 2 equivalents of TEOA were prepared in the presence of 1 µM $[Ru(bpy)_3]Cl_2 \cdot 6H_2O$. The absorbance of all compounds at 0.25 M concentration in DMF is less than 0.1 across the visible spectrum (350–850 nm, as verified by UV-vis absorption spectra), hence inner filter effects do not alter the luminescence measurements.[13]
The solutions were prepared under air, degassed for 15 minutes by bubbling N_2 and then transferred under N_2 into a 1 cm quartz cuvette. The excitation wavelength was set at 452 nm and the emission was recorded at 620 nm in arbitrary units.



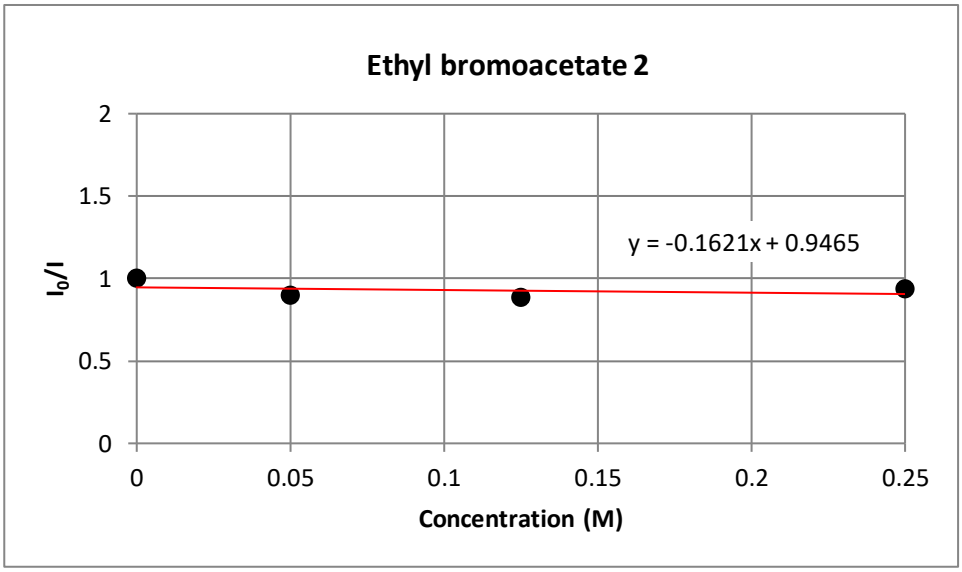
DIPEA (M)	I (a.u.)	I_0/I
0	403.3	1
0.05	359.5	1.122
0.125	322.3	1.252
0.25	283.7	1.421

$[Ru(bpy)_3]Cl_2 \cdot 6H_2O$ 1 µM in DMF; PMT voltage 900 V; λ_{exc} 452 nm; λ_{em} 620 nm.



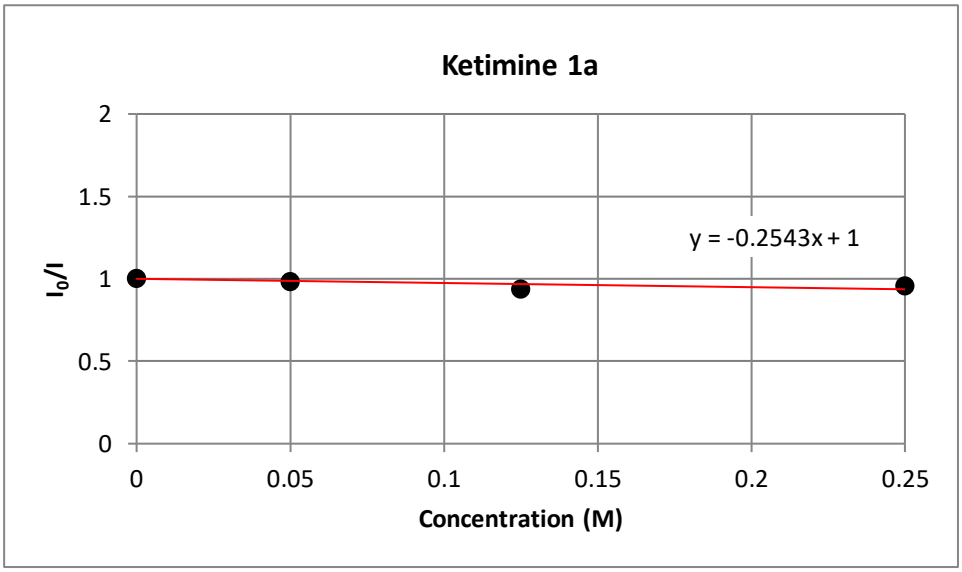
TEOA (M)	I (a.u.)	I_0/I
0	403.3	1
0.05	395.1	1.021
0.125	404.6	0.997
0.25	403.3	1.000

$[Ru(bpy)_3]Cl_2 \cdot 6H_2O$ 1 µM in DMF; PMT voltage 900 V; λ_{exc} 452 nm; λ_{em} 620 nm.



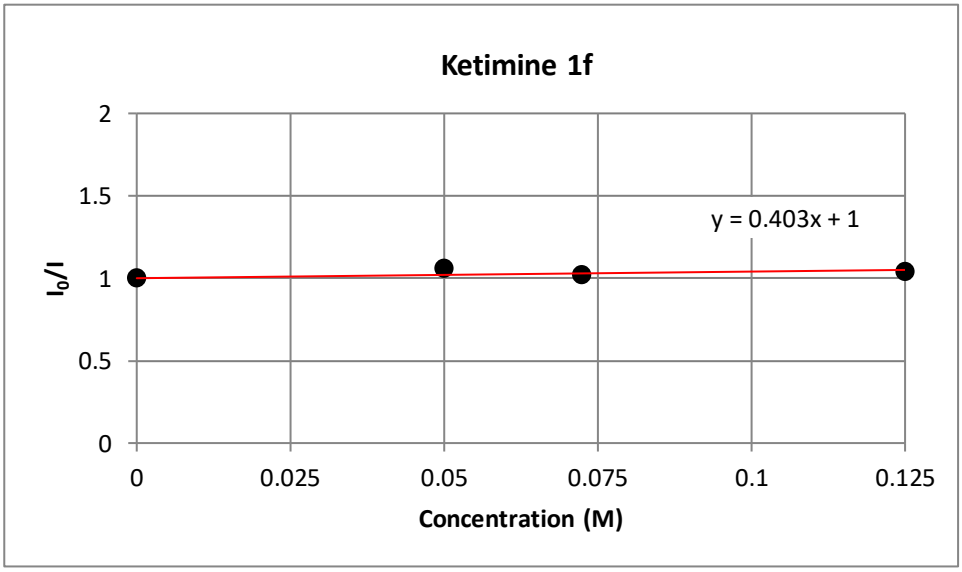
2 (M)	I (a.u.)	I_0/I
0	403.3	1
0.05	448.9	0.899
0.125	456.9	0.883
0.25	431.1	0.936

$[Ru(bpy)_3]Cl_2 \cdot 6H_2O$ 1 µM in DMF; PMT voltage 900 V; λ_{exc} 452 nm; λ_{em} 620 nm.



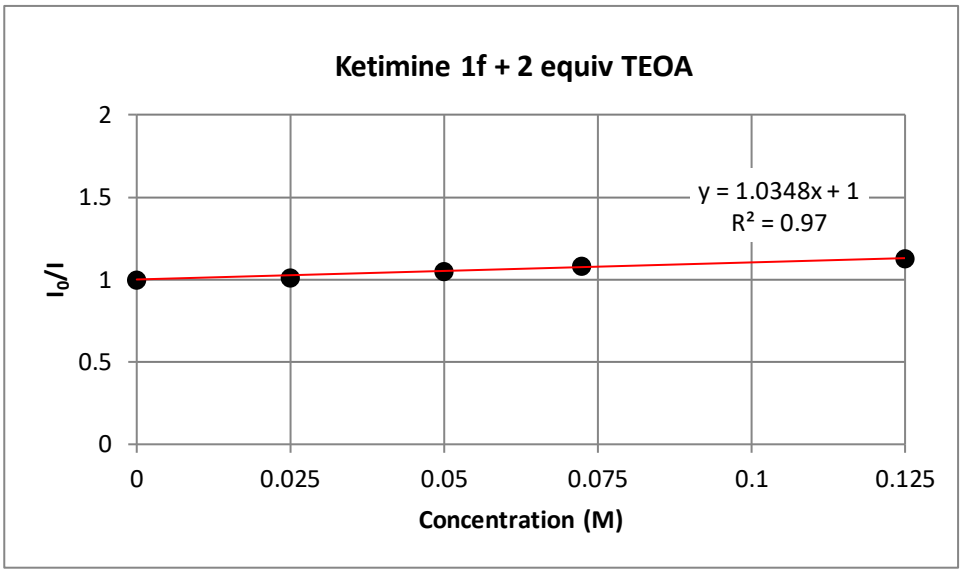
1a (M)	I (a.u.)	I_0/I
0	403.3	1
0.05	411.0	0.981
0.125	430.4	0.937
0.25	423.2	0.953

$[Ru(bpy)_3]Cl_2 \cdot 6H_2O$ 1 µM in DMF; PMT voltage 900 V; λ_{exc} 452 nm; λ_{em} 620 nm.



1f (M)	I (a.u.)	I_0/I
0	406.7	1
0.05	382.8	1.062
0.0725	399.1	1.019
0.125	391.3	1.039

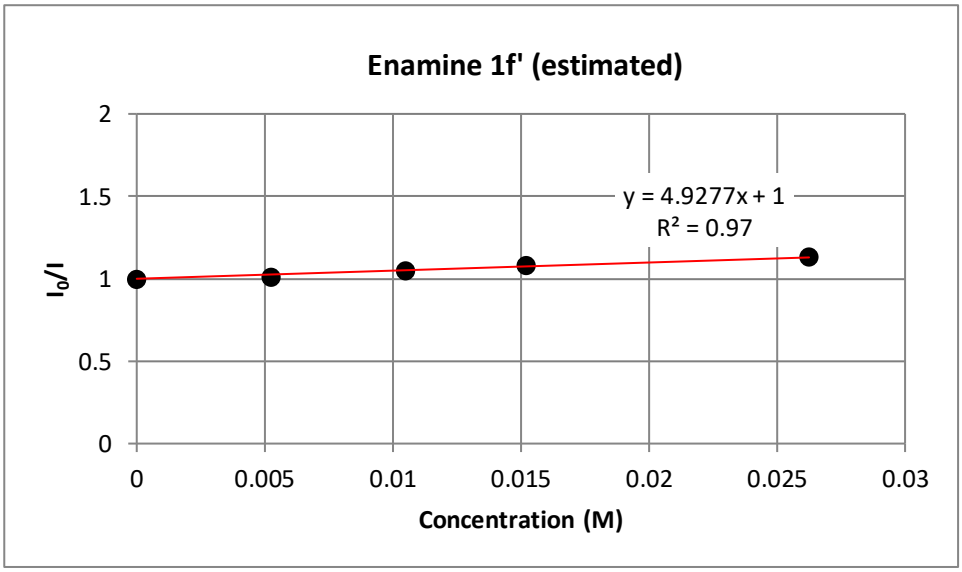
$[Ru(bpy)_3]Cl_2 \cdot 6H_2O$ 1 µM in DMF; PMT voltage 900 V; λ_{exc} 452 nm; λ_{em} 620 nm.



1f + TEOA (M)	I (a.u.)	I_0/I
0	406.7	1
0.025	403.4	1.008
0.05	387.7	1.049
0.0725	376.5	1.080
0.125	359.6	1.131

$[Ru(bpy)_3]Cl_2 \cdot 6H_2O$ 1 µM in DMF; PMT voltage 900 V; λ_{exc} 452 nm; λ_{em} 620 nm.

The percentage of enamine **1f'** present in the samples of **1f** with 2 equivalents of TEOA was measured by ^{31}P NMR analysis (100 µL of DMSO-d_6 were added to 400 µL of sample to allow locking and shimming). Regardless of their concentration (0.025–0.125 M), all samples displayed a 79:21 ketimine:enamine ratio, in good agreement with the 72:28 ratio observed in the NMR studies for 0.2 M solutions in pure DMSO-d_6 (see Section 4.1). The concentration of enamine **1f'** was therefore calculated by multiplying the nominal concentration of **1f** by a factor 0.21, and was plotted against I_0/I. As expected, the linear correlation between concentration of the quencher and I_0/I was maintained and the value of the angular coefficient (slope) increased.

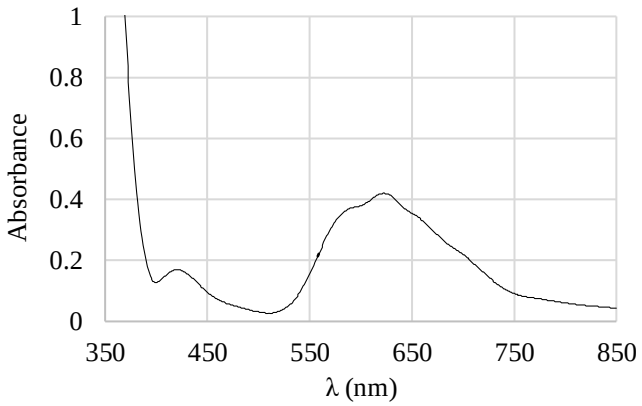


1f' (mM)	I (a.u.)	I_0/I
0	406.7	1
5.25	403.4	1.008
10.5	387.7	1.049
15.2	376.5	1.080
26.2	359.6	1.131

$[Ru(bpy)_3]Cl_2 \cdot 6H_2O$ 1 µM in DMF; PMT voltage 900 V; λ_{exc} 452 nm; λ_{em} 620 nm.

Overall, the luminescence quenching studies indicate that both DIPEA and the enamine **1'** of the starting ketimine **1** can act as quenchers for the excited ruthenium photocatalyst. TEOA, ethyl bromoacetate and ketimines (in the absence of base) did not quench the luminescence.[14] A sacrificial amount of the enamine tautomer of the starting material, whose formation is promoted by TEOA and DIPEA, can act as quencher/initiator for the catalytic cycle (see Section 4.4).

All the luminescence quenching experiments described above were performed without $[NiCl_2(PPh_3)_2]$, that was initially excluded by the studies in consideration of the fact that the reaction still takes place in its absence. $[NiCl_2(PPh_3)_2]$ absorbs light in the visible region at both the excitation and the emission wavelengths of the photocatalyst (452 nm and 620 nm, respectively) with a maximum at 622 nm.[1] Indeed, the samples used for the measurements displayed a range of colors from orange to dark green.



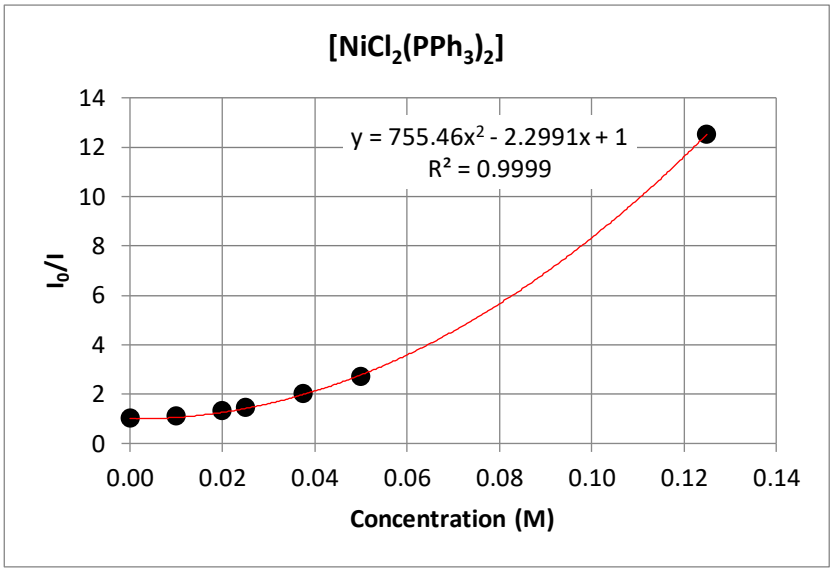
Electronic absorption spectrum of $[NiCl_2(PPh_3)_2]$ (12.5 mM in DMF). The visible region of the spectrum is dominated by a band at 622 nm.

The samples used for the Stern-Volmer studies displayed a range of colors from orange ($[Ru(bpy)_3]Cl_2 \cdot 6H_2O$ 200 µM only) to dark green ($[Ru(bpy)_3]Cl_2 \cdot 6H_2O$ 200 µM + $[NiCl_2(PPh_3)_2]$ 125 µM).

The luminescence intensity measured in the quenching experiments decreased with increasing concentration of $[NiCl_2(PPh_3)_2]$, and the Stern-Volmer plot shows the typical upward, positive deviation from linearity caused by inner filter effects or a mixed quenching process.[2] Unfortunately, based on this set of experiments alone, it remains unclear whether the observed behaviour is only a result of the diminished intensity of incident light at the excitation wavelength (primary inner filter

[1] This property is not obviously linked to the role of $[NiCl_2(PPh_3)_2]$. It is worth remembering that the colourless $Ni(OAc)_2 \cdot 4H_2O$ gave 45% yield of product (see Table S7).
[2] We unsuccesfully sought to apply corrections of inner filter effects to the raw data.[13,24]

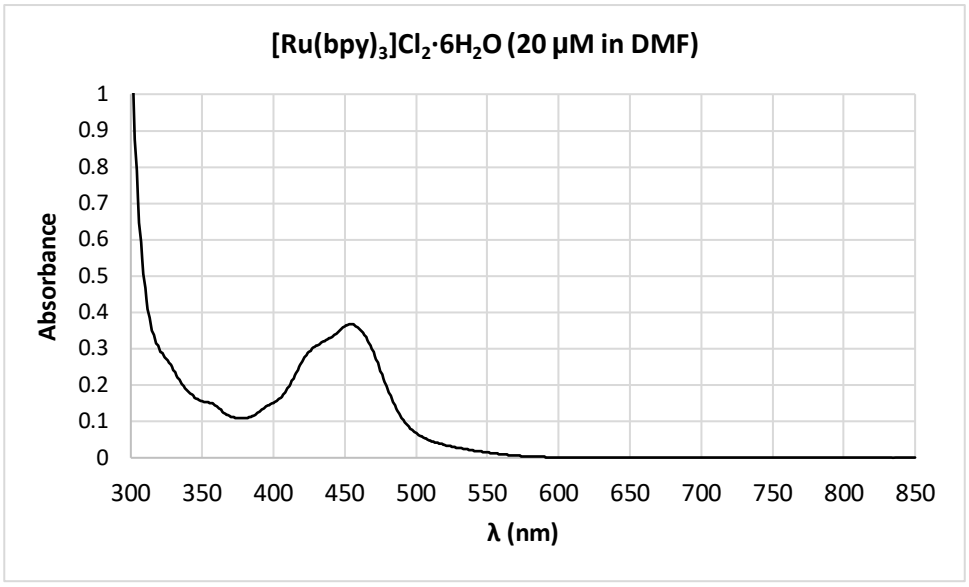
effects) and absorption of emitted photons (secondary inner filter effects) or can be, at least partially, attributed to a genuine quenching of $*[Ru(bpy)_3]^{2+}$ by $[NiCl_2(PPh_3)_2]$.

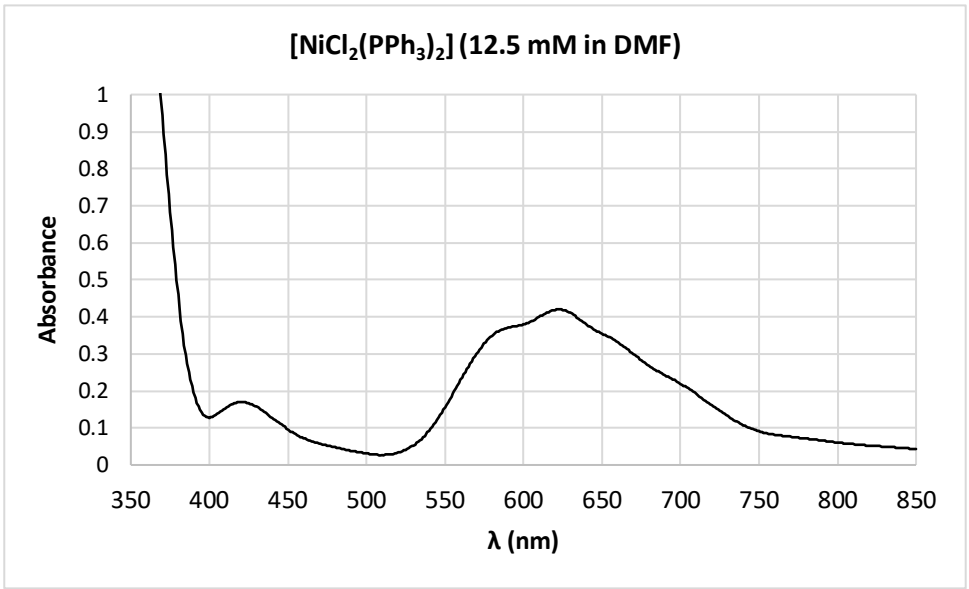


$[NiCl_2(PPh_3)_2]$ (mM)	I (a.u.)	I_0/I
0	222.1	1
10	208.0	1.101
20	175.0	1.302
25	153.2	1.450
37.5	114.3	2.004
50	82.70	2.686
125	17.73	12.53

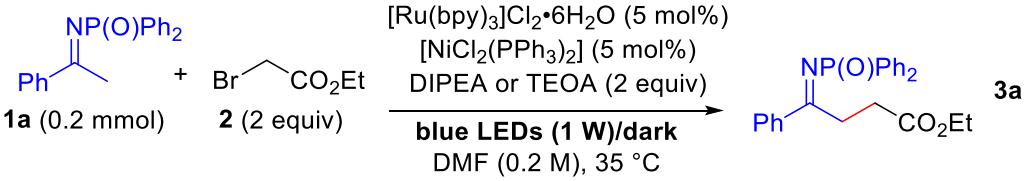
$[Ru(bpy)_3]Cl_2 \cdot 6H_2O$ 200 µM in DMF; PMT voltage 600 V; λ_{exc} 452 nm; λ_{em} 620 nm.

UV-visible absorption spectra

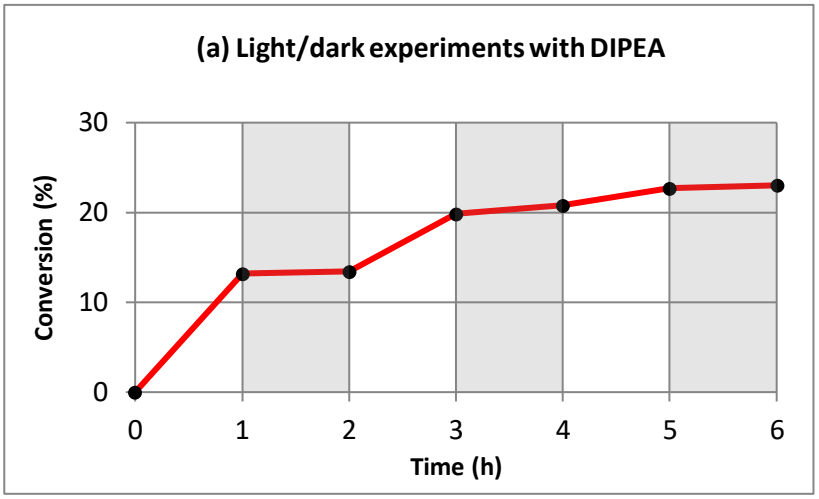




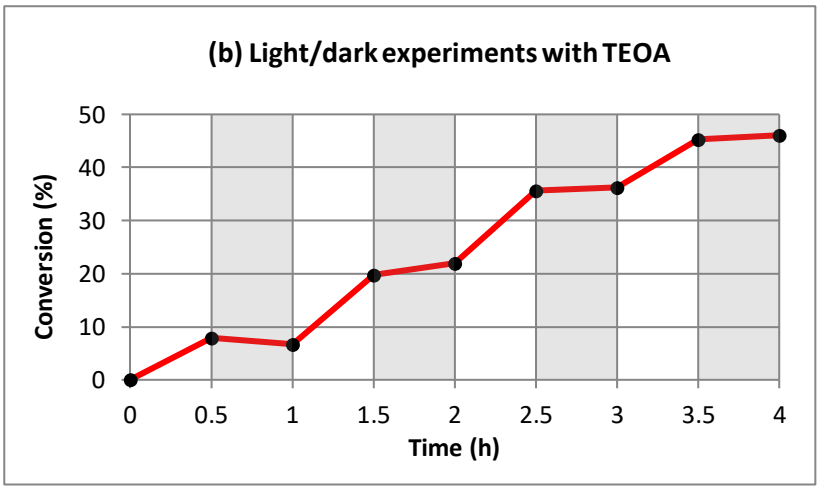
4.3 Light/dark cycles



Light dark/cycles for the reaction between **1a** and **2** using either DIPEA or TEOA were performed. The reaction vials were alternatively irradiated with blue light in the standard setup, then placed in a 35 °C oil bath covered with Al foil. Aliquots of the reaction mixture (50 µL) were taken every 30 or 60 minutes, diluted with $CDCl_3$ (400 µL) and analysed by 31P NMR. The conversion plotted in the graphs represents the consumption of **1a** as determined by the ratio of peaks in the 31P NMR spectrum. Each reaction was run in duplicate and the average value of conversion is plotted in the graphs.



Time (h)	Rxn 1 conv (%)	Rxn 2 conv (%)	Average conv (%)
1	12.9	13.6	13.3
2	12.8	14.0	13.4
3	21.0	18.8	19.9
4	21.9	19.8	20.9
5	23.2	22.3	22.7
6	23.0	23.1	23.0



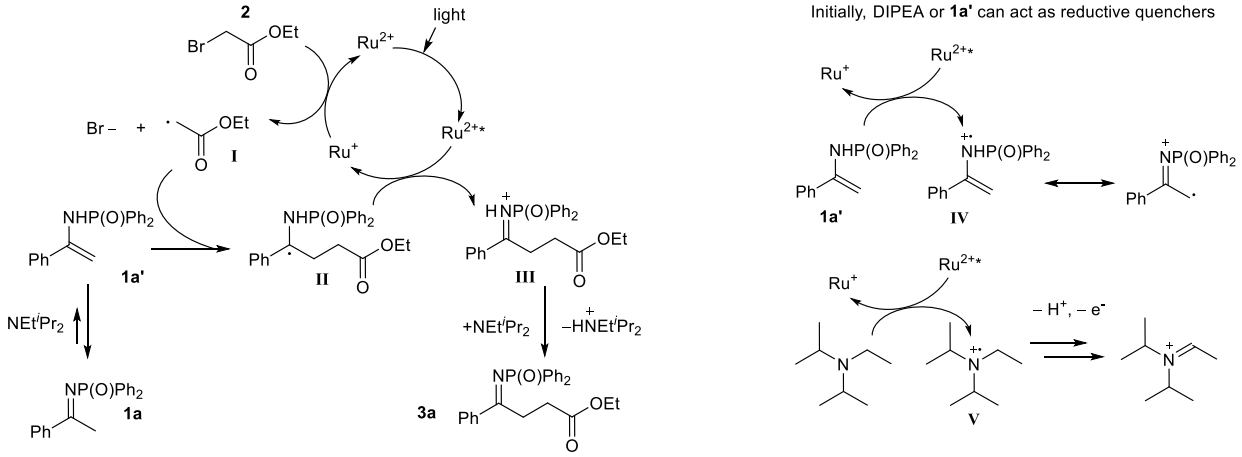
Time (h)	Rxn 1 conv (%)	Rxn 2 conv (%)	Average conv (%)
0.5	9.7	8.0	8.9
1	8.7	6.7	7.7
1.5	21.2	19.7	20.4
2	21.3	22.0	21.6
2.5	27.6	35.6	31.6
3	27.0	36.3	31.6
3.5	30.3	45.3	37.9
4	30.8	46.1	38.4

Using either base, the reaction proceeded significantly only under light irradiation. Minor positive and negative variations in conversion observed over dark periods are attributable to the error associated with the sampling technique. Variations between the duplicates are due to reproducibility issues; however please note that in every single reaction the start/stop trend with on/off irradiation is

evident. Over time, the rate of reaction promoted by DIPEA slows down, hence the steepness of the curve under light irradiation decreases.

4.4 Discussion of proposed mechanisms

Proposed mechanism



The equilibrium between **1a** and **1a'** is operative in the presence of DIPEA or TEOA, as demonstrated by NMR experiments (Section 4.1). DIPEA or the enamine form of electron-poor substrates can quench the luminescence of the excited Ru(II) complex, as determined by Stern-Volmer studies (Section 4.2). The α-aminoradical **II** can be oxidised to the protonated product **III** by the $*[Ru(bpy)_3]^{2+}$ or by the less oxidising but more abundant ethyl bromoacetate, in the case a radical chain mechanism is operative. Finally, deprotonation of compound **III** affords product **245a**. Depending on the nature of the ketimine and on the reaction conditions, **5a** may tautomerise and undergo a second alkylation.

The two SET steps are predicted to be spontaneous based on reduction potentials:

$E_{1/2}$ ($Ru^{2+}*/Ru^{+}$) = +0.77 V vs SCE in CH_3CN,[15]

$E_{1/2}$ (iminium/α-aminoradical) = ca –1.0 V vs SCE in CH_3CN,[16]

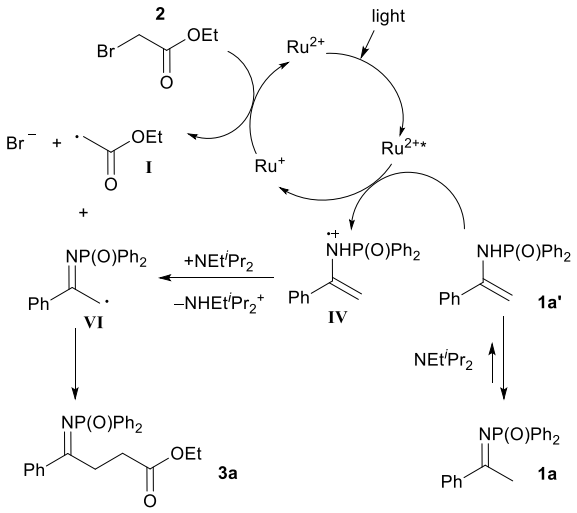
ΔE = +0.77 V – (–1.0 V) = +1.77 V, hence $Ru^{2+}*$ is reduced and α-aminoradical **II** oxidised.

$E_{p/2}^{red}$ (**2**) = –1.08 V vs SCE in CH_3CN,[17] $E_{1/2}^{red}$ (**2**) = –0.88 V vs SCE in DMF,[18]

$E_{1/2}$ (Ru^{2+}/Ru^{+}) = –1.33 V vs SCE in CH_3CN,[15]

ΔE = –1.08 V – (–1.33 V) = +0.25 V, hence ethyl bromoacetate **2** is reduced and Ru^{+} oxidised.

Alternative mechanism



At present, we cannot categorically exclude an alternative mechanism, where α-carbonyl radical **I** couples with enamine radical cation **IV**[19] that may be generated from the oxidation of **1a'** by the excited Ru^{2+}* (or with α-amino radical **VI** generated by subsequent proton abstraction). However, this mechanism appears to be less likely as α-aminoradicals ($E_{1/2}^{\text{iminium/α-aminoradical}}$ = ca −1.0 V in CH_3CN vs SCE)[16] are much easier to oxidise than enamines ($E_p^{\text{enamine radical cation/enamine}}$ = ca +0.4 V in CH_3CN vs SCE),[20] therefore **II** should be oxidised by Ru^{2+}* preferentially over **1a'**. Coupling between electron-poor radicals **I** and **VI** or **VI** would also suffer from unfavourable electronic effects.

The role of the nickel cocatalyst

The field of nickel metallaphotocatalysis has expanded at incredible pace in the last decade. While a large number of synthetic methods based on dual nickel/photoredox catalysis have been developed, the determination of the mechanisms involved is still object of debate.[21,22,23]

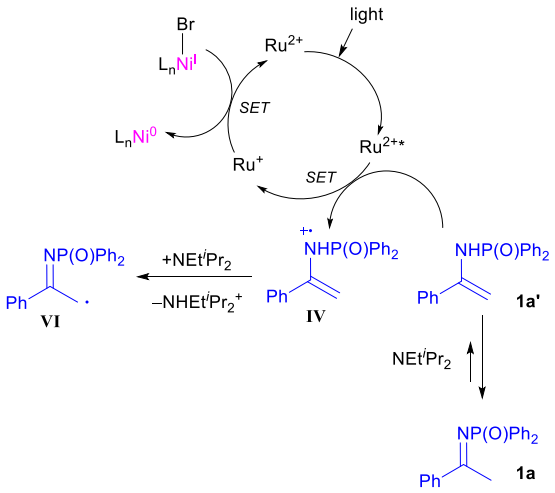
For very similar transformations, on some occasions completely different mechanisms have been proposed, as in the case of the photochemical Ni-catalysed α-arylations of cyclic ethers with aryl chlorides and bromides, published by the groups of Doyle[24] and Molander,[25] respectively.

In the present reaction, the beneficial effect of $[NiCl_2(PPh_3)_2]$ on yield and conversion might be linked to its ability to stabilise the radical species generated during the reaction or promote a more efficient reaction pathway.

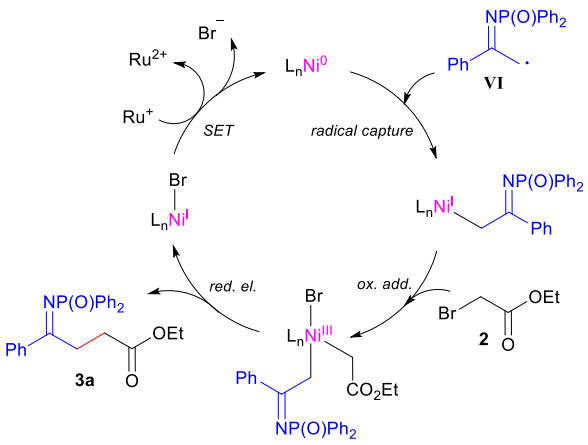
Based on the Stern-Volmer studies (see Section 4.2), both electron transfer[24] and energy transfer[25] (*eg* Dexter energy transfer)[26] from the excited photocatalyst to the nickel complex might take place.

In an alternative mechanistic picture, it is possible to imagine the intermediacy of organonickel species from which C–C bond-forming reductive elimination would occur. The often-invoked Ni(0)-Ni(I)-Ni(III)-Ni(I) and Ni(0)-Ni(II)-Ni(III)-Ni(I) catalytic cycles[22,23] can be proposed for the present alkylation of ketimines, as detailed in the scheme below. Under this hypothesis, reductive elimination from an organonickel (III) intermediate would help to overcome the unfavourable electronic effects associated with the direct coupling of two electron-poor radicals **I** and **VI**.

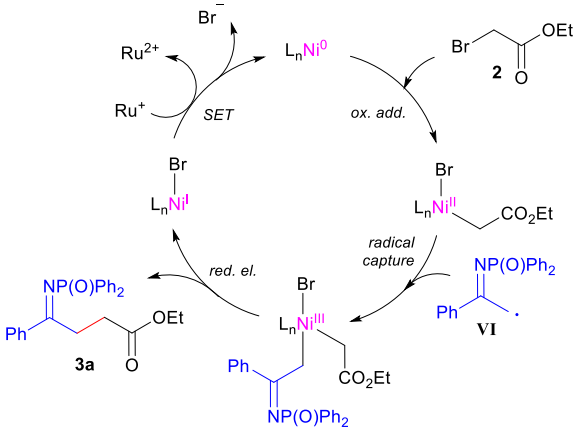
Common photocatalytic cycle



Ni (0)-(I)-(III)-(I) cycle [Molander][22]



Ni (0)-(II)-(III)-(I) cycle [MacMillan][23]



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