Supporting Information for:

A Multifaceted Approach Towards Understanding the Peculiar Behavior of α-Hydroxyiminophosphonates

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1. Additional experimental details

1.1 Chemicals

Chemicals, purity, CAS numbers and suppliers are provided in Table S1.

Table S1. Solvents, chemicals and suppliers

Solvents	Purity (%)	CAS Number	Supplier
THF	99.8	109-99-9	Fisher
Diethyl ether	>99	60-29-7	VWR
Ethanol (absolute)	>99	64-17-5	VWR
Hexane	98.5	110-54-3	VWR
Ethyl acetate	≥99.5	141-78-6	Aldrich
Methanol	>99	67-56-1	VWR
Petroleum ether (40-60)	>99	8032-32-4	VWR
Chloroform	>99.8	67-66-3	Fisher
Dichloromethane	>99.8	75-09-2	Fisher
Dimethylformamide	99	68-12-2	VWR

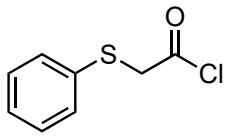
Chemicals	Purity (%)	CAS number	Supplier
Acetic acid (glacial)	≥ 99	64-19-7	VWR
Hydroxylamine hydrochloride	97	5470-11-1	TCI
Pyridine	99	110-86-1	TCI
Sodium bicarbonate	99	144-55-8	Sigma Aldrich
Triethyl phosphite	98	122-52-1	Sigma Aldrich
Trimethyl phosphite	97	121-45-9	Alfa Aesar
Triisopropyl phosphite	96	116-17-6	ACROS ORGANICS
Acetyl chloride	98	75-36-5	Sigma Aldrich
Phenylacetyl chloride	>98	103-80-0	TCI
Isovaleryl chloride	>99	108-12-3	TCI
4-Methoxyphenylacetyl chloride	98	4693-91-8	Alfa Aesar

3-(Methylthio)propionyl chloride	>98	7031-23-4	TCI
Isobutyryl chloride	>98	79-30-1	TCI
DL-2-Methylbutyryl chloride	98	57526-28-0	ACROS ORGANICS
3-Indoleacetic acid	>98	87-51-4	TCI
(Phenylthio)acetic acid	>98	103-04-8	TCI
Trimethylacetyl chloride	99	3282-30-2	Sigma Aldrich
Thionyl chloride	97	7719-09-7	Sigma Aldrich
Oxalyl chloride	98	79-37-8	Sigma Aldrich
Sodium cyanoborohydride	95	25895-60-7	ACROS ORGANICS
Sodium borohydride	95	16940-66-2	TCI
Borane pyridine complex	n.a.	110-51-0	Sigma Aldrich
Zinc dust	98	7440-66-6	Sigma Aldrich
Hydrogen chloride (2 N in Et_2O)	n.a.	7647-01-0	Sigma Aldrich

2.1 Additional experimental data

2.1.1 Procedures for the synthesis of acyl chlorides:

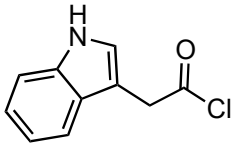
2.1.1.1 Batch procedure for the synthesis of 2-(phenylthio)acetyl chloride (**ac-15**)[1]



C_8H_7ClOS
MW 186,65

A mixture of thiophenoxyacetic acid (20.0 g, 118.90 mmol, 1 eq.) and $SOCl_2$ (21.56 mL, 297.20 mmol, 2.5 eq.) was refluxed (80°C) for 1h. The excess $SOCl_2$ was removed *in vacuo* (under a well ventilated fume hood) and the residual orange oil was purified by distillation to afford 2-(phenylthio)acetyl chloride (17.8 g, 80 %) as a yellow liquid; bp 162-166 °C/5 mbar.

2.1.1.2 Batch procedure for the synthesis of 2-(1*H*-indol-3-yl)acetyl chloride (**ac-16**)[2]



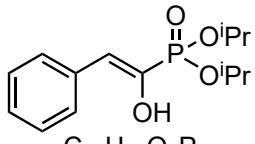
$C_{10}H_8ClNO$
MW193,63

Oxalyl chloride (2.7 mL, 31.40 mmol, 1.1 eq.) was added dropwise over 15 min to a stirred solution of indole-3-acetic acid (5.0 g, 28.55 mmol, 1 eq.) in 100 mL of dry dichloromethane under an argon atmosphere. The mixture was stirred at 0 °C for 5 min and then DMF (0.11 mL, 1.42 mmol, 0.05 eq.) was added in one portion. The solution was warmed at room temperature and then stirred until the evolution of gas ceased (roughly 30 min). The mixture was then concentrated under reduced pressure to leave the corresponding acyl chloride as an orange oil, which was used as is in the next step.

2.1.2 General procedure for the synthesis of α-keto-phosphonates (**1a – 16a**)

In a 250 mL flamed-dried round-bottomed flask was added the starting acyl chloride (100 mmol, 1 eq.) in 100 mL of dry diethyl ether. The mixture was then cooled down to 0 °C in an ice bath and the corresponding trialkylphosphite ($P(OMe)_3$, $P(OEt)_3$ or $P(O^iPr)_3$; 100 mmol, 1 eq.) was slowly added over 1 h using a syringe pump. Upon addition, the solution was heated to room temperature and left stirring overnight. The solvent was then evaporated under reduced pressure and the remaining product was either purified by recrystallisation (**iso-3a**), distillation under vacuum (**4a, 5a, 7a, 8a**), or used as is in the next step. Typical yields ranged from 62 to 97%

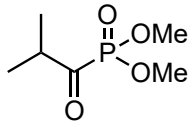
2.1.2.1 Batch procedure for the synthesis of diisopropyl (1-hydroxy-2-phenylvinyl)phosphonate (**iso-3a**)[3]



$C_{14}H_{21}O_4P$
MW 284,29

After evaporation of the solvent under reduced pressure, the crude oil was purified by recrystallization in hot hexane/ethyl acetate to yield the desired diisopropyl (1-hydroxy-2-phenylvinyl)phosphonate (enol form) (19.67 g, 69%) as white crystals; mp 81-84 °C.

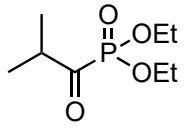
2.1.2.2 Batch procedure for the synthesis of dimethyl isobutyrylphosphonate (**4a**)[4]



$C_6H_{13}O_4P$
MW 180,14

After evaporation of the solvent under reduced pressure, the crude oil was purified by distillation under vacuum to afford dimethyl isobutyrylphosphonate (ketone form) (14.20 g, 79%) as a transparent oil; bp 140-142°C/10mbar.

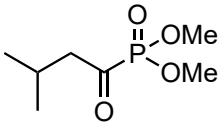
2.1.2.3 Batch procedure for the synthesis of diethyl isobutyrylphosphonate (**5a**)[5]



$C_8H_{17}O_4P$
MW 208,19

After evaporation of the solvent under reduced pressure, the crude oil was purified by distillation under vacuum to afford diethyl isobutyrylphosphonate (ketone form) (15.76 g, 76%) as a transparent oil; bp 144-150°C/10mbar.

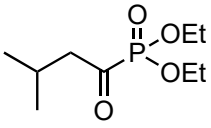
2.1.2.4 Batch procedure for the synthesis of dimethyl (3-methylbutanoyl)phosphonate (**7a**)[6]



$C_7H_{15}O_4P$
MW 194,17

After evaporation of the solvent under reduced pressure, the crude oil was purified by distillation under vacuum to afford dimethyl (3-methylbutanoyl)phosphonate (ketone form) (12.10 g, 62%) as a transparent oil; bp 148-152°C/10mbar.

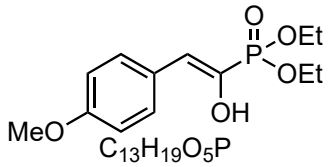
2.1.2.5 Batch procedure for the synthesis of diethyl (3-methylbutanoyl)phosphonate (**8a**)[7]



$C_9H_{19}O_4P$
MW 222,22

After evaporation of the solvent under reduced pressure, the crude oil was purified by distillation under vacuum to afford diethyl (3-methylbutanoyl)phosphonate (ketone form) (14.61 g, 66%) as a transparent oil; bp 150-154°C/10mbar.

2.1.2.6 Batch procedure for the synthesis of diethyl (1-hydroxy-2-(4-methoxyphenyl)vinyl)phosphonate (**iso-13a**)[5]



$C_{13}H_{19}O_5P$
MW 286,26

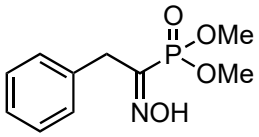
After evaporation of the solvent under reduced pressure we obtained the desired diethyl (1-hydroxy-2-(4-methoxyphenyl)vinyl)phosphonate (enol form) (18.34 g, 64%) as an off-white powder.

2.1.3 Procedures for the synthesis of α-hydroxyiminophosphonates (oximes)

2.1.3.1 General batch procedure for the preparation of α-hydroxyiminophosphonates (**1b – 16b**)

The corresponding (α)-ketophosphonate intermediate (1 eq.) was added to a solution of hydroxylamine hydrochloride (1.2 eq.) in dry pyridine (2.2 eq.) and absolute ethanol (30 mL). The reaction mixture was stirred at room temperature for 12 h and then concentrated under reduced pressure. The crude product was dissolved in dichloromethane (70 mL), washed with 3 N HCl (3 × 50 mL) and water (50 mL). the organic layer was dried with anhydrous Na_2SO_4, filtered and concentrated *in vacuo* to provide the desired (α)-hydroxyiminophosphonate as a mixture of two isomers (*E*/*Z*). In some cases, further purification by recrystallization (**2b**,**16b**) or column purification (**11b**, **12b**, **14b**, **15b**) was required to reach high purity. Typical yields ranged from 45 to 92%.

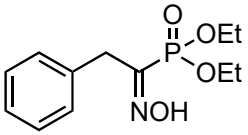
2.1.3.2 Batch procedure for the synthesis of dimethyl (1-(hydroxyimino)-2-phenylethyl)phosphonate (**1b**)[8]



$C_{10}H_{14}NO_4P$
MW 243,20

Dimethyl (2-phenylacetyl)phosphonate (2.5 g, 11.13 mmol, 1 eq.) was added to a solution of hydroxylamine hydrochloride (0.9 g, 13.36 mmol, 1.2 eq.) in dry pyridine (1.9 g, 24.49 mmol, 2.2 eq.) and absolute ethanol (20 mL). The reaction mixture was stirred at room temperature for 12 h and then concentrated under reduced pressure. The crude product was dissolved in ethyl acetate (50 mL), washed with 3 N HCl (3 × 40 mL) and water (40 mL). The organic layer was dried with anhydrous Na_2SO_4, filtered and concentrated *in vacuo* to provide the desired dimethyl (1-(hydroxyimino)-2-phenylethyl)phosphonate (1.7 g, 63% isolated yield) as a mixture of two isomers (*E*/*Z*, 47.4/52.6) (transparent oil).

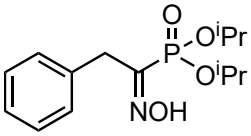
2.1.3.3 Batch procedure for the synthesis of diethyl (1-(hydroxyimino)-2-phenylethyl)phosphonate (**2b**)[9]



$C_{12}H_{18}NO_4P$
MW 271,25

Diethyl (2-phenylacetyl)phosphonate (4.0 g, 15.61 mmol, 1 eq.) was added to a solution of hydroxylamine hydrochloride (1.3 g, 18.73 mmol, 1.2 eq.) in dry pyridine (2.7 g, 34.34 mmol, 2.2 eq.) and absolute ethanol (30 mL). The reaction mixture was stirred at room temperature for 12 h and then concentrated under reduced pressure. The crude product was dissolved in dichloromethane (70 mL), washed with 3 N HCl (3 × 50 mL) and water (50 mL). The organic layer was dried with anhydrous Na_2SO_4, filtered and concentrated *in vacuo*. The residual sluggish oil was recrystallized from cyclohexane:EtOH to provide the desired diethyl (1-(hydroxyimino)-2-phenylethyl)phosphonate (2.8 g, 66% isolated yield) as a mixture of two isomers (*E*/*Z*, 71.4/28.6) (white crystals; mp 49-52 °C).

2.1.3.4 Batch procedure for the synthesis of diisopropyl (1-(hydroxyimino)-2-phenylethyl)phosphonate (**3b**)



$C_{14}H_{22}NO_4P$
MW 299,31

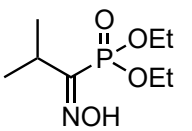
Diisopropyl (2-phenylacetyl)phosphonate (4.0 g, 14.07 mmol, 1 eq.) was added to a solution of hydroxylamine hydrochloride (1.2 g, 16.88 mmol, 1.2 eq.) in dry pyridine (2.4 g, 30.95 mmol, 2.2 eq.) and absolute ethanol (30 mL). The reaction mixture was stirred at room temperature for 12 h and then concentrated under reduced pressure. The crude product was dissolved in dichloromethane (70 mL), washed with 3 N HCl (3 × 50 mL) and water (50 mL). The organic layer was dried with anhydrous Na_2SO_4, filtered and concentrated *in vacuo*. Upon evaporation of the residual solvent, the oily residue solidified to yield the desired diisopropyl (1-(hydroxyimino)-2-phenylethyl)phosphonate (3.4 g, 81% isolated yield) as a mixture of two isomers (*E*/*Z*, 95.2/4.8) (white solid). Recrystallization of the crude solid in boiling EtOH enabled to obtain the product as the sole *E* isomer (white crystals; mp 94-97 °C).

2.1.3.5 Batch procedure for the synthesis of dimethyl (1-(hydroxyimino)-2-methylpropyl)phosphonate (**4b**)

$C_6H_{14}NO_4P$
MW 195,15

Dimethyl isobutyrylphosphonate (5.0 g, 27.75 mmol, 1 eq.) was added to a solution of hydroxylamine hydrochloride (2.3 g, 33.31 mmol, 1.2 eq.) in dry pyridine (4.8 g, 61.06 mmol, 2.2 eq.) and absolute ethanol (30 mL). The reaction mixture was stirred at room temperature for 12 h and then concentrated under reduced pressure. The crude product was dissolved in dichloromethane (70 mL), washed with 3 N HCl (3 × 50 mL) and water (50 mL). The organic layer was dried with anhydrous Na_2SO_4, filtered and concentrated *in vacuo* to provide the desired dimethyl (1-(hydroxyimino)-2-methylpropyl)phosphonate (3.6 g, 66% isolated yield) as a mixture of two isomers (*E*/*Z*, 45.7/54.3) (white solid).

2.1.3.6 Batch procedure for the synthesis of diethyl (1-(hydroxyimino)-2-methylpropyl)phosphonate (**5b**)[10]

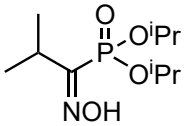


$C_8H_{18}NO_4P$
MW 223,21

Diethyl isobutyrylphosphonate (6.0 g, 28.82 mmol, 1 eq.) was added to a solution of hydroxylamine hydrochloride (2.4 g, 34.58 mmol, 1.2 eq.) in dry pyridine (5.0 g, 63.40 mmol, 2.2 eq.) and absolute ethanol (30 mL). The reaction mixture was stirred

at room temperature for 12 h and then concentrated under reduced pressure. The crude product was dissolved in dichloromethane (70 mL), washed with 3 N HCl (3 × 50 mL) and water (50 mL). The organic layer was dried with anhydrous Na_2SO_4, filtered and concentrated *in vacuo* to provide the desired diethyl (1-(hydroxyimino)-2-methylpropyl)phosphonate (5.2 g, 81% isolated yield) as a mixture of two isomers (*E*/*Z*, 52.6/47.4) (white solid).

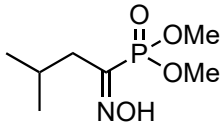
2.1.3.7 Batch procedure for the synthesis of diisopropyl (1-(hydroxyimino)-2-methylpropyl)phosphonate (**6b**)



$C_{10}H_{22}NO_4P$
MW 251,26

Diisopropyl isobutyrylphosphonate (7.0 g, 29.63 mmol, 1 eq.) was added to a solution of hydroxylamine hydrochloride (2.5 g, 35.55 mmol, 1.2 eq.) in dry pyridine (5.2 g, 65.18 mmol, 2.2 eq.) and absolute ethanol (30 mL). The reaction mixture was stirred at room temperature for 12 h and then concentrated under reduced pressure. The crude product was dissolved in dichloromethane (70 mL), washed with 3 N HCl (3 × 50 mL) and water (50 mL). The organic layer was dried with anhydrous Na_2SO_4, filtered and concentrated *in vacuo* to provide the desired diisopropyl (1-(hydroxyimino)-2-methylpropyl)phosphonate (6.6 g, 88% isolated yield) as a mixture of two isomers (*E*/*Z*, 73.5/26.5) (white solid).

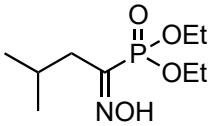
2.1.3.8 Batch procedure for the synthesis of dimethyl (1-(hydroxyimino)-3-methylbutyl)phosphonate (**7b**)[8]



$C_7H_{16}NO_4P$
MW 209,18

Dimethyl (3-methylbutanoyl)phosphonate (4.0 g, 20.60 mmol, 1 eq.) was added to a solution of hydroxylamine hydrochloride (1.7 g, 24.72 mmol, 1.2 eq.) in dry pyridine (3.6 g, 45.32 mmol, 2.2 eq.) and absolute ethanol (30 mL). The reaction mixture was stirred at room temperature for 12 h and then concentrated under reduced pressure. The crude product was dissolved in dichloromethane (70 mL), washed with 3 N HCl (3 × 50 mL) and water (50 mL). The organic layer was dried with anhydrous Na_2SO_4, filtered and concentrated *in vacuo* to provide the desired dimethyl (1-(hydroxyimino)-3-methylbutyl)phosphonate (3.1 g, 71% isolated yield) as a mixture of two isomers (*E*/*Z*, 39.8/60.2) (transparent oil).

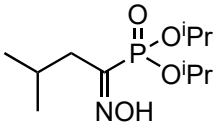
2.1.3.9 Batch procedure for the synthesis of diethyl (1-(hydroxyimino)-3-methylbutyl)phosphonate (**8b**)[10]



$C_9H_{20}NO_4P$
MW 237,24

Diethyl (3-methylbutanoyl)phosphonate (8.9 g, 40.0 mmol, 1 eq.) was added to a solution of hydroxylamine hydrochloride (3.3 g, 48.0 mmol, 1.2 eq.) in dry pyridine (6.9 g, 88.0 mmol, 2.2 eq.) and absolute ethanol (50 mL). The reaction mixture was stirred at room temperature for 12 h and then concentrated under reduced pressure. The crude product was dissolved in dichloromethane (100 mL), washed with 3 N HCl (3 × 60 mL) and water (60 mL). The organic layer was dried with anhydrous Na_2SO_4, filtered and concentrated *in vacuo* to provide the desired diethyl (1-(hydroxyimino)-3-methylbutyl)phosphonate (7.2 g, 76% isolated yield) as a mixture of two isomers (*E*/*Z*, 50.5/49.5) (transparent oil).

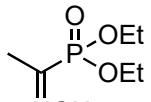
2.1.3.10 Batch procedure for the synthesis of diisopropyl (1-(hydroxyimino)-3-methylbutyl)phosphonate (**9b**)



$C_{11}H_{24}NO_4P$
MW 265,29

Diisopropyl (3-methylbutanoyl)phosphonate (4.0 g, 15.98 mmol, 1 eq.) was added to a solution of hydroxylamine hydrochloride (1.3 g, 19.20 mmol, 1.2 eq.) in dry pyridine (2.8 g, 35.16 mmol, 2.2 eq.) and absolute ethanol (30 mL). The reaction mixture was stirred at room temperature for 12 h and then concentrated under reduced pressure. The crude product was dissolved in dichloromethane (70 mL), washed with 3 N HCl (3 × 50 mL) and water (50 mL). The organic layer was dried with anhydrous Na_2SO_4, filtered and concentrated *in vacuo* to provide the desired diisopropyl (1-(hydroxyimino)-3-methylbutyl)phosphonate (3.9 g, 92% isolated yield) as a mixture of two isomers (*E*/*Z*, 58.5/41.5) (transparent oil).

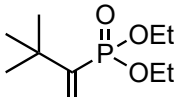
2.1.3.11 Batch procedure for the synthesis of diethyl (1-(hydroxyimino)ethyl)phosphonate (**10b**)[11]



$C_6H_{14}NO_4P$
MW 195,15

Diethyl acetylphosphonate (4.0 g, 22.21 mmol, 1 eq.) was added to a solution of hydroxylamine hydrochloride (1.8 g, 26.65 mmol, 1.2 eq.) in dry pyridine (3.8 g, 48.84 mmol, 2.2 eq.) and absolute ethanol (30 mL). The reaction mixture was stirred at room temperature for 12 h and then concentrated under reduced pressure. The crude product was dissolved in dichloromethane (70 mL), washed with 3 N HCl (3 × 50 mL) and water (50 mL). The organic layer was dried with anhydrous Na_2SO_4, filtered and concentrated *in vacuo* to provide the desired diethyl (1-(hydroxyimino)ethyl)phosphonate (3.6 g, 83% isolated yield) as a mixture of two isomers (*E*/*Z*, 98.0/2.0) (transparent oil).

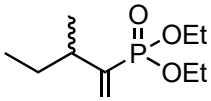
2.1.3.12 Batch procedure for the synthesis of diethyl (1-(hydroxyimino)-2,2-dimethylpropyl)phosphonate (**11b**)[12]



$C_9H_{20}NO_4P$
MW 237,24

Diethyl pivaloylphosphonate (5.0 g, 22.50 mmol, 1 eq.) was added to a solution of hydroxylamine hydrochloride (1.9 g, 27.00 mmol, 1.2 eq.) in dry pyridine (3.9 g, 49.50 mmol, 2.2 eq.) and absolute ethanol (30 mL). The reaction mixture was stirred at room temperature for 12 h and then concentrated under reduced pressure. The crude product was dissolved in ethyl acetate (70 mL), washed with 3 N HCl (3 × 50 mL) and water (50 mL). The organic layer was dried with anhydrous Na_2SO_4, filtered and concentrated *in vacuo*. The residual oil was purified by column chromatography using 70:30 (v:v) EtOAc:petroleum ether (40-60) to provide the desired diethyl (1-(hydroxyimino)-2,2-(dimethylpropyl)phosphonate (Rf = 0.49) (3.2 g, 60% isolated yield) as a mixture of two isomers (*E*/*Z*, 58.5/41.5) (transparent oil).

2.1.3.13 Batch procedure for the synthesis of diethyl (1-(hydroxyimino)-2-methylbutyl)phosphonate (**12b**)

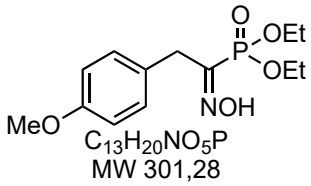


$C_9H_{20}NO_4P$
MW 237,24

Diethyl (2-methylbutanoyl)phosphonate (5.0 g, 22.50 mmol, 1 eq.) was added to a solution of hydroxylamine hydrochloride (1.9 g, 27.00 mmol, 1.2 eq.) in dry pyridine (3.9 g, 49.50 mmol, 2.2 eq.) and absolute ethanol (30 mL). The reaction mixture was stirred at room temperature for 12 h and then concentrated under reduced pressure. The crude product was dissolved in dichloromethane (70 mL), washed with 3 N HCl (3 × 50 mL) and water (50 mL). The organic layer was dried with anhydrous

Na_2SO_4, filtered and concentrated *in vacuo*. The residual oil was purified by column chromatography using 90:10 (v:v) EtOAc:petroleum ether (40-60) to provide the desired diethyl (1-(hydroxyimino)-2-methylbutyl)phosphonate (Rf = 0.61) (3.3 g, 62% isolated yield) as a mixture of two isomers (*E*/*Z*, 29.6/70.4) (transparent oil).

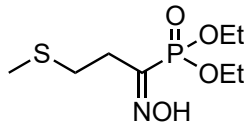
2.1.3.14 Batch procedure for the synthesis of diethyl (1-(hydroxyimino)-2-(4-methoxyphenyl)ethyl)phosphonate (**13b**)[13]



$C_{13}H_{20}NO_5P$
MW 301,28

Diethyl (2-(4-methoxyphenyl)acetyl)phosphonate (7.0 g, 24.45 mmol, 1 eq.) was added to a solution of hydroxylamine hydrochloride (2.0 g, 29.34 mmol, 1.2 eq.) in dry pyridine (4.2 g, 53.80 mmol, 2.2 eq.) and absolute ethanol (30 mL). The reaction mixture was stirred at room temperature for 12 h and then concentrated under reduced pressure. The crude product was dissolved in dichloromethane (70 mL), washed with 3 N HCl (3 × 50 mL) and water (50 mL). The organic layer was dried with anhydrous Na_2SO_4, filtered and concentrated *in vacuo* to provide the desired diethyl (1-(hydroxyimino)-2-(4-methoxyphenyl)ethyl)phosphonate (5.8 g, 79% isolated yield) as a mixture of two isomers (*E*/*Z*, 71.9/28.1) (transparent oil).

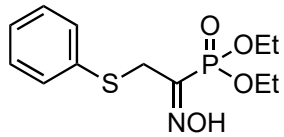
2.1.3.15 Batch procedure for the synthesis of diethyl (1-(hydroxyimino)-3-(methylthio)propyl)phosphonate (**14b**)[10]



$C_8H_{18}NO_4PS$
MW 255,27

Diethyl (3-(methylthio)propanoyl)phosphonate (5.0 g, 20.81 mmol, 1 eq.) was added to a solution of hydroxylamine hydrochloride (1.7 g, 24.97 mmol, 1.2 eq.) in dry pyridine (3.6 g, 45.78 mmol, 2.2 eq.) and absolute ethanol (30 mL). The reaction mixture was stirred at room temperature for 12 h and then concentrated under reduced pressure. The crude product was dissolved in dichloromethane (70 mL), washed with 3 N HCl (3 × 50 mL) and water (50 mL). The organic layer was dried with anhydrous Na_2SO_4, filtered and concentrated *in vacuo*. The residual oil was purified by column chromatography using 60:40 (v:v) EtOAc:petroleum ether (40-60) to provide the desired diethyl (1-(hydroxyimino)-3-(methylthio)propyl)phosphonate (Rf = 0.40) (2.8 g, 53% isolated yield) as a mixture of two isomers (*E*/*Z*, 94.3/5.7) (transparent oil).

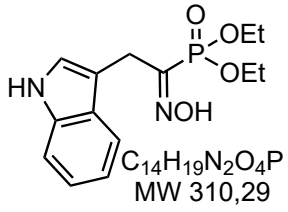
2.1.3.16 Batch procedure for the synthesis of diethyl (1-(hydroxyimino)-2-(phenylthio)ethyl)phosphonate (**15b**)



$C_{12}H_{18}NO_4PS$
MW 303,31

Diethyl (2-(phenylthio)acetyl)phosphonate (6.0 g, 21.05 mmol, 1 eq.) was added to a solution of hydroxylamine hydrochloride (1.7 g, 25.26 mmol, 1.2 eq.) in dry pyridine (3.6 g, 46.32 mmol, 2.2 eq.) and absolute ethanol (30 mL). The reaction mixture was stirred at room temperature for 12 h and then concentrated under reduced pressure. The crude product was dissolved in dichloromethane (70 mL), washed with 3 N HCl (3 × 50 mL) and water (50 mL). The organic layer was dried with anhydrous Na_2SO_4, filtered and concentrated *in vacuo*. The residual oil was purified by column chromatography using 70:30 (v:v) EtOAc:petroleum ether (40-60) to provide the desired diethyl (1-(hydroxyimino)-2-(phenylthio)ethyl)phosphonate (Rf = 0.30) (2.9 g, 45% isolated yield) as a mixture of two isomers (*E*/*Z*, 68.9/31.1) (transparent oil).

2.1.3.17 Batch procedure for the synthesis of diethyl (1-(hydroxyimino)-2-(1*H*-indol-3-yl)ethyl)phosphonate (**16b**)[2]



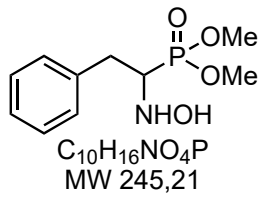
The crude diethyl (2-(1*H*-indol-3-yl)acetyl)phosphonate (8.4 g, 28.55 mmol, 1 eq.) was added to a solution of hydroxylamine hydrochloride (2.4 g, 34.26 mmol, 1.2 eq.) in dry pyridine (4.9 g, 62.81 mmol, 2.2 eq.) and absolute ethanol (30 mL). The reaction mixture was stirred at room temperature for 12 h and then concentrated under reduced pressure. The crude product was dissolved in dichloromethane (70 mL), washed with 3 N HCl (3 × 50 mL) and water (50 mL). The organic layer was dried with anhydrous Na_2SO_4, filtered and concentrated *in vacuo*. The residual brown sluggish oil was dissolved in cold dichloromethane and left in the fridge (+ 4 °C) overnight. The next morning, an off-white powder was filtered and dried under vacuum to provide the desired diethyl (1-(hydroxyimino)-2-(1*H*-indol-3-yl)ethyl)phosphonate (2.2 g, 25% isolated yield over 3 steps) as a mixture of two isomers (*E*/*Z*, 45.3/54.7) (off-white powder).

2.1.4 Procedures for the synthesis of α-hydroxyaminophosphonates (hydroxylamines)

2.1.4.1 General batch procedure for the final reduction step towards α-hydroxyaminophosphonates (**1c – 16c**)

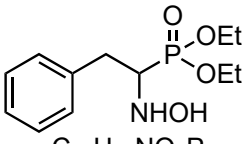
The corresponding (α)-hydroxyiminophosphonate intermediate (1 eq.) was dissolved in absolute ethanol (20 mL). Sodium cyanoborohydride (3 eq.) was then added to the reaction mixture in small portions and the pH of the solution was decreased down to pH ~ 3 by dropwise addition of freshly prepared 4 N HCl in methanol (4 mL). The reaction mixture was stirred overnight at room temperature and then concentrated under reduced pressure. The crude product was dissolved in dichloromethane (100 mL) and washed with 3N HCl (5 × 30 mL). The pH of the combined aqueous layers was adjusted to 8 with the slow addition of solid Na_2CO_3 and extracted with dichloromethane (4 × 30 mL). The combined organic layers were dried with anhydrous Na_2SO_4, filtered and concentrated *in vacuo* to provide the desired final (α)-hydroxyaminophosphonate derivative. Typical yields ranged from 1 to 46%.

2.1.4.2 Batch procedure for the synthesis of dimethyl (1-(hydroxyamino)-2-phenylethyl)phosphonate (**1c**)



Dimethyl (1-(hydroxyimino)-2-phenylethyl)phosphonate (3.65 g, 15.00 mmol, 1 eq.) was dissolved in absolute ethanol (20 mL). Sodium cyanoborohydride (2.83 g, 45.00 mmol, 3 eq.) was then added to the reaction mixture in small portions and the pH of the solution was decreased down to pH ~ 3 by dropwise addition of freshly prepared 4 N HCl in methanol (4 mL). The reaction mixture was stirred overnight at room temperature and then concentrated under reduced pressure. The crude product was dissolved in dichloromethane (100 mL) and washed with 3 N HCl (5 × 30 mL). The pH of the combined aqueous layers was adjusted to 8 with the slow addition of solid Na_2CO_3 and extracted with dichloromethane (4 × 30 mL). The combined organic layers were dried with anhydrous Na_2SO_4, filtered and concentrated *in vacuo* to provide the desired dimethyl (1-(hydroxyamino)-2-phenylethyl)phosphonate (0.75 g, 20% isolated yield) as a yellow oil.

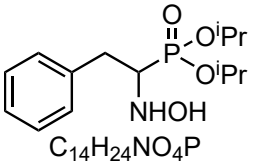
2.1.4.3 Batch procedure for the synthesis of diethyl (1-(hydroxyamino)-2-phenylethyl)phosphonate (**2c**)[14]



$C_{12}H_{20}NO_4P$
MW 273,27

Diethyl (1-(hydroxyimino)-2-phenylethyl)phosphonate (1.20 g, 4.42 mmol, 1 eq.) was dissolved in absolute ethanol (10 mL). Sodium cyanoborohydride (0.83 g, 13.26 mmol, 3 eq.) was then added to the reaction mixture in small portions and the pH of the solution was decreased down to pH ~ 3 by dropwise addition of freshly prepared 4 N HCl in methanol (3 mL). The reaction mixture was stirred overnight at room temperature and then concentrated under reduced pressure. The crude product was dissolved in dichloromethane (50 mL) and washed with 3 N HCl (5 × 20 mL). The pH of the combined aqueous layers was adjusted to 8 with the slow addition of solid Na_2CO_3 and extracted with dichloromethane (4 × 20 mL). The combined organic layers were dried with anhydrous Na_2SO_4, filtered and concentrated *in vacuo* to provide the desired diethyl (1-(hydroxyamino)-2-phenylethyl)phosphonate (0.31 g, 25% isolated yield) as a pink oil.

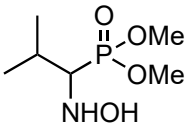
2.1.4.4 Batch procedure for the synthesis of diisopropyl (1-(hydroxyamino)-2-phenylethyl)phosphonate (**3c**)



$C_{14}H_{24}NO_4P$
MW 301,32

Diisopropyl (1-(hydroxyimino)-2-phenylethyl)phosphonate (1.83 g, 6.11 mmol, 1 eq.) was dissolved in absolute ethanol (15 mL). Sodium cyanoborohydride (1.15 g, 18.34 mmol, 3 eq.) was then added to the reaction mixture in small portions and the pH of the solution was decreased down to pH ~ 3 by dropwise addition of freshly prepared 4 N HCl in methanol (4 mL). The reaction mixture was stirred overnight at room temperature and then concentrated under reduced pressure. The crude product was dissolved in dichloromethane (50 mL) and washed with 3 N HCl (5 × 20 mL). The pH of the combined aqueous layers was adjusted to 8 with the slow addition of solid Na_2CO_3 and extracted with dichloromethane (4 × 20 mL). The combined organic layers were dried with anhydrous Na_2SO_4, filtered and concentrated *in vacuo* to provide the desired diisopropyl (1-(hydroxyamino)-2-phenylethyl)phosphonate (0.03 g, 1% isolated yield) as a pink oil.

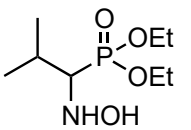
2.1.4.5 Batch procedure for the synthesis of dimethyl (1-(hydroxyamino)-2-methylpropyl)phosphonate (**4c**)[15]



$C_6H_{16}NO_4P$
MW 197,17

Dimethyl (1-(hydroxyimino)-2-methylpropyl)phosphonate (2.45 g, 12.55 mmol, 1 eq.) was dissolved in absolute ethanol (20 mL). Sodium cyanoborohydride (2.36 g, 37.66 mmol, 3 eq.) was then added to the reaction mixture in small portions and the pH of the solution was decreased down to pH ~ 3 by dropwise addition of freshly prepared 4 N HCl in methanol (4 mL). The reaction mixture was stirred overnight at room temperature and then concentrated under reduced pressure. The crude product was dissolved in dichloromethane (100 mL) and washed with 3 N HCl (5 × 30 mL). The pH of the combined aqueous layers was adjusted to 8 with the slow addition of solid Na_2CO_3 and extracted with dichloromethane (4 × 30 mL). The combined organic layers were dried with anhydrous Na_2SO_4, filtered and concentrated *in vacuo* to provide the desired dimethyl (1-(hydroxyamino)-2-methylpropyl)phosphonate (0.35 g, 14% isolated yield) as a colorless oil.

2.1.4.6 Batch procedure for the synthesis of diethyl (1-(hydroxyamino)-2-methylpropyl)phosphonate (**5c**)[16]

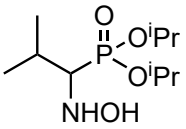


$C_8H_{20}NO_4P$
MW 225,22

Diethyl (1-(hydroxyimino)-2-methylpropyl)phosphonate (3.35 g, 15.00 mmol, 1 eq.) was dissolved in absolute ethanol (20 mL). Sodium cyanoborohydride (2.83 g, 45.00 mmol, 3 eq.) was then added to the reaction mixture in small portions and the pH

of the solution was decreased down to pH ~ 3 by dropwise addition of freshly prepared 4 N HCl in methanol (4 mL). The reaction mixture was stirred overnight at room temperature and then concentrated under reduced pressure. The crude product was dissolved in dichloromethane (100 mL) and washed with 3 N HCl (5 × 30 mL). The pH of the combined aqueous layers was adjusted to 8 with the slow addition of solid Na_2CO_3 and extracted with dichloromethane (4 × 30 mL). The combined organic layers were dried with anhydrous Na_2SO_4, filtered and concentrated *in vacuo* to provide the desired diethyl (1-(hydroxyamino)-2-methylpropyl)phosphonate (1.54 g, 46% isolated yield) as a pink oil.

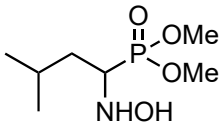
2.1.4.7 Batch procedure for the synthesis of diisopropyl (1-(hydroxyamino)-2-methylpropyl)phosphonate (**6c**)



$C_{10}H_{24}NO_4P$
MW 253,28

Diisopropyl (1-(hydroxyimino)-2-methylpropyl)phosphonate (3.77 g, 15.00 mmol, 1 eq.) was dissolved in absolute ethanol (20 mL). Sodium cyanoborohydride (2.83 g, 45.00 mmol, 3 eq.) was then added to the reaction mixture in small portions and the pH of the solution was decreased down to pH ~ 3 by dropwise addition of freshly prepared 4 N HCl in methanol (4 mL). The reaction mixture was stirred overnight at room temperature and then concentrated under reduced pressure. The crude product was dissolved in dichloromethane (100 mL) and washed with 3 N HCl (5 × 30 mL). The pH of the combined aqueous layers was adjusted to 8 with the slow addition of solid Na_2CO_3 and extracted with dichloromethane (4 × 30 mL). The combined organic layers were dried with anhydrous Na_2SO_4, filtered and concentrated *in vacuo* to provide the desired diisopropyl (1-(hydroxyamino)-2-methylpropyl)phosphonate (0.98 g, 26% isolated yield) as a pink oil.

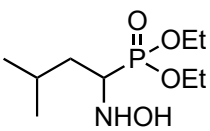
2.1.4.8 Batch procedure for the synthesis of dimethyl (1-(hydroxyamino)-3-methylbutyl)phosphonate (**7c**)



$C_7H_{18}NO_4P$
MW 211,20

Dimethyl (1-(hydroxyimino)-3-methylbutyl)phosphonate (2.80 g, 13.38 mmol, 1 eq.) was dissolved in absolute ethanol (20 mL). Sodium cyanoborohydride (2.52 g, 40.15 mmol, 3 eq.) was then added to the reaction mixture in small portions and the pH of the solution was decreased down to pH ~ 3 by dropwise addition of freshly prepared 4 N HCl in methanol (4 mL). The reaction mixture was stirred overnight at room temperature and then concentrated under reduced pressure. The crude product was dissolved in dichloromethane (100 mL) and washed with 3 N HCl (5 × 30 mL). The pH of the combined aqueous layers was adjusted to 8 with the slow addition of solid Na_2CO_3 and extracted with dichloromethane (4 × 30 mL). The combined organic layers were dried with anhydrous Na_2SO_4, filtered and concentrated *in vacuo* to provide the desired dimethyl (1-(hydroxyamino)-3-methylbutyl)phosphonate (1.19 g, 42% isolated yield) as a pink oil.

2.1.4.9 Batch procedure for the synthesis of diethyl (1-(hydroxyamino)-3-methylbutyl)phosphonate (**8c**)

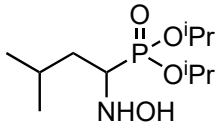


$C_9H_{22}NO_4P$
MW 239,25

Diethyl (1-(hydroxyimino)-3-methylbutyl)phosphonate (3.56 g, 15.00 mmol, 1 eq.) was dissolved in absolute ethanol (20 mL). Sodium cyanoborohydride (2.83 g, 45.00 mmol, 3 eq.) was then added to the reaction mixture in small portions and the pH of the solution was decreased down to pH ~ 3 by dropwise addition of freshly prepared 4 N HCl in methanol (4 mL). The reaction mixture was stirred overnight at room temperature and then concentrated under reduced pressure. The crude product was dissolved in dichloromethane (100 mL) and washed with 3 N HCl (5 × 30 mL). The pH of the combined aqueous layers was adjusted to 8 with the slow addition of solid Na_2CO_3 and extracted

with dichloromethane (4 × 30 mL). The combined organic layers were dried with anhydrous Na_2SO_4, filtered and concentrated *in vacuo* to provide the desired diethyl (1-(hydroxyamino)-3-methylbutyl)phosphonate (1.21 g, 33% isolated yield) as a pink oil.

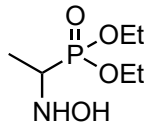
2.1.4.10 Batch procedure for the synthesis of diisopropyl (1-(hydroxyamino)-3-methylbutyl)phosphonate (**9c**)



$C_{11}H_{26}NO_4P$
MW 267,31

Diisopropyl (1-(hydroxyimino)-3-methylbutyl)phosphonate (3.58 g, 13.50 mmol, 1 eq.) was dissolved in absolute ethanol (20 mL). Sodium cyanoborohydride (2.54 g, 40.50 mmol, 3 eq.) was then added to the reaction mixture in small portions and the pH of the solution was decreased down to pH ~ 3 by dropwise addition of freshly prepared 4 N HCl in methanol (4 mL). The reaction mixture was stirred overnight at room temperature and then concentrated under reduced pressure. The crude product was dissolved in dichloromethane (100 mL) and washed with 3 N HCl (5 × 30 mL). The pH of the combined aqueous layers was adjusted to 8 with the slow addition of solid Na_2CO_3 and extracted with dichloromethane (4 × 30 mL). The combined organic layers were dried with anhydrous Na_2SO_4, filtered and concentrated *in vacuo* to provide the desired diisopropyl (1-(hydroxyamino)-3-methylbutyl)phosphonate (0.36 g, 10% isolated yield) as a pink oil.

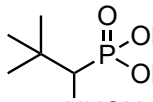
2.1.4.11 Batch procedure for the synthesis of diethyl (1-(hydroxyamino)ethyl)phosphonate (**10c**)



$C_6H_{16}NO_4P$
MW 197,17

Diethyl (1-(hydroxyimino)ethyl)phosphonate (2.93 g, 15.00 mmol, 1 eq.) was dissolved in absolute ethanol (20 mL). Sodium cyanoborohydride (2.83 g, 45.00 mmol, 3 eq.) was then added to the reaction mixture in small portions and the pH of the solution was decreased down to pH ~ 3 by dropwise addition of freshly prepared 4 N HCl in methanol (4 mL). The reaction mixture was stirred overnight at room temperature and then concentrated under reduced pressure. The crude product was dissolved in dichloromethane (100 mL) and washed with 3 N HCl (5 × 30 mL). The pH of the combined aqueous layers was adjusted to 8 with the slow addition of solid Na_2CO_3 and extracted with dichloromethane (4 × 30 mL). The combined organic layers were dried with anhydrous Na_2SO_4, filtered and concentrated *in vacuo*. The residual oil was triturated with 15 mL of 2 N HCl in Et_2O, the ethereal phase was then discarded to provide the desired diethyl (1-(hydroxyamino)ethyl)phosphonate (0.09 g, 2% isolated yield) as the hydrochloride salt (white powder).

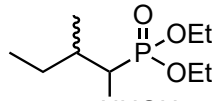
2.1.4.12 Batch procedure for the synthesis of diethyl (1-(hydroxyamino)-2,2-dimethylpropyl)phosphonate (**11c**)



$C_9H_{22}NO_4P$
MW 239,25

Diethyl (1-(hydroxyimino)-2,2-dimethylpropyl)phosphonate (4.74 g, 20.00 mmol, 1 eq.) was dissolved in absolute ethanol (20 mL). Sodium cyanoborohydride (3.77 g, 60.00 mmol, 3 eq.) was then added to the reaction mixture in small portions and the pH of the solution was decreased down to pH ~ 3 by dropwise addition of freshly prepared 4 N HCl in methanol (6 mL). The reaction mixture was stirred overnight at room temperature and then concentrated under reduced pressure. The crude product was dissolved in dichloromethane (100 mL) and washed with 3 N HCl (5 × 30 mL). The pH of the combined aqueous layers was adjusted to 8 with the slow addition of solid Na_2CO_3 and extracted with dichloromethane (4 × 30 mL). The combined organic layers were dried with anhydrous Na_2SO_4, filtered and concentrated *in vacuo* to provide the desired diethyl (1-(hydroxyamino)-2,2-dimethylpropyl)phosphonate (0.91 g, 19% isolated yield) as a pink oil.

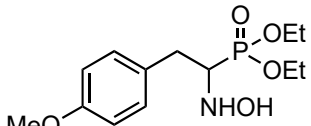
2.1.4.13 Batch procedure for the synthesis of diethyl (1-(hydroxyamino)-2-methylbutyl)phosphonate (**12c**)



$C_9H_{22}NO_4P$
MW 239,25

Diethyl (1-(hydroxyimino)-2-methylbutyl)phosphonate (4.74 g, 20.00 mmol, 1 eq.) was dissolved in absolute ethanol (20 mL). Sodium cyanoborohydride (3.77 g, 60.00 mmol, 3 eq.) was then added to the reaction mixture in small portions and the pH of the solution was decreased down to pH ~ 3 by dropwise addition of freshly prepared 4 N HCl in methanol (6 mL). The reaction mixture was stirred overnight at room temperature and then concentrated under reduced pressure. The crude product was dissolved in dichloromethane (100 mL) and washed with 3 N HCl (5 × 30 mL). The pH of the combined aqueous layers was adjusted to 8 with the slow addition of solid Na_2CO_3 and extracted with dichloromethane (4 × 30 mL). The combined organic layers were dried with anhydrous Na_2SO_4, filtered and concentrated *in vacuo* to provide diasteroisomers of the desired diethyl (1-(hydroxyamino)-2-methylbutyl)phosphonate (0.79 g, 17% isolated yield) as a pink oil.

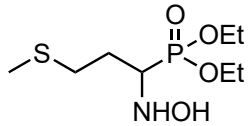
2.1.4.14 Batch procedure for the synthesis of diethyl (1-(hydroxyamino)-2-(4-methoxyphenyl)ethyl)phosphonate (**13c**)



$C_{13}H_{22}NO_5P$
MW 303,29

Diethyl (1-(hydroxyimino)-2-(4-methoxyphenyl)ethyl)phosphonate (1.00 g, 3.32 mmol, 1 eq.) was dissolved in absolute ethanol (10 mL). Sodium cyanoborohydride (0.62 g, 9.96 mmol, 3 eq.) was then added to the reaction mixture in small portions and the pH of the solution was decreased down to pH ~ 3 by dropwise addition of freshly prepared 4 N HCl in methanol (3 mL). The reaction mixture was stirred overnight at room temperature and then concentrated under reduced pressure. The crude product was dissolved in dichloromethane (50 mL) and washed with 3 N HCl (5 × 20 mL). The pH of the combined aqueous layers was adjusted to 8 with the slow addition of solid Na_2CO_3 and extracted with dichloromethane (4 × 20 mL). The combined organic layers were dried with anhydrous Na_2SO_4, filtered and concentrated *in vacuo* to provide the desired diethyl (1-(hydroxyamino)-2-(4-methoxyphenyl)ethyl)phosphonate (0.26 g, 26% isolated yield) as a pink oil.

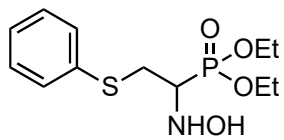
2.1.4.15 Batch procedure for the synthesis of diethyl (1-(hydroxyamino)-3-(methylthio)propyl)phosphonate (**14c**)



$C_8H_{20}NO_4PS$
MW 257,28

Diethyl (1-(hydroxyimino)-3-(methylthio)propyl)phosphonate (3.83 g, 15.00 mmol, 1 eq.) was dissolved in absolute ethanol (20 mL). Sodium cyanoborohydride (2.83 g, 45.00 mmol, 3 eq.) was then added to the reaction mixture in small portions and the pH of the solution was decreased down to pH ~ 3 by dropwise addition of freshly prepared 4 N HCl in methanol (4 mL). The reaction mixture was stirred overnight at room temperature and then concentrated under reduced pressure. The crude product was dissolved in dichloromethane (100 mL) and washed with 3 N HCl (5 × 30 mL). The pH of the combined aqueous layers was adjusted to 8 with the slow addition of solid Na_2CO_3 and extracted with dichloromethane (4 × 30 mL). The combined organic layers were dried with anhydrous Na_2SO_4, filtered and concentrated *in vacuo* to provide the desired diethyl (1-(hydroxyamino)-3-(methylthio)propyl)phosphonate (0.15 g, 4% isolated yield) as a pink oil.

2.1.4.16 Batch procedure for the synthesis of diethyl (1-(hydroxyamino)-2-(phenylthio)ethyl)phosphonate (**15c**)

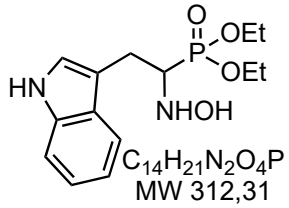


$C_{12}H_{20}NO_4PS$
MW 305,33

Diethyl (1-(hydroxyimino)-2-(phenylthio)ethyl)phosphonate (1.07 g, 3.53 mmol, 1 eq.) was dissolved in absolute ethanol (10 mL). Sodium

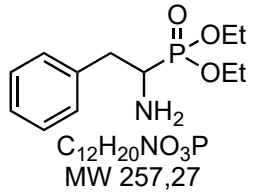
cyanoborohydride (0.66 g, 10.58 mmol, 3 eq.) was then added to the reaction mixture in small portions and the pH of the solution was decreased down to pH ~ 3 by dropwise addition of freshly prepared 4 N HCl in methanol (3 mL). The reaction mixture was stirred overnight at room temperature and then concentrated under reduced pressure. The crude product was dissolved in dichloromethane (50 mL) and washed with 3 N HCl (5 × 20 mL). The pH of the combined aqueous layers was adjusted to 8 with the slow addition of solid Na_2CO_3 and extracted with dichloromethane (4 × 20 mL). The combined organic layers were dried with anhydrous Na_2SO_4, filtered and concentrated *in vacuo* to provide the desired diethyl (1-(hydroxyamino)-2-(phenylthio)ethyl)phosphonate (0.15 g, 14% isolated yield) as a pink oil.

2.1.4.17 Batch procedure for the synthesis of diethyl (1-(hydroxyamino)-2-(1*H*-indol-3-yl)ethyl)phosphonate (**16c**)



Diethyl (1-(hydroxyimino)-2-(1*H*-indol-3-yl)ethyl)phosphonate (0.50 g, 1.60 mmol, 1 eq.) was dissolved in absolute ethanol (10 mL). Sodium cyanoborohydride (0.30 g, 4.83 mmol, 3 eq.) was then added to the reaction mixture in small portions and the pH of the solution was decreased down to pH ~ 3 by dropwise addition of freshly prepared 4 N HCl in methanol (3 mL). The reaction mixture was stirred overnight at room temperature and then concentrated under reduced pressure. The crude product was dissolved in dichloromethane (50 mL) and washed with 3 N HCl (5 × 20 mL). The pH of the combined aqueous layers was adjusted to 8 with the slow addition of solid Na_2CO_3 and extracted with dichloromethane (4 × 20 mL). The combined organic layers were dried with anhydrous Na_2SO_4, filtered and concentrated *in vacuo* to provide the desired diethyl (1-(hydroxyamino)-2-(1*H*-indol-3-yl)ethyl)phosphonate (0.08 g, 16% isolated yield) as a pink oil.

2.1.5 Batch procedure for the synthesis of diethyl (1-amino-2-phenylethyl)phosphonate (**am-2b**)[9]



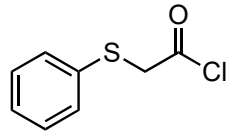
Diethyl (1-(hydroxyimino)-2-phenylethyl)phosphonate (6.32 g, 23.3 mmol, 1 eq.) was dissolved in 120 mL of a 2:1 (*v*/*v*) 1M HCl/Glacial HOAc mixture. To the resulting solution was added active zinc powder (18.31 g, 280 mmol, 12 eq.). After purging with N_2, the mixture was stirred overnight at room temperature. After filtration, the filtrate was concentrated in vacuo to afford a residue, which was washed with Et_2O (3 × 50 mL). The pH of the aqueous layer was then adjusted to 10 with the slow addition of solid Na_2CO_3 and extracted with dichloromethane (5 × 40 mL). The combined organic phases were then dried over Na_2SO_4, filtered and concentrated under reduced pressure to give the desired diethyl (1-amino-2-phenylethyl)phosphonate (4.25 g, 71% isolated yield) as a yellowish oil.

2.1.6 Batch procedure for the synthesis of 4 N HCl in MeOH[17]

<u>For the preparation of 100 mL of 4 N HCl in MeOH:</u>

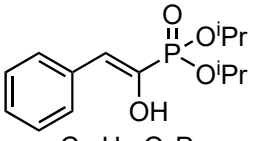
In a 250 mL round-bottomed flask, 28.4 mL of acetyl chloride was added dropwise to 71.6 mL of methanol in an ice bath and stirred at 0 °C for 10 min. The reaction medium was then heated to room temperature and the solution was used immediately while fresh.

2.2 Characterization of compounds



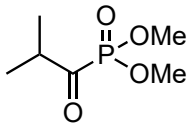
C_8H_7ClOS
MW 186,65

2-(phenylthio)acetyl chloride. (ac-15) ^{1}H NMR ($CDCl_3$, 400 MHz): δ = 7.50-7.44 (m, 2H), 7.39-7.29 (m, 3H), 4.06 (s, 2H) ppm. **^{13}C ($CDCl_3$, 100.6 MHz):** δ = 131.4, 129.4, 128.2, 48.4 ppm. **ESI HRMS** *m/z* $C_8H_7ClOS^+$ $[M+H]^+$: calcd 186.9978; found 186.9981.



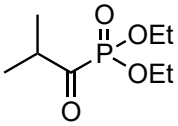
$C_{14}H_{21}O_4P$
MW 284,29

Diisopropyl (1-hydroxy-2-phenylvinyl)phosphonate. (iso-3a) ^{1}H NMR ($CDCl_3$, 400 MHz): δ = 7.74 (d, *J* = 7.1 Hz, 2H), 7.38 – 7.19 (m, 3H), 6.08 (d, *J* = 12.5 Hz, 1H), 4.83 – 4.68 (m, 2H), 1.40 (d, *J* = 6.2 Hz, 6H), 1.35 (d, *J* = 6.3 Hz, 6H) ppm. **^{13}C NMR ($CDCl_3$, 100.6 MHz):** δ = 143.3 (d, $J_{C\text{-}P}$ = 203.8 Hz), 134.8 (d, $J_{C\text{-}P}$ = 17.6 Hz), 129.6, 128.4, 127.5, 115.7 (d, $J_{C\text{-}P}$ = 26.4 Hz), 72.2 (d, $J_{C\text{-}P}$ = 5.4 Hz), 24.2 (d, $J_{C\text{-}P}$ = 3.8 Hz), 23.8 (d, $J_{C\text{-}P}$ = 5.1 Hz) ppm. **^{31}P NMR ($CDCl_3$, 161.9 MHz):** δ = 11.0 ppm. **ESI HRMS** *m/z* $C_{14}H_{21}O_4P^+$ $[M+H]^+$: calcd 285.1250; found 285.1255.



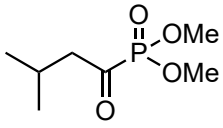
$C_6H_{13}O_4P$
MW 180,14

Dimethyl isobutyrylphosphonate. (4a) ^{1}H NMR ($CDCl_3$, 400 MHz): δ = 3.58 (d, *J* = 10.8 Hz, 6H), 2.86 (hept, *J* = 6.9 Hz, s1H), 0.90 (d, *J* = 7.1 Hz, 6H) ppm. **^{13}C NMR ($CDCl_3$, 100.6 MHz):** δ = 213.4 (d, $J_{C\text{-}P}$ = 156.8 Hz), 53.4 (d, $J_{C\text{-}P}$ = 7.5 Hz), 41.1 (d, $J_{C\text{-}P}$ = 54.9 Hz), 16.4 (d, $J_{C\text{-}P}$ = 1.4 Hz) ppm. **^{31}P NMR ($CDCl_3$, 161.9 MHz):** δ = -1.1 ppm. **ESI HRMS** *m/z* $C_6H_{13}O_4P^+$ $[M+H]^+$: calcd 181.0624; found 181.0626.



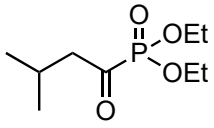
$C_8H_{17}O_4P$
MW 208,19

Diethyl isobutyrylphosphonate. (5a) ^{1}H NMR ($CDCl_3$, 400 MHz): δ = 3.98 (p, *J* = 7.3 Hz, 4H), 2.93 (hept, *J* = 6.9 Hz, 1H), 1.13 (t, *J* = 7.2 Hz, 6H), 0.94 (d, *J* = 7.2 Hz, 6H) ppm. **^{13}C NMR ($CDCl_3$, 100.6 MHz):** δ = 214.1 (d, $J_{C\text{-}P}$ = 158.0 Hz), 63.2 (d, $J_{C\text{-}P}$ = 7.4 Hz), 41.0 (d, $J_{C\text{-}P}$ = 54.6 Hz), 16.7 (d, $J_{C\text{-}P}$ = 1.4 Hz), 16.0 (d, $J_{C\text{-}P}$ = 5.7 Hz) ppm. **^{31}P NMR ($CDCl_3$, 161.9 MHz):** δ = -3.0 ppm. **ESI HRMS** *m/z* $C_8H_{17}O_4P^+$ $[M+H]^+$: calcd 209.0937; found 209.0941.



$C_7H_{15}O_4P$
MW 194,17

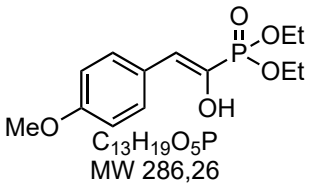
Dimethyl (3-methylbutanoyl)phosphonate. (7a) ^{1}H NMR ($CDCl_3$, 400 MHz): δ = 3.62 (d, *J* = 10.8 Hz, 6H), 2.46 (d, *J* = 6.9 Hz, 2H), 2.01 (dp, *J* = 13.4, 6.7 Hz, 1H), 0.70 (d, *J* = 7.0 Hz, 6H) ppm. **^{13}C NMR ($CDCl_3$, 100.6 MHz):** δ = 210.0 (d, $J_{C\text{-}P}$ = 163.7 Hz), 53.5 (d, $J_{C\text{-}P}$ = 7.4 Hz), 51.9 (d, $J_{C\text{-}P}$ = 52.9 Hz), 23.2 (d, $J_{C\text{-}P}$ = 3.7 Hz), 22.0 (d, $J_{C\text{-}P}$ = 1.4 Hz) ppm. **^{31}P NMR ($CDCl_3$, 161.9 MHz):** δ = -1.4 ppm. **ESI HRMS** *m/z* $C_7H_{15}O_4P^+$ $[M+H]^+$: calcd 195.0780; found 195.0781.



$C_9H_{19}O_4P$
MW 222,22

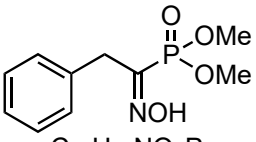
Diethyl (3-methylbutanoyl)phosphonate. (8a) ^{1}H NMR ($CDCl_3$, 400 MHz): δ = 4.17 – 4.05 (m, 4H), 2.61 (d, *J* = 6.8 Hz, 2H), 2.23 – 2.10 (m, 1H), 1.27 (t, *J* = 7.1 Hz, 6H), 0.84 (d, *J* = 6.9 Hz, 6H) ppm. **^{13}C NMR ($CDCl_3$, 100.6 MHz):** δ = 210.9 (d, $J_{C\text{-}P}$ = 164.4 Hz), 63.6 (d, $J_{C\text{-}P}$ = 7.3 Hz), 52.0 (d, $J_{C\text{-}P}$ = 52.5 Hz), 23.5 (d, $J_{C\text{-}P}$ = 3.7 Hz), 22.3 (d, $J_{C\text{-}P}$ = 1.3 Hz), 16.3 (d, $J_{C\text{-}P}$ = 5.5 Hz) ppm. **^{31}P NMR ($CDCl_3$, 161.9 MHz):** δ = -3.0 ppm. **ESI HRMS** *m/z* $C_9H_{19}O_4P^+$ $[M+H]^+$: calcd

223.1093; found 223.1097.



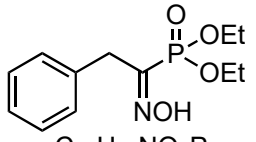
$C_{13}H_{19}O_5P$
MW 286,26

Diethyl (1-hydroxy-2-(4-methoxyphenyl)vinyl)phosphonate. (iso-13a) ^{1}H NMR ($CDCl_3$, 400 MHz): δ = 7.69 (d, *J* = 8.8 Hz, 2H), 6.84 (d, *J* = 8.8 Hz, 2H), 6.03 (d, *J* = 12.4 Hz, 1H), 4.22 – 4.07 (m, 4H), 3.77 (s, 3H), 1.34 (t, *J* = 7.1 Hz, 6H) ppm. **^{13}C NMR ($CDCl_3$, 100.6 MHz):** δ = 159.0, 139.8 (d, $J_{C\text{-}P}$ = 205.4 Hz), 131.1, 127.5 (d, $J_{C\text{-}P}$ = 18.0 Hz), 116.4 (d, $J_{C\text{-}P}$ = 27.5 Hz), 113.8, 63.0 (d, $J_{C\text{-}P}$ = 5.3 Hz), 55.2, 16.3 (d, $J_{C\text{-}P}$ = 6.5 Hz) ppm. **^{31}P NMR ($CDCl_3$, 161.9 MHz):** δ = 13.6 ppm. **ESI HRMS** *m/z* $C_{13}H_{19}O_5P^+$ $[M+H]^+$: calcd 287.1042; found 287.1045.



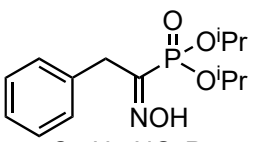
$C_{10}H_{14}NO_4P$
MW 243,20

Dimethyl (1-(hydroxyimino)-2-phenylethyl)phosphonate. (1b) ^{1}H NMR ($CDCl_3$, 400 MHz): δ = 11.21 (s, br, 1H), 7.39 – 7.14 (m, 5H), 3.92 (d, *J* = 14.5 Hz, 0.92H, $\mathbf{E}_{iso}$), 3.77 (d, *J* = 12.4 Hz, 1.11H, $\mathbf{Z}_{iso}$), 3.63 (d, *J* = 11.5 Hz, 3.2H, $\mathbf{Z}_{iso}$), 3.60 (d, *J* = 11.2 Hz, 3H, $\mathbf{E}_{iso}$) ppm. **^{13}C NMR ($CDCl_3$, 100.6 MHz):** δ = 151.7 (d, $J_{C\text{-}P}$ = 215.1 Hz, $\mathbf{E}_{iso}$), 150.2 (d, $J_{C\text{-}P}$ = 153.9 Hz, $\mathbf{Z}_{iso}$), 136.4 (d, $J_{C\text{-}P}$ = 2.0 Hz, $\mathbf{Z}_{iso}$), 135.6 (d, $J_{C\text{-}P}$ = 1.5 Hz, $\mathbf{E}_{iso}$), 129.4 ($\mathbf{E}_{iso}$), 129.1 ($\mathbf{Z}_{iso}$), 128.4 ($\mathbf{Z}_{iso}$), 128.4 ($\mathbf{E}_{iso}$), 126.7 ($\mathbf{Z}_{iso}$), 126.6 ($\mathbf{E}_{iso}$), 53.3 (d, $J_{C\text{-}P}$ = 5.9 Hz, $\mathbf{E}_{iso}$), 53.1 (d, $J_{C\text{-}P}$ = 5.9 Hz, $\mathbf{Z}_{iso}$), 38.6 (d, $J_{C\text{-}P}$ = 18.7 Hz, $\mathbf{Z}_{iso}$), 32.1 (d, $J_{C\text{-}P}$ = 16.7 Hz, $\mathbf{E}_{iso}$) ppm. **^{31}P NMR ($CDCl_3$, 161.9 MHz):** δ = 13.0 ($\mathbf{E}_{iso}$), 8.3 ($\mathbf{Z}_{iso}$) ppm. **ESI HRMS** *m/z* $C_{10}H_{14}NO_4P^+$ $[M+H]^+$: calcd 244.0733; found 244.0739.



$C_{12}H_{18}NO_4P$
MW 271,25

Diethyl (1-(hydroxyimino)-2-phenylethyl)phosphonate. (2b) ^{1}H NMR ($CDCl_3$, 400 MHz): δ = 11.43 (s, br, 1H), 7.40 – 7.16 (m, 5H), 4.12 – 3.89 (m, 5.45H), 3.80 (d, *J* = 12.4 Hz, 0.55H, $\mathbf{Z}_{iso}$), 1.24 – 1.14 (m, 6H) ppm. **^{13}C NMR ($CDCl_3$, 100.6 MHz):** δ = 152.0 (d, $J_{C\text{-}P}$ = 214.8 Hz, $\mathbf{E}_{iso}$), 150.3 (d, $J_{C\text{-}P}$ = 153.5 Hz, $\mathbf{Z}_{iso}$), 136.6 (d, $J_{C\text{-}P}$ = 1.8 Hz, $\mathbf{Z}_{iso}$), 135.8 (d, $J_{C\text{-}P}$ = 1.4 Hz, $\mathbf{E}_{iso}$), 129.4 ($\mathbf{E}_{iso}$), 129.1 ($\mathbf{Z}_{iso}$), 128.3 ($\mathbf{Z}_{iso}$), 128.2 ($\mathbf{E}_{iso}$), 126.6 ($\mathbf{Z}_{iso}$), 126.4 ($\mathbf{E}_{iso}$), 63.0 (d, $J_{C\text{-}P}$ = 5.9 Hz, $\mathbf{E}_{iso}$), 62.7 (d, $J_{C\text{-}P}$ = 5.9 Hz, $\mathbf{Z}_{iso}$), 38.7 (d, $J_{C\text{-}P}$ = 18.7 Hz, $\mathbf{Z}_{iso}$), 32.0 (d, $J_{C\text{-}P}$ = 16.6 Hz, $\mathbf{E}_{iso}$), 16.1 (d, $J_{C\text{-}P}$ = 6.5 Hz, $\mathbf{Z}_{iso}$), 16.0 (d, $J_{C\text{-}P}$ = 6.6 Hz, $\mathbf{E}_{iso}$) ppm. **^{31}P NMR ($CDCl_3$, 161.9 MHz):** δ = 10.3 ($\mathbf{E}_{iso}$), 5.4 ($\mathbf{Z}_{iso}$) ppm. **IR (neat)**: ν_{max} = 3155, 3026, 2922, 2856, 1441, 1428, 1395, 1237, 1215, 1016, 974, 953 cm^{-1}. **ESI HRMS** *m/z* $C_{12}H_{18}NO_4P^+$ $[M+H]^+$: calcd 272.1046; found 272.1048.



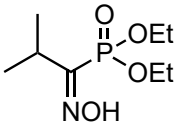
$C_{14}H_{22}NO_4P$
MW 299,31

Diisopropyl (1-(hydroxyimino)-2-phenylethyl)phosphonate. (3b) ^{1}H NMR ($CDCl_3$, 400 MHz): δ = 7.39 – 7.16 (m, 5H), 4.66 (dh, *J* = 12.2, 6.3 Hz, 2H), 3.92 (d, *J* = 14.0 Hz, 1.89H, $\mathbf{E}_{iso}$), 3.77 (d, *J* = 11.6 Hz, 0.12H, $\mathbf{Z}_{iso}$), 1.28 (d, *J* = 6.1 Hz, 6H), 1.15 (d, *J* = 6.2 Hz, 6H) ppm. **^{13}C NMR ($CDCl_3$, 100.6 MHz):** δ = 153.8 (d, $J_{C\text{-}P}$ = 215.4 Hz, $\mathbf{E}_{iso}$), 136.6 ($\mathbf{Z}_{iso}$), 136.0 (d, $J_{C\text{-}P}$ = 1.6 Hz, $\mathbf{E}_{iso}$), 129.7 ($\mathbf{E}_{iso}$), 129.4 ($\mathbf{Z}_{iso}$), 128.4 ($\mathbf{Z}_{iso}$), 128.4 ($\mathbf{E}_{iso}$), 126.8 ($\mathbf{Z}_{iso}$), 126.6 ($\mathbf{E}_{iso}$), 72.2 (d, $J_{C\text{-}P}$ = 6.2 Hz, $\mathbf{Z}_{iso}$), 72.0 (d, $J_{C\text{-}P}$ = 6.2 Hz, $\mathbf{E}_{iso}$), 39.3 (d, $J_{C\text{-}P}$ = 17.8 Hz,

$\mathbf{Z}_{iso}$), 32.2 (d, $J_{C\text{-}P}$ = 15.8 Hz, $\mathbf{E}_{iso}$), 24.1 (d, $J_{C\text{-}P}$ = 3.8 Hz) , 23.6 (d, $J_{C\text{-}P}$ = 5.2 Hz) ppm. **^{31}P NMR ($CDCl_3$, 161.9 MHz):** δ = 7.6 ($\mathbf{E}_{iso}$), 3.2 ($\mathbf{Z}_{iso}$) ppm. **ESI HRMS** *m/z* $C_{14}H_{22}NO_4P^+$ $[M+H]^+$: calcd 300.1359; found 300.1361.

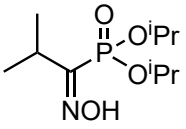
$C_6H_{14}NO_4P$
MW 195,15

Dimethyl (1-(hydroxyimino)-2-methylpropyl)phosphonate. (4b) ^{1}H NMR ($CDCl_3$, 400 MHz): δ = 10.78 (s, br, 1H), 3.76 (dd, *J* = 12.3, 11.3 Hz, 6H), 3.40 – 3.23 (m, 0.45 H, $\mathbf{E}_{iso}$), 2.89 – 2.71 (m, 0.54, $\mathbf{Z}_{iso}$), 1.18 (d, *J* = 7.1 Hz, 3 H), 1.12 (d, *J* = 6.9 Hz, 3 H) ppm. **^{13}C NMR ($CDCl_3$, 100.6 MHz):** δ = 157.9 (d, $J_{C\text{-}P}$ = 206.6 Hz, $\mathbf{E}_{iso}$), 155.7 (d, $J_{C\text{-}P}$ = 148.2 Hz, $\mathbf{Z}_{iso}$), 53.3 (d, $J_{C\text{-}P}$ = 6.3 Hz, $\mathbf{E}_{iso}$), 53.0 (d, $J_{C\text{-}P}$ = 6.0 Hz, $\mathbf{Z}_{iso}$), 32.3 (d, $J_{C\text{-}P}$ = 17.7 Hz, $\mathbf{Z}_{iso}$), 27.1 (d, $J_{C\text{-}P}$ = 16.3 Hz, $\mathbf{E}_{iso}$), 20.7 (d, $J_{C\text{-}P}$ = 3.6 Hz, $\mathbf{Z}_{iso}$), 18.6 (d, $J_{C\text{-}P}$ = 2.4 Hz, $\mathbf{E}_{iso}$) ppm. **^{31}P NMR ($CDCl_3$, 161.9 MHz):** δ = 13.1 ($\mathbf{E}_{iso}$), 9.1 ($\mathbf{Z}_{iso}$) ppm. **ESI HRMS** *m/z* $C_6H_{14}NO_4P^+$ $[M+H]^+$: calcd 196.0733; found 196.0741.



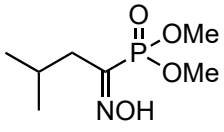
$C_8H_{18}NO_4P$
MW 223,21

Diethyl (1-(hydroxyimino)-2-methylpropyl)phosphonate. (5b) ^{1}H NMR ($CDCl_3$, 400 MHz): δ = 10.95 (s, br, 1H), 4.20 – 3.99 (m, 4H), 3.40 – 3.18 (m, 0.48 H, $\mathbf{E}_{iso}$), 2.87 – 2.70 (m, 0.43 H, $\mathbf{Z}_{iso}$), 1.25 (t, J = 7.1 Hz, 6H), 1.15 (d, *J* = 7.1 Hz, 3H), 1.09 (d, *J* = 6.9 Hz, 3H) ppm. **^{13}C NMR ($CDCl_3$, 100.6 MHz):** δ = 158.1 (d, $J_{C\text{-}P}$ = 206.8 Hz, $\mathbf{E}_{iso}$), 155.7 (d, $J_{C\text{-}P}$ = 147.9 Hz, $\mathbf{Z}_{iso}$), 62.8 (d, $J_{C\text{-}P}$ = 6.3 Hz, $\mathbf{E}_{iso}$), 62.5 (d, $J_{C\text{-}P}$ = 5.9 Hz, $\mathbf{Z}_{iso}$), 32.3 (d, $J_{C\text{-}P}$ = 17.9 Hz, $\mathbf{Z}_{iso}$), 27.2 (d, $J_{C\text{-}P}$ = 16.4 Hz, $\mathbf{E}_{iso}$), 20.7 (d, $J_{C\text{-}P}$ = 3.3 Hz, $\mathbf{Z}_{iso}$), 18.6 (d, $J_{C\text{-}P}$ = 2.4 Hz, $\mathbf{E}_{iso}$), 16.2 (t, $J_{C\text{-}P}$ = 6.0 Hz) ppm. **^{31}P NMR ($CDCl_3$, 161.9 MHz):** δ = 10.4 ($\mathbf{E}_{iso}$), 6.1 ($\mathbf{Z}_{iso}$) ppm. **ESI HRMS** *m/z* $C_8H_{18}NO_4P^+$ $[M+H]^+$: calcd 224.1046; found 224.1087.



$C_{10}H_{22}NO_4P$
MW 251,26

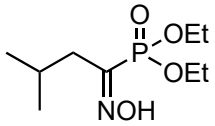
Diisopropyl (1-(hydroxyimino)-2-methylpropyl)phosphonate. (6b) ^{1}H NMR ($CDCl_3$, 400 MHz): δ = 4.84 – 4.63 (m, 2H), 3.38 – 3.14 (m, 0.69H, $\mathbf{E}_{iso}$), 2.89 – 2.70 (m, 0.28 H, $\mathbf{Z}_{iso}$), 1.32 – 1.21 (m, 12H), 1.17 (d, *J* = 7.1 Hz, 4.16 H), 1.10 (d, *J* = 6.9 Hz, 1.74 H) ppm. **^{13}C NMR ($CDCl_3$, 100.6 MHz):** δ = 158.7 (d, $J_{C\text{-}P}$ = 208.7 Hz, $\mathbf{E}_{iso}$), 156.2 (d, $J_{C\text{-}P}$ = 148.0 Hz, $\mathbf{Z}_{iso}$), 71.6 (d, $J_{C\text{-}P}$ = 6.4 Hz, $\mathbf{E}_{iso}$), 71.5 (d, $J_{C\text{-}P}$ = 6.3 Hz, $\mathbf{Z}_{iso}$), 32.3 (d, $J_{C\text{-}P}$ = 17.9 Hz, $\mathbf{Z}_{iso}$), 27.4 (d, $J_{C\text{-}P}$ = 16.2 Hz, $\mathbf{E}_{iso}$), 24.2 (d, $J_{C\text{-}P}$ = 3.5 Hz, $\mathbf{Z}_{iso}$), 24.0 (d, $J_{C\text{-}P}$ = 3.9 Hz, $\mathbf{E}_{iso}$), 23.8 (d, $J_{C\text{-}P}$ = 4.8 Hz, $\mathbf{E}_{iso}$), 23.8 (d, $J_{C\text{-}P}$ = 3.9 Hz, $\mathbf{Z}_{iso}$), 20.9 (d, $J_{C\text{-}P}$ = 3.4 Hz, $\mathbf{Z}_{iso}$), 18.7 (d, $J_{C\text{-}P}$ = 2.5 Hz, $\mathbf{E}_{iso}$) ppm. **^{31}P NMR ($CDCl_3$, 161.9 MHz):** δ = 8.6 ($\mathbf{E}_{iso}$), 3.7 ($\mathbf{Z}_{iso}$) ppm. **ESI HRMS** *m/z* $C_{10}H_{22}NO_4P^+$ $[M+H]^+$: calcd 252.1359; found 252.1364.



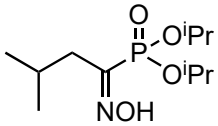
$C_7H_{16}NO_4P$
MW 209,18

Dimethyl (1-(hydroxyimino)-3-methylbutyl)phosphonate. (7b) ^{1}H NMR ($CDCl_3$, 400 MHz): δ = 11.08 (s, br, 1H), 3.72 (t, *J* = 11.6 Hz, 6H), 2.35 (dd, *J* = 15.3, 7.5 Hz, 0.78 H, $\mathbf{E}_{iso}$), 2.20 (dd, *J* = 12.9, 7.1 Hz, 1.19 H, $\mathbf{Z}_{iso}$), 2.10 – 2.00 (m, 0.36 H, $\mathbf{E}_{iso}$), 1.97 – 1.86 (m, 0.58 H, $\mathbf{Z}_{iso}$), 0.83 (t, *J* = 7.1 Hz, 6H) ppm. **^{13}C NMR ($CDCl_3$, 100.6 MHz):** δ = 153.1 (d, $J_{C\text{-}P}$ = 212.9 Hz, $\mathbf{E}_{iso}$), 150.5 (d, $J_{C\text{-}P}$ = 151.5 Hz,

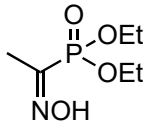
$\mathbf{Z}_{iso}$), 53.4 (d, $J_{C\text{-}P}$ = 6.3 Hz, $\mathbf{E}_{iso}$), 53.0 (d, $J_{C\text{-}P}$ = 6.0 Hz, $\mathbf{Z}_{iso}$), 41.4 (d, $J_{C\text{-}P}$ = 17.5 Hz, $\mathbf{Z}_{iso}$), 35.0 (d, $J_{C\text{-}P}$ = 16.0 Hz, $\mathbf{E}_{iso}$), 26.5 (d, $J_{C\text{-}P}$ = 1.8 Hz, $\mathbf{Z}_{iso}$), 26.3 (d, $J_{C\text{-}P}$ = 1.6 Hz, $\mathbf{E}_{iso}$), 22.6, 22.2 ppm. **^{31}P NMR ($CDCl_3$, 161.9 MHz):** δ = 13.5 ($\mathbf{E}_{iso}$), 9.1 ($\mathbf{Z}_{iso}$) ppm. **ESI HRMS** *m/z* $C_7H_{16}NO_4P^+$ $[M+H]^+$: calcd 210.0889; found 210.0893.


$C_9H_{20}NO_4P$
MW 237,24

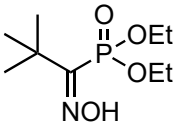
Diethyl (1-(hydroxyimino)-3-methylbutyl)phosphonate. (8b) ^{1}H NMR ($CDCl_3$, 400 MHz): δ = 4.25 – 4.06 (m, 4H), 2.42 (dd, J = 15.0, 7.5 Hz, 1H), 2.26 (dd, J = 12.5, 7.1 Hz, 1H), 2.20 – 2.08 (m, 0.5 H), 2.07 – 1.92 (m, 0.5 H), 1.31 (t, J = 7.1 Hz, 6H), 0.91 (t, J = 6.9 Hz, 6H) ppm. **^{13}C NMR ($CDCl_3$, 100.6 MHz):** δ = 154.5 (d, $J_{C\text{-}P}$ = 211.3 Hz, $\mathbf{E}_{iso}$), 151.7 (d, $J_{C\text{-}P}$ = 150.7 Hz, $\mathbf{Z}_{iso}$), 63.0 (d, $J_{C\text{-}P}$ = 6.2 Hz), 62.7 (d, $J_{C\text{-}P}$ = 6.1 Hz), 41.7 (d, $J_{C\text{-}P}$ = 17.1 Hz), 35.2 (d, $J_{C\text{-}P}$ = 15.4 Hz), 26.6 (d, $J_{C\text{-}P}$ = 1.8 Hz), 26.4 (d, $J_{C\text{-}P}$ = 1.5 Hz), 22.8, 22.4, 16.4 (t, $J_{C\text{-}P}$ = 6.2 Hz, 2C) ppm. **^{31}P NMR ($CDCl_3$, 161.9 MHz):** δ = 10.5 ($\mathbf{E}_{iso}$), 5.9 ($\mathbf{Z}_{iso}$) ppm. **ESI HRMS** *m/z* $C_9H_{20}NO_4P^+$ $[M+H]^+$: calcd 238.1202; found 238.1211.


$C_{11}H_{24}NO_4P$
MW 265,29

Diisopropyl (1-(hydroxyimino)-3-methylbutyl)phosphonate. (9b) ^{1}H NMR ($CDCl_3$, 400 MHz): δ = 4.85 – 4.53 (m, 2H), 2.43 – 1.89 (m, 3H), 1.26 (dt, J = 11.8, 6.0 Hz, 12H), 0.89 – 0.81 (m, 6H) ppm. **^{13}C NMR ($CDCl_3$, 100.6 MHz):** δ = 154.6 (d, $J_{C\text{-}P}$ = 214.1 Hz, $\mathbf{E}_{iso}$), 151.6 (d, $J_{C\text{-}P}$ = 151.5 Hz, $\mathbf{Z}_{iso}$), 71.6 (d, $J_{C\text{-}P}$ = 6.3 Hz, $\mathbf{E}_{iso}$), 71.5 (d, $J_{C\text{-}P}$ = 6.3 Hz, $\mathbf{Z}_{iso}$), 41.8 (d, $J_{C\text{-}P}$ = 17.5 Hz, $\mathbf{Z}_{iso}$), 35.1 (d, $J_{C\text{-}P}$ = 15.8 Hz, $\mathbf{E}_{iso}$), 26.5 (d, $J_{C\text{-}P}$ = 1.8 Hz, $\mathbf{Z}_{iso}$), 26.3 (d, $J_{C\text{-}P}$ = 1.5 Hz, $\mathbf{E}_{iso}$), 24.2 (d, $J_{C\text{-}P}$ = 3.3 Hz, $\mathbf{Z}_{iso}$), 24.0 (d, $J_{C\text{-}P}$ = 3.9 Hz, $\mathbf{E}_{iso}$), 23.8 (d, $J_{C\text{-}P}$ = 5.3 Hz, $\mathbf{Z}_{iso}$), 23.7 (d, $J_{C\text{-}P}$ = 5.1 Hz, $\mathbf{E}_{iso}$), 22.8, 22.3 ppm. **^{31}P NMR ($CDCl_3$, 161.9 MHz):** δ = 8.7 ($\mathbf{E}_{iso}$), 3.5 ($\mathbf{Z}_{iso}$) ppm. **ESI HRMS** *m/z* $C_{11}H_{24}NO_4P^+$ $[M+H]^+$: calcd 266.1515; found 266.1516.

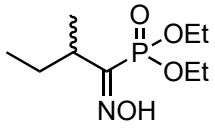

$C_6H_{14}NO_4P$
MW 195,15

Diethyl (1-(hydroxyimino)ethyl)phosphonate. (10b) ^{1}H NMR ($CDCl_3$, 400 MHz): δ = 11.09 (s, br, 1H), 4.15 – 3.99 (m, 4H), 1.95 (d, J = 11.2 Hz, 3H), 1.26 (t, J = 7.1 Hz, 6H) ppm. **^{13}C NMR ($CDCl_3$, 100.6 MHz):** δ = 150.3 (d, $J_{C\text{-}P}$ = 217.8 Hz, $\mathbf{E}_{iso}$), 62.9 (d, $J_{C\text{-}P}$ = 5.9 Hz), 16.2 (d, $J_{C\text{-}P}$ = 6.4 Hz), 11.7 (d, $J_{C\text{-}P}$ = 16.6 Hz) ppm. **^{31}P NMR ($CDCl_3$, 161.9 MHz):** δ = 10.7 ($\mathbf{E}_{iso}$), 5.3 ($\mathbf{Z}_{iso}$) ppm. **ESI HRMS** *m/z* $C_6H_{14}NO_4P^+$ $[M+H]^+$: calcd 196.0733; found 196.0788.


$C_9H_{20}NO_4P$
MW 237,24

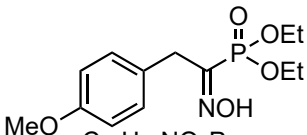
Diethyl (1-(hydroxyimino)-2,2-dimethylpropyl)phosphonate. (11b) ^{1}H NMR ($CDCl_3$, 400 MHz): δ = 4.24 – 4.03 (m, 4H), 1.37 – 1.20 (m, 15H) ppm. **^{13}C NMR ($CDCl_3$, 100.6 MHz):** δ = 158.4 (d, $J_{C\text{-}P}$ = 202.1 Hz, $\mathbf{E}_{iso}$), 157.6 (d, $J_{C\text{-}P}$ = 141.3 Hz, $\mathbf{Z}_{iso}$), 62.8 (d, $J_{C\text{-}P}$ = 6.4 Hz, $\mathbf{E}_{iso}$), 62.4 (d, $J_{C\text{-}P}$ = 6.1 Hz, $\mathbf{Z}_{iso}$), 38.3 (d, $J_{C\text{-}P}$ = 18.7 Hz, $\mathbf{Z}_{iso}$), 37.0 (d, $J_{C\text{-}P}$ = 17.3 Hz, $\mathbf{E}_{iso}$), 28.5 (d, $J_{C\text{-}P}$ = 2.8 Hz, $\mathbf{Z}_{iso}$), 27.6 (d, $J_{C\text{-}P}$ = 3.8 Hz, $\mathbf{E}_{iso}$), 16.3 (t, $J_{C\text{-}P}$ = 7.0 Hz) ppm. **^{31}P NMR ($CDCl_3$, 161.9 MHz):** δ = 11.4 ($\mathbf{E}_{iso}$), 6.7 ($\mathbf{Z}_{iso}$) ppm. **IR (neat)**: ν_{max} = 3152, 2979, 2911, 1436, 1237, 1215, 1016, 974, 954 cm^{-1}. **ESI HRMS** *m/z* $C_9H_{20}NO_4P^+$

[M+H]$^+$: calcd 238.1202; found 238.1208.



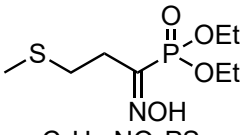
$C_9H_{20}NO_4P$
MW 237,24

Diethyl (1-(hydroxyimino)-2-methylbutyl)phosphonate. (12b) ^{1}H NMR ($CDCl_3$, 400 MHz): δ = 10.74 (s, br, 1H), 4.26 – 3.98 (m, 4H), 3.19 – 3.00 (m, 0.30H, $\mathbf{E}_{iso}$), 2.71 – 2.52 (m, 0.67H, $\mathbf{Z}_{iso}$), 1.84 – 1.33 (m, 2H), 1.29 (t, *J* = 7.1 Hz, 6H), 1.16 (d, *J* = 7.1 Hz, 0.90H, $\mathbf{E}_{iso}$), 1.10 (d, *J* = 6.9 Hz, 2.05H, $\mathbf{Z}_{iso}$), 0.85 (t, *J* = 7.4 Hz, 3H) ppm. **^{13}C NMR ($CDCl_3$, 100.6 MHz):** δ = 157.9 (d, $J_{C\text{-}P}$ = 206.1 Hz, $\mathbf{E}_{iso}$), 155.5 (d, $J_{C\text{-}P}$ = 147.4 Hz, $\mathbf{Z}_{iso}$), 62.8 (d, $J_{C\text{-}P}$ = 6.3 Hz, $\mathbf{E}_{iso}$), 62.6 (dd, $J_{C\text{-}P}$ = 7.5, 6.1 Hz, $\mathbf{Z}_{iso}$), 39.0 (d, $J_{C\text{-}P}$ = 17.0 Hz, $\mathbf{Z}_{iso}$), 34.6 (d, $J_{C\text{-}P}$ = 16.0 Hz, $\mathbf{E}_{iso}$), 27.7 (d, $J_{C\text{-}P}$ = 2.9 Hz, $\mathbf{Z}_{iso}$), 26.3 (d, $J_{C\text{-}P}$ = 2.5 Hz, $\mathbf{E}_{iso}$), 18.2 (d, $J_{C\text{-}P}$ = 3.3 Hz), 16.3 (t, $J_{C\text{-}P}$ = 6.1 Hz), 12.4 ($\mathbf{E}_{iso}$), 11.8 ($\mathbf{Z}_{iso}$) ppm. **^{31}P NMR ($CDCl_3$, 161.9 MHz):** δ = 10.5 ($\mathbf{E}_{iso}$), 6.2 ($\mathbf{Z}_{iso}$) ppm. **IR (neat)**: ν_{max} = 3162, 2968, 2875, 1444, 1392, 1221, 1017, 973, 946 cm^{-1}. **ESI HRMS** *m/z* $C_9H_{20}NO_4P^+$ [M+H]$^+$: calcd 238.1202; found 238.1205.



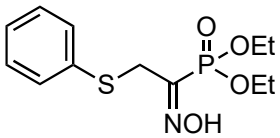
$C_{13}H_{20}NO_5P$
MW 301,28

Diethyl (1-(hydroxyimino)-2-(4-methoxyphenyl)ethyl)phosphonate. (13b) ^{1}H NMR ($CDCl_3$, 400 MHz): δ = 11.49 (s, br, 1H), 7.39 – 7.21 (m, 2H), 6.86 (t, *J* = 7.9 Hz, 2H), 4.25 – 3.96 (m, 4H), 3.93 (d, *J* = 14.5 Hz, 1.47H, $\mathbf{E}_{iso}$), 3.87 – 3.72 (m, 3.50H), 1.32 – 1.19 (m, 6H) ppm. **^{13}C NMR ($CDCl_3$, 100.6 MHz):** δ = 158.3 ($\mathbf{Z}_{iso}$), 158.1 ($\mathbf{E}_{iso}$), 152.3 (d, $J_{C\text{-}P}$ = 213.9 Hz, $\mathbf{E}_{iso}$), 150.4 (d, $J_{C\text{-}P}$ = 152.7 Hz, $\mathbf{Z}_{iso}$), 130.4 ($\mathbf{E}_{iso}$), 130.1 ($\mathbf{Z}_{iso}$), 128.5 ($\mathbf{Z}_{iso}$), 127.8 ($\mathbf{E}_{iso}$), 113.6 ($\mathbf{Z}_{iso}$), 113.6 ($\mathbf{E}_{iso}$), 62.9 (d, $J_{C\text{-}P}$ = 5.9 Hz, $\mathbf{E}_{iso}$), 62.5 (d, $J_{C\text{-}P}$ = 5.8 Hz, $\mathbf{Z}_{iso}$), 55.1, 37.8 (d, $J_{C\text{-}P}$ = 18.8 Hz, $\mathbf{Z}_{iso}$), 31.0 (d, $J_{C\text{-}P}$ = 16.8 Hz, $\mathbf{E}_{iso}$), 16.0 (d, $J_{C\text{-}P}$ = 6.6 Hz, $\mathbf{Z}_{iso}$), 15.9 (d, $J_{C\text{-}P}$ = 6.5 Hz, $\mathbf{E}_{iso}$) ppm. **^{31}P NMR ($CDCl_3$, 161.9 MHz):** δ = 10.4 ($\mathbf{E}_{iso}$), 5.5 ($\mathbf{Z}_{iso}$) ppm. **IR (neat)**: ν_{max} = 3155, 2988, 1611, 1511, 1442, 1244, 1211, 1177, 1016, 974, 953 cm^{-1}. **ESI HRMS** *m/z* $C_{13}H_{20}NO_5P^+$ [M+H]$^+$: calcd 302.1151; found 302.1154.



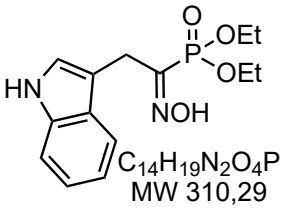
$C_8H_{18}NO_4PS$
MW 255,27

Diethyl (1-(hydroxyimino)-3-(methylthio)propyl)phosphonate. (14b) ^{1}H NMR ($CDCl_3$, 400 MHz): δ = 10.91 (s, br, 1H, $\mathbf{E}_{iso}$), 4.23 – 4.04 (m, 4H), 2.82 – 2.71 (m, 2H), 2.70 – 2.62 (m, 2H), 2.10 (s, 2.76H, $\mathbf{E}_{iso}$), 2.07 (s, 0.23H, $\mathbf{Z}_{iso}$), 1.29 (t, *J* = 7.1 Hz, 6H) ppm. **^{13}C NMR ($CDCl_3$, 100.6 MHz):** δ = 152.3 (d, $J_{C\text{-}P}$ = 214.9 Hz, $\mathbf{E}_{iso}$), 150.1 (d, $J_{C\text{-}P}$ = 153.0 Hz, $\mathbf{Z}_{iso}$), 63.2 (d, $J_{C\text{-}P}$ = 6.2 Hz, $\mathbf{E}_{iso}$), 62.9 (d, $J_{C\text{-}P}$ = 6.0 Hz, $\mathbf{Z}_{iso}$), 33.0 (d, $J_{C\text{-}P}$ = 17.8 Hz, $\mathbf{Z}_{iso}$), 31.4 (d, $J_{C\text{-}P}$ = 3.0 Hz, $\mathbf{Z}_{iso}$), 29.6 (d, $J_{C\text{-}P}$ = 2.1 Hz, $\mathbf{E}_{iso}$), 26.6 (d, $J_{C\text{-}P}$ = 15.8 Hz, $\mathbf{E}_{iso}$), 16.3 (d, $J_{C\text{-}P}$ = 6.4 Hz), 16.2 ppm. **^{31}P NMR ($CDCl_3$, 161.9 MHz):** δ = 10.1 ($\mathbf{E}_{iso}$), 5.1 ($\mathbf{Z}_{iso}$) ppm. **ESI HRMS** *m/z* $C_8H_{18}NO_4PS^+$ [M+H]$^+$: calcd 256.0766; found 256.0803.



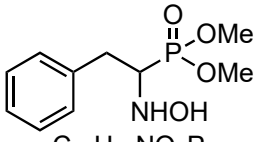
$C_{12}H_{18}NO_4PS$
MW 303,31

Diethyl (1-(hydroxyimino)-2-(phenylthio)ethyl)phosphonate. (15b) ^{1}H NMR ($CDCl_3$, 400 MHz): δ = 11.28 (s, br, 0.66H, **E**$_{iso}$), 10.97 (s, br, 0.28H, **Z**$_{iso}$), 7.48 – 7.13 (m, 5H), 4.28 – 4.02 (m, 4H), 3.97 (d, *J* = 13.6 Hz, 1.36H, **E**$_{iso}$), 3.84 (d, *J* = 12.0 Hz, 0.62H, **Z**$_{iso}$), 1.35 – 1.22 (m, 6H) ppm. **^{13}C NMR ($CDCl_3$, 100.6 MHz):** δ = 150.0 (d, $J_{C\text{-}P}$ = 219.3 Hz, **E**$_{iso}$), 147.7 (d, $J_{C\text{-}P}$ = 159.2 Hz, **Z**$_{iso}$), 135.9 (**E**$_{iso}$), 134.9 (**Z**$_{iso}$), 131.2, 130.1, 128.9, 127.0, 126.6, 63.4 (d, $J_{C\text{-}P}$ = 5.9 Hz, **E**$_{iso}$), 63.2 (d, $J_{C\text{-}P}$ = 6.1 Hz, **Z**$_{iso}$), 36.7 (d, $J_{C\text{-}P}$ = 20.2 Hz, **Z**$_{iso}$), 27.9 (d, $J_{C\text{-}P}$ = 18.2 Hz, **E**$_{iso}$), 16.3 (d, $J_{C\text{-}P}$ = 6.6 Hz, **Z**$_{iso}$), 16.2 (d, $J_{C\text{-}P}$ = 6.6 Hz, **E**$_{iso}$) ppm. **^{31}P NMR ($CDCl_3$, 161.9 MHz):** δ = 9.1 (**E**$_{iso}$), 4.2 (**Z**$_{iso}$) ppm. **ESI HRMS** *m/z* $C_{12}H_{18}NO_4PS^+$ $[M+H]^+$: calcd 304.0766; found 304.0783.



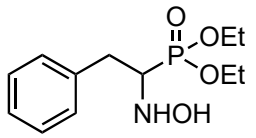
$C_{14}H_{19}N_2O_4P$
MW 310,29

Diethyl (1-(hydroxyimino)-2-(1*H*-indol-3-yl)ethyl)phosphonate. (16b) ^{1}H NMR ($CDCl_3$, 400 MHz): δ = 10.35 (s, br, 1H), 8.61 (s, 0.52H, **Z**$_{iso}$), 8.49 (s, 0.46H, **E**$_{iso}$), 7.68 (d, *J* = 8.0 Hz, 0.46H, **E**$_{iso}$), 7.59 (d, *J* = 8 Hz, 0.55H, **Z**$_{iso}$), 7.30 (d, *J* = 0.9 Hz, 0.44H, **E**$_{iso}$), 7.28 (d, *J* = 1.0 Hz, 0.55H, **Z**$_{iso}$), 7.18 - 6.99 (m, 3H), 4.10 - 3.77 (m, 6H), 1.12 (td, *J* = 7.1, 0.5 Hz, 3.24H, **Z**$_{iso}$), 1.07 (td, *J* = 7.0, 0.6 Hz, 2.71H, **E**$_{iso}$) ppm. **^{13}C NMR ($CDCl_3$, 100.6 MHz):** δ = 153.7 (d, $J_{C\text{-}P}$ = 212.1 Hz, **E**$_{iso}$), 150.9 (d, $J_{C\text{-}P}$ = 152.0 Hz, **Z**$_{iso}$), 136.4 (**Z**$_{iso}$), 136.1 (**E**$_{iso}$), 127.5 (**E**$_{iso}$), 127.3 (**Z**$_{iso}$), 124.4 (**E**$_{iso}$), 124.1 (**Z**$_{iso}$), 121.9 (**Z**$_{iso}$), 121.8 (**E**$_{iso}$), 119.3 (**Z**$_{iso}$), 119.3 (**E**$_{iso}$), 119.0 (**E**$_{iso}$), 118.8 (**Z**$_{iso}$), 111.4 (**Z**$_{iso}$), 111.3 (**E**$_{iso}$), 110.2 (d, $J_{C\text{-}P}$ = 2.2 Hz, **Z**$_{iso}$), 108.7 (d, $J_{C\text{-}P}$ = 1.6 Hz, **E**$_{iso}$), 63.1 (d, $J_{C\text{-}P}$ = 5.8 Hz, **E**$_{iso}$), 63.0 (d, $J_{C\text{-}P}$ = 5.9 Hz, **Z**$_{iso}$), 29.0 (d, $J_{C\text{-}P}$ = 18.3 Hz, **Z**$_{iso}$), 22.0 (d, $J_{C\text{-}P}$ = 16.0 Hz, **E**$_{iso}$), 16.2 (d, $J_{C\text{-}P}$ = 6.4 Hz, **Z**$_{iso}$), 16.1 (d, $J_{C\text{-}P}$ = 6.6 Hz, **E**$_{iso}$) ppm. **^{31}P NMR ($CDCl_3$, 161.9 MHz):** δ = 10.0 (**E**$_{iso}$), 5.8 (**Z**$_{iso}$) ppm. **ESI HRMS** *m/z* $C_{14}H_{19}N_2O_4P^+$ $[M+H]^+$: calcd 311.1155; found 311.1159.



$C_{10}H_{16}NO_4P$
MW 245,21

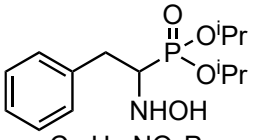
Dimethyl (1-(hydroxyamino)-2-phenylethyl)phosphonate. (1c) ^{1}H NMR ($CDCl_3$, 400 MHz): δ = 7.39 – 7.22 (m, 5H), 3.82 (d, *J* = 10.7 Hz, 3H), 3.75 (d, *J* = 10.7 Hz, 3H), 3.48 (dt, *J* = 14.3, 7.1 Hz, 1H), 3.13 (t, *J* = 9.2 Hz, 2H) ppm. **^{13}C NMR ($CDCl_3$, 100.6 MHz):** δ = 137.4 (d, $J_{C\text{-}P}$ = 12.8 Hz), 129.3, 128.6, 126.8, 60.7 (d, $J_{C\text{-}P}$ = 152.7 Hz), 53.0 (d, $J_{C\text{-}P}$ = 6.3 Hz), 52.6 (d, $J_{C\text{-}P}$ = 6.8 Hz), 32.6 ppm. **^{31}P NMR ($CDCl_3$, 161.9 MHz):** δ = 28.9 ppm. **ESI HRMS** *m/z* $C_{10}H_{16}NO_4P^+$ $[M+H]^+$: calcd 246.0889; found 246.0891.



$C_{12}H_{20}NO_4P$
MW 273,27

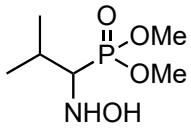
Diethyl (1-(hydroxyamino)-2-phenylethyl)phosphonate. (2c) ^{1}H NMR ($CDCl_3$, 400 MHz): δ = 7.40 – 7.22 (m, 5H), 6.26 (s, br, 1H), 4.27 – 4.06 (m, 4H), 3.45 (ddd, *J* = 13.9, 8.9, 5.5 Hz, 1H), 3.19 – 3.02 (m, 2H), 1.37 (t, *J* = 7.1 Hz, 3H), 1.30 (t, *J* = 7.1 Hz, 3H) ppm. **^{13}C NMR ($CDCl_3$, 100.6 MHz):** δ = 137.6 (d, $J_{C\text{-}P}$ = 12.5 Hz), 129.4, 128.7, 126.9, 62.5 (d, $J_{C\text{-}P}$ = 6.6 Hz), 62.2 (d, $J_{C\text{-}P}$ = 6.9 Hz), 61.3 (d, $J_{C\text{-}P}$ = 153.6 Hz), 32.8, 16.6 (d, $J_{C\text{-}P}$ = 6.0 Hz), 16.5 (d, $J_{C\text{-}P}$ = 7.0 Hz) ppm. **^{31}P NMR ($CDCl_3$, 161.9 MHz):** δ = 26.0 ppm. **ESI HRMS** *m/z*

$C_{12}H_{20}NO_4P^+$ [M+H]$^+$: calcd 274.1202; found 274.1204.



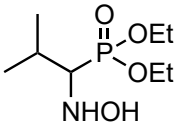
$C_{14}H_{24}NO_4P$
MW 301,32

Diisopropyl (1-(hydroxyamino)-2-phenylethyl)phosphonate. (3c) ^{1}H NMR ($CDCl_3$, 400 MHz): δ = 7.41 – 7.23 (m, 5H), 4.90 – 4.71 (m, 2H), 3.39 (ddd, *J* = 12.8, 9.7, 4.6 Hz, 1H), 3.06 (m, 2H), 1.42 – 1.24 (m, 12H) ppm. **^{13}C NMR ($CDCl_3$, 100.6 MHz):** δ = 137.7 (d, $J_{C\text{-}P}$ = 12.9 Hz), 129.5, 128.7, 126.9, 71.3 (d, $J_{C\text{-}P}$ = 6.9 Hz), 71.0 (d, $J_{C\text{-}P}$ = 7.0 Hz), 62.0 (d, $J_{C\text{-}P}$ = 156.2 Hz), 33.0, 24.4 (d, $J_{C\text{-}P}$ = 3.2 Hz), 24.2 (d, $J_{C\text{-}P}$ = 3.6 Hz), 24.1 – 24.0 (m, 2C) ppm. **^{31}P NMR ($CDCl_3$, 161.9 MHz):** δ = 23.9 ppm. **ESI HRMS** *m/z* $C_{14}H_{24}NO_4P^+$ [M+H]$^+$: calcd 302.1515; found 302.1517.



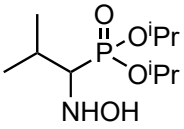
$C_6H_{16}NO_4P$
MW 197,17

Dimethyl (1-(hydroxyamino)-2-methylpropyl)phosphonate. (4c) ^{1}H NMR ($CDCl_3$, 400 MHz): δ = 3.79 (d, *J* = 5.1 Hz, 3H), 3.76 (d, *J* = 5.1 Hz, 3H), 3.02 (dd, *J* = 14.3, 6.2 HZ, 1H), 2.23 (dq, *J* = 13.3, 6.6 Hz, 1H), 1.08 (dd, *J* = 10.9, 6.9 Hz, 6H) ppm. **^{13}C NMR ($CDCl_3$, 100.6 MHz):** δ = 65.6 (d, $J_{C\text{-}P}$ = 142.2 Hz), 52.8 (d, $J_{C\text{-}P}$ = 6.7 Hz), 52.6 (d, $J_{C\text{-}P}$ = 7.0 Hz), 27.3, 20.8 (d, $J_{C\text{-}P}$ = 7.5 Hz), 19.3 (d, $J_{C\text{-}P}$ = 7.2 Hz) ppm. **^{31}P NMR ($CDCl_3$, 161.9 MHz):** δ = 30.2 ppm. **ESI HRMS** *m/z* $C_6H_{16}NO_4P^+$ [M+H]$^+$: calcd 198.0889; found 198.0891.



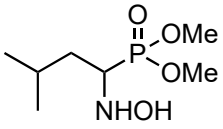
$C_8H_{20}NO_4P$
MW 225,22

Diethyl (1-(hydroxyamino)-2-methylpropyl)phosphonate. (5c) ^{1}H NMR ($CDCl_3$, 400 MHz): δ = 7.04 (s, br, 1H), 5.52 (s, br, 1H), 4.09 - 3.95 (m, 4H), 2.87 (dd, *J* = 15.0, 5.9 Hz, 1H), 2.15 (dq, *J* = 13.7, 6.8 Hz, 1H), 1.19 (td, *J* = 7.1, 2.2 Hz, 6H), 0.96 (dd, *J* = 10.0, 6.9 Hz, 6H) ppm. **^{13}C NMR ($CDCl_3$, 100.6 MHz):** δ = 65.5 (d, $J_{C\text{-}P}$ = 141.5 Hz), 61.7 (d, $J_{C\text{-}P}$ = 6.7 Hz), 61.6 (d, $J_{C\text{-}P}$ = 7.0 Hz), 27.0 (d, $J_{C\text{-}P}$ = 1.5 Hz), 20.5 (d, $J_{C\text{-}P}$ = 7.6 Hz), 19.1 (d, $J_{C\text{-}P}$ = 6.7 Hz), 16.3 (d, $J_{C\text{-}P}$ = 1.6 Hz), 16.2 (d, $J_{C\text{-}P}$ = 1.6 Hz) ppm. **^{31}P NMR ($CDCl_3$, 161.9 MHz):** δ = 27.6 ppm. **ESI HRMS** *m/z* $C_8H_{20}NO_4P^+$ [M+H]$^+$: calcd 226.1202; found 226.1204.



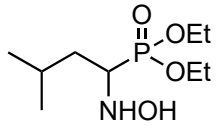
$C_{10}H_{24}NO_4P$
MW 253,28

Diisopropyl (1-(hydroxyamino)-2-methylpropyl)phosphonate. (6c) ^{1}H NMR ($CDCl_3$, 400 MHz): δ = 4.75 – 4.60 (m, 2H), 2.83 (dd, *J* = 14.8, 6.0 Hz, 1H), 2.15 (dq, *J* = 13.4, 6.7 Hz, 1H), 1.23 (dd, *J* = 6.7, 5.3 Hz, 12H), 0.99 (dd, *J* = 9.2, 6.9 Hz, 6H) ppm. **^{13}C ($CDCl_3$, 100.6 MHz):** δ = 70.5 (d, $J_{C\text{-}P}$ = 7.1 Hz), 70.4 (d, $J_{C\text{-}P}$ = 7.4 Hz), 66.3 (d, $J_{C\text{-}P}$ = 142.7 Hz), 27.2, 24.1 (d, $J_{C\text{-}P}$ = 3.6 Hz), 24.1 (d, $J_{C\text{-}P}$ = 3.8 Hz), 23.9 (d, $J_{C\text{-}P}$ = 5.0 Hz), 23.8 (d, $J_{C\text{-}P}$ = 5.2 Hz), 20.7 (d, $J_{C\text{-}P}$ = 7.4 Hz), 19.3 (d, $J_{C\text{-}P}$ = 7.0) ppm. **^{31}P NMR ($CDCl_3$, 161.9 MHz):** δ = 25.6 ppm. **ESI HRMS** *m/z* $C_{10}H_{24}NO_4P^+$ [M+H]$^+$: calcd 254.1515; found 254.1517.



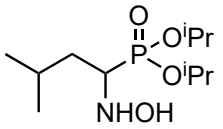
$C_7H_{18}NO_4P$
MW 211,20

Dimethyl (1-(hydroxyamino)-3-methylbutyl)phosphonate. (7c) ^{1}H NMR ($CDCl_3$, 400 MHz): δ = 3.46 (dd, *J* = 11.0, 4.4 Hz, 6H), 2.94 (ddd, *J* = 13.9, 9.7, 4.6 Hz, 1H), 1.59 (hept, *J* = 6.7 Hz, 1H), 1.51 – 1.36 (m, 1H), 1.22 – 1.09 (m, 1H), 0.62 (dd, *J* = 16.8, 6.8 Hz, 6H) ppm. **^{13}C NMR ($CDCl_3$, 100.6 MHz):** δ = 56.9 (d, $J_{C\text{-}P}$ = 143.7 Hz), 52.1 (d, $J_{C\text{-}P}$ = 6.3 Hz), 51.8 (d, $J_{C\text{-}P}$ = 7.2 Hz), 35.3, 24.1 (d, $J_{C\text{-}P}$ = 11.0 Hz), 22.6, 21.1 ppm. **^{31}P NMR ($CDCl_3$, 161.9 MHz):** δ = 31.5 ppm. **ESI HRMS** *m/z* $C_7H_{18}NO_4P^+$ $[M+H]^+$: calcd 212.1046; found 212.1047.



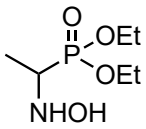
$C_9H_{22}NO_4P$
MW 239,25

Diethyl (1-(hydroxyamino)-3-methylbutyl)phosphonate. (8c) ^{1}H NMR ($CDCl_3$, 400 MHz): δ = 4.14 – 3.97 (m, 4H), 3.16 (ddd, *J* = 13.6, 9.2, 4.8 Hz, 1H), 1.85 – 1.72 (m, 1H), 1.68 – 1.57 (m, 1H), 1.48 – 1.36 (m, 1H), 1.24 (t, *J* = 7.1 Hz, 6H), 0.85 (dd, *J* = 14.2, 6.6 Hz, 6H) ppm. **^{13}C NMR ($CDCl_3$, 100.6 MHz):** δ = 62.1 (d, $J_{C\text{-}P}$ = 6.5 Hz), 61.9 (d, $J_{C\text{-}P}$ = 7.0 Hz), 57.7 (d, $J_{C\text{-}P}$ = 146.7 Hz), 35.9, 24.8 (d, $J_{C\text{-}P}$ = 10.6 Hz), 23.0, 21.7, 16.4 (dd, $J_{C\text{-}P}$ = 5.9, 1.0 Hz, 2C) ppm. **^{31}P NMR ($CDCl_3$, 161.9 MHz):** δ = 28.2 ppm. **ESI HRMS** *m/z* $C_9H_{22}NO_4P^+$ $[M+H]^+$: calcd 240.1359; found 240.1361.



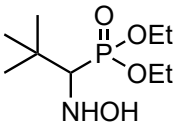
$C_{11}H_{26}NO_4P$
MW 267,31

Diisopropyl (1-(hydroxyamino)-3-methylbutyl)phosphonate. (9c) ^{1}H NMR ($CDCl_3$, 400 MHz): δ = 7.21 (s, br, 1H), 5.37 (s, br, 1H), 4.67 – 4.51 (m, 2H), 3.00 (ddd, *J* = 13.6, 8.8, 4.9 Hz, 1H), 1.80 – 1.69 (m, 1H), 1.59 – 1.47 (m, 1H), 1.39 – 1.28 (m, 1H), 1.22 – 1.12 (m, 12H), 0.76 (dd, *J* = 13.7, 6.5 Hz, 6H) ppm. **^{13}C NMR ($CDCl_3$, 100.6 MHz):** δ = 70.4 (d, $J_{C\text{-}P}$ = 6.7 Hz), 70.2 (d, $J_{C\text{-}P}$ = 7.2 Hz), 58.1 (d, $J_{C\text{-}P}$ = 147.1 Hz), 36.1, 24.6 (d, $J_{C\text{-}P}$ = 10.1 Hz), 24.0 (d, $J_{C\text{-}P}$ = 2.8 Hz), 23.9 (d, $J_{C\text{-}P}$ = 3.6 Hz), 23.8 (d, $J_{C\text{-}P}$ = 4.9 Hz), 23.7 (d, $J_{C\text{-}P}$ = 5.5 Hz), 22.9, 21.7 ppm. **^{31}P NMR ($CDCl_3$, 161.9 MHz):** δ = 26.1 ppm. **ESI HRMS** *m/z* $C_{11}H_{26}NO_4P^+$ $[M+H]^+$: calcd 268.1672; found 268.1673.



$C_6H_{16}NO_4P$
MW 197,17

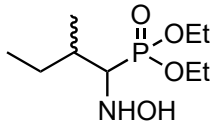
Diethyl (1-(hydroxyamino)ethyl)phosphonate. (10c) ^{1}H NMR (D_2O, 400 MHz): δ = 4.22 – 4.10 (m, 4H), 3.96 (dq, *J* = 14.6, 7.2 Hz, 1H), 1.43 (dd, *J* = 16.6, 7.3 Hz, 3H), 1.24 (td, *J* = 7.1, 1.6 Hz, 6H) ppm. **^{13}C NMR (D_2O, 100.6 MHz):** δ = 65.2 (d, $J_{C\text{-}P}$ = 2.2 Hz), 65.1 (d, $J_{C\text{-}P}$ = 2.0 Hz), 52.7 (d, $J_{C\text{-}P}$ = 155.6 Hz), 15.6 (d, $J_{C\text{-}P}$ = 3.6 Hz), 15.6 (d, $J_{C\text{-}P}$ = 3.6 Hz), 9.3 (d, $J_{C\text{-}P}$ = 3.1 Hz) ppm. **^{31}P NMR (D_2O, 161.9 MHz):** δ = 19.0 ppm. **ESI HRMS** *m/z* $C_6H_{16}NO_4P^+$ $[M+H]^+$: calcd 198.0889; found 198.0891.



$C_9H_{22}NO_4P$
MW 239,25

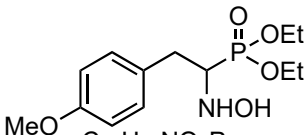
Diethyl (1-(hydroxyamino)-2,2-dimethylpropyl)phosphonate. (11c) ^{1}H NMR ($CDCl_3$, 400 MHz): δ = 4.13 – 4.01 (m, 4H), 2.85 (d, *J* = 15.6 Hz, 1H), 1.23 (td, *J* = 7.1, 3.7 Hz, 6H), 1.01 (s, 9H) ppm. **^{13}C NMR ($CDCl_3$, 100.6 MHz):** δ = 69.5 (d, $J_{C\text{-}P}$ = 139.4 Hz), 61.9 (d, $J_{C\text{-}P}$ = 4.3 Hz), 61.8 (d, $J_{C\text{-}P}$ = 4.3 Hz), 34.0 (d, $J_{C\text{-}P}$ = 3.4 Hz), 28.1 (d, $J_{C\text{-}P}$ = 6.2 Hz, 3C), 16.4 (d, $J_{C\text{-}P}$ = 2.0 Hz), 16.3 (d, $J_{C\text{-}P}$ = 2.1 Hz) ppm. **^{31}P**

NMR ($CDCl_3$, 161.9 MHz): δ = 27.5 ppm. **ESI HRMS** *m/z* $C_9H_{22}NO_4P^+$ $[M+H]^+$: calcd 240.1359; found 240.1361.



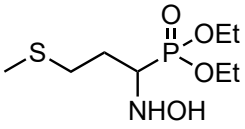
$C_9H_{22}NO_4P$
MW 239,25

Diethyl (1-(hydroxyamino)-2-methylbutyl)phosphonate (exist as a pair of diastereoisomers). (12c) ^{1}H NMR ($CDCl_3$, 400 MHz): δ = 7.13 (s, br, 1H), 5.44 (s, br, 1H), 4.08 – 3.94 (m, 4H), 3.07 (dd, *J* = 15.5, 4.3 Hz, 0.5H), 2.98 (dd, *J* = 15.4, 5.7 Hz, 0.5H), 2.01 – 1.81 (m, 1H), 1.66 – 1. 40 (m, 1H), 1.32 – 1.11 (m, 7H), 0.92 (dd, *J* = 10.8, 7.0 Hz, 3H), 0.84 – 0.70 (m, 3H) ppm. **^{13}C NMR ($CDCl_3$, 100.6 MHz):** δ = 63.9 (d, $J_{C\text{-}P}$ = 141.8 Hz), 62.8 (d, $J_{C\text{-}P}$ = 141.8 Hz), 61.7 (m, 2C), 33.9, 33.3, 27.4 (d, $J_{C\text{-}P}$ = 10.6 Hz), 25.5 (d, $J_{C\text{-}P}$ = 5.6 Hz), 16.2 (m, 2C), 15.2, 15.2, 11.8, 11.3 ppm. **^{31}P NMR ($CDCl_3$, 161.9 MHz):** δ = 27.7, 27.6 ppm (diastereoisomers). **ESI HRMS** *m/z* $C_9H_{22}NO_4P^+$ $[M+H]^+$: calcd 240.1359; found 240.1361.



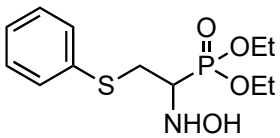
$C_{13}H_{22}NO_5P$
MW 303,29

Diethyl (1-(hydroxyamino)-2-(4-methoxyphenyl)ethyl)phosphonate. (13c) ^{1}H NMR ($CDCl_3$, 400 MHz): δ = 7.17 (d, *J* = 8.4 Hz, 2H), 6.83 (d, *J* = 8.5 Hz, 2H), 4.21 – 4.02 (m, 4H), 3.77 (s, 3H), 3.35 (ddd, *J* = 13.8, 9.2, 5.1 Hz, 1H), 3.08 – 2.92 (m, 2H), 1.32 (t, *J* = 7.1 Hz, 3H), 1.27 (t, *J* = 7.1 Hz, 3H) ppm. **^{13}C NMR ($CDCl_3$, 100.6 MHz):** δ = 158.6, 130.4, 129.4 (d, $J_{C\text{-}P}$ = 12.9 Hz), 114.1, 62.5 (d, $J_{C\text{-}P}$ = 6.6 Hz), 62.2, 61.5 (d, $J_{C\text{-}P}$ = 152.9 Hz), 55.4, 31.9, 16.5 (t, $J_{C\text{-}P}$ = 6.1 Hz, 2C) ppm. **^{31}P NMR ($CDCl_3$, 161.9 MHz):** δ = 26.1 ppm. **ESI HRMS** *m/z* $C_{13}H_{22}NO_5P^+$ $[M+H]^+$: calcd 304.1308; found 304.1311.



$C_8H_{20}NO_4PS$
MW 257,28

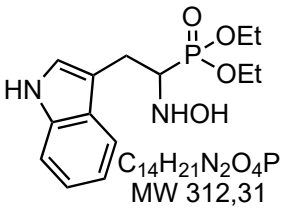
Diethyl (1-(hydroxyamino)-3-(methylthio)propyl)phosphonate. (14c) ^{1}H NMR ($CDCl_3$, 400 MHz): δ = 7.18 (s, br, 1H), 5.58 (s, br, 1H), 4.00 – 3.88 (m, 4H), 3.24 – 3.12 (m, 1H), 2.60 – 2.41 (m, 2H), 1.98 – 1.70 (m, 5H), 1.12 (td, *J* = 7.0, 2.4 Hz, 6H) ppm. **^{13}C NMR ($CDCl_3$, 100.6 MHz):** δ = 61.8 (d, $J_{C\text{-}P}$ = 6.4 Hz), 61.6 (d, $J_{C\text{-}P}$ = 6.8 Hz), 57.6 (d, $J_{C\text{-}P}$ = 144.3 Hz), 30.5 (d, $J_{C\text{-}P}$ = 11.8 Hz), 25.8, 16.1 (d, $J_{C\text{-}P}$ = 2.3 Hz), 16.0 (d, $J_{C\text{-}P}$ = 2.5 Hz), 14.6 ppm. **^{31}P NMR ($CDCl_3$, 161.9 MHz):** δ = 27.5 ppm. **ESI HRMS** *m/z* $C_8H_{20}NO_4PS^+$ $[M+H]^+$: calcd 258.0923; found 258.0924.



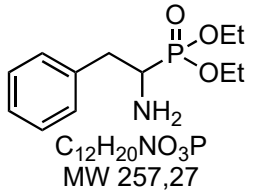
$C_{12}H_{20}NO_4PS$
MW 305,33

Diethyl (1-(hydroxyamino)-2-(phenylthio)ethyl)phosphonate. (15c) ^{1}H NMR ($CDCl_3$, 400 MHz): δ = 7.42 – 7.15 (m, 5H), 6.65 (s, br, 1H), 5.87 (s, br, 1H), 4.23 – 4.04 (m, 4H), 3.42 – 3.19 (m, 3H), 1.29 (dt, *J* = 11.1, 7.1 Hz, 6H) ppm. **^{13}C NMR ($CDCl_3$, 100.6 MHz):** δ = 135.0, 130.0, 129.2, 126.7, 62.7 (d, $J_{C\text{-}P}$ = 6.5 Hz), 62.4 (d, $J_{C\text{-}P}$ = 6.9 Hz), 58.6 (d, $J_{C\text{-}P}$ = 151.5 Hz), 31.4 (d, $J_{C\text{-}P}$ = 4.8 Hz), 16.5 (d, $J_{C\text{-}P}$ = 3.9 Hz), 16.4 (d, $J_{C\text{-}P}$ = 4.0 Hz) ppm. **^{31}P NMR ($CDCl_3$, 161.9 MHz):** δ = 24.5 ppm. **ESI HRMS** *m/z* $C_{12}H_{20}NO_4PS^+$ $[M+H]^+$: calcd 306.0923; found 306.0925.

Diethyl (1-(hydroxyamino)-2-(1*H*-indol-3-yl)ethyl)phosphonate. (16c) ^{1}H NMR ($CDCl_3$, 400 MHz): δ = 8.46 (s, 1H), 7.61 – 7.55 (m,



1H), 7.34 (d, *J* = 8.1 Hz, 1H), 7.26 – 7.04 (m, 3H), 4.27 – 4.04 (m, 4H), 3.53 – 3.40 (m, 1H), 3.23 (t, *J* = 7.0 Hz, 2H), 1.35 (t, *J* = 7.1 Hz, 3H), 1.31 (t, *J* = 7.0 Hz, 3H) ppm. **^{13}C NMR ($CDCl_3$, 100.6 MHz):** δ = 136.5, 127.2, 123.9, 122.3,119.7, 118.6, 111.6, 110.3, 62.9 (d, $J_{C\text{-}P}$ = 6.6 Hz), 62.5 (d, $J_{C\text{-}P}$ = 6.9 Hz), 59.8 (d, $J_{C\text{-}P}$ = 155.2 Hz), 22.1, 16.6 (t, $J_{C\text{-}P}$ = 5.9 Hz, 2C) ppm. **^{31}P NMR ($CDCl_3$, 161.9 MHz):** δ = 25.7 ppm. **ESI HRMS** *m/z* $C_{14}H_{21}N_2O_4P^+$ $[M+H]^+$: calcd 313.1311; found 313.1313.



Diethyl (1-amino-2-phenylethyl)phosphonate. (am-2b) ^{1}H NMR ($CDCl_3$, 400 MHz): δ = 7.21 – 7. 05 (m, 5H), 4.09 – 3.98 (m, 4H), 3.18 – 3.02 (m, 2H), 2.61 – 2.47 (m, 1H), 1.20 (td, *J* = 7.1, 2.0 Hz, 6H) ppm. **^{13}C NMR ($CDCl_3$, 100.6 MHz):** δ = 137.6 (d, $J_{C\text{-}P}$ = 15.7 Hz), 128.9, 128.2, 126.4, 62.0, 50.0 (d, $J_{C\text{-}P}$ = 154.1 Hz), 37.5, 16.2 (d, $J_{C\text{-}P}$ = 5.5 Hz) ppm. **^{31}P NMR ($CDCl_3$, 161.9 MHz):** δ = 27.9 ppm. **IR (neat)**: ν_{max} = 2981, 1603, 1495, 1454, 1391, 1231, 1163, 1050, 1020, 956 cm^{-1}. **ESI HRMS** *m/z* $C_{12}H_{20}NO_3P^+$ $[M+H]^+$: calcd 258.1253; found 258.1251.

2.3 LC analysis

2.3.1 Analytical Method

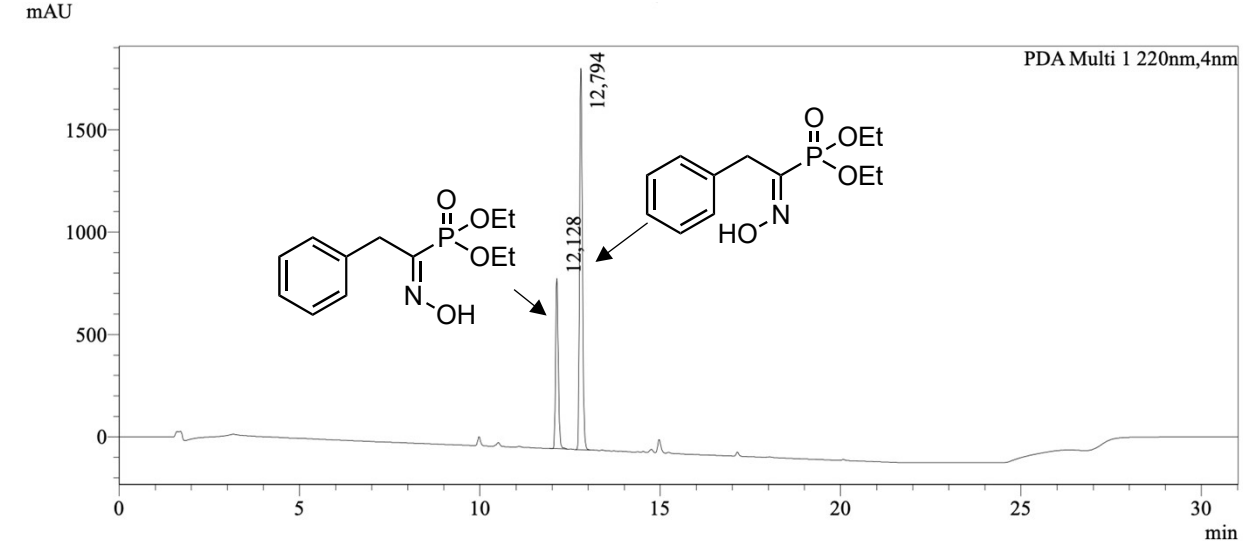
Eluent: A: Water + 0.1% Formic acid (*v*/*v*)
B: Acetonitrile

Gradient Table:

Time [min]	A [%]	B [%]
0	100	0
20	20	80
23	20	80
23.01	100	0
26	100	0

Flow : 1 mL min^{-1}
Injection Volume : 5-10 µL
Column : C18, 100 × 4.6 mm, 3 µm
Oven Temperature : 40 °C
Diode Array Detector : 180-800 nm

2.3.2 Copies of representative LC traces



Peak Table

PDA Ch1 220nm

Peak#	Ret. Time	Area	Height	Area%
1	12,128	4350887	831958	30,091
2	12,794	10108313	1862825	69,909
Total		14459201	2694782	100,000

Figure S1. LC trace of the reduction of diethyl (1-(hydroxyimino)-2-phenylethyl)phosphonate (**2b**). Crude reaction mixture at t = 0 min. Peak identification was conducted using purified substances by micropreparative HPLC and analyzed by HRMS as well as comparison with the ^{31}P NMR ratios. Peak #1 (12.128 min) = compound **2b (*Z*$_{iso}$)**, peak #2 (12.794 min) = compound **2b (*E*$_{iso}$)**.

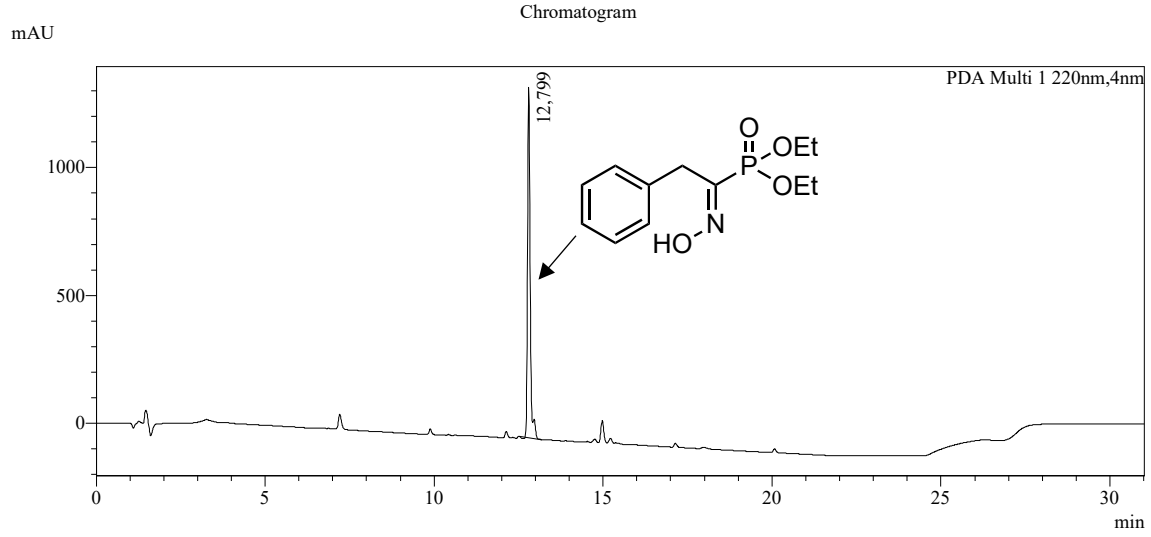


Figure S2. LC trace of the reduction of diethyl (1-(hydroxyimino)-2-phenylethyl)phosphonate (**2b**). Crude reaction mixture at t = 60 min highlighting the total reduction of the ***Z*$_{iso}$** while the ***E*$_{iso}$** remains untouched. Peak identification was conducted using purified substances by micropreparative HPLC and analyzed by HRMS. Peak #1 (12.799 min) = compound **2b (*E*$_{iso}$)**.

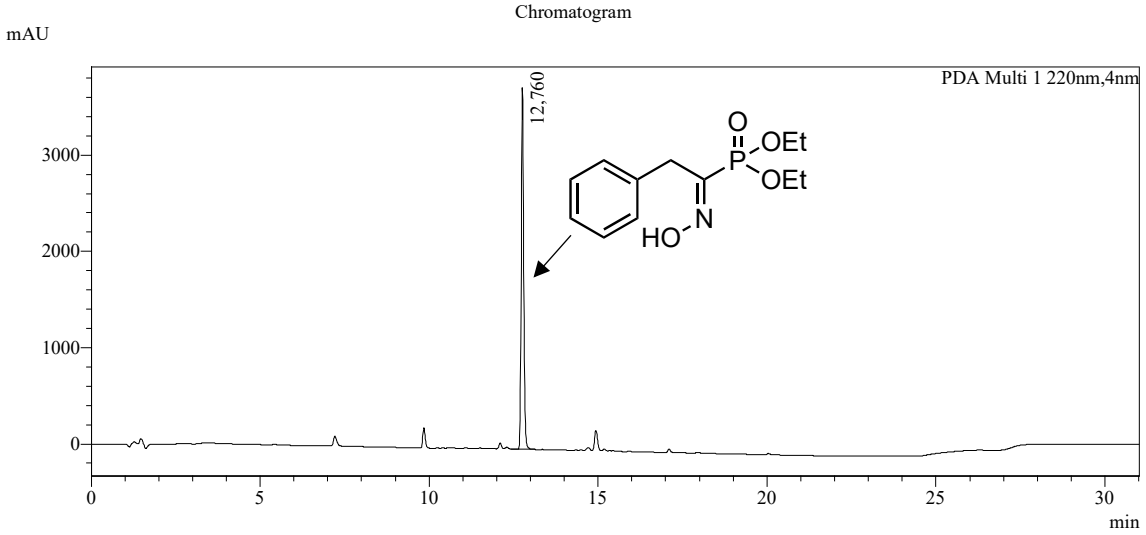


Figure S3. LC trace of the reduction of diethyl (1-(hydroxyimino)-2-phenylethyl)phosphonate (**2b**). Crude reaction mixture at t = 1 day highlighting the total reduction of the $\boldsymbol{Z}_{\mathbf{iso}}$ while the $\boldsymbol{E}_{\mathbf{iso}}$ remains untouched. Peak identification was conducted using purified substances by micropreparative HPLC and analyzed by HRMS. Peak #1 (12.760 min) = compound **2b ($\boldsymbol{E}_{\mathbf{iso}}$)**.

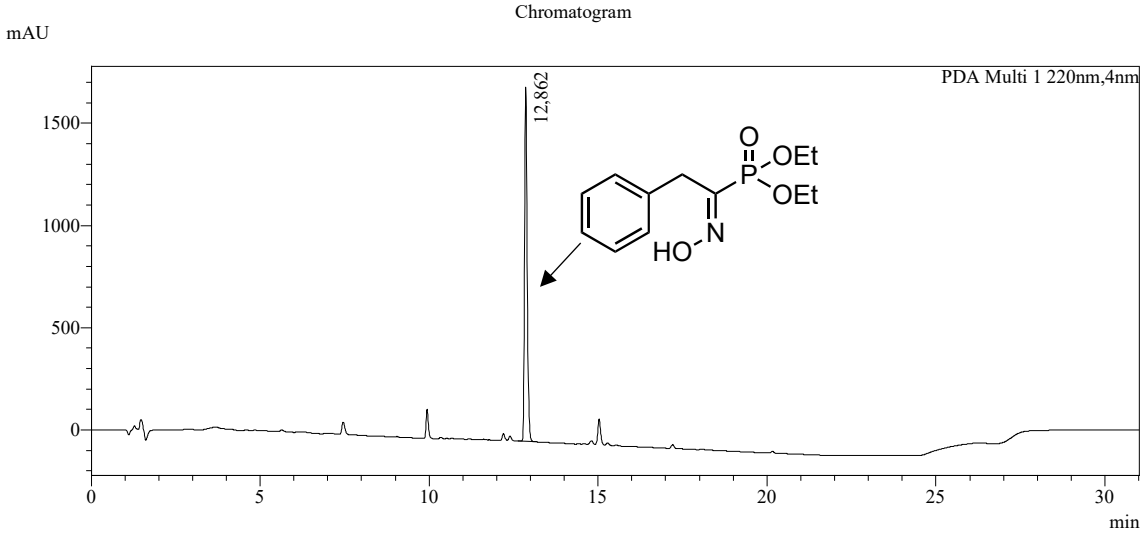


Figure S4. LC trace of the reduction of diethyl (1-(hydroxyimino)-2-phenylethyl)phosphonate (**2b**). Crude reaction mixture at t = 1 week highlighting the total reduction of the $\boldsymbol{Z}_{\mathbf{iso}}$ while the $\boldsymbol{E}_{\mathbf{iso}}$ remains untouched. Peak identification was conducted using purified substances by micropreparative HPLC and analyzed by HRMS. Peak #1 (12.862 min) = compound **2b ($\boldsymbol{E}_{\mathbf{iso}}$)**.

2.4 Copies of ^{1}H, ^{13}C and ^{31}P NMR spectra

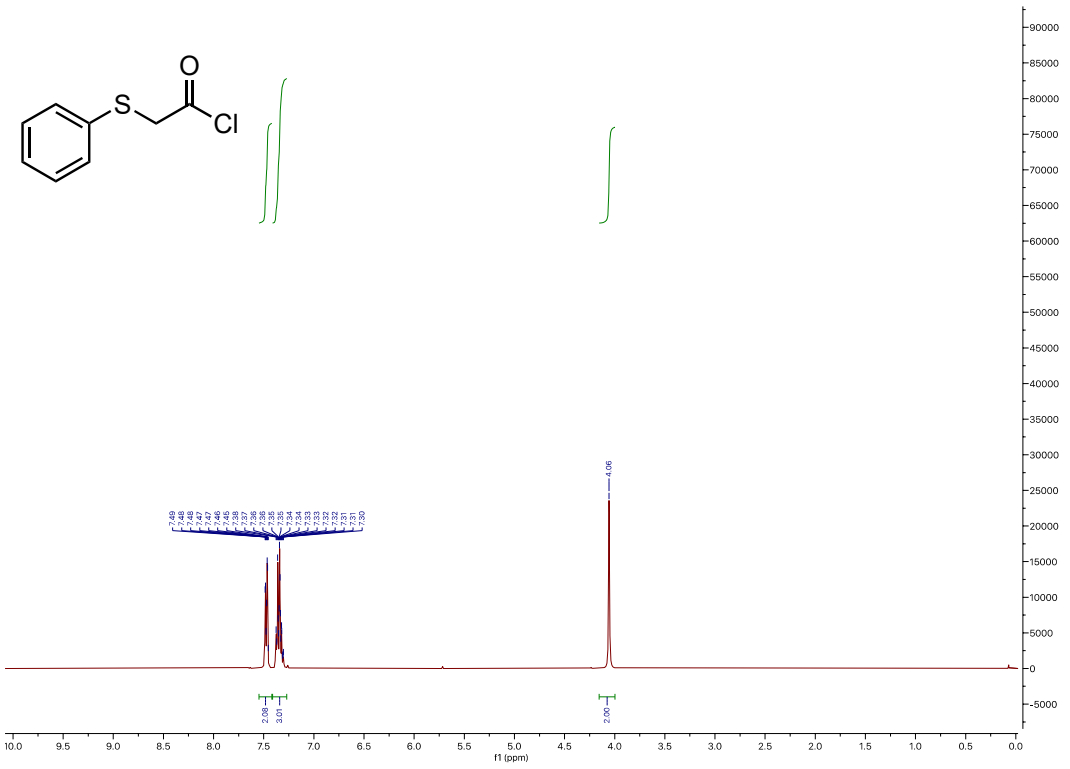


Figure S5. ^{1}H NMR spectrum (400 MHz) of 2-(phenylthio)acetyl chloride (**ac-15**) in $CDCl_3$.

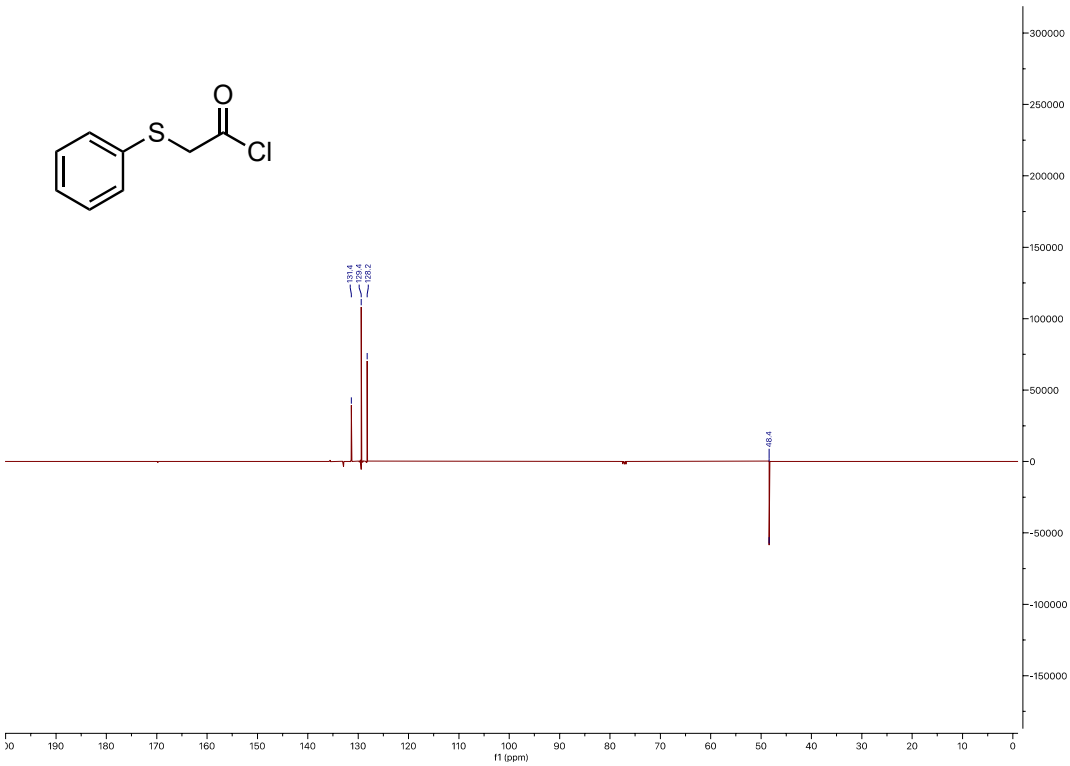


Figure S6. ^{13}C APT NMR spectrum (100.6 MHz) of 2-(phenylthio)acetyl chloride (**ac-15**) in $CDCl_3$.

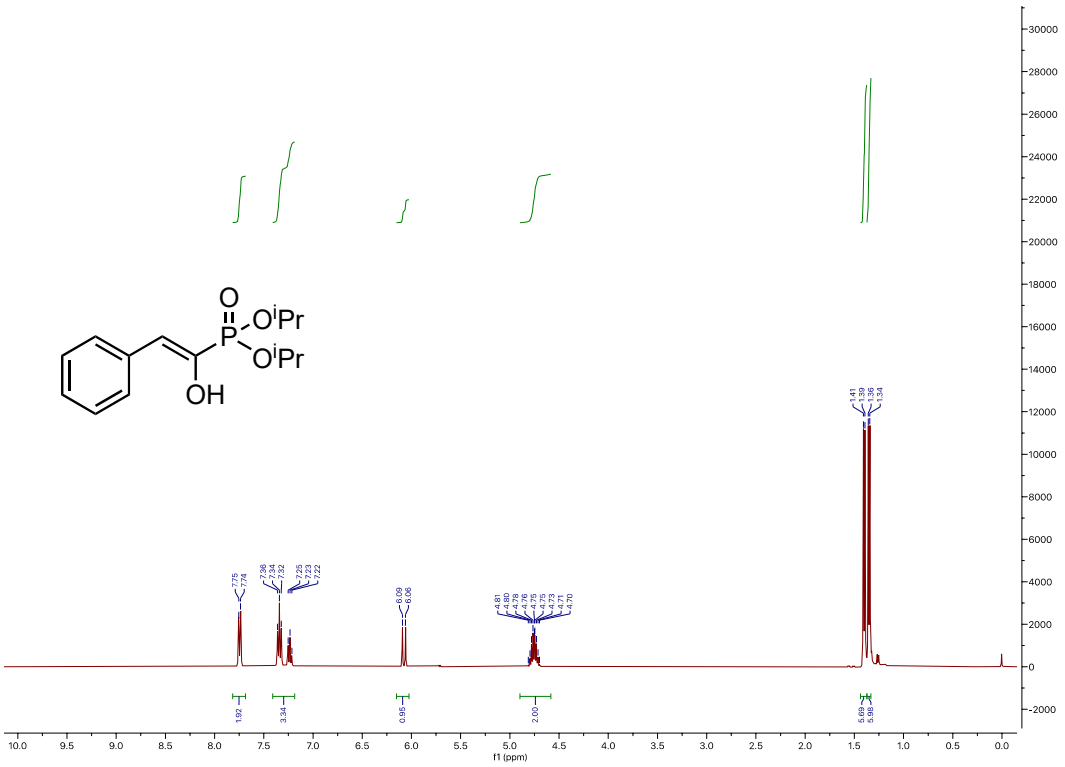


Figure S7. ^{1}H NMR spectrum (400 MHz) of diisopropyl (1-hydroxy-2-phenylvinyl)phosphonate (**iso-3a**) in $CDCl_3$.

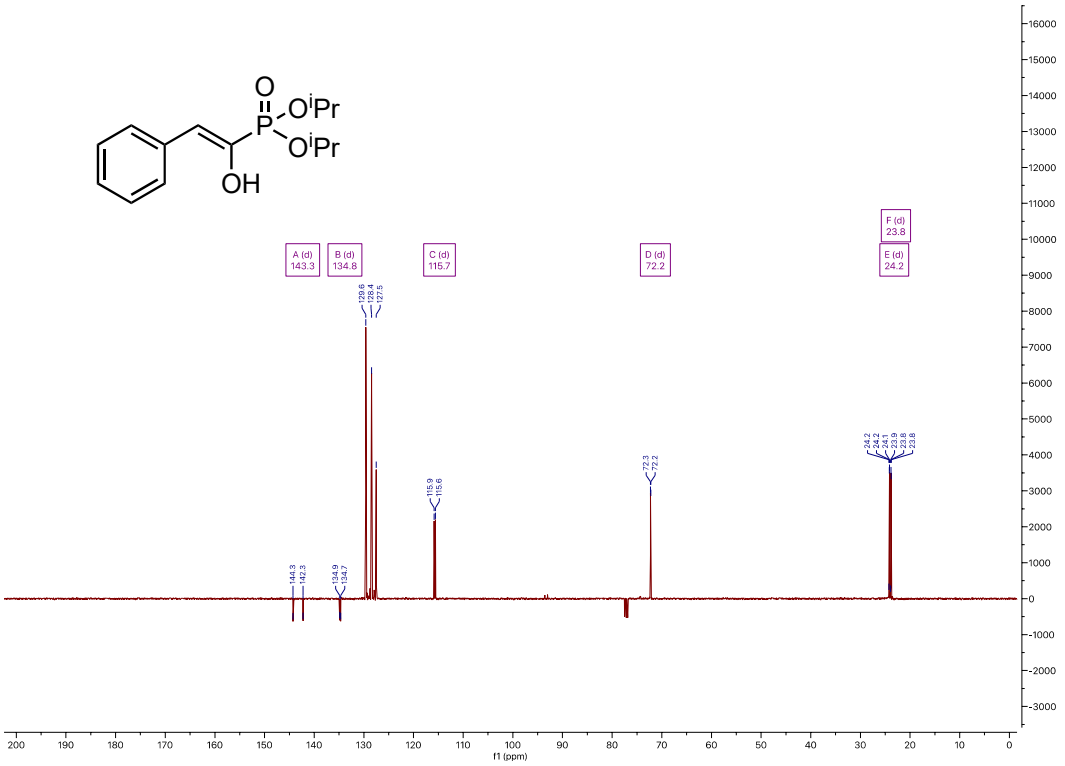


Figure S8. ^{13}C APT NMR spectrum (100.6 MHz) of diisopropyl (1-hydroxy-2-phenylvinyl)phosphonate (**iso-3a**) in $CDCl_3$.

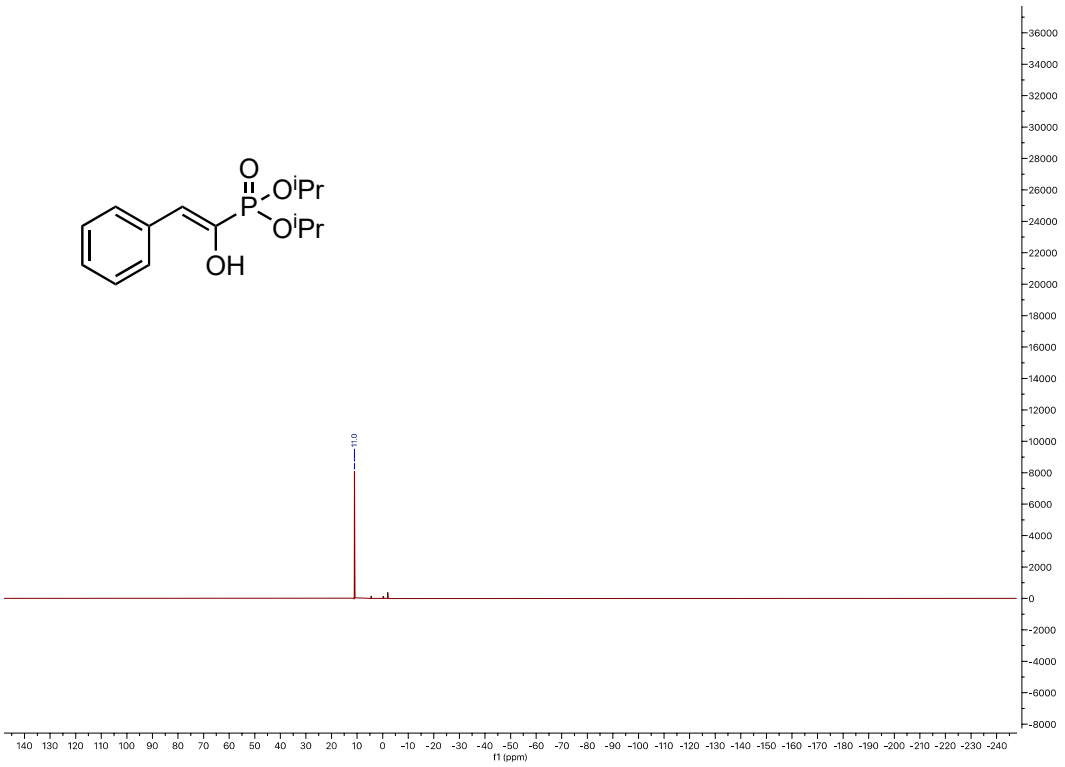


Figure S9. ^{31}P NMR spectrum (161.9 MHz) of diisopropyl (1-hydroxy-2-phenylvinyl)phosphonate (**iso-3a**) in $CDCl_3$.

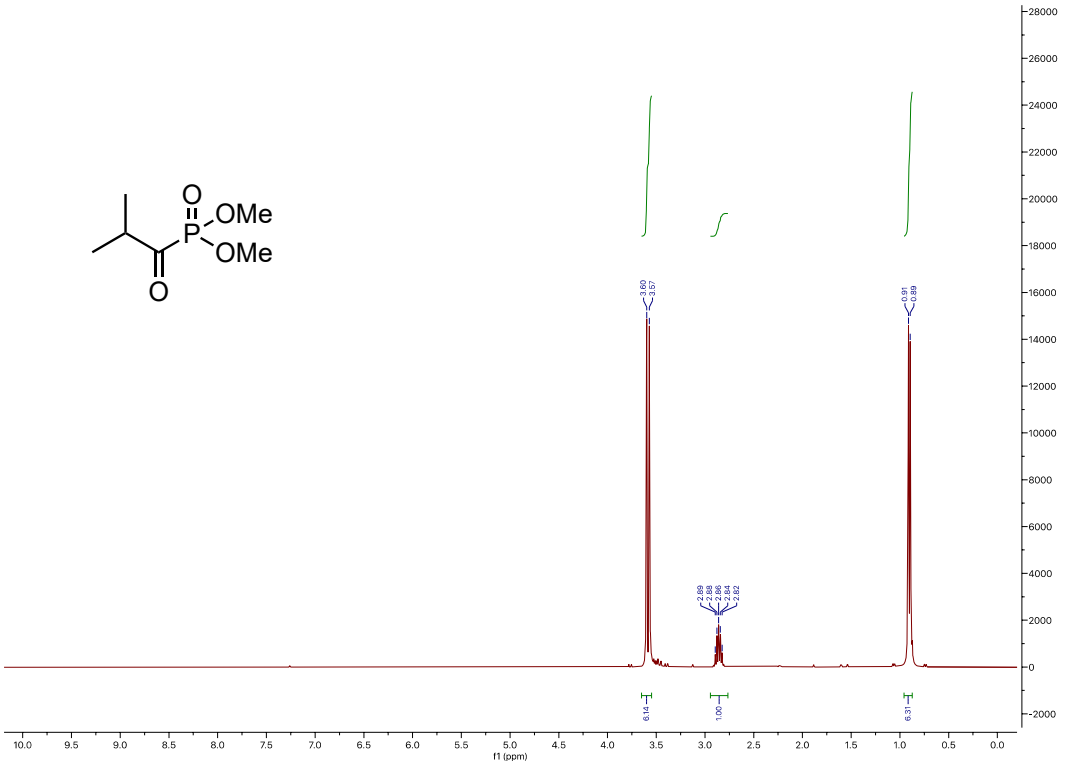


Figure S10. ^{1}H NMR spectrum (400 MHz) of dimethyl isobutyrylphosphonate (**4a**) in $CDCl_3$.

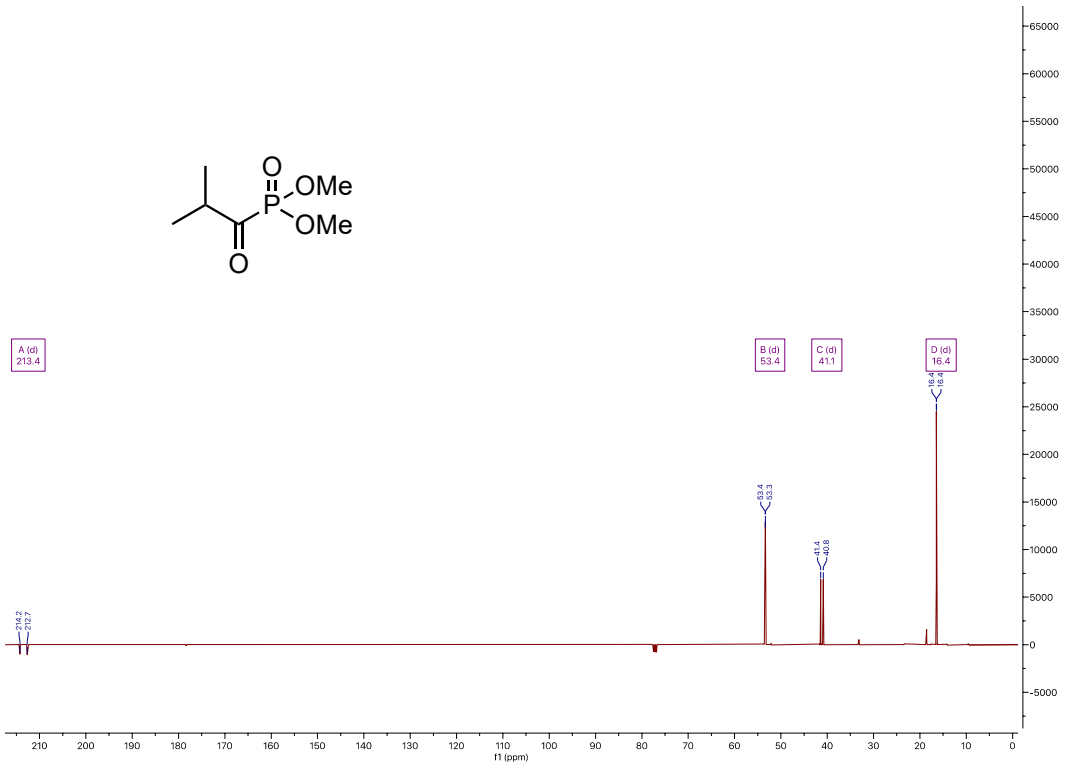


Figure S11. ^{13}C APT NMR spectrum (100.6 MHz) of dimethyl isobutyrylphosphonate (**4a**) in $CDCl_3$.

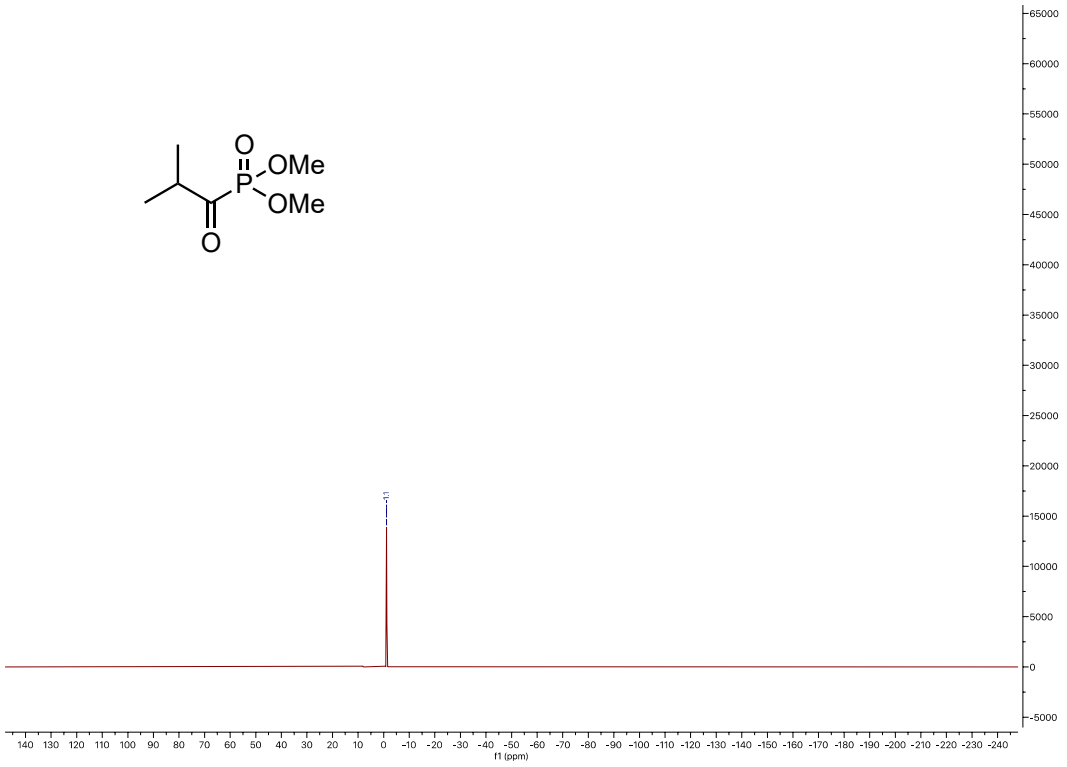


Figure S12. ^{31}P NMR spectrum (161.9 MHz) of dimethyl isobutyrylphosphonate (**4a**) in $CDCl_3$.

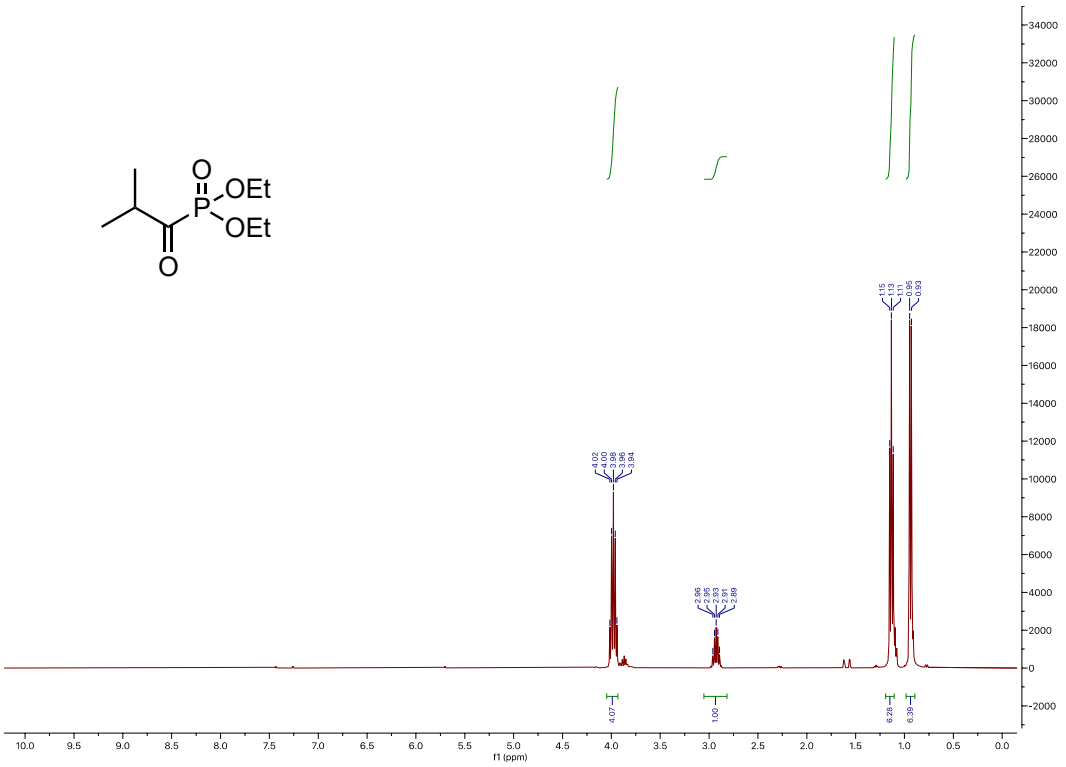


Figure S13. ^{1}H NMR spectrum (400 MHz) of diethyl isobutyrylphosphonate (**5a**) in $CDCl_3$.

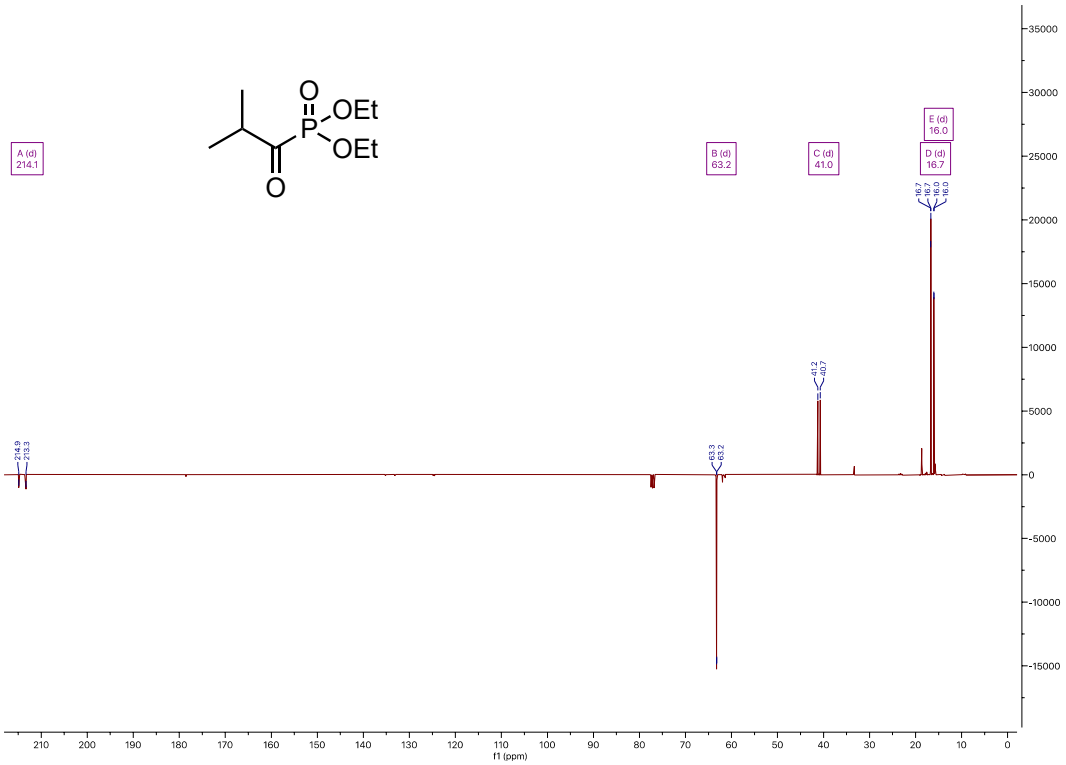


Figure S14. ^{13}C APT NMR spectrum (100.6 MHz) of diethyl isobutyrylphosphonate (**5a**) in $CDCl_3$.

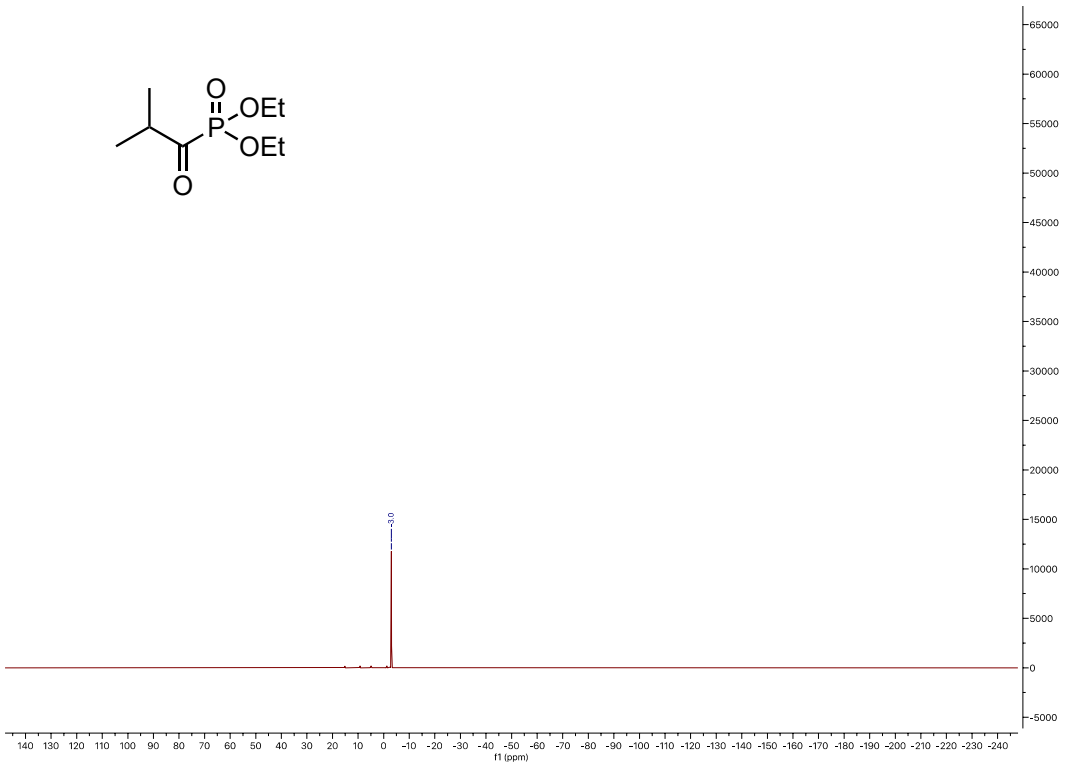


Figure S15. ^{31}P NMR spectrum (161.9 MHz) of diethyl isobutyrylphosphonate (**5a**) in $CDCl_3$.

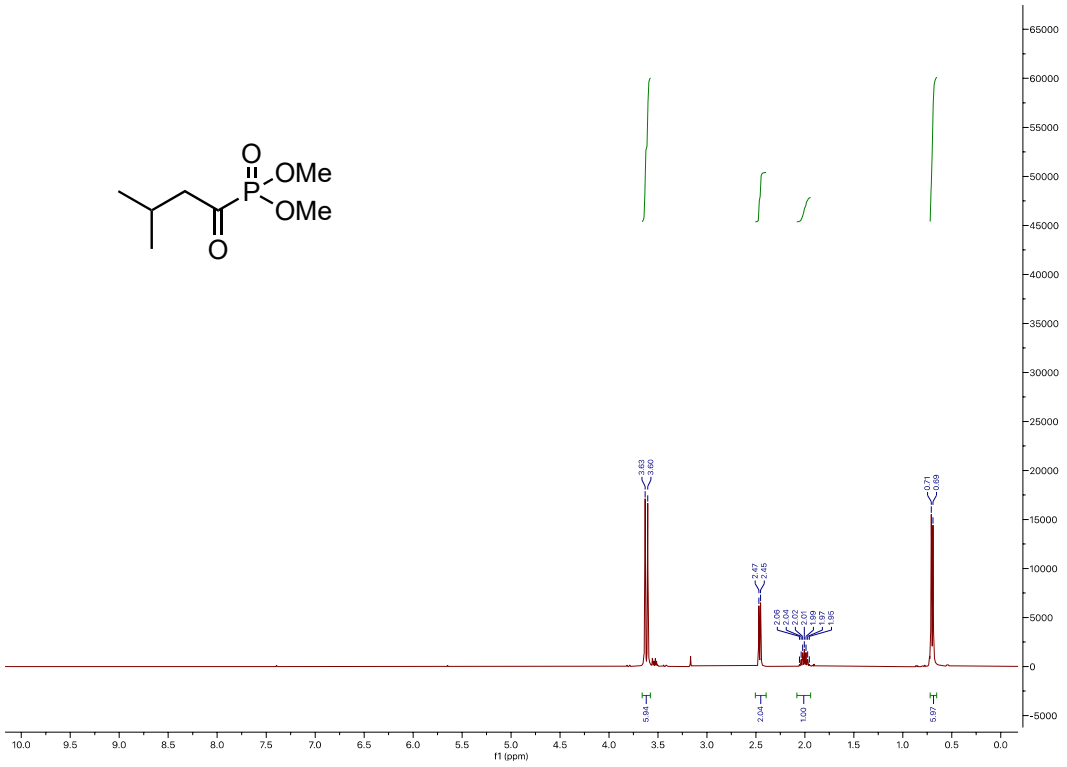


Figure S16. ^{1}H NMR spectrum (400 MHz) of dimethyl (3-methylbutanoyl)phosphonate (**7a**) in $CDCl_3$.

Figure S17. ^{13}C APT NMR spectrum (100.6 MHz) of dimethyl (3-methylbutanoyl)phosphonate (**7a**) in $CDCl_3$.

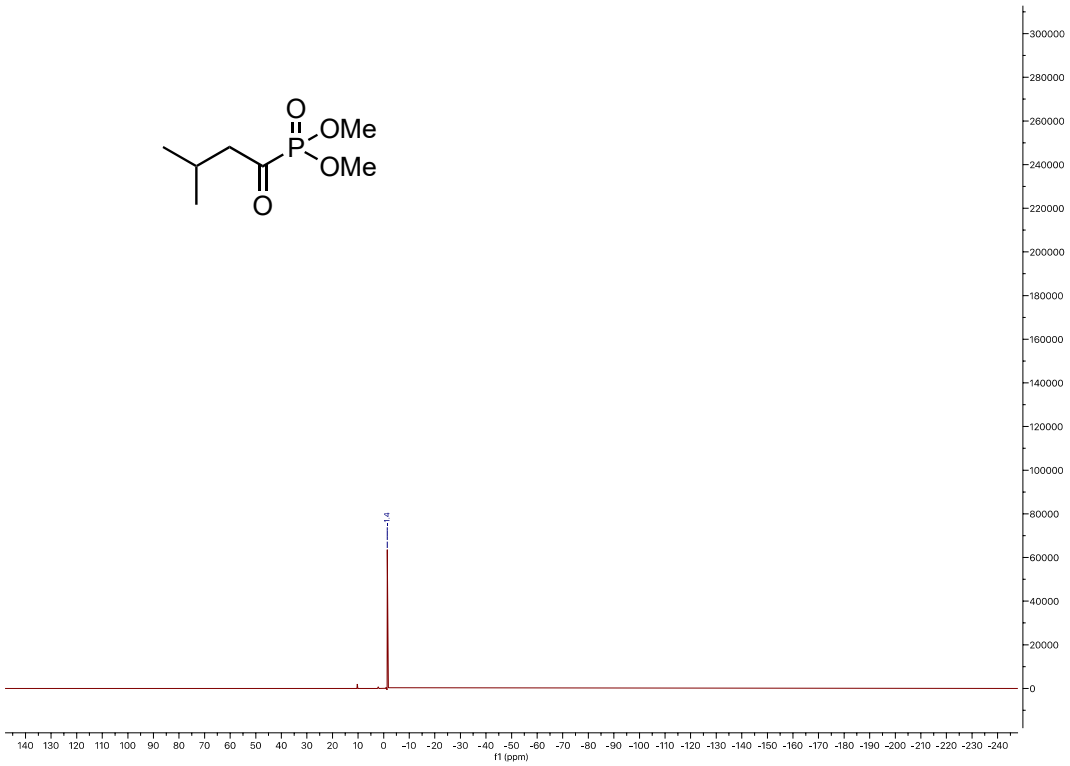


Figure S18. ^{31}P NMR spectrum (161.9 MHz) of dimethyl (3-methylbutanoyl)phosphonate (**7a**) in $CDCl_3$.

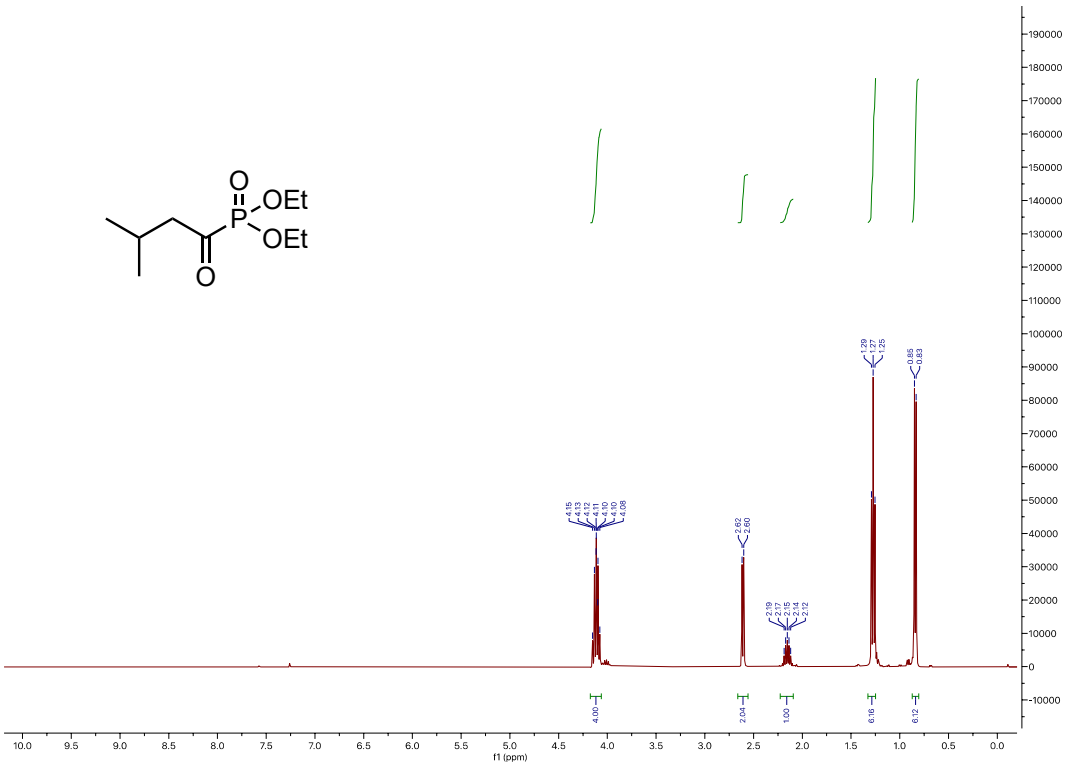


Figure S19. ^{1}H NMR spectrum (400 MHz) of diethyl (3-methylbutanoyl)phosphonate (**8a**) in $CDCl_3$.

Figure S20. ^{13}C APT NMR spectrum (100.6 MHz) of diethyl (3-methylbutanoyl)phosphonate (**8a**) in $CDCl_3$.

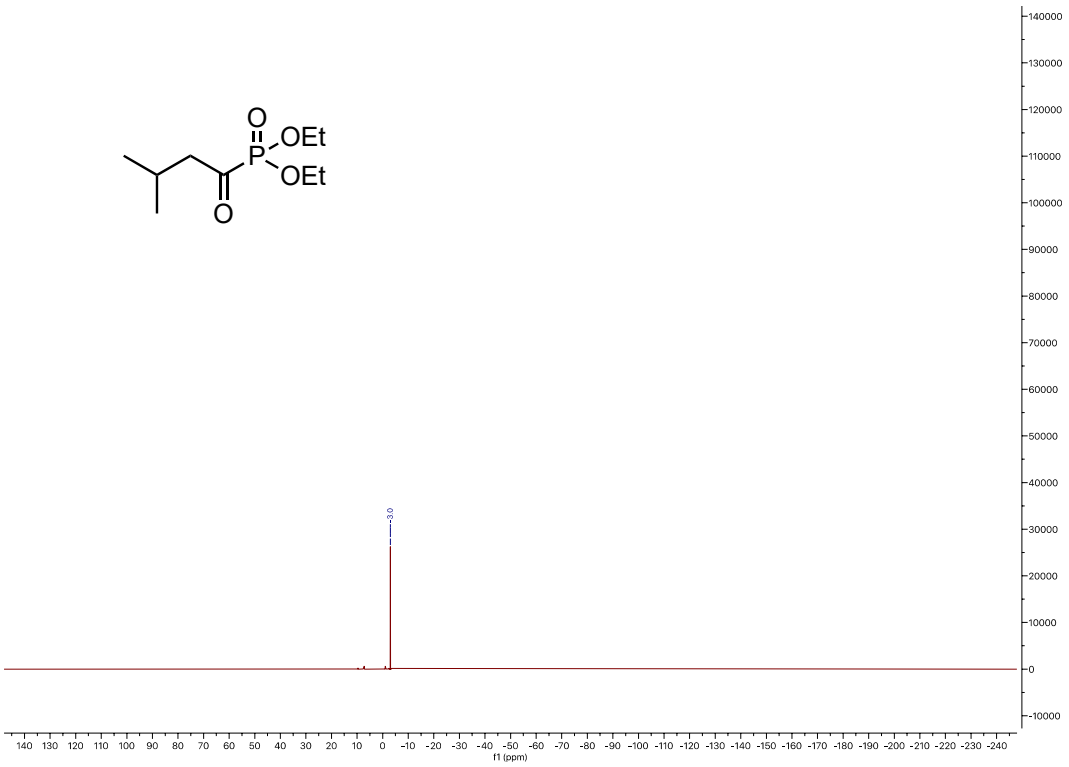


Figure S21. ^{31}P NMR spectrum (161.9 MHz) of diethyl (3-methylbutanoyl)phosphonate (**8a**) in $CDCl_3$.

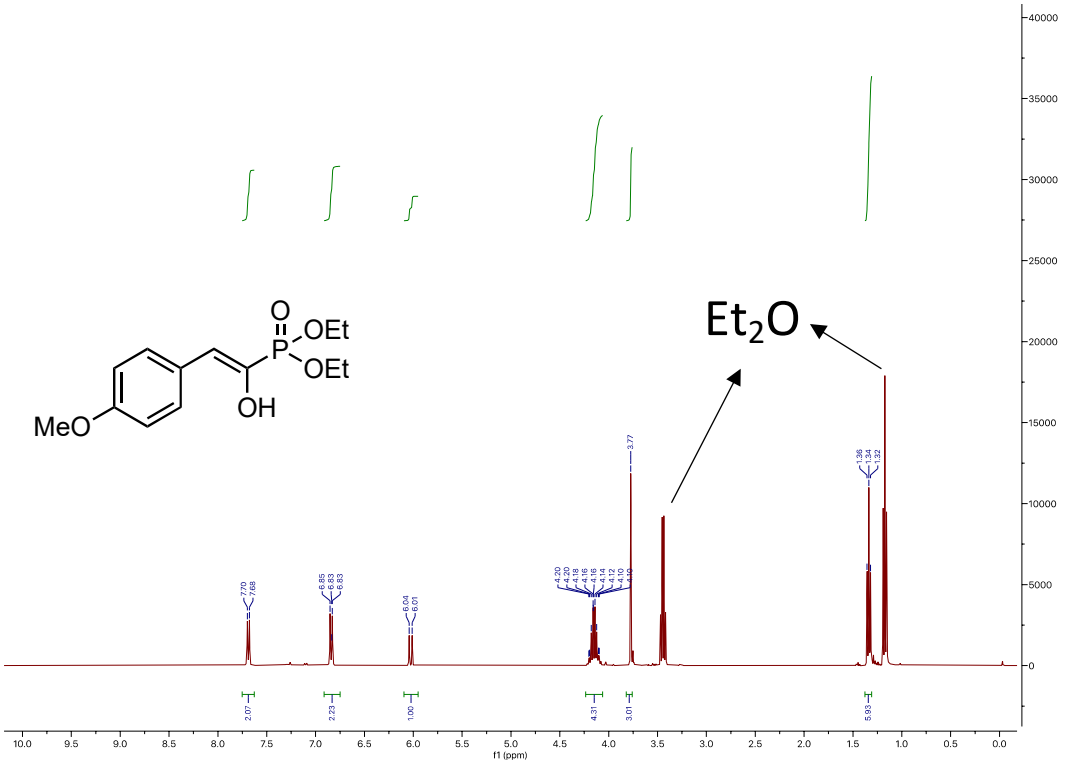


Figure S22. ^{1}H NMR spectrum (400 MHz) of diethyl (1-hydroxy-2-(4-methoxyphenyl)vinyl)phosphonate (**iso-13a**) in $CDCl_3$.

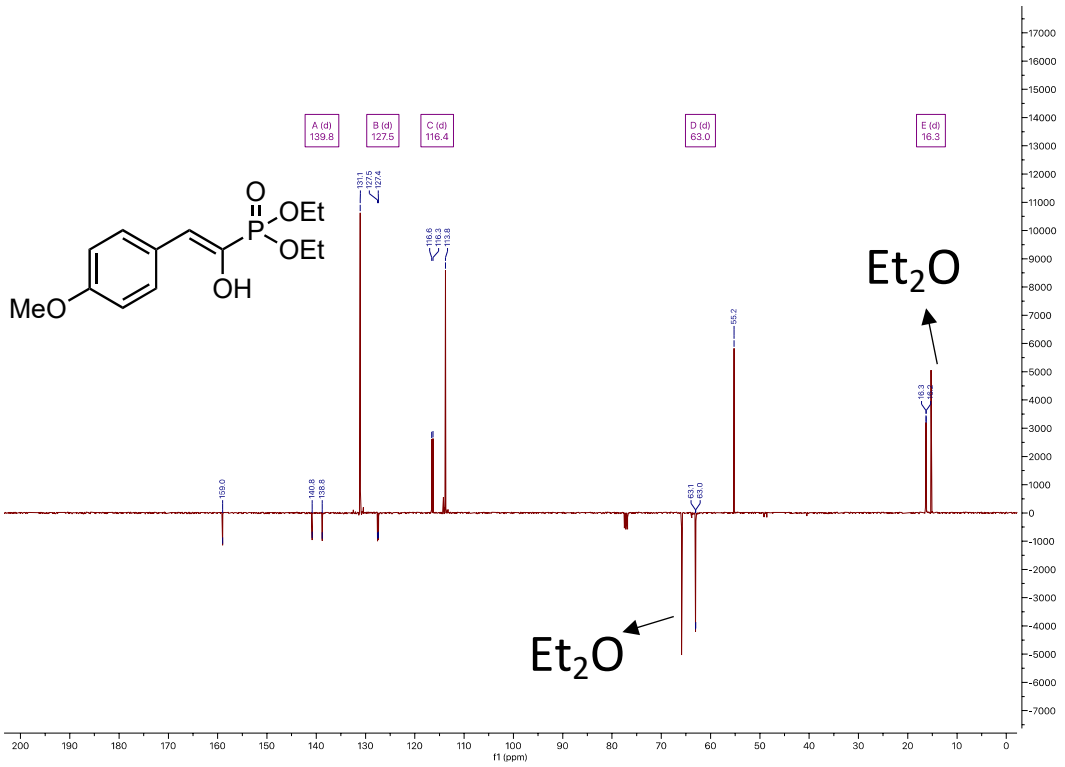


Figure S23. ^{13}C APT NMR spectrum (100.6 MHz) of diethyl (1-hydroxy-2-(4-methoxyphenyl)vinyl)phosphonate (**iso-13a**) in $CDCl_3$.

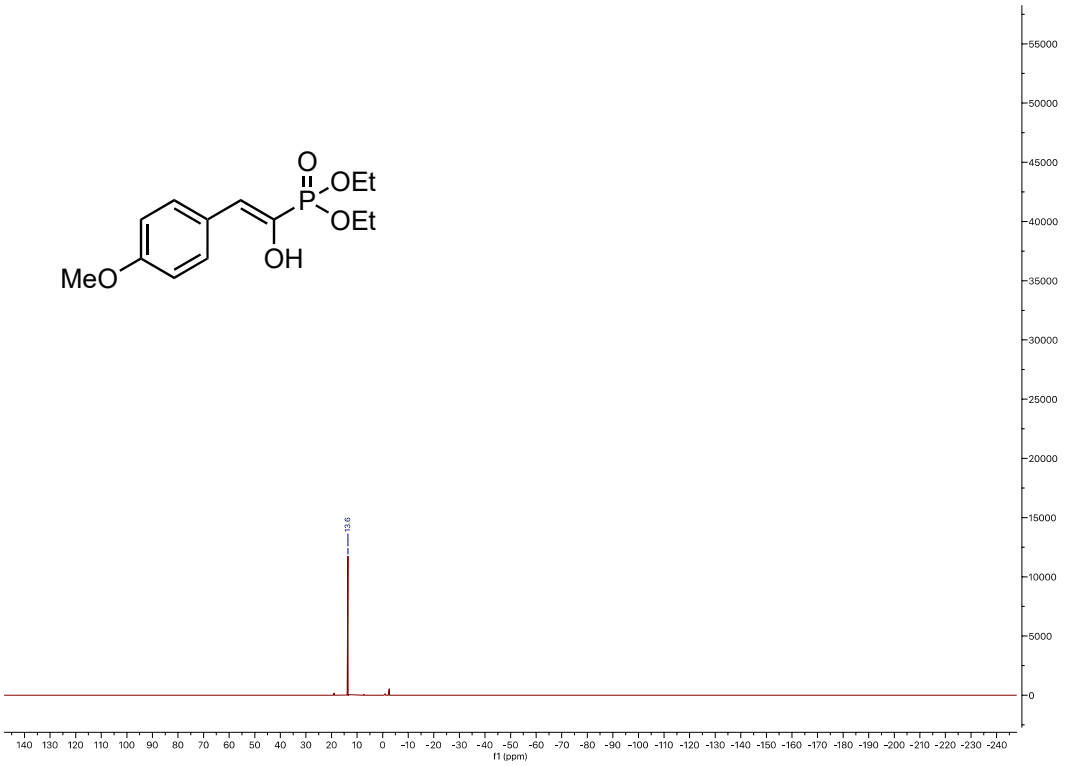


Figure S24. ^{31}P NMR spectrum (161.9 MHz) of diethyl (1-hydroxy-2-(4-methoxyphenyl)vinyl)phosphonate (**iso-13a**) in $CDCl_3$.

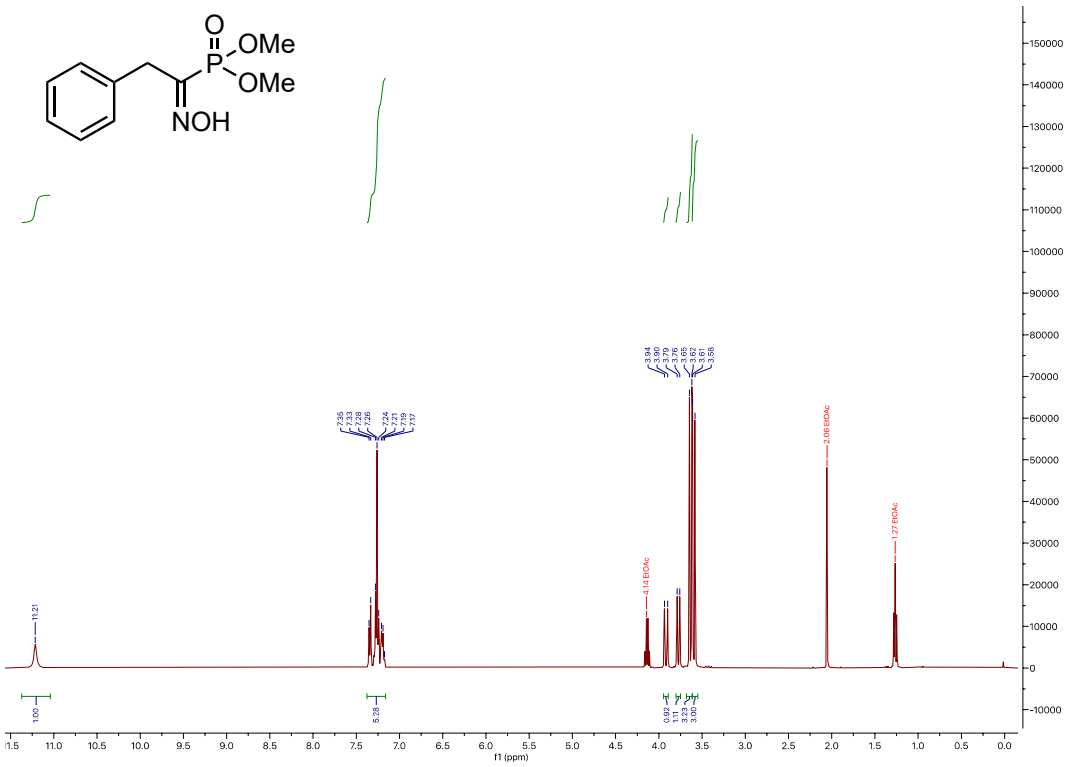


Figure S25. ^{1}H NMR spectrum (400 MHz) of dimethyl (1-(hydroxyimino)-2-phenylethyl)phosphonate (**1b**) in $CDCl_3$.

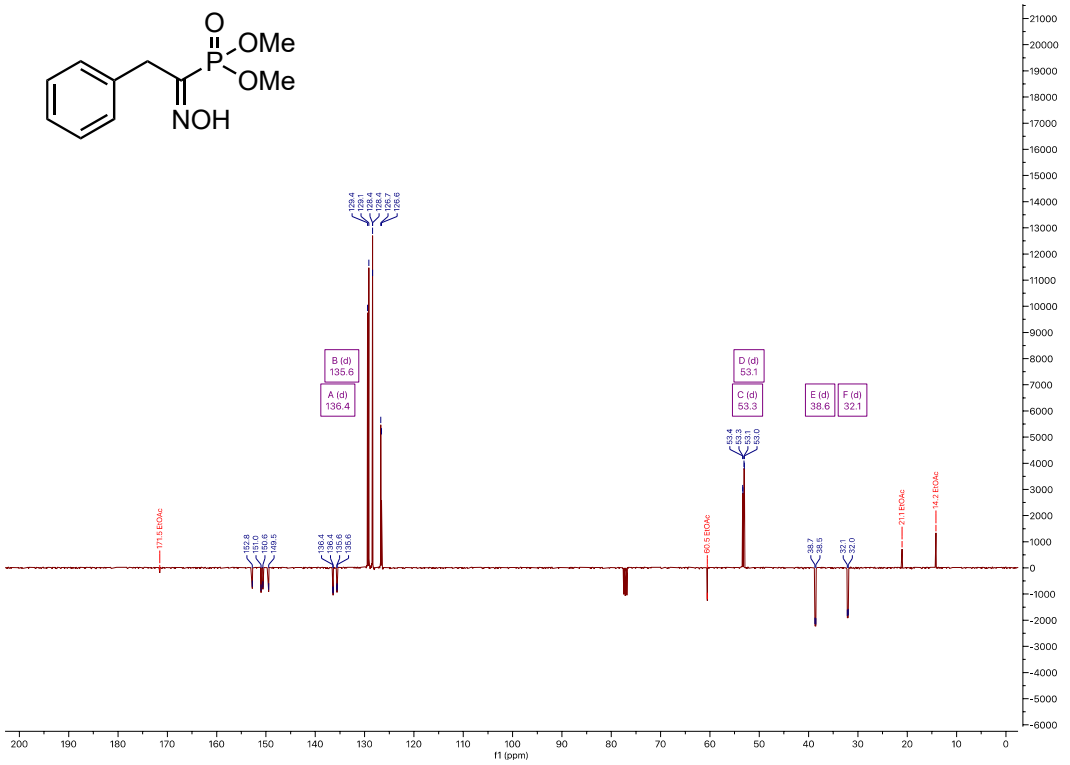


Figure S26. ^{13}C APT NMR spectrum (100.6 MHz) of dimethyl (1-(hydroxyimino)-2-phenylethyl)phosphonate (**1b**) in $CDCl_3$.

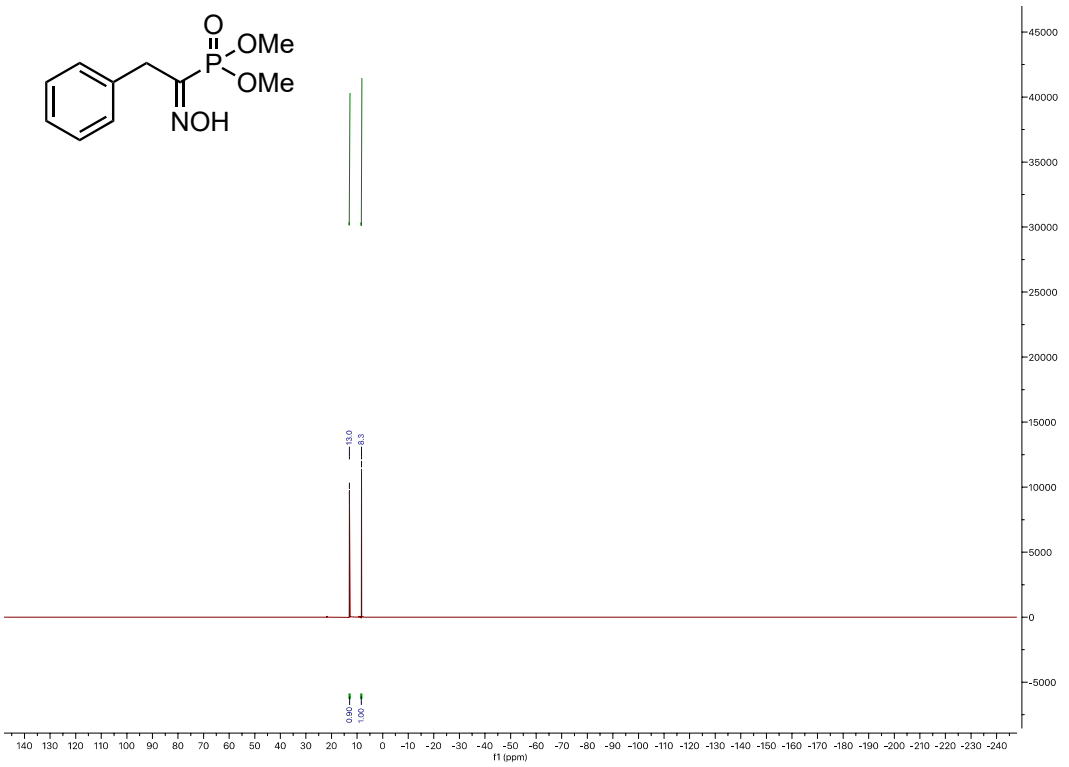


Figure S27. ^{31}P NMR spectrum (161.9 MHz) of dimethyl (1-(hydroxyimino)-2-phenylethyl)phosphonate (**1b**) in $CDCl_3$.

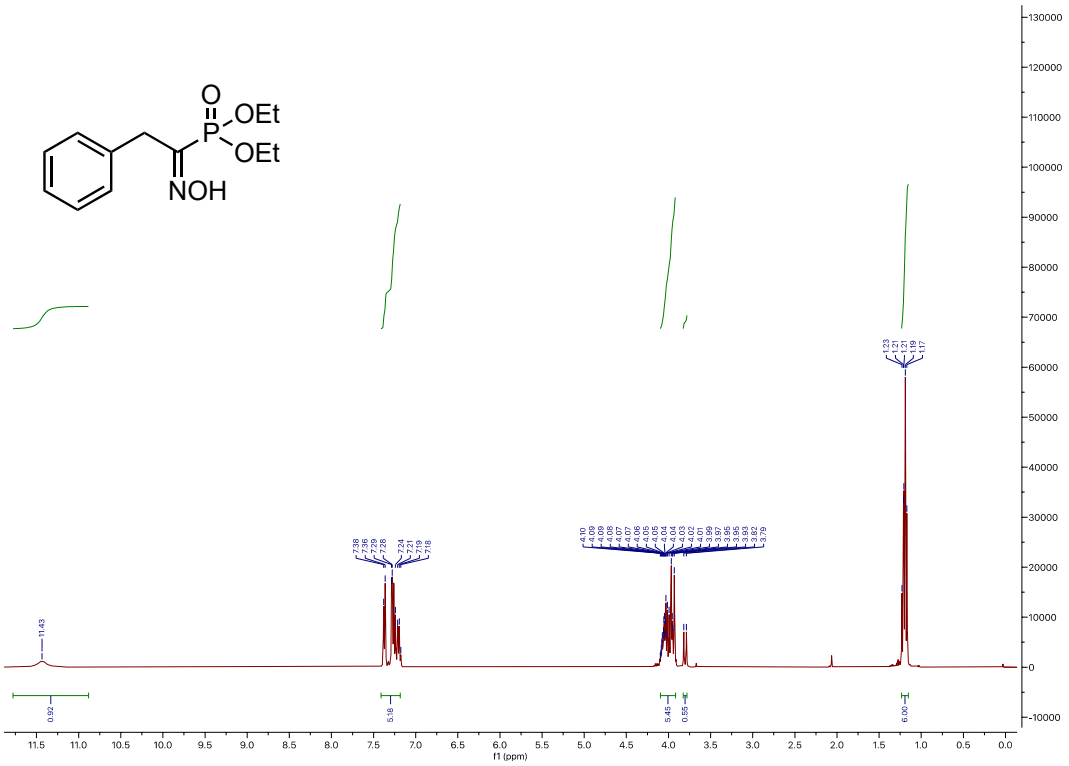


Figure S28. ^{1}H NMR spectrum (400 MHz) of diethyl (1-(hydroxyimino)-2-phenylethyl)phosphonate (**2b**) in $CDCl_3$.

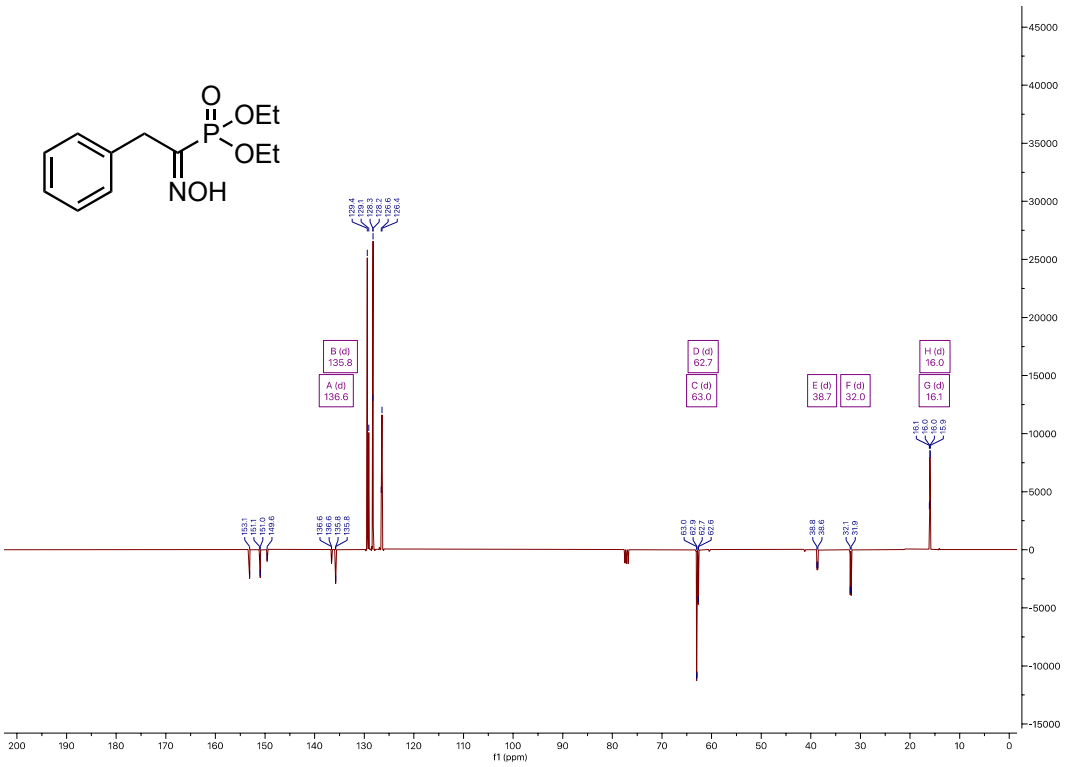


Figure S29. ^{13}C APT NMR spectrum (100.6 MHz) of diethyl (1-(hydroxyimino)-2-phenylethyl)phosphonate (**2b**) in $CDCl_3$.

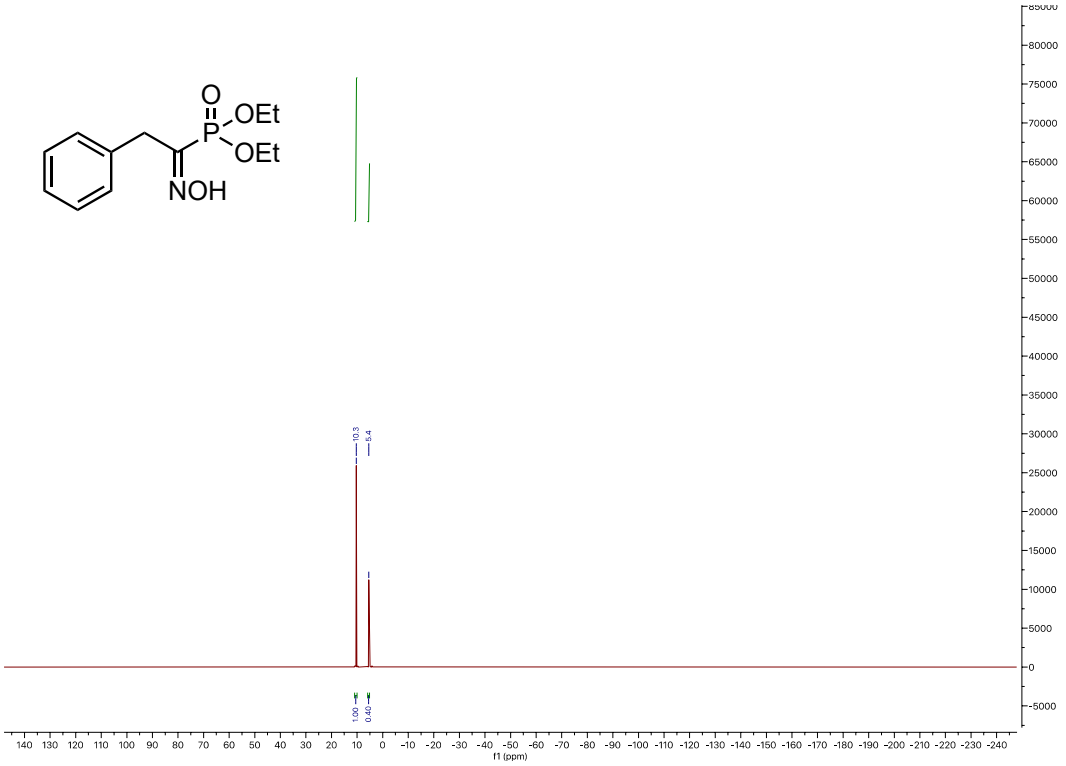


Figure S30. ^{31}P NMR spectrum (161.9 MHz) of diethyl (1-(hydroxyimino)-2-phenylethyl)phosphonate (**2b**) in $CDCl_3$.

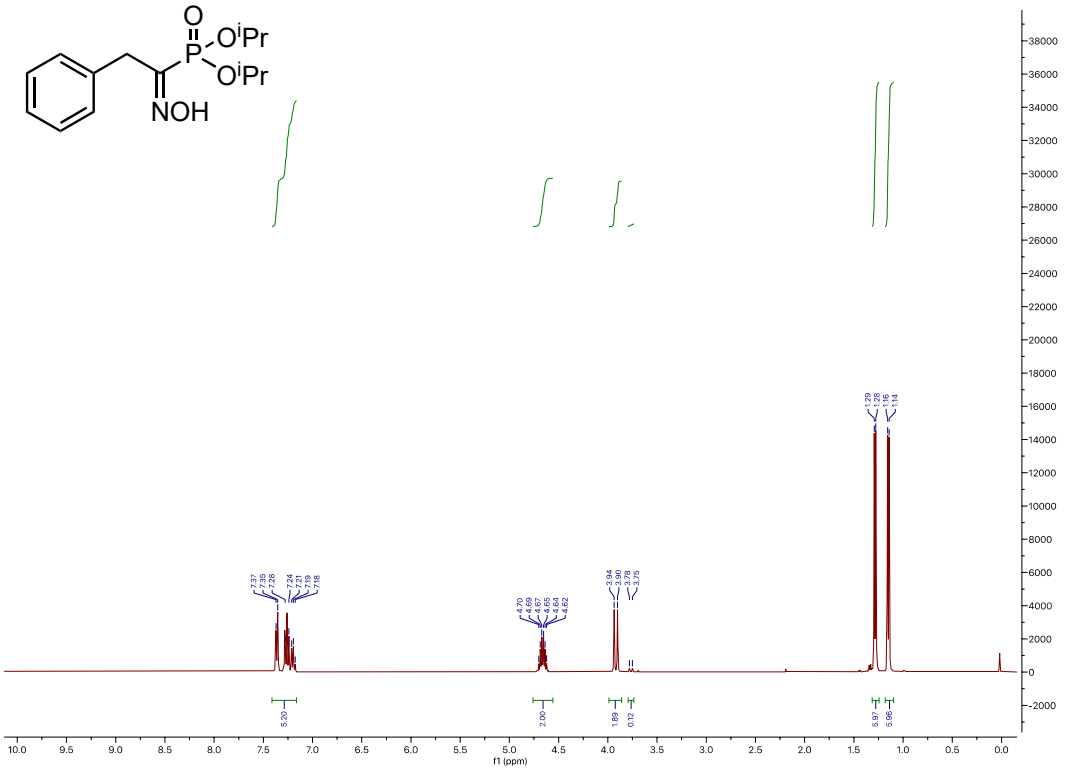


Figure S31. ^{1}H NMR spectrum (400 MHz) of diisopropyl (1-(hydroxyimino)-2-phenylethyl)phosphonate (**3b**) in $CDCl_3$.

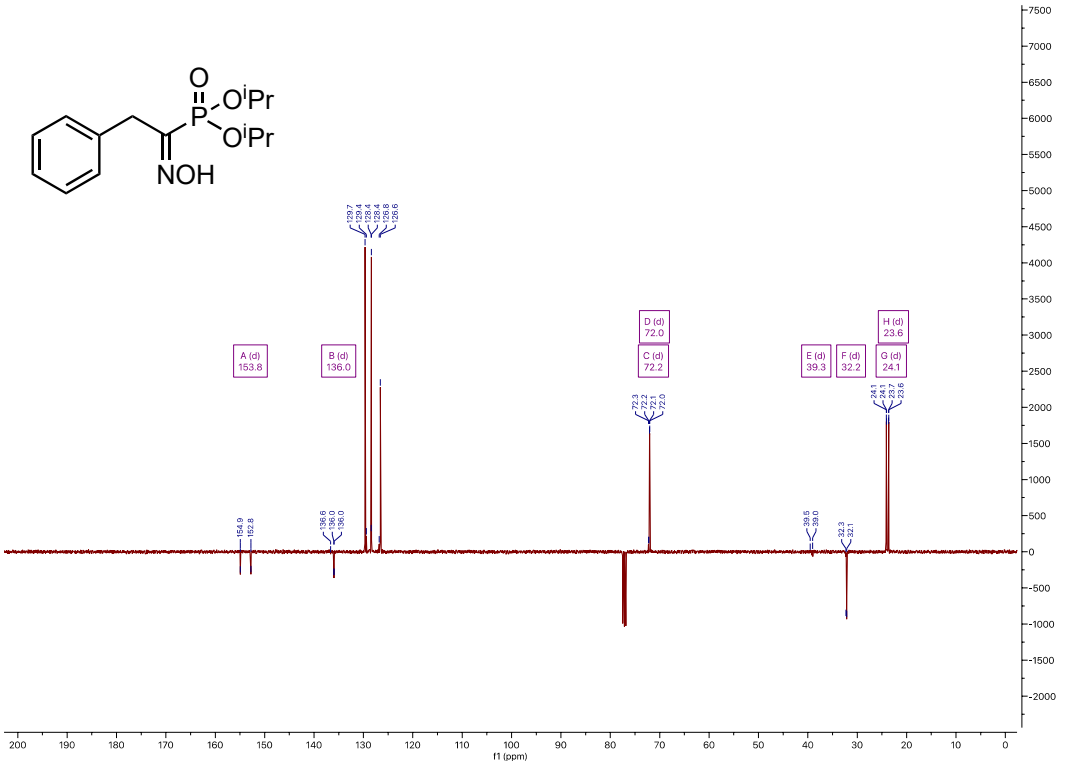


Figure S32. ^{13}C APT NMR spectrum (100.6 MHz) of diisopropyl (1-(hydroxyimino)-2-phenylethyl)phosphonate (**3b**) in $CDCl_3$.

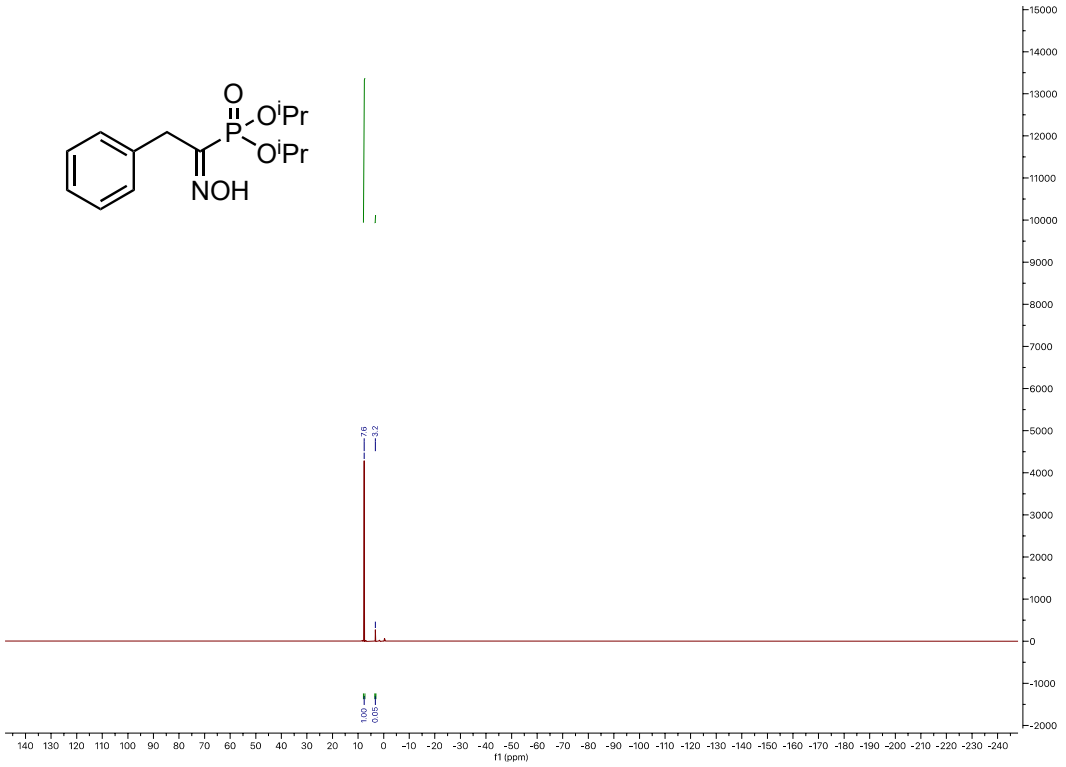


Figure S33. ^{31}P NMR spectrum (161.9 MHz) of diisopropyl (1-(hydroxyimino)-2-phenylethyl)phosphonate (**3b**) in $CDCl_3$.

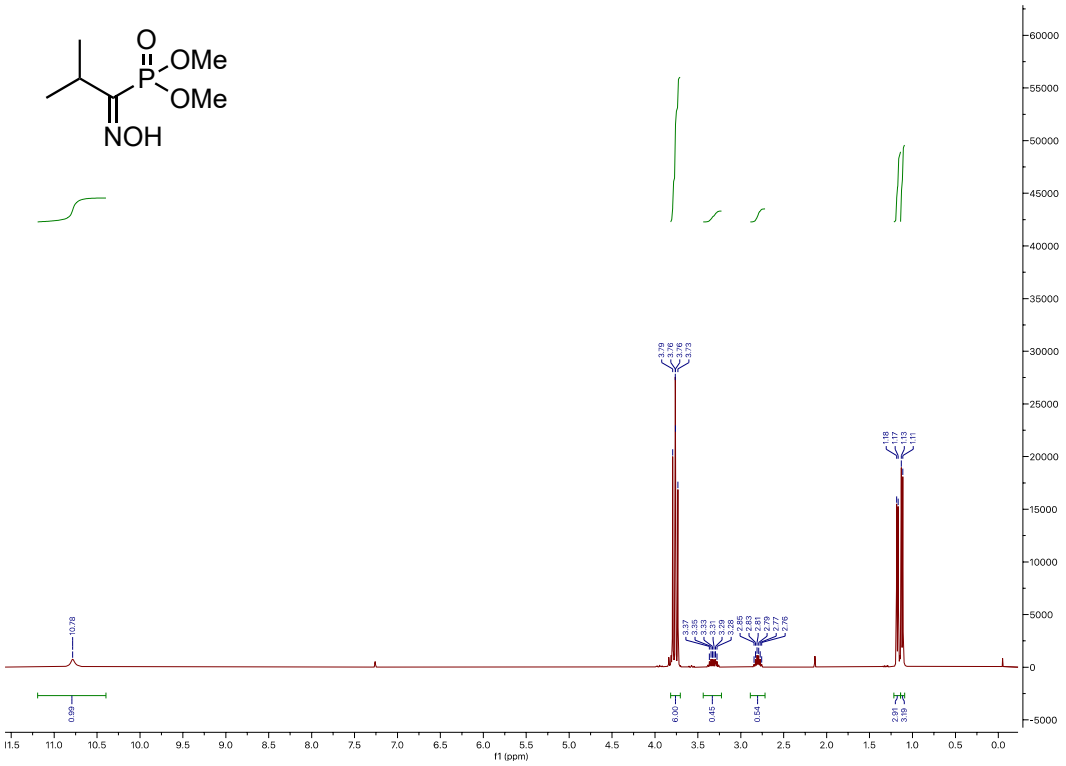


Figure S34. ^{1}H NMR spectrum (400 MHz) of dimethyl (1-(hydroxyimino)-2-methylpropyl)phosphonate (**4b**) in $CDCl_3$.

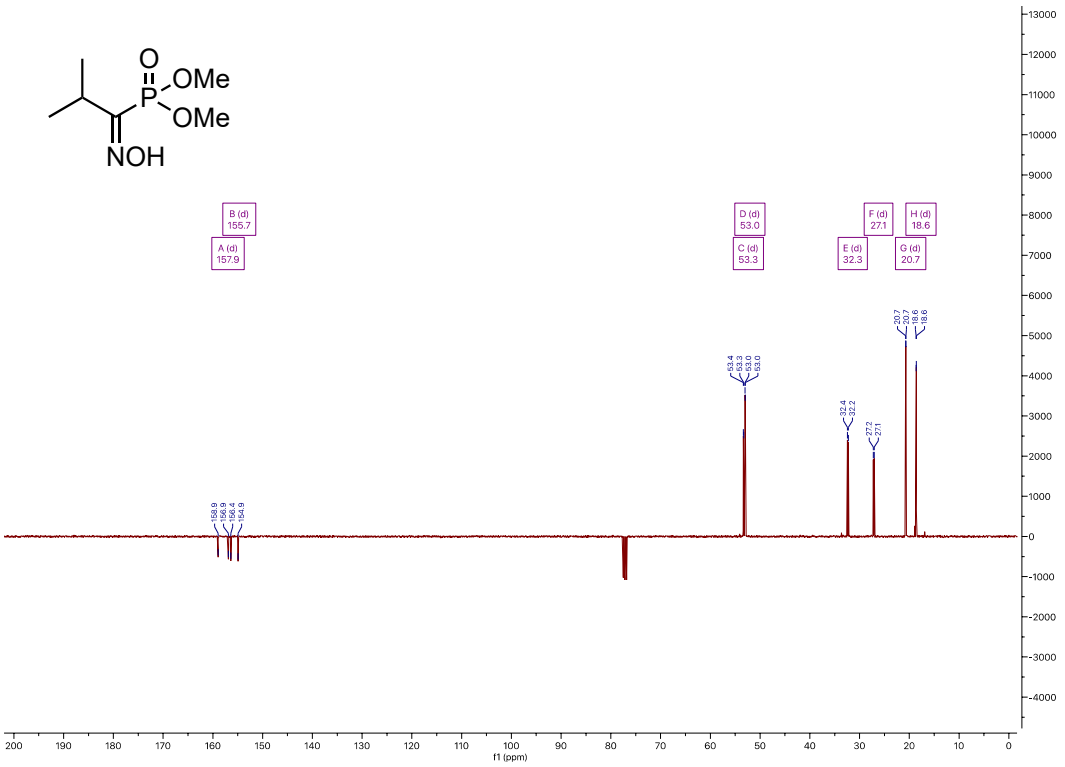


Figure S35. ^{13}C APT NMR spectrum (100.6 MHz) of dimethyl (1-(hydroxyimino)-2-methylpropyl)phosphonate (**4b**) in $CDCl_3$.

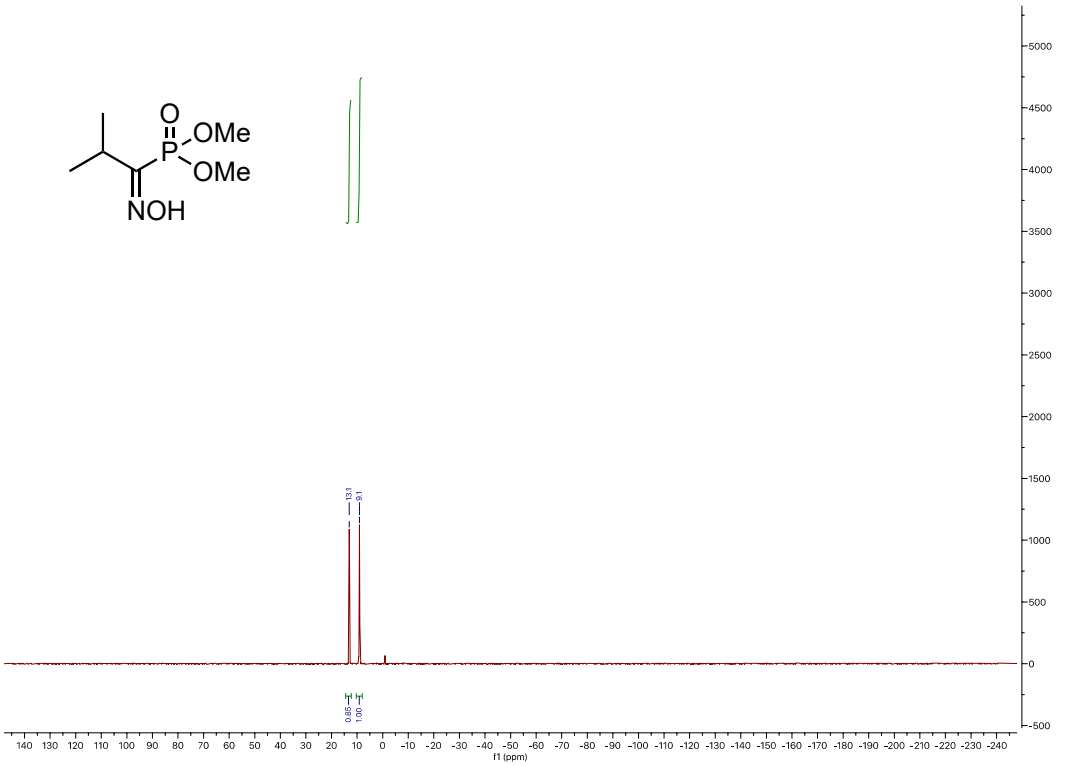


Figure S36. ^{31}P NMR spectrum (161.9 MHz) of dimethyl (1-(hydroxyimino)-2-methylpropyl)phosphonate (**4b**) in $CDCl_3$.

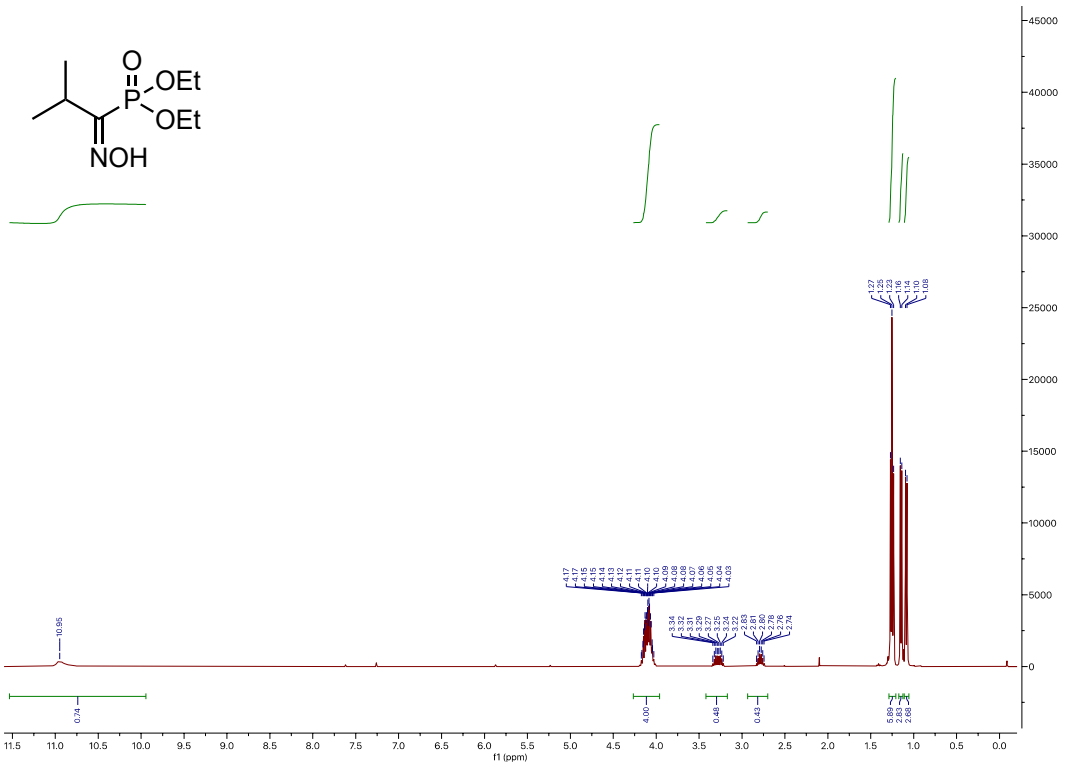


Figure S37. ^{1}H NMR spectrum (400 MHz) of diethyl (1-(hydroxyimino)-2-methylpropyl)phosphonate (**5b**) in $CDCl_3$.

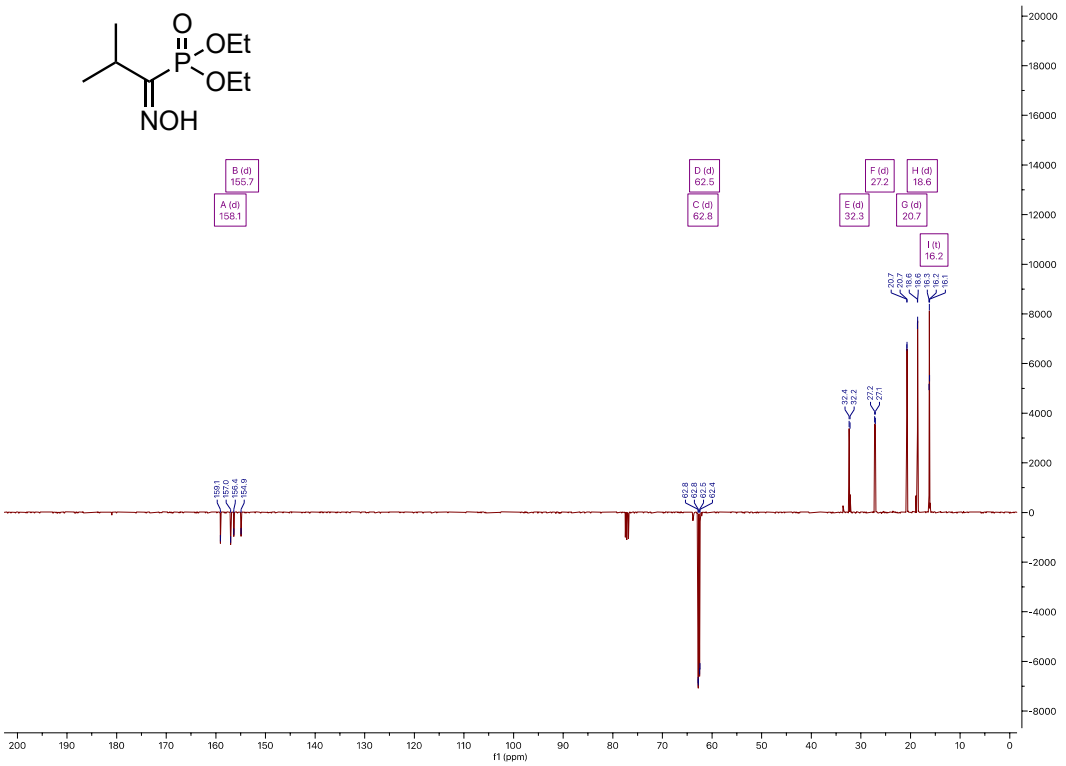


Figure S38. ^{13}C APT NMR spectrum (100.6 MHz) of diethyl (1-(hydroxyimino)-2-methylpropyl)phosphonate (**5b**) in $CDCl_3$.

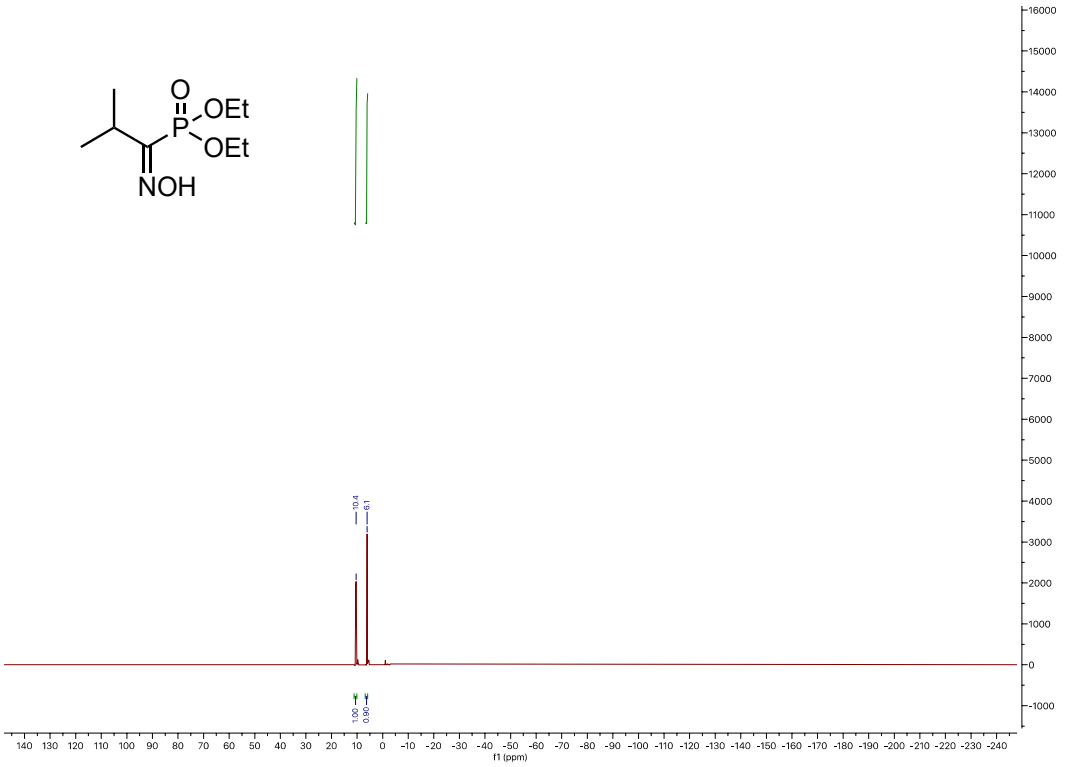


Figure S39. ^{31}P NMR spectrum (161.9 MHz) of diethyl (1-(hydroxyimino)-2-methylpropyl)phosphonate (**5b**) in $CDCl_3$.

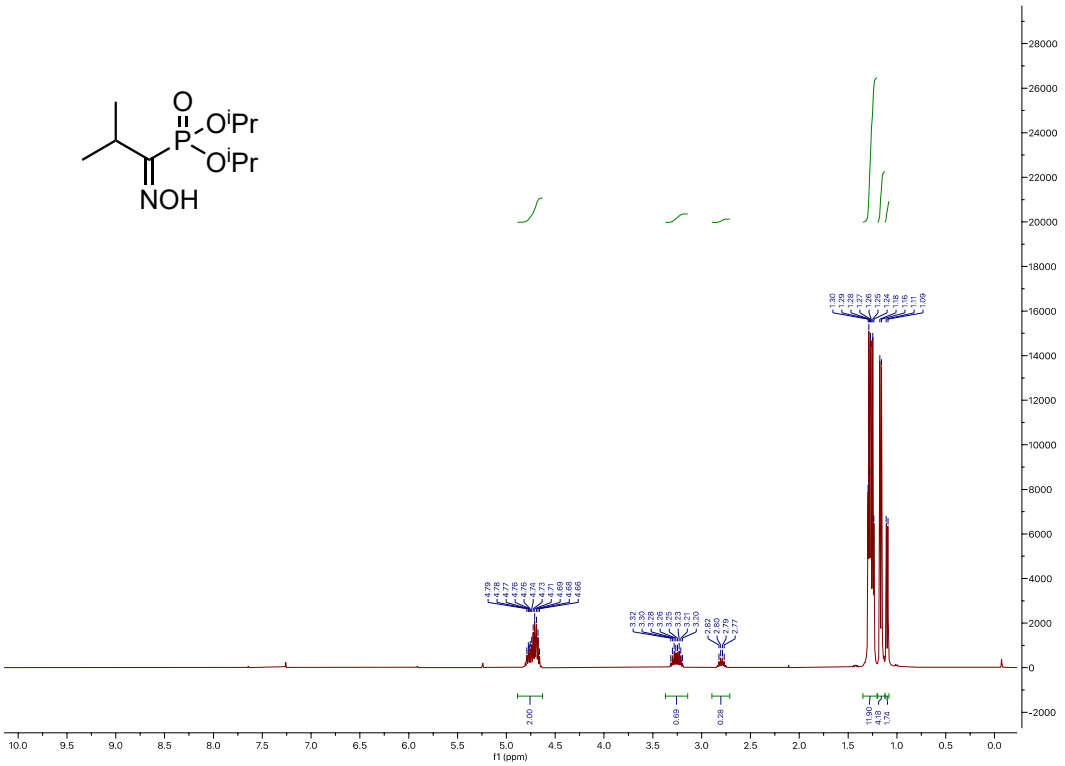


Figure S40. ^{1}H NMR spectrum (400 MHz) of diisopropyl (1-(hydroxyimino)-2-methylpropyl)phosphonate (**6b**) in $CDCl_3$.

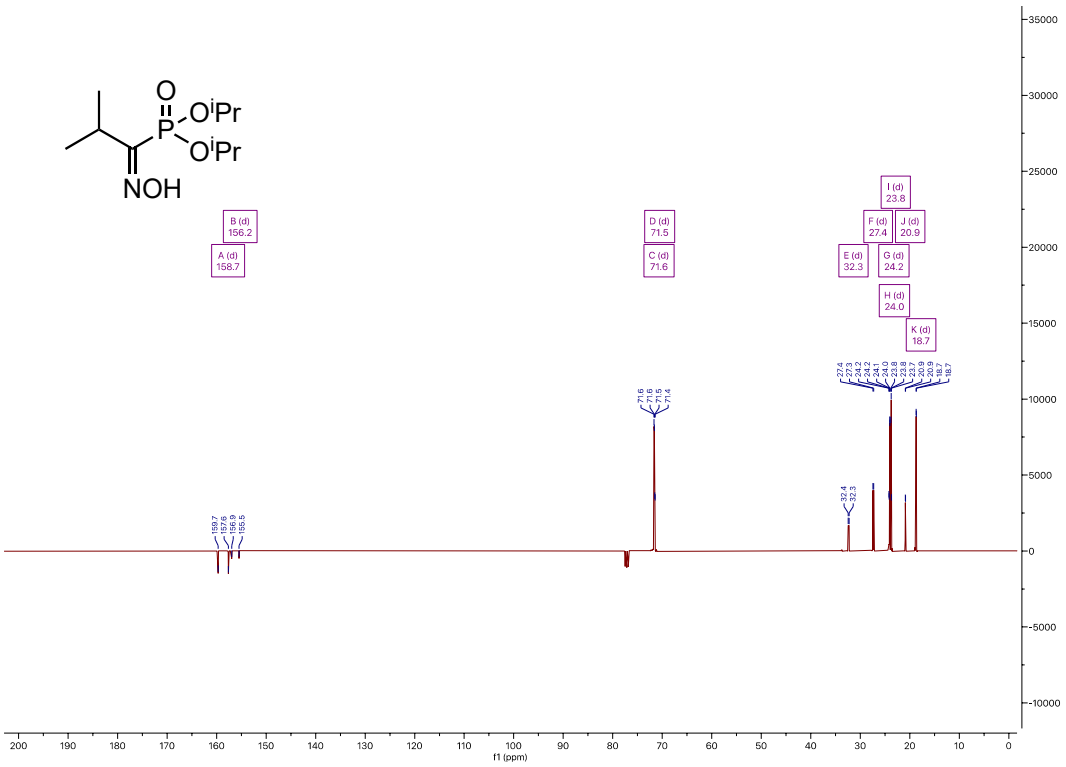


Figure S41. ^{13}C APT NMR spectrum (100.6 MHz) of diisopropyl (1-(hydroxyimino)-2-methylpropyl)phosphonate (**6b**) in $CDCl_3$.

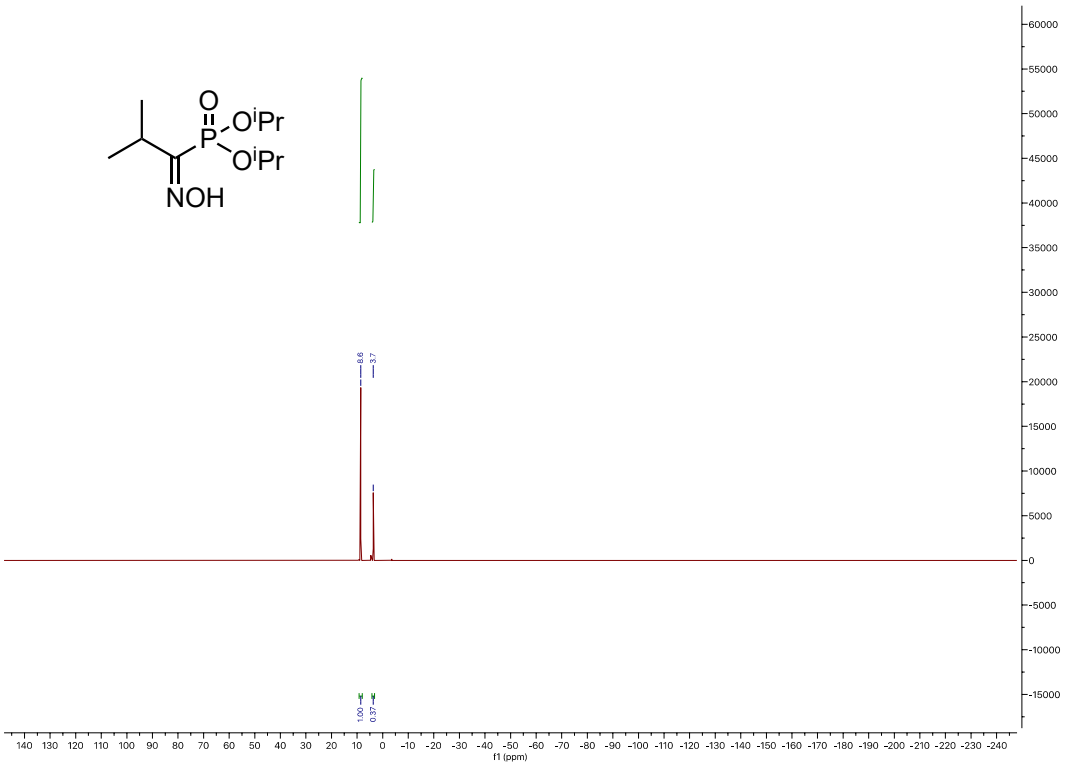


Figure S42. ^{31}P NMR spectrum (161.9 MHz) of diisopropyl (1-(hydroxyimino)-2-methylpropyl)phosphonate (**6b**) in $CDCl_3$.

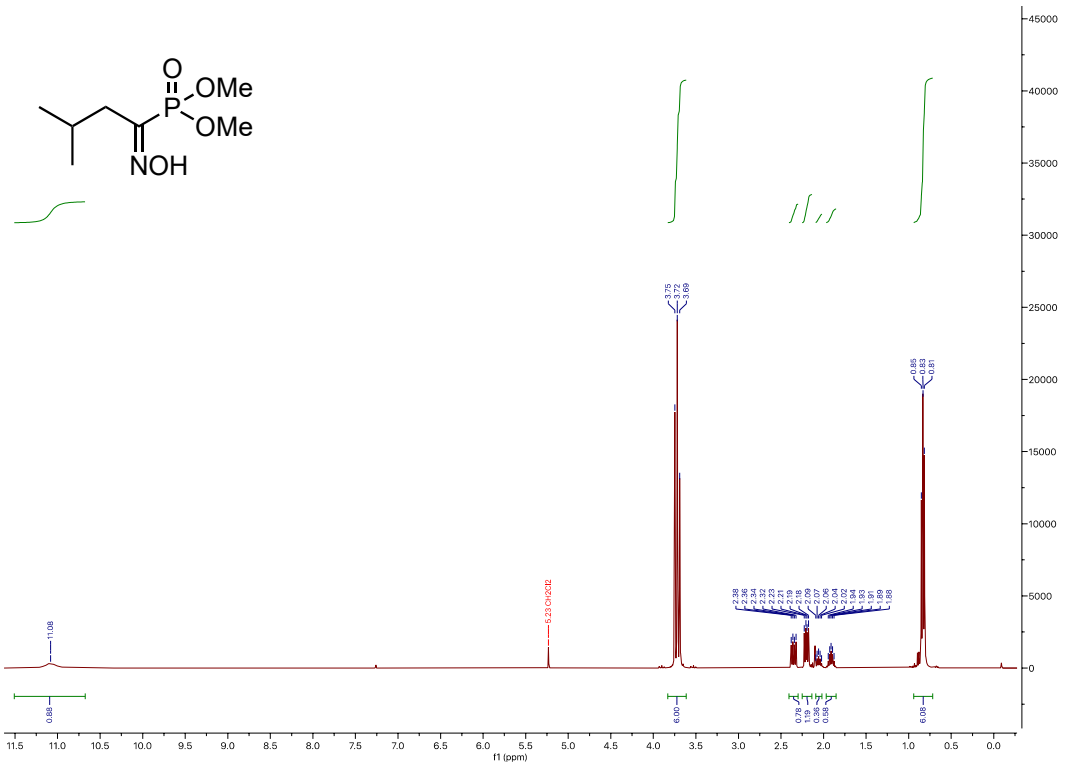


Figure S43. ^{1}H NMR spectrum (400 MHz) of dimethyl (1-(hydroxyimino)-3-methylbutyl)phosphonate (**7b**) in $CDCl_3$.

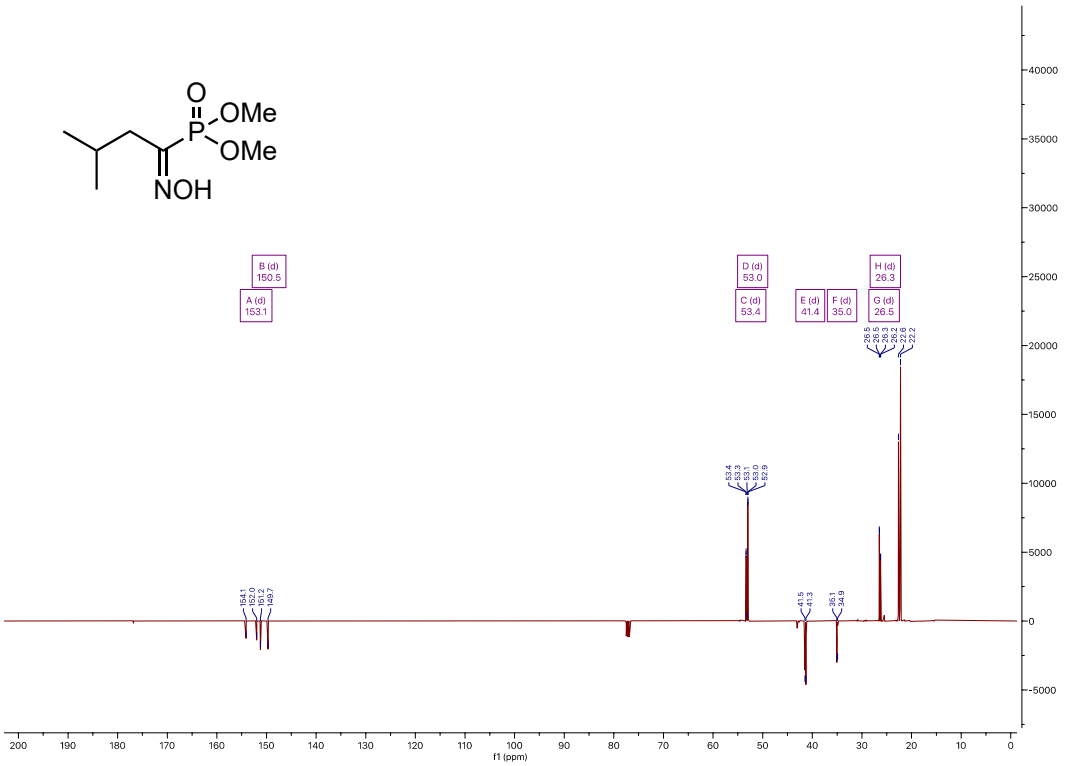


Figure S44. ^{13}C APT NMR spectrum (100.6 MHz) of dimethyl (1-(hydroxyimino)-3-methylbutyl)phosphonate (**7b**) in $CDCl_3$.

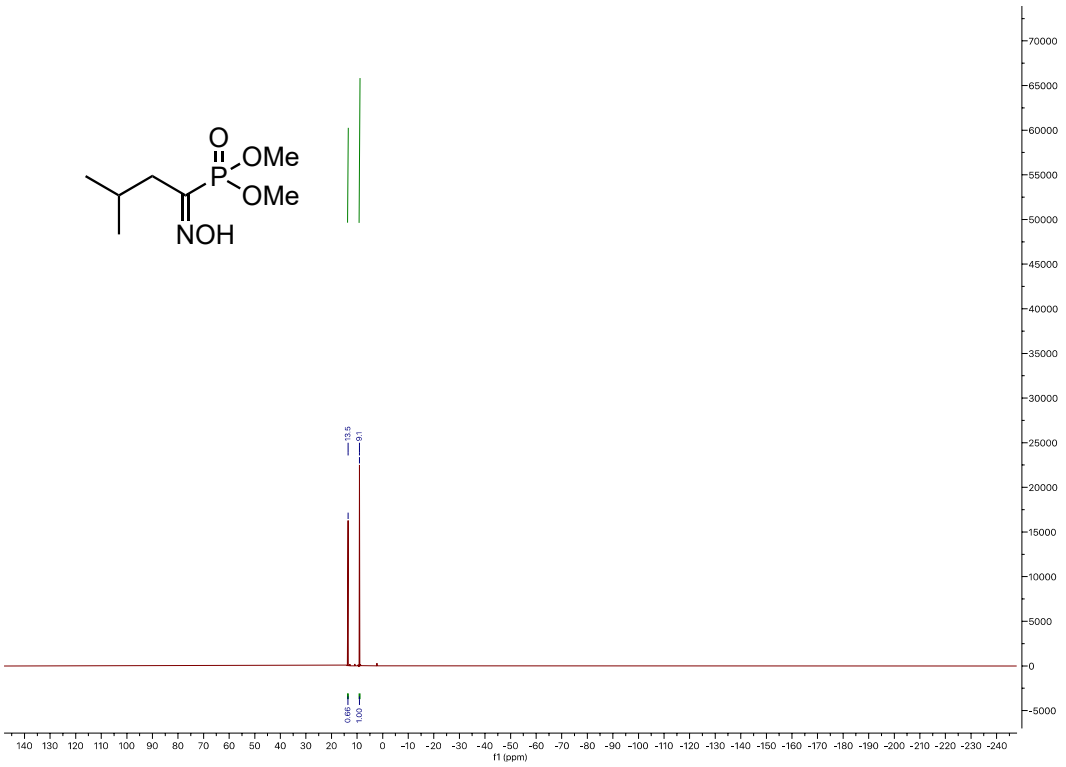


Figure S45. ^{31}P NMR spectrum (161.9 MHz) of dimethyl (1-(hydroxyimino)-3-methylbutyl)phosphonate (**7b**) in $CDCl_3$.

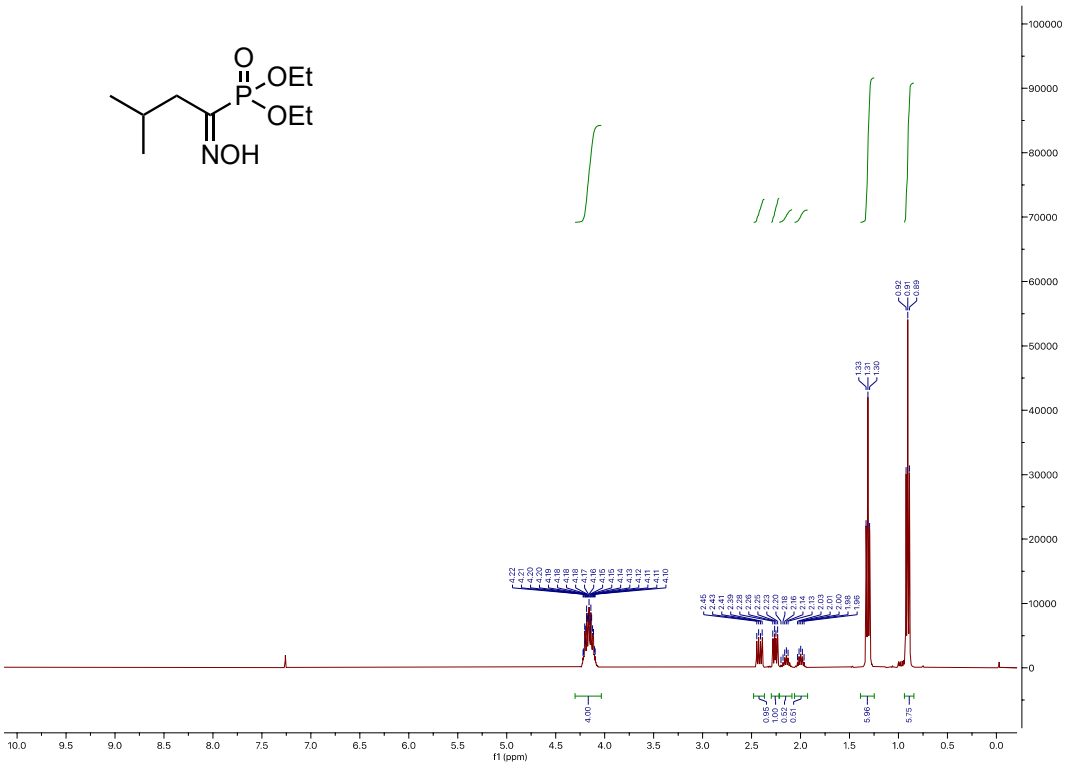


Figure S46. ^{1}H NMR spectrum (400 MHz) of diethyl (1-(hydroxyimino)-3-methylbutyl)phosphonate (**8b**) in $CDCl_3$.

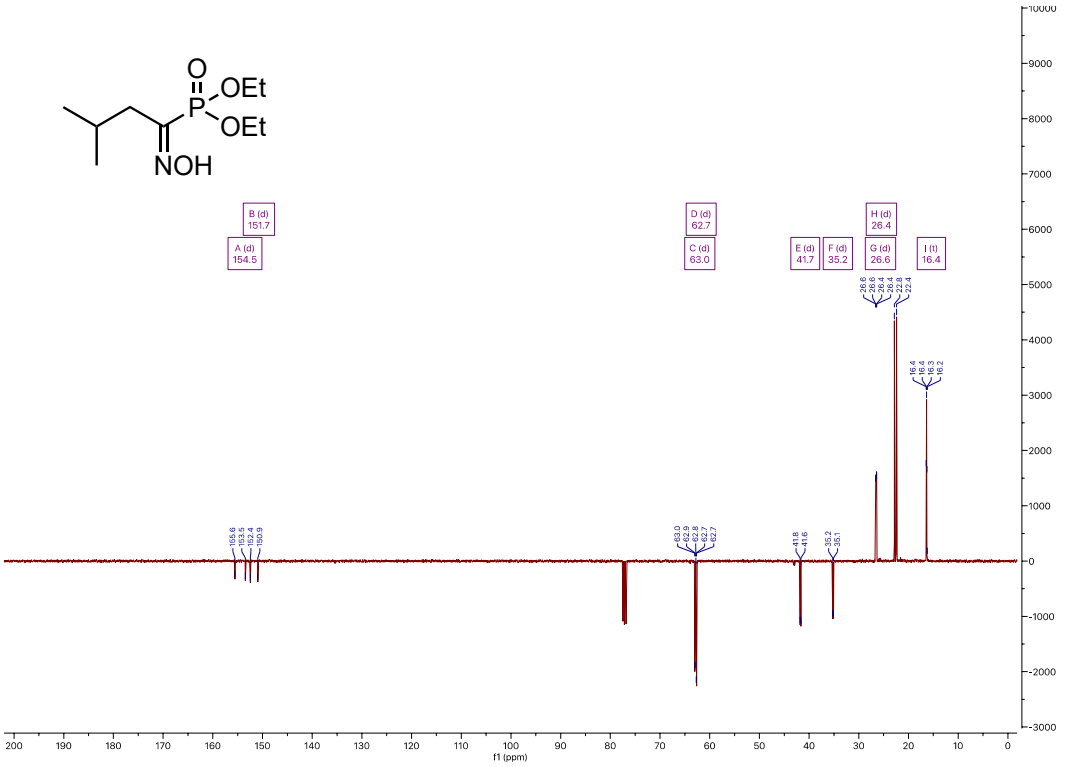


Figure S47. ^{13}C APT NMR spectrum (100.6 MHz) of diethyl (1-(hydroxyimino)-3-methylbutyl)phosphonate (**8b**) in $CDCl_3$.

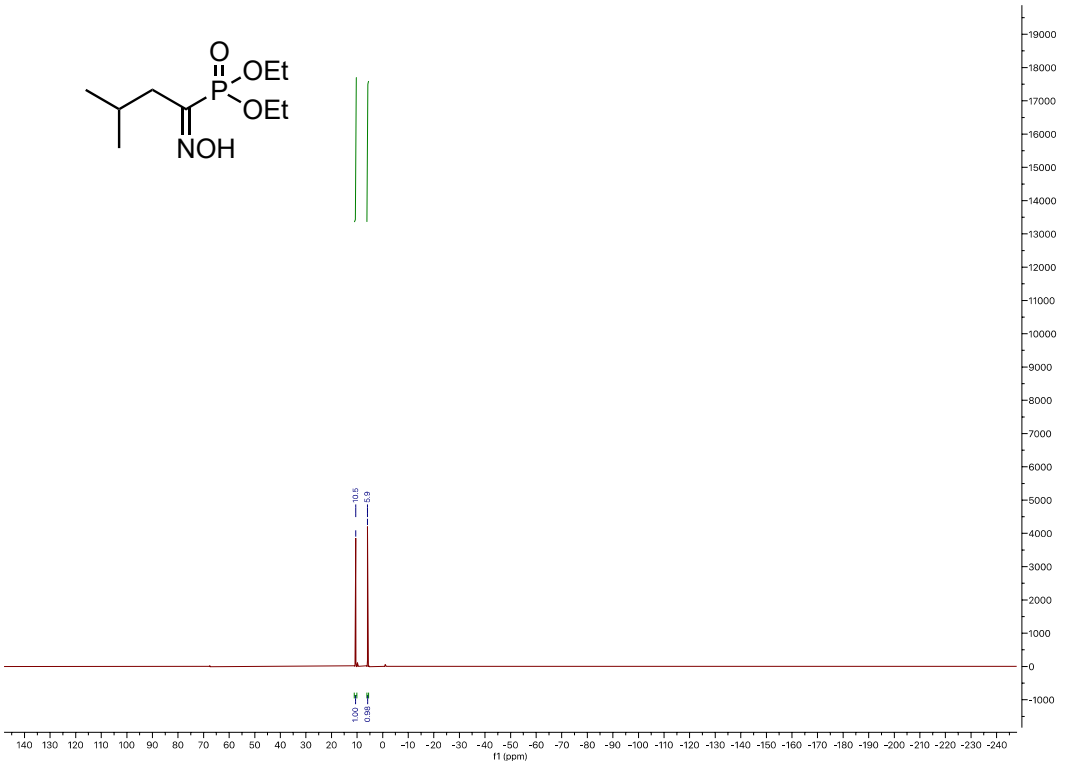


Figure S48. ^{31}P NMR spectrum (161.9 MHz) of diethyl (1-(hydroxyimino)-3-methylbutyl)phosphonate (**8b**) in $CDCl_3$.

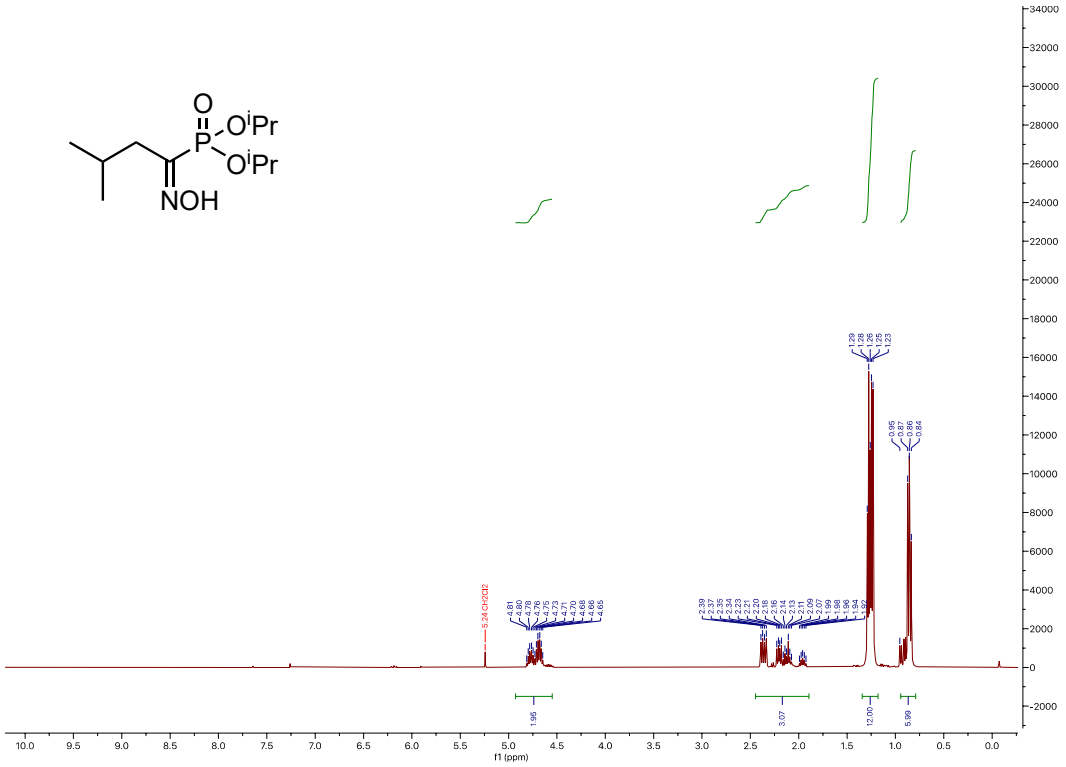


Figure S49. ^{1}H NMR spectrum (400 MHz) of diisopropyl (1-(hydroxyimino)-3-methylbutyl)phosphonate (**9b**) in $CDCl_3$.

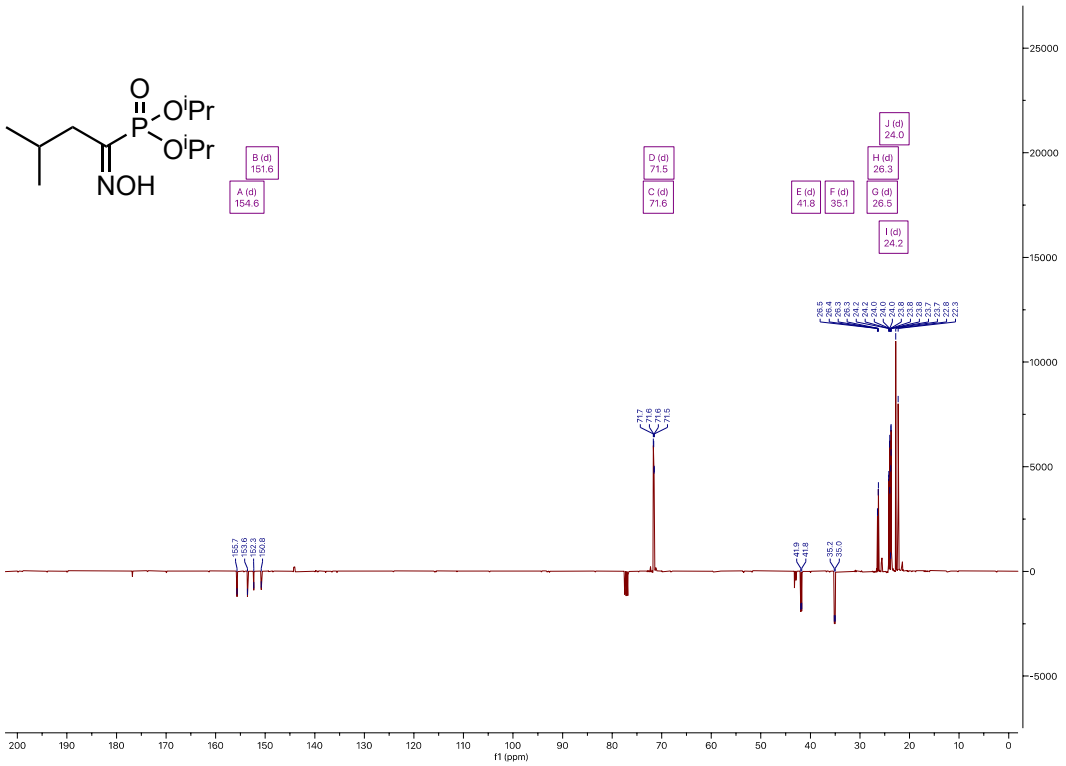


Figure S50. ^{13}C APT NMR spectrum (100.6 MHz) of diisopropyl (1-(hydroxyimino)-3-methylbutyl)phosphonate (**9b**) in $CDCl_3$.

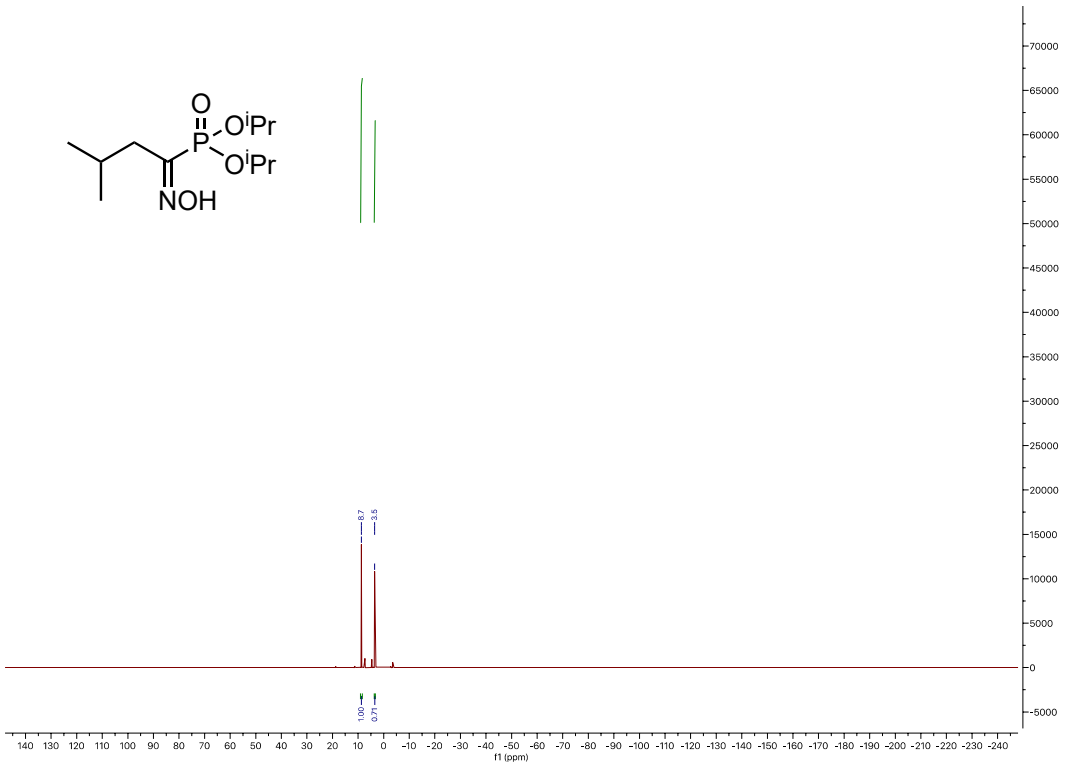


Figure S51. ^{31}P NMR spectrum (161.9 MHz) of diisopropyl (1-(hydroxyimino)-3-methylbutyl)phosphonate (**9b**) in $CDCl_3$.

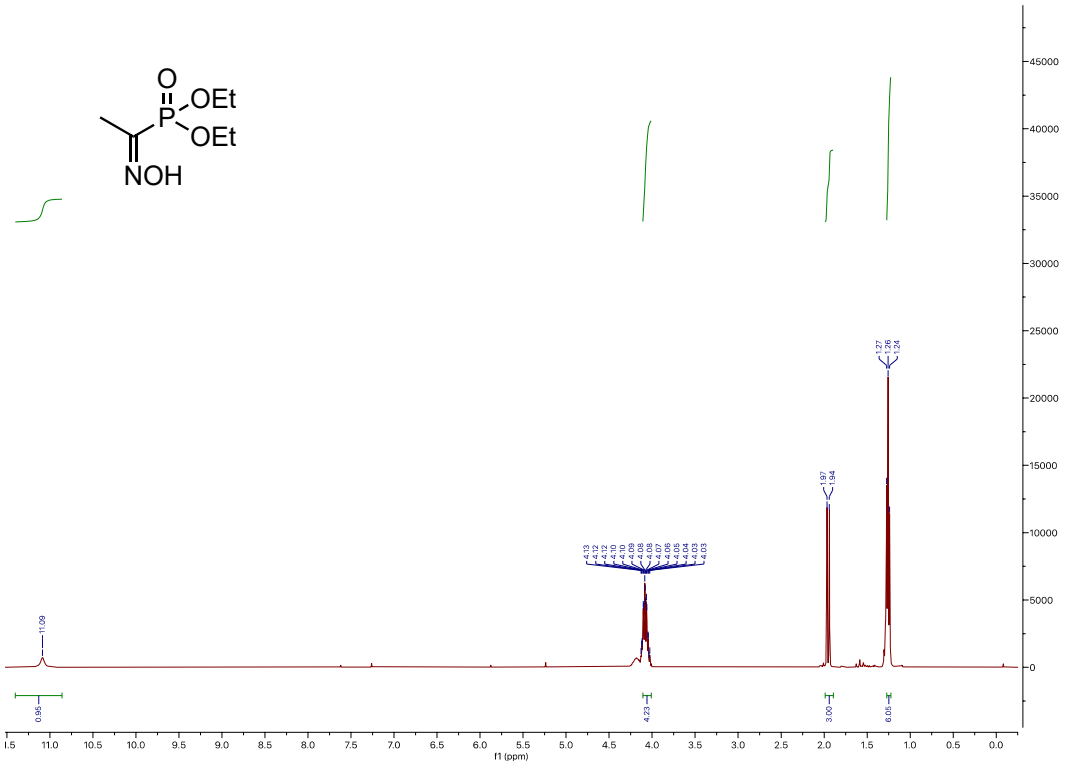


Figure S52. ^{1}H NMR spectrum (400 MHz) of diethyl (1-(hydroxyimino)ethyl)phosphonate (**10b**) in $CDCl_3$.

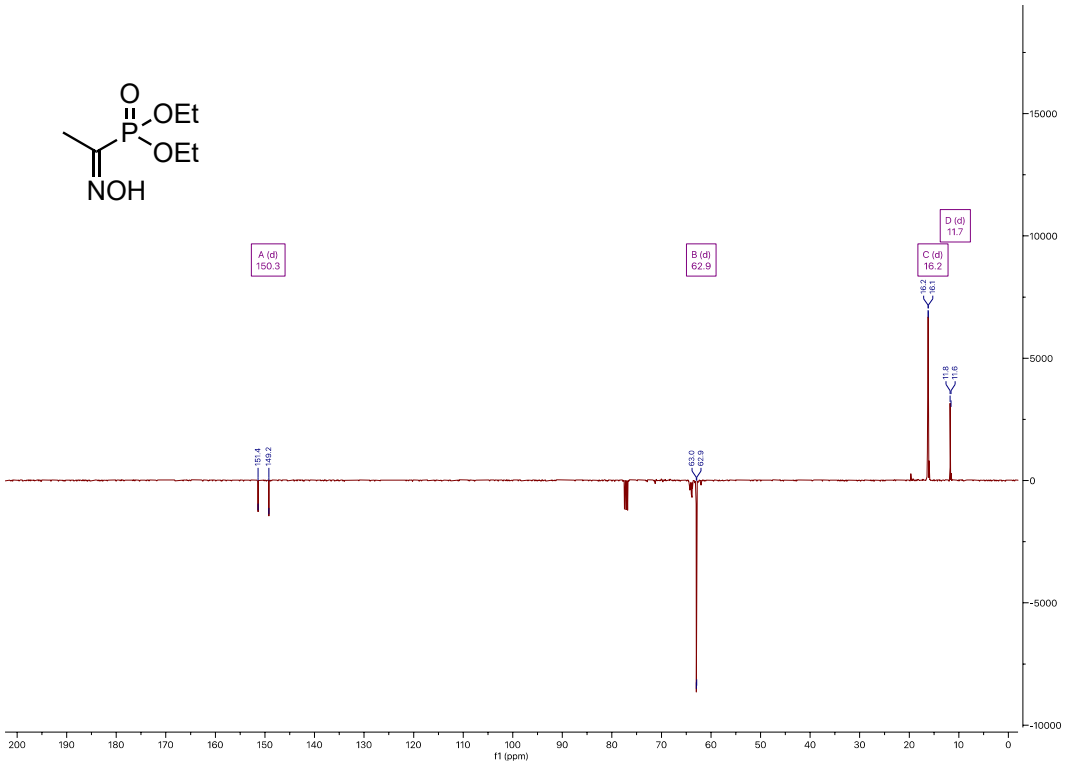


Figure S53. ^{13}C APT NMR spectrum (100.6 MHz) of diethyl (1-(hydroxyimino)ethyl)phosphonate (**10b**) in $CDCl_3$.

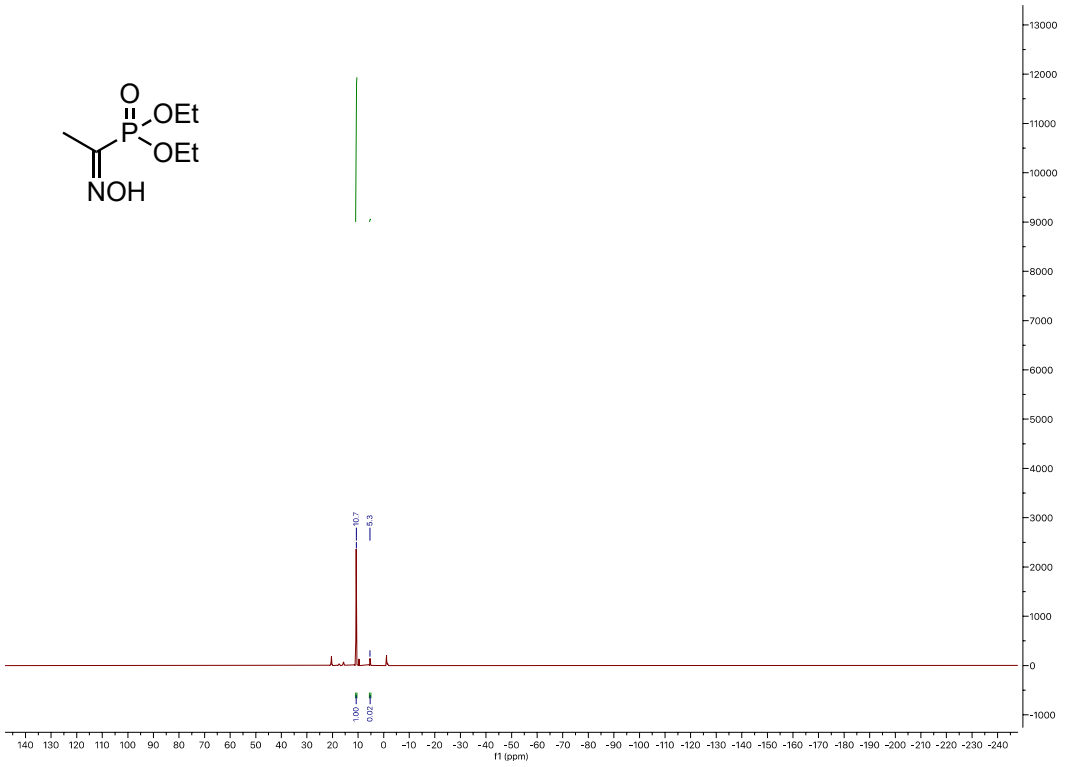


Figure S54. ^{31}P NMR spectrum (161.9 MHz) of diethyl (1-(hydroxyimino)ethyl)phosphonate (**10b**) in $CDCl_3$.

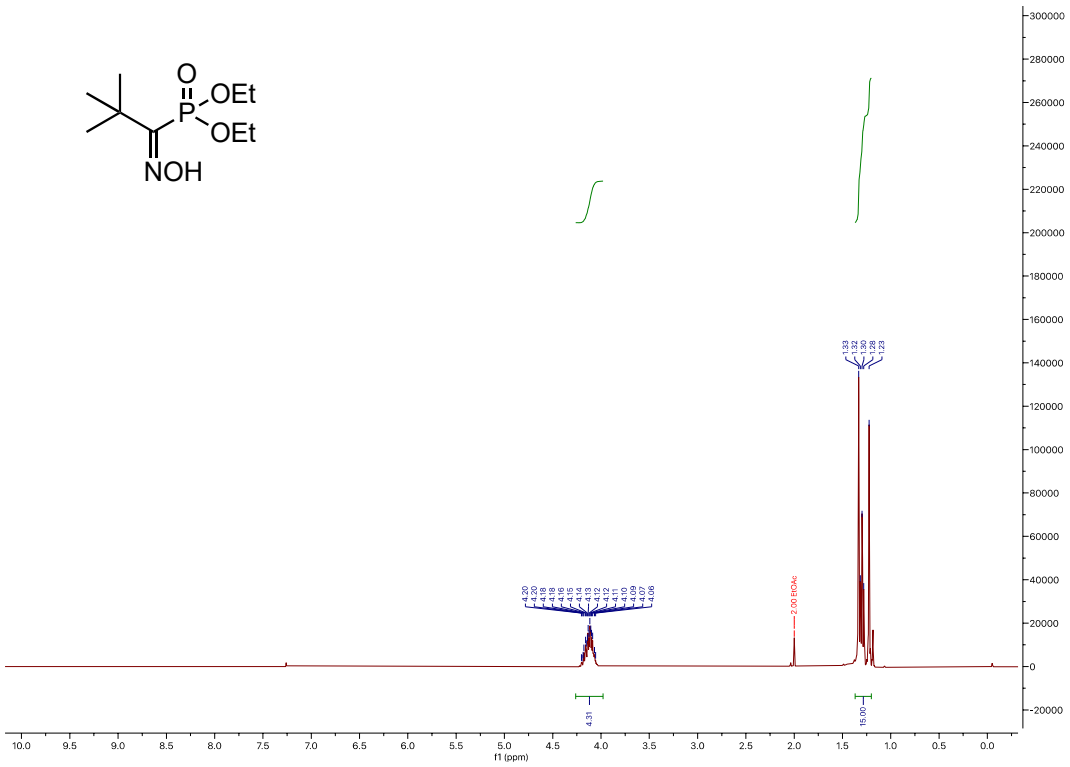


Figure S55. ^{1}H NMR spectrum (400 MHz) of diethyl (1-(hydroxyimino)-2,2-dimethylpropyl)phosphonate (**11b**) in $CDCl_3$.

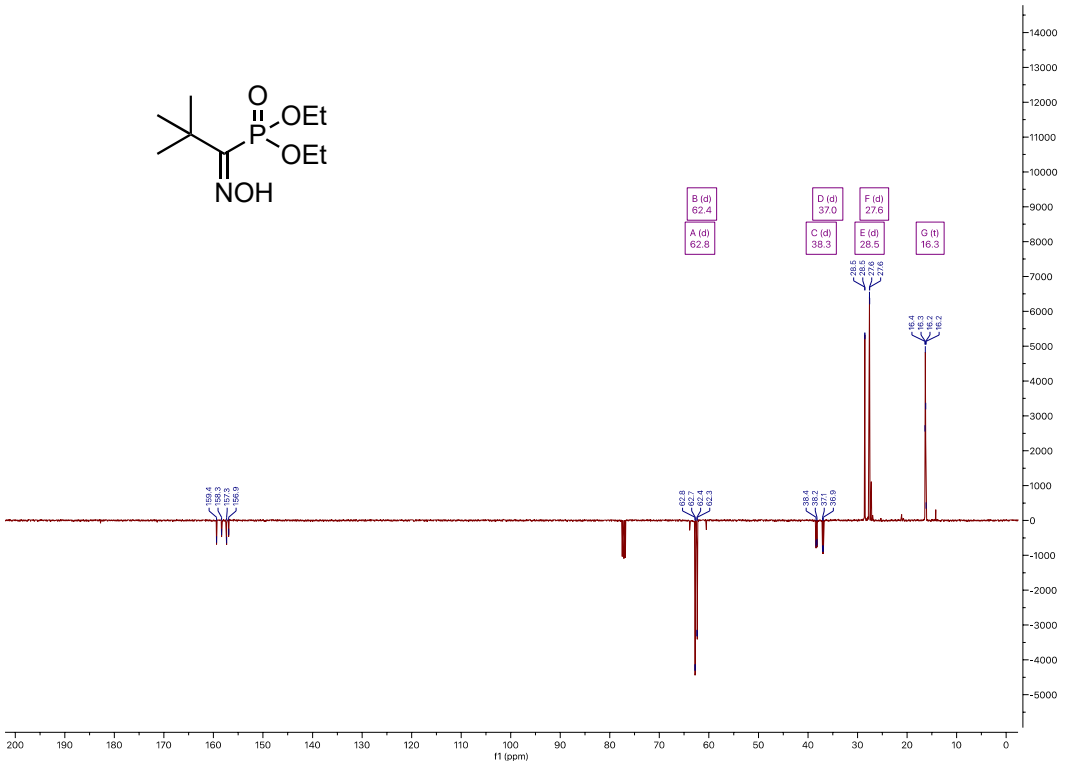


Figure S56. ^{13}C APT NMR spectrum (100.6 MHz) of diethyl (1-(hydroxyimino)-2,2-dimethylpropyl)phosphonate (**11b**) in $CDCl_3$.

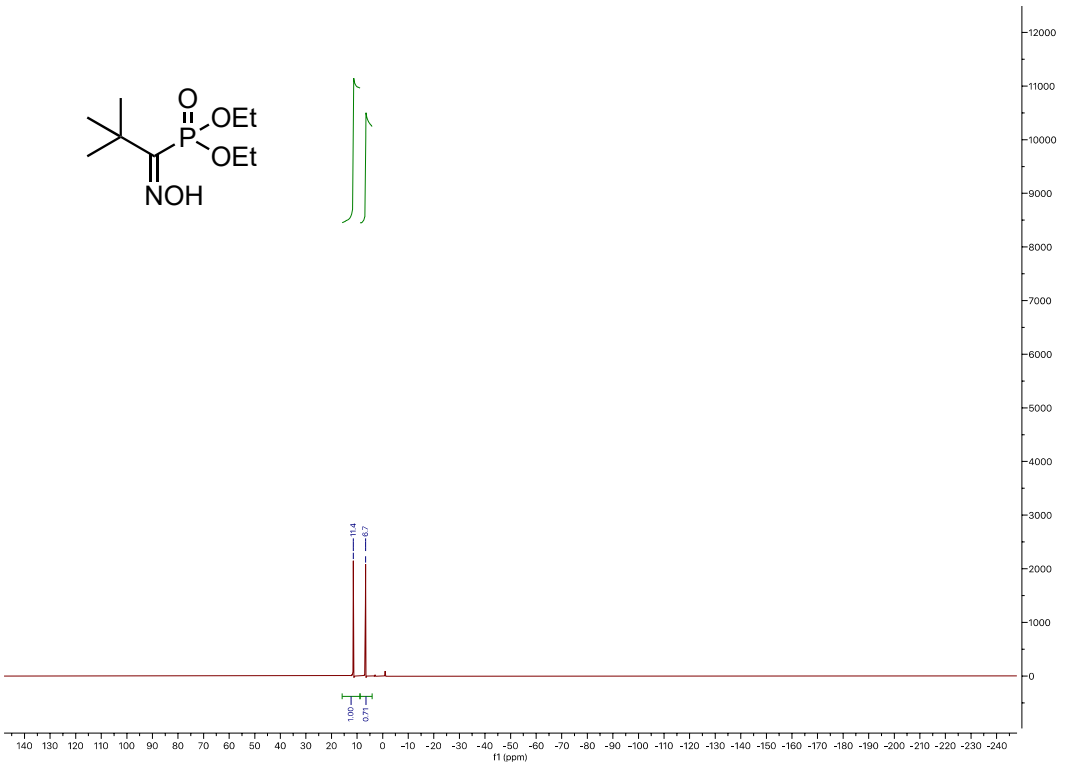


Figure S57. ^{31}P NMR spectrum (161.9 MHz) of diethyl (1-(hydroxyimino)-2,2-dimethylpropyl)phosphonate (**11b**) in $CDCl_3$.

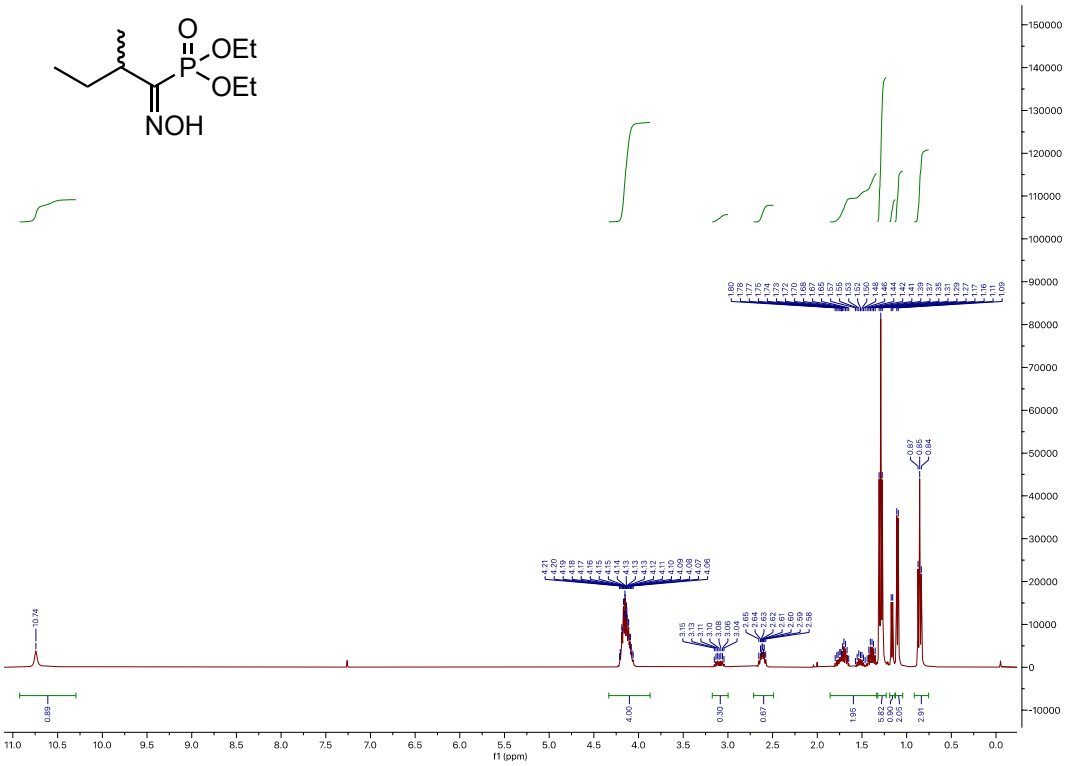


Figure S58. ^{1}H NMR spectrum (400 MHz) of diethyl (1-(hydroxyimino)-2-methylbutyl)phosphonate (**12b**) in $CDCl_3$.

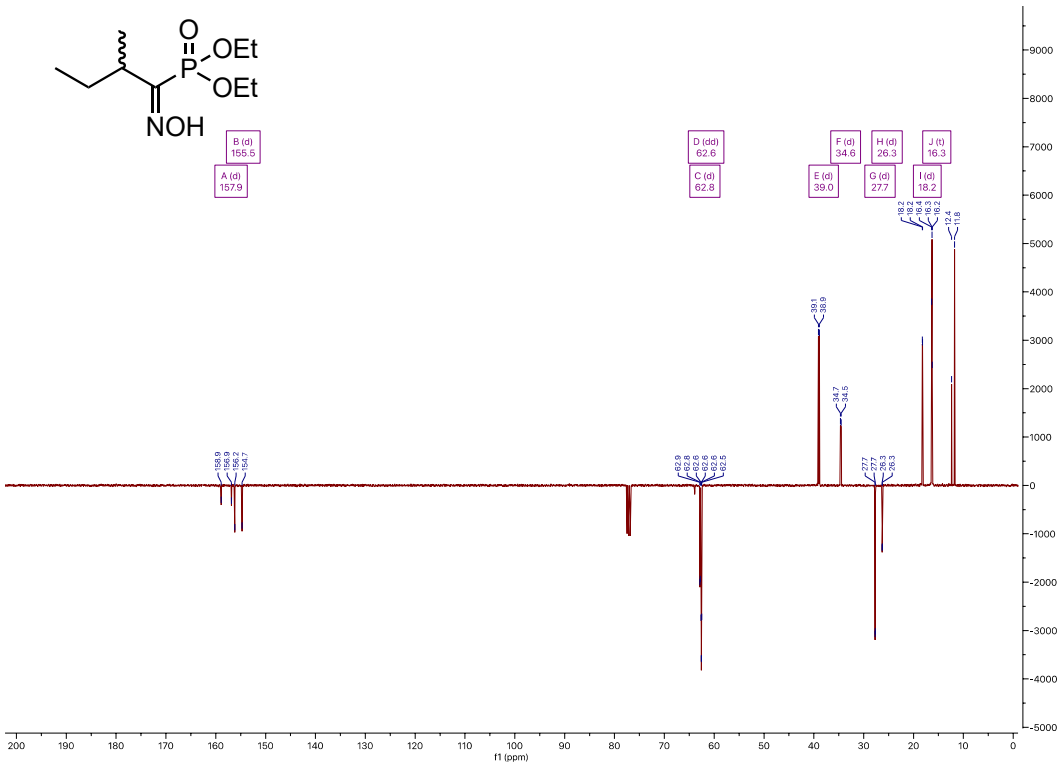


Figure S59. ^{13}C APT NMR spectrum (100.6 MHz) of diethyl (1-(hydroxyimino)-2-methylbutyl)phosphonate (**12b**) in $CDCl_3$.

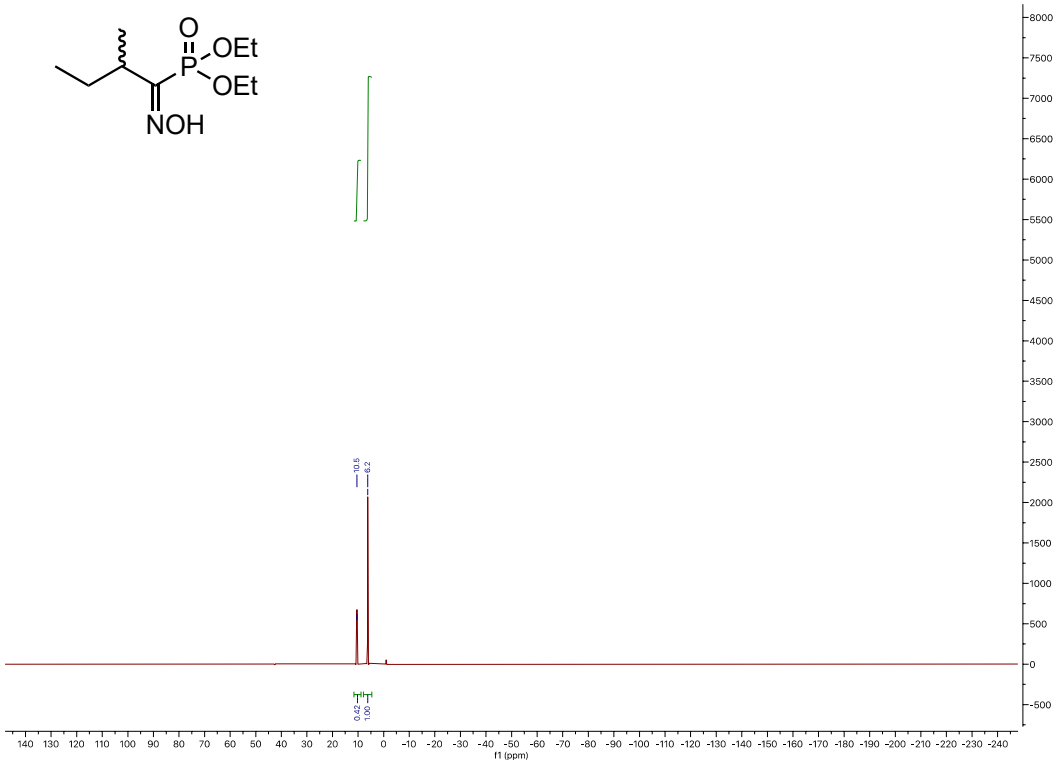


Figure S60. ^{31}P NMR spectrum (161.9 MHz) of diethyl (1-(hydroxyimino)-2-methylbutyl)phosphonate (**12b**) in $CDCl_3$.

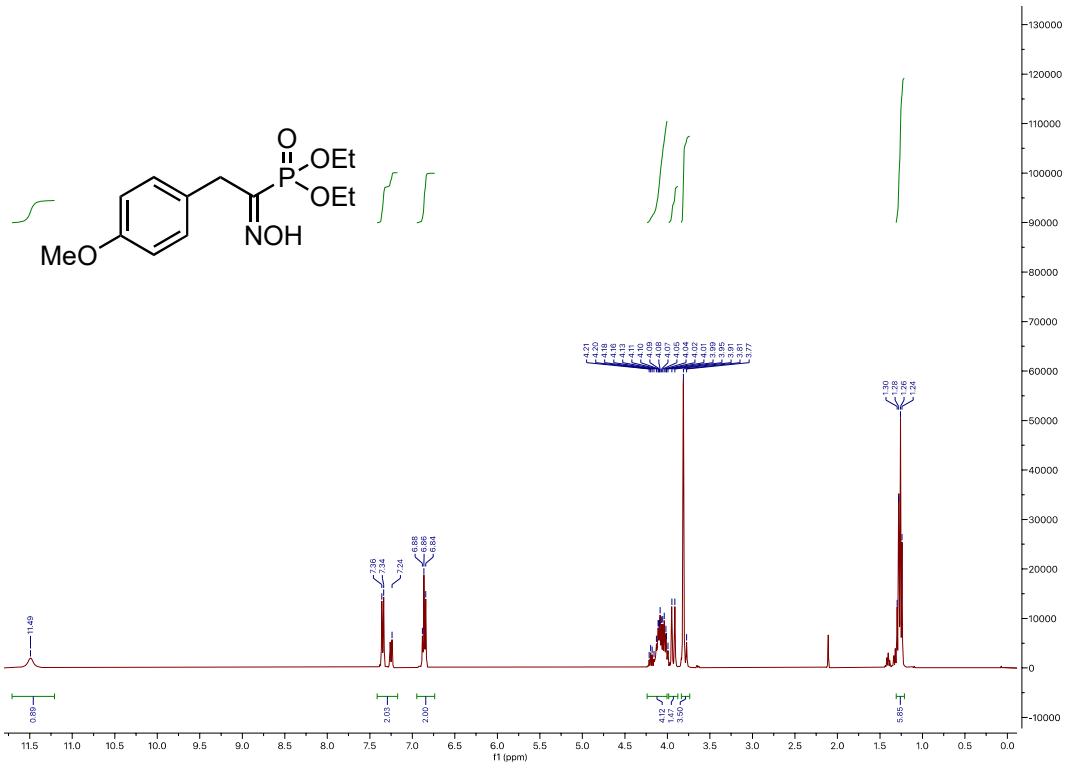


Figure S61. ^{1}H NMR spectrum (400 MHz) of diethyl (1-(hydroxyimino)-2-(4-methoxyphenyl)ethyl)phosphonate (**13b**) in $CDCl_3$.

Figure S62. ^{13}C APT NMR spectrum (100.6 MHz) of diethyl (1-(hydroxyimino)-2-(4-methoxyphenyl)ethyl)phosphonate (**13b**) in $CDCl_3$.

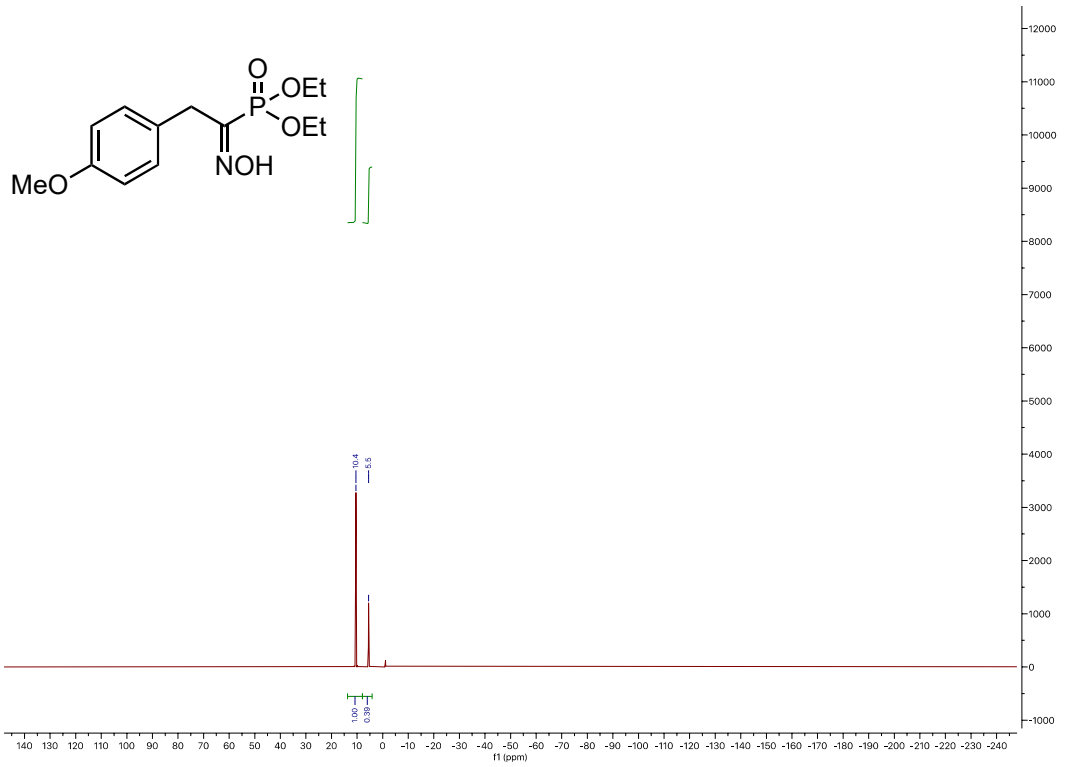


Figure S63. ^{31}P NMR spectrum (161.9 MHz) of diethyl (1-(hydroxyimino)-2-(4-methoxyphenyl)ethyl)phosphonate (**13b**) in $CDCl_3$.

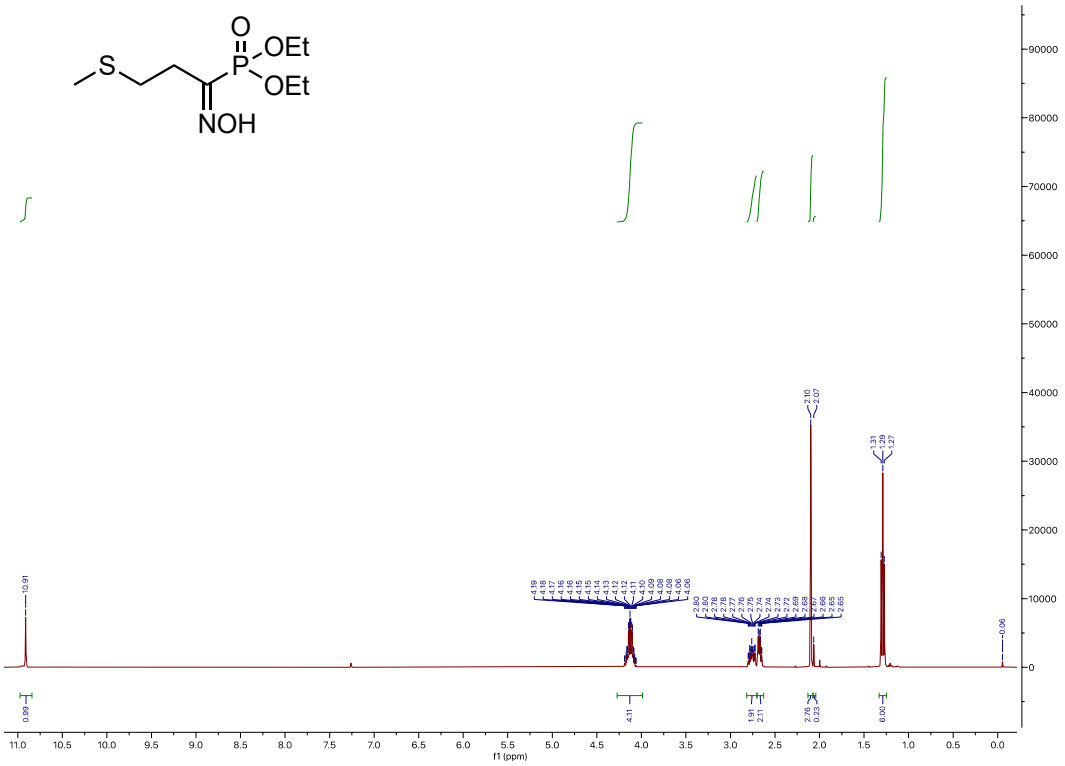


Figure S64. ^{1}H NMR spectrum (400 MHz) of diethyl (1-(hydroxyimino)-3-(methylthio)propyl)phosphonate (**14b**) in $CDCl_3$.

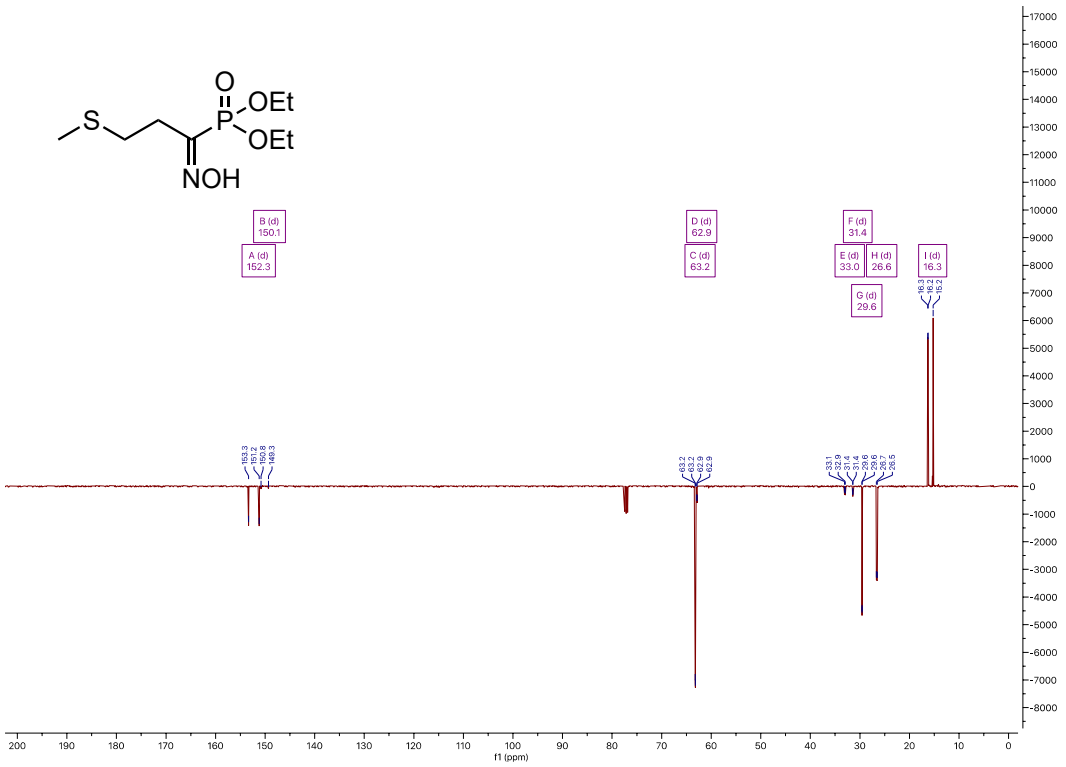


Figure S65. ^{13}C APT NMR spectrum (100.6 MHz) of diethyl (1-(hydroxyimino)-3-(methylthio)propyl)phosphonate (**14b**) in $CDCl_3$.

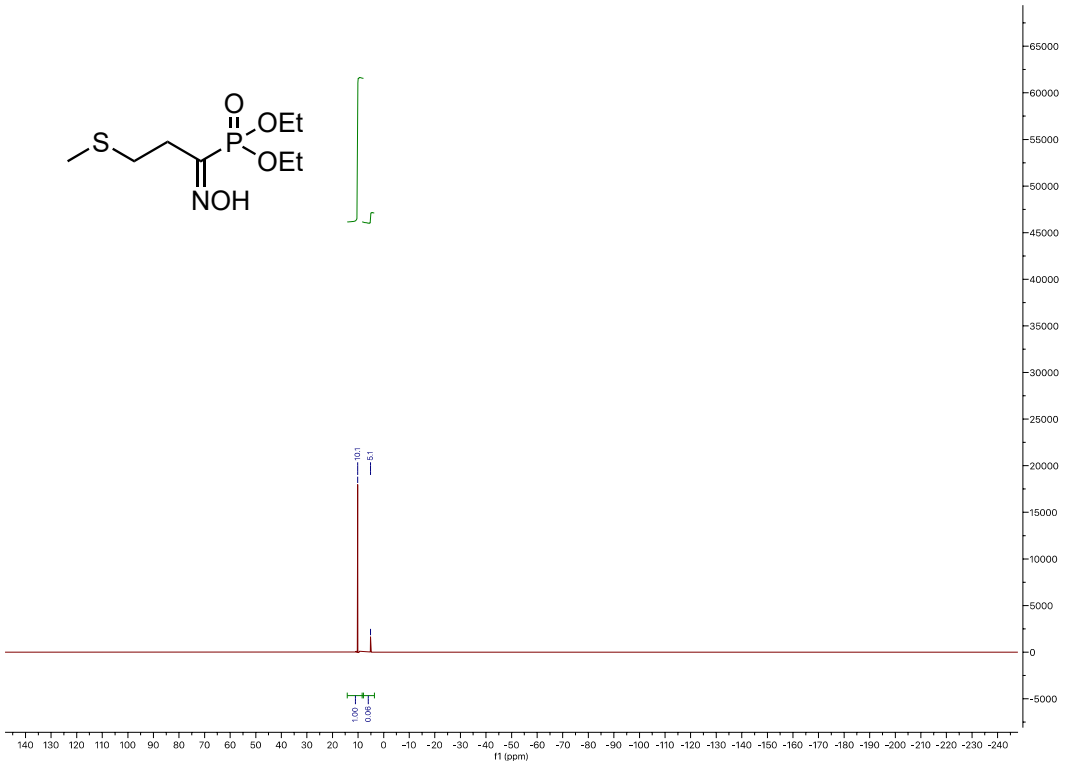


Figure S66. ^{31}P NMR spectrum (161.9 MHz) of diethyl (1-(hydroxyimino)-3-(methylthio)propyl)phosphonate (**14b**) in $CDCl_3$.

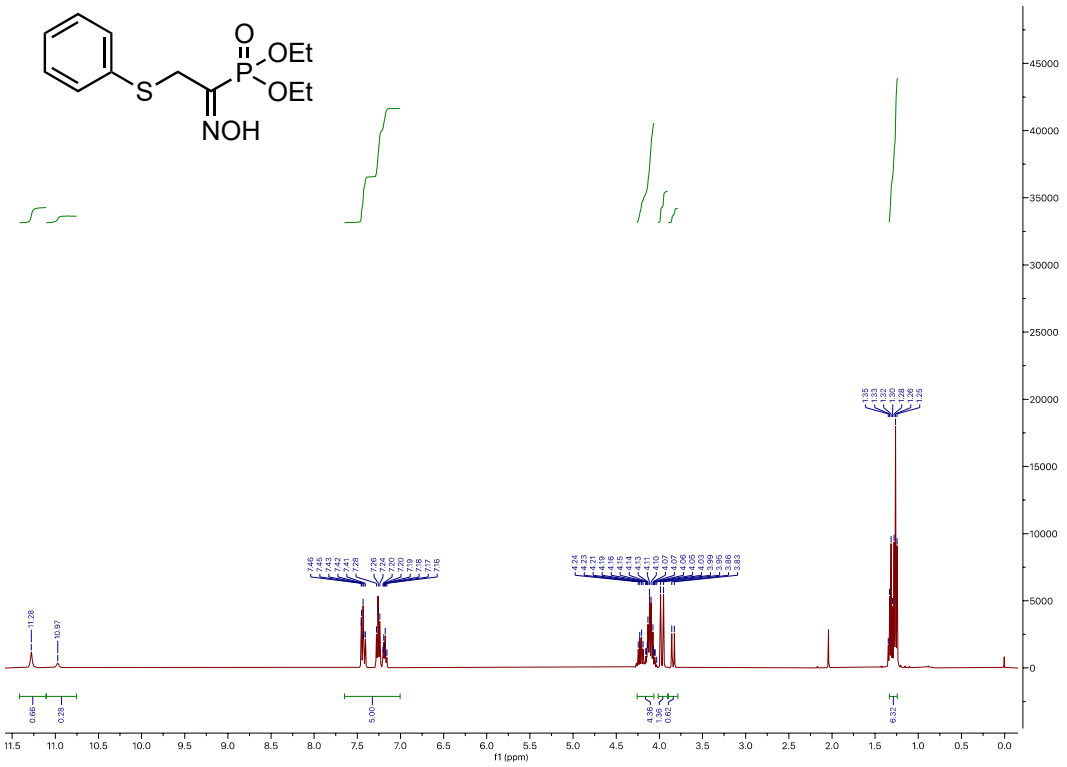


Figure S67. ^{1}H NMR spectrum (400 MHz) of diethyl (1-(hydroxyimino)-2-(phenylthio)ethyl)phosphonate (**15b**) in $CDCl_3$.

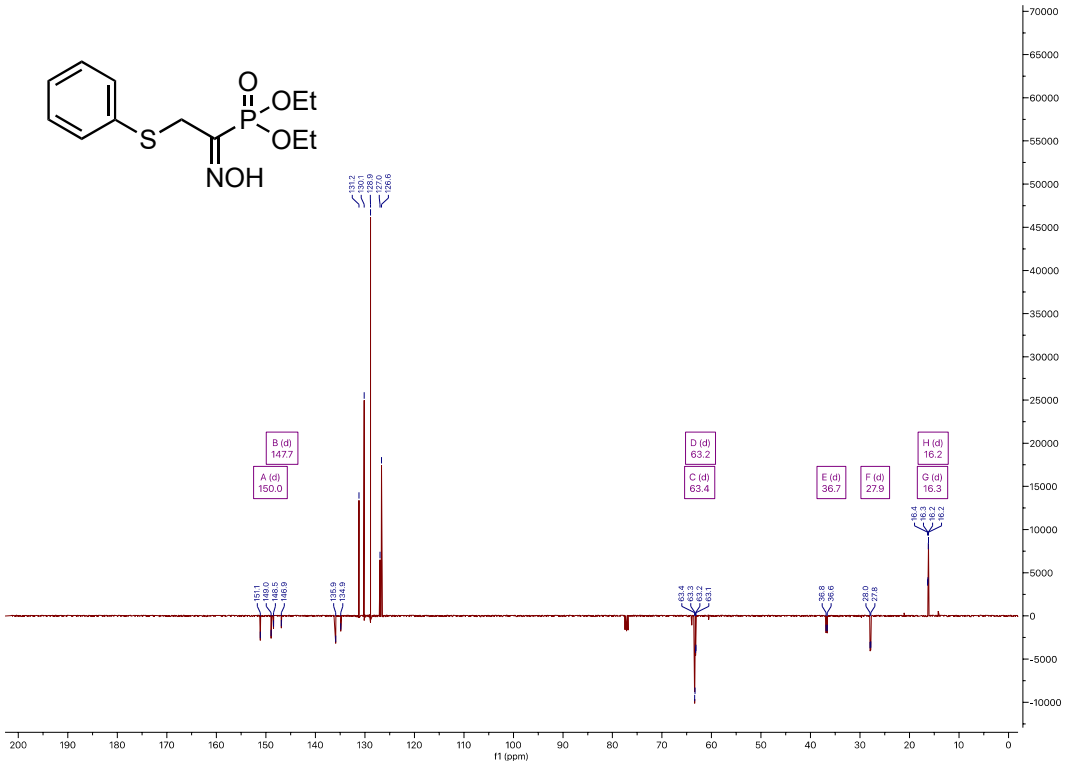


Figure S68. ^{13}C APT NMR spectrum (100.6 MHz) of diethyl (1-(hydroxyimino)-2-(phenylthio)ethyl)phosphonate (**15b**) in $CDCl_3$.

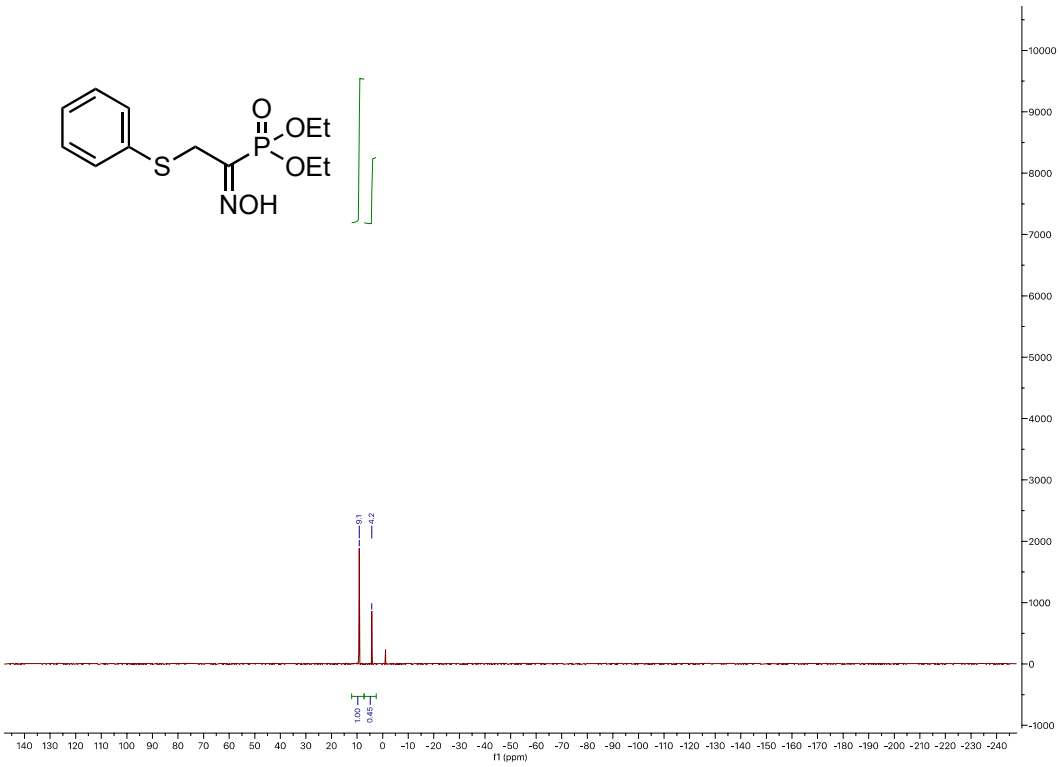


Figure S69. ^{31}P NMR spectrum (161.9 MHz) of diethyl (1-(hydroxyimino)-2-(phenylthio)ethyl)phosphonate (**15b**) in $CDCl_3$.

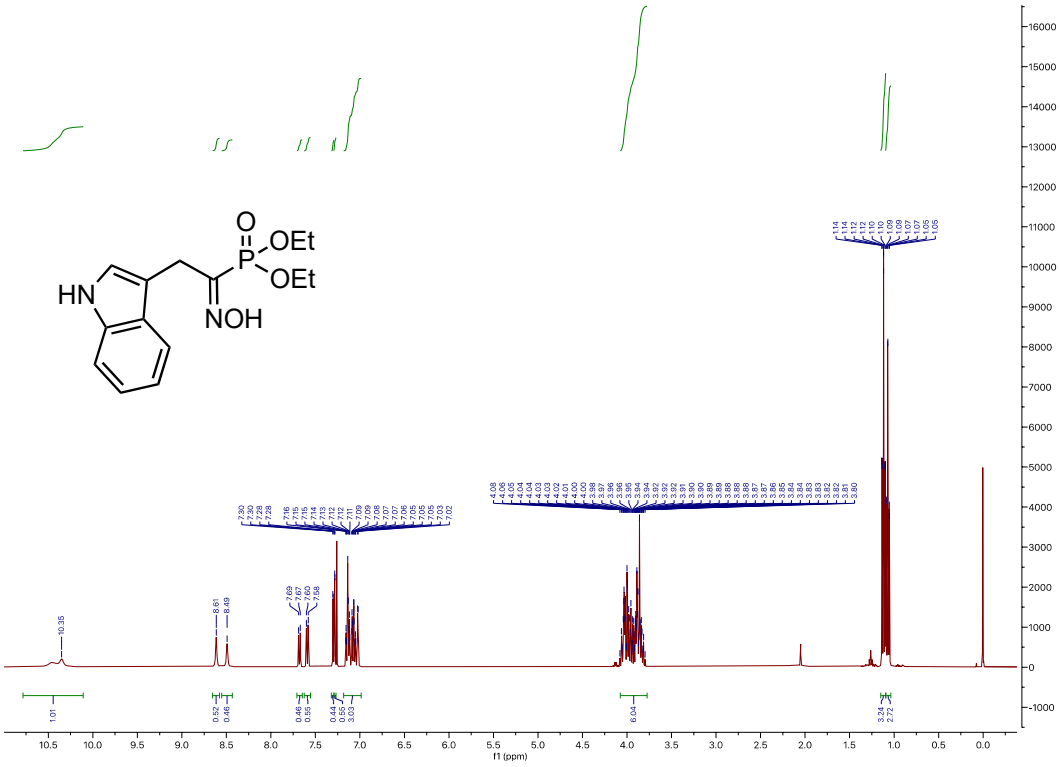


Figure S70. ^{1}H NMR spectrum (400 MHz) of diethyl (1-(hydroxyimino)-2-(1*H*-indol-3-yl)ethyl)phosphonate (**16b**) in $CDCl_3$.

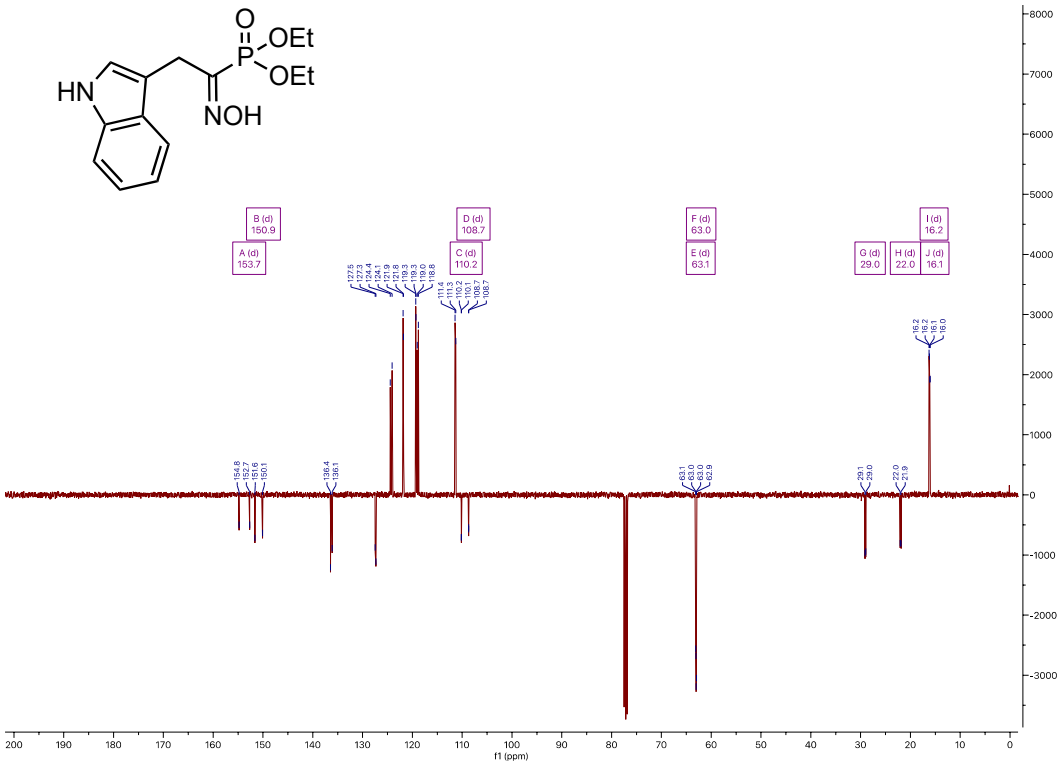


Figure S71. ^{13}C APT NMR spectrum (100.6 MHz) of diethyl (1-(hydroxyimino)-2-(1*H*-indol-3-yl)ethyl)phosphonate (**16b**) in $CDCl_3$.

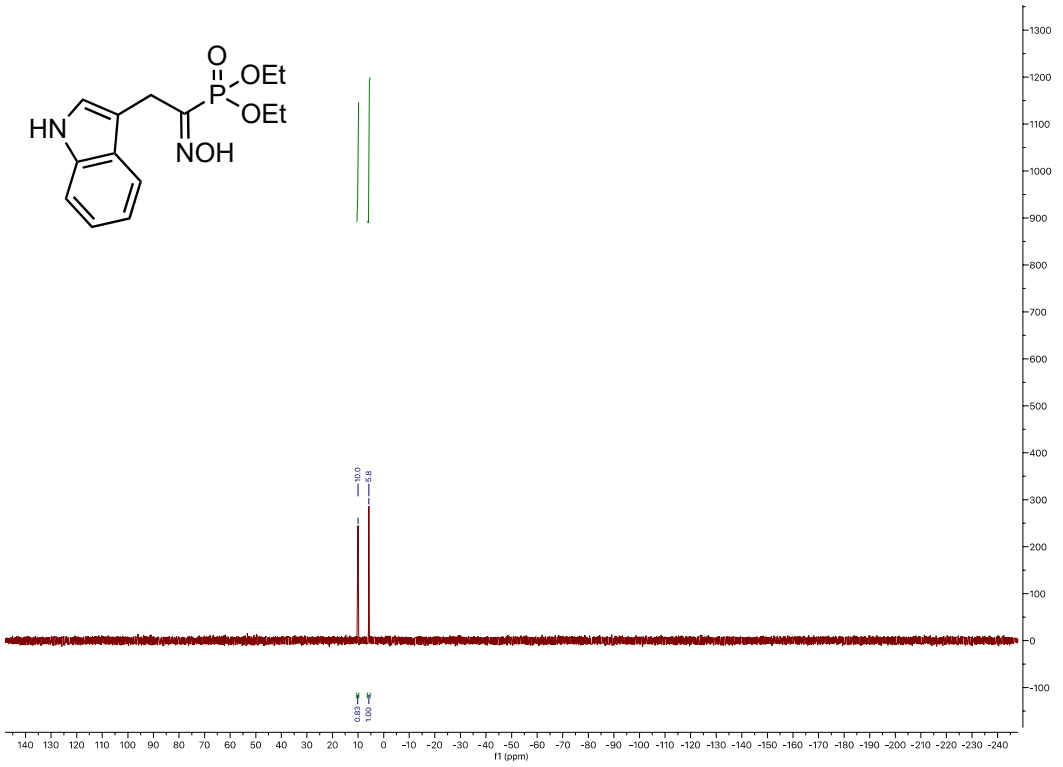


Figure S72. ^{31}P NMR spectrum (161.9 MHz) of diethyl (1-(hydroxyimino)-2-(1*H*-indol-3-yl)ethyl)phosphonate (**16b**) in $CDCl_3$.

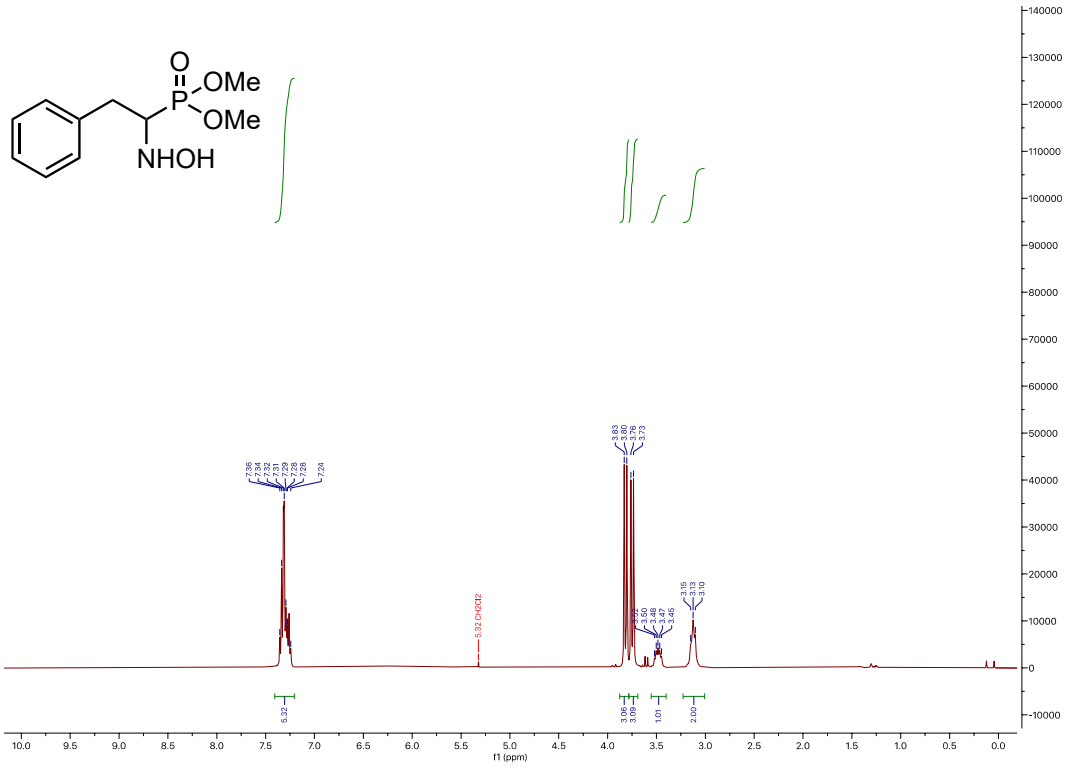


Figure S73. ^{1}H NMR spectrum (400 MHz) of dimethyl (1-(hydroxyamino)-2-phenylethyl)phosphonate (**1c**) in $CDCl_3$.

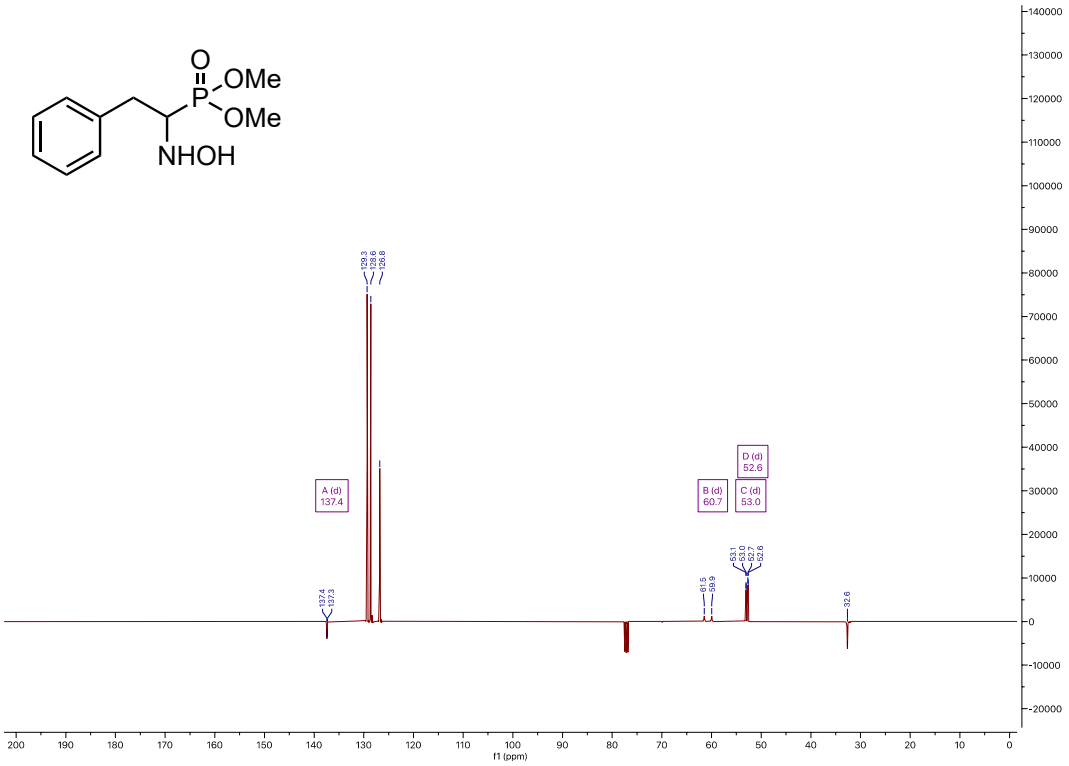


Figure S74. ^{13}C APT NMR spectrum (100.6 MHz) of dimethyl (1-(hydroxyamino)-2-phenylethyl)phosphonate (**1c**) in $CDCl_3$.

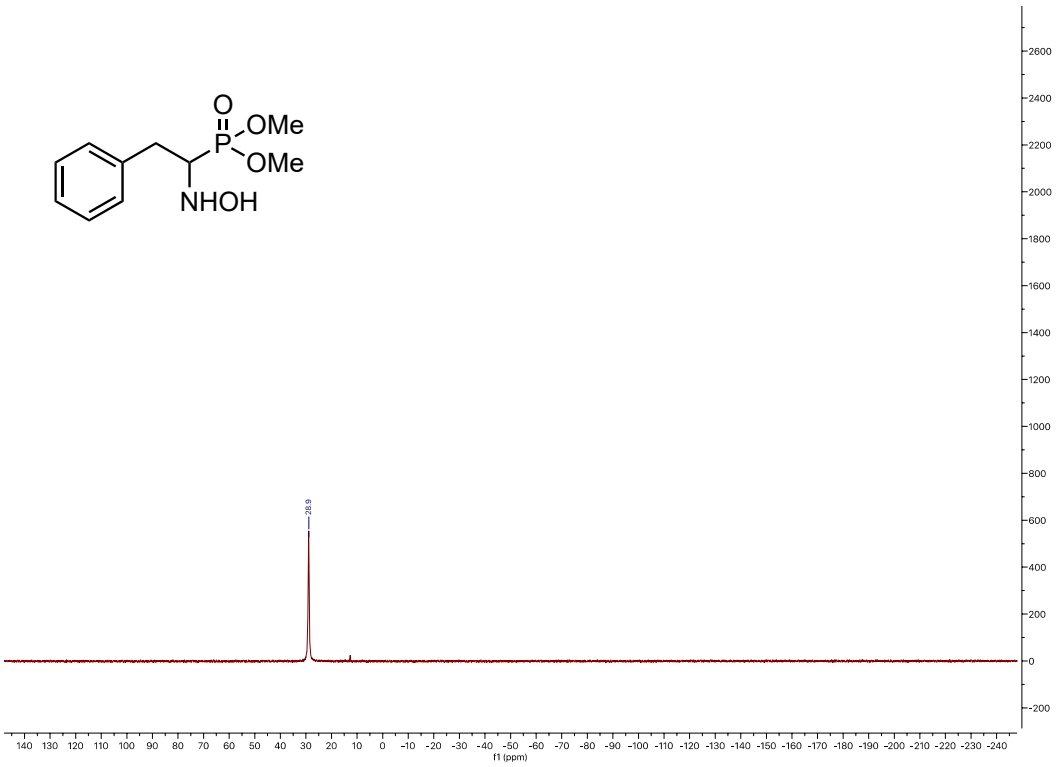


Figure S75. ^{31}P NMR spectrum (161.9 MHz) of dimethyl (1-(hydroxyamino)-2-phenylethyl)phosphonate (**1c**) in $CDCl_3$.

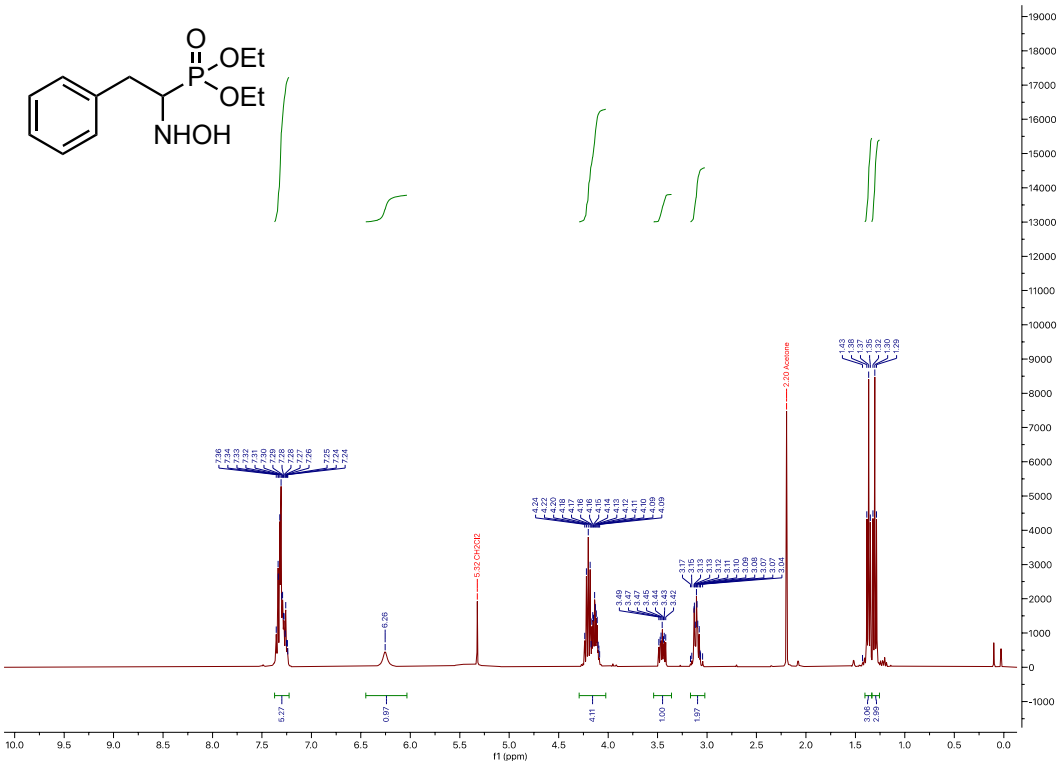


Figure S76. ^{1}H NMR spectrum (400 MHz) of diethyl (1-(hydroxyamino)-2-phenylethyl)phosphonate (**2c**) in $CDCl_3$.

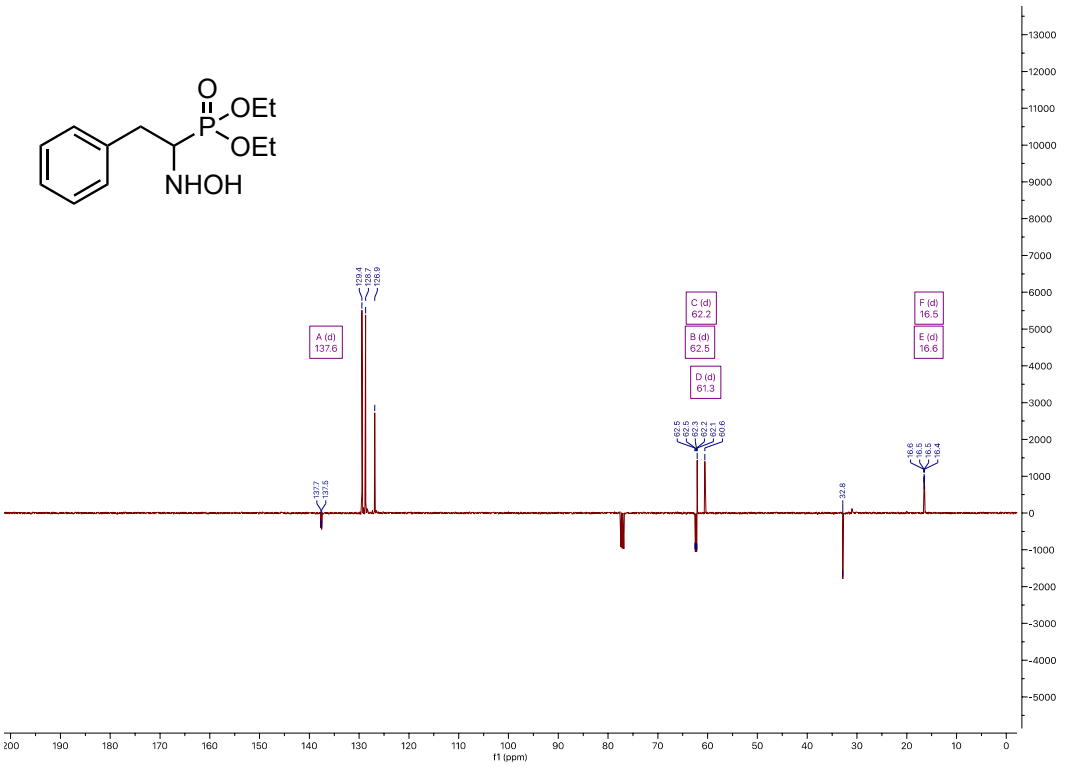


Figure S77. ^{13}C APT NMR spectrum (100.6 MHz) of diethyl (1-(hydroxyamino)-2-phenylethyl)phosphonate (**2c**) in $CDCl_3$.

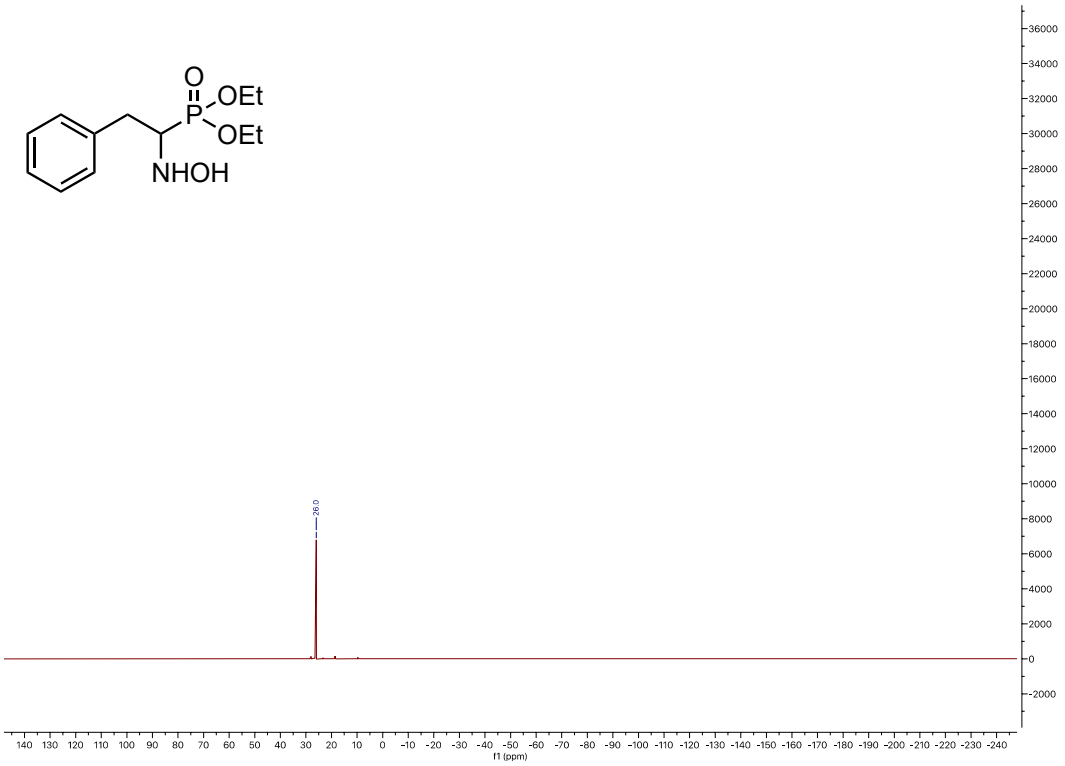


Figure S78. ^{31}P NMR spectrum (161.9 MHz) of diethyl (1-(hydroxyamino)-2-phenylethyl)phosphonate (**2c**) in $CDCl_3$.

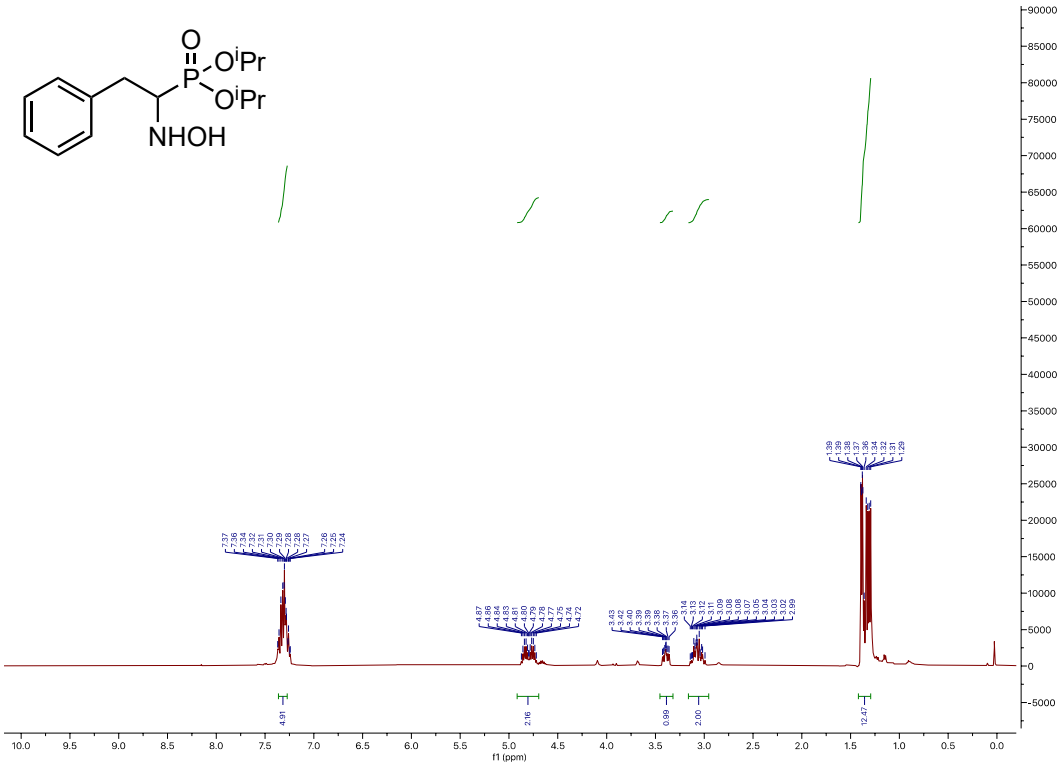


Figure S79. ^{1}H NMR spectrum (400 MHz) of diisopropyl (1-(hydroxyamino)-2-phenylethyl)phosphonate (**3c**) in $CDCl_3$.

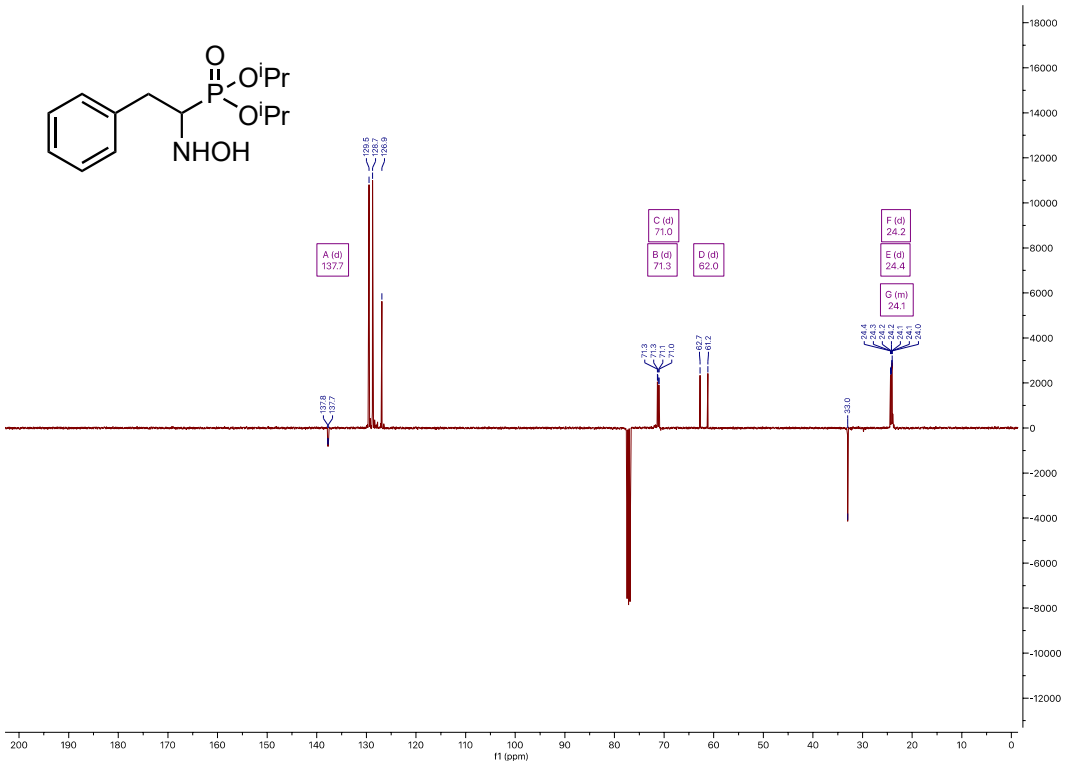


Figure S80. ^{13}C APT NMR spectrum (100.6 MHz) of diisopropyl (1-(hydroxyamino)-2-phenylethyl)phosphonate (**3c**) in $CDCl_3$.

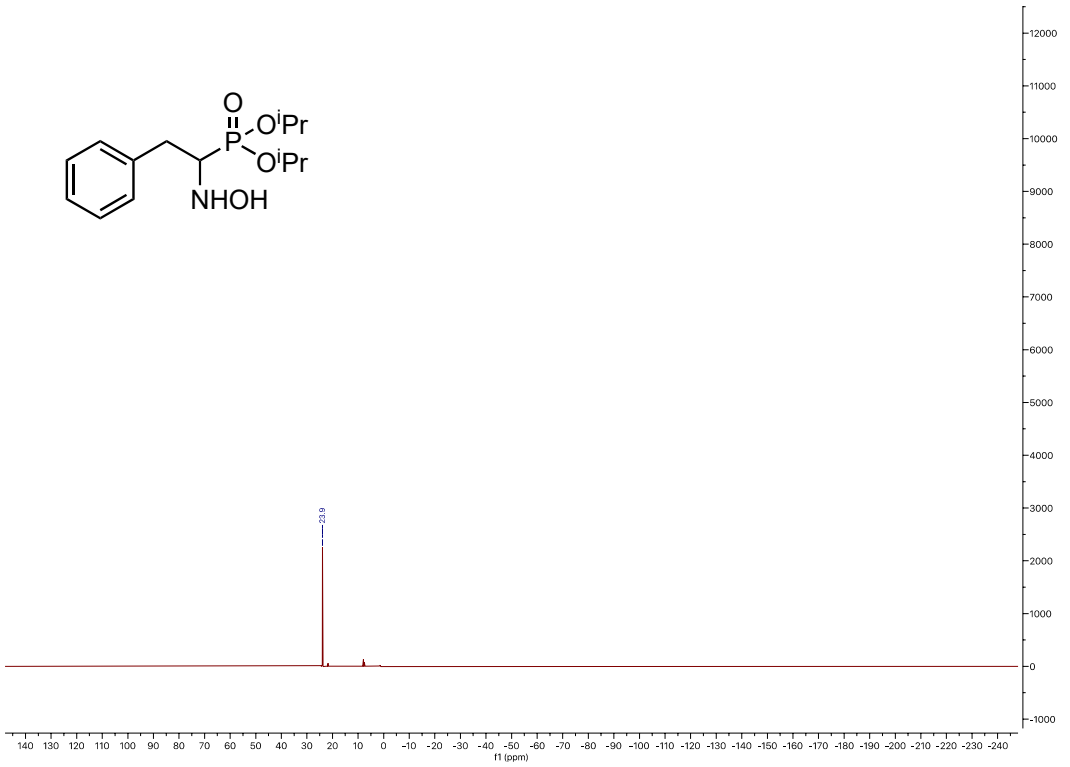


Figure S81. ^{31}P NMR spectrum (161.9 MHz) of diisopropyl (1-(hydroxyamino)-2-phenylethyl)phosphonate (**3c**) in $CDCl_3$.

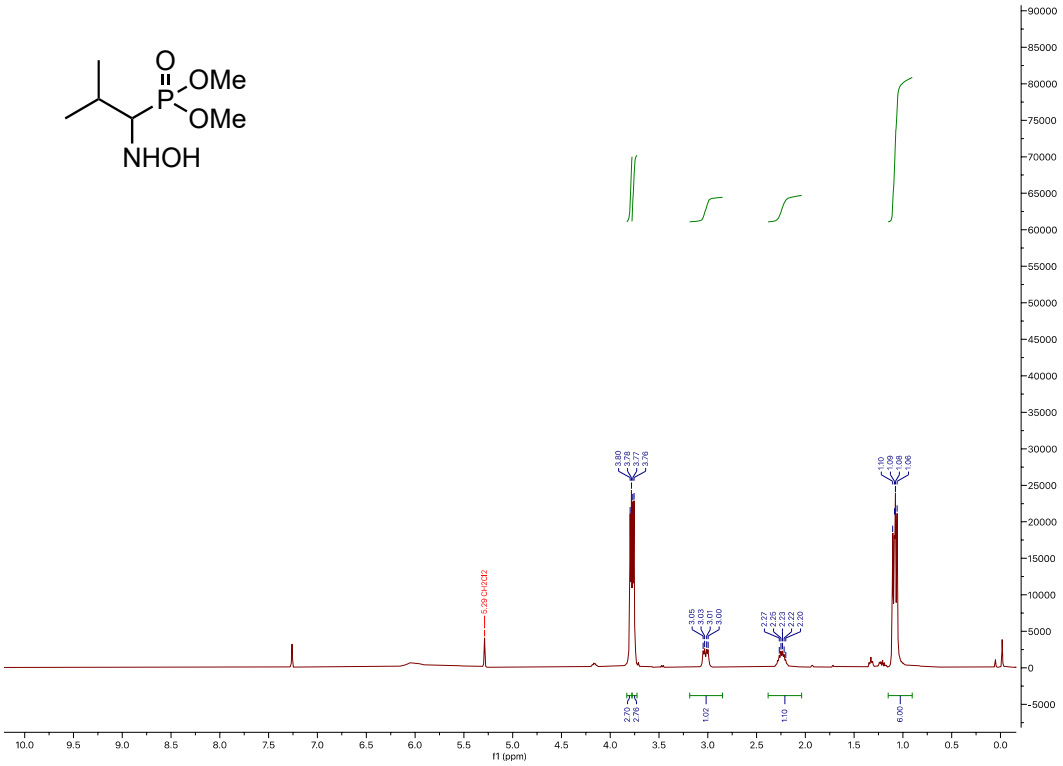


Figure S82. ^{1}H NMR spectrum (400 MHz) of dimethyl (1-(hydroxyamino)-2-methylpropyl)phosphonate (**4c**) in $CDCl_3$.

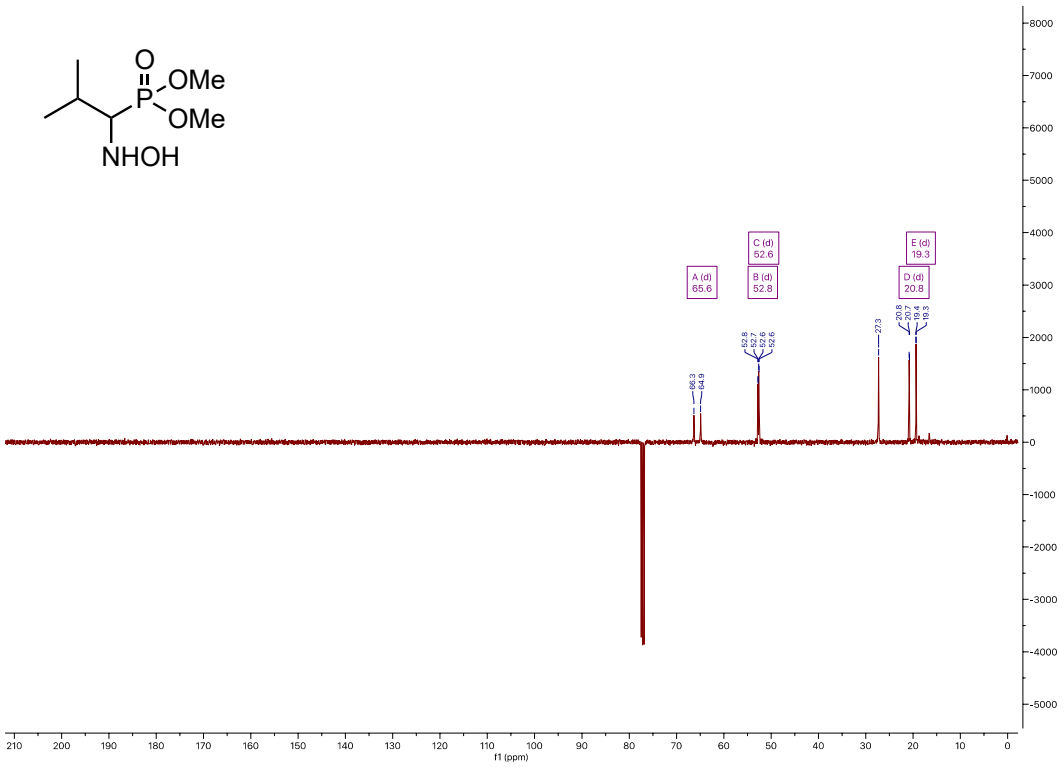


Figure S83. ^{13}C APT NMR spectrum (100.6 MHz) of dimethyl (1-(hydroxyamino)-2-methylpropyl)phosphonate (**4c**) in $CDCl_3$.

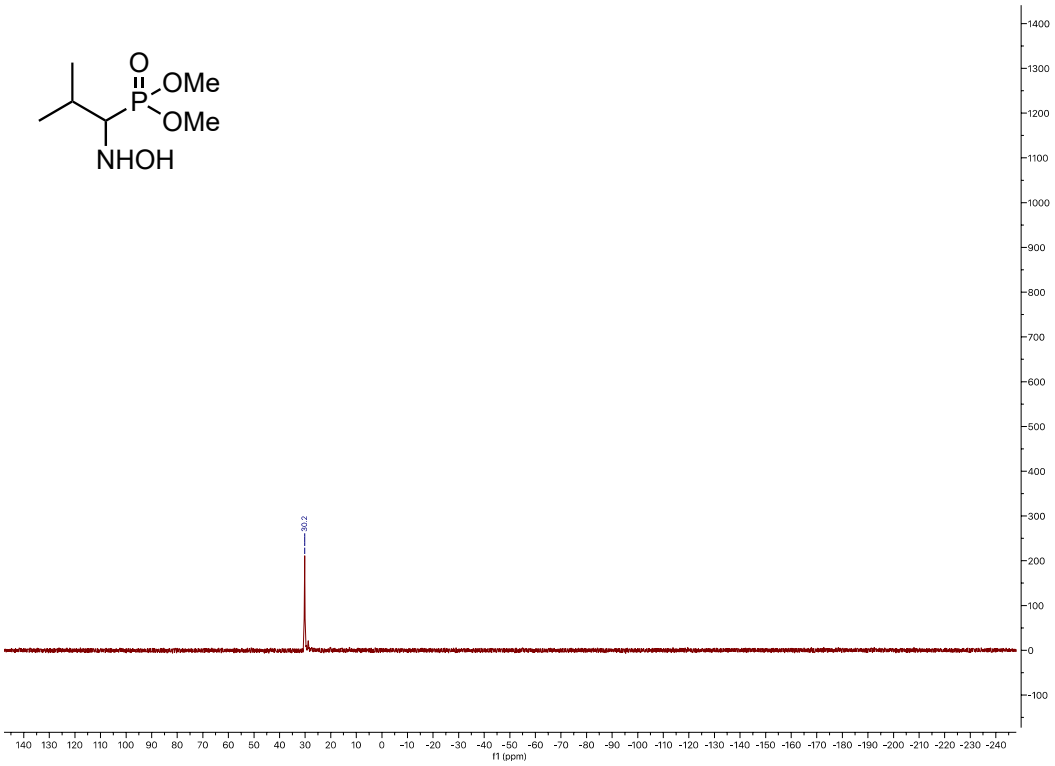


Figure S84. ^{31}P NMR spectrum (161.9 MHz) of dimethyl (1-(hydroxyamino)-2-methylpropyl)phosphonate (**4c**) in $CDCl_3$.

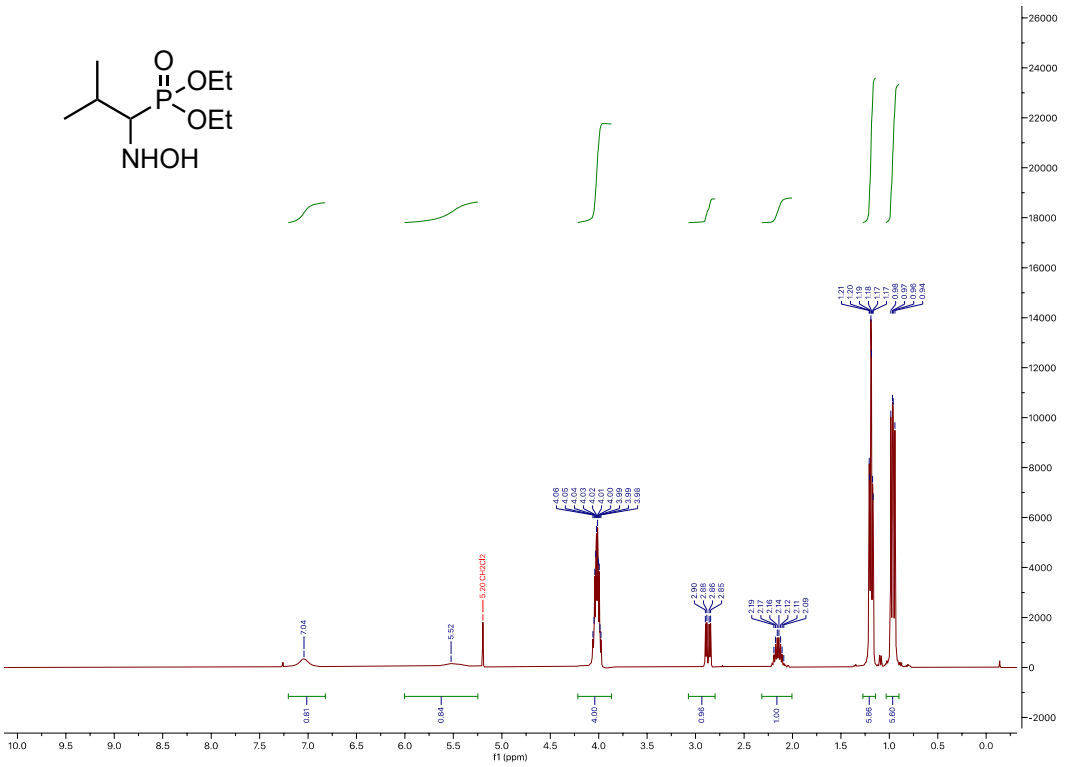


Figure S85. ^{1}H NMR spectrum (400 MHz) of diethyl (1-(hydroxyamino)-2-methylpropyl)phosphonate (**5c**) in $CDCl_3$.

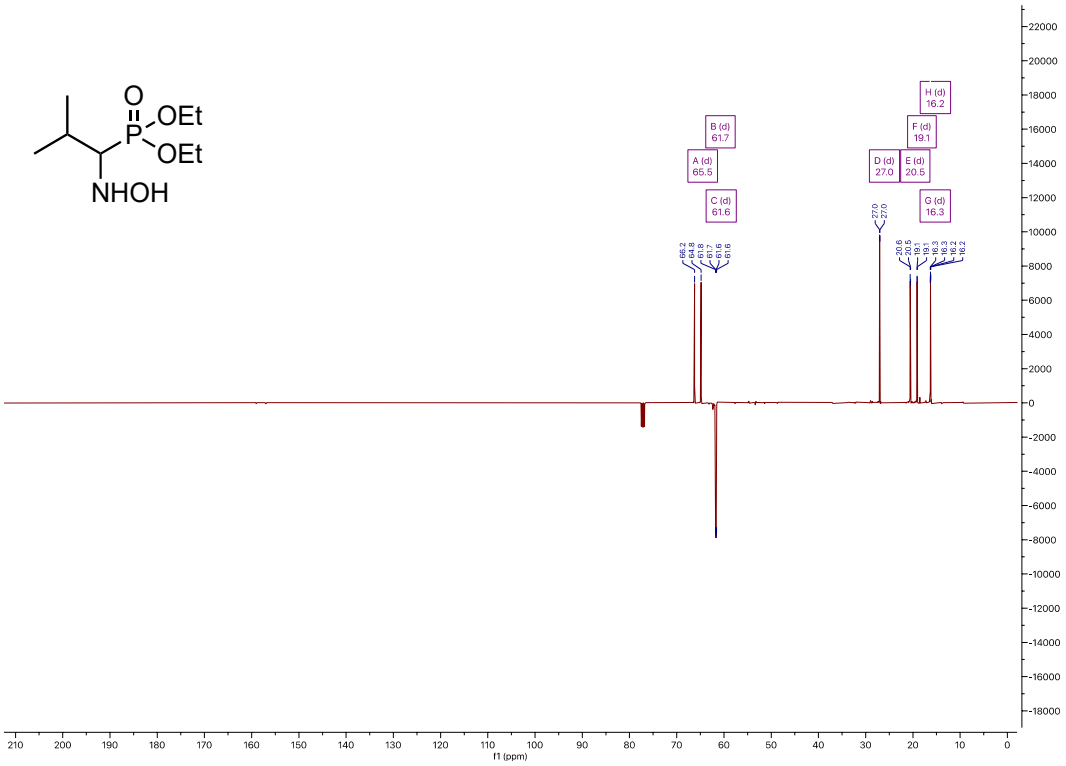


Figure S86. ^{13}C APT NMR spectrum (100.6 MHz) of diethyl (1-(hydroxyamino)-2-methylpropyl)phosphonate (**5c**) in $CDCl_3$.

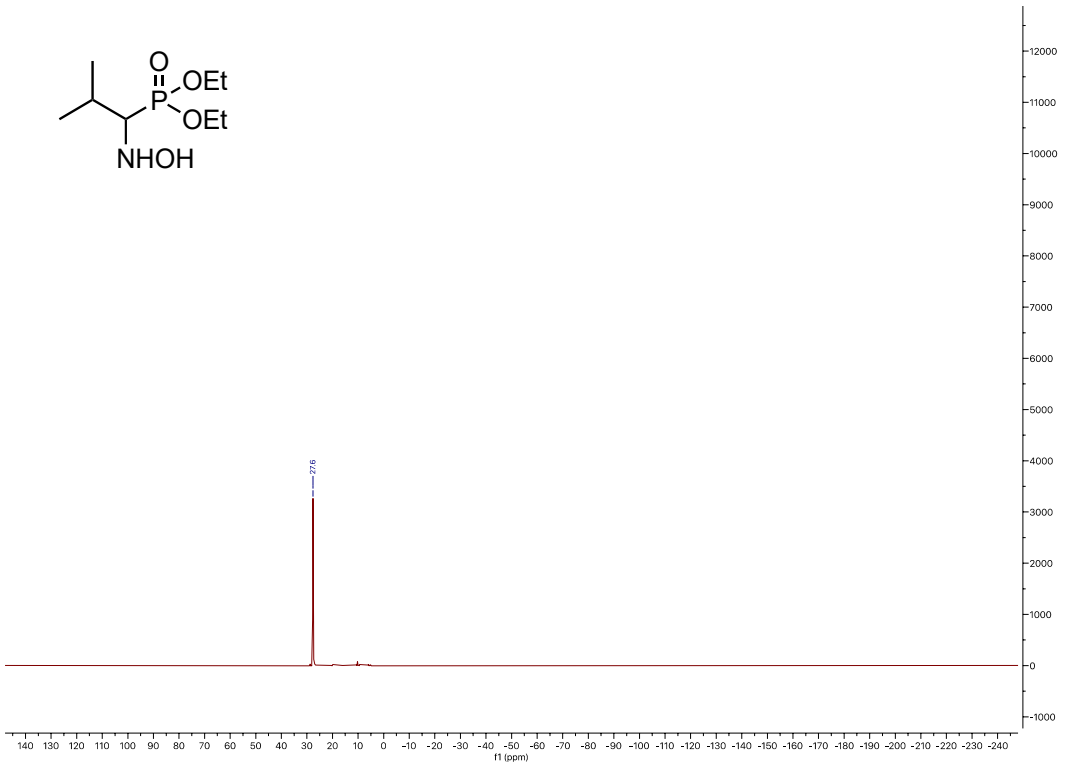


Figure S87. ^{31}P NMR spectrum (161.9 MHz) of diethyl (1-(hydroxyamino)-2-methylpropyl)phosphonate (**5c**) in $CDCl_3$.

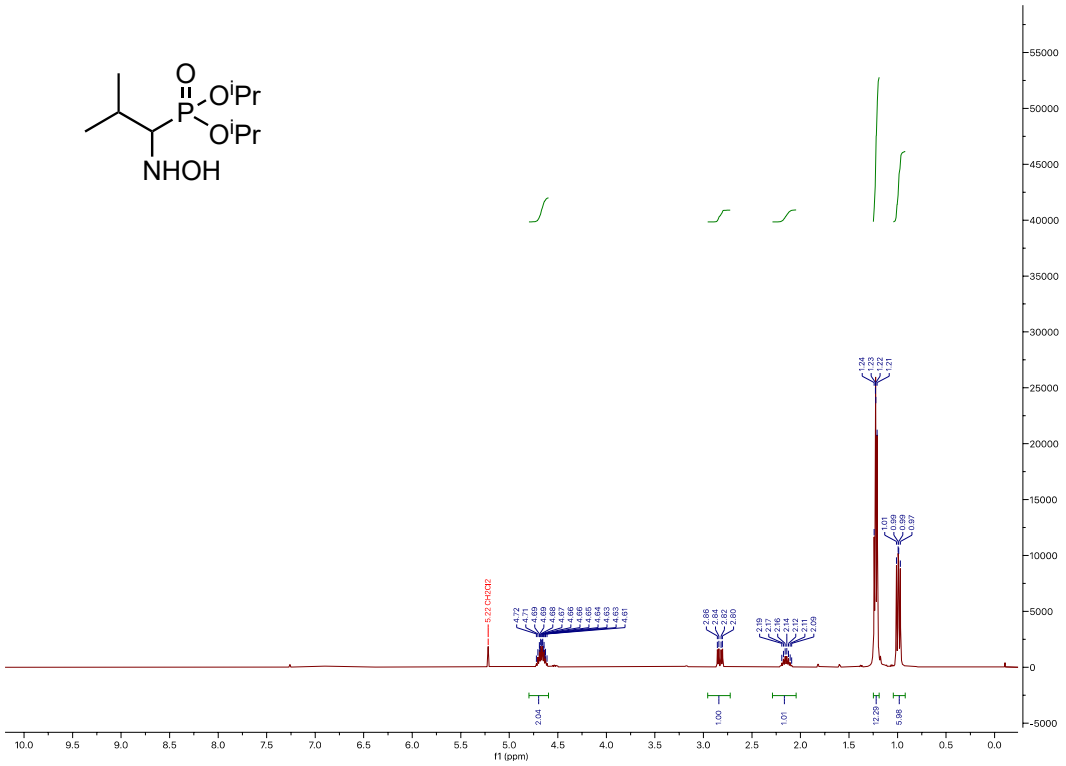


Figure S88. ^{1}H NMR spectrum (400 MHz) of diisopropyl (1-(hydroxyamino)-2-methylpropyl)phosphonate (**6c**) in $CDCl_3$.

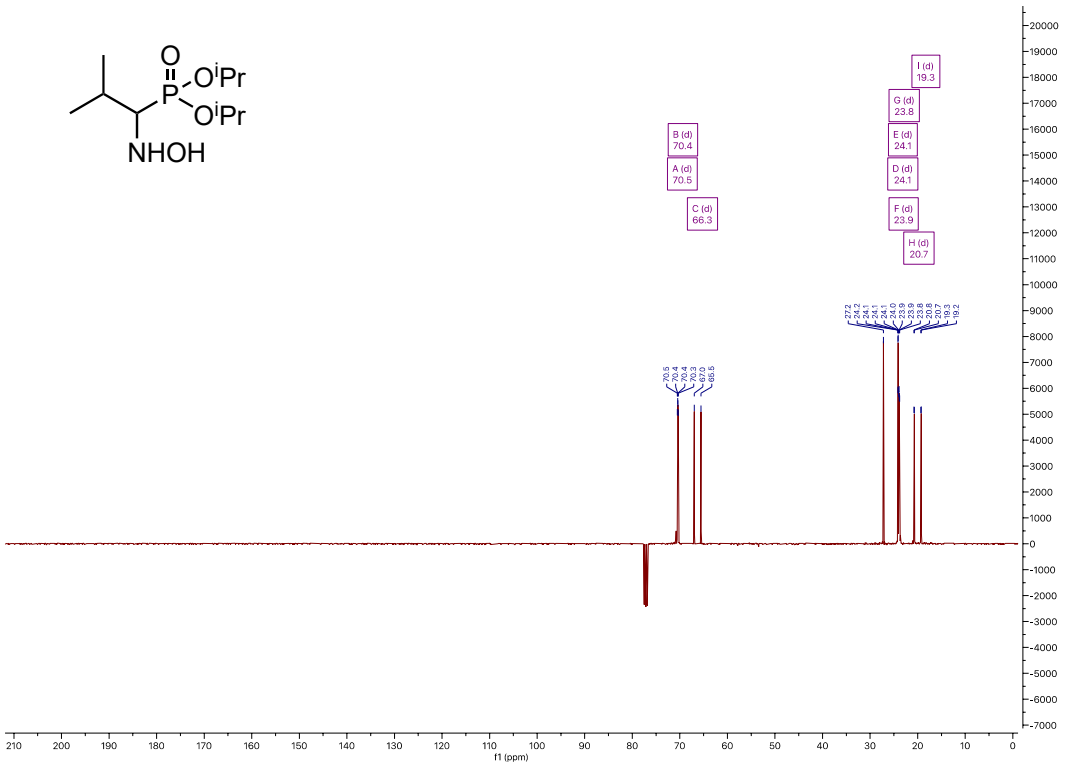


Figure S89. ^{13}C APT NMR spectrum (100.6 MHz) of diisopropyl (1-(hydroxyamino)-2-methylpropyl)phosphonate (**6c**) in $CDCl_3$.

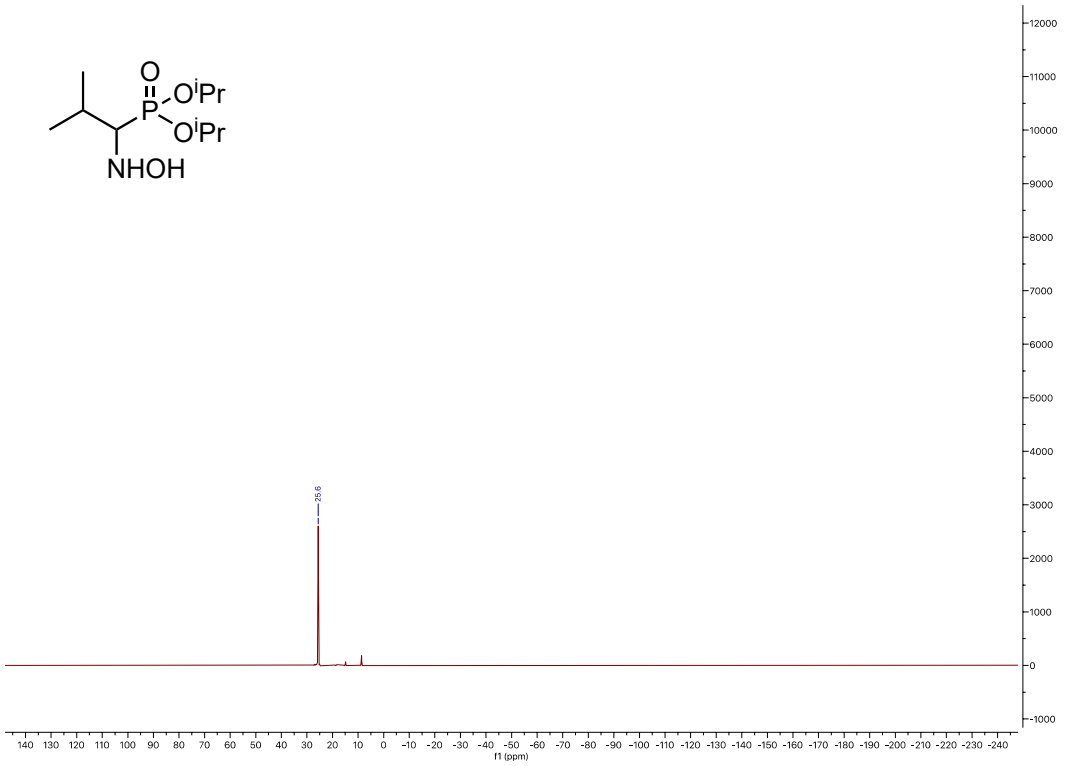


Figure S90. ^{31}P NMR spectrum (161.9 MHz) of diisopropyl (1-(hydroxyamino)-2-methylpropyl)phosphonate (**6c**) in $CDCl_3$.

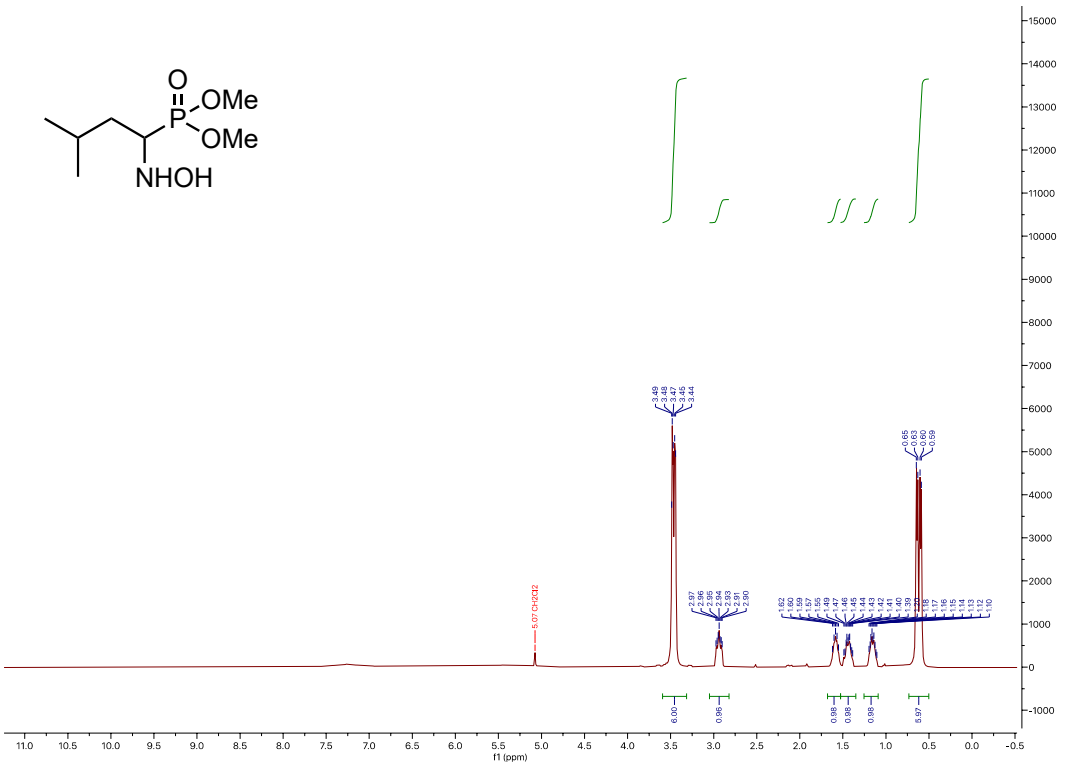


Figure S91. ^{1}H NMR spectrum (400 MHz) of dimethyl (1-(hydroxyamino)-3-methylbutyl)phosphonate (**7c**) in $CDCl_3$.

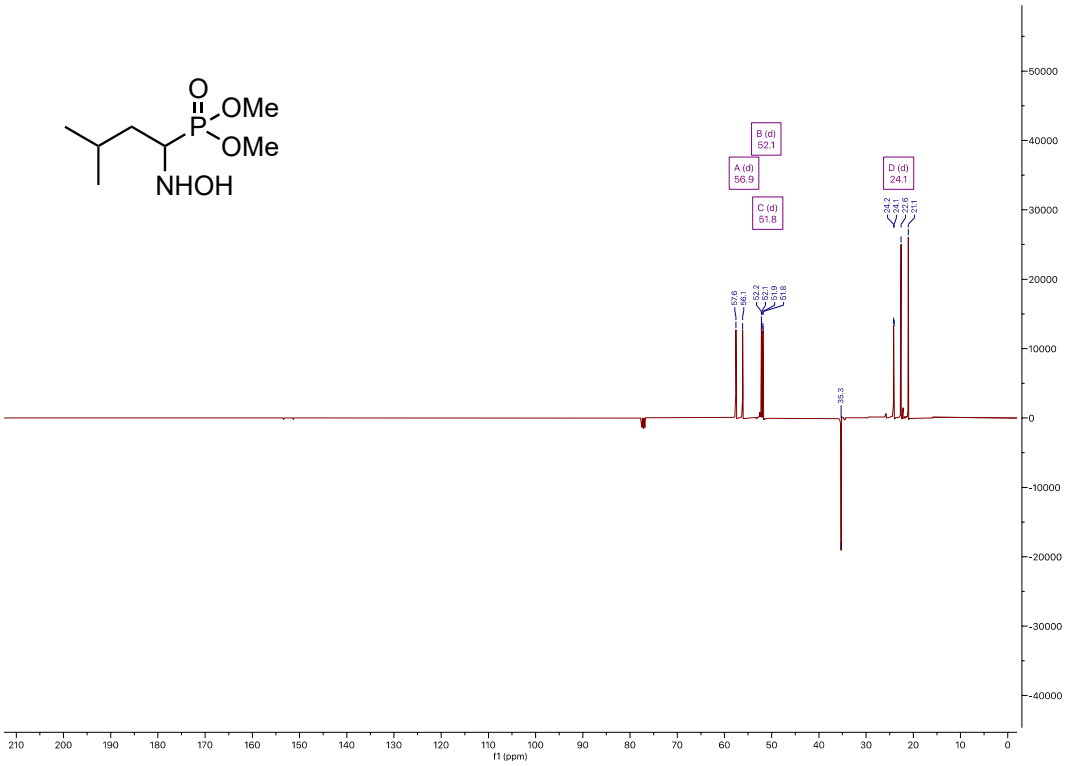


Figure S92. ^{13}C APT NMR spectrum (100.6 MHz) of dimethyl (1-(hydroxyamino)-3-methylbutyl)phosphonate (**7c**) in $CDCl_3$.

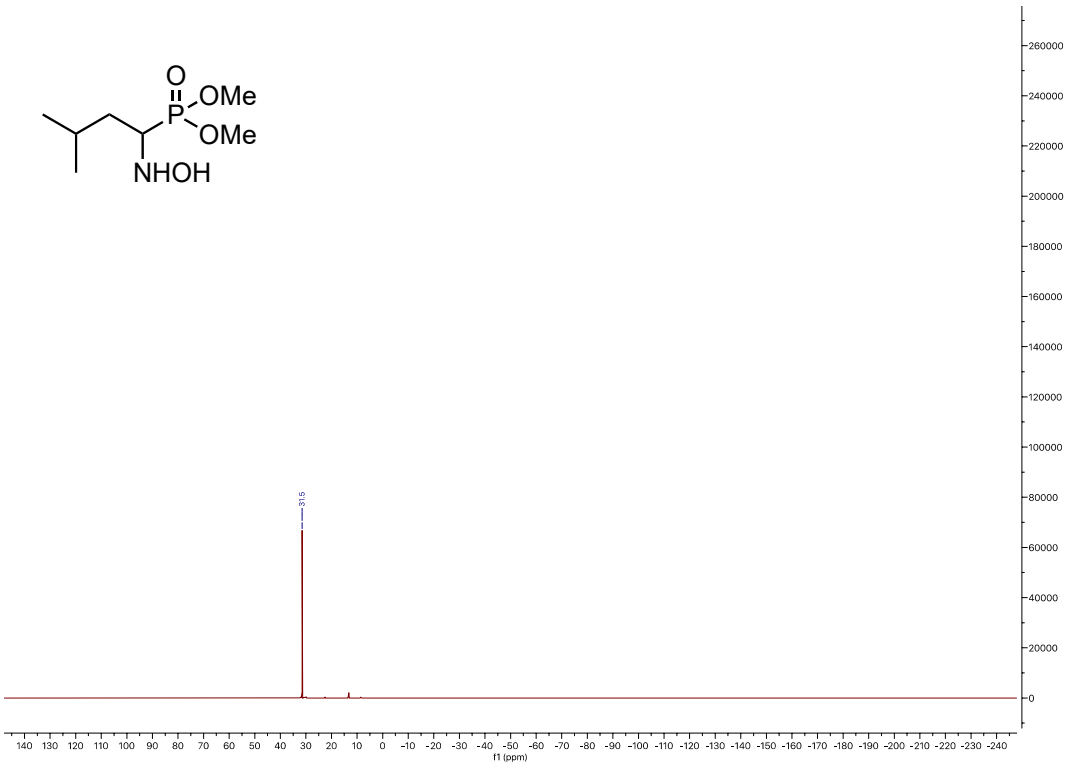


Figure S93. ^{31}P NMR spectrum (161.9 MHz) of dimethyl (1-(hydroxyamino)-3-methylbutyl)phosphonate (**7c**) in $CDCl_3$.

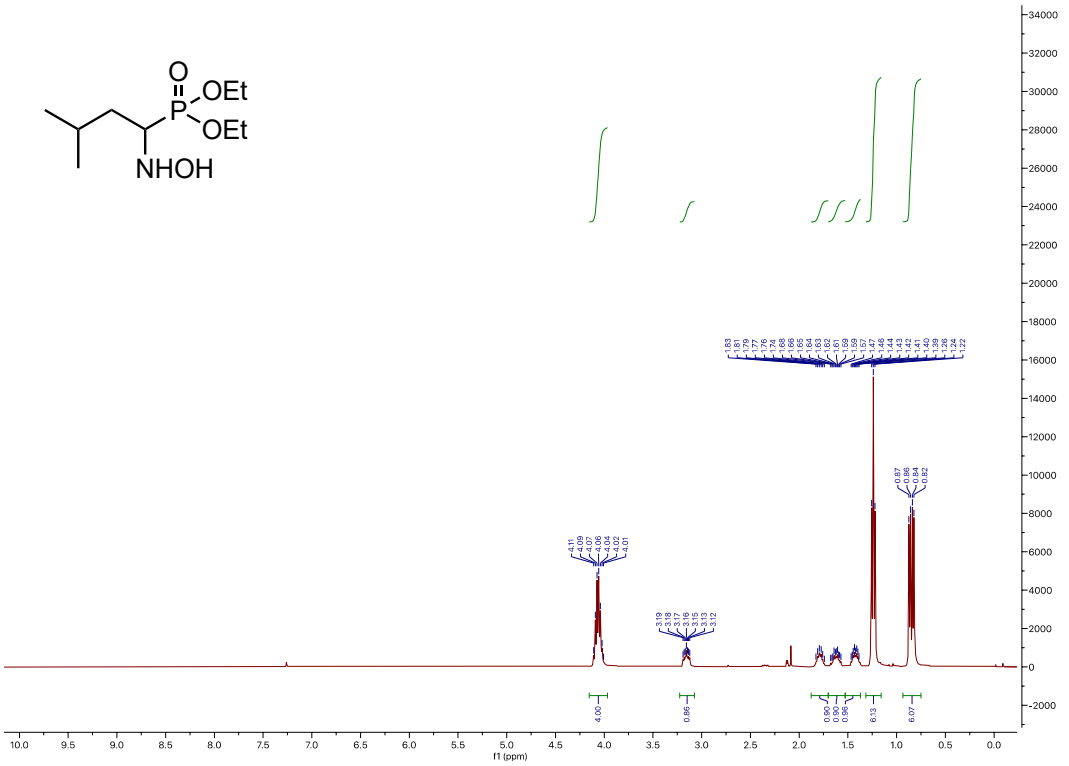


Figure S94. ^{1}H NMR spectrum (400 MHz) of diethyl (1-(hydroxyamino)-3-methylbutyl)phosphonate (**8c**) in $CDCl_3$.

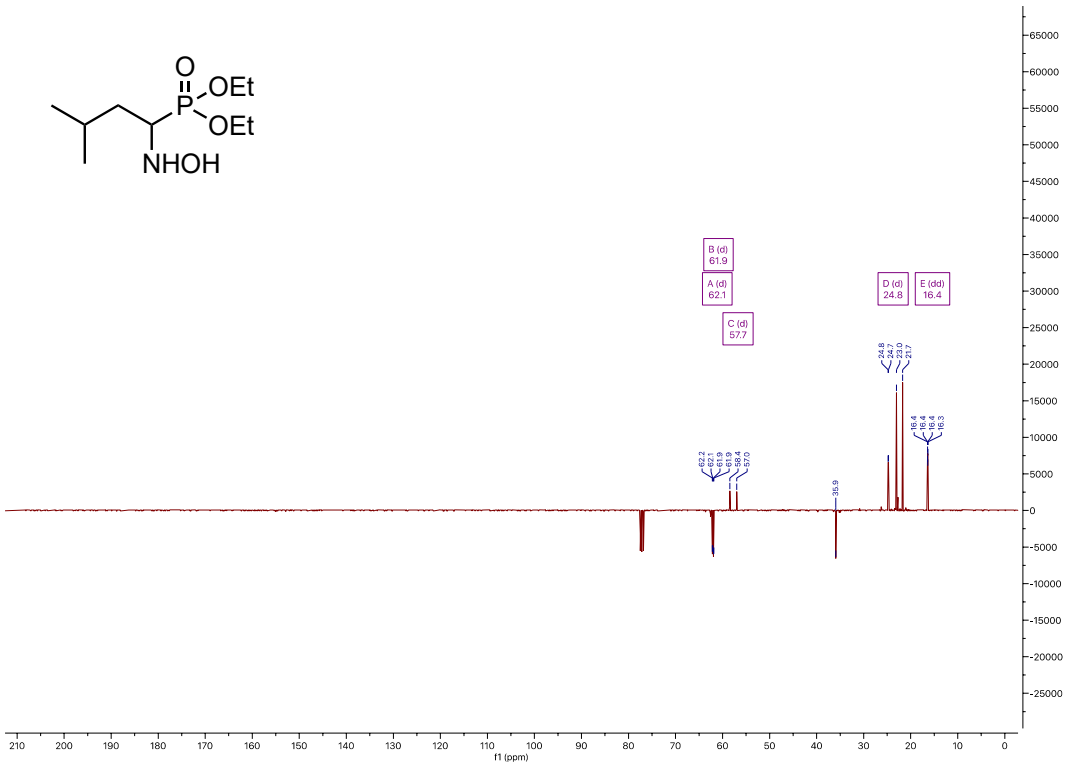


Figure S95. ^{13}C APT NMR spectrum (100.6 MHz) of diethyl (1-(hydroxyamino)-3-methylbutyl)phosphonate (**8c**) in $CDCl_3$.

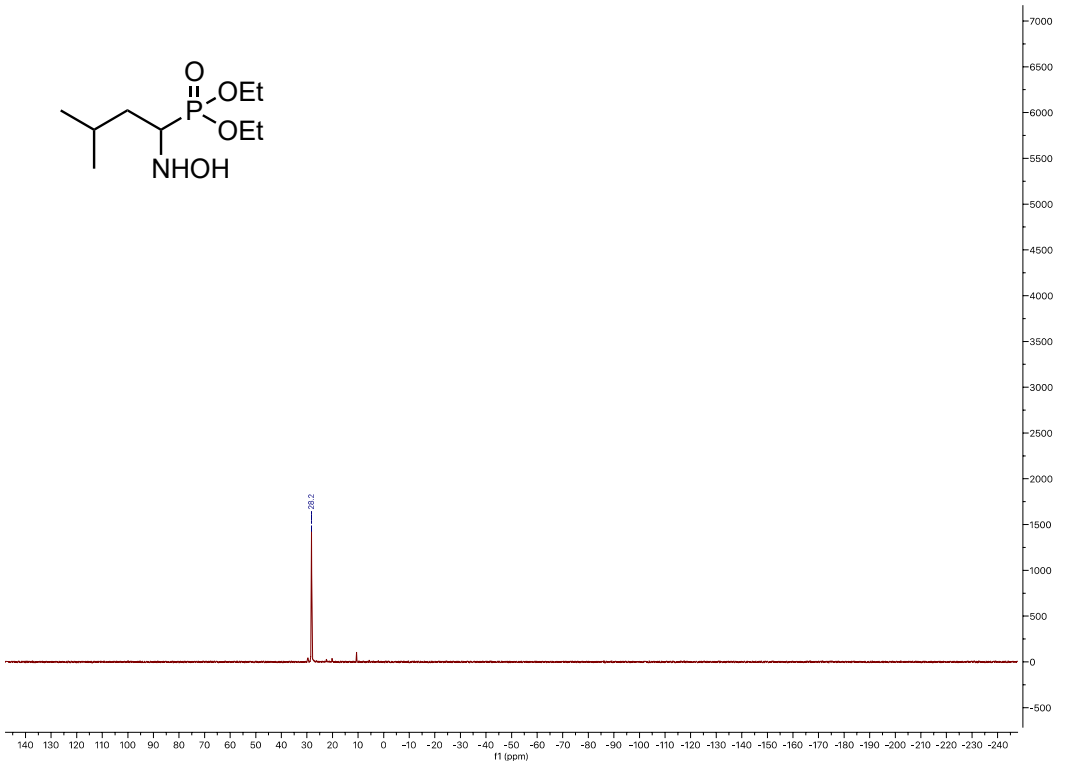


Figure S96. ^{31}P NMR spectrum (161.9 MHz) of diethyl (1-(hydroxyamino)-3-methylbutyl)phosphonate (**8c**) in $CDCl_3$.

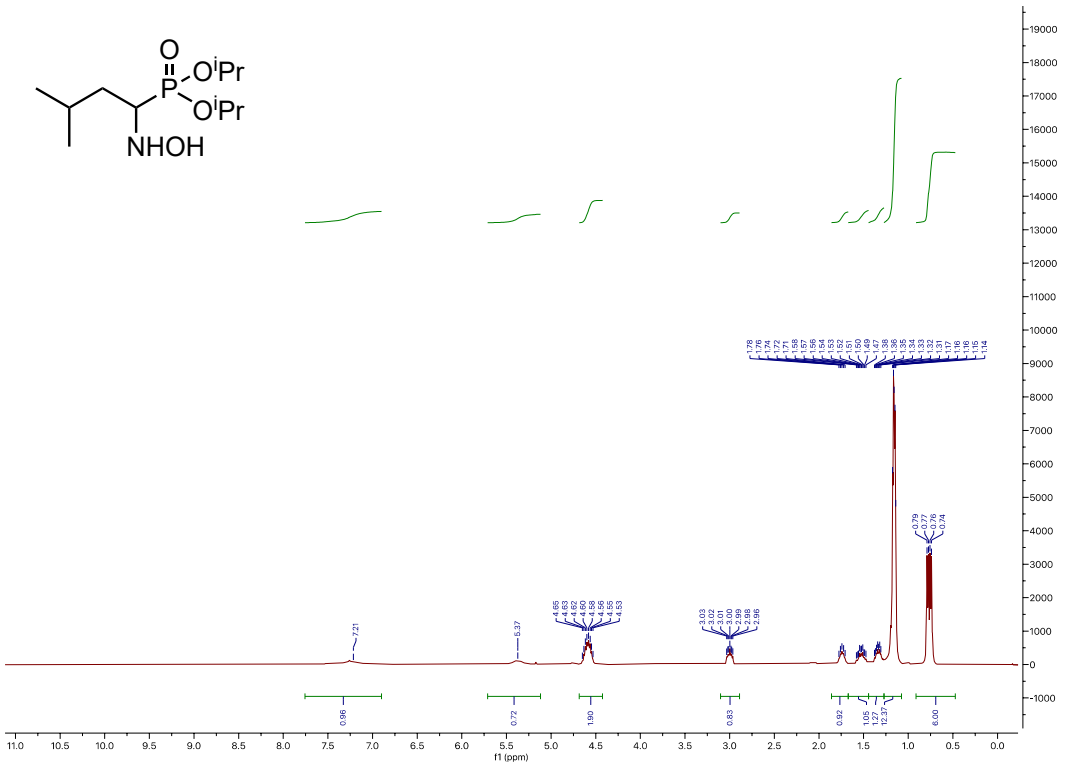


Figure S97. ^{1}H NMR spectrum (400 MHz) of diisopropyl (1-(hydroxyamino)-3-methylbutyl)phosphonate (**9c**) in $CDCl_3$.

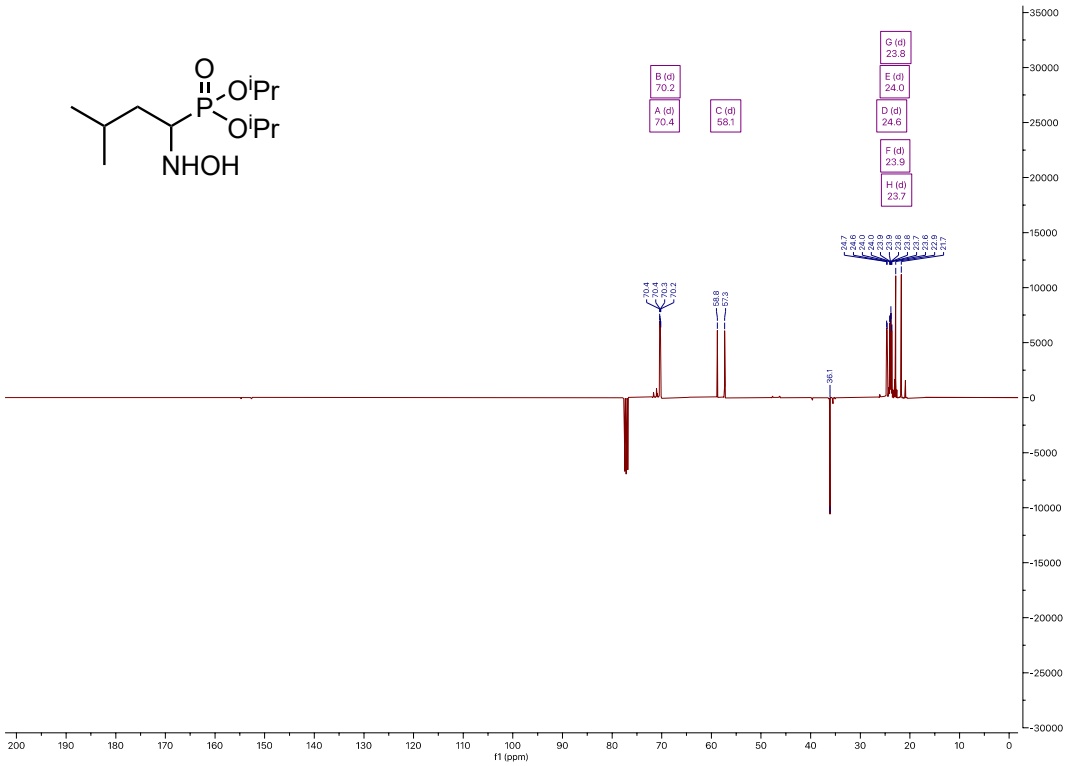


Figure S98. ^{13}C APT NMR spectrum (100.6 MHz) of diisopropyl (1-(hydroxyamino)-3-methylbutyl)phosphonate (**9c**) in $CDCl_3$.

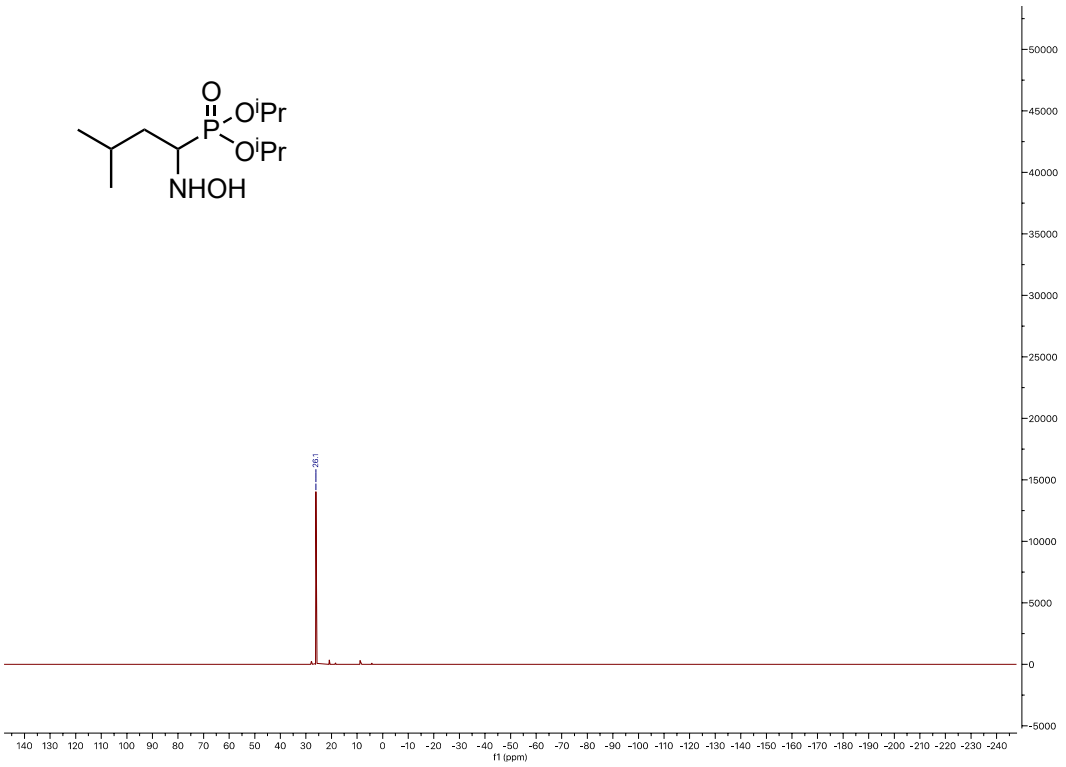


Figure S99. ^{31}P NMR spectrum (161.9 MHz) of diisopropyl (1-(hydroxyamino)-3-methylbutyl)phosphonate (**9c**) in $CDCl_3$.

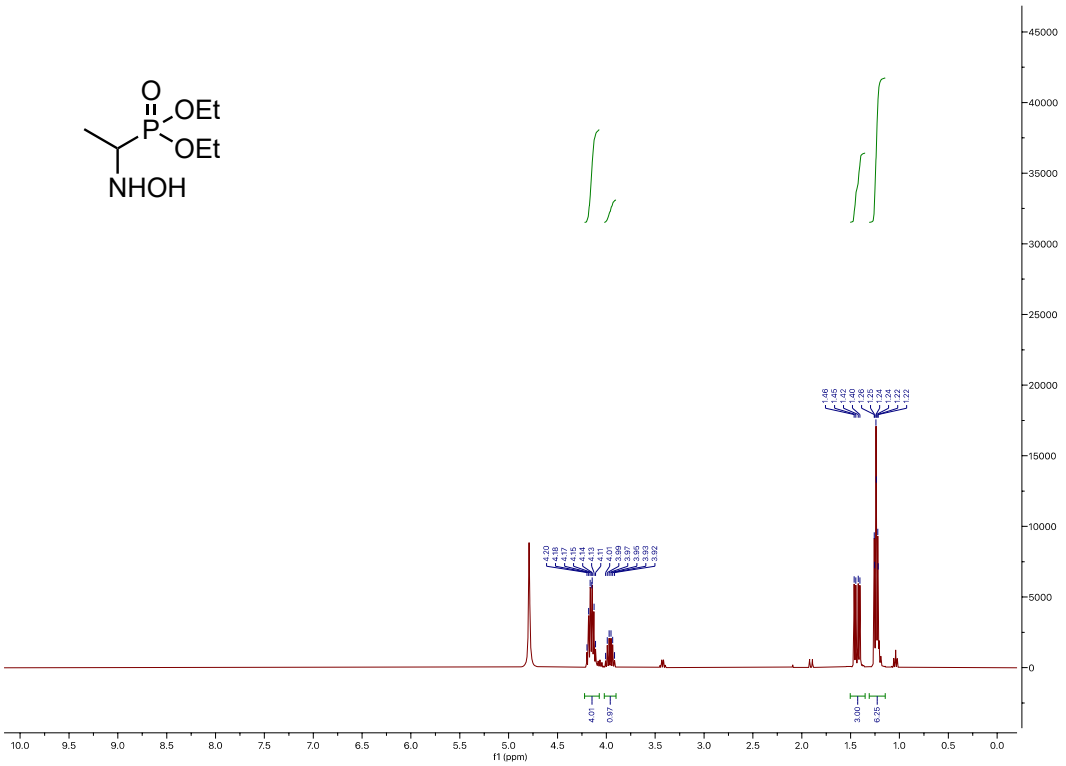


Figure S100. ^{1}H NMR spectrum (400 MHz) of diethyl (1-(hydroxyamino)ethyl)phosphonate (**10c**) in D_2O.

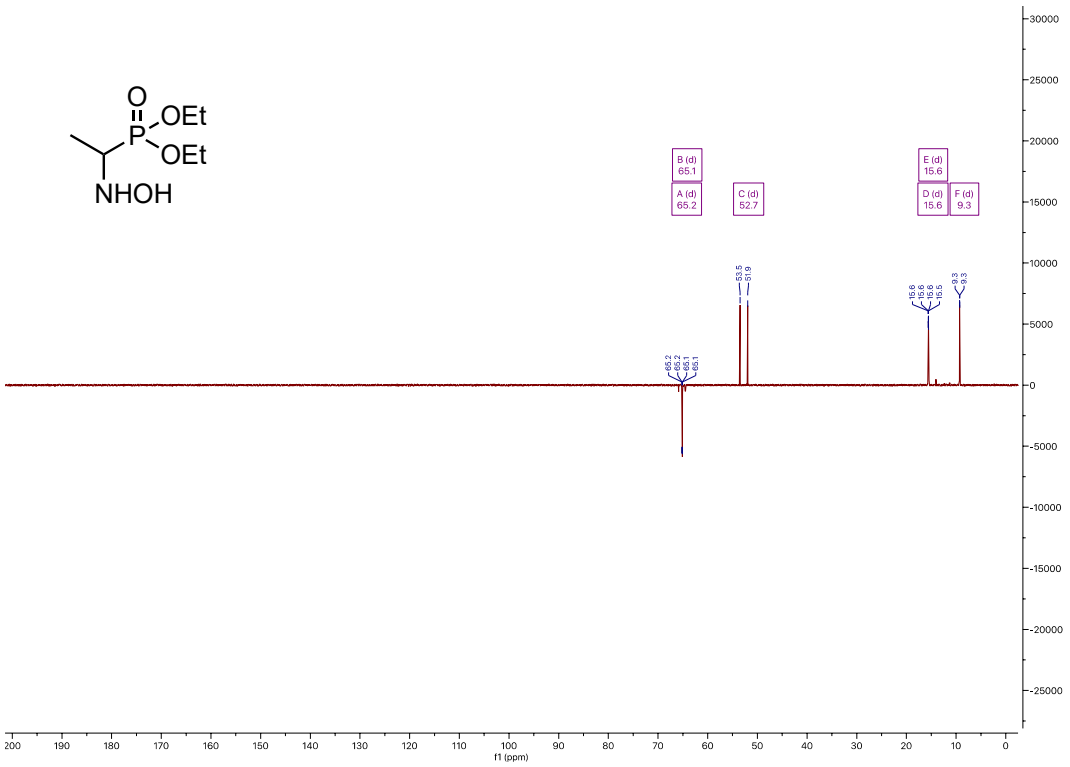


Figure S101. ^{13}C APT NMR spectrum (100.6 MHz) of diethyl (1-(hydroxyamino)ethyl)phosphonate (**10c**) in D_2O.

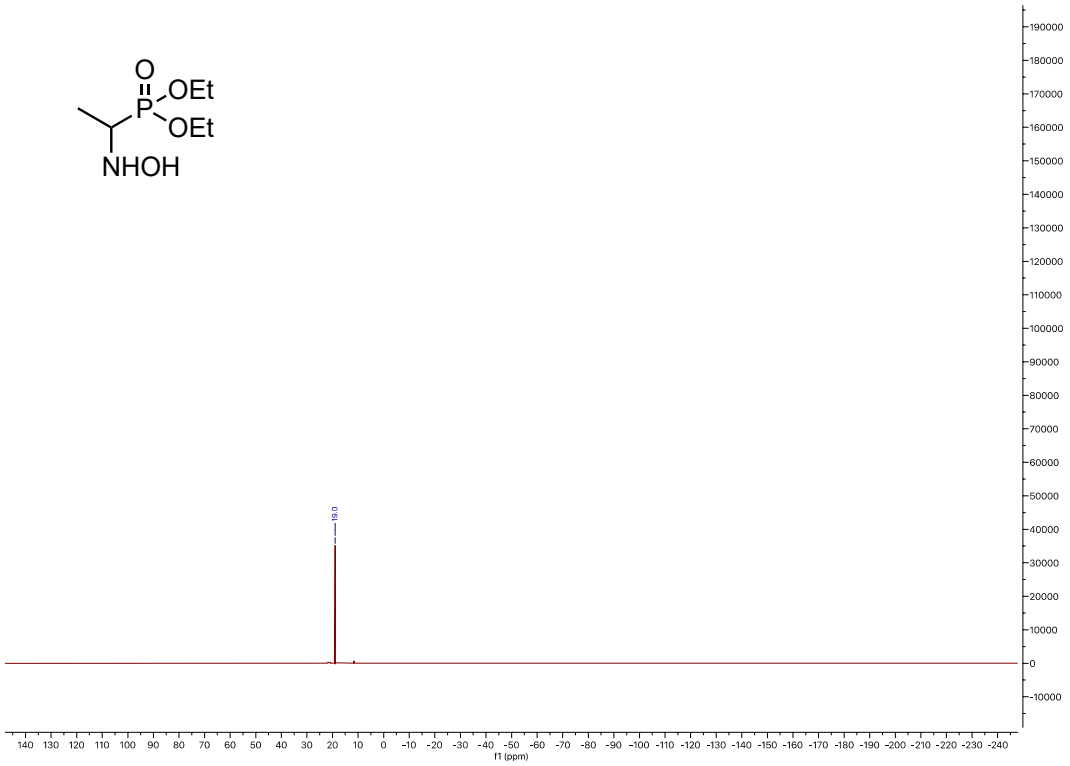


Figure S102. ^{31}P NMR spectrum (161.9 MHz) of diethyl (1-(hydroxyamino)ethyl)phosphonate (**10c**) in D_2O.

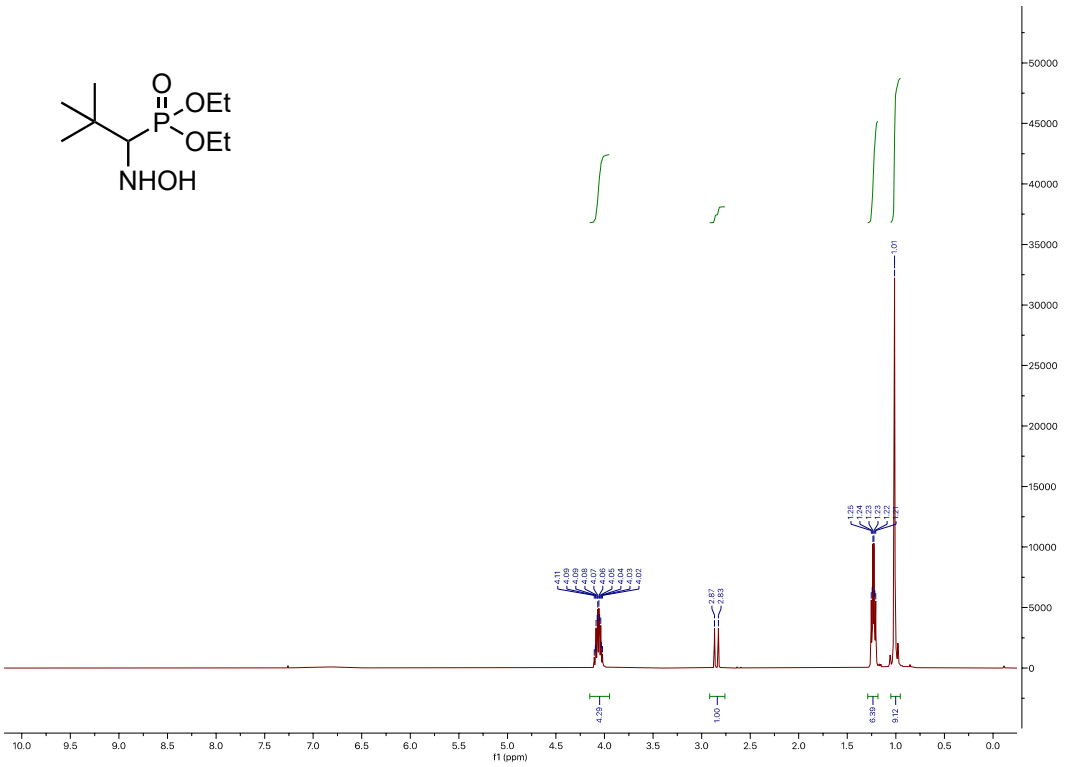


Figure S103. ^{1}H NMR spectrum (400 MHz) of diethyl (1-(hydroxyamino)-2,2-dimethylpropyl)phosphonate (**11c**) in $CDCl_3$.

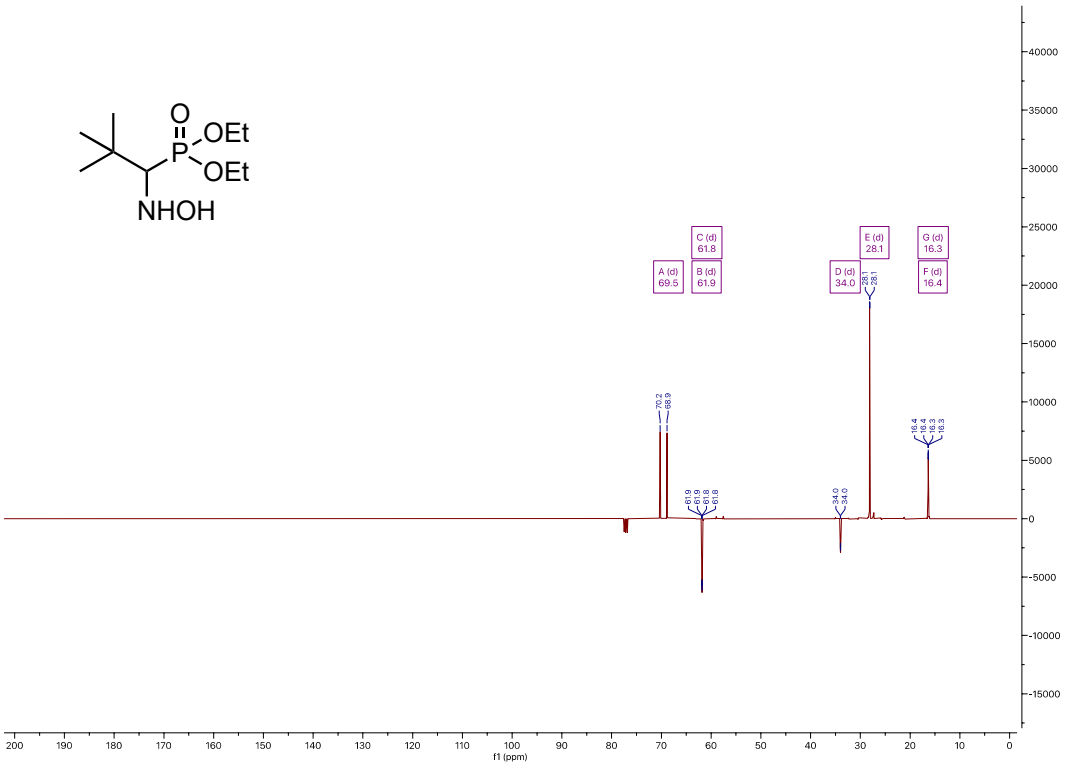


Figure S104. ^{13}C APT NMR spectrum (100.6 MHz) of diethyl (1-(hydroxyamino)-2,2-dimethylpropyl)phosphonate (**11c**) in $CDCl_3$.

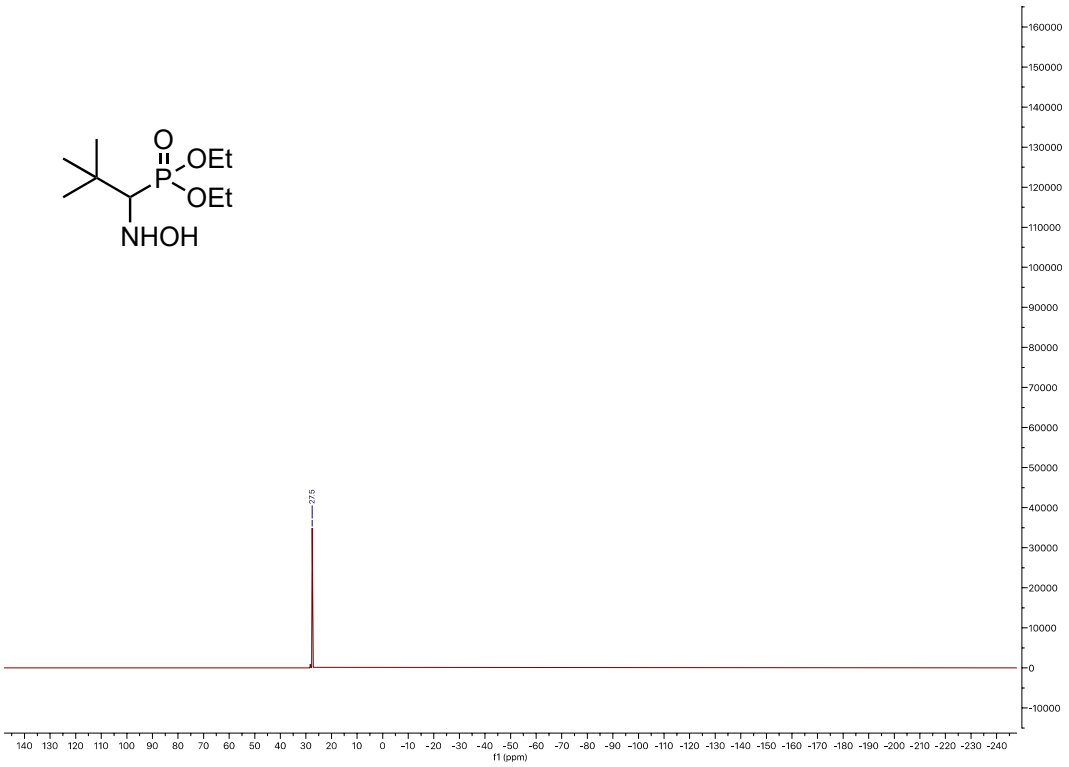


Figure S105. ^{31}P NMR spectrum (161.9 MHz) of diethyl (1-(hydroxyamino)-2,2-dimethylpropyl)phosphonate (**11c**) in $CDCl_3$.

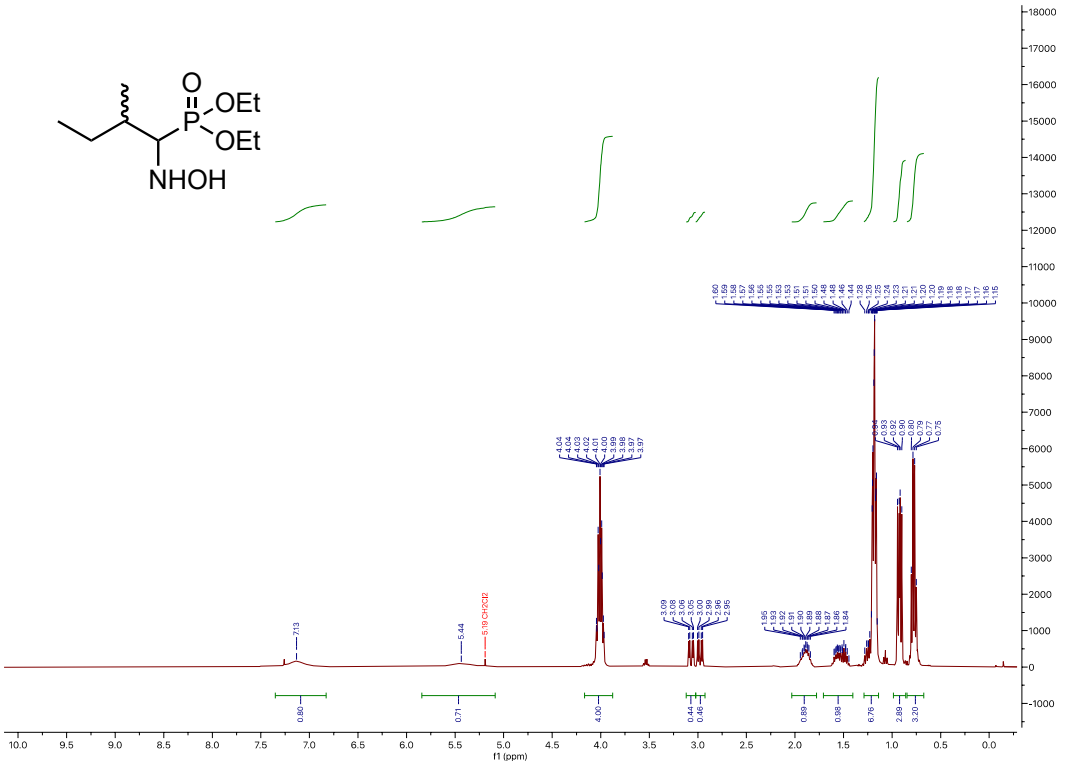


Figure S106. ^{1}H NMR spectrum (400 MHz) of diethyl (1-(hydroxyamino)-2-methylbutyl)phosphonate (**12c**) in $CDCl_3$.

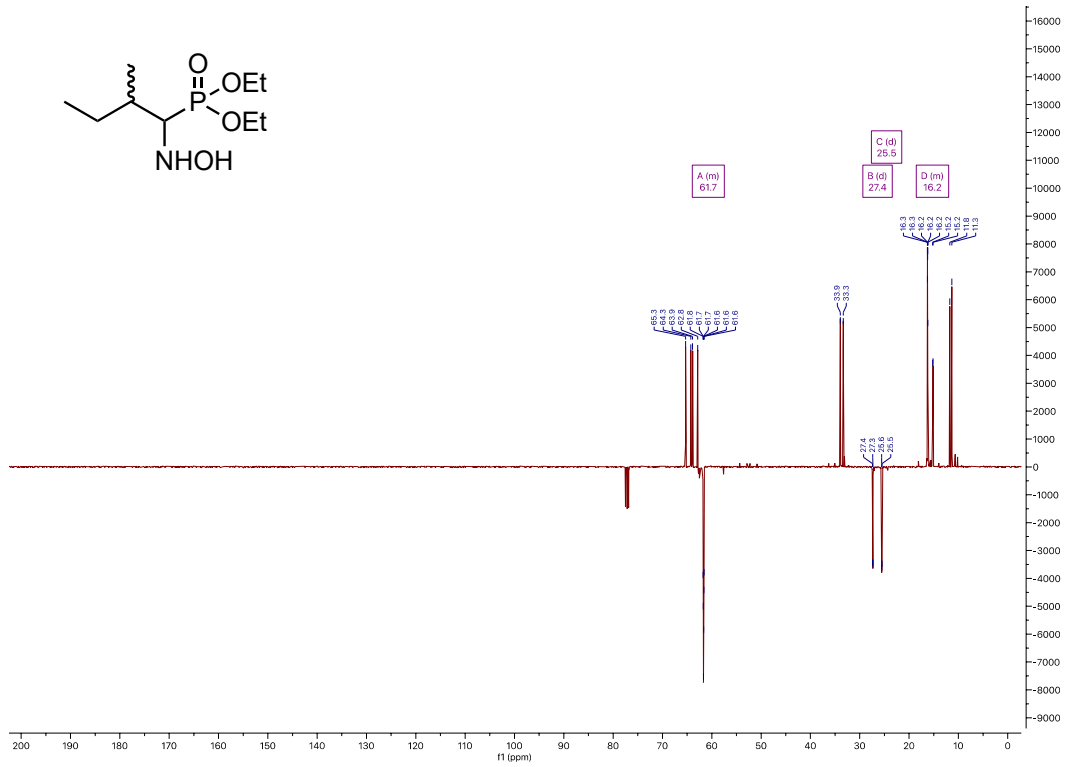


Figure S107. ^{13}C APT NMR spectrum (100.6 MHz) of diethyl (1-(hydroxyamino)-2-methylbutyl)phosphonate (**12c**) in $CDCl_3$.

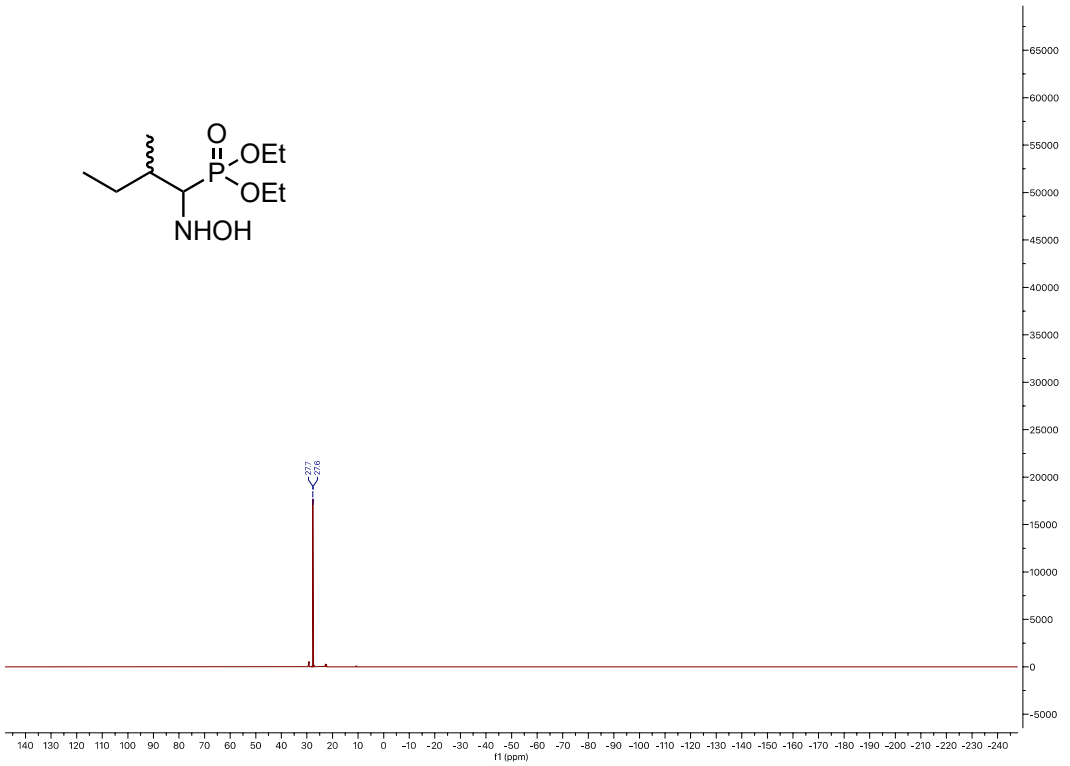


Figure S108. ^{31}P NMR spectrum (161.9 MHz) of diethyl (1-(hydroxyamino)-2-methylbutyl)phosphonate (**12c**) in $CDCl_3$.

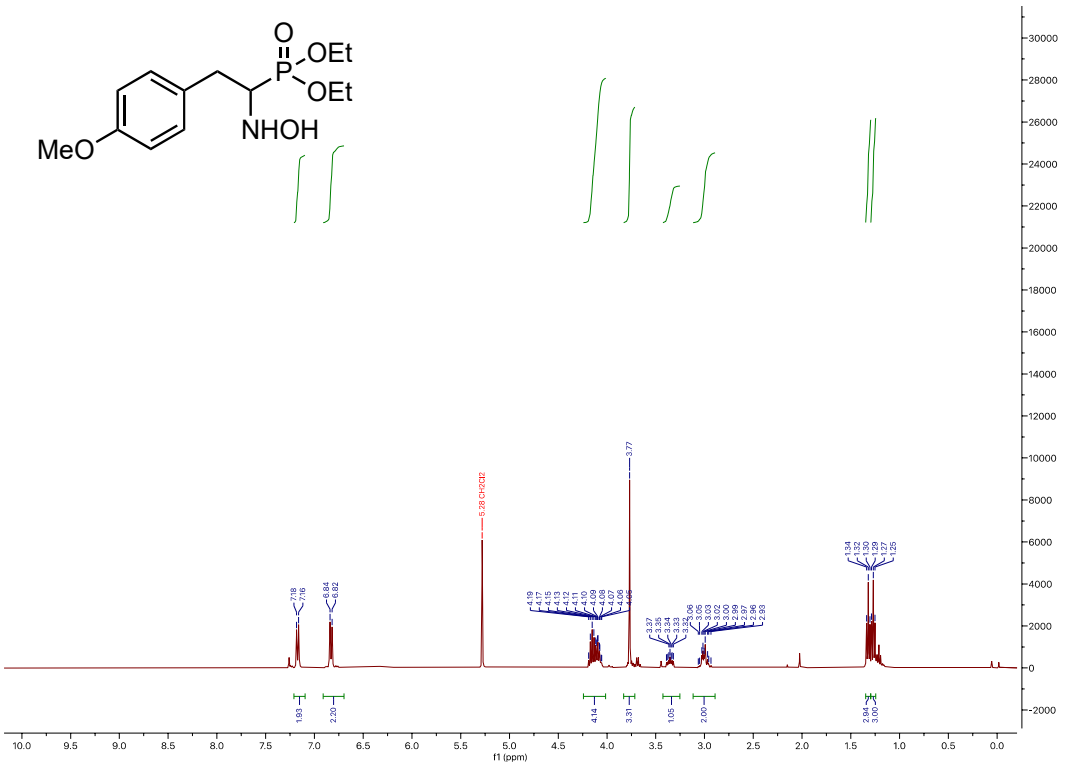


Figure S109. ^{1}H NMR spectrum (400 MHz) of diethyl (1-(hydroxyamino)-2-(4-methoxyphenyl)ethyl)phosphonate (**13c**) in $CDCl_3$.

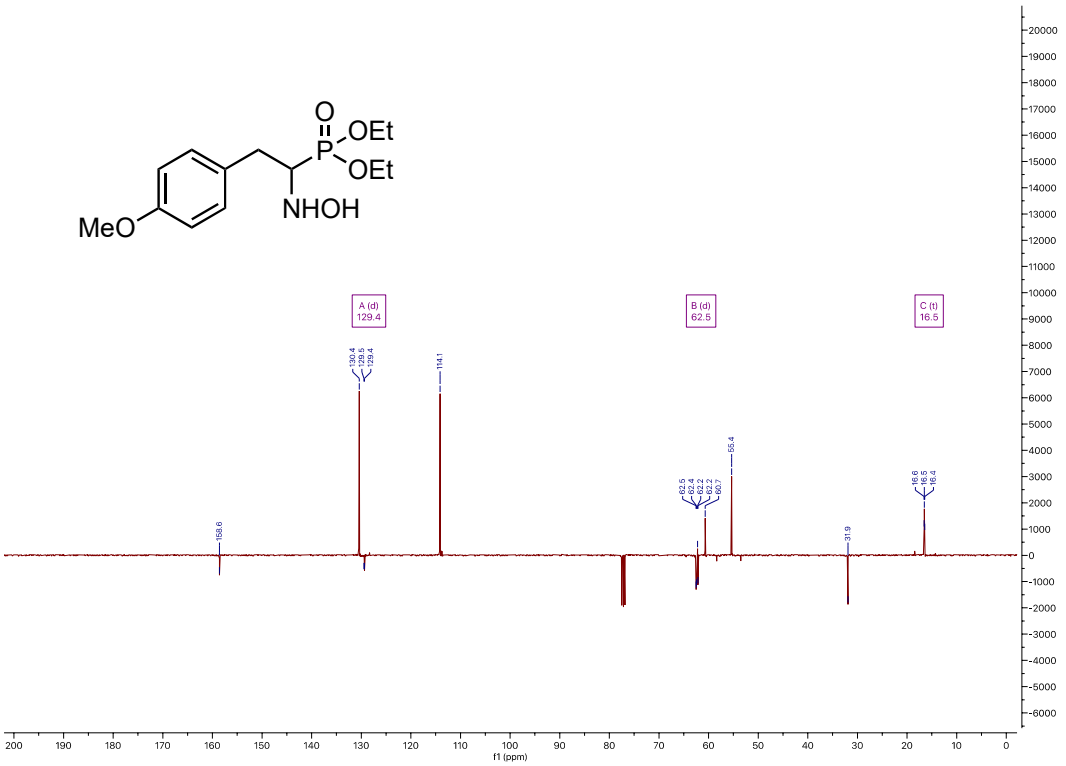


Figure S110. ^{13}C APT NMR spectrum (100.6 MHz) of diethyl (1-(hydroxyamino)-2-(4-methoxyphenyl)ethyl)phosphonate (**13c**) in $CDCl_3$.

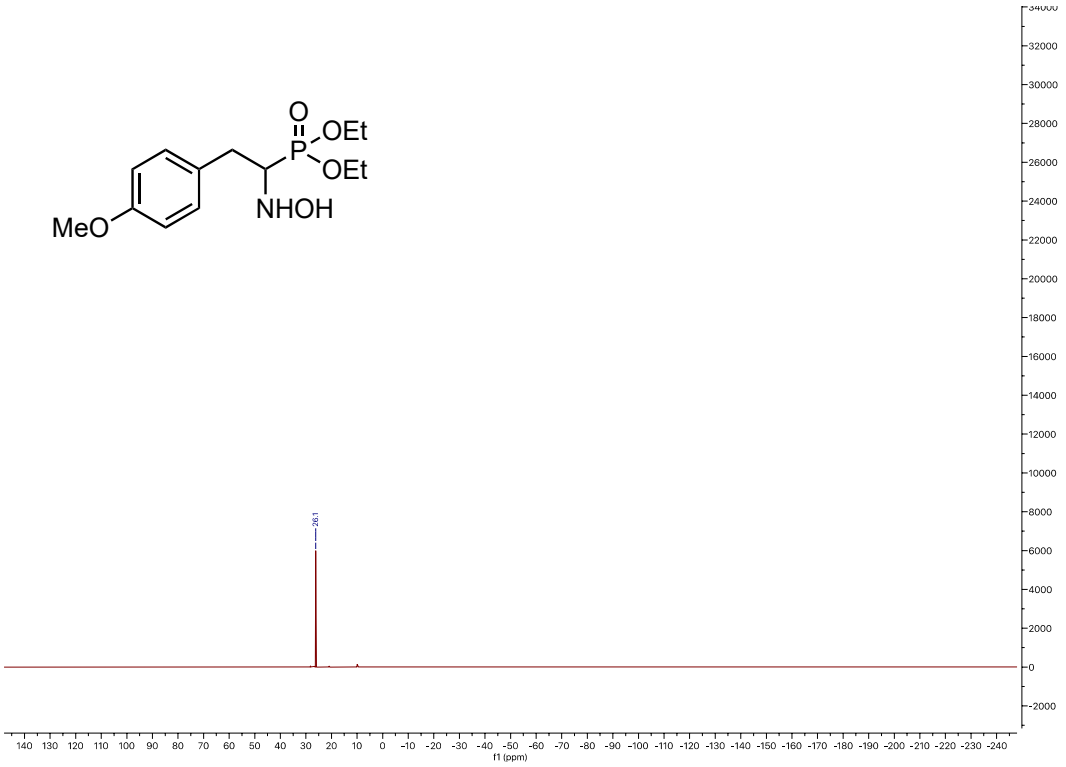


Figure S111. ^{31}P NMR spectrum (161.9 MHz) of diethyl (1-(hydroxyamino)-2-(4-methoxyphenyl)ethyl)phosphonate (**13c**) in $CDCl_3$.

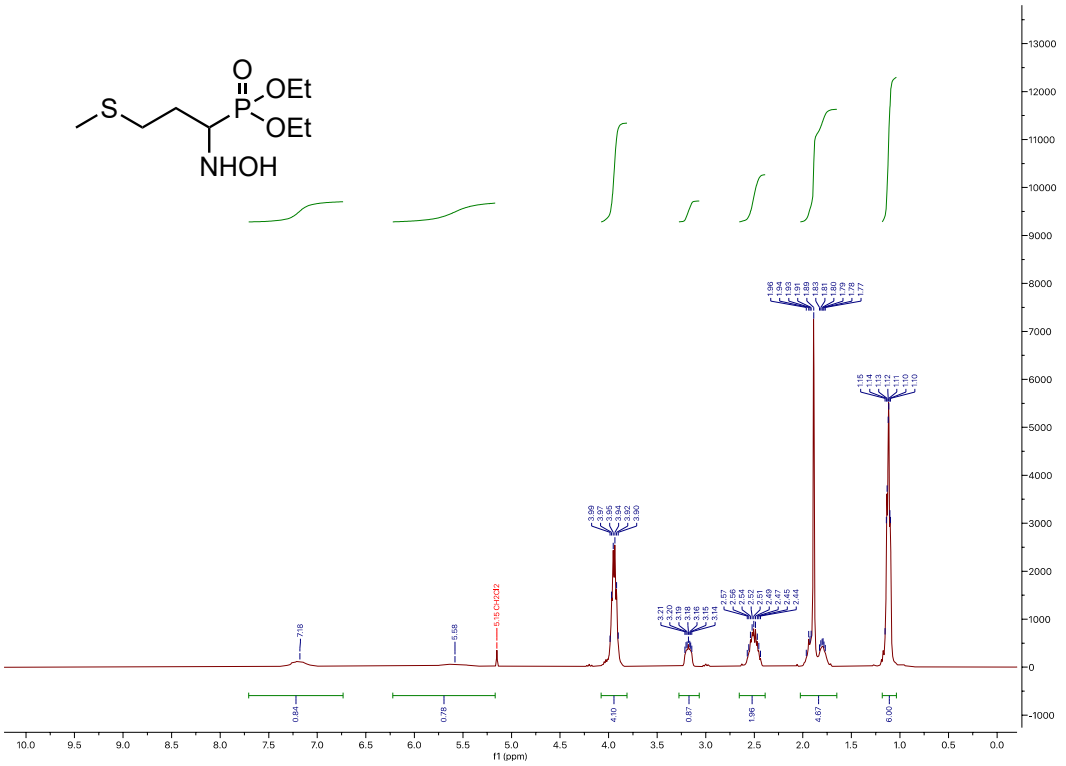


Figure S112. ^{1}H NMR spectrum (400 MHz) of diethyl (1-(hydroxyamino)-3-(methylthio)propyl)phosphonate (**14c**) in $CDCl_3$.

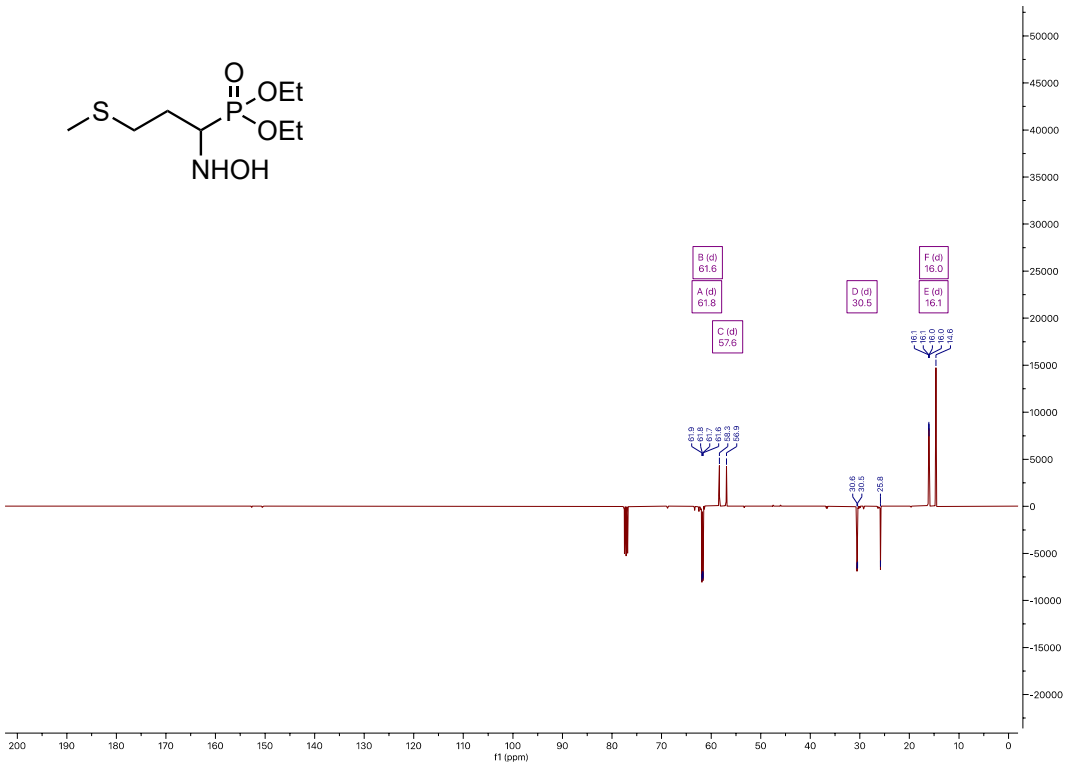


Figure S113. ^{13}C APT NMR spectrum (100.6 MHz) of diethyl (1-(hydroxyamino)-3-(methylthio)propyl)phosphonate (**14c**) in $CDCl_3$.

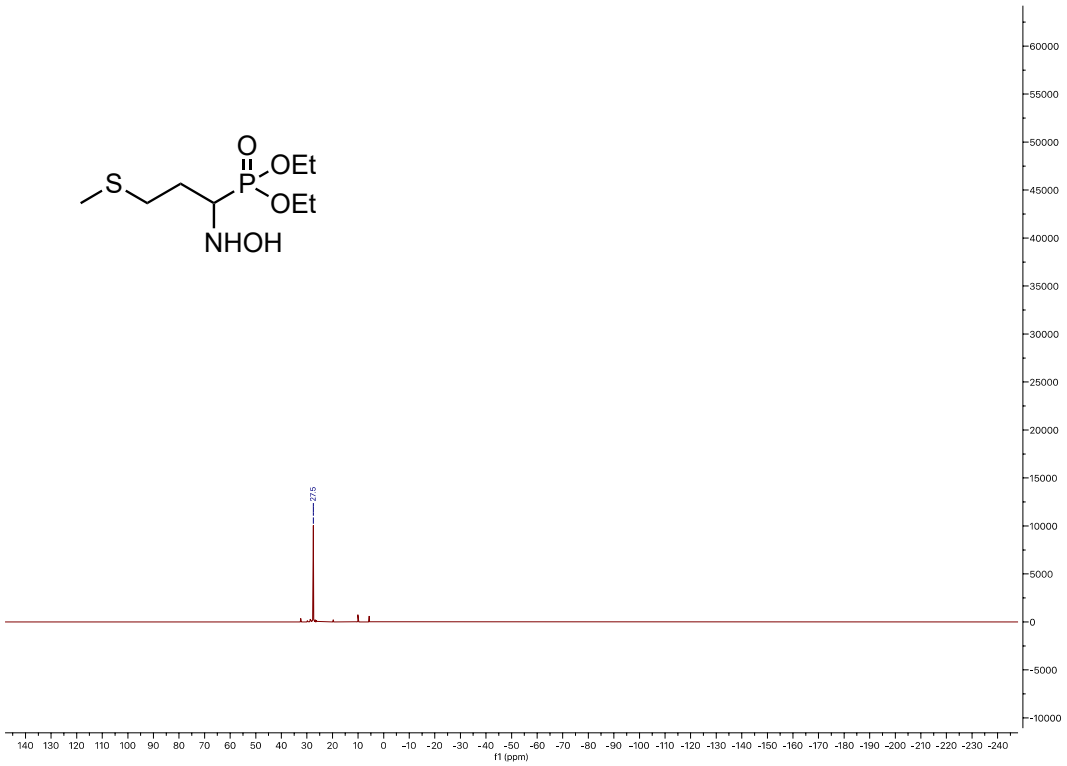


Figure S114. ^{31}P NMR spectrum (161.9 MHz) of diethyl (1-(hydroxyamino)-3-(methylthio)propyl)phosphonate (**14c**) in $CDCl_3$.

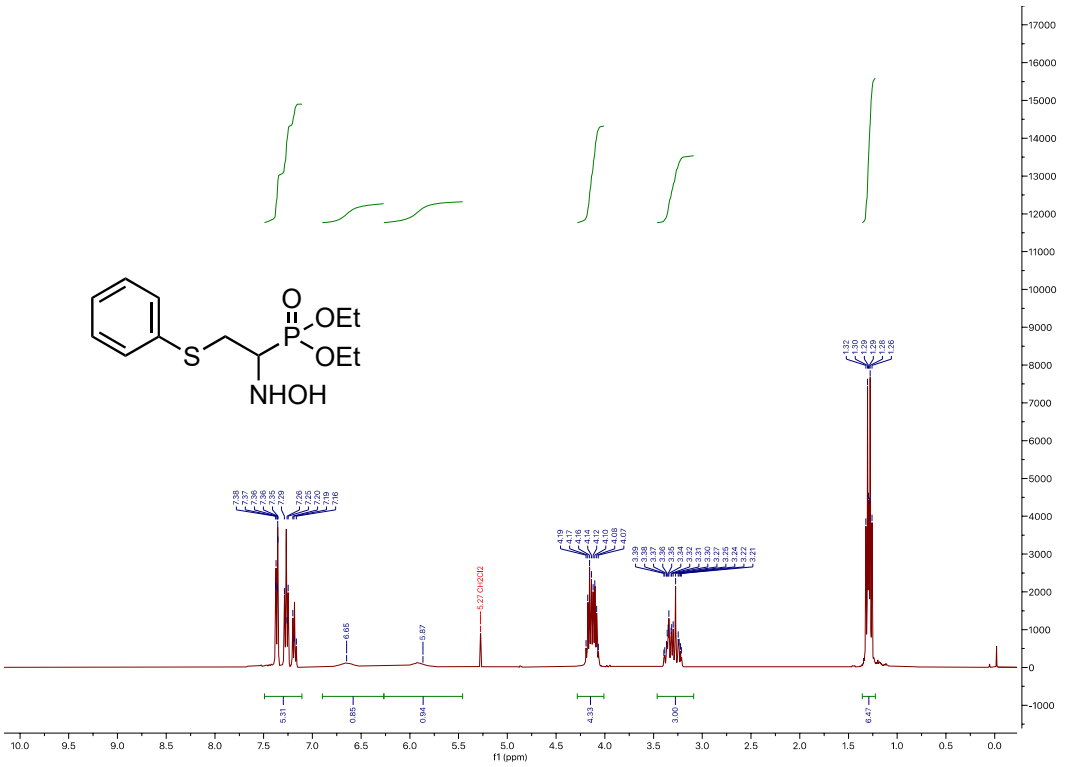


Figure S115. ^{1}H NMR spectrum (400 MHz) of diethyl (1-(hydroxyamino)-2-(phenylthio)ethyl)phosphonate (**15c**) in $CDCl_3$.

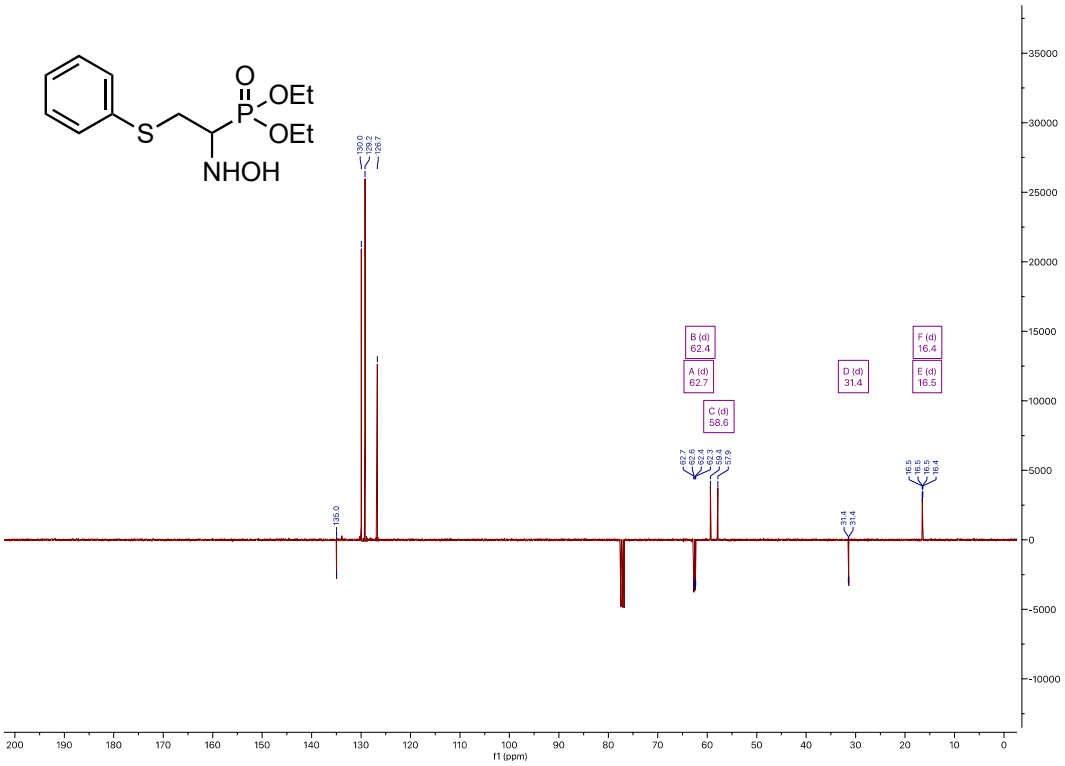


Figure S116. ^{13}C APT NMR spectrum (100.6 MHz) of diethyl (1-(hydroxyamino)-2-(phenylthio)ethyl)phosphonate (**15c**) in $CDCl_3$.

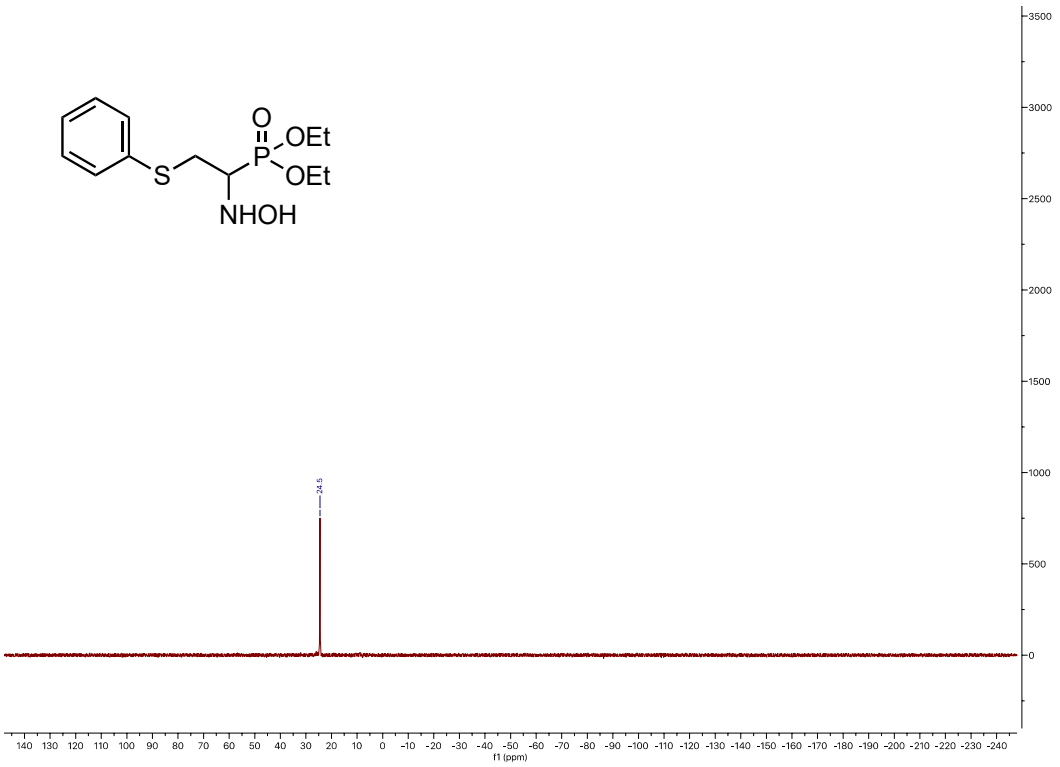


Figure S117. ^{31}P NMR spectrum (161.9 MHz) of diethyl (1-(hydroxyamino)-2-(phenylthio)ethyl)phosphonate (**15c**) in $CDCl_3$.

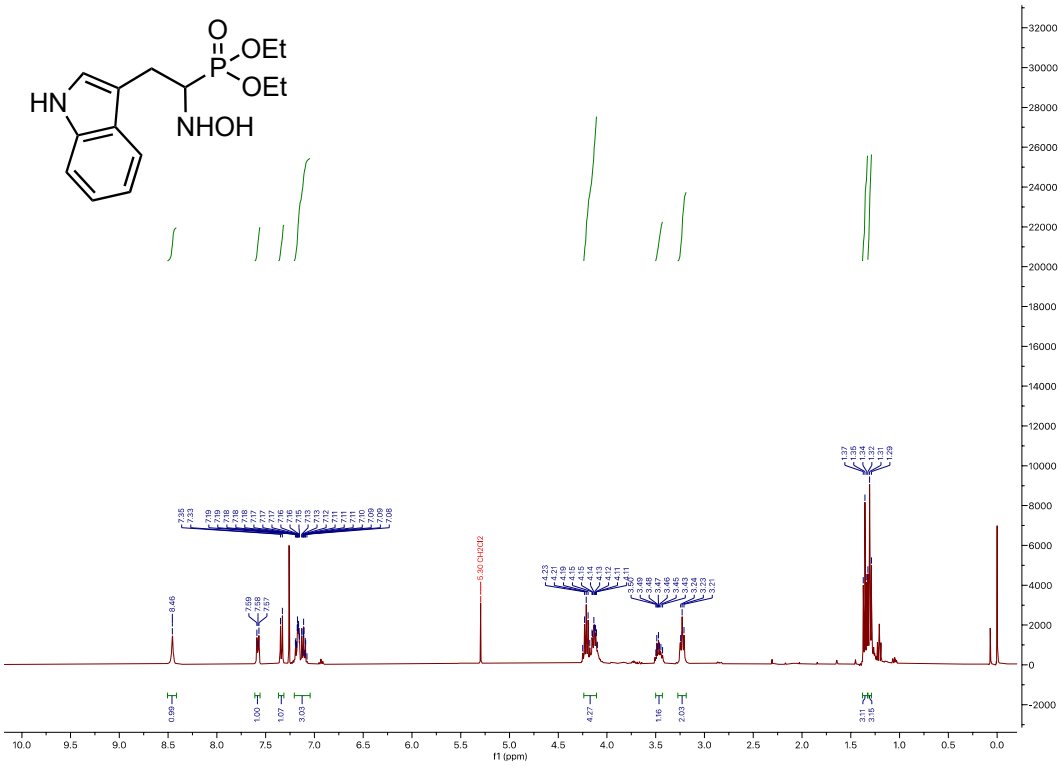


Figure S118. ^{1}H NMR spectrum (400 MHz) of diethyl (1-(hydroxyamino)-2-(1*H*-indol-3-yl)ethyl)phosphonate (**16c**) in $CDCl_3$.

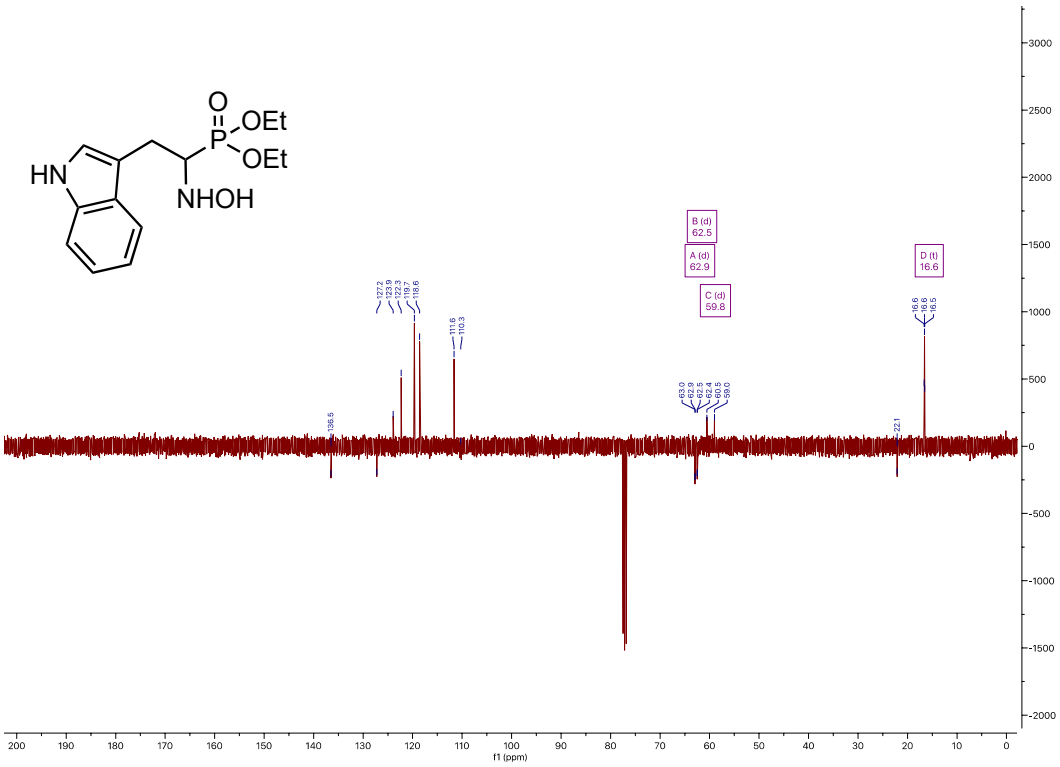


Figure S119. ^{13}C APT NMR spectrum (100.6 MHz) of diethyl (1-(hydroxyamino)-2-(1*H*-indol-3-yl)ethyl)phosphonate (**16c**) in $CDCl_3$.

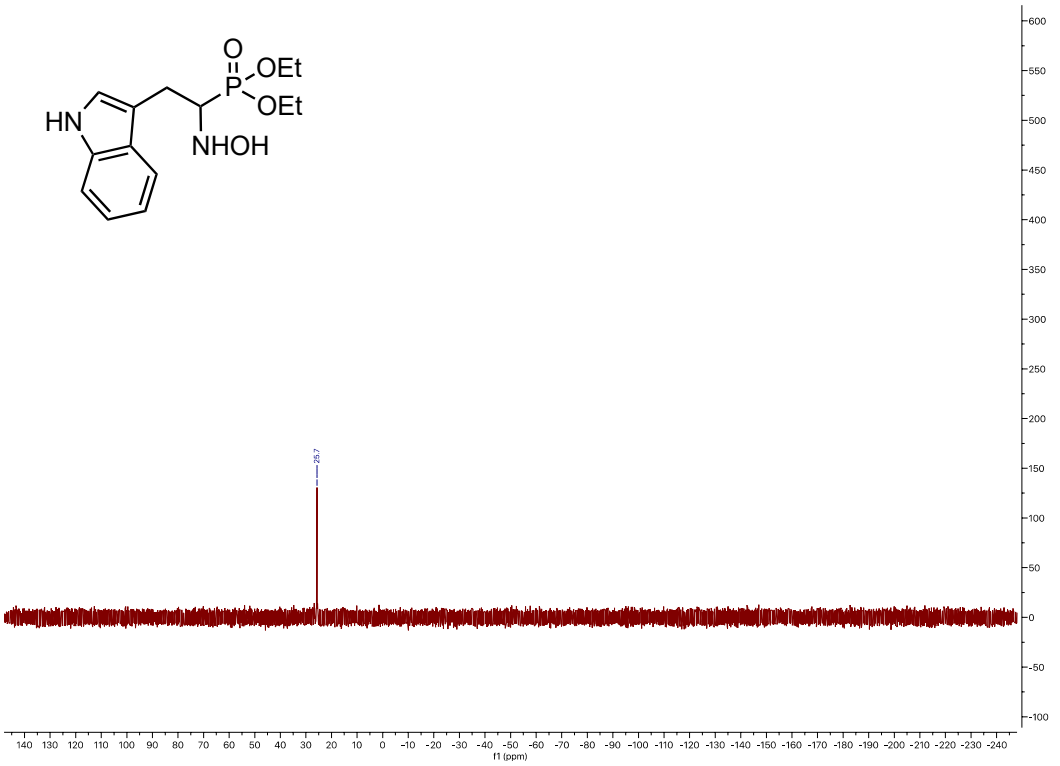


Figure S120. ^{31}P NMR spectrum (161.9 MHz) of diethyl (1-(hydroxyamino)-2-(1*H*-indol-3-yl)ethyl)phosphonate (**16c**) in $CDCl_3$.

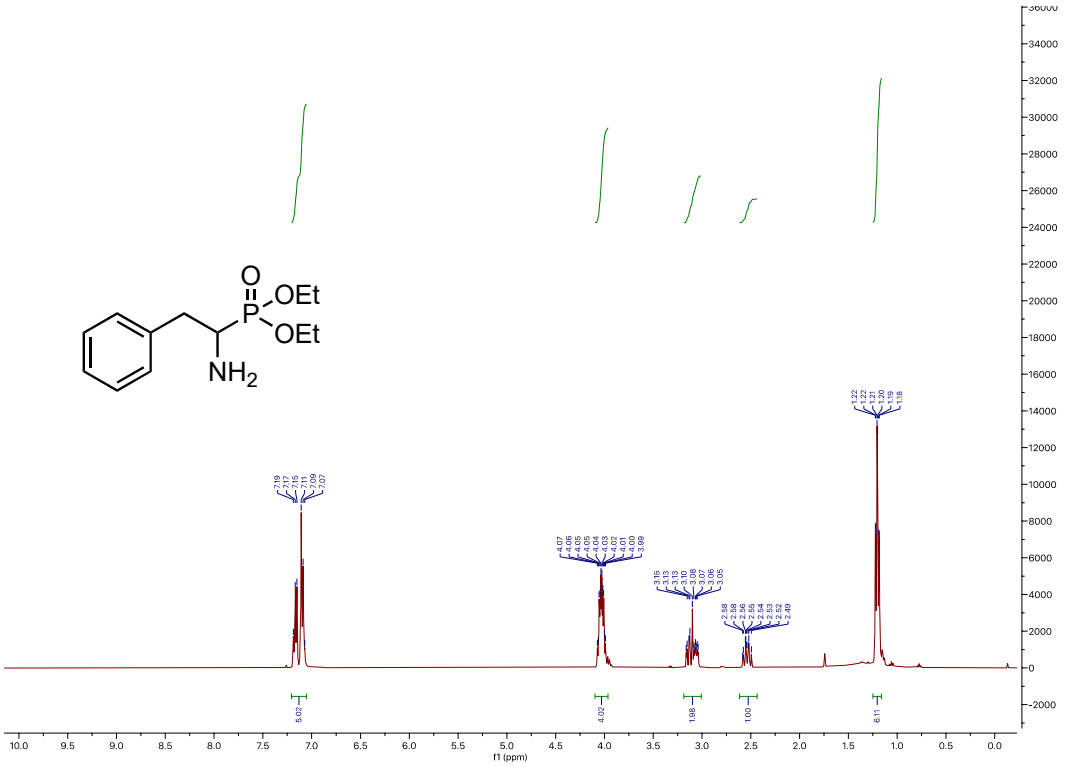


Figure S121. ^{1}H NMR spectrum (400 MHz) of diethyl (1-amino-2-phenylethyl)phosphonate (**am-2b**) in $CDCl_3$.

Figure S122. ^{13}C APT NMR spectrum (100.6 MHz) of diethyl (1-amino-2-phenylethyl)phosphonate (**am-2b**) in $CDCl_3$.

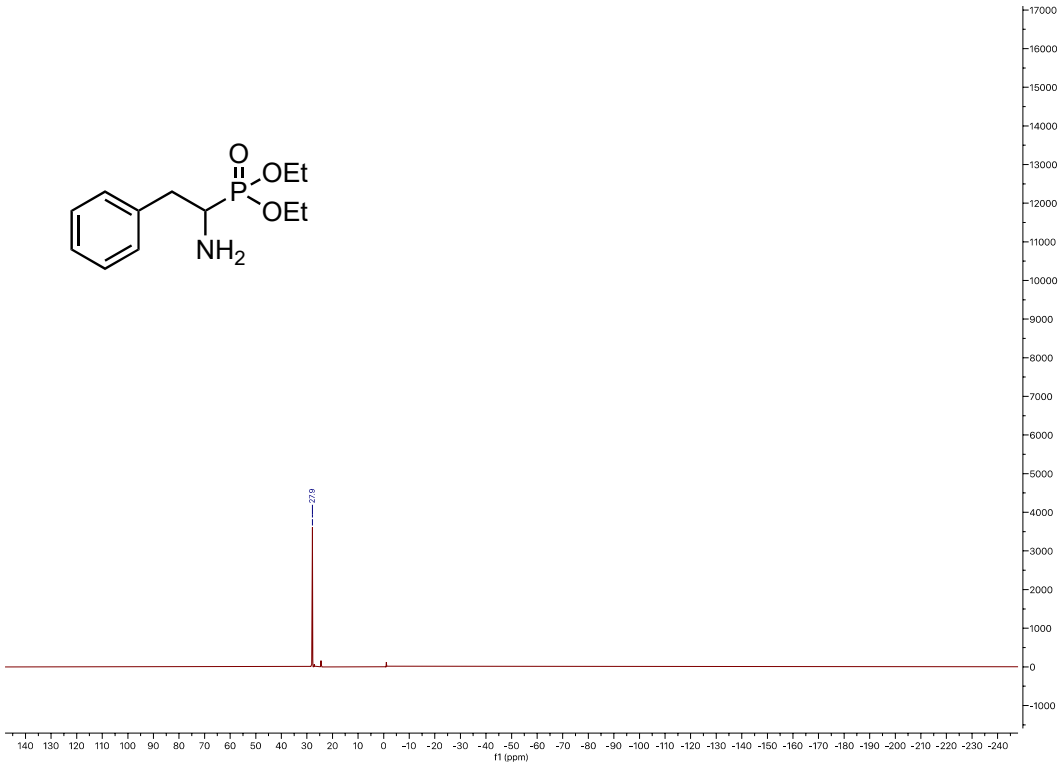


Figure S123. ^{31}P NMR spectrum (161.9 MHz) of diethyl (1-amino-2-phenylethyl)phosphonate (**am-2b**) in $CDCl_3$.

2.5 Copies of IR spectra

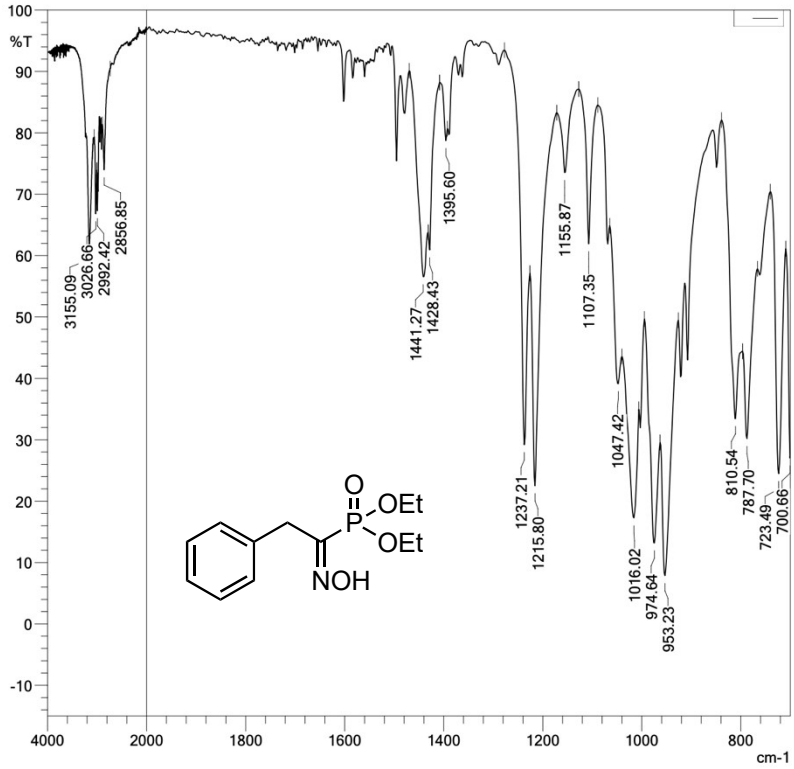


Figure S124. Infrared spectrum of diethyl (1-(hydroxyimino)-2-phenylethyl)phosphonate (neat) (**2b**).

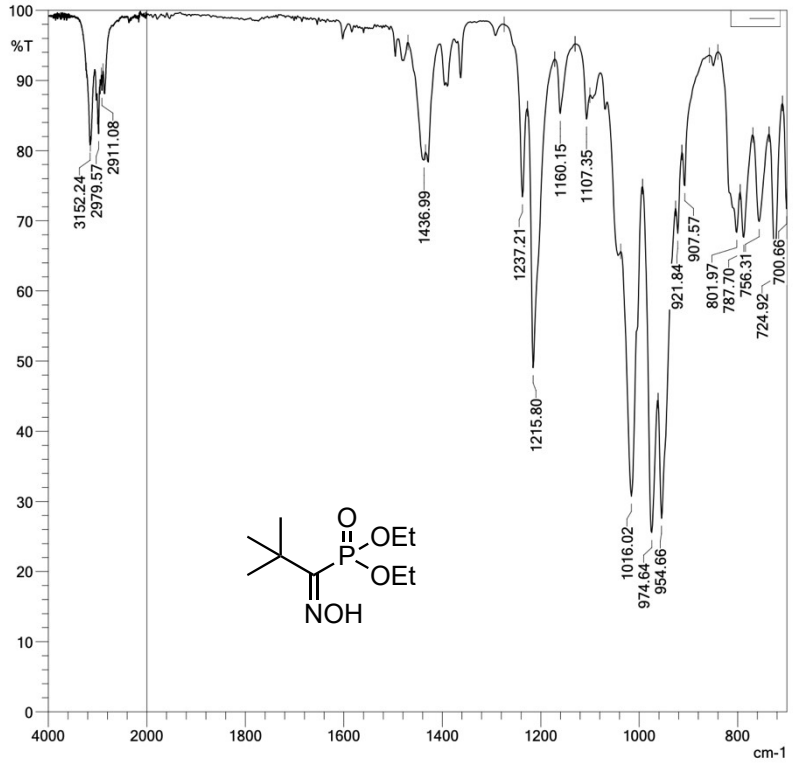


Figure S125. Infrared spectrum of diethyl (1-(hydroxyimino)-2,2-dimethylpropyl)phosphonate (neat) (**11b**).

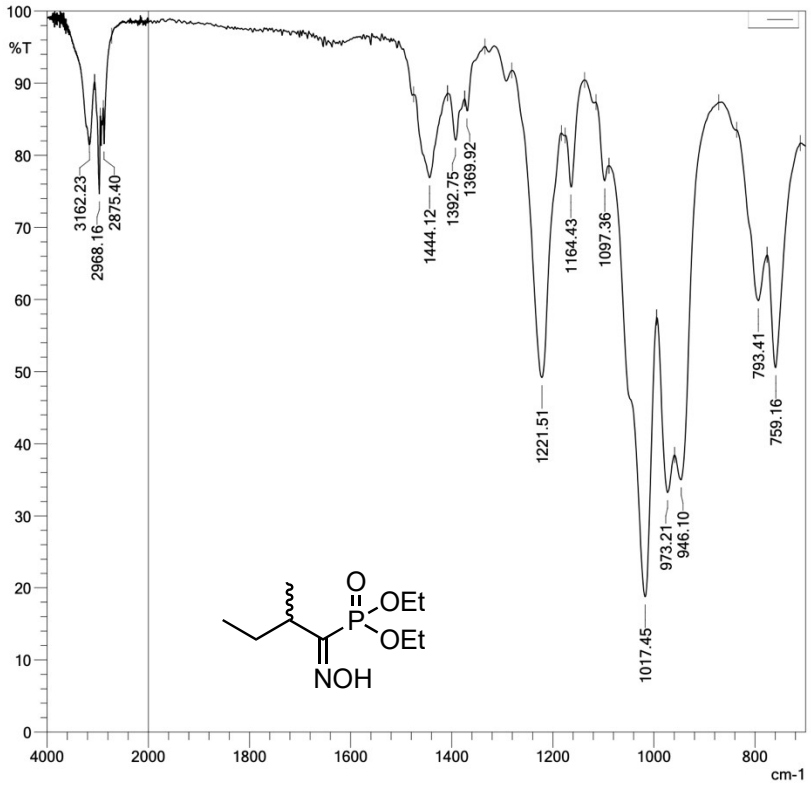


Figure S126. Infrared spectrum of diethyl (1-(hydroxyimino)-2-methylbutyl)phosphonate (PIleu-OEt) (neat) (**12b**).

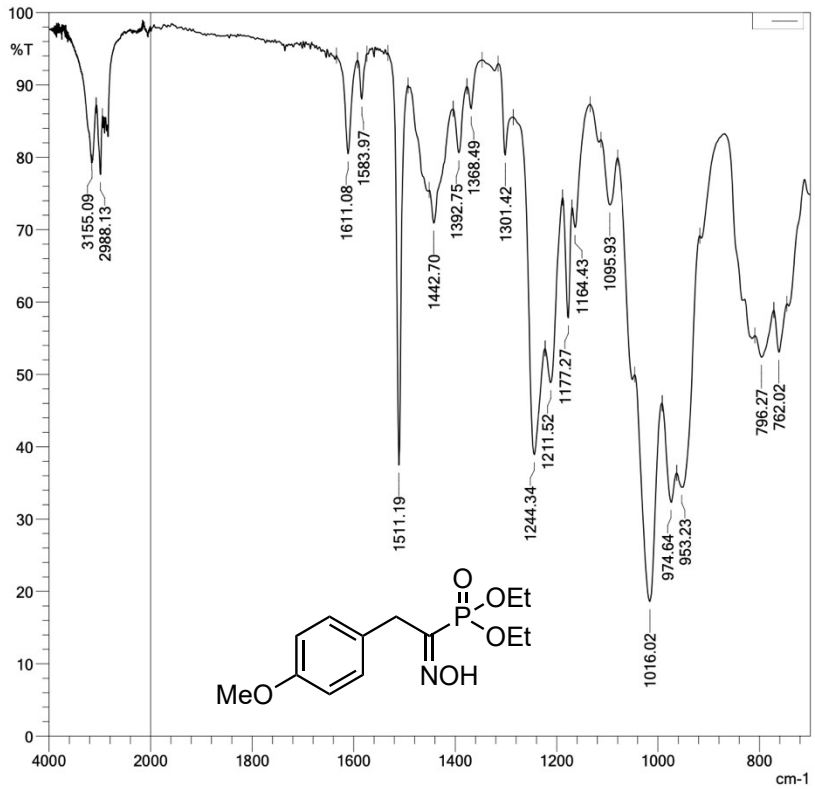


Figure S127. Infrared spectrum of diethyl (1-(hydroxyimino)-2-(4-methoxyphenyl)ethyl)phosphonate (PTyr-OEt) (neat) (**13b**).

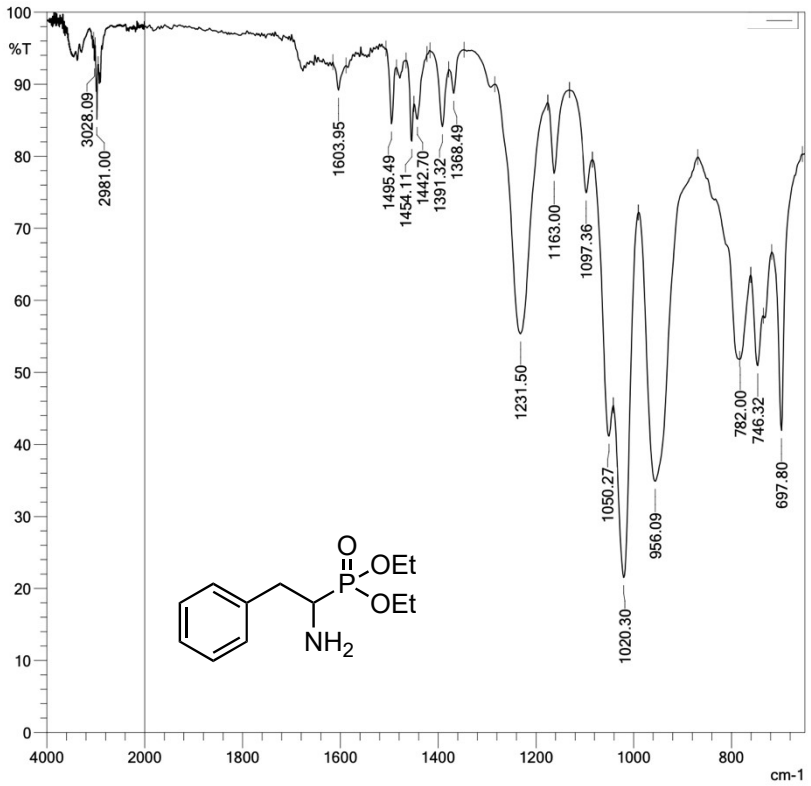


Figure S128. Infrared spectrum of diethyl (1-amino-2-phenylethyl)phosphonate (neat) (**am-2b**).

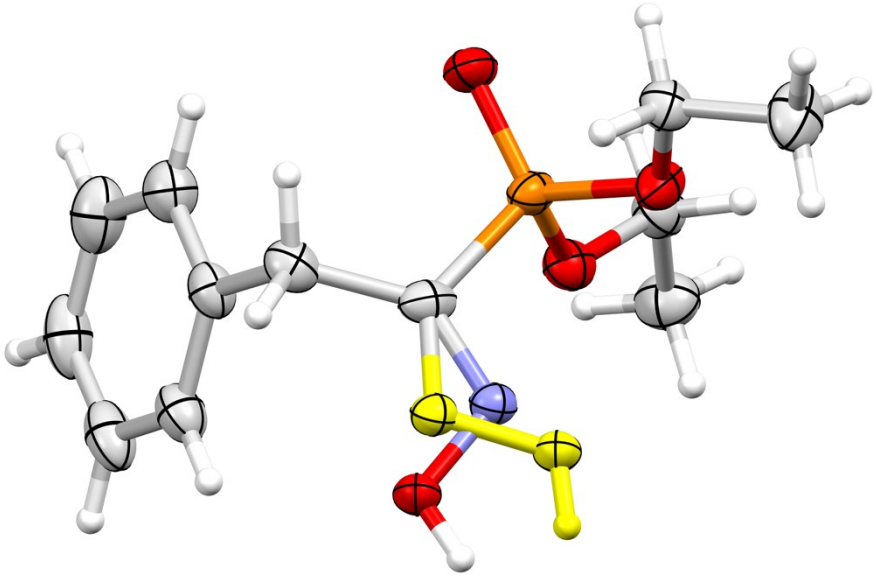
2.6 Molecular structure by single crystal X-ray diffraction analysis of compounds 2b and 3b

For the structures of **2b** and **3b**, X-ray intensity data were collected at 100 K, on a Rigaku Oxford Diffraction Supernova Dual Source (Cu at zero) diffractometer equipped with an Atlas CCD detector using ω scans and CuKα (λ = 1.54184 Å) radiation. The images were interpreted and integrated with the program CrysAlisPro.[18] Using Olex2,[19] the structures were solved by direct methods using the ShelXS/T structure solution programs and refined by full-matrix least-squares on F^2 using the ShelXL program package.[20,21] Non-hydrogen atoms were anisotropically refined and the hydrogen atoms in the riding mode with isotropic temperature factors fixed at 1.2 times U(eq) of the parent atoms (1.5 times for methyl and hydroxyl groups). Hydroxyl hydrogen atoms were located from a difference Fourier electron density map.

*Crystal data for compound **2b**.* $C_{12}H_{18}NO_4P$, M = 271.24, monoclinic, space group $P2_1/n$ (No. 14), a = 10.6343(2) Å, b = 6.96240(10) Å, c = 18.1231(3) Å, β = 91.140(2)˚, V = 1341.57(4) Å^3, Z = 4, T = 100(1) K, ρ_{calc} = 1.343 g cm^{-3}, μ(Cu-Kα) = 1.896 mm^{-1}, 24185 reflections measured (9.56° ≤ 2Θ ≤ 150.418°), 2755 unique (R_{int} = 0.0648, R_{sigma} = 0.0300) which were used in all calculations. The final $R1$ was 0.0386 ($I > 2\sigma(I)$) and $wR2$ was 0.1095 (all data). The structure was refined as a mixture of two isomers with respect to the oxime C=N double bound (*E*/*Z*, 67:33) both isomers are present in the crystal structure.

*Crystal data for compound **3b***. $C_{14}H_{22}NO_4P$, M = 299.30, monoclinic, space group $P2_1/c$ (no. 14), a = 17.0855(2) Å, b = 8.08470(10) Å, c = 11.59340(10) Å, β = 96.2960(10)˚, V = 1591.75(3) Å^3, Z = 4, T = 100(1) K, ρ_{calc} = 1.249 g cm^{-3}, μ(Cu-Kα) = 1.644 mm^{-1}, 28966 reflections measured (5.204° ≤ 2Θ ≤ 147.924°), 3197 unique (R_{int} = 0.0432, R_{sigma} = 0.0198) which were used in all calculations. The final $R1$ was 0.0339 ($I > 2\sigma(I)$) and $wR2$ was 0.0923 (all data). Only the *E* isomer with respect to the oxime C=N double bound is present in the crystal structure.

CCDC 2115990-2115991 contain the supplementary crystallographic data for this paper. These data can be obtained free of charge from The Cambridge Crystallographic Data Centre via www.ccdc.cam.ac.uk/structures.



S129. Asymmetric unit of the crystal structure of ***(2b)***, showing thermal displacement ellipsoids at the 50% probability level. The structure highlights the presence of both isomers with respect to the oxime C=N double bound (*E* = blue + red, *Z* = yellow).

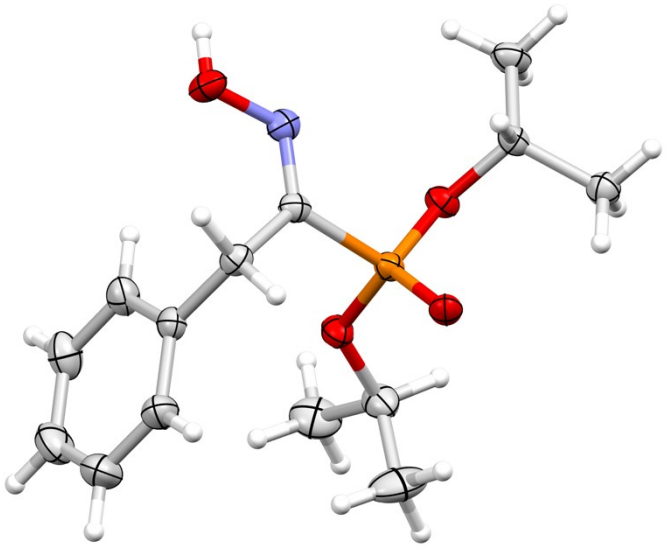


Figure S130. Asymmetric unit of the crystal structure of ***(3b)***, showing thermal displacement ellipsoids at the 50% probability level. The structure highlights the presence of only the *E* isomer with respect to the oxime C=N double bound.

3 Collision energy breakdown curves and survival yields

The structures of the main fragments for each breakdown curve have been identified and summarized in Table S2.

3.1 Dimethyl (1-(hydroxyimino)-2-phenylethyl)phosphonate (1b)

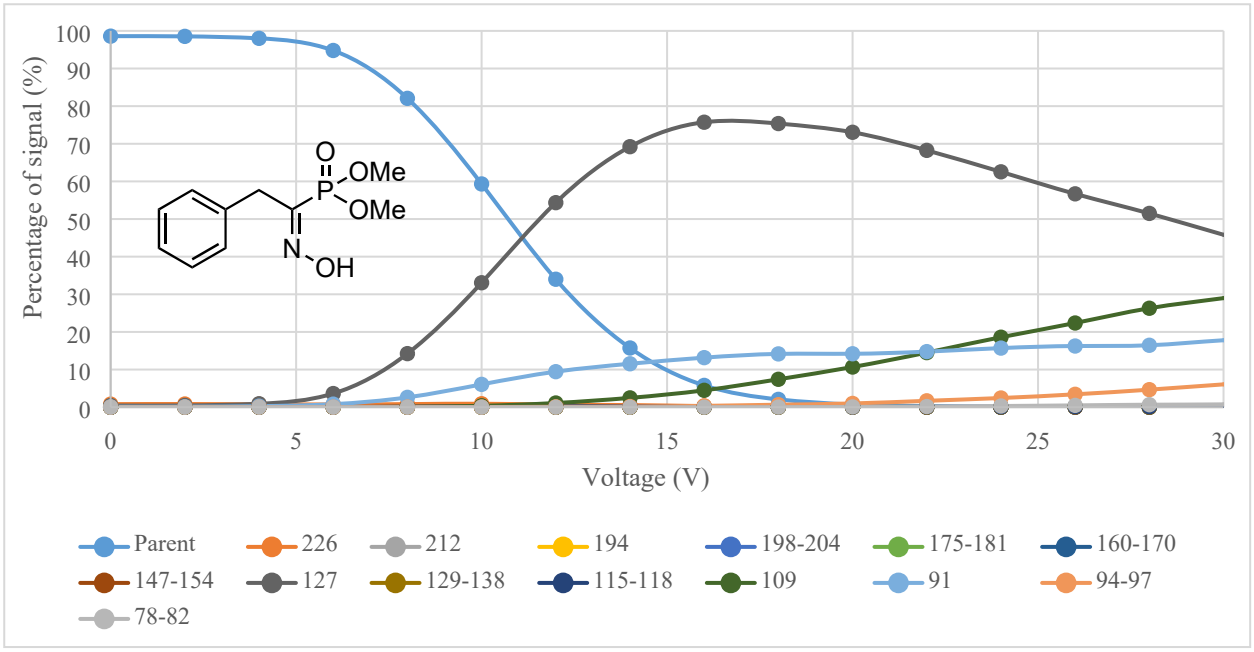


Figure S131. Breakdown curve of dimethyl (1-(hydroxyimino)-2-phenylethyl)phosphonate (**1b, Z_{iso}**).

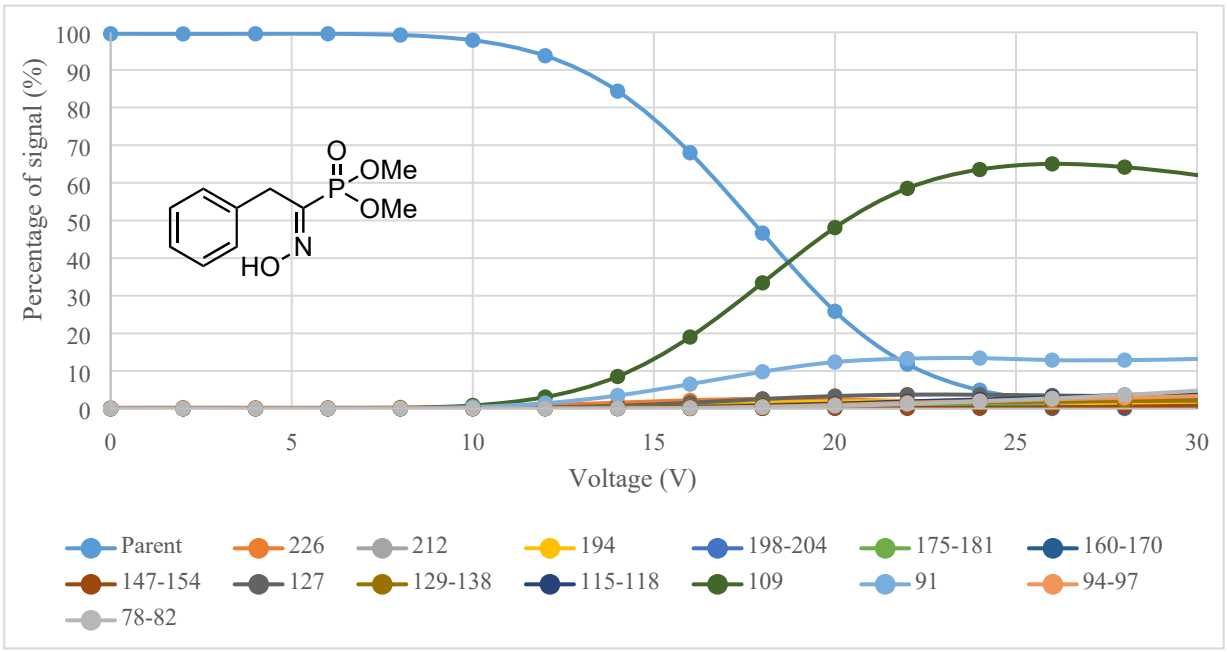


Figure S132. Breakdown curve of dimethyl (1-(hydroxyimino)-2-phenylethyl)phosphonate (**1b, E_{iso}**).

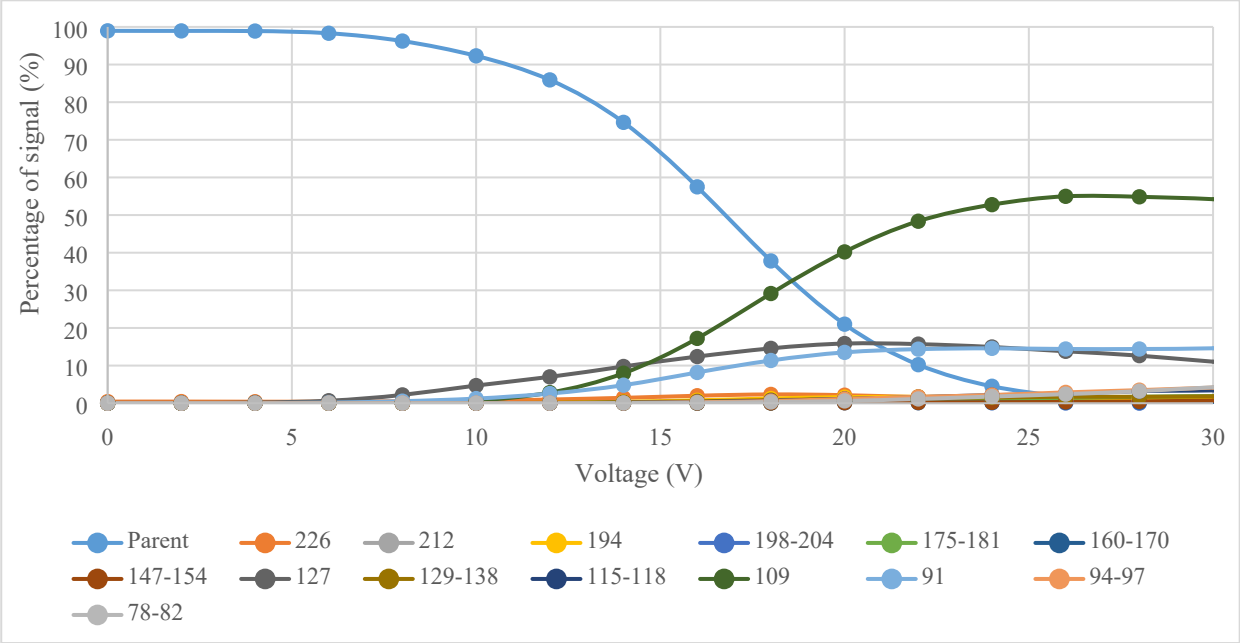


Figure S133. Breakdown curve of dimethyl (1-(hydroxyimino)-2-phenylethyl)phosphonate (**1b, Mix**).

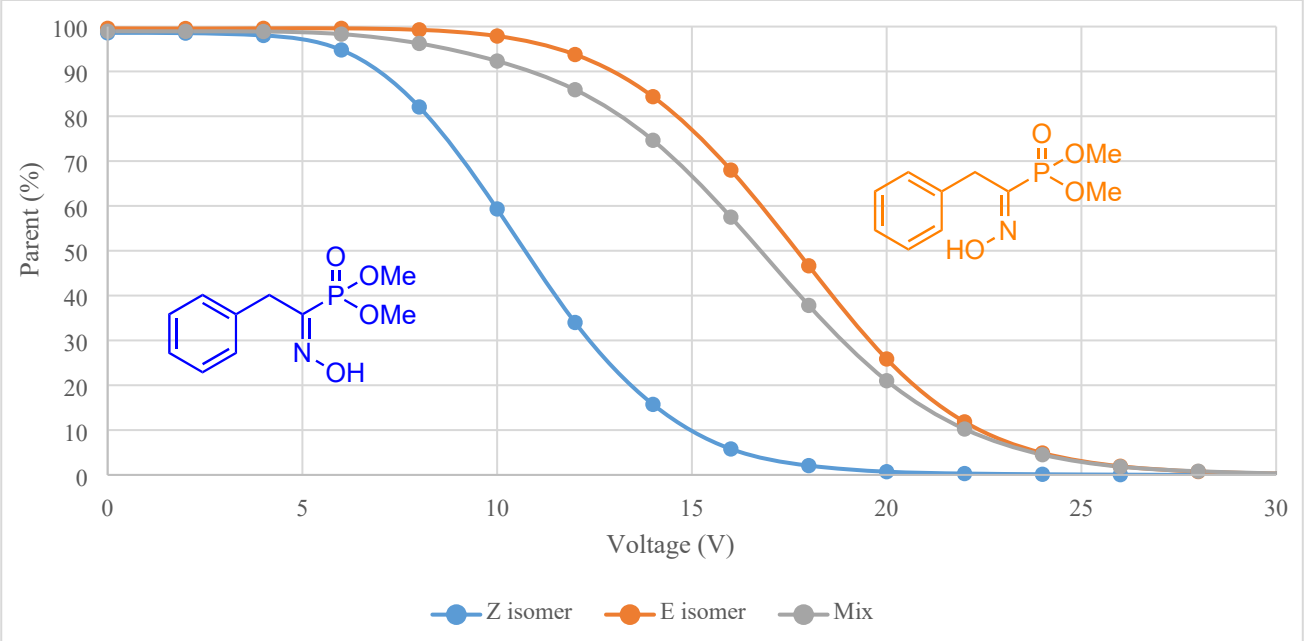


Figure S134. Survival yield of dimethyl (1-(hydroxyimino)-2-phenylethyl)phosphonate (**1b**).

3.2 Diethyl (1-(hydroxyimino)-2-phenylethyl)phosphonate (2b)

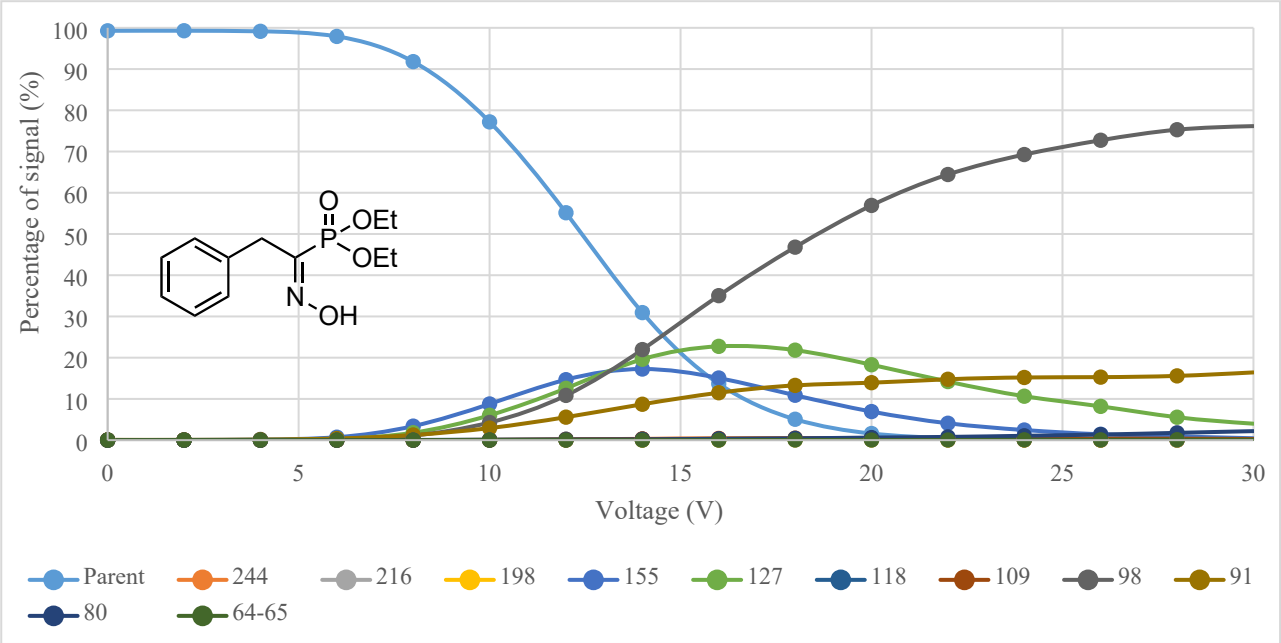


Figure S135. Breakdown curve of diethyl (1-(hydroxyimino)-2-phenylethyl)phosphonate (**2b, Z_{iso}**).

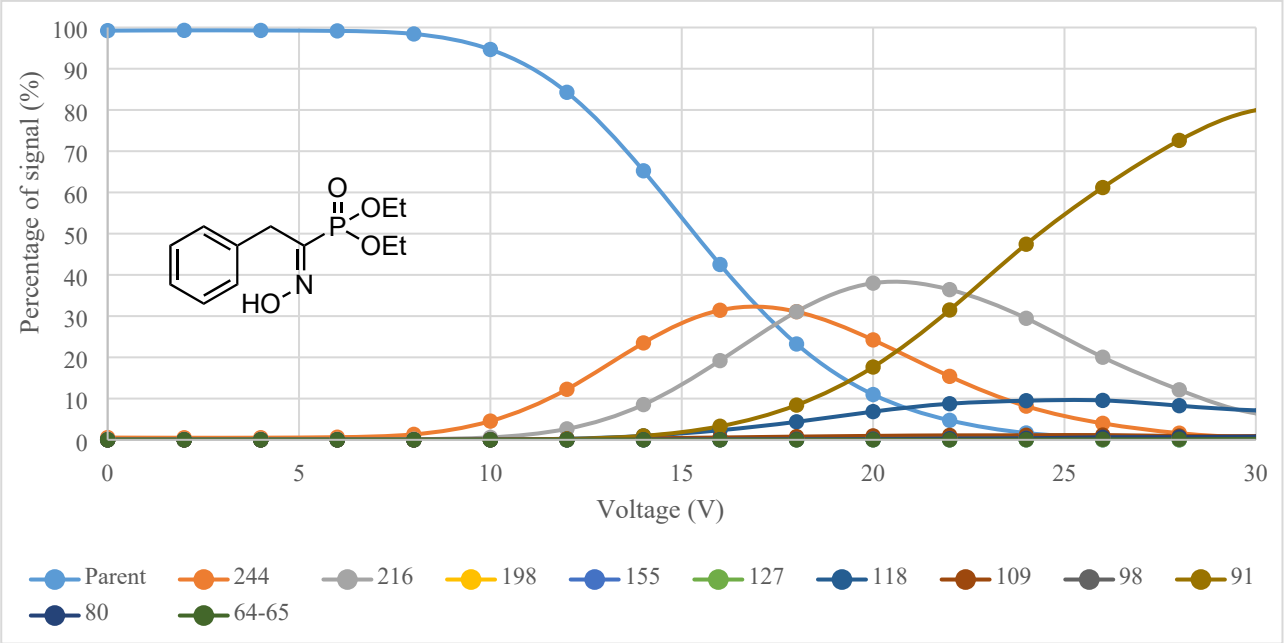


Figure S136. Breakdown curve of diethyl (1-(hydroxyimino)-2-phenylethyl)phosphonate (**2b, E_{iso}**).

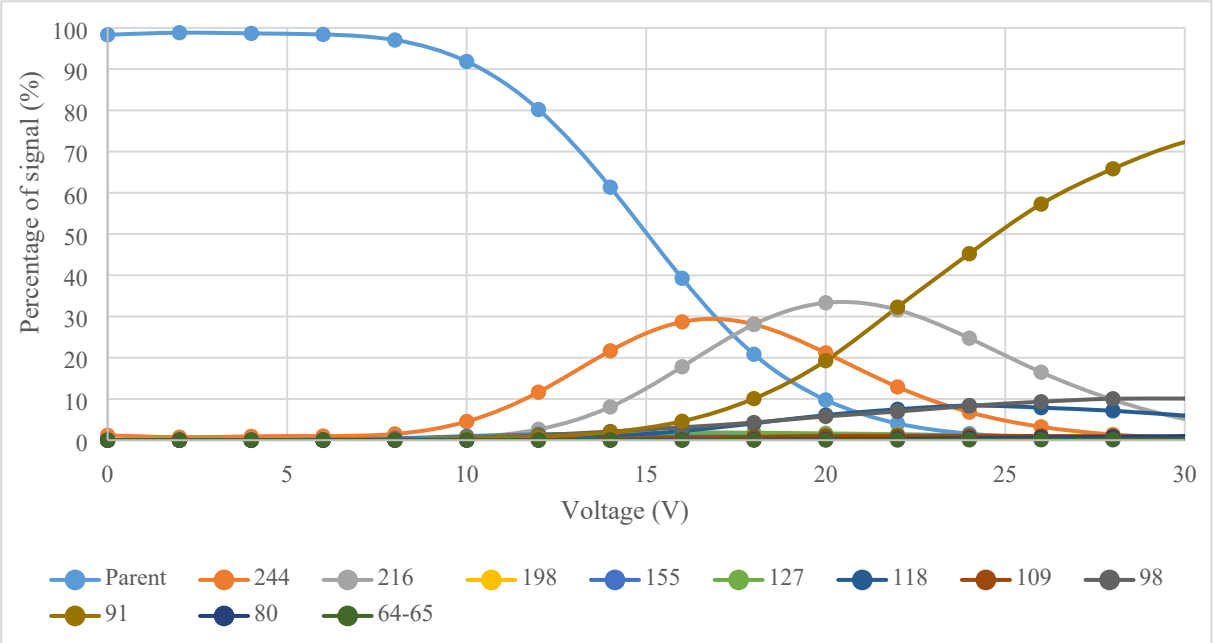


Figure S137. Breakdown curve of diethyl (1-(hydroxyimino)-2-phenylethyl)phosphonate (**2b, Mix**).

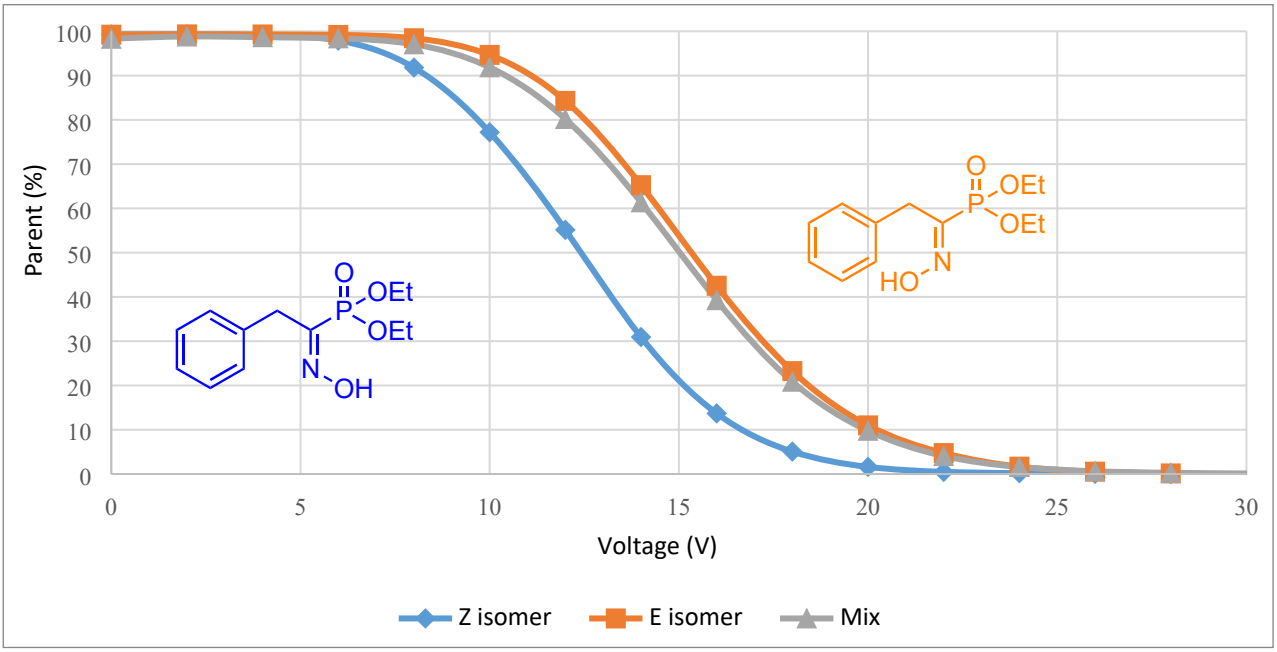


Figure S138. Survival yield of diethyl (1-(hydroxyimino)-2-phenylethyl)phosphonate (**2b**).

3.3 Diethyl (1-(hydroxyimino)-2-phenylethyl)phosphonate (3b)

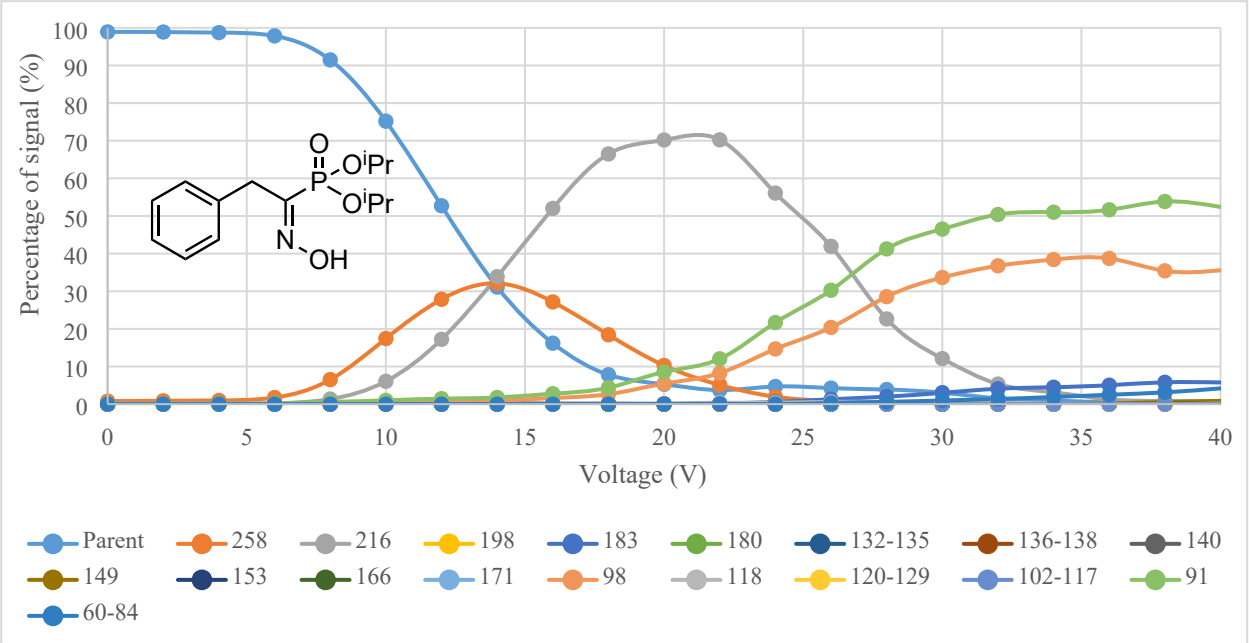


Figure S139. Breakdown curve of diisopropyl (1-(hydroxyimino)-2-phenylethyl)phosphonate (**3b, Z_{iso}**).

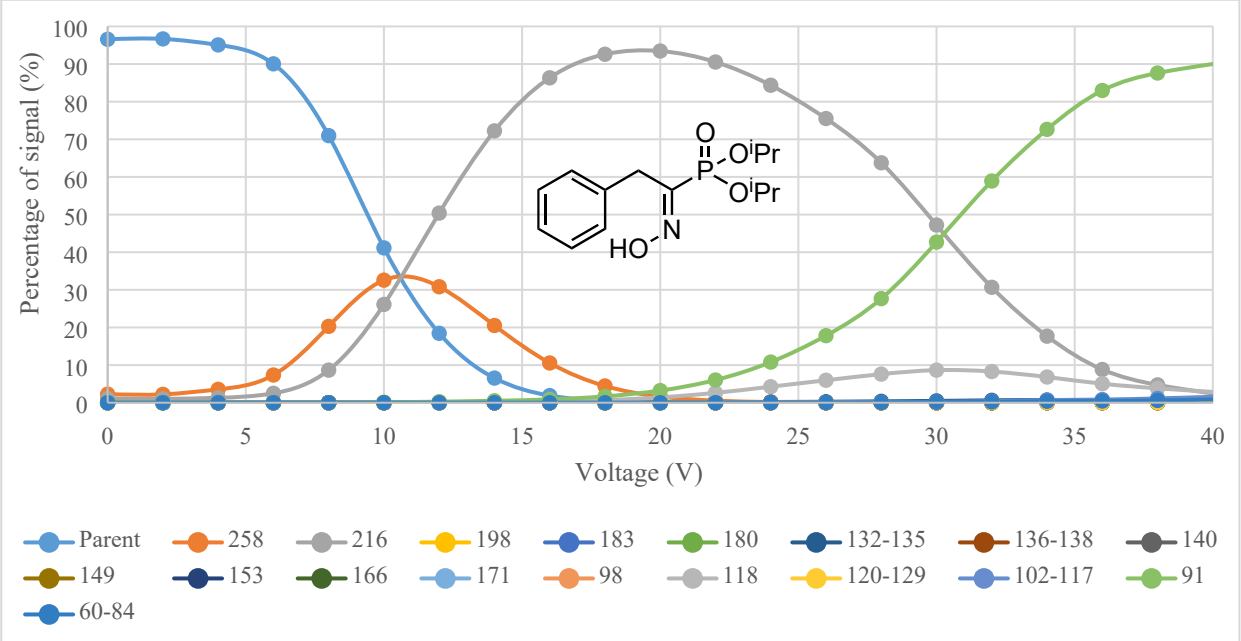


Figure S140. Breakdown curve of diisopropyl (1-(hydroxyimino)-2-phenylethyl)phosphonate (**3b, E_{iso}**).

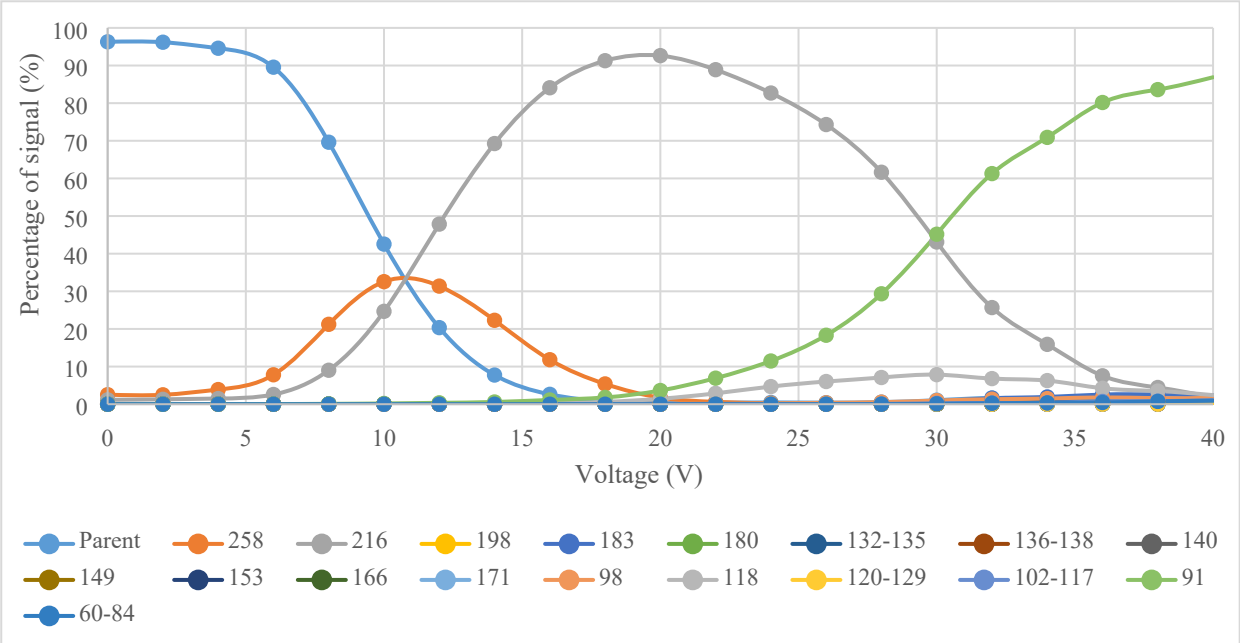


Figure S141. Breakdown curve of diisopropyl (1-(hydroxyimino)-2-phenylethyl)phosphonate (**3b, Mix**).

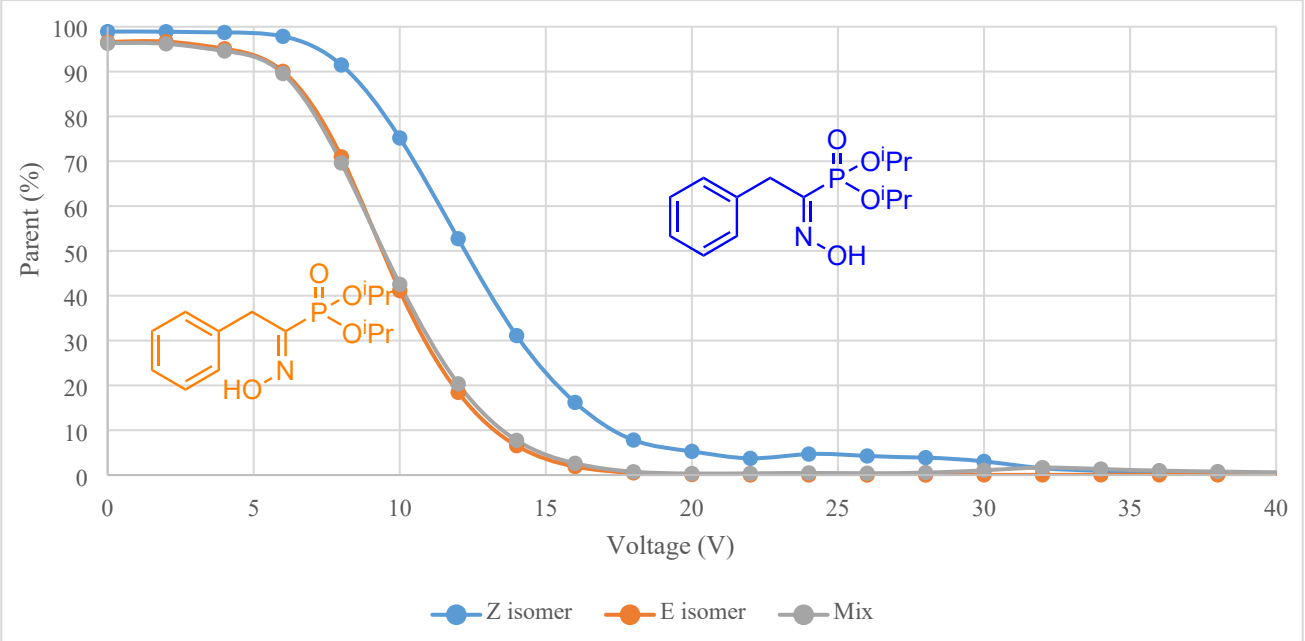


Figure S142. Survival yield of diisopropyl (1-(hydroxyimino)-2-phenylethyl)phosphonate (**3b**).

3.4 Dimethyl (1-(hydroxyimino)-2-methylpropyl)phosphonate (4b)

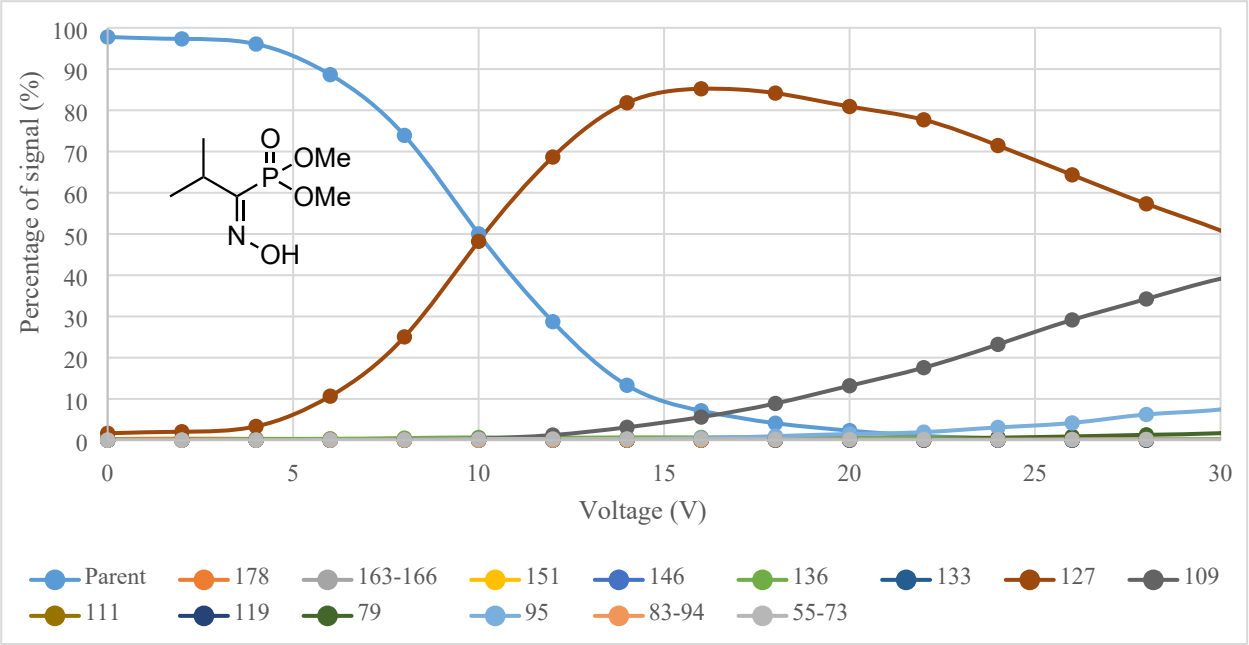


Figure S143. Breakdown curve of dimethyl (1-(hydroxyimino)-2-methylpropyl)phosphonate (**4b, Z_{iso}**).

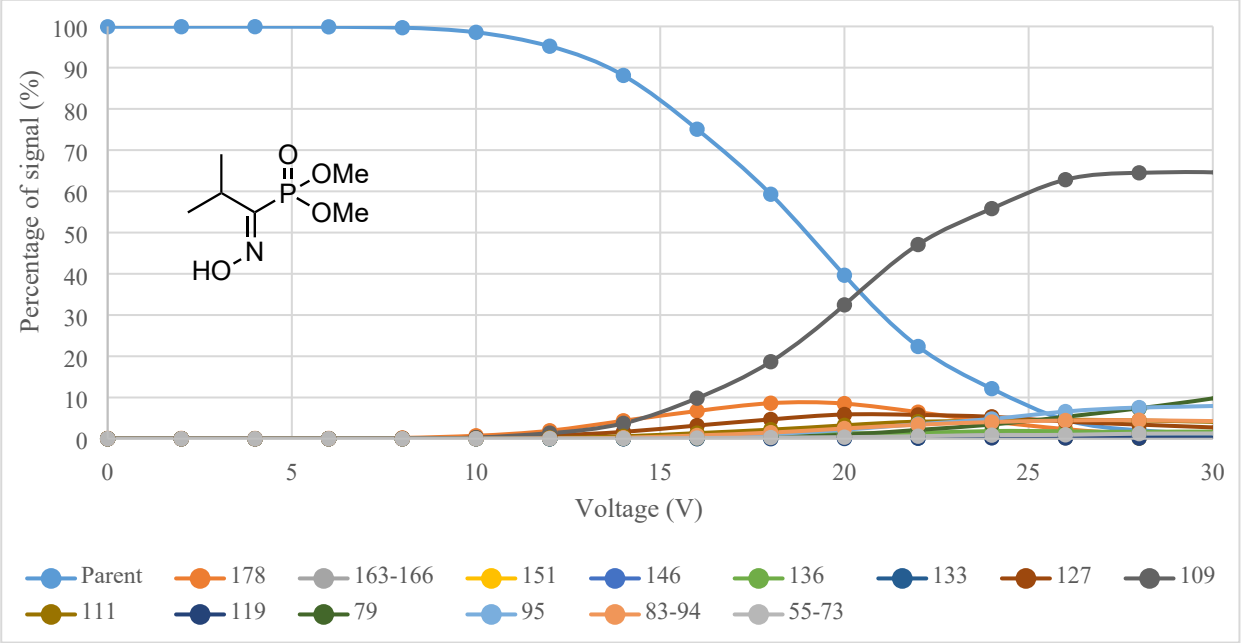


Figure S144. Breakdown curve of dimethyl (1-(hydroxyimino)-2-methylpropyl)phosphonate (**4b, E_{iso}**).

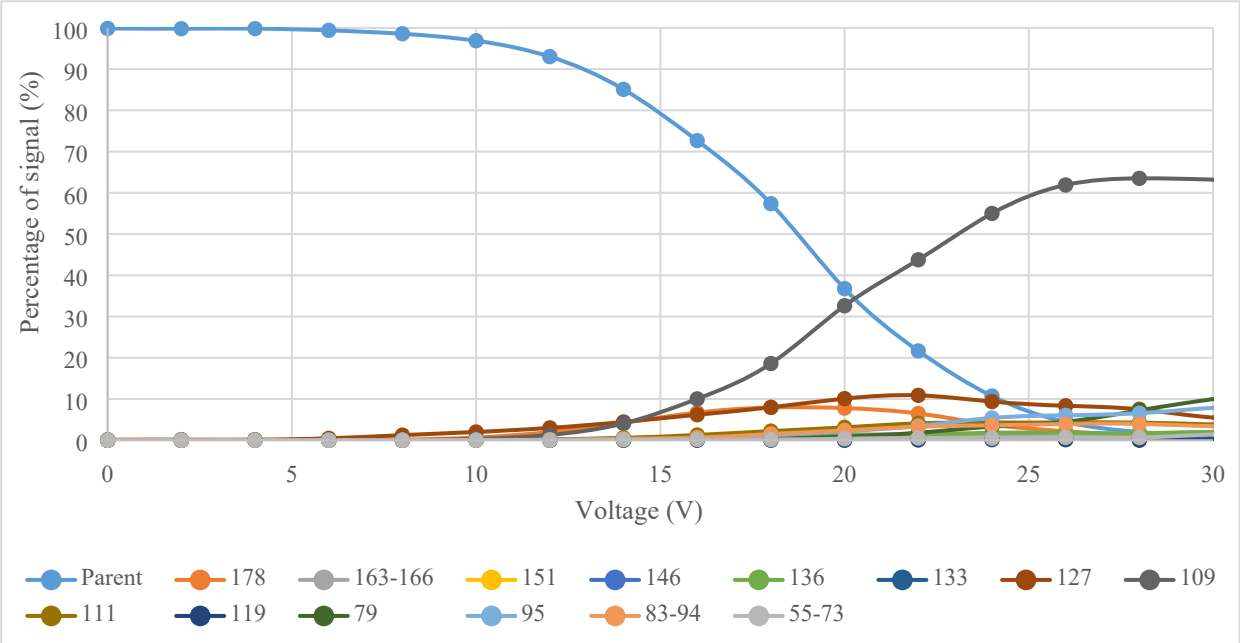


Figure S145. Breakdown curve of dimethyl (1-(hydroxyimino)-2-methylpropyl)phosphonate (**4b, Mix**).

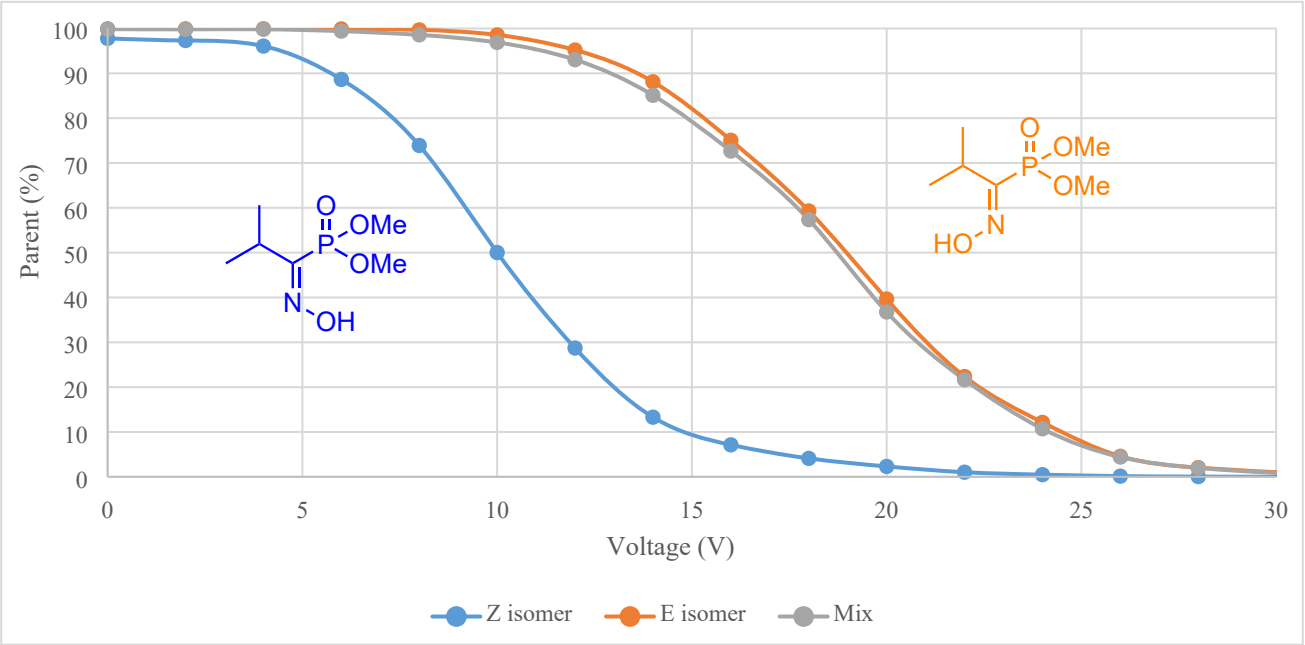


Figure S146. Survival yield of dimethyl (1-(hydroxyimino)-2-methylpropyl)phosphonate (**4b**).

3.5 Diethyl (1-(hydroxyimino)-2-methylpropyl)phosphonate (5b)

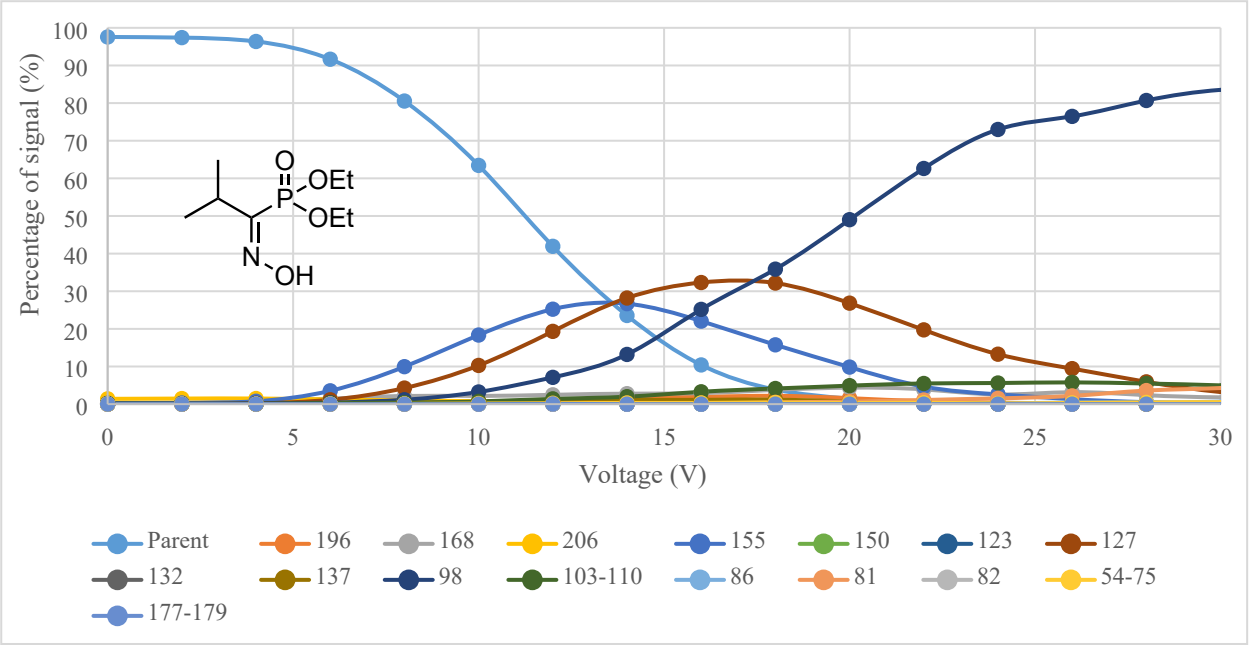


Figure S147. Breakdown curve of diethyl (1-(hydroxyimino)-2-methylpropyl)phosphonate (**5b, Z_{iso}**).

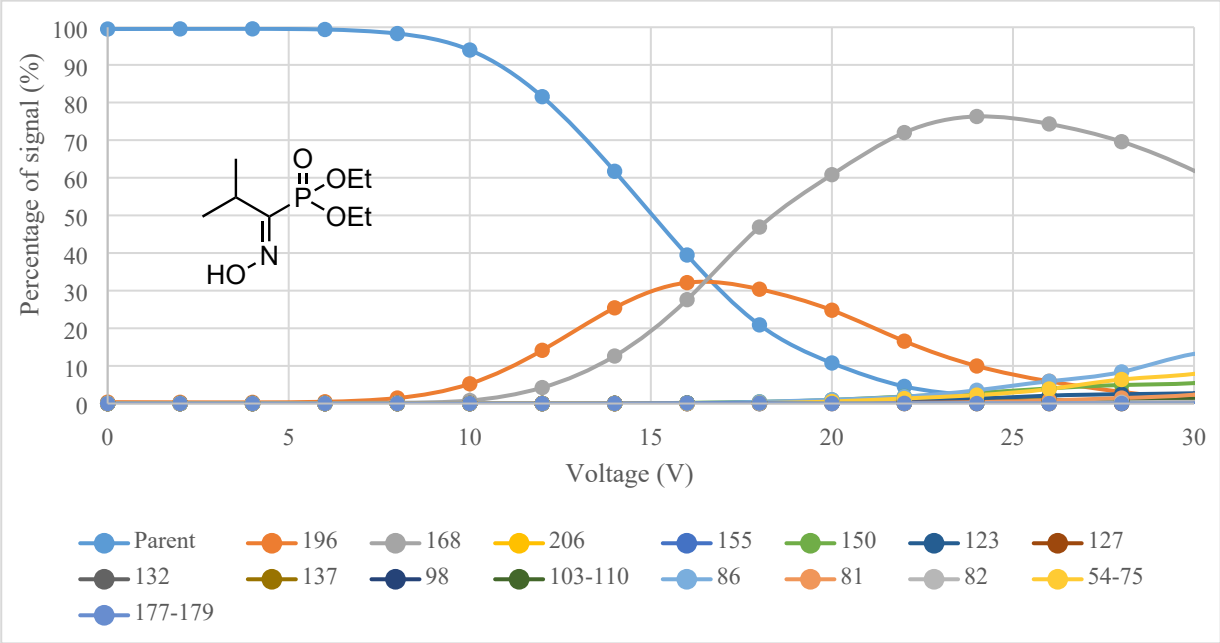


Figure S148. Breakdown curve of diethyl (1-(hydroxyimino)-2-methylpropyl)phosphonate (**5b, E_{iso}**).

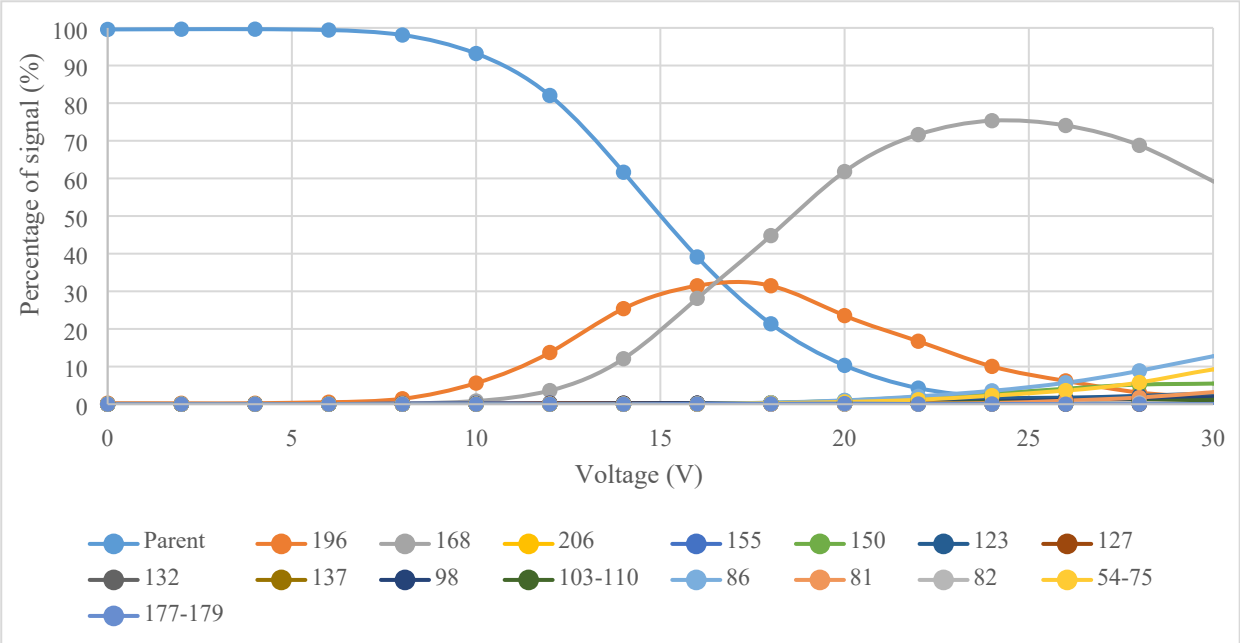


Figure S149. Breakdown curve of diethyl (1-(hydroxyimino)-2-methylpropyl)phosphonate (**5b, Mix**).

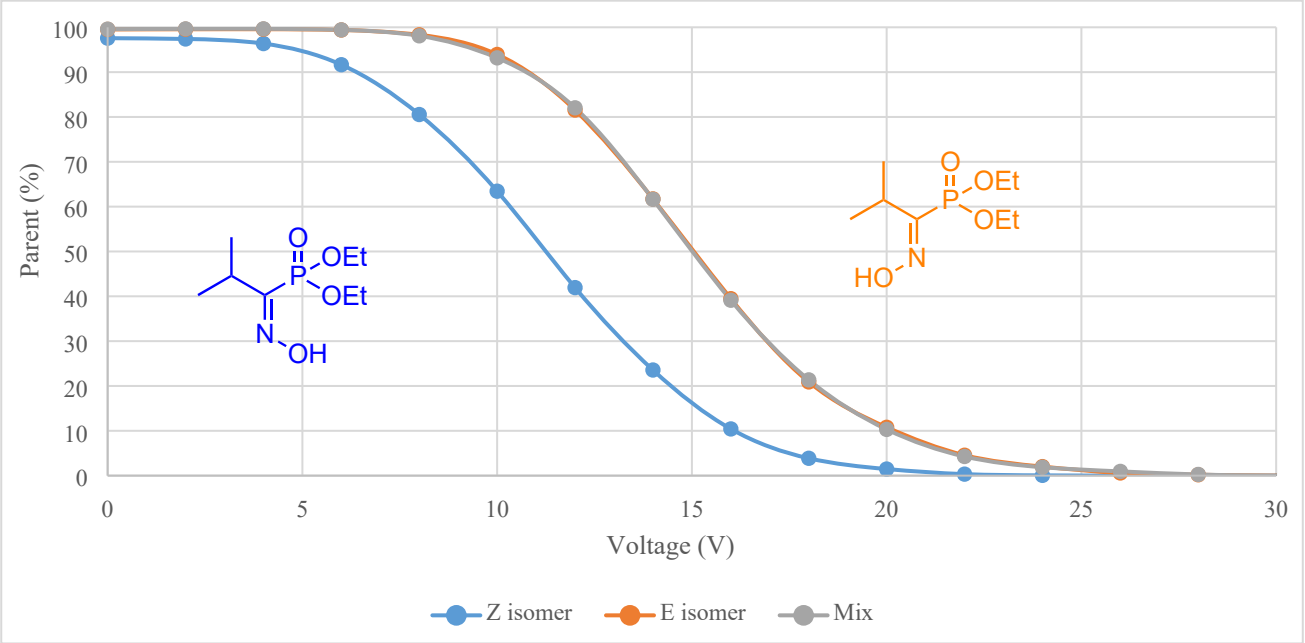


Figure S150. Survival yield of diethyl (1-(hydroxyimino)-2-methylpropyl)phosphonate (**5b**).

3.6 Diisopropyl (1-(hydroxyimino)-2-methylpropyl)phosphonate (6b)

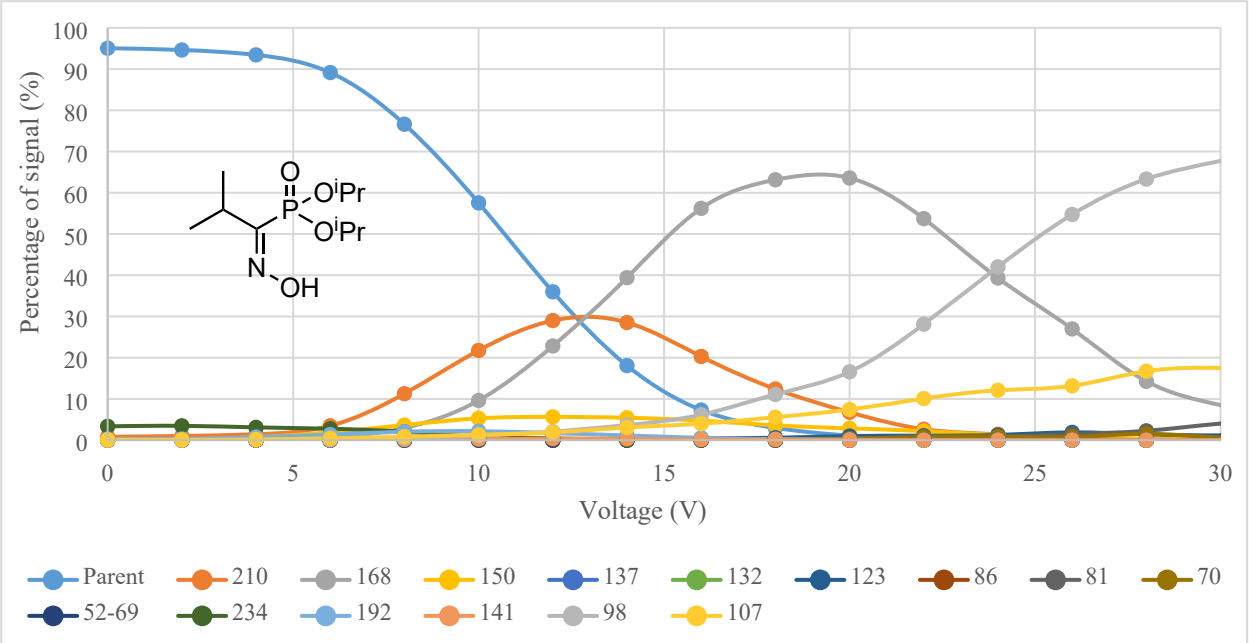


Figure S151. Breakdown curve of diisopropyl (1-(hydroxyimino)-2-methylpropyl)phosphonate (**6b, Z_{iso}**).

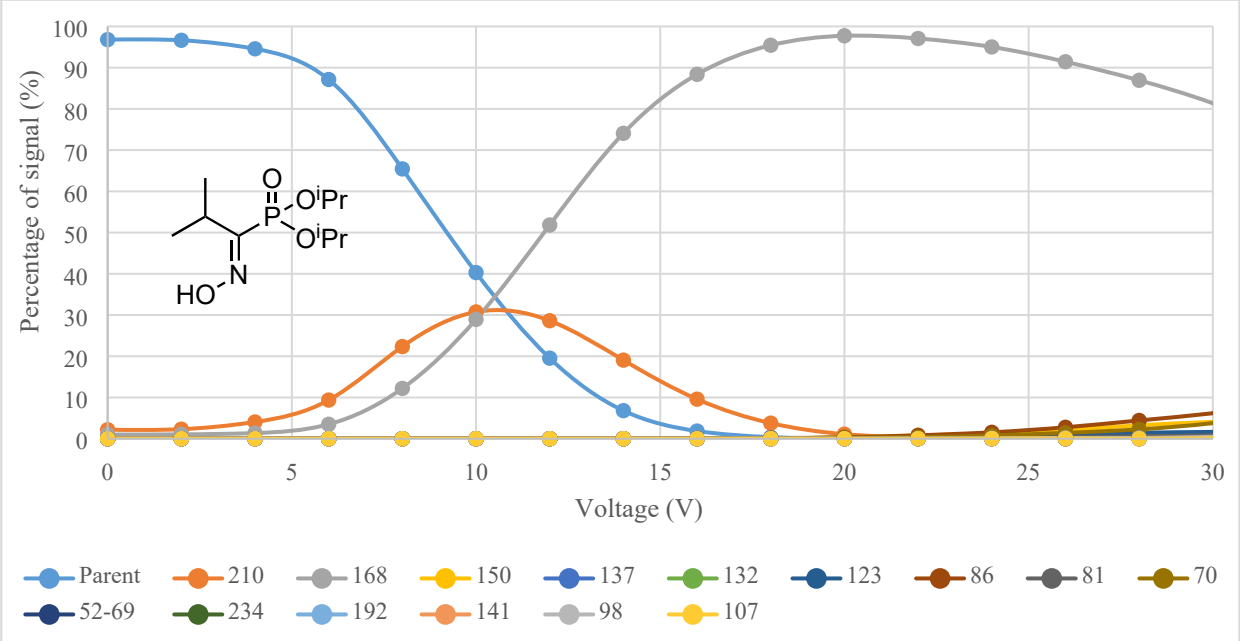


Figure S152. Breakdown curve of diisopropyl (1-(hydroxyimino)-2-methylpropyl)phosphonate (**6b, E_{iso}**).

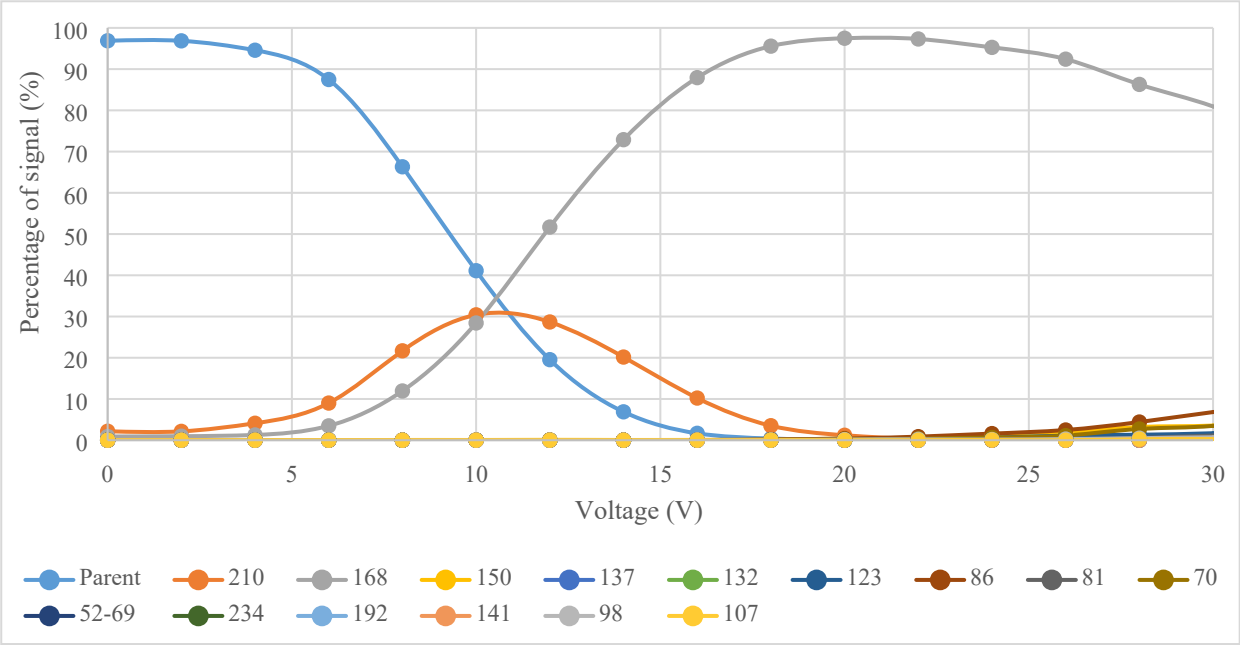


Figure S153. Breakdown curve of diisopropyl (1-(hydroxyimino)-2-methylpropyl)phosphonate (**6b, Mix**).

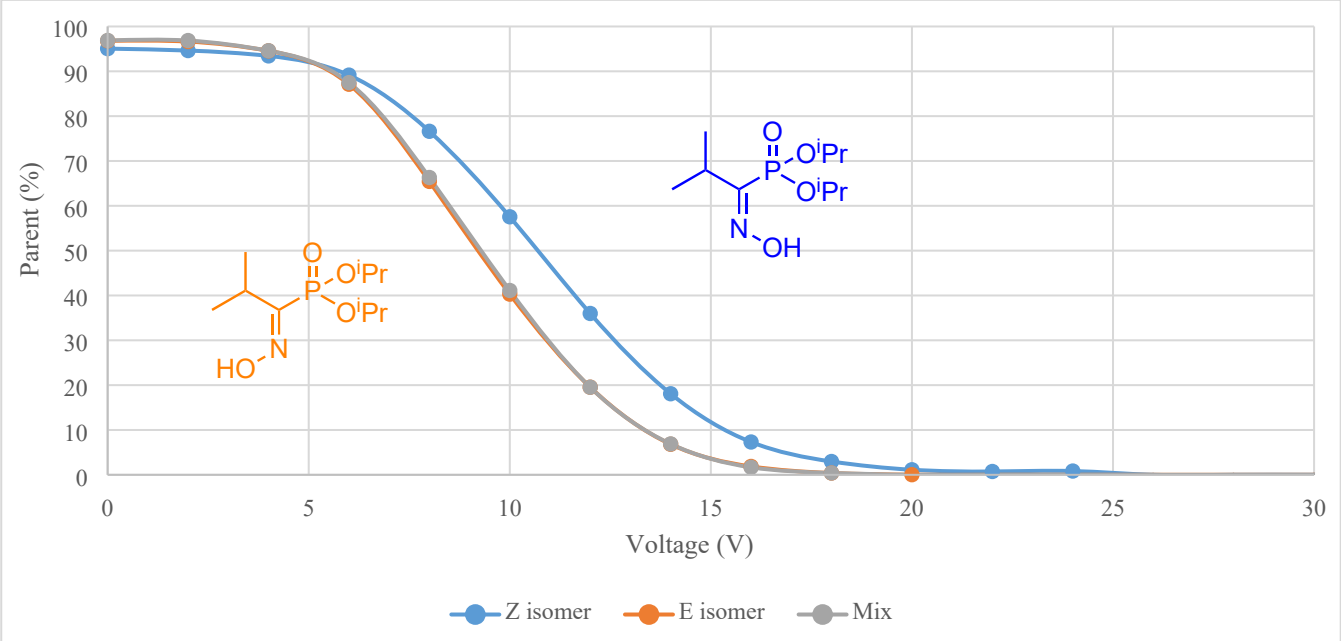


Figure S154. Survival yield of diisopropyl (1-(hydroxyimino)-2-methylpropyl)phosphonate (**6b**).

3.7 Dimethyl (1-(hydroxyimino)-3-methylbutyl)phosphonate (7b)

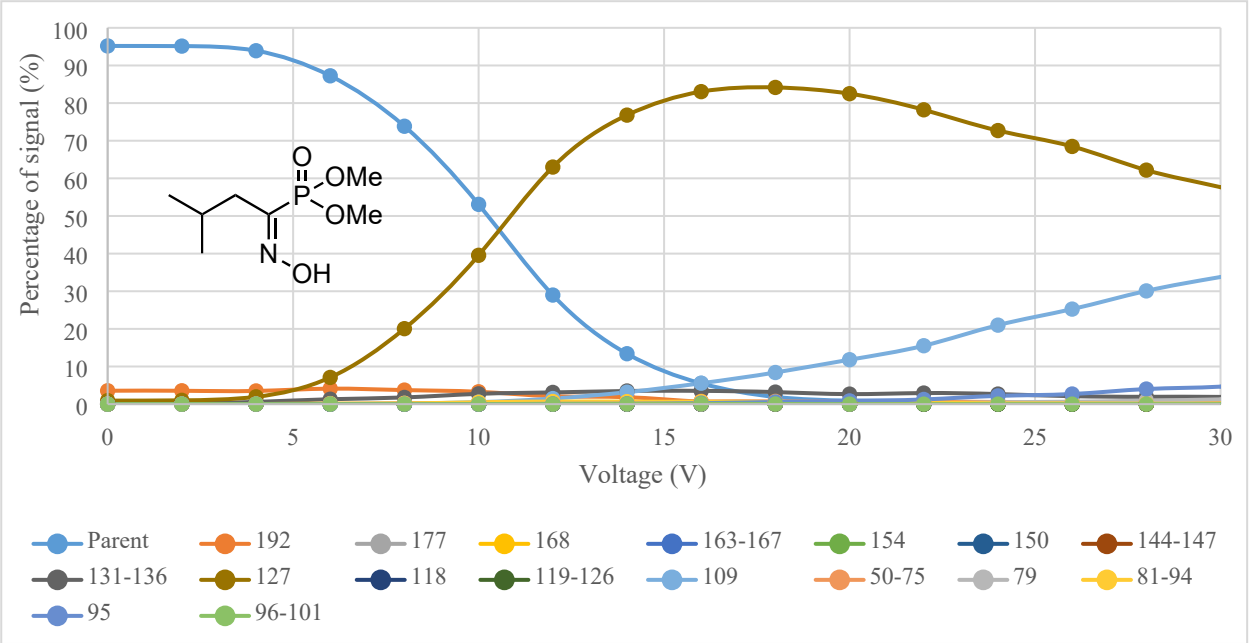


Figure S155. Breakdown curve of dimethyl (1-(hydroxyimino)-3-methylbutyl)phosphonate (**7b, Z_{iso}**).

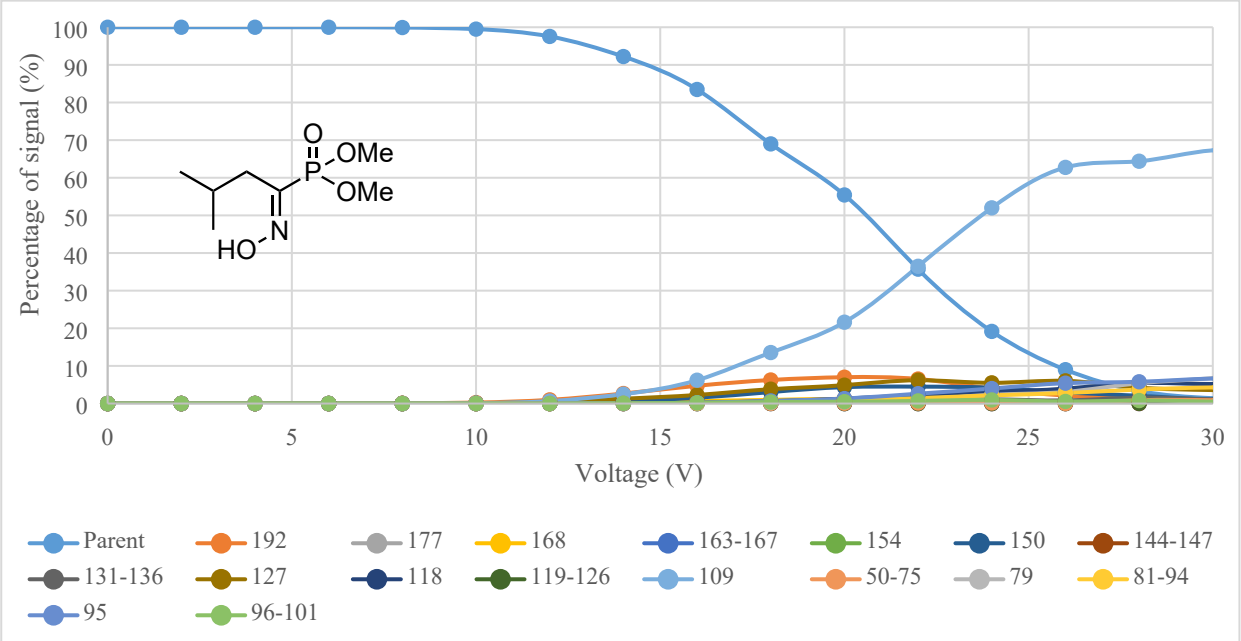


Figure S156. Breakdown curve of dimethyl (1-(hydroxyimino)-3-methylbutyl)phosphonate (**7b, E_{iso}**).

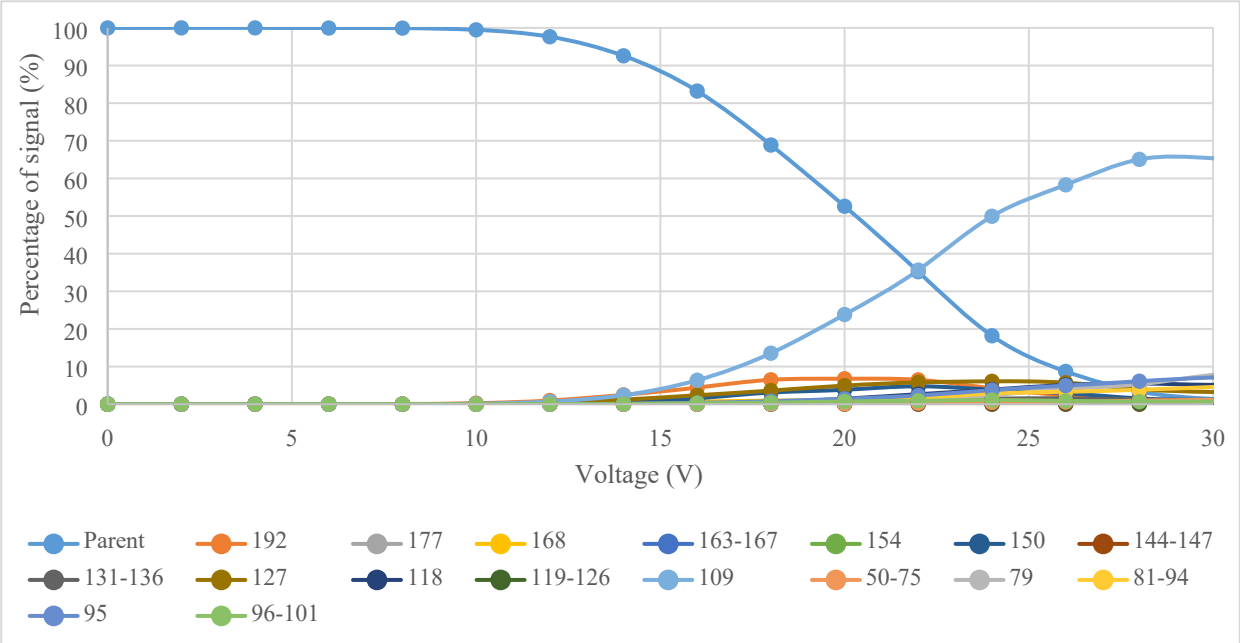


Figure S157. Breakdown curve of dimethyl (1-(hydroxyimino)-3-methylbutyl)phosphonate (**7b, Mix**).

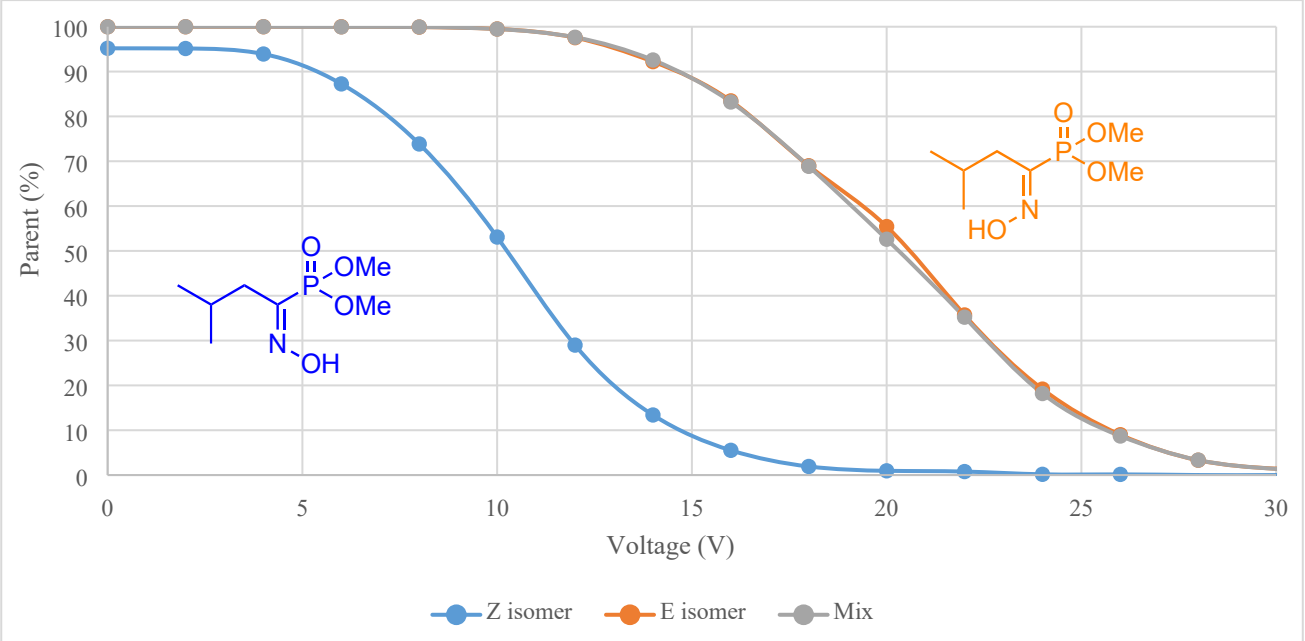


Figure S158. Survival yield of dimethyl (1-(hydroxyimino)-3-methylbutyl)phosphonate (**7b**).

3.8 Diethyl (1-(hydroxyimino)-3-methylbutyl)phosphonate (8b)

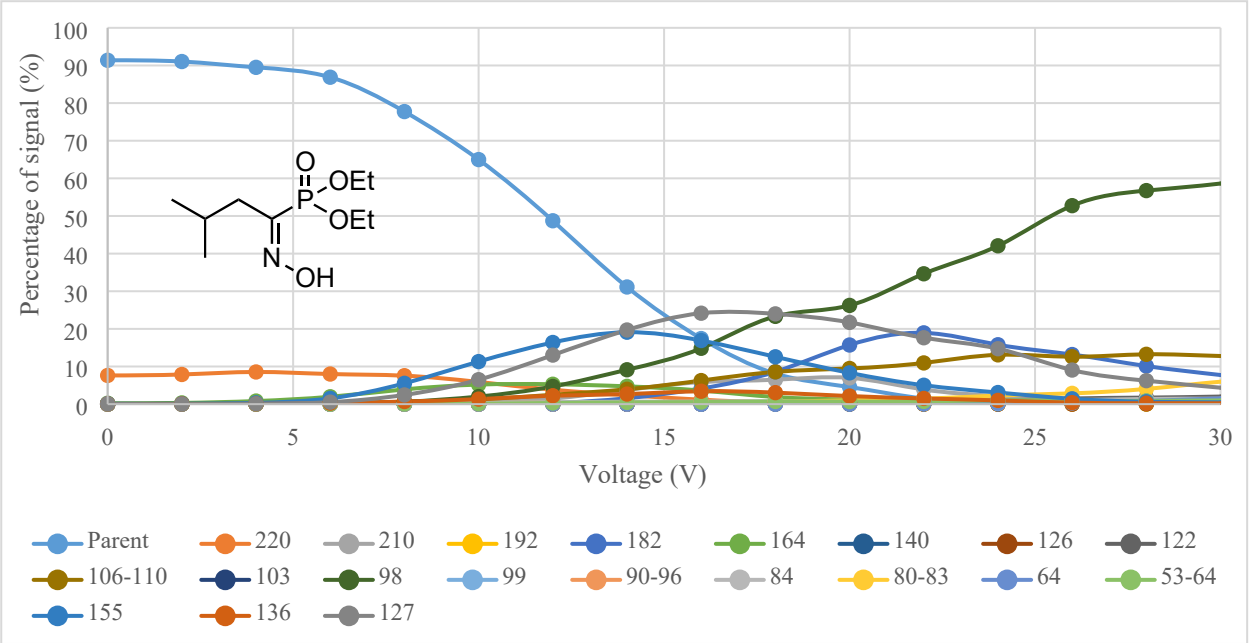


Figure S159. Breakdown curve of diethyl (1-(hydroxyimino)-3-methylbutyl)phosphonate (**8b, Z_{iso}**).

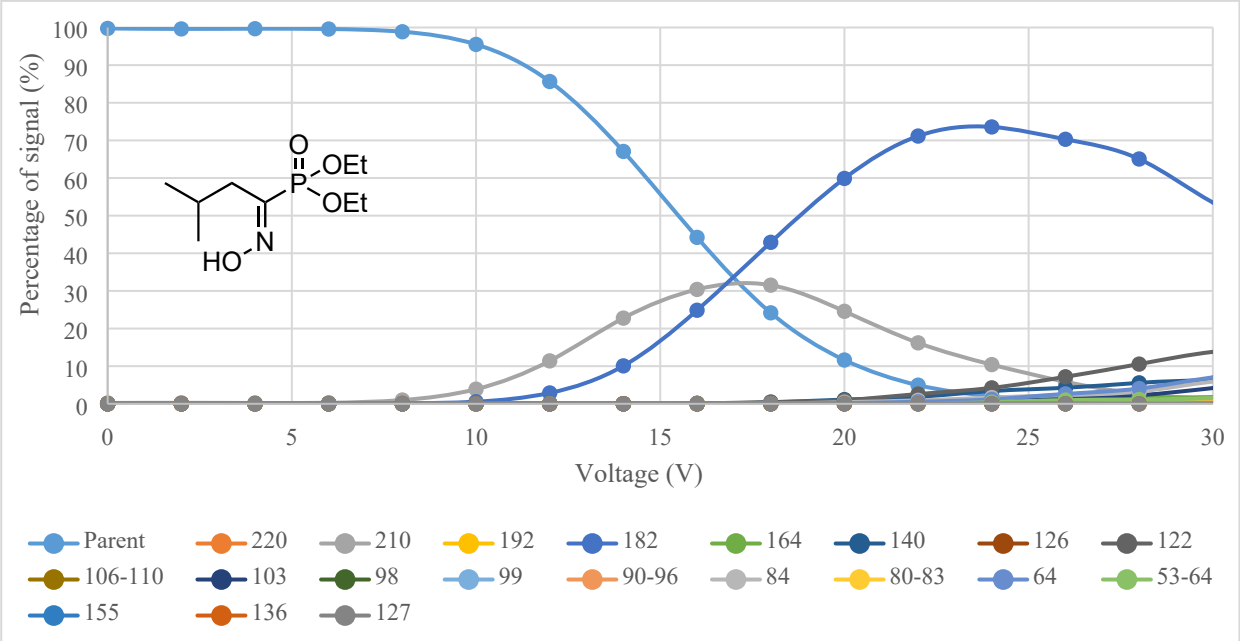


Figure S160. Breakdown curve of diethyl (1-(hydroxyimino)-3-methylbutyl)phosphonate (**8b, E_{iso}**).

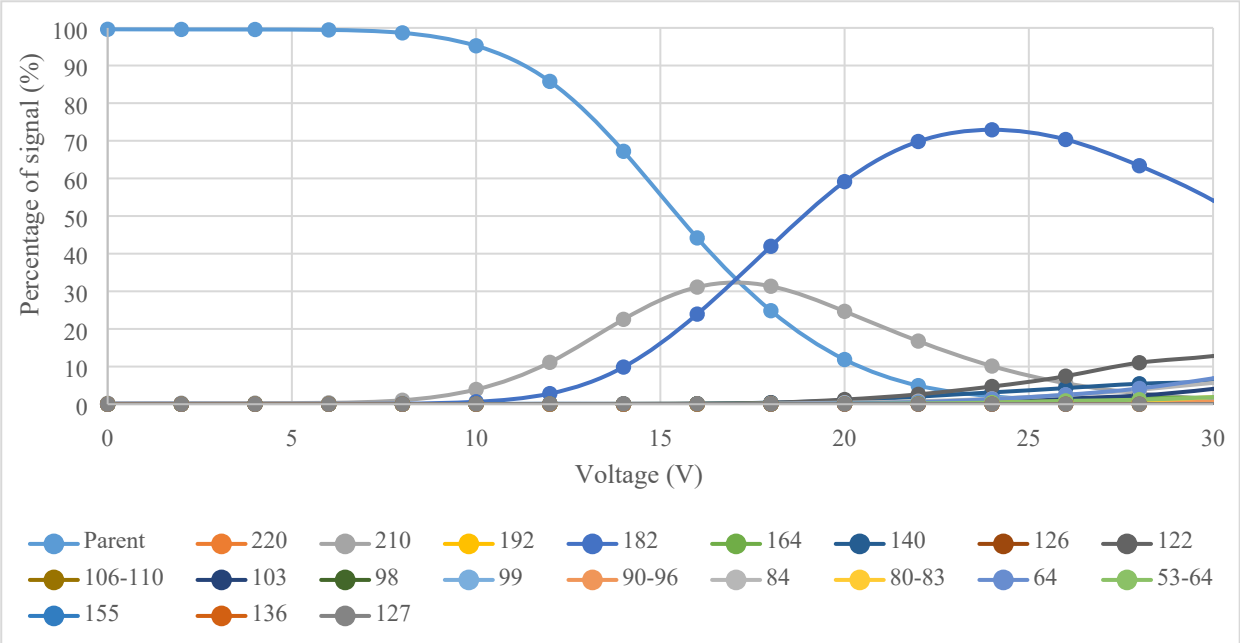


Figure S161. Breakdown curve of diethyl (1-(hydroxyimino)-3-methylbutyl)phosphonate (**8b, Mix**).

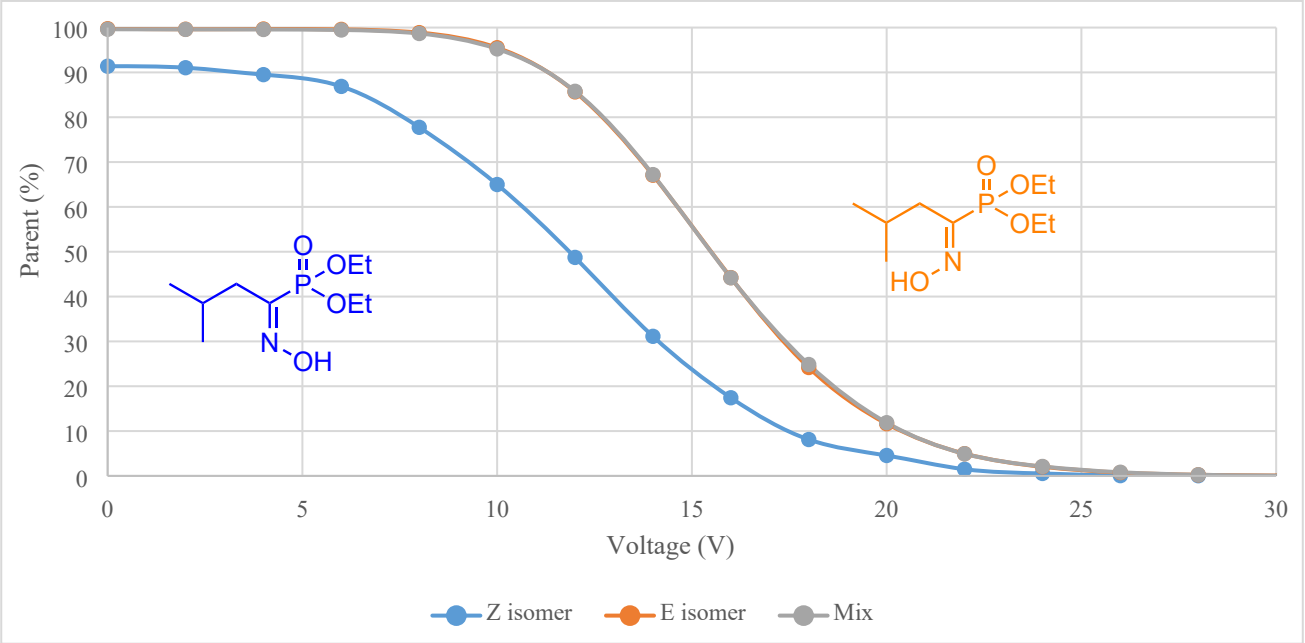


Figure S162. Survival yield of diethyl (1-(hydroxyimino)-3-methylbutyl)phosphonate (**8b**).

3.9 Diisopropyl (1-(hydroxyimino)-3-methylbutyl)phosphonate (9b)

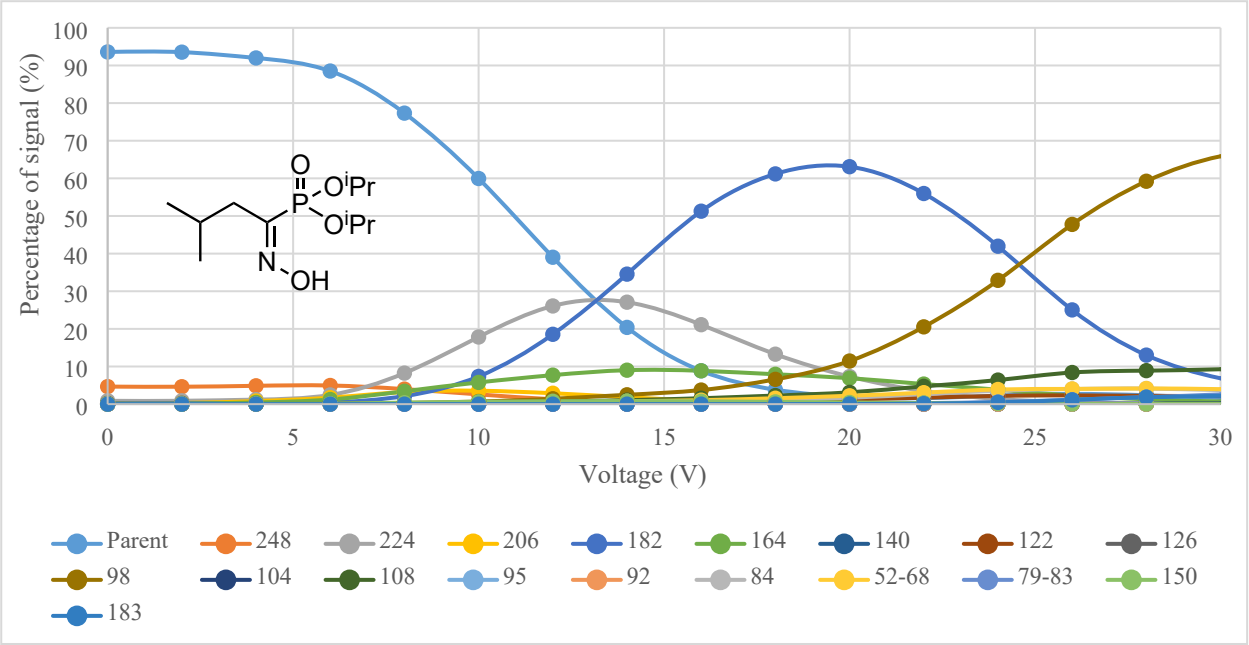


Figure S163. Breakdown curve of diisopropyl (1-(hydroxyimino)-3-methylbutyl)phosphonate (**9b, Z_{iso}**).

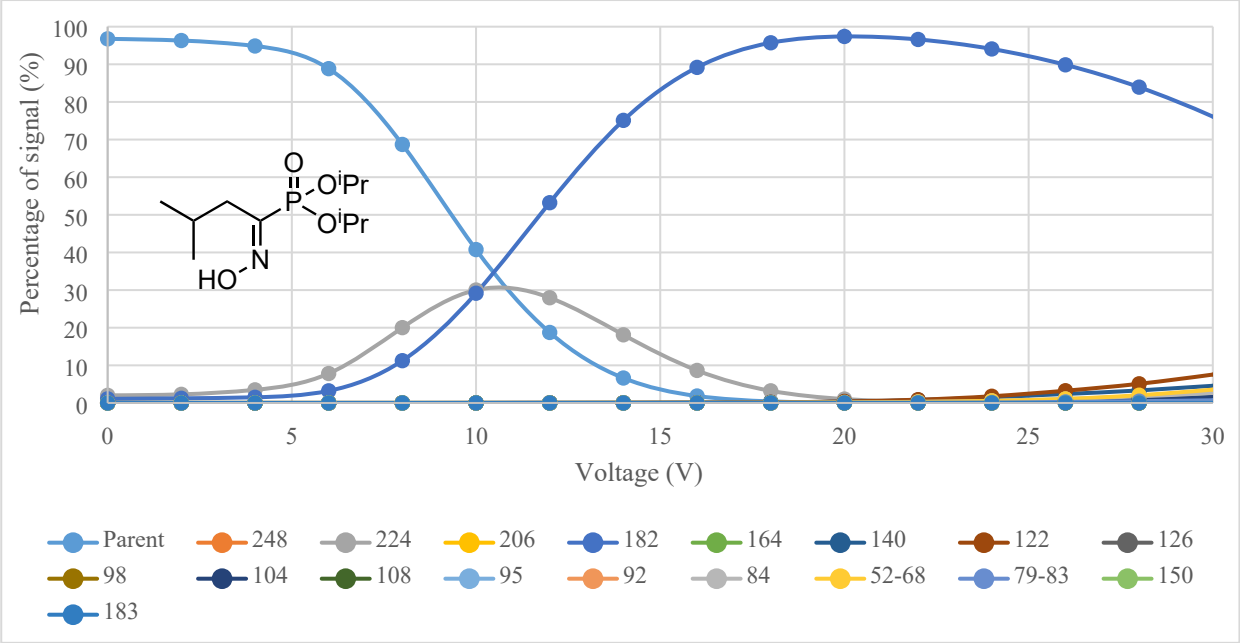


Figure S164. Breakdown curve of diisopropyl (1-(hydroxyimino)-3-methylbutyl)phosphonate (**9b, E_{iso}**).

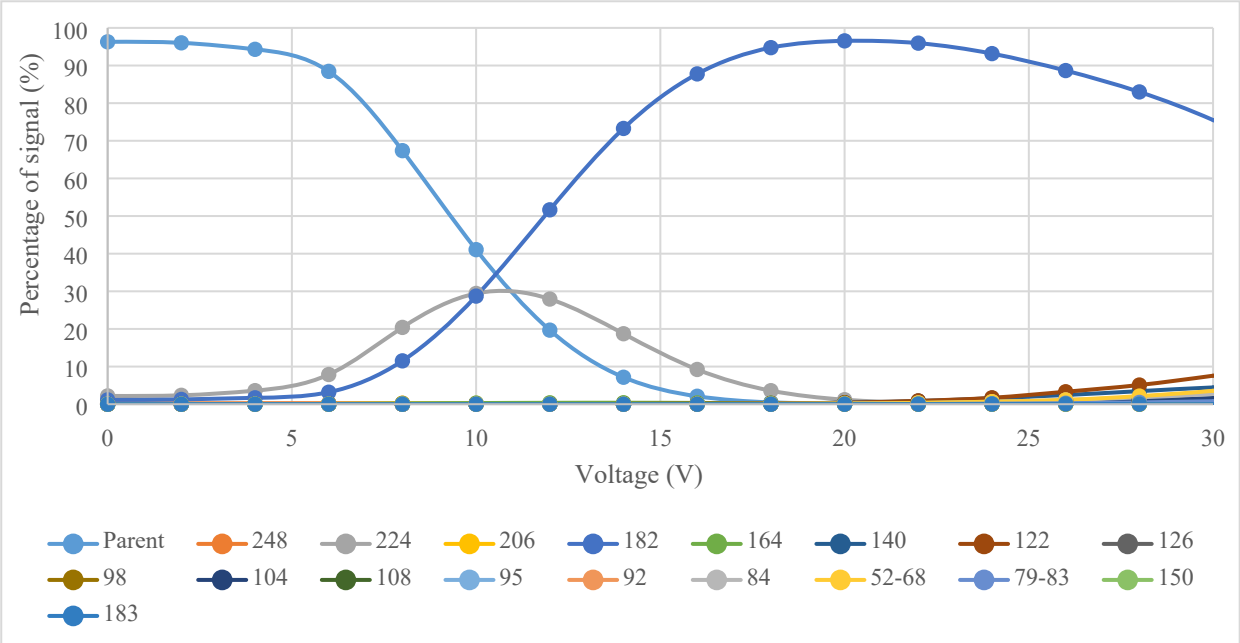


Figure S165. Breakdown curve of diisopropyl (1-(hydroxyimino)-3-methylbutyl)phosphonate (**9b, Mix**).

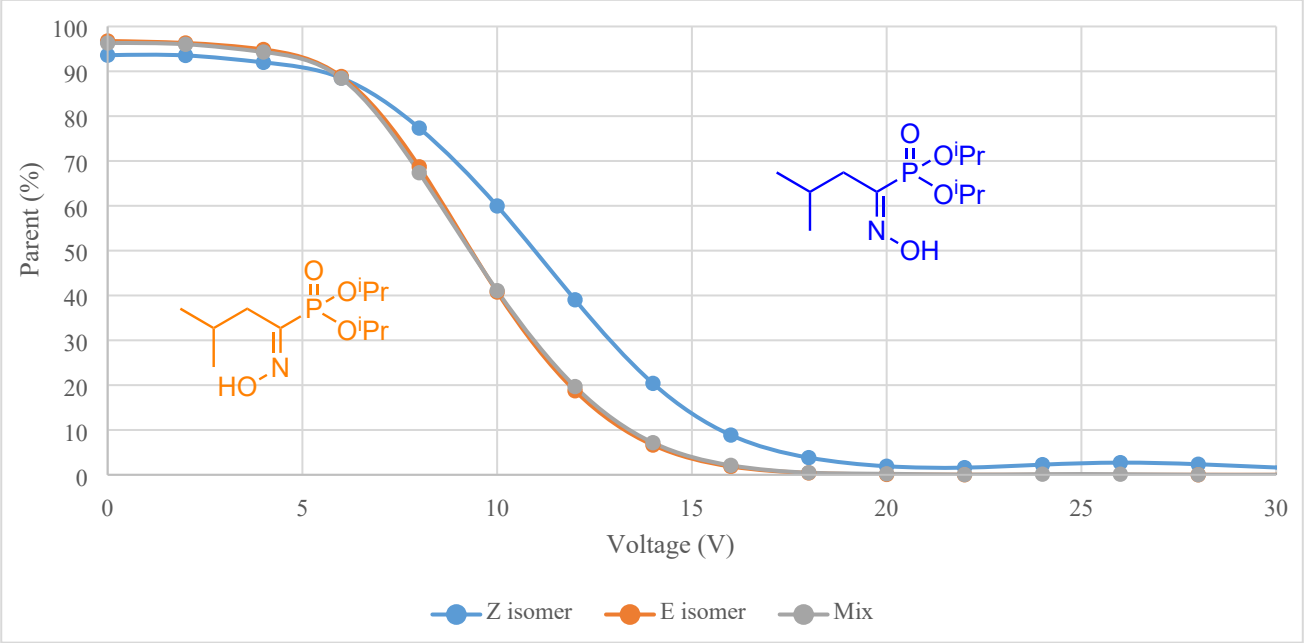


Figure S166. Survival yield of diisopropyl (1-(hydroxyimino)-3-methylbutyl)phosphonate (**9b**).

3.10 Diethyl (1-(hydroxyimino)ethyl)phosphonate (10b)

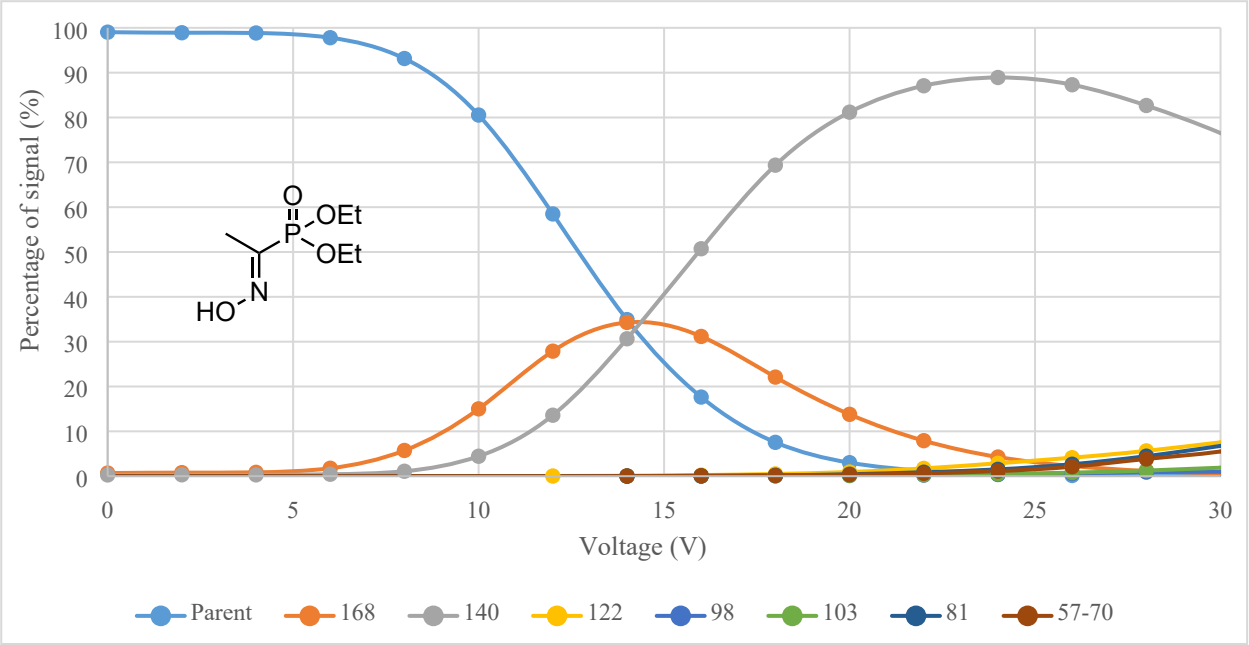


Figure S167. Breakdown curve of diethyl (1-(hydroxyimino)ethyl)phosphonate (**10b, E_{iso}**).

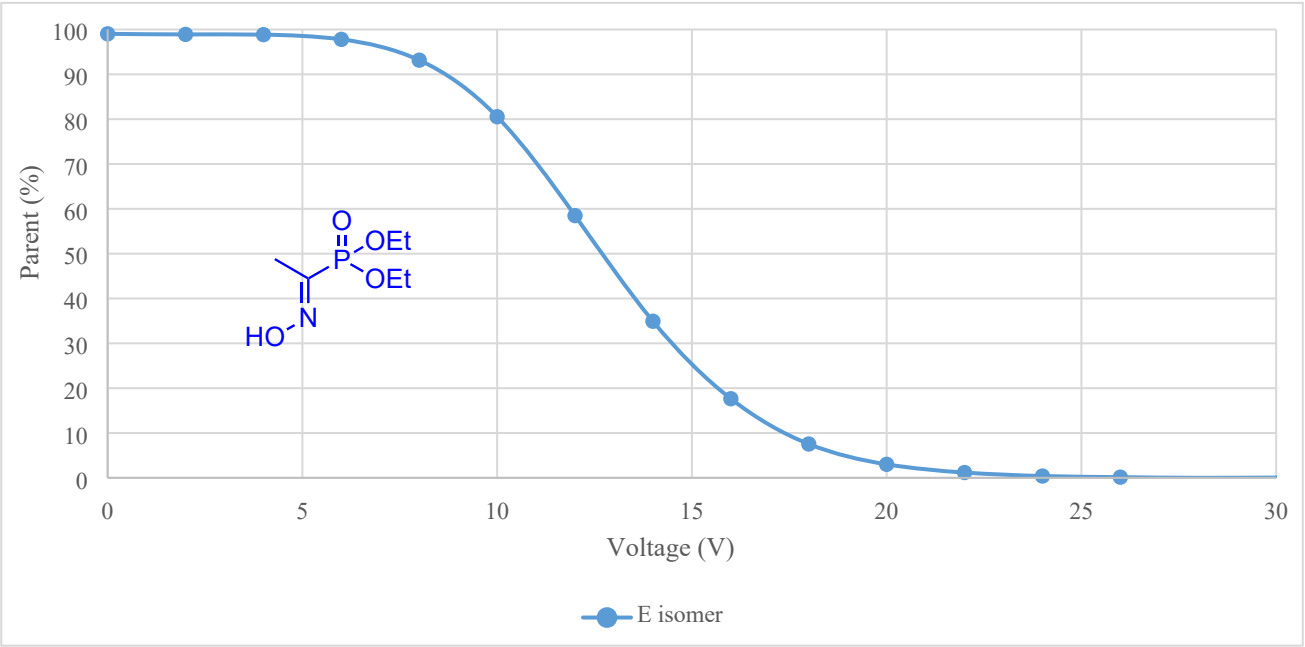


Figure S168. Survival yield of diethyl (1-(hydroxyimino)ethyl)phosphonate (**10b**).

3.11 Diethyl (1-(hydroxyimino)-2,2-dimethylpropyl)phosphonate (11b)

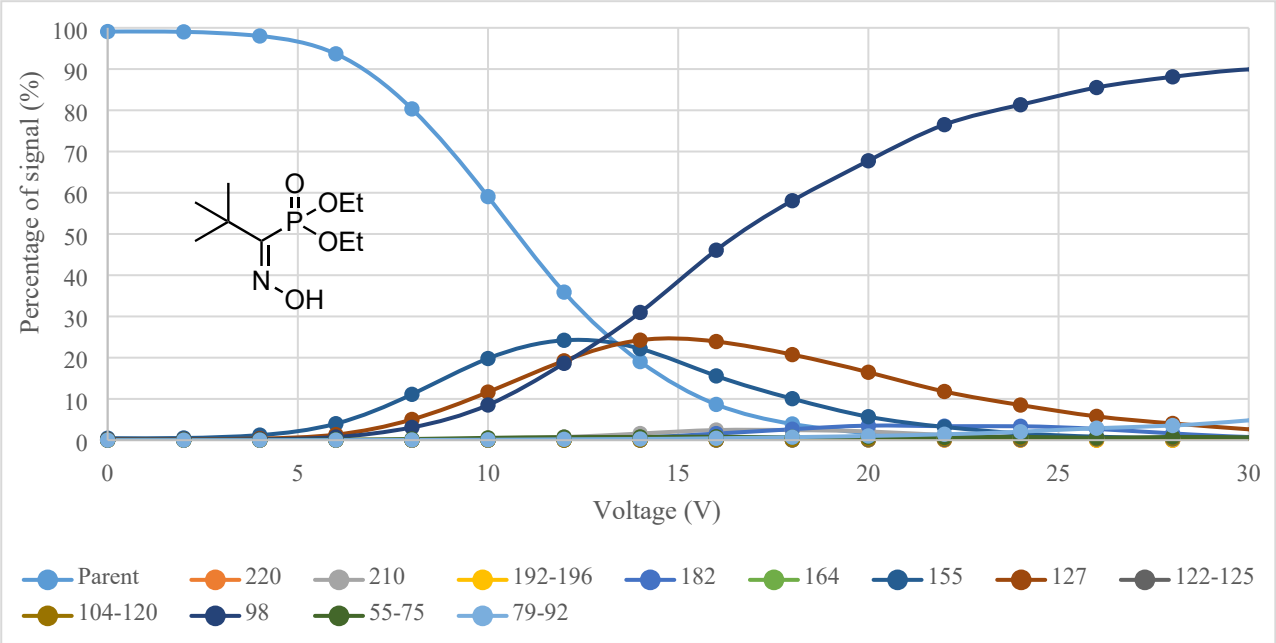


Figure S169. Breakdown curve of diethyl (1-(hydroxyimino)-2,2-dimethylpropyl)phosphonate (**11b, Z_{iso}**).

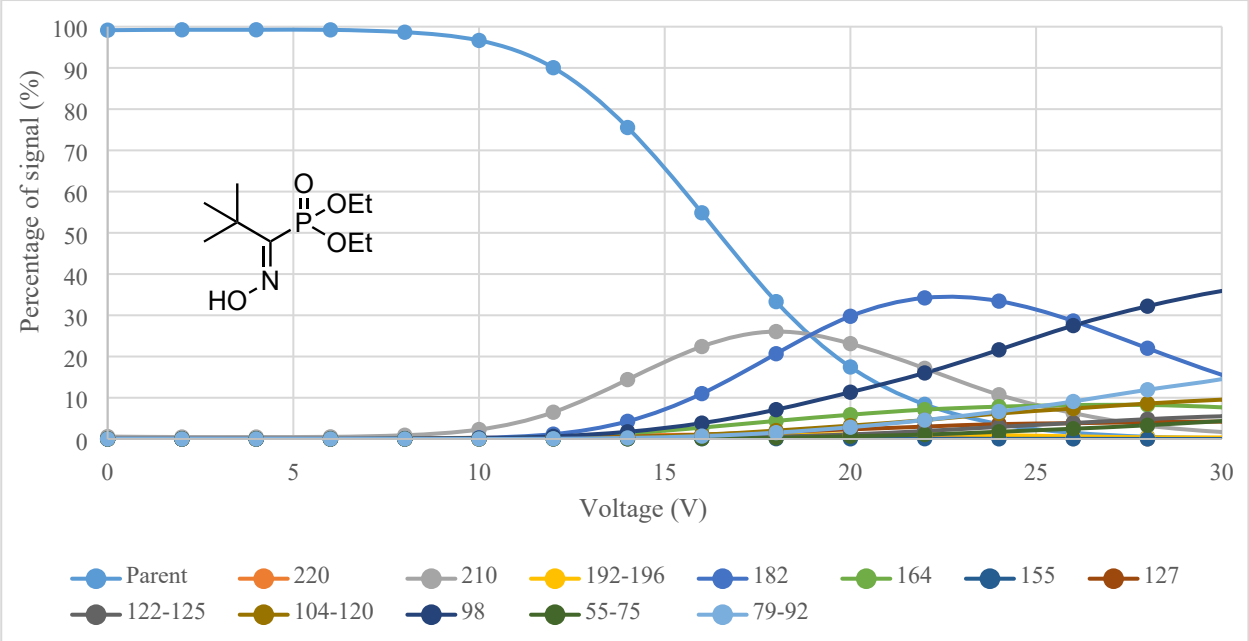


Figure S170. Breakdown curve of diethyl (1-(hydroxyimino)-2,2-dimethylpropyl)phosphonate (**11b, E_{iso}**).

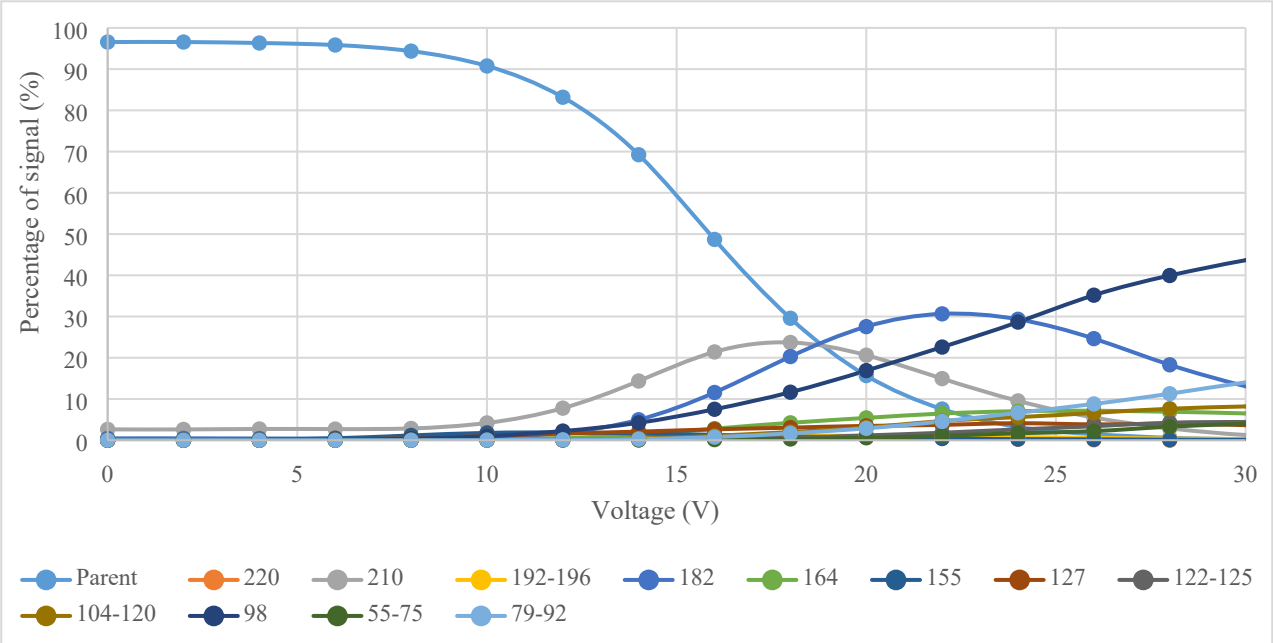


Figure S171. Breakdown curve of diethyl (1-(hydroxyimino)-2,2-dimethylpropyl)phosphonate (**11b, Mix**).

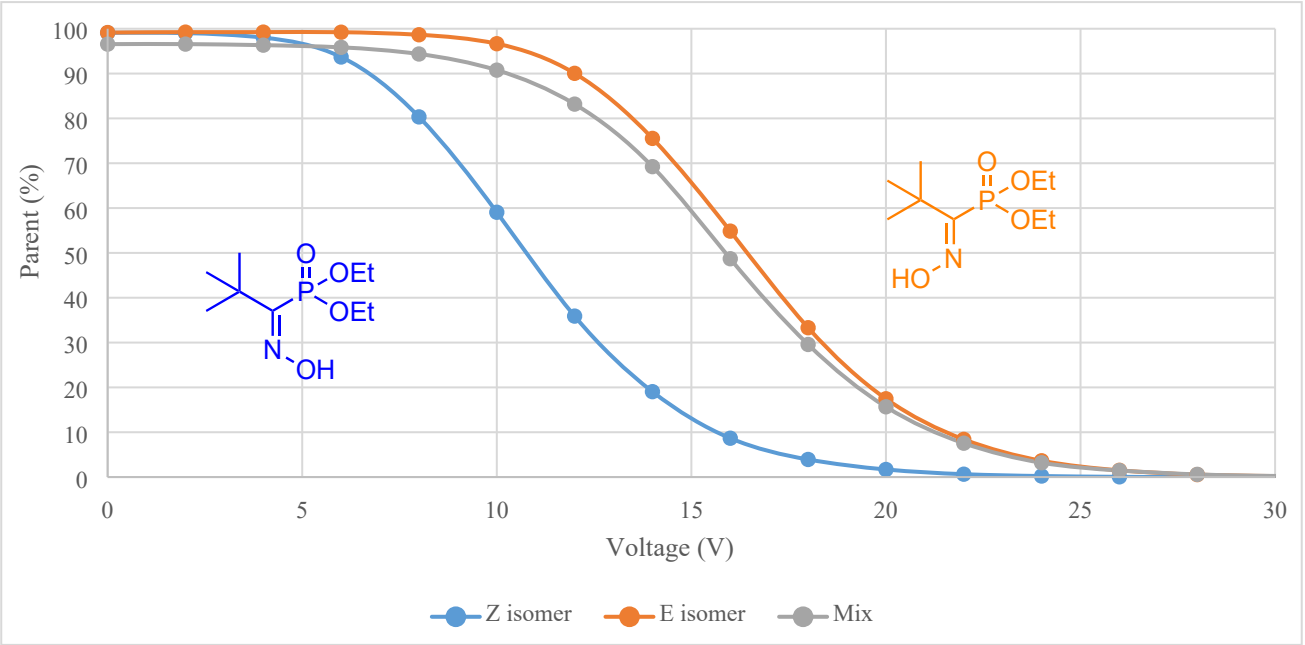


Figure S172. Survival yield of diethyl (1-(hydroxyimino)-2,2-dimethylpropyl)phosphonate (**11b**).

3.12 Diethyl (1-(hydroxyimino)-2-methylbutyl)phosphonate (12b)

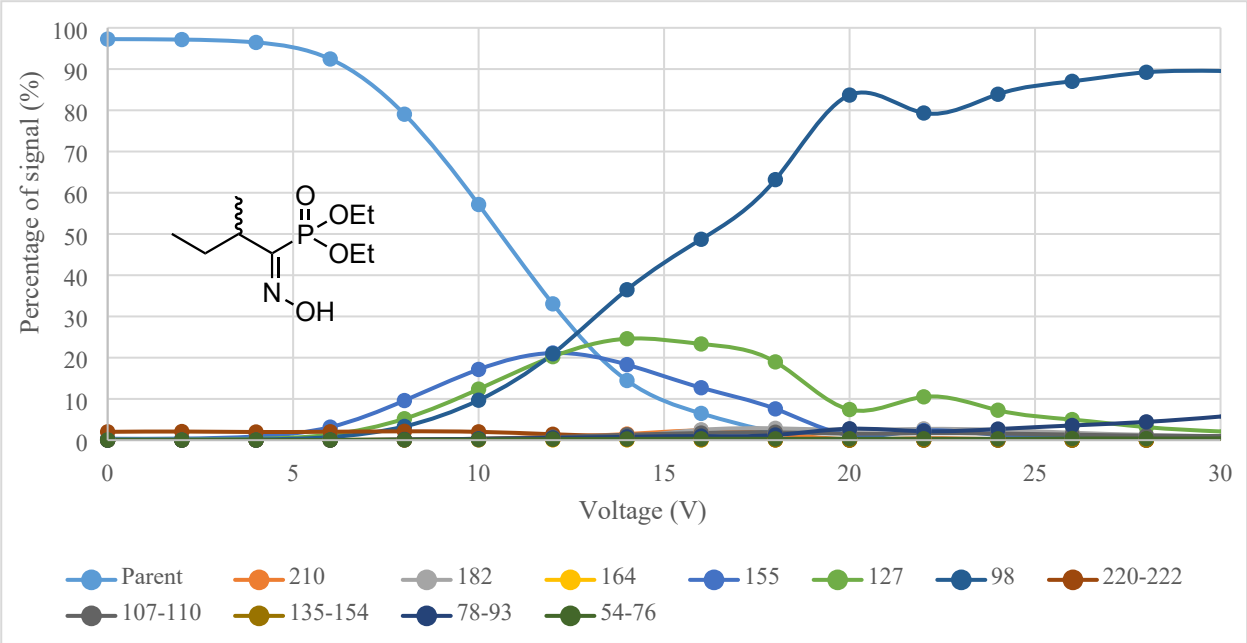


Figure S173. Breakdown curve of diethyl (1-(hydroxyimino)-2-methylbutyl)phosphonate (**12b, Z_{iso}**).

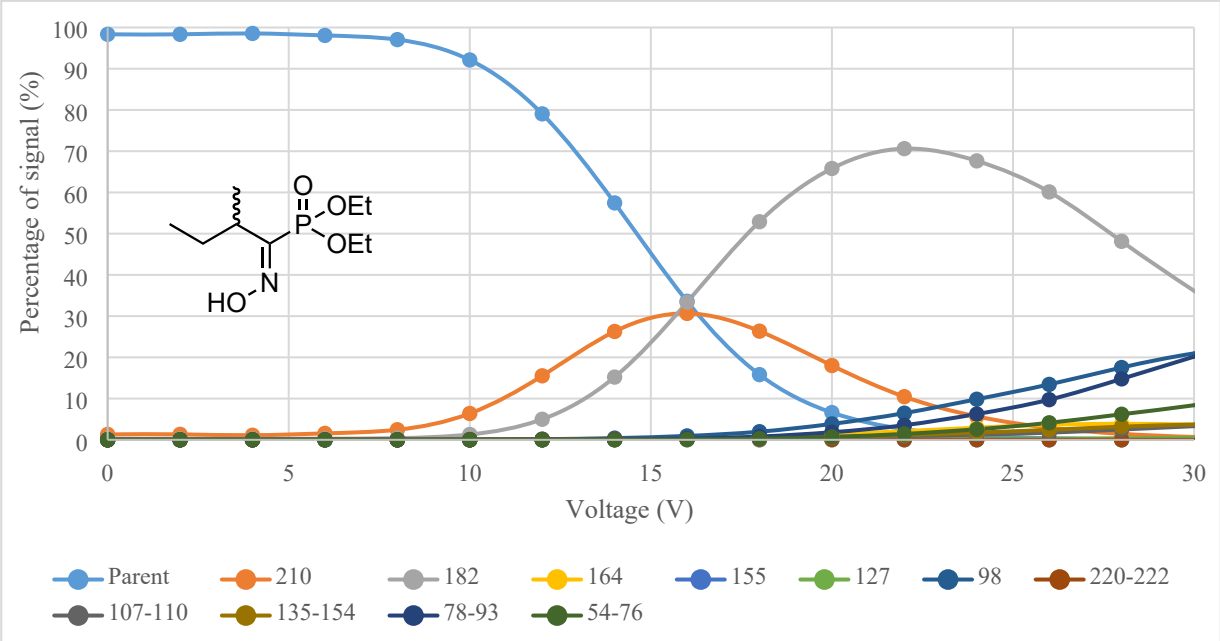


Figure S174. Breakdown curve of diethyl (1-(hydroxyimino)-2-methylbutyl)phosphonate (**12b, E_{iso}**).

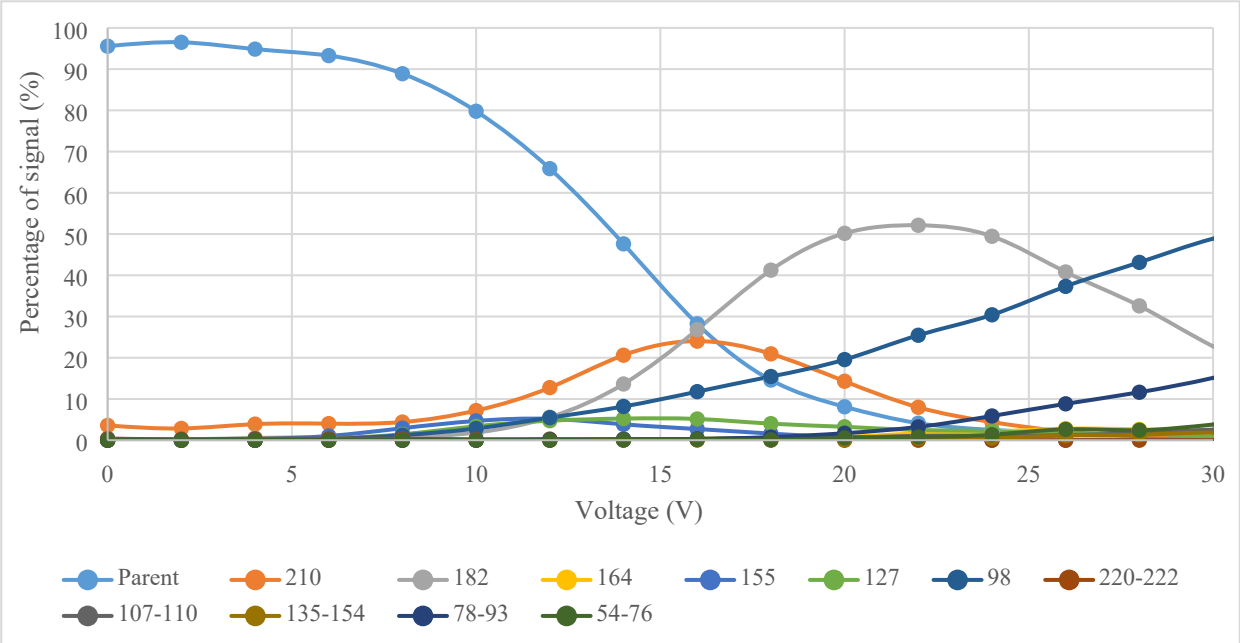


Figure S175. Breakdown curve of diethyl (1-(hydroxyimino)-2-methylbutyl)phosphonate (**12b, Mix**).

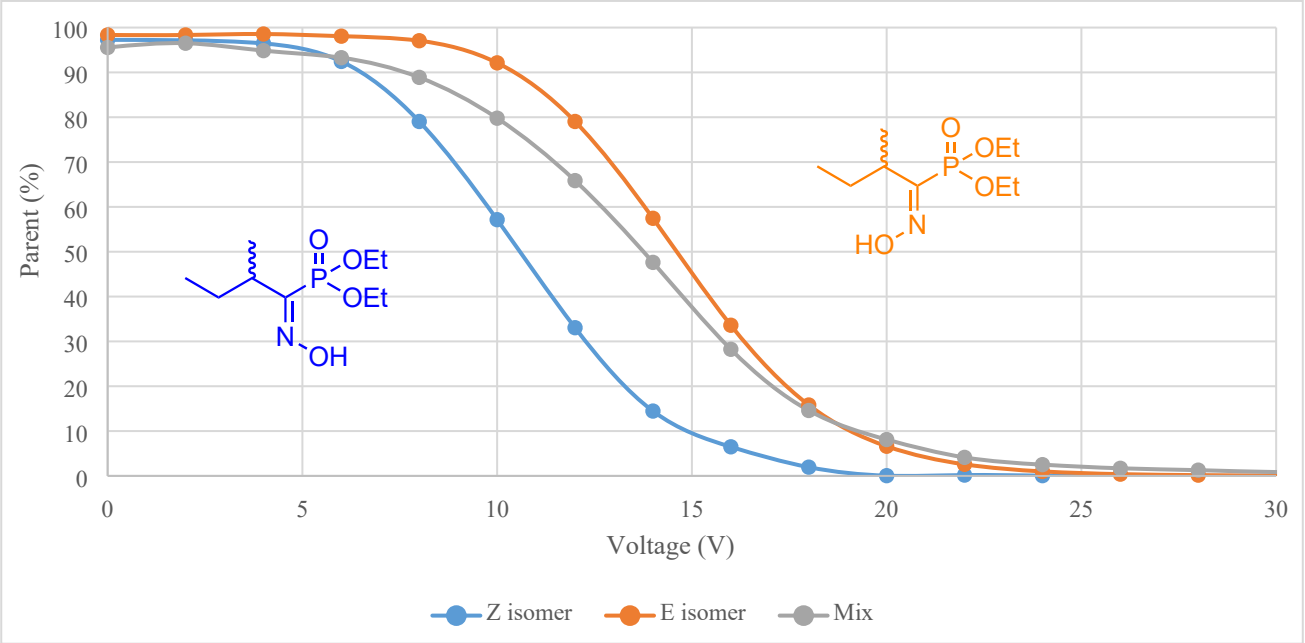


Figure S176. Survival yield of diethyl (1-(hydroxyimino)-2-methylbutyl)phosphonate (**12b**).

3.13 Diethyl (1-(hydroxyimino)-2-(4-methoxyphenyl)ethyl)phosphonate (13b)

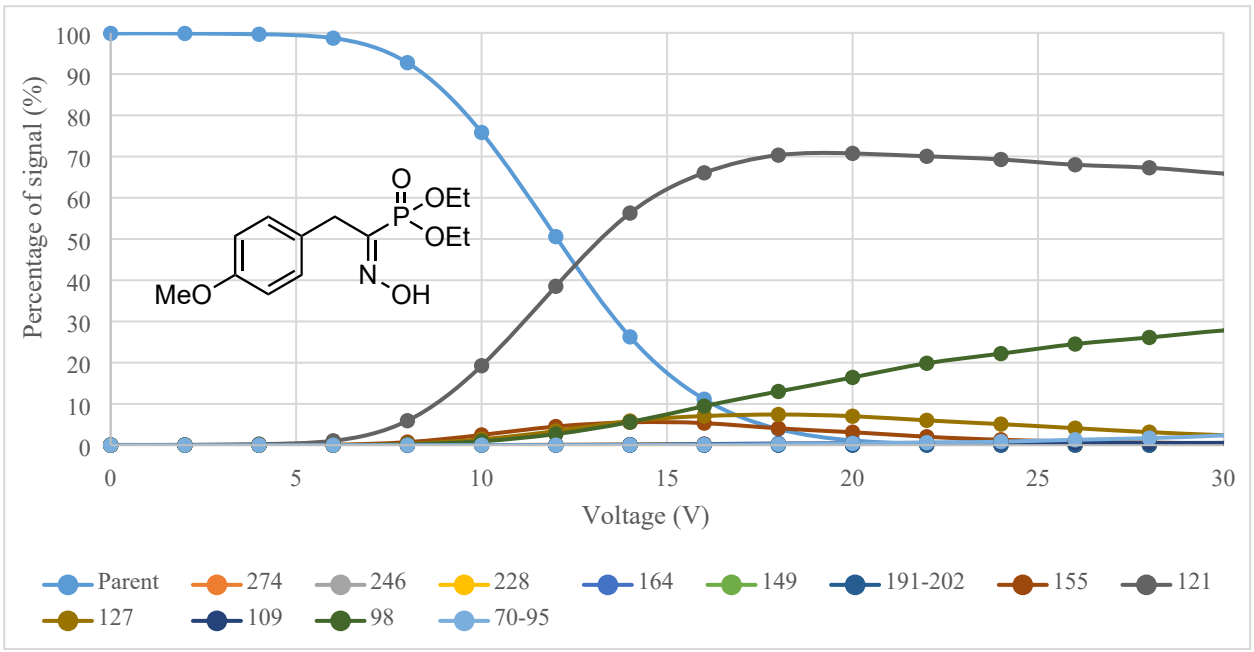


Figure S177. Breakdown curve of diethyl (1-(hydroxyimino)-2-(4-methoxyphenyl)ethyl)phosphonate (**13b, Z_{iso}**).

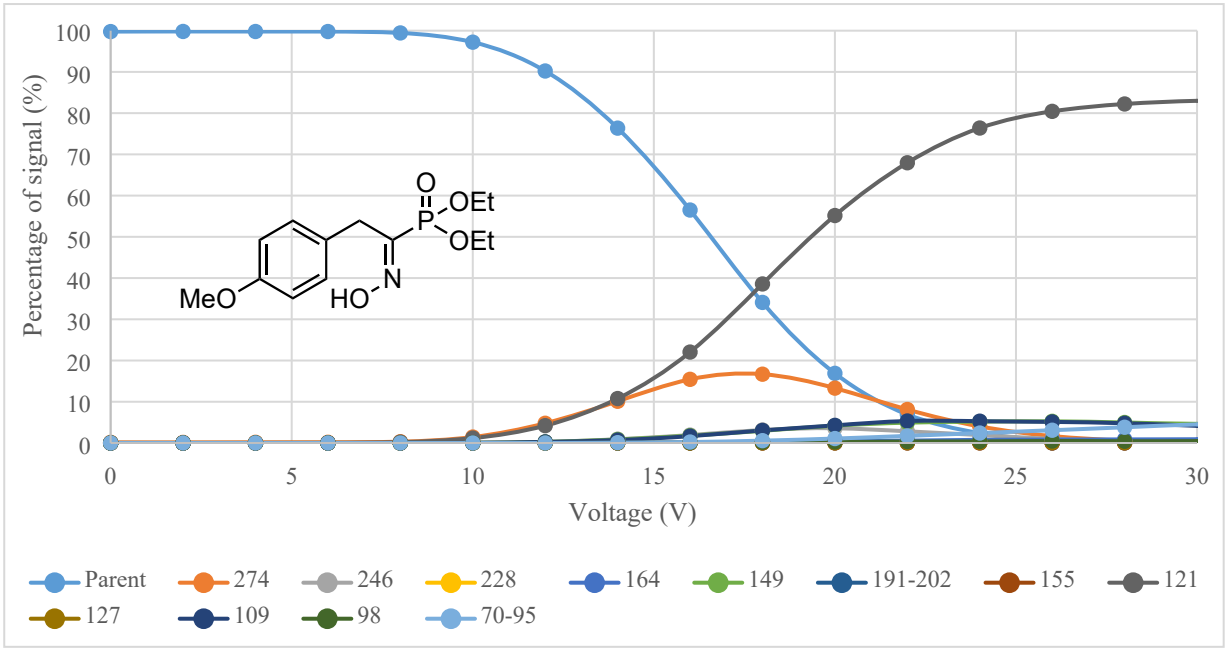


Figure S178. Breakdown curve of diethyl (1-(hydroxyimino)-2-(4-methoxyphenyl)ethyl)phosphonate (**13b, E_{iso}**).

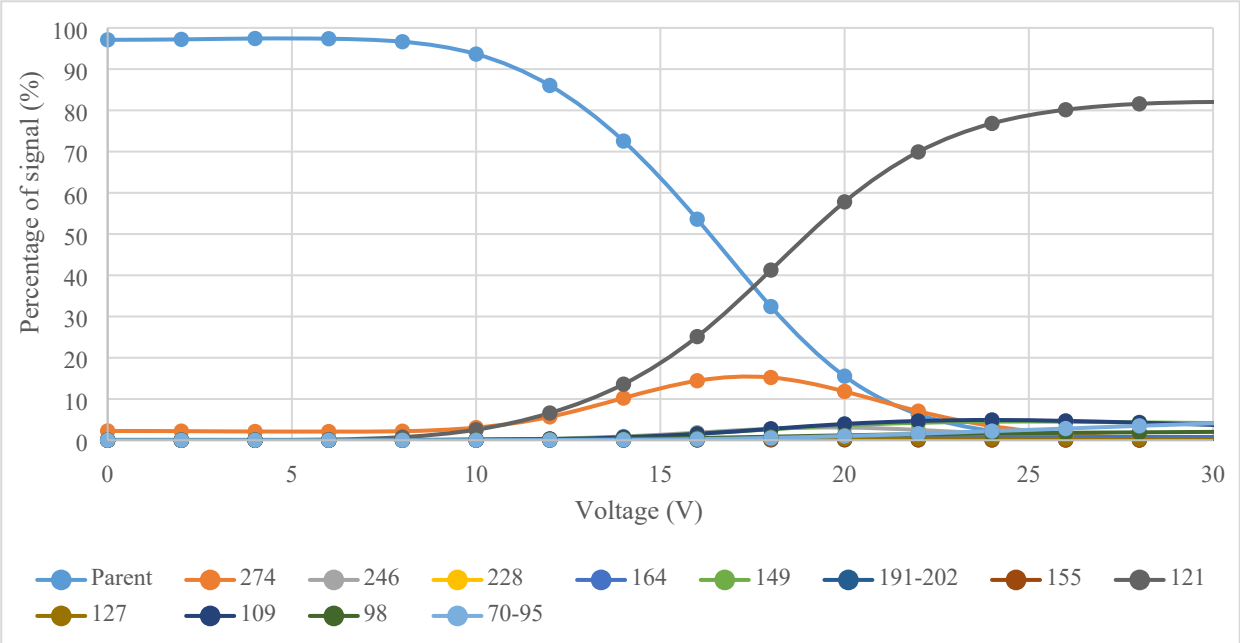


Figure S179. Breakdown curve of diethyl (1-(hydroxyimino)-2-(4-methoxyphenyl)ethyl)phosphonate (**13b, Mix**).

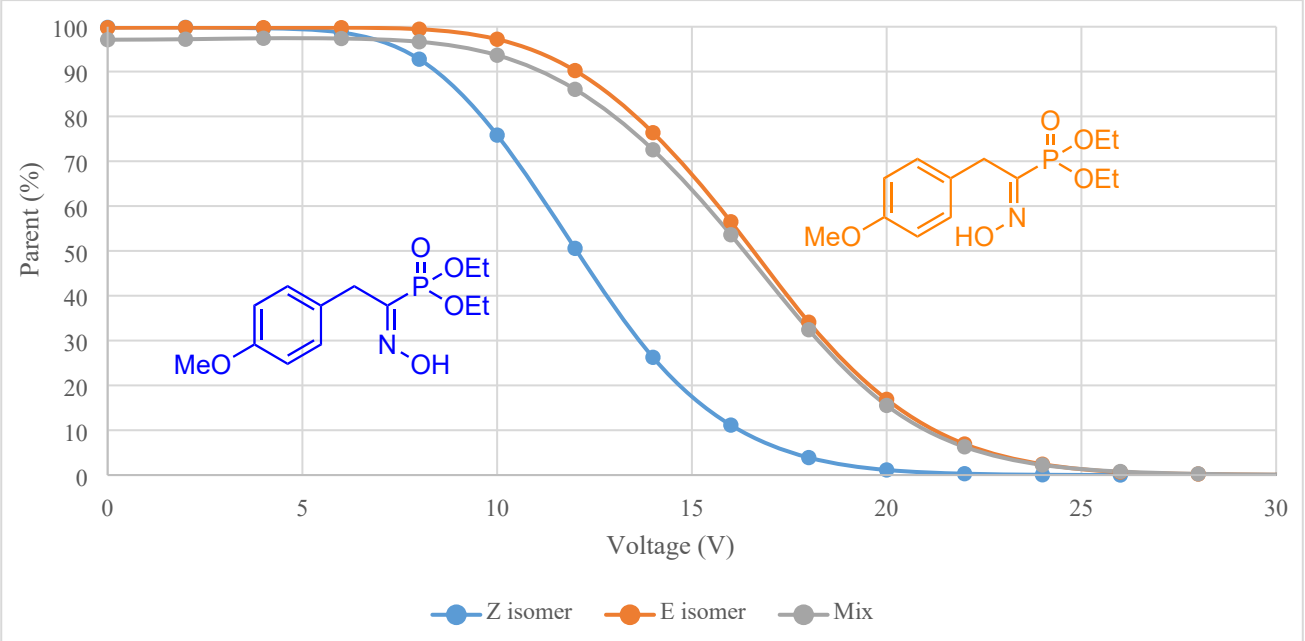


Figure S180. Survival yield of diethyl (1-(hydroxyimino)-2-(4-methoxyphenyl)ethyl)phosphonate (**13b**).

3.14 Diethyl (1-(hydroxyimino)-3-(methylthio)propyl)phosphonate (14b)

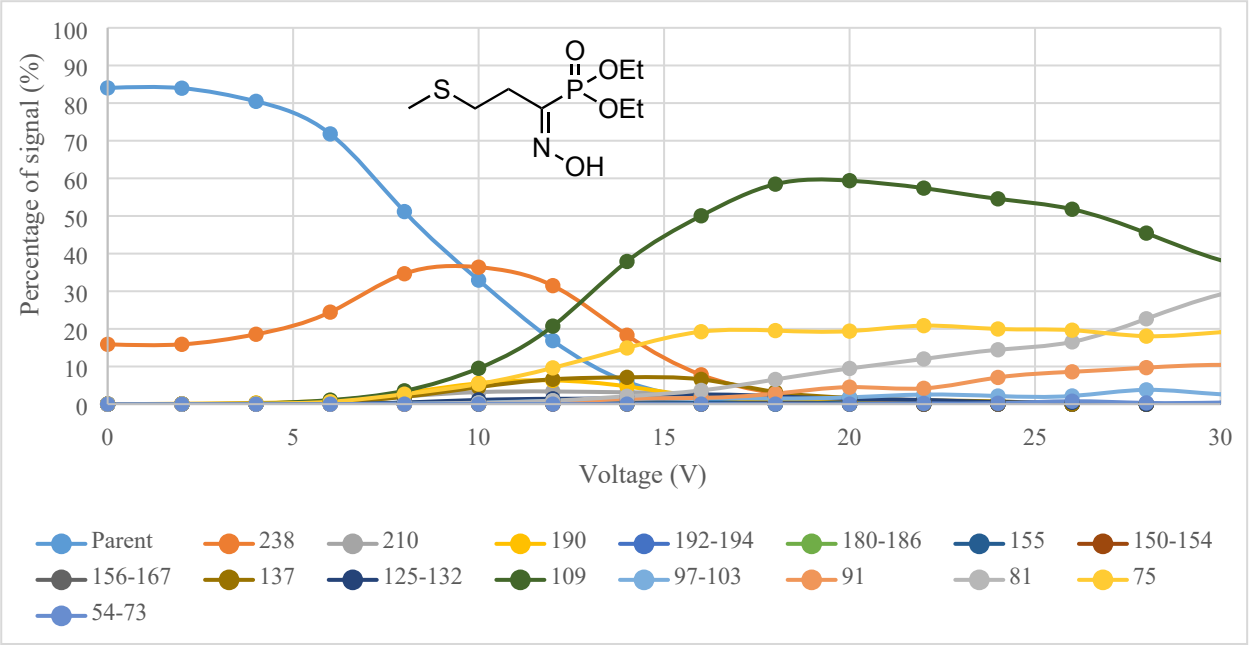


Figure S181. Breakdown curve of diethyl (1-(hydroxyimino)-3-(methylthio)propyl)phosphonate (**14b, Z_{iso}**).

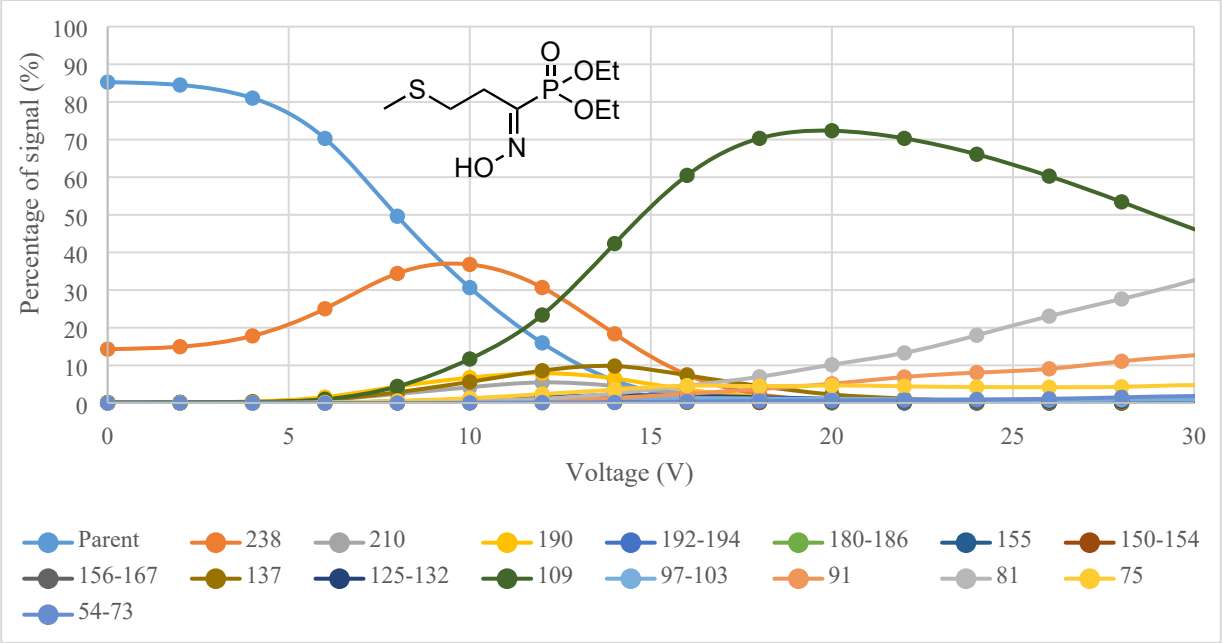


Figure S182. Breakdown curve of diethyl (1-(hydroxyimino)-3-(methylthio)propyl)phosphonate (**14b, E_{iso}**).

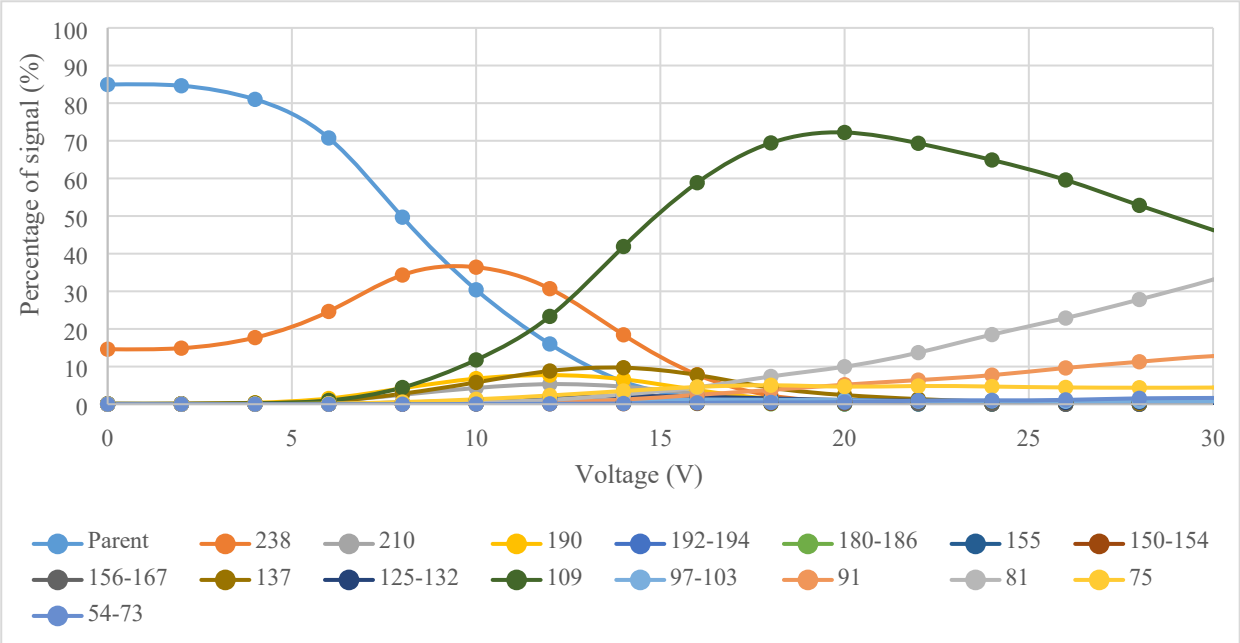


Figure S183. Breakdown curve of diethyl (1-(hydroxyimino)-3-(methylthio)propyl)phosphonate (**14b, Mix**).

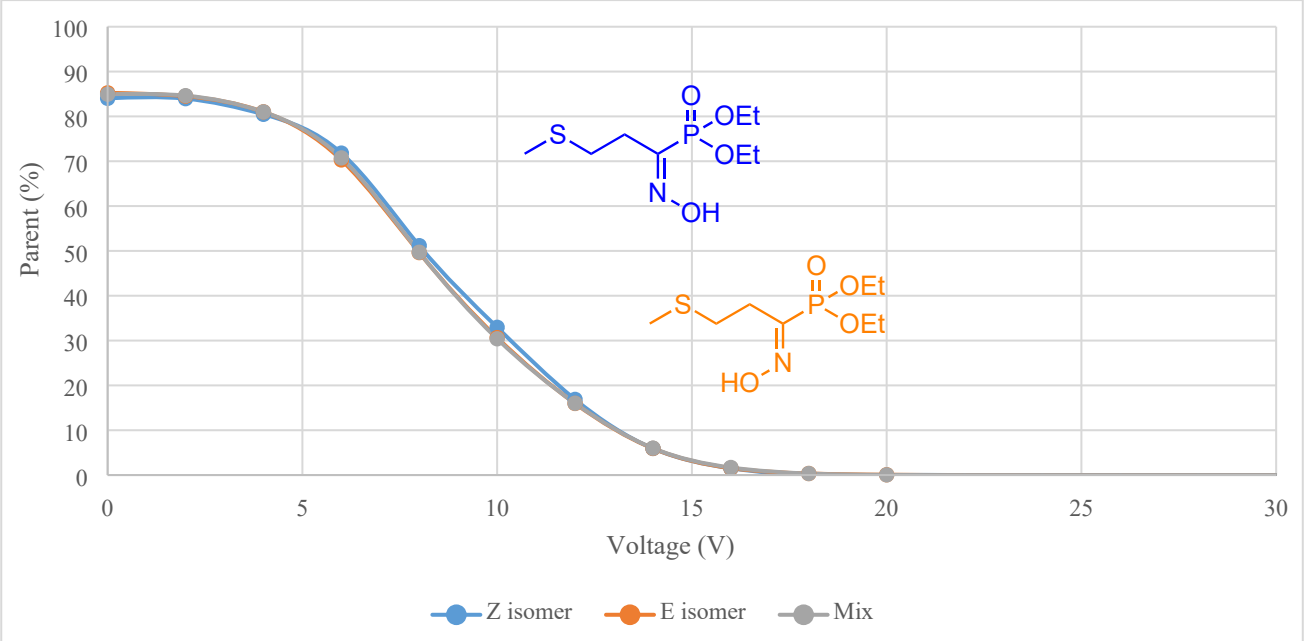


Figure S184. Survival yield of diethyl (1-(hydroxyimino)-3-(methylthio)propyl)phosphonate (**14b**).

3.15 Diethyl (1-(hydroxyimino)-2-(phenylthio)ethyl)phosphonate (15b)

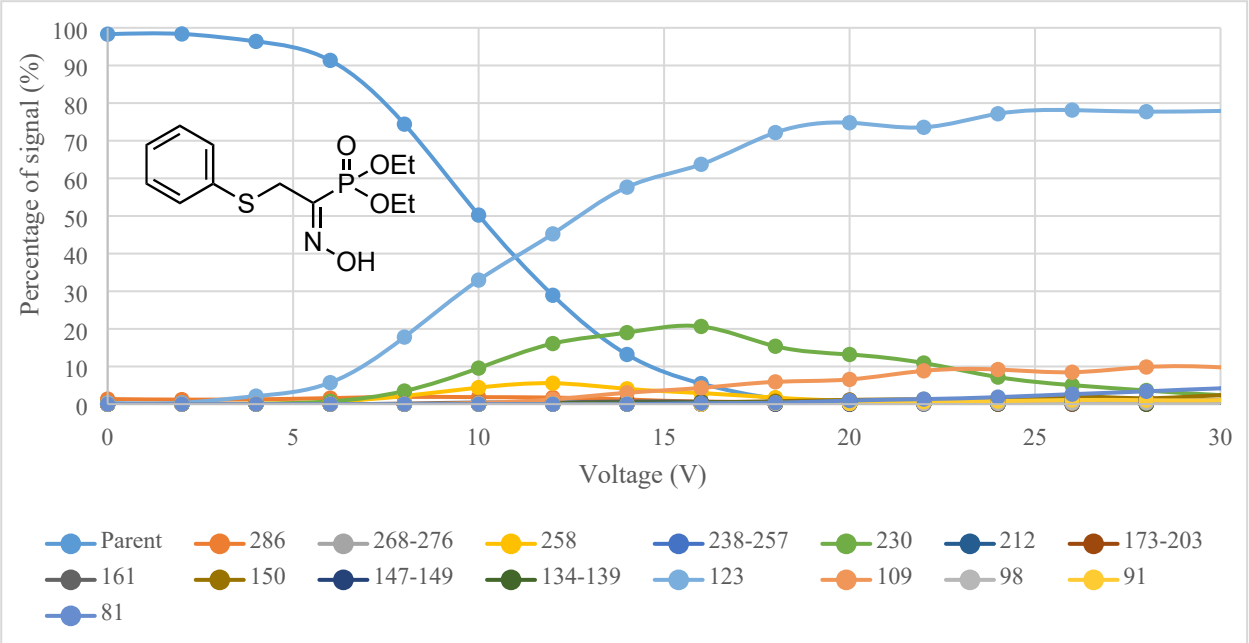


Figure S185. Breakdown curve of diethyl (1-(hydroxyimino)-2-(phenylthio)ethyl)phosphonate (**15b, Z_{iso}**).

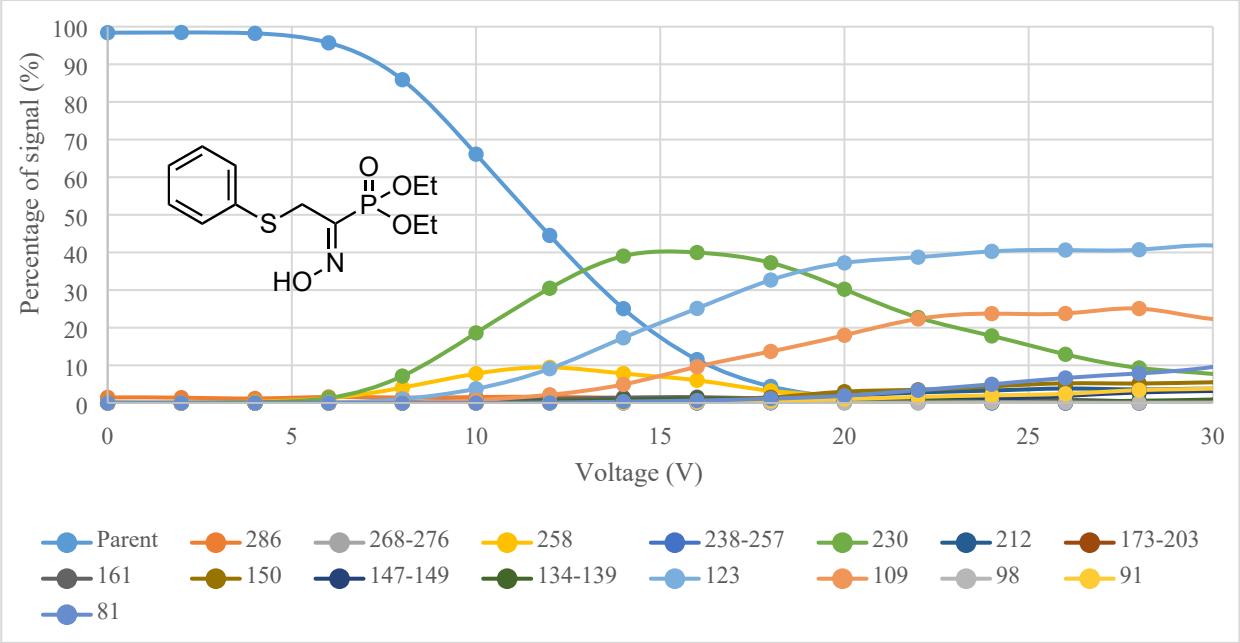


Figure S186. Breakdown curve of diethyl (1-(hydroxyimino)-2-(phenylthio)ethyl)phosphonate (**15b, E_{iso}**).

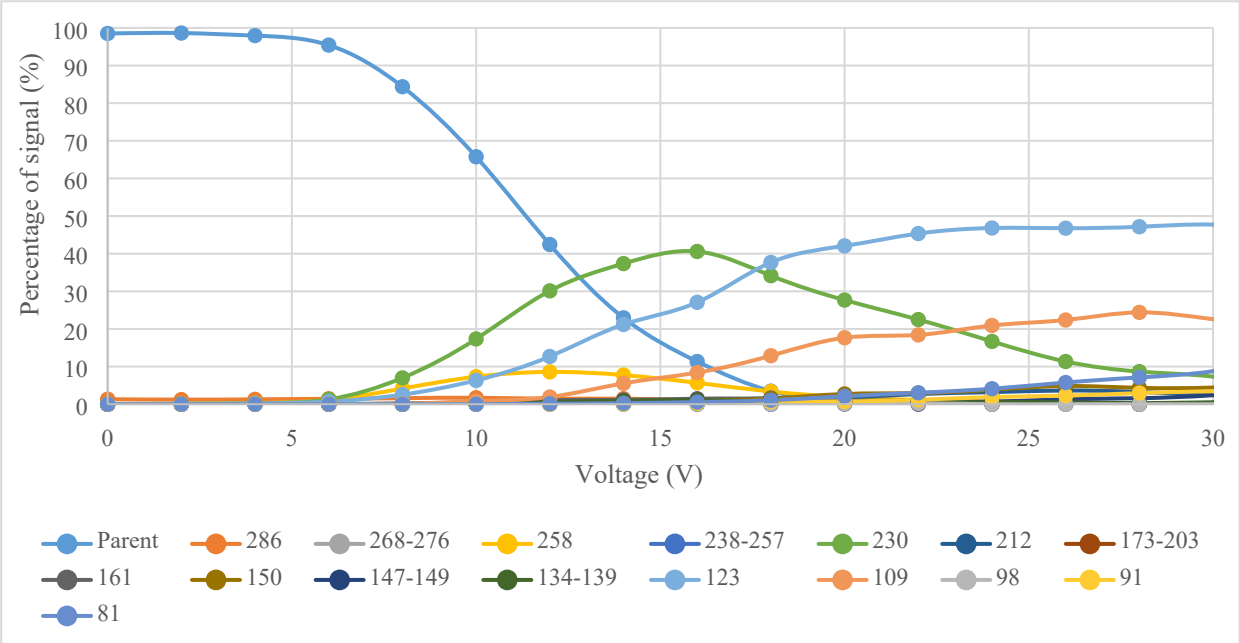


Figure S187. Breakdown curve of diethyl (1-(hydroxyimino)-2-(phenylthio)ethyl)phosphonate (**15b, Mix**).

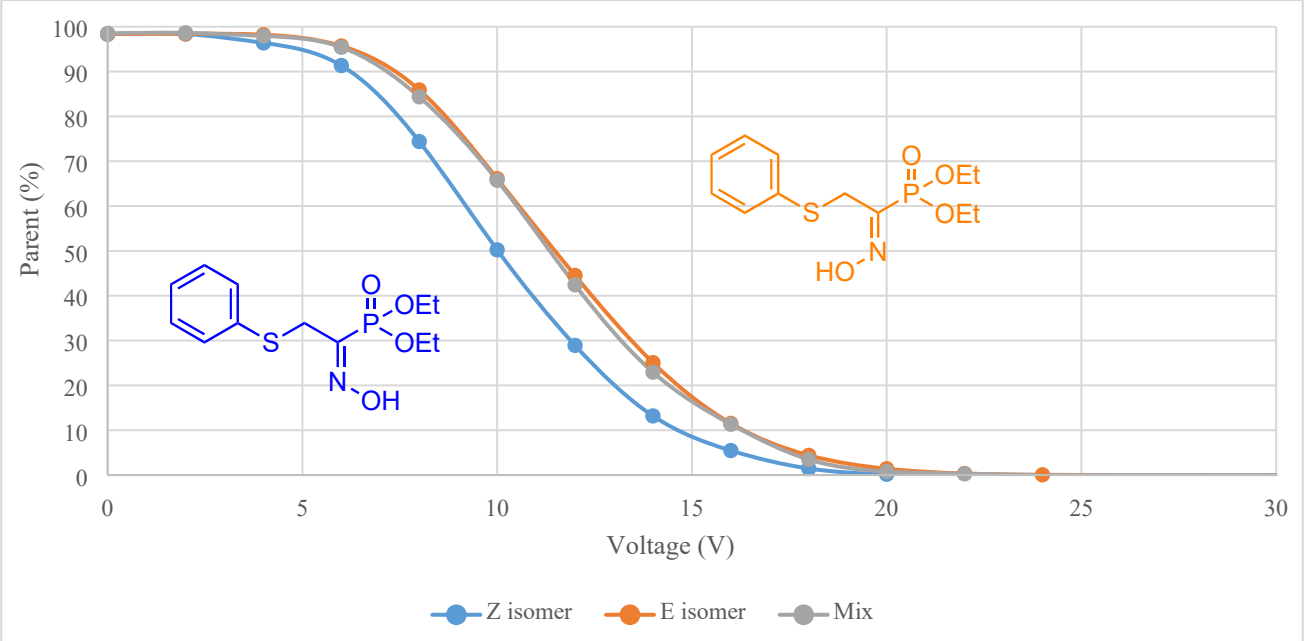


Figure S188. Survival yield of diethyl (1-(hydroxyimino)-2-(phenylthio)ethyl)phosphonate (**15b**).

3.16 Diethyl (1-(hydroxyimino)-2-(1H-indol-3-yl)ethyl)phosphonate (16b)

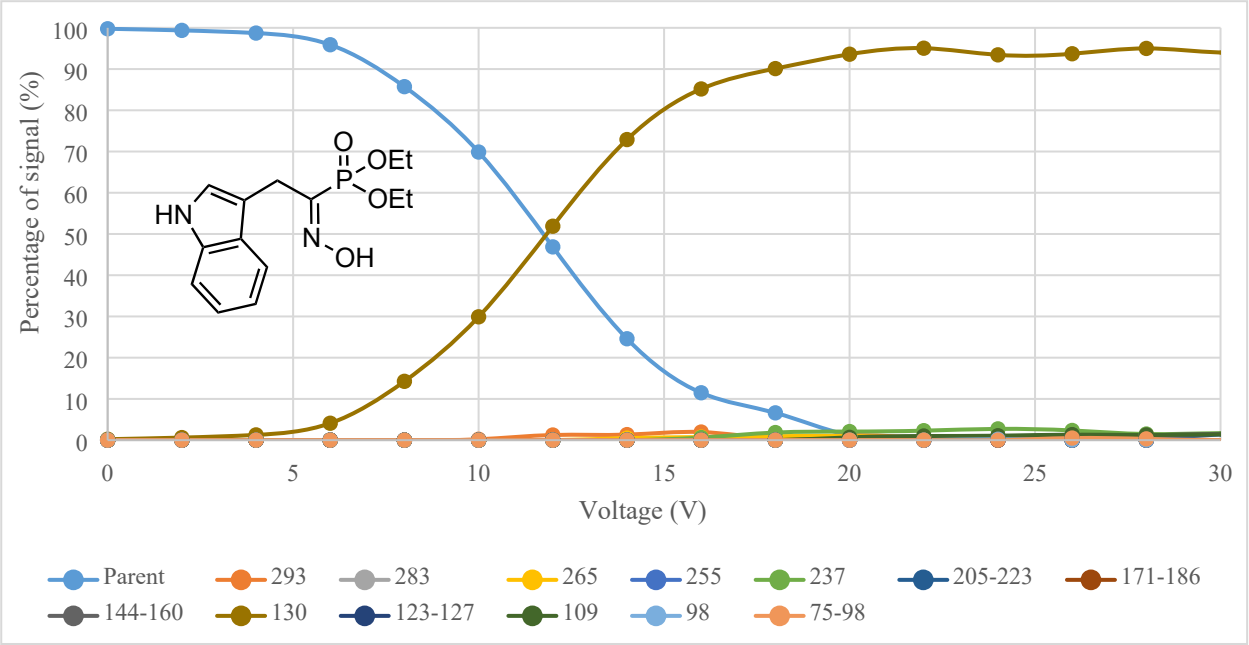


Figure S189. Breakdown curve of diethyl (1-(hydroxyimino)-2-(1H-indol-3-yl)ethyl)phosphonate (**16b, Z_{iso}**).

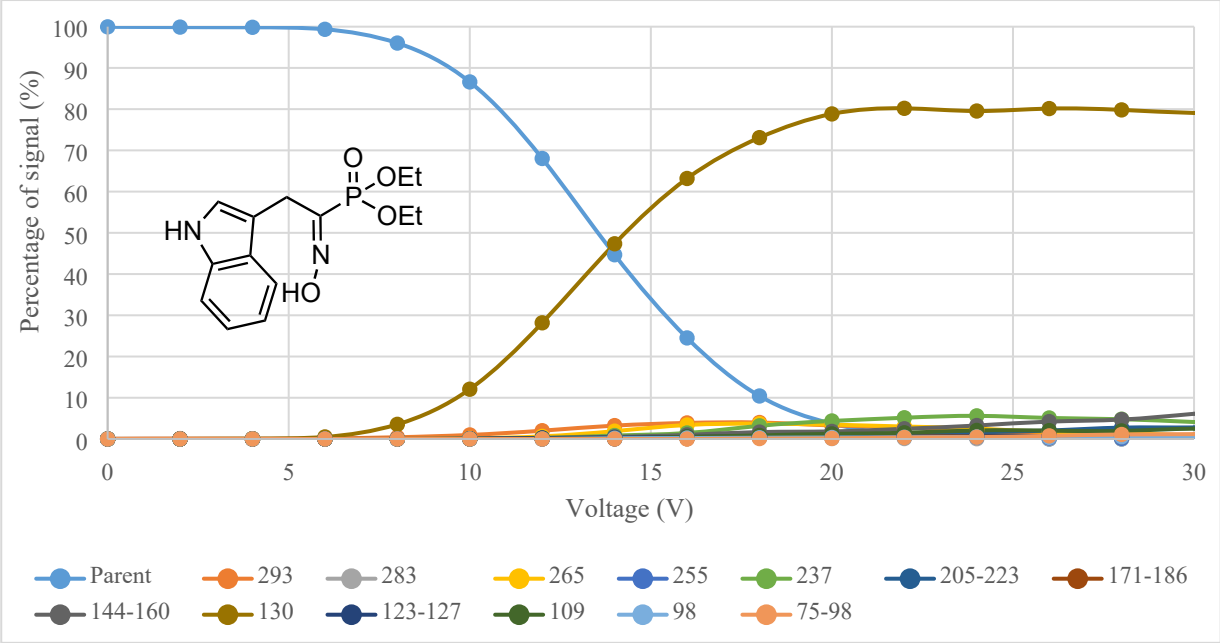


Figure S190. Breakdown curve of diethyl (1-(hydroxyimino)-2-(1H-indol-3-yl)ethyl)phosphonate (**16b, E_{iso}**).

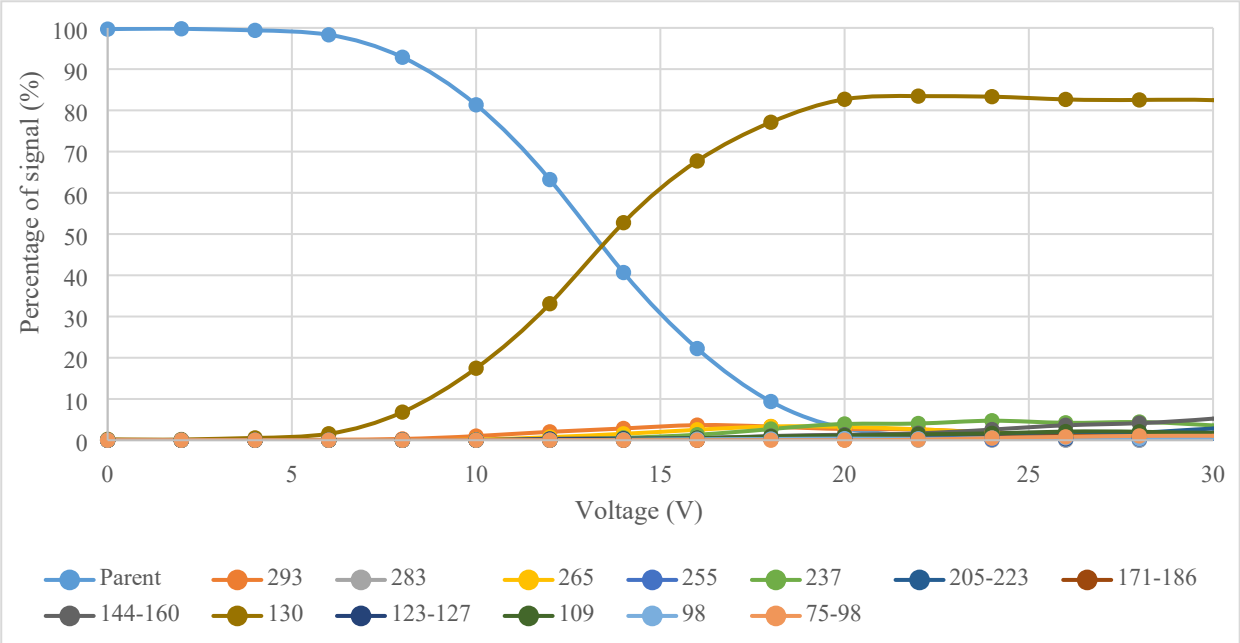


Figure S191. Breakdown curve of diethyl (1-(hydroxyimino)-2-(1H-indol-3-yl)ethyl)phosphonate (**16b, Mix**).

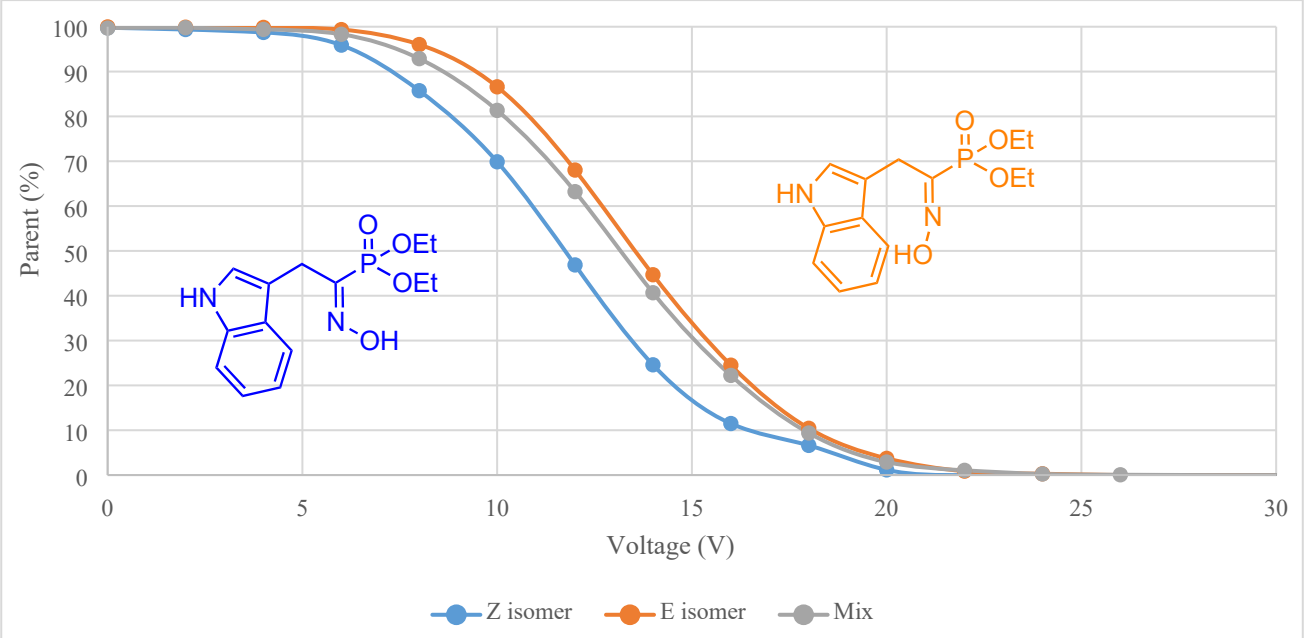
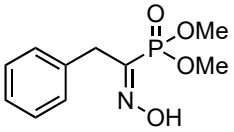
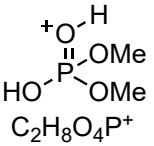
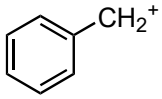
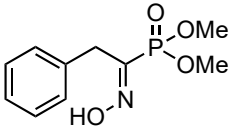
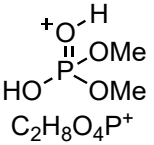
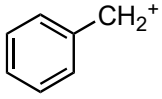
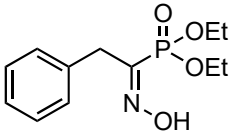
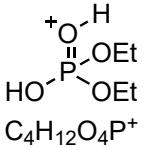
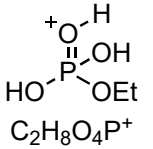
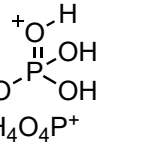
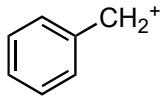
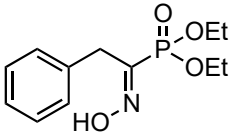
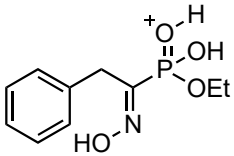
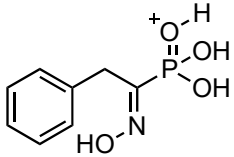
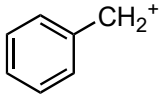
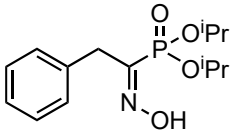
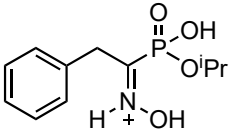
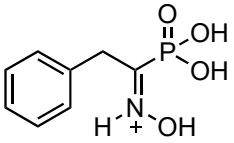
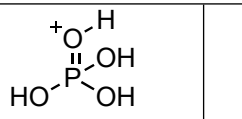
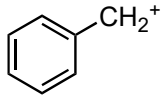
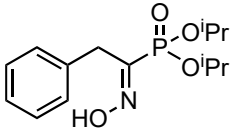
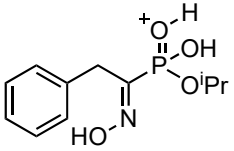
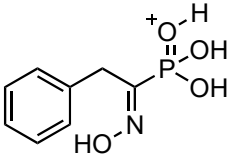
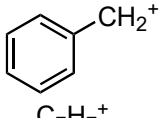
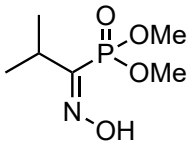
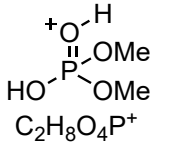
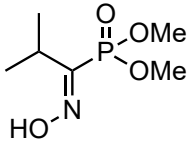
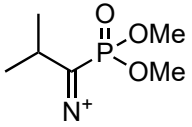
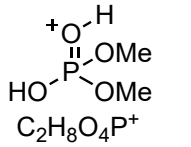
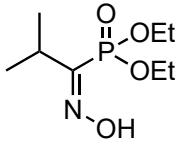
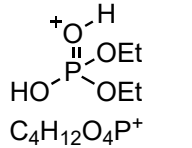
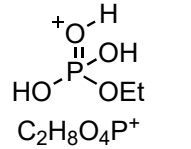
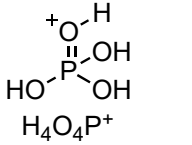
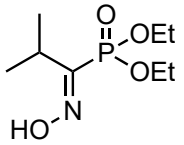
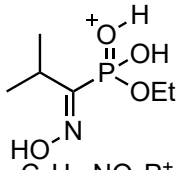
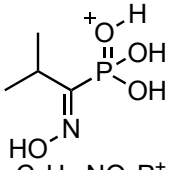
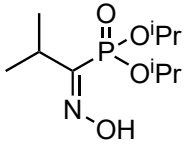
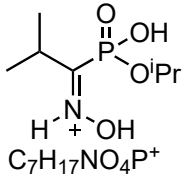
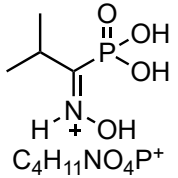
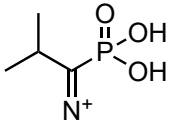
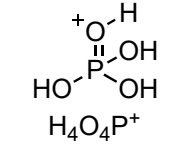
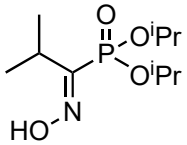
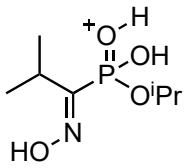
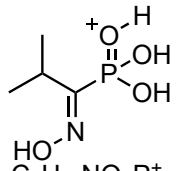
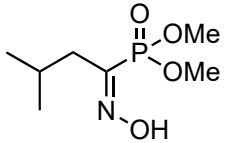
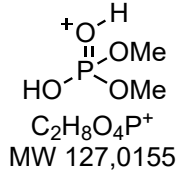
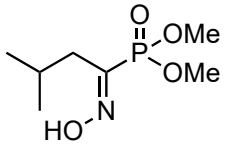
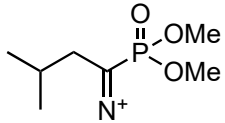
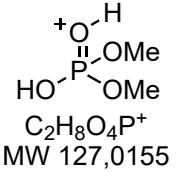


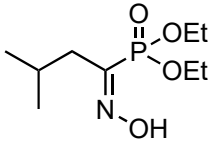
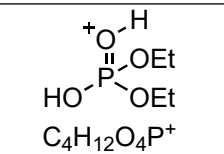
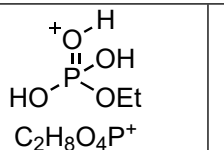
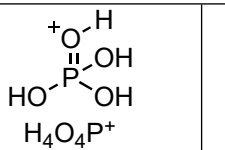
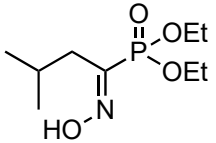
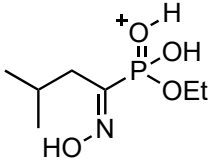
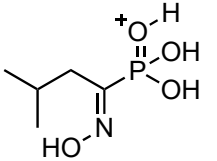
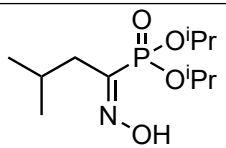
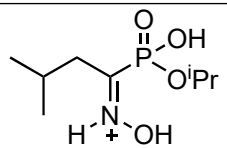
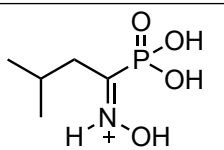
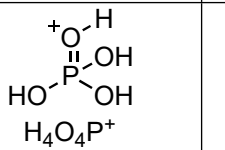
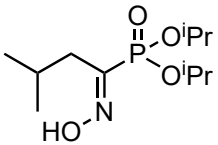
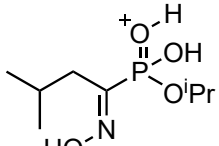
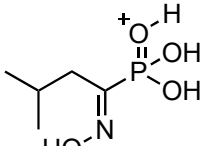
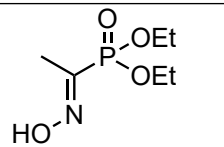
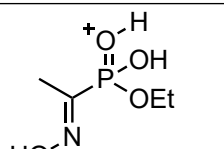
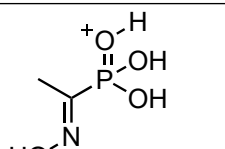
Figure S192. Survival yield of diethyl (1-(hydroxyimino)-2-(1H-indol-3-yl)ethyl)phosphonate (**16b**).

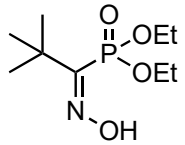
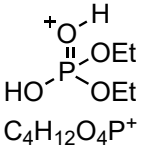
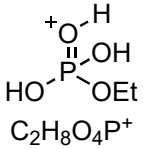
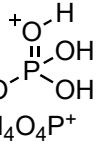
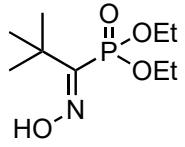
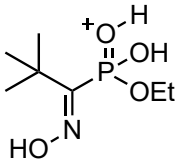
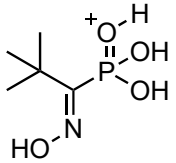
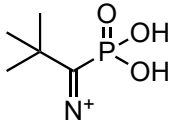
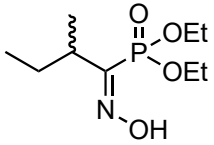
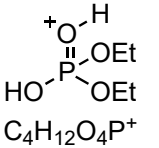
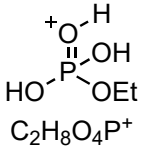
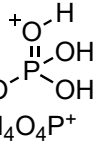
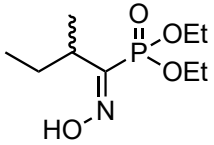
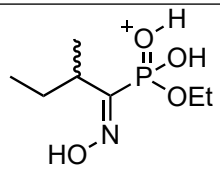
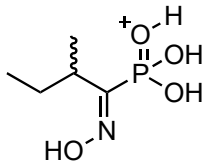
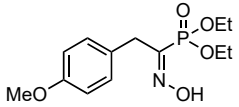
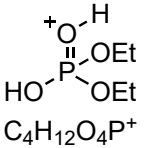
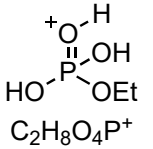
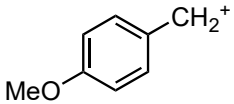
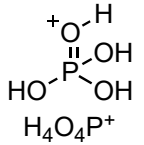
Table S2. Summary of the major fragments observed in MS for each isomer

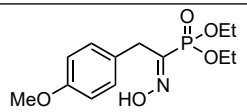
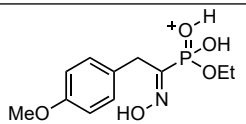
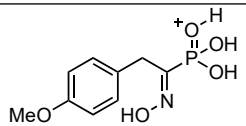
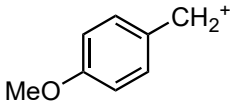
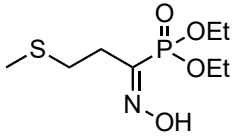
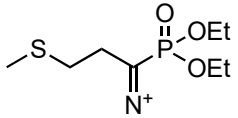
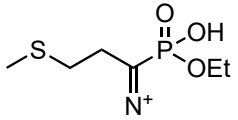
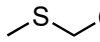
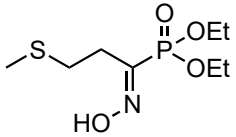
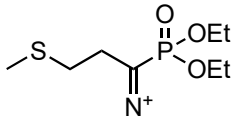
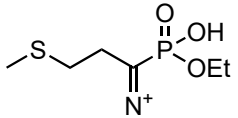
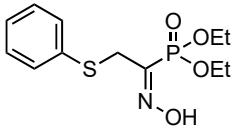
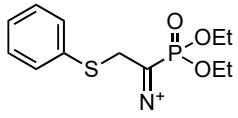
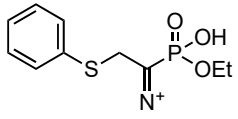
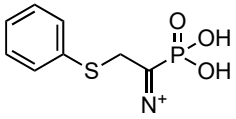
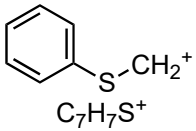
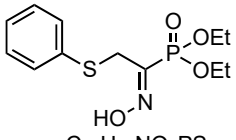
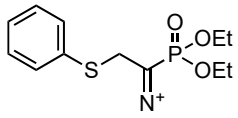
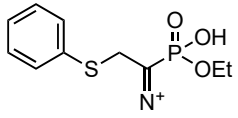
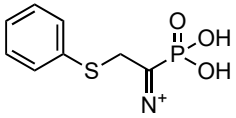
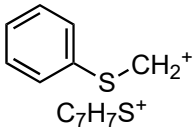
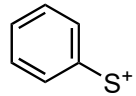
Compound	Structure	Fragment 1	Fragment 2	Fragment 3	Fragment 4	Fragment 5
1b (Z_{iso})	 $C_{10}H_{14}NO_4P$ MW 243,20	 $C_2H_8O_4P^+$ MW 127,0155	MW 109.0088	 $C_7H_7^+$ MW 91,0542		
1b (E_{iso})	 $C_{10}H_{14}NO_4P$ MW 243,20	 $C_2H_8O_4P^+$ MW 127,0155	MW 109.0088	 $C_7H_7^+$ MW 91,0542		
2b (Z_{iso})	 $C_{12}H_{18}NO_4P$ MW 271,25	 $C_4H_{12}O_4P^+$ MW 155,0468	 $C_2H_8O_4P^+$ MW 127,0155	 $H_4O_4P^+$ MW 98,9842	 $C_7H_7^+$ MW 91,0542	
2b (E_{iso})	 $C_{12}H_{18}NO_4P$ MW 271,25	 $C_{10}H_{15}NO_4P^+$ MW 244,0733	 $C_8H_{11}NO_4P^+$ MW 216,0420	 $C_7H_7^+$ MW 91,0542		

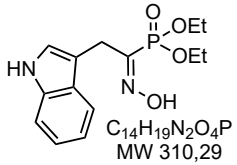
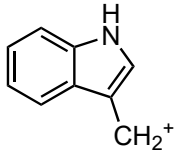
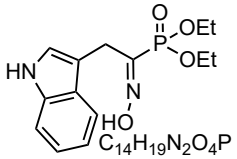
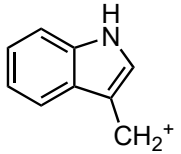
3b (Z_{iso})	 $C_{14}H_{22}NO_4P$ MW 299,31	 $C_{11}H_{17}NO_4P^+$ MW 258,0890	 $C_8H_{11}NO_4P^+$ MW 216,0420	 $H_4O_4P^+$ MW 98,9842	 $C_7H_7^+$ MW 91,0542	
3b (E_{iso})	 $C_{14}H_{22}NO_4P$ MW 299,31	 $C_{11}H_{17}NO_4P^+$ MW 258,0890	 $C_8H_{11}NO_4P^+$ MW 216,0420	 $C_7H_7^+$ MW 91,0542		
4b (Z_{iso})	 $C_6H_{14}NO_4P$ MW 195,15	 $C_2H_8O_4P^+$ MW 127,0155	MW 109.0095			
4b (E_{iso})	 $C_6H_{14}NO_4P$ MW 195,15	 $C_6H_{13}NO_3P^+$ MW 178,0628	 $C_2H_8O_4P^+$ MW 127,0155	MW 109.0095		
5b (Z_{iso})	 $C_8H_{18}NO_4P$ MW 223,21	 $C_4H_{12}O_4P^+$ MW 155,0468	 $C_2H_8O_4P^+$ MW 127,0155	 $H_4O_4P^+$ MW 98,9842		

5b (E_{iso})	 $C_8H_{18}NO_4P$ MW 223,21	 $C_6H_{15}NO_4P^+$ MW 196,0733	 $C_4H_{11}NO_4P^+$ MW 168,0420			
6b (Z_{iso})	 $C_{10}H_{22}NO_4P$ MW 251,26	 $C_7H_{17}NO_4P^+$ MW 210,0890	 $C_4H_{11}NO_4P^+$ MW 168,0420	 $C_4H_9NO_3P^+$ MW 150,0315	 $H_4O_4P^+$ MW 98,9842	
6b (E_{iso})	 $C_{10}H_{22}NO_4P$ MW 251,26	 $C_7H_{17}NO_4P^+$ MW 210,0890	 $C_4H_{11}NO_4P^+$ MW 168,0420			
7b (Z_{iso})	 $C_7H_{16}NO_4P$ MW 209,18	 $C_2H_8O_4P^+$ MW 127,0155	MW 109.0057			
7b (E_{iso})	 $C_7H_{16}NO_4P$ MW 209,18	 $C_7H_{15}NO_3P^+$ MW 192,0784	 $C_2H_8O_4P^+$ MW 127,0155	MW 109.0057		

8b (Z_{iso})	 $C_9H_{20}NO_4P$ MW 237,24	 $C_4H_{12}O_4P^+$ MW 155,0468	 $C_2H_8O_4P^+$ MW 127,0155	 $H_4O_4P^+$ MW 98,9842		
8b (E_{iso})	 $C_9H_{20}NO_4P$ MW 237,24	 $C_7H_{17}NO_4P^+$ MW 210,0890	 $C_5H_{13}NO_4P^+$ MW 182,0577			
9b (Z_{iso})	 $C_{11}H_{24}NO_4P$ MW 265,29	 $C_8H_{19}NO_4P^+$ MW 224,1046	 $C_5H_{13}NO_4P^+$ MW 182,0577	 $H_4O_4P^+$ MW 98,9842		
9b (E_{iso})	 $C_{11}H_{24}NO_4P$ MW 265,29	 $C_8H_{19}NO_4P^+$ MW 224,1046	 $C_5H_{13}NO_4P^+$ MW 182,0577			
10b (E_{iso})	 $C_6H_{14}NO_4P$ MW 195,15	 $C_4H_{11}NO_4P^+$ MW 168,0420	 $C_2H_7NO_4P^+$ MW 140,0107			

11b (Z_{iso})	 $C_9H_{20}NO_4P$ MW 237,24	 $C_4H_{12}O_4P^+$ MW 155,0468	 $C_2H_8O_4P^+$ MW 127,0155	 $H_4O_4P^+$ MW 98,9842		
11b (E_{iso})	 $C_9H_{20}NO_4P$ MW 237,24	 $C_7H_{17}NO_4P^+$ MW 210,0890	 $C_5H_{13}NO_4P^+$ MW 182,0577	 $C_5H_{11}NO_3P^+$ MW 164,0471		
12b (Z_{iso})	 $C_9H_{20}NO_4P$ MW 237,24	 $C_4H_{12}O_4P^+$ MW 155,0468	 $C_2H_8O_4P^+$ MW 127,0155	 $H_4O_4P^+$ MW 98,9842		
12b (E_{iso})	 $C_9H_{20}NO_4P$ MW 237,24	 $C_7H_{17}NO_4P^+$ MW 210,0890	 $C_5H_{13}NO_4P^+$ MW 182,0577			
13b (Z_{iso})	 $C_{13}H_{20}NO_5P$ MW 301,28	 $C_4H_{12}O_4P^+$ MW 155,0468	 $C_2H_8O_4P^+$ MW 127,0155	 $C_8H_9O^+$ MW 121,0648	 $H_4O_4P^+$ MW 98,9842	

13b (E_{iso})	 $C_{13}H_{20}NO_5P$ MW 301,28	 $C_{11}H_{17}NO_5P^+$ MW 274,0839	 $C_9H_{13}NO_5P^+$ MW 246,0526	 $C_8H_9O^+$ MW 121,0648		
14b (Z_{iso})	 $C_8H_{18}NO_4PS$ MW 255,27	 $C_8H_{17}NO_3PS^+$ MW 238,0661	 $C_6H_{13}NO_3PS^+$ MW 210,0348	MW 109.0096	MW 80.9766	 $C_3H_7S^+$ MW 75,0263
14b (E_{iso})	 $C_8H_{18}NO_4PS$ MW 255,27	 $C_8H_{17}NO_3PS^+$ MW 238,0661	 $C_6H_{13}NO_3PS^+$ MW 210,0348	MW 109.0096	MW 80.9766	
15b (Z_{iso})	 $C_{12}H_{18}NO_4PS$ MW 303,31	 $C_{12}H_{17}NO_3PS^+$ MW 286,0661	 $C_{10}H_{13}NO_3PS^+$ MW 258,0348	 $C_8H_9NO_3PS^+$ MW 230,0035	 $C_7H_7S^+$ MW 123,0263	
15b (E_{iso})	 $C_{12}H_{18}NO_4PS$ MW 303,31	 $C_{12}H_{17}NO_3PS^+$ MW 286,0661	 $C_{10}H_{13}NO_3PS^+$ MW 258,0348	 $C_8H_9NO_3PS^+$ MW 230,0035	 $C_7H_7S^+$ MW 123,0263	 $C_6H_5S^+$ MW 109,0106

16b (Z_{iso})	 $C_{14}H_{19}N_2O_4P$ MW 310,29	 $C_9H_8N^+$ MW 130,1695				
16b (E_{iso})	 $C_{14}H_{19}N_2O_4P$ MW 310,29	 $C_9H_8N^+$ MW 130,1695				

4 Computational study

4.1 Oxime isomers

4.1.1 Protonation site with regards to the isomers

Favorable protonation site calculations on 9 couple of oxime isomers (i.e. **1b**-**9b**) have been performed with Gaussian 09 (version D.01) by DFT at the B3LYP/6-31G(d) level of theory.[22] Each isomer exhibits two stable protonation sites: one in the amine moiety (-N-H$^+$) and the other on the phosphonate moiety (-P=O-H$^+$). Enthalpy, entropy and free enthalpy variations at 298.15K ($\Delta H^\circ_{298.15K}$, $\Delta S^\circ_{298.15K}$, and $\Delta G^\circ_{298.15K}$, respectively) of the -N-H$^+$ ⇌ -P=O-H$^+$ reaction (proton transfer) are reported in Table S3. A negative value of $\Delta G^\circ_{298.15K}$ indicates that -P=O-H$^+$ is more stable than -N-H$^+$. Inversely, a positive value of $\Delta G^\circ_{298.15K}$ indicates that -N-H$^+$ is more stable than -P=O-H$^+$. The calculated $\Delta G^\circ_{298.15K}$ values support that the phosphonate moiety is the more favorable protonation site for *E* isomers while protonation occurs preferentially on the amino moiety for *Z* isomers. These calculations are in good agreement with the experimental observations done by ion mobility mass spectrometry.

Table S3 : Calculated enthalpy, entropy and free enthalpy variations at 298.15K ($\Delta H^\circ_{298.15K}$, $\Delta S^\circ_{298.15K}$, and $\Delta G^\circ_{298.15K}$, respectively) for the proton transfer reaction from the amino moiety (reactant) to the phosphonate moiety (product) of investigated oxime isomers, -N-H$^+$ ⇌ -P=O-H$^+$.

Compound	Isomer	-N-H$^+$ ⇌ -P=O-H$^+$		
		$\Delta H^\circ_{298.15K}$	$\Delta S^\circ_{298.15K}$	ΔG°_{29815K}
1b	*E*	-10.21	-7.78	-7.89
	Z	70.58	11.78	67.07
2b	*E*	-14.27	-5.07	-12.75
	Z	53.71	-11.94	57.27
3b	*E*	-18.58	6.11	-20.40
	Z	8.02	-5.79	9.74
4b	*E*	-20.86	-14.69	-16.48
	Z	6.95	4.84	5.51
5b	*E*	-14.44	-7.35	-12.25
	Z	71.98	22.29	65.34
6b	*E*	-24.96	-7.70	-22.67
	Z	69.26	47.58	55.07
7b	*E*	-17.37	-2.71	-16.56
	Z	81.18	23.05	74.30
8b	*E*	-22.61	4.63	-23.99
	Z	74.88	21.52	68.47
9b	*E*	-36.08	-8.05	-33.68
	Z	64.52	13.59	60.46

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