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Triphenylphosphine as an effective catalyst for ketoximes addition to acylacetylenes: regio- and stereospecific synthesis of (*E*)-(*O*)-2-(acyl) vinylketoximes

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ABSTRACT

Triphenylphosphine catalyzes the regio- and stereospecific addition of ketoximes to acylacetylenes, whereas classical conditions using acetylene (KOH/DMSO, 70 °C) are unsuitable for this purpose. The reaction proceeds under mild conditions (CH_2Cl_2, rt, 7 h) to afford (*E*)-(*O*)-2-(acyl)vinylketoximes (92–98% stereoselectivity) in a yield of up to 85%. The (*E*)-adducts obtained are energetically less favorable than the corresponding (*Z*)-isomers and are gradually enriched with (*Z*)-isomers, thus indicating the kinetic control of (*E*)-stereoselectivity of the reaction.

1. Introduction

Oximes and their derivatives are known to be important substrates in organic and medicinal chemistry. Compounds containing the oxime pharmacophore motif exert diverse biological activities (antiviral, fungicidal, cytotoxic, antispasmodic, anticonvulsive, etc.).[1] Depending on the substituents, reagents, and reaction conditions, oximes can behave as *N*-, *O*-, and *C*-nucleophiles, 1,3-dipoles (in the NH-nitrone form), electrophiles (objects of nucleophilic attack across the C=N bond), and selective ligands for transition metal cations.[2]

O-Vinyloximes are the key intermediates in the synthesis of pyrroles from ketones (via ketoximes) and acetylenes.[2e,3] Of special importance is the preparation and study of properties of *O*-vinyloximes bearing the carbonyl group at the double bond. The combination of the ketovinyl fragment (the known phaprmacophore[4]) and oxime moiety in a one molecule could lead to synergism of properties of these two important chemical functions and extent substantially the applications of these highly functionalized compounds. One of the approaches to the synthesis of such *O*-vinyloximes could be the vinylation of oximes with available acylacetylenes (commercial or easily prepared by the known protocols[5]).

To the best of our knowledge, the literature lacks data on the interaction of oximes with acylacetylenes. The addition of oximes to electrophilic (activated) acetylenes was reported only in a few publications dealing with the reactions of oximes with ethers of propiolic and acetylene dicarboxylic acids.[6]

2. Results and discussion

O-Vinyloximes are commonly prepared by the vinylation of ketoximes with acetylene in the superbase systems MOH/DMSO (M=Na, K, Cs).[7] These conditions (KOH/DMSO, 20–70 °C, up to 6 h) turned out to be invalid for the addition of ketoximes to acylacetylenes (the reaction was accompanied by the intense tar formation and the anticipated adducts were not formed). This result is also in agreement with the known data on instability of acylacetylenes in strongly basic (superbasic) media.[8] When conducted in benzene (80 °C, 24 h), methanol (reflux, 24 h), tetrahydrofuran (reflux, 40 h), dichloromethane (rt, 4 days) as well as in the system MeOH/Et_3N (reflux, 24 h), the reaction furnished the addition products in only negligible yields (8–10%, ^{1}H NMR).

Our further systematic investigations have shown that in the presence of triphenylphosphine (10 mol %) ketoximes **1**–**4** are readily added to acylacetylenes **5**–**7** in dichloromethane at room temperature (7 h) to deliver the expected (*E*)-(*O*)-2-(acyl)vinylketoximes **8a**–**l** in a yield of up to 85% (Table 1).

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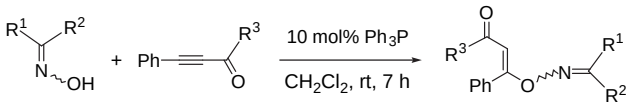
Table 1
Synthesis of (*E*)-(*O*)-2-(acyl)vinylketoximes **3a**–**l**[a]



1-4 **5-7** **8a-l**

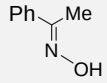
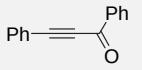
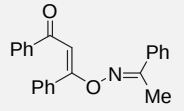
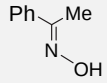
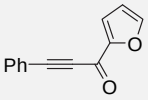
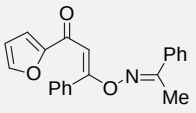
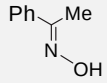
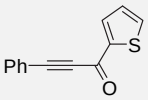
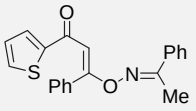
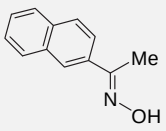
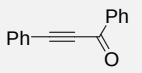
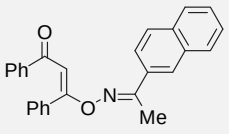
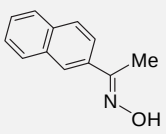
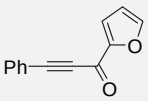
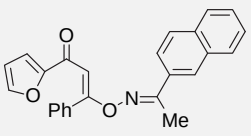
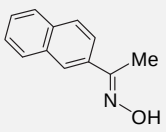
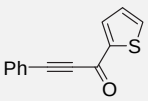
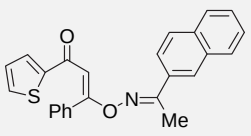
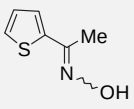
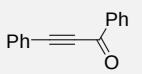
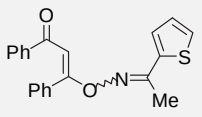
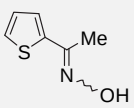
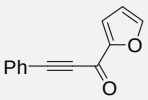
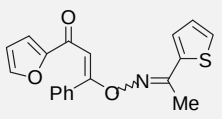
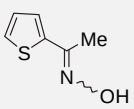
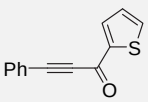
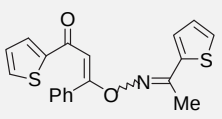
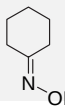
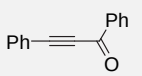
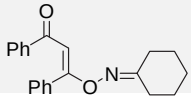
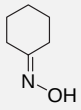
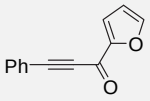
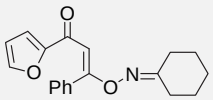
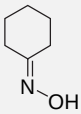
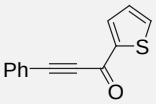
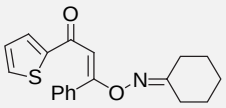
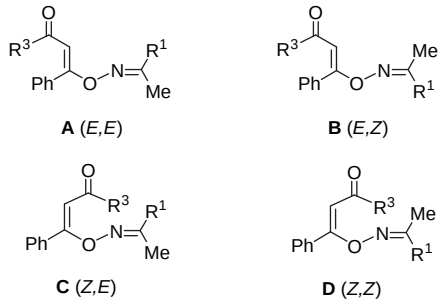
Entry	Oximes **1**–**4**		Acylacetylenes **5**–**7**		Product **8a**–**l**		Isolated yields,[b] % (isomer)
1		**1**		**5**		**8a**	83 (*E*,*E*)
2		**1**		**6**		**8b**	83 (*E*,*E*)
3		**1**		**7**		**8c**	85 (*E*,*E*)
4		**2**		**5**		**8d**	82 (*E*,*E*)
5		**2**		**6**		**8e**	83 (*E*,*E*)
6		**2**		**7**		**8f**	84 (*E*,*E*)
7		**3**		**5**		**8g**	82 (*E*,*E*/*E*,*Z*≈2:1)[c]
8		**3**		**6**		**8h**	80 (*E*,*E*/*E*,*Z*≈2:1)[c]
9		**3**		**7**		**8i**	84 (*E*,*E*/*E*,*Z*≈2:1)[c]
10		**4**		**5**		**8j**	37 (75)[d] (*E*)

Table 1 (*continued*)

Entry	Oximes **1**–**4**	Acylacetylenes **5**–**7**	Product **8a**–**l**	Isolated yields,[b] % (isomer)
11	 **4**	 **6**	 **8k**	76 (*E*)
12	 **4**	 **7**	 **8l**	63 (79)[e] (*E*)

[a] Reagents and conditions: **1**–**4** (2 mmol), **5**–**7** (2 mmol), Ph_3P (0.2 mmol), CH_2Cl_2 (5 mL), rt, 7 h, under Ar.
[b] The yield was calculated by the ketoxime consumed.
[c] 2-Acetylthiophene oxime **3** was used as a mixture of (*E*)- and (*Z*)-isomers in a ratio of *E*:*Z*≈2:1 (^{1}H, ^{13}C NMR).
[d] Based in the reacted oxime, conversion of which was 50% (^{1}H NMR).
[e] Based in the reacted oxime, conversion of which was 80% (^{1}H NMR).

Theoretically, (*O*)-2-(acyl)vinylketoximes **8a**–**i** can exist as four spatial isomers **A**–**D** (Scheme 1) differing in the location of the carbonyl moiety and oxygen atom at the double bond ((*E*)-or (*Z*)) as well as in the position of oxygen atom and senior substitutent relative to the C=N bond in the oxime fragment of the molecule ((*E*)- or (*Z*)).



Scheme 1. Possible isomers of (*O*)-2-(acyl)vinylketoximes **8**.

The experiments have shown that the reaction of ketoximes **1**–**4** with acylacetylenes **5**–**7** proceeds with high (*E*)-stereoselectivity for the ketovinyl function formation (isomers **A** and **B**, Scheme 1). The relative content of (*Z*)-isomers (**C** and **D**) in the crude product for compounds **8a**–**i** did not exceed 8%, the total conversion being 96–100% (^{1}H NMR). In the case of ketoximes **1**,**2** (presented by (*E*)-isomers with respect to the C=N bond), only (*E*,*E*)-isomers **A** of the corresponding oximes **8a**–**f** were isolated. For 2-acetylthiophene oxime **3** (a mixture of (*E*)- and (*Z*)-isomers in a ratio of ≈2:1), compounds **8g**–**i** were obtained as a mixture of (*E*,*E*)- (**A**) and (*E*,*Z*)-isomers (**B**) (Scheme 1) in a ratio of ≈2:1 (^{1}H NMR). Individual (*E*,*E*)- and (*E*,*Z*)-isomers of compounds **8h** and **8i** were isolated by fractional recrystallization from petroleum ether (70–100 °C).

Evidently, the nature and bulk of the substituents in starting oximes **1**–**4** do not practically affect their ability to be added to the triple bond of acylacetylenes, more exactly the isolated yields of the adducts **8a**–**i** (Table 1).

The reaction of acylacetylenes **5**–**7** with cyclohexanone oxime **4** under the same conditions was not so unambiguous. The yields of the corresponding *O*-vinyloximes **8l** and **8j** were 63 and 37%, respectively (Table 1). Attempts to improve the latter result by increasing the loading to 20 mol % triphenylphosphine and increasing the reaction time to 40 h was not fully successful (the yield of **8j** does not exceeding 36%, ^{1}H NMR).

In the ^{15}N NMR spectra of compounds **8a**–**l**, the values of chemical shifts of nitrogen atoms range from −15.7 to −31.1 ppm that is typical for the *O*-vinyloxime fragments C=N–O–C=C.[9] In the case of the possible nitrone form [C=N(→O)–C=C], the ^{15}N NMR resonance should be pronouncedly high-field shifted (up to −100 ppm).[9] The vinyl proton in (*E*)-isomers (**A** and **B**, Scheme 1) resonates in the region 7.02–7.21 ppm. The spin–spin coupling constant between the proton and C_i of the phenyl ring $^3J_{H-Ci}$ equals 6.6–6.8 Hz and is indicative of the trans-configuration of the isomers.[10]

Configuration assignments for the oxime fragments of compounds **8a**–**i** have been done using analysis of the ^{1}H and ^{13}C chemical shifts in the NMR spectra of the methyl group. These values are in good agreement with known data on chemical shifts of the methyl moieties in ^{1}H and ^{13}C NMR spectra for (*E*)- and (*Z*)-isomers of *O*-vinylketoximes.[11]

The presence of (*Z*)-ketovinyl isomers (**C** and **D**, Scheme 1) and their relative content in the crude product follows from the vinyl proton resonance in the region 6.16–6.36 ppm in the ^{1}H NMR spectra ($^3J_{H-Ci}$≈3.5 Hz). This confirms the cis-configuration of the vinyl proton and phenyl ring[10] that is supported by the data of 2D NOESY experiments.

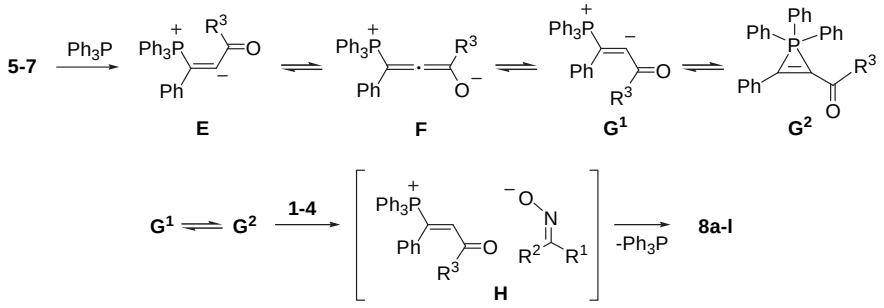
The NMR monitoring of isomers **8a** (*E*,*E*), **8i** (*E*,*Z*), and **8k** (*E*) interconversion has been performed in $CDCl_3$ at room temperature to check their thermodynamic stability. It has been found that none of the compounds studied undergo the isomeric transformations in the oxime part of the molecules. However, in the ketovinyl group, (*E*)→(*Z*)-isomerization (up to 40% for 1.5 month, *E*:*Z* ratio ≈3:2) occurred, indicated by the appearance of high-field signals of the vinyl proton CH= (δ 6.25, 6.30, and 6.24 ppm for compounds **8a**, **8i**, and **8k**, respectively; $^3J_{H-Ci}$≈3.5 Hz) in the ^{1}H NMR spectra as well as by doubling of the other signals in the ^{1}H and ^{13}C NMR spectra. In this case, the values of chemical shifts ^{13}C of the methyl group for compounds **8a** and **8i** remained almost the same ($\Delta\delta$≈1 ppm) that evidences to the preservation of initial configuration of the oxime fragment, the configuration of the ketovinyl part being significantly changed. The monitoring of compound **8i**, employed in the reaction as a mixture of (*E*,*E*)- and (*E*,*Z*)-isomers in a ratio of ≈2:1 (**A** and **B**, Scheme 1) have demonstrated the similar behavior. In this experiment, we observed all four possible isomeric forms of compound **8i** (**A**–**D**, Scheme 1). (*E*)→(*Z*) Isomerization of the ketovinyl fragment upon storage of the adduct is proved by the emergence (^{1}H NMR spectra) of two new signals CH= at 6.26 and 6.30 ppm, assignable to (*Z*,*E*)- and (*Z*,*Z*)-isomers of compound **8i** (**C** and **D**, Scheme 1) in a ratio of ≈2:1. The retention of the isomeric ratio under partial (*E*,*E*)→(*Z*,*E*) and (*E*,*Z*)→(*Z*,*Z*) isomerization is indicative of the independence of this process from the configuration of the oxime fragment.

Thus, the results obtained testify that the (*E*)-stereoselectivity relative to the C=C bond is kinetically controlled. The (*E*)-isomers

are energetically less favorable than the corresponding (*Z*)-isomers. Eventually, the (*E*)-isomers even at room temperature are gradually transformed to (*Z*)-isomers, approaching the thermodynamical equilibrium with isomers in the ratio of *E*:*Z*≈3:2. In the case of oxime **8a** it has been shown that the equilibrium (^{1}H NMR) is reached after 17 h (C_6D_6 at 60–63 °C), and further heating does not change the isomers ratio.

The published data on the properties of trivalent phosphorus nucleophiles[6b,12] allows one to assume that *O*-vinyloximes **8a**–**l** are generated due to the initial attack of triphenylphosphine at β-carbon atom of acylacetylene **5**–**7**.

The high stereoselectivity of the reaction, i.e., the predominant formation of (*E*)-adducts (i.e., violation of the '*trans*-nucleophilic addition' rule[13]) can be rationalized as follows. Normally, nucleophilic addition of triphenylphosphine to acetylenes **5**–**7** should lead to the zwitterion **E** of trans-configuration (in accordance with '*trans*-nucleophilic addition' rule[13]). However, this zwitterion is easily isomerized to its cis-form (**G^1**⇌**G^2**) via allenolate zwitterion **F** due to a strong attractive electrostatic interaction between negative and positive charges up to the possible closing up the three-membered ring **G^2**. When the zwitterion (**G^1**⇌**G^2**) is attacked by the ketoxime molecule, its carbanionic center is quenched to result in the formation of the intermediate phosphonium salt **H**, which then is transformed into the target *O*-vinyloximes **8a**–**l** (Scheme 2). This is accompanied by the releasing of triphenylphosphine and its returning as a catalyst to the reaction mixture.



Scheme 2. Tentative mechanism for the reaction of ketoximes with acylacetylenes in the presence of Ph_3P.

3. Conclusion

In conclusion, a facile and convenient approach to the synthesis of hitherto unknown (*O*)-2-(acyl)vinylketoximes has been developed. The oximes obtained are promising building blocks and monomers for organic synthesis, ligands for new metal-complex catalysts as well as the models for studying the reactivity of the *O*-vinyloxime function.

4. Experimental

4.1. General

The IR spectra were recorded on a Bruker IFS25 spectrophotometer from samples prepared as KBr pellets. The NMR spectra were measured from solutions in $CDCl_3$ on Bruker DPX-400 and AV-400 spectrometers (400.1 MHz for ^{1}H, 100.6 MHz for ^{13}C, and 40.5 MHz for ^{15}N) using hexamethyldisiloxane (^{1}H, ^{13}C) and nitromethane (^{15}N) as internal references. The assignments of ^{1}H and ^{13}C NMR spectra were performed by COSY, NOESY, HSQC, and HMBC experiments.

Solvents were purified and dried using reported methods[14] and stored over 4 Å molecular sieves. Oximes **1**,**4** are commercial products. Oximes **2**,**3** were prepared by the known procedure.[15] Acylacetylenes **5**–**7** were synthesized from phenylacetylene and the corresponding aldehydes by the Yozych reaction with subsequent oxidation of the alcohols with active MnO_2 according to the protocol.[5a]

4.2. General procedure for synthesis of *O*-vinyloximes (8a–l)

A mixture of ketoxime **1**–**4** (2 mmol), acylacetylene **5**–**7** (2 mmol), and Ph_3P (52 mg, 0.2 mmol) in CH_2Cl_2 (5 mL) was stirred at rt for 7 h under Ar and then the solution was evaporated. The crystalline products were ground in Et_2O (5 mL) and allowed to stand at −12→−8 °C overnight. The residue was filtered off, dried under vacuum, and recrystallized from hexane or petroleum ether. Compound **8j** was purified by column chromatography on Al_2O_3 using Et_2O/hexane (1:3) as eluent.

*4.2.1. (E)-1,3-Diphenyl-3-({[(E)-1-phenylethylidene]amino}oxy)-2-propen-1-one (**8a**).* Yield: 0.57 g (83%); pale yellow crystals, mp 82–84 °C (hexane); [Found: C, 80.8; H, 5.6; N, 4.0. $C_{23}H_{19}NO_2$ requires C, 80.92; H, 5.61; N, 4.10%]; ν_{max}(KBr) 1663, 1584, 1560 cm^{-1}; δ_H (400.1 MHz, $CDCl_3$) 2.46 (s, 3H, CH_3), 7.17 (s, 1H, CH=), 7.41–7.97 (m, 15H, Ar); δ_C (100.6 MHz, $CDCl_3$) 14.0, 101.1, 126.7, 127.9, 128.2, 128.6, 129.6, 130.2, 130.9, 131.4, 131.9, 133.5, 135.0, 139.6, 160.9, 168.4, 190.6; δ_N (40.5 MHz, $CDCl_3$) −16.4.

*4.2.2. (E)-1-(2-Furyl)-3-phenyl-3-({[(E)-1-phenylethylidene]amino}oxy)-2-propen-1-one (**8b**).* Yield: 0.55 g (83%); pale yellow crystals, mp 112–114 °C (hexane); [Found: C, 76.4; H, 5.1; N, 4.2. $C_{21}H_{17}NO_3$ requires C, 76.12; H, 5.17; N, 4.23%]; ν_{max}(KBr) 1648, 1586, 1569 cm^{-1}; δ_H (400.1 MHz, $CDCl_3$) 2.45 (s, 3H, CH_3), 6.50 (dd, ^3J=3.6, 1.7 Hz, 1H, H^4_{furyl}), 7.15 (dd, ^3J=3.6 Hz, ^4J=0.7 Hz, 1H, H^3_{furyl}),7.17 (s, 1H, CH=), 7.43–7.84 (m, 11H, Ar, HetAr); δ_C (100.6 MHz, $CDCl_3$) 14.2, 99.7, 112.1, 115.8, 126.9, 127.9, 128.8, 129.4, 130.2, 130.6, 133.5, 135.1, 145.4, 154.6, 161.2, 169.0, 178.1; δ_N (40.5 MHz, $CDCl_3$) −16.7.

*4.2.3. (E)-1-(2-Thienyl)-3-phenyl-3-({[(E)-1-phenylethylidene]amino}oxy)-2-propen-1-one (**8c**).* Yield: 0.59 g (85%); pale yellow crystals, mp 117–118 °C (petroleum ether 40–70 °C); [Found: C, 72.2; H, 4.5; N, 4.1; S, 9.1. $C_{21}H_{17}NO_2S$ requires C, 72.60; H, 4.93; N, 4.03; S, 9.23%]; ν_{max}(KBr) 1639, 1585, 1565 cm^{-1}; δ_H (400.1 MHz, $CDCl_3$) 2.45 (s, 3H, CH_3), 7.10 (dd, ^3J=4.8, 3.7 Hz, 1H, $H^4_{thienyl}$), 7.16 (s, 1H, CH=), 7.44–7.85 (m, 12H, Ar, HetAr); δ_C (100.6 MHz, $CDCl_3$) 13.8, 99.9, 126.5, 127.5, 127.6, 128.4, 129.0, 129.8, 130.2, 130.4, 132.2, 133.1, 134.7, 147.1, 160.8, 168.2, 181.7.

*4.2.4. (E)-3-({[(E)-1-(2-Naphthyl)ethylidene]amino}oxy)-1,3-diphenyl-2-propen-1-one (**8d**).* Yield: 0.64 g (82%); pale yellow crystals, mp 71–73 °C (hexane); [Found: C, 83.0; H, 5.5; N, 3.5. $C_{27}H_{21}NO_2$ requires C, 82.84; H, 5.41; N, 3.58%]; ν_{max}(KBr) 1658, 1581, 1567 cm^{-1}; δ_H (400.1 MHz, $CDCl_3$) 2.57 (s, 3H, CH_3), 7.22 (s, 1H, CH=), 7.39–8.20 (m, 17H, Ar); δ_C (100.6 MHz, $CDCl_3$) 14.0, 101.5, 123.6, 126.8, 127.4, 127.5, 127.9, 128.1, 128.4, 128.5, 128.6, 128.8,

129.5, 130.2, 132.2, 132.5, 133.1, 133.7, 134.4, 139.8, 160.8, 168.6, 191.0; δ_N (40.5 MHz, $CDCl_3$) −15.8.

*4.2.5. (E)-1-(2-Furyl)-3-({[(E)-1-(2-naphthyl)ethylidene]amino}oxy)-3-phenyl-2-propen-1-one (**8e**).* Yield: 0.63 g (83%); pale yellow crystals, mp 75–77 °C (hexane); [Found: C, 79.1; H, 5.3; N, 3.5. $C_{25}H_{19}NO_3$ requires C, 78.72; H, 5.02; N, 3.67%]; ν_{max}(KBr) 1654, 1587, 1562 cm^{-1}; δ_H (400.1 MHz, $CDCl_3$) 2.56 (s, 3H, CH_3), 6.51 (dd, ^3J=3.6, 1.7 Hz, 1H, H^4_{furyl}), 7.16 (dd, ^3J=3.6 Hz, ^4J=0.7 Hz, 1H, H^3_{furyl}), 7.21 (s, 1H, CH=), 7.45–8.20 (m, 13H, Ar, HetAr); δ_C (100.6 MHz, $CDCl_3$) 14.1, 99.8, 112.2, 115.9, 123.6, 126.8, 127.5, 127.9, 128.0, 128.5, 128.8, 129.5, 130.3, 132.5, 133.1, 133.5, 134.4, 145.5, 154.7, 161.1, 169.1, 178.2; δ_N (40.5 MHz, $CDCl_3$) −15.7.

*4.2.6. (E)-3-({[(E)-1-(2-Naphthyl)ethylidene]amino}oxy)-3-phenyl-1-(2-thienyl)-2-propen-1-one (**8f**).* Yield: 0.67 g (84%); pale yellow crystals, mp 109–110 °C (petroleum ether 70–100 °C); [Found: C, 75.6; H, 4.9; N, 3.2; S, 8.2. $C_{25}H_{19}NO_2S$ requires C, 75.54; H, 4.82; N, 3.52; S, 8.07%]; ν_{max}(KBr) 1642, 1591, 1570 cm^{-1}; δ_H (400.1 MHz, $CDCl_3$) 2.57 (s, 3H, CH_3), 7.11 (dd, ^3J=4.8, 3.7 Hz, 1H, $H^4_{thienyl}$), 7.21 (s, 1H, CH=), 7.45–8.20 (m, 14H, Ar, HetAr); δ_C (100.6 MHz, $CDCl_3$) 14.0, 100.5, 123.5, 126.8, 127.4, 127.8, 127.9, 128.0, 128.5, 128.8, 129.5, 130.2, 130.9, 132.5, 132.6, 133.1, 133.5, 134.4, 135.8, 147.5, 160.9, 168.7, 182.1; δ_N (40.5 MHz, $CDCl_3$) −15.7.

*4.2.7. (E)-1,3-Diphenyl-3-({[(E)-1-(2-thienyl)ethylidene]amino}oxy)-2-propen-1-one and (E)-1,3-diphenyl-3-({[(Z)-1-(2-thienyl)ethylidene]amino}oxy)-2-propen-1-one (**8g**).* Yield: 0.57 g (82%); pale yellow crystals, mp 78–85 °C (for mixture of (*E*,*E*)- and (*E*,*Z*)-isomers); [Found: C, 72.2; H, 4.8; N, 4.1; S, 9.1. $C_{21}H_{17}NO_2S$ requires C, 72.60; H, 4.93; N, 4.03; S, 9.23%]; ν_{max}(KBr) 1667, 1583, 1573 cm^{-1}; δ_H (400.1 MHz, $CDCl_3$) (for mixture of (*E*,*E*)- and (*E*,*Z*)-isomers) 2.46 (s, 3H, CH_3, *E*,*E*), 2.57 (s, 3H, CH_3, *E*,*Z*), 7.12 (m, 2H, $H^4_{thienyl}$), 7.16 (s, 1H, CH=, *E*,*E*), 7.19 (s, 1H, CH=, *E*,*Z*), 7.40–7.98 (m, 24H, Ar, HetAr); δ_C (100.6 MHz, $CDCl_3$) (for mixture of (*E*,*E*)- and (*E*,*Z*)-isomers) 14.1 (CH_3, *E*,*E*), 20.1 (CH_3, *E*,*Z*), 101.2, 101.4, 126.1, 127.4, 127.8, 127.9, 128.2, 128.3, 128.8, 129.0, 129.3, 129.6, 130.0, 131.9, 132.0, 132.8, 139.6, 156.4, 168.1, 190.4.

*4.2.8. (E)-1-(2-Furyl)-3-phenyl-3-({[(E)-1-(2-thienyl)ethylidene]amino}oxy)-2-propen-1-one and (E)-1-(2-furyl)-3-phenyl-3-({[(Z)-1-(2-thienyl)ethylidene]amino}oxy)-2-propen-1-one (**8h**).* Yield: 0.54 g (80%); mp 88–102 °C (for mixture of (*E*,*E*)- and (*E*,*Z*)-isomers); pale yellow crystals, mp 108–110 °C (for (*E*,*E*)-isomer from petroleum ether 70–100 °C); (*E*,*Z*)-isomer is a viscous oil; [Found: C, 67.3; H, 4.4; N, 4.2; S, 9.2. $C_{19}H_{15}NO_3S$ requires C, 67.64; H, 4.48; N, 4.15; S, 9.50%]; ν_{max}(KBr) 1650, 1584, 1571 cm^{-1}; δ_H (400.1 MHz, $CDCl_3$) ((*E*,*E*)-isomer) 2.45 (s, 3H, CH_3), 6.50 (dd, ^3J=3.6, 1.7 Hz, 1H, H^4_{furyl}), 7.11 (s, 1H, CH=), 7.12–7.15 (m, 2H, $H^4_{thienyl}$, H^3_{furyl}), 7.40–7.62 (m, 8H, Ar, HetAr); for (*E*,*Z*)-isomer: 2.57 (s, 3H, CH_3), 6.50 (dd, ^3J=3.6, 1.7 Hz, 1H, H^4_{furyl}), 7.10 (dd, ^3J=4.4, 3.4 Hz, 1H, $H^4_{thienyl}$), 7.15 (dd, ^3J=3.2 Hz, ^4J=0.7 Hz, 1H, H^3_{furyl}), 7.18 (s, 1H, CH=), 7.42–7.68 (m, 8H, Ar, HetAr); δ_C (100.6 MHz, $CDCl_3$) ((*E*,*E*)-isomer) 13.7, 99.3, 111.6, 115.4, 127.0, 127.4, 128.5, 128.6, 128.9, 129.7, 132.8, 137.9, 145.1, 154.1, 156.2, 168.1, 177.4; for (*E*,*Z*)-isomer: 20.1, 99.9, 112.2, 115.9, 126.2, 127.4, 128.5, 129.4, 129.7, 130.1, 132.1, 132.9, 145.5, 154.7, 156.6, 168.8, 178.0.

*4.2.9. (E)-1-(2-Thienyl)-3-phenyl-3-({[(E)-1-(2-thienyl)ethylidene]amino}oxy)-2-propen-1-one and (E)-1-(2-thienyl)-3-phenyl-3-({[(Z)-1-(2-thienyl)ethylidene]amino}oxy)-2-propen-1-one (**8i**).* Yield: 0.59 g (84%); mp 112–118 °C (for mixture of (*E*,*E*)- and (*E*,*Z*)-isomers); pale yellow crystals, 120–122 °C (for (*E*,*E*)-isomer from petroleum ether 70–100 °C); pale yellow crystals, 108–110 °C (for (*E*,*Z*)-isomer from petroleum ether 70–100 °C); [Found: C, 64.9; H, 4.3; N, 3.8; S, 18.5. $C_{19}H_{15}NO_2S_2$ requires C, 64.56; H, 4.28; N, 3.96; S, 18.14%]; ν_{max}(KBr) 1642, 1582, 1567 cm^{-1}; δ_H (400.1 MHz, $CDCl_3$) ((*E*,*E*)-isomer) 2.43 (s, 3H, CH_3), 7.11 (m, 2H, $H^4_{thienyl}$), 7.15 (s, 1H, CH=), 7.39–7.74 (m, 9H, Ar, HetAr); for (*E*,*Z*)-isomer: 2.58 (s, 3H, CH_3), 7.11 (m, 2H, $H^4_{thienyl}$), 7.18 (s, 1H, CH=), 7.43–7.77 (m, 9H, Ar, HetAr); δ_C (100.6 MHz, $CDCl_3$) ((*E*,*E*)-isomer) 14.2, 100.4, 127.5, 127.9, 128.9, 129.1, 129.5, 130.2, 130.8, 132.6, 133.2, 138.5, 147.5, 156.6, 168.3, 181.8; for (*E*,*Z*)-isomer: 20.2, 100.5, 126.2, 127.5, 127.9, 128.6, 129.7, 130.2, 130.9, 131.6, 132.1, 132.6, 133.0, 147.5, 152.0, 168.4, 182.1.

*4.2.10. Cyclohexanone O-[(E)-3-oxo-1,3-diphenyl-1-propenyl]oxime (**8j**).* Yield: 0.24 g (37%); colorless crystals, mp 77–79 °C (hexane); [Found: C, 78.6; H, 6.4; N, 4.5. $C_{21}H_{21}NO_2$ requires C, 78.97; H, 6.63; N, 4.39%]; R_f (25% Et_2O/hexane) 0.13; ν_{max}(KBr) 2936, 1657, 1583, 1564 cm^{-1}; δ_H (400.1 MHz, $CDCl_3$) 1.69 (m, 4H, CH_2), 1.82 (m, 2H, CH_2), 2.43 (m, 2H, CH_2), 2.62 (m, 2H, CH_2), 7.03 (s, 1H, CH=), 7.36–7.94 (m, 10H, Ar); δ_C (100.6 MHz, $CDCl_3$) 25.6, 26.0, 26.8, 27.1, 32.3, 100.3, 127.9, 128.2, 128.4, 129.4, 129.9, 131.9, 140.0, 167.3, 169.7, 190.6.

*4.2.11. Cyclohexanone O-[(E)-3-(2-furyl)-3-oxo-1-phenyl-1-propenyl]oxime (**8k**).* Yield: 0.47 g (76%); colorless crystals, mp 104–106 °C (hexane); [Found: C, 73.6; H, 5.9; N, 4.5. $C_{19}H_{19}NO_3$ requires C, 73.77; H, 6.19; N, 4.53%]; ν_{max}(KBr) 2934, 1654, 1585, 1569 cm^{-1}; δ_H (400.1 MHz, $CDCl_3$) 1.68 (m, 4H, CH_2), 1.82 (m, 2H, CH_2), 2.44 (m, 2H, CH_2), 2.60 (m, 2H, CH_2), 6.48 (dd, ^3J=3.6, 1.7 Hz, 1H, H^4_{furyl}), 7.02 (s, 1H, CH=), 7.11 (dd, ^3J=3.6 Hz, ^4J=0.7 Hz, 1H, H^3_{furyl}), 7.40–7.57 (m, 6H, Ar, HetAr); δ_C (100.6 MHz, $CDCl_3$) 25.6, 26.0, 26.8, 27.1, 32.3, 98.6, 112.1, 115.6, 127.9, 129.4, 130.0, 133.8, 145.3, 154.8, 167.6, 169.6, 178.1; δ_N (40.5 MHz, $CDCl_3$) −31.1.

*4.2.12. Cyclohexanone O-[(E)-3-oxo-1-phenyl-3-(2-thienyl)-1-propenyl]oxime (**8l**).* Yield: 0.41 g (63%); pale yellow crystals, mp 90–92 °C (hexane); [Found: C, 69.9; H, 5.8; N, 4.4; S, 9.6. $C_{19}H_{19}NO_2S$ requires C, 70.12; H, 5.88; N, 4.30; S, 9.85%]; ν_{max}(KBr) 2934, 1632, 1584, 1562 cm^{-1}; δ_H (400.1 MHz, $CDCl_3$) 1.65 (m, 4H, CH_2), 1.79 (m, 2H, CH_2), 2.41 (m, 2H, CH_2), 2.59 (m, 2H, CH_2), 7.03 (s, 1H, CH=), 7.09 (dd, ^3J=4.8, 3.7 Hz, 1H, $H^4_{thienyl}$), 7.43–7.74 (m, 7H, Ar, HetAr); δ_C (100.6 MHz, $CDCl_3$) 25.6, 25.9, 26.8, 27.1, 32.2, 99.2, 127.8, 127.9, 129.3, 130.0, 130.6, 132.3, 133.8, 147.7, 167.5, 169.2, 182.0; δ_N (40.5 MHz, $CDCl_3$) −31.1.

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