Monatsh Chem (2013) 144:205–216
DOI 10.1007/s00706-012-0865-7

ORIGINAL PAPER

Homoallenyl azines in criss-cross cycloaddition reactions

Juraj Galeta · Stanislav Man · Aneta Valoušková · Milan Potáček

Received: 10 June 2012 / Accepted: 24 September 2012 / Published online: 7 November 2012
© Springer-Verlag Wien 2012

Abstract Thermally initiated combined intra-intermolecular criss-cross cycloadditions of substituted nonsymmetrical allenyl azines with isocyanate or isothiocyanate dipolarophiles were investigated. Substituted 1,3,10-triazatricyclo[5.2.1.0^{4,10}]dec-6-en-2-ones or -dec-6-ene-2-thiones were obtained as the main products in moderate to very good yields. The thermal stabilities of the tricyclic adducts in reactions with the competing reactive dipolarophile dimethyl acetylenedicarboxylate were studied and are discussed. In some cases, substituted 5,6-dihydro-4*H*-pyrrolo[1,2-*b*]pyrazoles were found as side products. This reaction showed high atom economy and in all cases we observed the presence of one diastereoisomer and regioisomer only, which was clearly revealed by crystallographic analysis.

Keywords 1,3-Dipole · Dipolarophile · Stereoselective synthesis · Heterocycles · Retro reactions

Introduction

The presence of azine and allene moieties in one molecule can lead under thermal stress to the formation of new structures with four fused five-membered rings in so-called intramolecular criss-cross cycloadditions [1, 2]. Because such reactions proceed via a 1,3-dipolar intermediate (Scheme 1) we decided to trap it with reactive heterocumulenes.

Intermolecular 1,3-dipolar cycloaddition between a 1,3-dipole and an added dipolarophile is an elegant and powerful method for the formation of heterocycles with three fused five-membered rings [3–5]. Theoretical studies proved that the whole reaction proceeds as an intra-intermolecular and not as an inter-intramolecular process. Similar applications of nonsymmetrical azines with substituted alkynes have already been published [6–8]. Moreover, we are even able to prepare bicyclic pyrrolo-[1,2-*b*]pyrazoles when no dipolarophile is present or we can observe their formation as side products in the presence of less reactive dipolarophiles [3, 4, 8, 9].

In this paper, we conclude our research into reactions of aromatic allenyl aldazines with isocyanates and isothiocyanates and focus on allenyl azines containing an adamantyl group [10]. The introduction of an adamantane moiety allows better transport of a molecule through cell membranes and thereby exerts a favorable effect upon its biological properties. Derivatives of adamantane have already found numerous applications in medicinal chemistry [11–16] and material science [17–24]. Our method could serve as one of the easiest and most accessible procedures for the preparation of heterocyclic compounds bearing an adamantyl fragment. Besides, heterocycles bearing pyrrolidinomethyl and morpholinomethyl fragments are also synthesized.

Results and discussion

In our research we initially followed our previous procedure, in which we introduced and demonstrated a thermally initiated combined intra-intermolecular criss-cros cycloaddition

Electronic supplementary material The online version of this article (doi:10.1007/s00706-012-0865-7) contains supplementary material, which is available to authorized users.

J. Galeta · S. Man · A. Valoušková · M. Potáček (✉)
Department of Chemistry, Faculty of Science,
Masaryk University, Kotlářská 2, 611 37 Brno,
Czech Republic
e-mail: potacek@chemi.muni.cz

Scheme 1

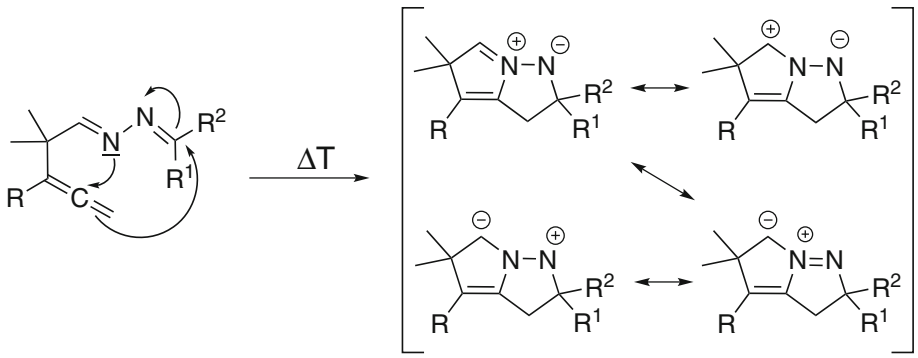
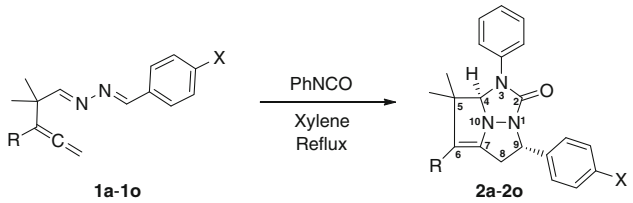


Table 1 Isolated yields/% and reaction times/h (in parentheses) of two-component cycloaddition reactions of azines **1a–1o** with PhNCO



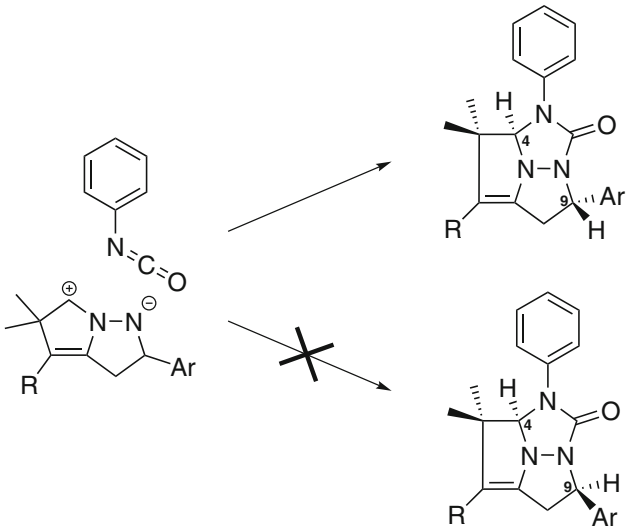
R	X				
	OMe	Me	H	Cl	NO_2
H (**a–e**)	68 (6)	71 (6)	64 (6)	62 (6)	81 (3)
Me (**f–j**)	81 (3)[a]	85 (3)	91 (3)	81 (3)	82 (0.5)
Et (**k–o**)	79 (3)[a]	84 (3)	72 (3)	73 (3)	72 (0.5)

[a] Previously published results [1, 2]

reaction for the first time [3]. Thus, we prepared several nonsymmetrical allenyl azines (**1a–1o**) from various *p*-substituted benzaldehydes [10] and tested their reactivity in criss-cross cycloadditions with phenylisocyanate (Table 1). The reactivity strongly depends upon the substituent R on the allene moiety, where a methyl and ethyl group could probably facilitate interaction between the azine and allene parts. This was demonstrated by shorter reaction time and higher yield. Moreover, electron-withdrawing groups (EWG) in the aromatic part of the azine also showed a significant influence on the reaction time. In addition, the concentration of the reactants plays an important role and after several optimization steps the best conditions were characterized by higher dilution ($\sim$30 mmol dm^{-3}) and the presence of a small excess of phenylisocyanate (10 %). Solvent-free reactions or microwave initiation afforded either comparable or even worse yields. The purity of the azines also significantly affected the resulting purity and yield of cycloadducts **2**. It is worth noting that stopping the reaction before the full conversion of azines **1a–1d** is better than its prolongation, which always led to an increase in colored impurities and lower yields only.

The obtained criss-cross products **2** are partially unsaturated compounds with three fused five-membered rings. This reaction was found to be regio- and stereoselective. We observed one diastereoisomer only as a racemic mixture of two enantiomers differing in the configuration at stereogenic centers C4 and C9. The formation of the second diastereoisomer was never observed (Scheme 2). Such behavior was not associated just with phenylisocyanate reactions, but was observed with any kind of dipolarophile. The relative configurations at the stereogenic centers were determined by crystallographic measurements.

We repeated the reaction protocol but using phenylisothiocyanate, benzylisocyanate, and benzylisothiocyanate as dipolarophiles and azines **1k** (R = Et, X = OCH_3) and **1m** (R = Et, X = H). Beside the expected cycloadducts (**2p**, **2q**, **2r**), we observed the formation of substituted 5,6-dihydro-4*H*-pyrrolo[1,2-*b*]pyrazoles **3** as side products in high quantity ($\sim$50 %). This observation can be rationalized by the low stability of the formed adducts **2** and low reactivity of the dipolarophiles. This instability was demonstrated in the competing reaction of cycloadduct **2f** with an excess of the reactive dipolarophile dimethyl acetylenedicarboxylate (DMAD, 3 equiv.) in refluxing

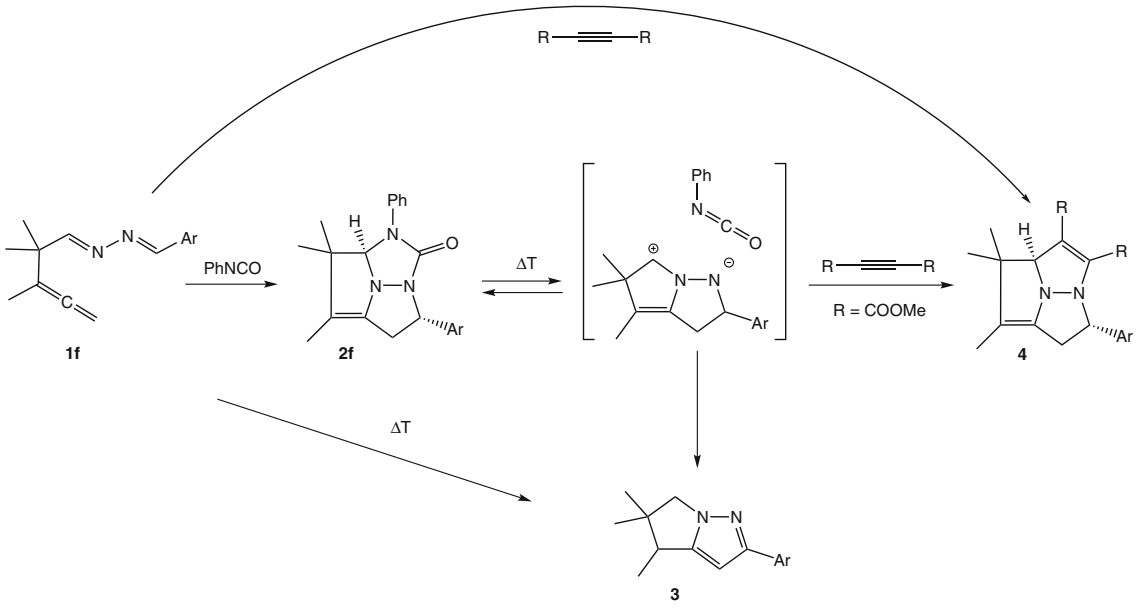


Scheme 2

xylene (Scheme 3). After 7 h, we obtained both possible criss-cross products **2f** and **4** in 1:1 ratio. This demonstrates that the reaction of **1** with isocyanates is reversible. Any prolongation of the reaction time leads to the production of either bicyclic products **3** or a mixture of unidentified side products. In other words, the lower the yield of **2** is, the higher the yield of **3**. When compound **2f** was heated for 7 h in xylene, only 25 % of the final mixture was product **3**. This lower conversion to product **3** is evidence of the probability that when compound **2f** is heated, its decomposition proceeds to dipole and PhNCO and ends by retrocycloaddition. The derivative **2j** with *p*-NO_2-Ph substitution at C9 afforded, under the same conditions, less than 5 % of product **3**. This illustrates the stabilizing effect of the EWG group upon the formed bicyclic 1,3-dipole, which then reacts reversibly with released PhNCO rather than rearranging into compound **3**. Yet, when the competing reagent DMAD is added to the reaction with **2j**, the mixture after the reaction contains compounds **2** and **4** in 1:1 ratio, which can be explained by the same reactivity of 1,3-dipole towards DMAD and released PhNCO.

After the analogous competing reaction of cycloadduct **2p** from PhNCS (see Fig. 1) in the presence of DMAD, we observed a significant difference in the composition of the reaction mixture. The NMR spectrum of the crude reaction mixture after 3 h showed the presence of the pure cycloadduct **4**. However, in the reaction of **2p** without a dipolarophile, we also obtained a very pure spectrum after 4 h but of bicyclic product **3** only. PhNCS was therefore shown to be a less reactive and, at the same time, more stable component than the more reactive DMAD. Thus, we observed the formation of either pure compound **4** or, without dipolarophile, pure product **3** as a 1,3-dipole transformation product. This also indicates that the type of substituent at C9 does not play any important role in determining the reaction path followed. The preparation of heterocycles **3** and **4** is discussed elsewhere [3, 4, 6–9].

The colorless or light yellow crystalline solids **2** are stable at room temperature and we did not observe any decomposition or any visible changes, even after several years. Crystal structures of all the presented compounds were obtained after the slow evaporation of diethyl ether or acetone solution. Again, we observed the formation of just one diastereoisomer only (Fig. 1).



Scheme 3

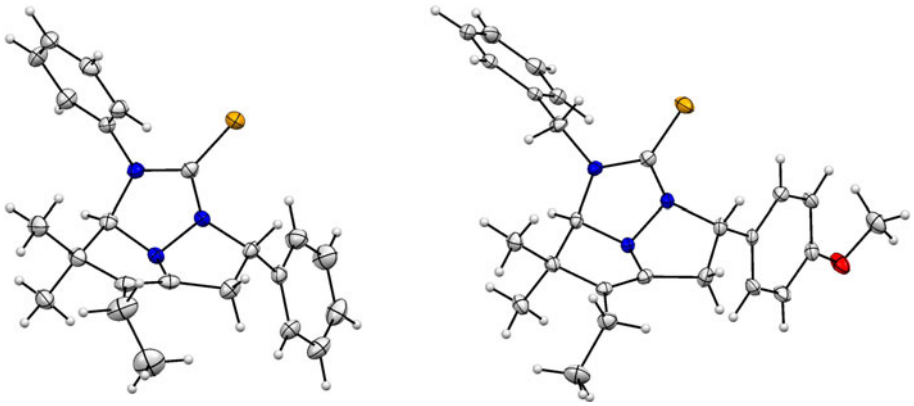
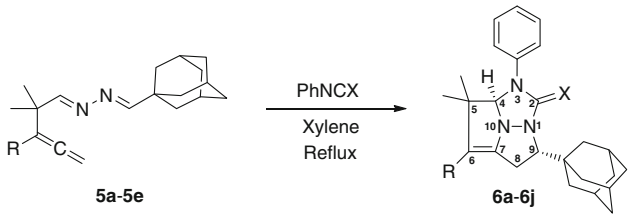


Fig. 1 ORTEP representations of cycloadducts **2p** (*left*) and **2r** (*right*) shown at the 50 % probability level (*blue* N, *red* O, *orange* S) (color figure online)

Table 2 Isolated yields/% and reaction times/h (in parentheses) of two-component cycloaddition reactions of azines **5a–5e** with PhNCO and PhNCS



	R				
	H	Me	Pyrr	Morph	Ad
PhNCO (**a–e**)	75 (8)	65 (2)	76 (2)	60 (2)	31 (4)
PhNCS (**f–j**)	50 (5)	55 (2)	55 (2)	50 (2)	14 (4)

Pyrr pyrrolidinomethyl, *Morph* morpholinomethyl, *Ad* 1-adamantyl

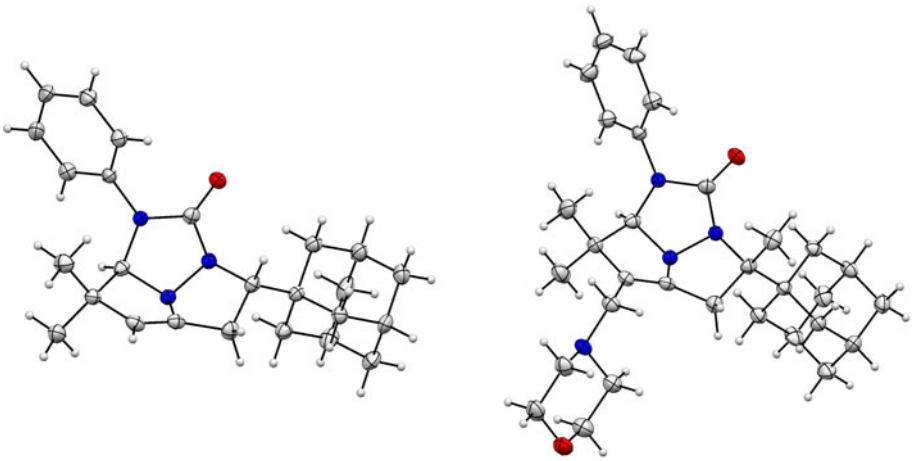


Fig. 2 ORTEP representations of cycloadducts **6a** (*left*) and **6k** (*right*) shown at the 50 % probability level (*blue* N, *red* O) (color figure online)

Our further attention was devoted to the synthesis of adamantane-containing heterocycles **6** and, therefore, we synthesized several allenyl azines **5a–5e** for their preparation (Table 2) [10]. Positive results were obtained in reactions with isocyanates and isothiocyanates. Not surprisingly, NMR and X-ray measurements confirmed the formation of one diastereoisomer only (Fig. 2 and Supplementary Material). We isolated stable and very pure colorless products after crystallization from acetone or petroleum ether. The uniform yields suggest that the influence of the adamantyl moiety is negligible and that the result of the reaction depends exclusively upon the type of

Table 3 Overview of stability measurements of criss-cross products with/without DMAD in refluxing xylene

Product	DMAD	Reaction time/h	Product **2**	Product **3**	Product **4**
2f	–	7	75 %	25 %	–
2f	3 equiv.	7	50 %	–	50 %
2j	–	7	>95 %	<5 %	–
2j	3 equiv.	7	50 %	–	50 %
2p	–	4	–	100 %	–
2p	3 equiv.	3	–	–	100 %
6b	–	7	90 %	10 %	–
6b	3 equiv.	7	90 %	–	10 %
Product with 2 hydrogen atoms at C9 [4]	–	7	90 %	10 %	–
	3 equiv.	7	90 %	–	10 %

dipolarophile. The influence of the allenyl part substituent (R) is reflected almost exclusively by different reaction times. There is actually just one exception for both dipolarophiles, where the formation of tricyclic compounds with two adamantyl groups (**6e** and **6j**) was suppressed by the creation of the side product 2,4-di(1-adamantyl)-5,5-dimethyl-5,6-dihydro-4*H*-pyrrolo[1,2-*b*]pyrazole.

Stability measurements of product **6b** without a dipolarophile and with added DMAD in refluxing xylene showed the same results. This means that after 7 h almost 90 % of compound **6b** did not change and we observed only around 10 % of **3**-like and **4**-like product, respectively. To determine the electronic influence of C9 substitution we used a particular compound containing two hydrogen atoms at C9 prepared previously [4]. Again, we obtained around 90 % of unchanged starting material **6** and about 10 % of by-product **3** or **4**. In other words, this means that the stabilizing or destabilizing effect of *p*-OMe (**2f**) or *p*-NO_2 (**2j**) substitution is missing and that the stability of such systems is significantly higher (Table 3).

To demonstrate the diastereoselectivity of the reaction, we prepared an allenyl azine from 1-adamantyl methyl ketone and subsequently the appropriate criss-cross product **6k**. X-ray structure analysis confirmed our assumption: the bulky adamantyl group at C9 was again directed towards one side of the molecule as is the hydrogen atom at C4 (Fig. 2).

Conclusion

The preparation of several substituted 1,3,10-triazatricyclo[5.2.1.$0^{4,10}$]dec-6-en-2-ones **2** and -dec-6-ene-2-thiones **6** was investigated. Their formation proceeds through a bicyclic 1,3-dipolar intermediate. The scope of the reaction was also tested with several azines containing an adamantyl group. Thus, we introduced a new synthetic procedure for the preparation of heterocycles bearing an adamantyl moiety. The stability of the prepared tricyclic compounds **2** and **6** was checked in the presence of added active dipolarophile. The 1,3-dipolar cycloaddition reaction was shown to be reversible. After the reaction we identified either substituted 5,6-dihydro-4*H*-pyrrolo[1,2-*b*]pyrazoles **3** or, in the presence of reactive DMAD, the products of retro-1,3-dipolar cycloaddition, namely 1,10-diazatricyclo[5.2.1.$0^{4,10}$]deca-2,6-dienes **4**.

Experimental

Dipolarophiles were purchased from commercial suppliers and used as received. Xylene (mixture of isomers) was dried and distilled from sodium/benzophenone and stored over dry 4 Å molecular sieves. All reactions were carried out under a dry argon atmosphere and were monitored by TLC (Merck F254 silica gel). Products were separated by preparative TLC or by liquid chromatography with a Horizon HPFC system (Biotage, Inc.) fitted with a Biotage Si 25+M column. Melting points were determined in open capillaries with an MPM-HV2 thermometer. FTIR spectra were recorded with a GENESIS ATI (Unicam) spectrometer. ^{1}H and ^{13}C NMR spectra were recorded with a Bruker Avance 500 spectrometer operating at 500.13 MHz (^{1}H) and 126 MHz (^{13}C) with $CDCl_3$ as solvent. Chemical shifts are reported in ppm, and tetramethylsilane ($\delta = 0.00$ ppm) and $CDCl_3$ ($\delta = 77.23$ ppm) served as internal standards for ^{1}H NMR and ^{13}C NMR analysis, respectively. MS data were obtained with a Fisons Instruments TRIO 1000 spectrometer at 70 eV in the EI mode. Elemental analyses were performed with a Perkin-Elmer CHN 2400 apparatus. High-resolution mass spectra (HRMS) were recorded on a Micromass Q-Tof micro instrument in the positive ESI (CV = 30 V) mode.

X-ray diffraction data were collected on a Kuma KM-4 four-circle CCD diffractometer and corrected for Lorentz and polarization effects. The structures were resolved by

direct methods and refined by full-matrix least-squares methods using the SHELXTL program package [25]. Hydrogen atoms were placed in calculated idealized positions. The crystal structures of compounds **2p**, **2r**, **6a**, **6g**, **6i**, **6k**, **6m**, and **6o** (see Supplementary Material) have been deposited at the Cambridge Crystallographic Data Centre and allocated the deposition numbers CCDC 875425–875431 and 875881. The CCDC numbers are shown in the experimental section for each compound individually.

*General procedure for the synthesis of criss-cross cycloadducts **2** and **6***

A mixture of allenyl azine **1** or **5** (1 mmol) and dipolarophile (1.1 mmol) in 30 cm^3 dry xylene was heated under reflux for the time given for each compound. The solvent was then removed under vacuum and, in the case of cycloadducts **2**, the residue was purified by recrystallization from $EtOH/H_2O = 60/40$. An analytically pure sample was obtained after preparative TLC (SiO_2, AcOEt/PE = 20/80) followed by crystallization from Et_2O/PE = 1/1. Pure samples of adamantane-containing heterocycles **6** were isolated by liquid chromatography (DCM) or by recrystallization from acetone or PE.

(4R,9S*)-9-(4-Methoxyphenyl)-5,5-dimethyl-3-phenyl-1,3,10-triazatricyclo[5.2.1.$0^{4,10}$]dec-6-en-2-one* (**2a**, $C_{22}H_{23}N_3O_2$)

Yield 68 % (6 h); m.p.: 157.0–158.0 °C; ^{1}H NMR: δ = 0.84 (s, 3H, CH_3), 1.38 (s, 3H, CH_3), 2.62 (ddd, ^2J = 15.5 Hz, ^3J = 5.3 Hz, ^4J = 2.0 Hz, 1H, H8), 3.13 (dd, ^2J = 15.5 Hz, ^3J = 8.9 Hz, 1H, H8), 3.79 (s, 3H, O-CH_3), 4.73 (d, ^4J = 2.0 Hz, 1H, H6), 5.35 (dd, ^3J = 8.9 Hz, ^3J = 5.3 Hz, 1H, H9), 5.47 (s, 1H, H4), 6.89 (d, ^3J = 8.6 Hz, 2H, Ph), 7.12–7.22 (m, 1H, Ph), 7.31–7.47 (m, 6H, Ph) ppm; ^{13}C NMR: δ = 24.4 (CH_3), 27.4 (CH_3), 33.5 (C8), 55.1 (C5), 55.5 (O-CH_3), 65.3 (C9), 85.1 (C4), 110.2 (C6), 114.2 (2 × CH), 122.5 (2 × CH), 125.4 (CH), 127.4 (2 × CH), 129.1 (2 × CH), 135.3 (C, Ph), 139.1 (C, Ph), 149.8 (C7), 159.1 (C, Ph), 161.8 (C2) ppm; IR: $\bar{\nu}$ = 3,061, 2,965, 2,927, 2,861, 1,704 (C=O), 1,597, 1,508, 1,409, 1,295, 1,245, 1,172, 1,030 cm^{-1}; MS: *m/z* (%) = 361 (M^+, 38), 345 (25), 199 (44), 162 (100), 134 (21), 77 (35).

(4R,9S*)-5,5-Dimethyl-9-(4-methylphenyl)-3-phenyl-1,3,10-triazatricyclo[5.2.1.$0^{4,10}$]dec-6-en-2-one* (**2b**, $C_{22}H_{23}N_3O$)

Yield 71 % (6 h); m.p.: 126.0–127.5 °C; ^{1}H NMR: δ = 0.84 (s, 3H, CH_3), 1.38 (s, 3H, CH_3), 2.33 (s, 3H, Ph-CH_3), 2.62 (ddd, ^2J = 15.4 Hz, ^3J = 5.5 Hz, ^4J = 1.8 Hz, 1H, H8), 3.14 (dd, ^2J = 15.4 Hz, ^3J = 8.9 Hz, 1H, H8), 4.73 (d, ^4J = 1.8 Hz, 1H, H6), 5.37 (dd, ^3J = 8.9 Hz, ^3J = 5.5 Hz, 1H, H9), 5.48 (s, 1H, H4), 7.12–7.20 (m, 3H, Ph), 7.31–7.38 (m, 4H, Ph), 7.39–7.47 (m, 2H, Ph) ppm; ^{13}C NMR: δ = 21.3 (Ph-CH_3), 24.4 (CH_3), 27.4 (CH_3), 33.5 (C8), 55.1 (C5), 65.5 (C9), 85.1 (C4), 110.2 (C6), 122.5 (2 × CH), 125.4 (CH), 126.1 (2 × CH), 129.1 (2 × CH), 129.5 (2 × CH), 137.1 (C, Ph), 139.1 (C, Ph), 140.1 (C, Ph), 149.8 (C7), 161.8 (C2) ppm; IR: $\bar{\nu}$ = 3,062, 2,964, 2,921, 2,863, 1,702 (C=O), 1,597, 1,501, 1,408, 1,305, 1,145 cm^{-1}; MS: *m/z* (%) = 345 (M^+, 47), 330 (13), 199 (57), 146 (85), 104 (39), 91 (46), 77 (100).

(4R,9S*)-5,5-Dimethyl-3,9-diphenyl-1,3,10-triazatricyclo[5.2.1.$0^{4,10}$]dec-6-en-2-one* (**2c**, $C_{21}H_{21}N_3O$)

Yield 64 % (6 h); m.p.: 153.5–155.0 °C; ^{1}H NMR: δ = 0.84 (s, 3H, CH_3), 1.38 (s, 3H, CH_3), 2.63 (ddd, ^2J = 15.4 Hz, ^3J = 5.4 Hz, ^4J = 2.4 Hz, 1H, H8), 3.17 (dd, ^2J = 15.4 Hz, ^3J = 9.0 Hz, 1H, H8), 4.74 (d, ^4J = 2.4 Hz, 1H, H6), 5.41 (dd, ^3J = 9.0 Hz, ^3J = 5.4 Hz, 1H, H9), 5.49 (s, 1H, H4), 7.14–7.19 (m, 1H, Ph), 7.23–7.28 (m, 1H, Ph), 7.33–7.38 (m, 4H, Ph), 7.42–7.49 (m, 4H, Ph) ppm; ^{13}C NMR: δ = 24.4 (CH_3), 27.4 (CH_3), 33.5 (C8), 55.2 (C5), 65.6 (C9), 85.1 (C4), 110.3 (C6), 122.5 (2 × CH), 125.5 (CH), 126.2 (2 × CH), 127.5 (CH), 128.9 (2 × CH), 129.1 (2 × CH), 139.1 (C, Ph), 143.1 (C, Ph), 149.7 (C7), 161.8 (C2) ppm; IR: $\bar{\nu}$ = 3,063, 2,964, 2,924, 2,862, 1,701 (C=O), 1,595, 1,495, 1,409, 1,304 cm^{-1}; MS: *m/z* (%) = 331 (M^+, 88), 316 (31), 199 (55), 132 (44), 103 (54), 77 (100).

(4R,9S*)-9-(4-Chlorophenyl)-5,5-dimethyl-3-phenyl-1,3,10-triazatricyclo[5.2.1.$0^{4,10}$]dec-6-en-2-one* (**2d**, $C_{21}H_{20}ClN_3O$)

Yield 62 % (6 h); m.p.: 148.0–149.5 °C; ^{1}H NMR: δ = 0.84 (s, 3H, CH_3), 1.38 (s, 3H, CH_3), 2.56 (ddd, ^2J = 15.4 Hz, ^3J = 5.3 Hz, ^4J = 2.0 Hz, 1H, H8), 3.17 (dd, ^2J = 15.4 Hz, ^3J = 9.0 Hz, 1H, H8), 4.75 (d, ^4J = 2.0 Hz, 1H, H6), 5.37 (dd, ^3J = 9.0 Hz, ^3J = 5.3 Hz, 1H, H9), 5.49 (s, 1H, H4), 7.12–7.20 (m, 1H, Ph), 7.28–7.46 (m, 8H, Ph) ppm; ^{13}C NMR: δ = 24.4 (CH_3), 27.4 (CH_3), 33.5 (C8), 55.2 (C5), 65.0 (C9), 85.1 (C4), 110.6 (C6), 122.6 (2 × CH), 125.6 (CH), 127.6 (2 × CH), 129.0 (2 × CH), 129.2 (2 × CH), 133.3 (C, Ph), 139.0 (C, Ph), 141.6 (C, Ph), 149.4 (C7), 161.6 (C2) ppm; IR: $\bar{\nu}$ = 3,059, 2,962, 2,927, 2,862, 1,706 (C=O), 1,596, 1,492, 1,401, 1,302, 1,203, 1,143 cm^{-1}; MS: *m/z* (%) = 365 (M^+, 30), 350 (12), 199 (42), 166 (46), 104 (33), 96 (44), 77 (100).

(4R,9S*)-5,5-Dimethyl-9-(4-nitrophenyl)-3-phenyl-1,3,10-triazatricyclo[5.2.1.$0^{4,10}$]dec-6-en-2-one* (**2e**, $C_{21}H_{20}N_4O_3$)

Yield 81 % (3 h); m.p.: 172.5–173.5 °C; ^{1}H NMR: δ = 0.85 (s, 3H, CH_3), 1.39 (s, 3H, CH_3), 2.55 (ddd,

$^2J = 15.4$ Hz, $^3J = 5.3$ Hz, $^4J = 2.0$ Hz, 1H, H8), 3.25 (dd, $^2J = 15.4$ Hz, $^3J = 9.2$ Hz, 1H, H8), 4.80 (d, $^4J = 2.0$ Hz, 1H, H6), 5.48 (dd, $^3J = 9.2$ Hz, $^3J = 5.3$ Hz, 1H, H9), 5.52 (s, 1H, H4), 7.17–7.23 (m, 1H, Ph), 7.35–7.47 (m, 4H, Ph), 7.63 (d, $^3J = 8.7$ Hz, 2H, Ph), 8.22 (d, $^3J = 8.7$ Hz, 2H, Ph) ppm; ^{13}C NMR: $\delta = 24.3$ (CH_3), 27.4 (CH_3), 33.4 (C8), 55.3 (C5), 64.9 (C9), 85.2 (C4), 111.0 (C6), 122.6 (2 × CH), 124.2 (2 × CH), 125.8 (CH), 127.1 (2 × CH), 129.2 (2 × CH), 138.7 (C, Ph), 147.4 (C, Ph), 148.8 (C7), 150.3 (C, Ph), 161.4 (C2) ppm; IR: $\bar{\nu} = 3{,}052$, 2,961, 2,928, 2,863, 1,711 (C=O), 1,599, 1,518, 1,347, 1,294 cm^{-1}; MS: *m/z* (%) = 376 (M^+, 100), 361 (47), 199 (23), 104 (31), 96 (43), 77 (59).

(4R,9S*)-9-(4-Methoxyphenyl)-5,5,6-trimethyl-3-phenyl-1,3,10-triazatricyclo[5.2.1.0^{4,10}]dec-6-en-2-one*
(**2f**, $C_{23}H_{25}N_3O_2$)
Yield 81 % (3 h); m.p.: 177.0–178.0 °C; ^{1}H NMR: $\delta = 0.76$ (s, 3H, CH_3), 1.30 (s, 3H, CH_3), 1.52 (d, $^5J = 1.7$ Hz, 3H, C6-CH_3), 2.52 (ddm, $^2J = 15.1$ Hz, $^3J = 5.2$ Hz, 1H, H8), 3.12 (dd, $^2J = 15.1$ Hz, $^3J = 8.9$ Hz, 1H, H8), 3.79 (s, 3H, O-CH_3), 5.30 (dd, $^3J = 8.9$ Hz, $^3J = 5.2$ Hz, 1H, H9), 5.49 (s, 1H, H4), 6.88 (d, $^3J = 8.7$ Hz, 2H, Ph), 7.13–7.19 (m, 1H, Ph), 7.32–7.45 (m, 6H, Ph) ppm; ^{13}C NMR: $\delta = 8.6$ (C6-*C*H_3), 22.1 (CH_3), 25.6 (CH_3), 32.3 (C8), 55.5 (C5), 55.5 (O-CH_3), 64.8 (C9), 84.7 (C4), 114.2 (2 × CH), 116.1 (C6), 122.8 (2 × CH), 125.4 (CH), 127.5 (2 × CH), 129.1 (2 × CH), 135.5 (C, Ph), 139.2 (C, Ph), 143.3 (C7), 159.0 (C, Ph), 162.1 (C2) ppm; IR: $\bar{\nu} = 3{,}061$, 2,959, 2,924, 2,833, 1,701 (C=O), 1,597, 1,514, 1,410, 1,305, 1,244, 1,182, 1,034 cm^{-1}; MS: *m/z* (%) = 375 (M^+, 35), 280 (26), 162 (100), 134 (21), 77 (35).

(4R,9S*)-5,5,6-Trimethyl-9-(4-methylphenyl)-3-phenyl-1,3,10-triazatricyclo[5.2.1.0^{4,10}]dec-6-en-2-one*
(**2g**, $C_{23}H_{25}N_3O$)
Yield 85 % (3 h); m.p.: 161.5–163.0 °C; ^{1}H NMR: $\delta = 0.76$ (s, 3H, CH_3), 1.30 (s, 3H, CH_3), 1.52 (d, $^5J = 1.7$ Hz, 3H, C6-CH_3), 2.33 (s, 3H, Ph-CH_3), 2.53 (ddm, $^2J = 15.0$ Hz, $^3J = 5.2$ Hz, 1H, H8), 3.13 (dd, $^2J = 15.0$ Hz, $^3J = 8.9$ Hz, 1H, H8), 5.32 (dd, $^3J = 8.9$ Hz, $^3J = 5.2$ Hz, 1H, H9), 5.50 (s, 1H, H4), 7.11–7.20 (m, 3H, Ph), 7.32–7.47 (m, 6H, Ph) ppm; ^{13}C NMR: $\delta = 8.6$ (C6-*C*H_3), 21.3 (Ph-CH_3), 22.1 (CH_3), 25.6 (CH_3), 32.3 (C8), 55.5 (C5), 65.1 (C9), 84.7 (C4), 116.1 (C6), 122.7 (2 × CH), 125.4 (CH), 126.2 (2 × CH), 129.1 (2 × CH), 129.5 (2 × CH), 137.0 (C, Ph), 139.3 (C, Ph), 140.3 (C, Ph), 143.3 (C7), 162.1 (C2) ppm; IR: $\bar{\nu} = 3{,}061$, 2,969, 2,918, 2,861, 1,705 (C=O), 1,599, 1,504, 1,406, 1,298 cm^{-1}; MS: *m/z* (%) = 359 (M^+, 41), 344 (12), 264 (51), 231 (25), 146 (62), 110 (42), 91 (47), 77 (100).

(4R,9S*)-5,5,6-Trimethyl-3,9-diphenyl-1,3,10-triazatricyclo[5.2.1.0^{4,10}]dec-6-en-2-one* (**2h**, $C_{22}H_{23}N_3O$)
Yield 91 % (3 h); m.p.: 194.0–196.0 °C; ^{1}H NMR: $\delta = 0.77$ (s, 3H, CH_3), 1.31 (s, 3H, CH_3), 1.53 (d, $^5J = 1.8$ Hz, 3H, C6-CH_3), 2.53 (ddm, $^2J = 15.1$ Hz, $^3J = 5.3$ Hz, 1H, H8), 3.16 (dd, $^2J = 15.1$ Hz, $^3J = 9.0$ Hz, 1H, H8), 5.36 (dd, $^3J = 9.0$ Hz, $^3J = 5.3$ Hz, 1H, H9), 5.51 (s, 1H, H4), 7.14–7.19 (m, 1H, Ph), 7.23–7.28 (m, 1H, Ph), 7.32–7.38 (m, 4H, Ph), 7.41–7.49 (m, 4H, Ph) ppm; ^{13}C NMR: $\delta = 8.7$ (C6-*C*H_3), 22.1 (CH_3), 25.7 (CH_3), 32.4 (C8), 55.6 (C5), 65.2 (C9), 84.7 (C4), 116.2 (C6), 122.8 (2 × CH), 125.5 (CH), 126.2 (2 × CH), 127.4 (CH), 128.8 (2 × CH), 129.1 (2 × CH), 139.2 (C, Ph), 143.2 (C, Ph), 143.3 (C7), 162.1 (C2) ppm; IR: $\bar{\nu} = 3{,}053$, 2,973, 2,934, 2,861, 1,696 (C=O), 1,596, 1,493, 1,409, 1,294 cm^{-1}; MS: *m/z* (%) = 345 (M^+, 37), 250 (18), 104 (43), 77 (100).

(4R,9S*)-9-(4-Chlorophenyl)-5,5,6-trimethyl-3-phenyl-1,3,10-triazatricyclo[5.2.1.0^{4,10}]dec-6-en-2-one*
(**2i**, $C_{22}H_{22}ClN_3O$)
Yield 81 % (3 h); m.p.: 147.5–148.5 °C; ^{1}H NMR: $\delta = 0.76$ (s, 3H, CH_3), 1.30 (s, 3H, CH_3), 1.52 (d, $^5J = 1.6$ Hz, 3H, C6-CH_3), 2.46 (ddm, $^2J = 15.0$ Hz, $^3J = 5.2$ Hz, 1H, H8), 3.15 (dd, $^2J = 15.0$ Hz, $^3J = 9.0$ Hz, 1H, H8), 5.32 (dd, $^3J = 9.0$ Hz, $^3J = 5.2$ Hz, 1H, H9), 5.50 (s, 1H, H4), 7.14–7.20 (m, 1H, Ph), 7.29–7.44 (m, 8H, Ph) ppm; ^{13}C NMR: $\delta = 8.6$ (C6-*C*H_3), 22.0 (CH_3), 25.6 (CH_3), 32.3 (C8), 55.6 (C5), 64.6 (C9), 84.7 (C4), 116.5 (C6), 122.8 (2 × CH), 125.6 (CH), 127.7 (2 × CH), 128.9 (2 × CH), 129.1 (2 × CH), 133.1 (C, Ph), 139.1 (C, Ph), 141.8 (C, Ph), 142.9 (C7), 162.0 (C2) ppm; IR: $\bar{\nu} = 3{,}062$, 2,969, 2,922, 2,869, 1,704 (C=O), 1,598, 1,490, 1,404, 1,296, 1,221 cm^{-1}; MS: *m/z* (%) = 379 (M^+, 25), 284 (28), 166 (26), 110 (58), 77 (100).

(4R,9S*)-5,5,6-Trimethyl-9-(4-nitrophenyl)-3-phenyl-1,3,10-triazatricyclo[5.2.1.0^{4,10}]dec-6-en-2-one*
(**2j**, $C_{22}H_{22}N_4O_3$)
Yield 82 % (0.5 h); m.p.: 151.0–152.0 °C; ^{1}H NMR: $\delta = 0.78$ (s, 3H, CH_3), 1.31 (s, 3H, CH_3), 1.54 (d, $^5J = 1.5$ Hz, 3H, C6-CH_3), 2.45 (ddm, $^2J = 15.1$ Hz, $^3J = 5.2$ Hz, 1H, H8), 3.24 (dd, $^2J = 15.1$ Hz, $^3J = 9.1$ Hz, 1H, H8), 5.43 (dd, $^3J = 9.1$ Hz, $^3J = 5.2$ Hz, 1H, H9), 5.53 (s, 1H, H4), 7.17–7.22 (m, 1H, Ph), 7.35–7.45 (m, 4H, Ph), 7.64 (d, $^3J = 8.7$ Hz, 2H, Ph), 8.21 (d, $^3J = 8.7$ Hz, 2H, Ph) ppm; ^{13}C NMR: $\delta = 8.7$ (C6-*C*H_3), 22.0 (CH_3), 25.6 (CH_3), 32.3 (C8), 55.7 (C5), 64.5 (C9), 84.8 (C4), 117.1 (C6), 122.9 (2 × CH), 124.1 (2 × CH), 125.8 (CH), 127.1 (2 × CH), 129.2 (2 × CH), 138.9 (C, Ph), 142.3 (C7), 147.4 (C, Ph), 150.5 (C, Ph), 161.7 (C2) ppm; IR: $\bar{\nu} = 3{,}064$, 2,968, 2,935, 2,863, 1,712 (C=O), 1,600, 1,524, 1,347, 1,290 cm^{-1}; MS: *m/z* (%) = 390

(M^+, 100), 375 (37), 295 (41), 271 (29), 197 (31), 110 (42), 77 (80).

(4R,9S*)-6-Ethyl-9-(4-methoxyphenyl)-5,5-dimethyl-3-phenyl-1,3,10-triazatricyclo[5.2.1.0^{4,10}]dec-6-en-2-one* (**2k**, $C_{24}H_{27}N_3O_2$)

Yield 79 % (3 h); m.p.: 155.5–156.0 °C; ^{1}H NMR: $\delta = 0.78$ (s, 3H, CH_3), 1.07 (t, $^3J = 7.6$ Hz, 3H, Et), 1.34 (s, 3H, CH_3), 1.83–2.10 (m, 2H, Et), 2.59 (ddm, $^2J = 15.3$ Hz, $^3J = 5.0$ Hz, 1H, H8), 3.20 (dd, $^2J = 15.3$ Hz, $^3J = 8.9$ Hz, 1H, H8), 3.79 (s, 3H, O-CH_3), 5.32 (dd, $^3J = 8.9$ Hz, $^3J = 5.0$ Hz, 1H, H9), 5.44 (s, 1H, H4), 6.89 (d, $^3J = 8.6$ Hz, 2H, Ph), 7.12–7.22 (m, 1H, Ph), 7.30–7.45 (m, 6H, Ph) ppm; ^{13}C NMR: $\delta = 13.8$ (Et), 17.7 (Et), 22.3 (CH_3), 26.6 (CH_3), 32.9 (C8), 55.5 (O-CH_3), 55.9 (C5), 64.8 (C9), 84.9 (C4), 114.2 (2 × CH), 121.5 (C6), 123.0 (2 × CH), 125.5 (CH), 127.5 (2 × CH), 129.1 (2 × CH), 135.5 (C, Ph), 139.3 (C, Ph), 143.1 (C7), 159.0 (C, Ph), 162.2 (C2) ppm; IR: $\bar{\nu} = 3{,}061$, 2,965, 2,929, 2,864, 1,709 (C=O), 1,597, 1,506, 1,387, 1,296, 1,167, 1,027 cm^{-1}; MS: *m/z* (%) = 389 (M^+, 23), 280 (35), 162 (100), 134 (43), 77 (80).

(4R,9S*)-6-Ethyl-5,5-dimethyl-9-(4-methylphenyl)-3-phenyl-1,3,10-triazatricyclo[5.2.1.0^{4,10}]dec-6-en-2-one* (**2l**, $C_{24}H_{27}N_3O$)

Yield 84 % (3 h); m.p.: 143.5–145.0 °C; ^{1}H NMR: $\delta = 0.78$ (s, 3H, CH_3), 1.06 (t, $^3J = 7.6$ Hz, 3H, Et), 1.34 (s, 3H, CH_3), 1.83–2.10 (m, 2H, Et), 2.33 (s, 3H, Ph-CH_3), 2.58 (ddm, $^2J = 15.1$ Hz, $^3J = 5.1$ Hz, 1H, H8), 3.21 (dd, $^2J = 15.1$ Hz, $^3J = 8.9$ Hz, 1H, H8), 5.34 (dd, $^3J = 8.9$ Hz, $^3J = 5.1$ Hz, 1H, H9), 5.45 (s, 1H, H4), 7.11–7.22 (m, 3H, Ph), 7.30–7.46 (m, 6H, Ph) ppm; ^{13}C NMR: $\delta = 13.8$ (Et), 17.7 (Et), 21.3 (Ph-CH_3), 22.3 (CH_3), 26.6 (CH_3), 32.9 (C8), 56.0 (C5), 65.1 (C9), 84.9 (C4), 121.5 (C6), 123.0 (2 × CH), 125.5 (CH), 126.2 (2 × CH), 129.1 (2 × CH), 129.4 (2 × CH), 137.0 (C, Ph), 139.3 (C, Ph), 140.3 (C, Ph), 143.1 (C7), 162.2 (C2) ppm; IR: $\bar{\nu} = 3{,}066$, 2,963, 2,932, 2,871, 1,710 (C=O), 1,598, 1,495, 1,387, 1,302, 1,213 cm^{-1}; MS: *m/z* (%) = 373 (M^+, 36), 358 (11), 264 (55), 146 (47), 124 (35), 104 (35), 91 (53), 77 (100).

(4R,9S*)-6-Ethyl-5,5-dimethyl-3,9-diphenyl-1,3,10-triazatricyclo[5.2.1.0^{4,10}]dec-6-en-2-one* (**2m**, $C_{23}H_{25}N_3O$)

Yield 72 % (3 h); m.p.: 132.0–133.0 °C; ^{1}H NMR: $\delta = 0.78$ (s, 3H, CH_3), 1.07 (t, $^3J = 7.6$ Hz, 3H, Et), 1.34 (s, 3H, CH_3), 1.88–2.06 (m, 2H, Et), 2.59 (ddm, $^2J = 15.3$ Hz, $^3J = 5.1$ Hz, 1H, H8), 3.24 (dd, $^2J = 15.3$ Hz, $^3J = 9.0$ Hz, 1H, H8), 5.37 (dd, $^3J = 9.0$ Hz, $^3J = 5.1$ Hz, 1H, H9), 5.46 (s, 1H, H4), 7.14–7.19 (m, 1H, Ph), 7.22–7.27 (m, 1H, Ph), 7.32–7.50 (m, 8H, Ph) ppm; ^{13}C NMR: $\delta = 13.8$ (Et), 17.7 (Et), 22.3 (CH_3), 26.6 (CH_3), 32.9 (C8), 56.0 (C5), 65.2 (C9), 85.0 (C4), 121.6 (C6), 123.0 (2 × CH), 125.5 (CH), 126.2 (2 × CH), 127.4 (CH), 128.8 (2 × CH), 129.1 (2 × CH), 139.2 (C, Ph), 143.0 (C, Ph), 143.3 (C7), 162.2 (C2) ppm; IR: $\bar{\nu} = 3{,}062$, 2,965, 2,930, 2,877, 1,701 (C=O), 1,599, 1,504, 1,402, 1,302, 1,229 cm^{-1}; MS: *m/z* (%) = 359 (M^+, 42), 250 (38), 211 (23), 132 (25), 124 (32), 104 (49), 77 (100).

(4R,9S*)-9-(4-Chlorophenyl)-6-ethyl-5,5-dimethyl-3-phenyl-1,3,10-triazatricyclo[5.2.1.0^{4,10}]dec-6-en-2-one* (**2n**, $C_{23}H_{24}ClN_3O$)

Yield 73 % (3 h); m.p.: 146.0–147.0 °C; ^{1}H NMR: $\delta = 0.78$ (s, 3H, CH_3), 1.07 (t, $^3J = 7.6$ Hz, 3H, Et), 1.34 (s, 3H, CH_3), 1.83–2.07 (m, 2H, Et), 2.52 (ddm, $^2J = 15.3$ Hz, $^3J = 5.1$ Hz, 1H, H8), 3.24 (dd, $^2J = 15.3$ Hz, $^3J = 9.0$ Hz, 1H, H8), 5.33 (dd, $^3J = 9.0$ Hz, $^3J = 5.1$ Hz, 1H, H9), 5.45 (s, 1H, H4), 7.13–7.20 (m, 1H, Ph), 7.28–7.48 (m, 8H, Ph) ppm; ^{13}C NMR: $\delta = 13.8$ (Et), 17.7 (Et), 22.3 (CH_3), 26.6 (CH_3), 32.9 (C8), 56.0 (C5), 64.6 (C9), 85.0 (C4), 121.9 (C6), 123.0 (2 × CH), 125.7 (CH), 127.7 (2 × CH), 128.9 (2 × CH), 129.1 (2 × CH), 133.2 (C, Ph), 139.1 (C, Ph), 141.8 (C, Ph), 142.7 (C7), 162.1 (C2) ppm; IR: $\bar{\nu} = 3{,}067$, 2,968, 2,928, 2,879, 1,702 (C=O), 1,599, 1,492, 1,402, 1,300, 1,226 cm^{-1}; MS: *m/z* (%) = 393 (M^+, 25), 284 (29), 166 (27), 124 (44), 104 (35), 77 (100).

(4R,9S*)-6-Ethyl-5,5-dimethyl-9-(4-nitrophenyl)-3-phenyl-1,3,10-triazatricyclo[5.2.1.0^{4,10}]dec-6-en-2-one* (**2o**, $C_{23}H_{24}N_4O_3$)

Yield 72 % (0.5 h); m.p.: 146.5–147.5 °C; ^{1}H NMR: $\delta = 0.79$ (s, 3H, CH_3), 1.08 (t, $^3J = 7.6$ Hz, 3H, Et), 1.35 (s, 3H, CH_3), 1.90–2.07 (m, 2H, Et), 2.51 (ddm, $^2J = 15.2$ Hz, $^3J = 5.1$ Hz, 1H, H8), 3.32 (dd, $^2J = 15.2$ Hz, $^3J = 9.2$ Hz, 1H, H8), 5.45 (dd, $^3J = 9.2$ Hz, $^3J = 5.1$ Hz, 1H, H9), 5.48 (s, 1H, H4), 7.17–7.22 (m, 1H, Ph), 7.35–7.44 (m, 4H, Ph), 7.64 (d, $^3J = 8.7$ Hz, 2H, Ph), 8.21 (d, $^3J = 8.7$ Hz, 2H, Ph) ppm; ^{13}C NMR: $\delta = 13.7$ (Et), 17.7 (Et), 22.2 (CH_3), 26.6 (CH_3), 32.8 (C8), 56.1 (C5), 64.5 (C9), 85.1 (C4), 122.5 (C6), 123.1 (2 × CH), 124.1 (2 × CH), 125.9 (CH), 127.1 (2 × CH), 129.2 (2 × CH), 138.9 (C, Ph), 142.1 (C7), 147.4 (C, Ph), 150.5 (C, Ph), 161.9 (C2) ppm; IR: $\bar{\nu} = 3{,}068$, 2,973, 2,931, 2,867, 1,708 (C=O), 1,599, 1,518, 1,349, 1,301 cm^{-1}; MS: *m/z* (%) = 404 (M^+, 29), 295 (16), 285 (35), 256 (35), 124 (40), 104 (53), 77 (100).

(4R,9S*)-6-Ethyl-5,5-dimethyl-3,9-diphenyl-1,3,10-triazatricyclo[5.2.1.0^{4,10}]dec-6-ene-2-thione* (**2p**, $C_{23}H_{25}N_3S$)

Yield 54 % (2 h); m.p.: 127.5–128.5 °C; ^{1}H NMR: $\delta = 0.74$ (s, 3H, CH_3), 1.09 (t, $^3J = 7.6$ Hz, 3H, Et), 1.30 (s, 3H, CH_3), 1.87–2.09 (m, 2H, Et), 2.71 (ddm, $^2J = 15.3$ Hz, $^3J = 4.7$ Hz, 1H, H8), 3.29 (dd, $^2J = 15.3$ Hz, $^3J = 9.0$ Hz, 1H, H8), 5.39 (s, 1H, H4),

5.88 (dd, ^3J = 9.0 Hz, ^3J = 4.7 Hz, 1H, H9), 7.23–7.56 (m, 10H, Ph) ppm; ^{13}C NMR: δ = 13.7 (Et), 17.5 (Et), 22.0 (CH_3), 27.4 (CH_3), 32.5 (C8), 56.6 (C5), 69.0 (C9), 90.5 (C4), 121.4 (C6), 126.3 (2 × CH), 127.2 (2 × CH), 127.6 (CH), 127.8 (CH), 128.9 (2 × CH), 129.1 (2 × CH), 140.1 (C, Ph), 141.7 (C, Ph), 142.4 (C7), 188.0 (C2) ppm; IR: $\bar{\nu}$ = 3,050, 2,972, 2,919, 2,887, 2,830, 1,706, 1,601, 1,503, 1,401, 1,315, 1,272, 1,211, 1,187, 1,106, 1,099, 1,048 cm^{-1}; MS: *m/z* (%) = 375 (M^+, 57), 360 (14), 301 (19), 240 (81), 225 (30), 211 (47), 163 (17), 148 (19), 137 (34), 122 (49), 109 (52), 91 (32), 77 (100); HRMS: *m/z* calcd. for $C_{23}H_{26}N_3S^+$ 376.1842, found 376.1847; CCDC number 875425.

(4R,9S*)-3-Benzyl-6-ethyl-9-(4-methoxyphenyl)-5,5-dimethyl-1,3,10-triazatricyclo[5.2.1.0^{4,10}]dec-6-en-2-one* (**2q**, $C_{25}H_{29}N_3O_2$)

Yield 23 % (2.5 h); m.p.: 113.0–113.5 °C; ^{1}H NMR: δ = 1.06 (t, ^3J = 7.6 Hz, 3H, Et), 1.18 (s, 3H, CH_3), 1.21 (s, 3H, CH_3), 1.88–2.03 (m, 2H, Et), 2.51 (ddm, ^2J = 15.2 Hz, ^3J = 5.0 Hz, 1H, H8), 3.12 (dd, ^2J = 15.2 Hz, ^3J = 8.8 Hz, 1H, H8), 3.78 (s, 3H, O-CH_3), 4.04 (d, ^2J = 15.5 Hz, 1H, Ph-CH_2), 4.39 (s, 1H, H4), 5.03 (d, ^2J = 15.5 Hz, 1H, Ph-CH_2), 5.24 (dd, ^3J = 8.8 Hz, ^3J = 5.0 Hz, 1H, H9), 6.87 (d, ^3J = 8.6 Hz, 2H, Ph), 7.18–7.42 (m, 7H, Ph) ppm; ^{13}C NMR: δ = 13.8 (Et), 17.7 (Et), 22.0 (CH_3), 26.4 (CH_3), 32.9 (C8), 48.2 (Ph-CH_2), 55.3 (C5), 55.5 (O-CH_3), 64.3 (C9), 84.3 (C4), 114.1 (2 × CH), 121.1 (C6), 127.6 (2 × CH), 128.0 (CH), 128.5 (2 × CH), 129.0 (2 × CH), 135.7 (C, Ph), 135.9 (C, Ph), 143.5 (C7), 159.0 (C, Ph), 164.8 (C2) ppm; IR: $\bar{\nu}$ = 3,061, 3,029, 2,960, 2,929, 2,871, 2,836, 1,704 (C=O), 1,611, 1,511, 1,247, 1,175, 1,030 cm^{-1}; MS: *m/z* (%) = 403 (M^+, 38), 333 (23), 231 (45), 91 (100); HRMS: *m/z* calcd. for $C_{25}H_{30}N_3O_2^+$ 404.2333, found 404.2343.

(4R,9S*)-3-Benzyl-6-ethyl-9-(4-methoxyphenyl)-5,5-dimethyl-1,3,10-triazatricyclo[5.2.1.0^{4,10}]dec-6-ene-2-thione* (**2r**, $C_{25}H_{29}N_3OS$)

Yield 23 % (2.5 h); m.p.: 129.0–129.5 °C; ^{1}H NMR: δ = 1.07 (t, ^3J = 7.6 Hz, 3H, Et), 1.20 (s, 3H, CH_3), 1.26 (s, 3H, CH_3), 1.86–2.10 (m, 2H, Et), 2.64 (ddm, ^2J = 15.2 Hz, ^3J = 5.1 Hz, 1H, H8), 3.16 (dd, ^2J = 15.2 Hz, ^3J = 9.0 Hz, 1H, H8), 3.79 (s, 3H, O-CH_3), 4.29 (d, ^2J = 15.0 Hz, 1H, Ph-CH_2), 4.50 (s, 1H, H4), 5.81 (dd, ^3J = 9.0 Hz, ^3J = 5.1 Hz, 1H, H9), 5.84 (d, ^2J = 15.0 Hz, 1H, Ph-CH_2), 6.89 (d, ^3J = 8.6 Hz, 2H, Ph), 7.26–7.36 (m, 5H, Ph), 7.42 (d, ^3J = 8.6 Hz, 2H, Ph) ppm; ^{13}C NMR: δ = 13.7 (Et), 17.6 (Et), 22.1 (CH_3), 27.3 (CH_3), 32.4 (C8), 51.5 (Ph-CH_2), 55.6 (O-CH_3), 56.4 (C5), 67.4 (C9), 87.6 (C4), 114.3 (2 × CH), 121.0 (C6), 127.8 (2 × CH), 128.2 (CH), 128.5 (2 × CH), 129.1 (2 × CH), 134.6 (C, Ph), 135.1 (C, Ph), 142.3 (C7), 159.2 (C, Ph), 188.4 (C2) ppm; IR: $\bar{\nu}$ = 3,058, 3,029, 2,964, 2,956, 2,930, 2,873, 2,835, 1,609, 1,514, 1,446, 1,315, 1,249, 1,177, 1,029 cm^{-1}; MS: *m/z* (%) = 420 (M^+, 4), 419 (15), 255 (11), 194 (17), 178 (52), 148 (20), 121 (25), 91 (100); HRMS: *m/z* calcd. for $C_{25}H_{30}N_3OS^+$ 420.2104, found 420.2113; CCDC number 875426.

(4R,9R*)-9-(1-Adamantyl)-5,5-dimethyl-3-phenyl-1,3,10-triazatricyclo[5.2.1.0^{4,10}]dec-6-en-2-one* (**6a**, $C_{25}H_{31}N_3O$)

Yield 75 % (8 h); m.p.: 202.0–203.0 °C; ^{1}H NMR: δ = 0.81 (s, 3H, CH_3), 1.35 (s, 3H, CH_3), 1.54–1.59 (m, 3H, Ad), 1.63–1.74 (m, 9H, Ad), 1.99–2.03 (m, 3H, Ad), 2.42 (dd, ^2J = 15.1 Hz, ^3J = 8.7 Hz, 1H, H8), 2.55 (ddd, ^2J = 15.1 Hz, ^3J = 6.6 Hz, ^4J = 2.3 Hz, 1H, H8), 3.78 (dd, ^3J = 8.7 Hz, ^3J = 6.6 Hz, 1H, H9), 4.65 (d, ^4J = 2.3 Hz, 1H, H6), 5.41 (s, 1H, H4), 7.11–7.15 (m, 1H, Ph), 7.31–7.36 (m, 2H, Ph), 7.41–7.45 (m, 2H, Ph) ppm; ^{13}C NMR: δ = 23.9 (C8), 24.4 (CH_3), 27.7 (CH_3), 28.4 (CH), 35.9 (C9-*C*), 37.3 (CH_2), 38.7 (CH_2), 54.9 (C5), 73.4 (C9), 84.7 (C4), 109.9 (C6), 121.9 (2 × CH), 125.0 (CH), 128.9 (2 × CH), 139.3 (C, Ph), 150.1 (C7), 162.8 (C2) ppm; IR: $\bar{\nu}$ = 2,963, 2,908, 2,850, 1,708 (C=O), 1,599, 1,501, 1,456, 1,384, 1,299, 1,144, 1,074, 1,027 cm^{-1}; MS: *m/z* (%) = 389 (M^+, 93), 374 (59), 199 (22), 135 (100), 119 (17), 104 (21), 93 (24), 77 (34), 67 (19); CCDC number 875427.

(4R,9R*)-9-(1-Adamantyl)-5,5,6-trimethyl-3-phenyl-1,3,10-triazatricyclo[5.2.1.0^{4,10}]dec-6-en-2-one* (**6b**, $C_{26}H_{33}N_3O$)

Yield 65 % (2 h); m.p.: 204.0–206.0 °C; ^{1}H NMR: δ = 0.74 (s, 3H, CH_3), 1.27 (s, 3H, CH_3), 1.49 (d, ^5J = 1.1 Hz, 3H, C6-CH_3), 1.54–1.60 (m, 3H, Ad), 1.63–1.74 (m, 9H, Ad), 1.99–2.03 (m, 3H, Ad), 2.40 (dd, ^2J = 14.8 Hz, ^3J = 8.5 Hz, 1H, H8), 2.46 (ddm, ^2J = 14.8 Hz, ^3J = 6.7 Hz, 1H, H8), 3.72 (dd, ^3J = 8.5 Hz, ^3J = 6.7 Hz, 1H, H9), 5.44 (s, 1H, H4), 7.11–7.15 (m, 1H, Ph), 7.31–7.36 (m, 2H, Ph), 7.40–7.44 (m, 2H, Ph) ppm; ^{13}C NMR: δ = 8.5 (C6-*C*H_3), 22.0 (CH_3), 22.7 (C8), 25.9 (CH_3), 28.4 (CH), 35.9 (C9-*C*), 37.3 (CH_2), 38.8 (CH_2), 55.4 (C5), 72.9 (C9), 84.2 (C4), 115.5 (C6), 122.2 (2 × CH), 125.0 (CH), 128.9 (2 × CH), 139.4 (C, Ph), 143.7 (C7), 163.2 (C2) ppm; IR: $\bar{\nu}$ = 2,966, 2,930, 2,885, 2,849, 1,700 (C=O), 1,601, 1,503, 1,447, 1,401, 1,338, 1,302, 1,242, 1,222, 1,147, 1,121, 1,056, 1,012 cm^{-1}; MS: *m/z* (%) = 403 (M^+, 48), 388 (31), 308 (17), 149 (100), 135 (27), 93 (16), 77 (24).

(4R,9R*)-9-(1-Adamantyl)-5,5-dimethyl-3-phenyl-6-(pyrrolidinomethyl)-1,3,10-triazatricyclo[5.2.1.0^{4,10}]dec-6-en-2-one* (**6c**, $C_{30}H_{40}N_4O$)

Yield 76 % (2 h); m.p.: 191.5–192.0 °C; ^{1}H NMR: δ = 0.81 (s, 3H, CH_3), 1.39 (s, 3H, CH_3), 1.54–1.60 (m, 3H, Ad), 1.63–1.75 (m, 13H, Ad + Pyrr), 1.99–2.03 (m,

3H, Ad), 2.33–2.49 (m, 5H, H8 + Pyrr), 2.55 (dd, ^2J = 15.0 Hz, ^3J = 8.5 Hz, 1H, H8), 2.80 (d, ^2J = 13.3 Hz, 1H, C6-CH_2), 3.11 (d, ^2J = 13.3 Hz, 1H, C6-CH_2), 3.72 (dd, ^3J = 8.5 Hz, ^3J = 6.9 Hz, 1H, H9), 5.39 (s, 1H, H4), 7.11–7.16 (m, 1H, Ph), 7.30–7.35 (m, 2H, Ph), 7.38–7.42 (m, 2H, Ph) ppm; ^{13}C NMR: δ = 22.0 (CH_3), 22.9 (C8), 23.8 (CH_2, Pyrr), 26.9 (CH_3), 28.4 (CH), 35.9 (C9-*C*), 37.3 (CH_2), 38.8 (CH_2), 51.1 (C6-*C*H_2), 54.6 (CH_2, Pyrr), 55.5 (C5), 73.0 (C9), 85.0 (C4), 117.7 (C6), 122.5 (2 × CH), 125.2 (CH), 128.9 (2 × CH), 139.4 (C, Ph), 146.7 (C7), 163.3 (C2) ppm; IR: $\bar{\nu}$ = 2,966, 2,851, 2,781, 2,757, 2,729, 1,702 (C=O), 1,597, 1,503, 1,459, 1,402, 1,378, 1,302, 1,263, 1,240, 1,151, 1,111, 1,051, 1,012 cm^{-1}; MS: *m*/*z* (%) = 472 (M^+, 28), 457 (13), 402 (21), 337 (100), 283 (14), 218 (36), 164 (28), 147 (50), 135 (41), 107 (16), 84 (46), 70 (29).

(4R,9R*)-9-(1-Adamantyl)-5,5-dimethyl-6-(morpholinomethyl)-3-phenyl-1,3,10-triazatricyclo[5.2.1.0^{4,10}]dec-6-en-2-one* (**6d**, $C_{30}H_{40}N_4O_2$)

Yield 60 % (2 h); m.p.: 210.5–211.0 °C; ^{1}H NMR: δ = 0.81 (s, 3H, CH_3), 1.39 (s, 3H, CH_3), 1.54–1.60 (m, 3H, Ad), 1.63–1.75 (m, 9H, Ad), 1.99–2.04 (m, 3H, Ad), 2.22–2.33 (m, 2H, N-CH_2), 2.38–2.45 (m, 2H, N-CH_2), 2.45 (ddm, ^2J = 15.2 Hz, ^3J = 6.6 Hz, 1H, H8), 2.52 (d, ^2J = 15.2 Hz, ^3J = 8.4 Hz, 1H, H8), 2.75 (d, ^2J = 13.3 Hz, 1H, C6-CH_2), 2.95 (d, ^2J = 13.3 Hz, 1H, C6-CH_2), 3.61–3.70 (m, 4H, O-CH_2), 3.73 (dd, ^3J = 8.4 Hz, ^3J = 6.6 Hz, 1H, H9), 5.40 (s, 1H, H4), 7.12–7.17 (m, 1H, Ph), 7.31–7.41 (m, 4H, Ph) ppm; ^{13}C NMR: δ = 21.9 (CH_3), 22.8 (C8), 26.9 (CH_3), 28.4 (CH), 35.9 (C9-*C*), 37.3 (CH_2), 38.7 (CH_2), 54.0 (C6-*C*H_2), 54.0 (N-CH_2), 55.5 (C5), 67.2 (O-CH_2), 72.9 (C9), 85.0 (C4), 115.3 (C6), 122.5 (2 × CH), 125.3 (CH), 129.0 (2 × CH), 139.2 (C, Ph), 148.3 (C7), 163.2 (C2) ppm; IR: $\bar{\nu}$ = 2,935, 2,886, 2,853, 2,811, 2,789, 1,699 (C=O), 1,599, 1,503, 1,455, 1,402, 1,379, 1,346, 1,303, 1,217, 1,149, 1,119, 1,031 cm^{-1}; MS: *m*/*z* (%) = 488 (M^+, 46), 473 (48), 402 (24), 353 (100), 283 (24), 234 (42), 180 (31), 166 (75), 147 (78), 135 (52), 100 (40), 93 (17), 79 (18).

(4R,9R*)-6,9-Di-(1-adamantyl)-5,5-dimethyl-3-phenyl-1,3,10-triazatricyclo[5.2.1.0^{4,10}]dec-6-en-2-one* (**6e**, $C_{35}H_{45}N_3O$)

Yield 31 % (4 h); ^{1}H NMR: δ = 0.98 (s, 3H, CH_3), 1.41 (s, 3H, CH_3), 1.53–2.05 (m, 30H, 2 × Ad), 2.59 (dd, ^2J = 15.5 Hz, ^3J = 6.0 Hz, 1H, H8), 2.73 (dd, ^2J = 15.5 Hz, ^3J = 8.8 Hz, 1H, H8), 3.70 (dd, ^3J = 8.8 Hz, ^3J = 6.0 Hz, 1H, H9), 5.16 (s, 1H, H4), 7.14–7.19 (m, 1H, Ph), 7.30–7.36 (m, 4H, Ph) ppm; ^{13}C NMR: δ = 25.0 (CH_3), 26.2 (C8), 28.4 (CH), 28.9 (CH), 29.0 (CH_3), 35.8 (C9-*C*), 36.5 (C6-*C*), 37.0 (CH_2), 37.3 (CH_2), 38.8 (CH_2), 42.6 (CH_2), 57.1 (C5), 72.2 (C9), 86.2 (C4), 124.2 (2 × CH), 125.8 (CH), 126.3 (C6), 129.0 (2 × CH), 139.8 (C, Ph), 144.0 (C7), 163.9 (C2) ppm; IR: $\bar{\nu}$ = 2,960, 2,929, 2,893, 2,850, 1,701 (C=O), 1,605, 1,511, 1,423, 1,399, 1,367, 1,280, 1,245, 1,226, 1,186, 1,111, 1,029 cm^{-1}; MS: *m*/*z* (%) = 523 (M^+, 21), 404 (24), 269 (100), 135 (55).

(4R,9R*)-9-(1-Adamantyl)-5,5-dimethyl-3-phenyl-1,3,10-triazatricyclo[5.2.1.0^{4,10}]dec-6-ene-2-thione* (**6f**, $C_{25}H_{31}N_3S$)

Yield 50 % (5 h); m.p.: 197.5–200.0 °C; ^{1}H NMR: δ = 0.75 (s, 3H, CH_3), 1.28 (s, 3H, CH_3), 1.62–1.77 (m, 12H, Ad), 1.99–2.07 (m, 3H, Ad), 2.47 (dd, ^2J = 15.5 Hz, ^3J = 8.8 Hz, 1H, H8), 2.63 (ddd, ^2J = 15.5 Hz, ^3J = 5.4 Hz, ^4J = 2.2 Hz, 1H, H8), 4.34 (dd, ^3J = 8.8 Hz, ^3J = 5.4 Hz, 1H, H9), 4.66 (d, ^4J = 2.2 Hz, 1H, H6), 5.31 (s, 1H, H4), 7.24–7.32 (m, 1H, Ph), 7.37–7.48 (m, 4H, Ph) ppm; ^{13}C NMR: δ = 23.8 (C8), 23.9 (CH_3), 28.3 (CH_3), 28.4 (CH), 36.4 (C9-*C*), 37.2 (CH_2), 39.0 (CH_2), 55.7 (C5), 76.5 (C9), 90.0 (C4), 109.0 (C6), 127.2 (2 × CH), 127.5 (CH), 128.9 (2 × CH), 140.2 (C, Ph), 149.1 (C7), 188.6 (C2) ppm; IR: $\bar{\nu}$ = 2,963, 2,906, 2,849, 1,679, 1,597, 1,499, 1,455, 1,403, 1,302, 1,256, 1,047 cm^{-1}; MS: *m*/*z* (%) = 405 (M^+, 18), 390 (16), 270 (20), 135 (100), 77 (15).

(4R,9R*)-9-(1-Adamantyl)-5,5,6-trimethyl-3-phenyl-1,3,10-triazatricyclo[5.2.1.0^{4,10}]dec-6-ene-2-thione* (**6g**, $C_{26}H_{33}N_3S$)

Yield 55 % (2 h); m.p.: 196.0–196.5 °C; ^{1}H NMR: δ = 0.68 (s, 3H, CH_3), 1.20 (s, 3H, CH_3), 1.50 (d, ^5J = 1.6 Hz, 3H, C6-CH_3), 1.64–1.75 (m, 12H, Ad), 2.00–2.05 (m, 3H, Ad), 2.45 (dd, ^2J = 15.2 Hz, ^3J = 8.7 Hz, 1H, H8), 2.53 (ddm, ^2J = 15.2 Hz, ^3J = 5.4 Hz, 1H, H8), 4.29 (dd, ^3J = 8.7 Hz, ^3J = 5.4 Hz, 1H, H9), 5.32 (s, 1H, H4), 7.26–7.30 (m, 1H, Ph), 7.37–7.45 (m, 4H, Ph) ppm; ^{13}C NMR: δ = 8.2 (C6-*C*H_3), 21.8 (CH_3), 22.7 (C8), 26.5 (CH_3), 28.4 (CH), 36.4 (C9-*C*), 37.2 (CH_2), 39.1 (CH_2), 56.0 (C5), 76.0 (C9), 89.8 (C4), 115.0 (C6), 127.4 (2 × CH), 127.5 (CH), 128.9 (2 × CH), 140.4 (C, Ph), 142.5 (C7), 188.8 (C2) ppm; IR: $\bar{\nu}$ = 2,967, 2,921, 2,897, 2,846, 1,716, 1,596, 1,498, 1,452, 1,403, 1,335, 1,299, 1,261, 1,213, 1,187, 1,119, 1,085, 1,024 cm^{-1}; MS: *m*/*z* (%) = 419 (M^+, 18), 404 (15), 284 (32), 149 (100); CCDC number 875428.

(4R,9R*)-9-(1-Adamantyl)-5,5-dimethyl-3-phenyl-6-(pyrrolidinomethyl)-1,3,10-triazatricyclo[5.2.1.0^{4,10}]dec-6-ene-2-thione* (**6h**, $C_{30}H_{40}N_4S$)

Yield 55 % (2 h); m.p.: 188.5–190.0 °C; ^{1}H NMR: δ = 0.75 (s, 3H, CH_3), 1.32 (s, 3H, CH_3), 1.60–1.77 (m, 16H, Ad + Pyrr), 1.99–2.07 (m, 3H, Ad), 2.30–2.60 (m, 6H, Pyrr + H8), 2.80 (d, ^2J = 13.3 Hz, 1H, C6-CH_2), 3.11 (d, ^2J = 13.3 Hz, 1H, C6-CH_2), 4.30 (dd, ^3J = 8.0 Hz, ^3J = 6.2 Hz, 1H, H9), 5.27 (s, 1H, H4), 7.23–7.33 (m, 1H, Ph), 7.37–7.44 (m, 4H, Ph) ppm; ^{13}C NMR: δ = 21.7

(CH_3), 22.9 (C8), 23.8 (CH_2, Pyrr), 27.5 (CH_3), 28.4 (CH), 36.3 (C9-*C*), 37.2 (CH_2), 39.1 (CH_2), 50.8 (C6-*C*H_2), 54.6 (CH_2, Pyrr), 56.1 (C5), 76.0 (C9), 90.5 (C4), 117.1 (C6), 127.4 (2 × CH), 127.5 (CH), 128.9 (2 × CH), 140.4 (C, Ph), 145.5 (C7), 189.1 (C2) ppm; IR: $\bar{\nu}$ = 3,020, 2,975, 2,910, 2,851, 1,711, 1,600, 1,418, 1,364, 1,219, 1,047 cm^{-1}; MS: *m/z* (%) = 488 (M^+, 23), 353 (46), 283 (40), 218 (100), 147 (69), 135 (39), 93 (15), 72 (21).

(4R,9R*)-9-(1-Adamantyl)-5,5-dimethyl-6-(morpholinomethyl)-3-phenyl-1,3,10-triazatricyclo[5.2.1.0^{4,10}]dec-6-ene-2-thione* (**6i**, $C_{30}H_{40}N_4OS$)

Yield 50 % (2 h); m.p.: 210.0–211.0 °C; ^{1}H NMR: δ = 0.75 (s, 3H, CH_3), 1.32 (s, 3H, CH_3), 1.62–1.76 (m, 12H, Ad), 1.99–2.07 (m, 3H, Ad), 2.21–2.57 (m, 6H, H8 + N-CH_2), 2.76 (d, ^2J = 13.3 Hz, 1H, C6-CH_2), 2.94 (d, ^2J = 13.3 Hz, 1H, C6-CH_2), 3.59–3.71 (m, 4H, O-CH_2), 4.31 (t, ^3J = 6.9 Hz, 1H, H9), 5.28 (s, 1H, H4), 7.24–7.33 (m, 1H, Ph), 7.35–7.44 (m, 4H, Ph) ppm; ^{13}C NMR: δ = 21.6 (CH_3), 22.8 (C8), 27.5 (CH_3), 28.4 (CH), 36.3 (C9-*C*), 37.2 (CH_2), 39.0 (CH_2), 53.7 (C6-*C*H_2), 53.9 (N-CH_2), 56.0 (C5), 67.2 (O-CH_2), 76.0 (C9), 90.5 (C4), 114.8 (C6), 127.4 (2 × CH), 127.6 (CH), 129.0 (2 × CH), 140.3 (C, Ph), 147.1 (C7), 189.1 (C2) ppm; IR: $\bar{\nu}$ = 3,017, 2,969, 2,905, 2,851, 2,810, 1,712, 1,598, 1,498, 1,455, 1,405, 1,333, 1,257, 1,218, 1,114, 1,046 cm^{-1}; MS: *m/z* (%) = 504 (M^+, 19), 369 (40), 283 (44), 234 (82), 147 (100), 135 (32); HRMS: *m/z* calcd. for $C_{30}H_{41}N_4OS^+$ 505.2996, found 505.3008; CCDC number 875881.

(4R,9R*)-6,9-Di-(1-adamantyl)-5,5-dimethyl-3-phenyl-1,3,10-triazatricyclo[5.2.1.0^{4,10}]dec-6-ene-2-thione* (**6j**, $C_{35}H_{45}N_3S$)

Yield 14 % (4 h); m.p.: 211.0–212.0 °C; ^{1}H NMR: δ = 0.92 (s, 3H, CH_3), 1.37 (s, 3H, CH_3), 1.53–2.18 (m, 30H, 2 × Ad), 2.60–2.85 (m, 2H, H8), 4.23–4.35 (m, 1H, H9), 5.01 (s, 1H, H4), 7.20–7.50 (m, 5H, Ph) ppm; ^{13}C NMR: δ = 24.7 (CH_3), 26.1 (C8), 28.5 (CH), 28.9 (CH), 29.8 (CH_3), 35.8 (C9-*C*), 36.1 (C6-*C*), 37.0 (CH_2), 37.3 (CH_2), 39.0 (CH_2), 42.6 (CH_2), 57.4 (C5), 75.3 (C9), 91.6 (C4), 126.2 (C6), 127.8 (CH), 127.9 (2 × CH), 129.1 (2 × CH), 141.0 (C, Ph), 142.7 (C7), 190.2 (C2) ppm; IR: $\bar{\nu}$ = 2,957, 2,920, 2,888, 2,847, 1,598, 1,499, 1,453, 1,408, 1,387, 1,293, 1,275, 1,226 cm^{-1}; MS: *m/z* (%) = 539 (M^+, 7), 404 (43), 269 (100), 135 (88).

(4R,9R*)-9-(1-Adamantyl)-5,5,9-trimethyl-6-(morpholinomethyl)-3-phenyl-1,3,10-triazatricyclo-[5.2.1.0^{4,10}]dec-6-en-2-one* (**6k**, $C_{31}H_{42}N_4O_2$)

Yield 28 % (4 h); m.p.: 206.0–208.0 °C; ^{1}H NMR: δ = 0.87 (s, 3H, CH_3), 1.38 (s, 3H, CH_3), 1.50 (s, 3H, CH_3), 1.61–1.76 (m, 12H, Ad), 2.01–2.06 (m, 3H, Ad), 2.14 (d, ^2J = 14.3 Hz, 1H, H8), 2.23–2.50 (m, 4H, N-CH_2), 2.80 (d, ^2J = 13.0 Hz, 1H, C6-CH_2), 2.87 (d, ^2J = 14.3 Hz, 1H, H8), 3.02 (d, ^2J = 13.0 Hz, 1H, C6-CH_2), 3.60–3.74 (m, 4H, O-CH_2), 5.33 (s, 1H, H4), 7.11–7.17 (m, 1H, Ph), 7.31–7.41 (m, 4H, Ph) ppm; ^{13}C NMR: δ = 19.1 (CH_3), 21.8 (CH_3), 27.5 (CH_3), 28.6 (CH), 33.5 (C8), 36.9 (CH_2), 37.2 (CH_2), 39.2 (C9-*C*), 53.8 (C6-*C*H_2), 54.0 (N-CH_2), 55.6 (C5), 67.2 (O-CH_2), 77.1 (C9), 83.5 (C4), 122.7 (2 × CH), 125.1 (CH), 128.9 (2 × CH), 139.4 (C, Ph), 159.5 (C2) ppm; IR: $\bar{\nu}$ = 2,934, 2,899, 2,850, 2,807, 2,764, 1,714 (C=O), 1,599, 1,501, 1,454, 1,379, 1,342, 1,293, 1,196, 1,163, 1,118, 1,006 cm^{-1}; MS: *m/z* (%) = 502 (M^+, 44), 417 (18), 367 (100), 282 (24), 248 (29), 180 (24), 161 (85), 135 (64), 100 (54), 93 (37), 79 (37); HRMS: *m/z* calcd. for $C_{31}H_{43}N_4O_2^+$ 503.3381, found 503.3396; CCDC number 875429.

(4R,9R*)-9-(1-Adamantyl)-3-benzyl-5,5-dimethyl-1,3,10-triazatricyclo[5.2.1.0^{4,10}]dec-6-en-2-one* (**6l**, $C_{26}H_{33}N_3O$)

Yield 31 % (5 h); m.p.: 163.0–165.0 °C; ^{1}H NMR: δ = 1.17 (s, 3H, CH_3), 1.20 (s, 3H, CH_3), 1.50–1.75 (m, 12H, Ad), 1.96–2.05 (m, 3H, Ad), 2.34 (dd, ^2J = 15.2 Hz, ^3J = 8.7 Hz, 1H, H8), 2.49 (ddd, ^2J = 15.2 Hz, ^3J = 6.5 Hz, ^4J = 2.1 Hz, 1H, H8), 3.70 (dd, ^3J = 8.7 Hz, ^3J = 6.5 Hz, 1H, H9), 4.02 (d, ^2J = 15.3 Hz, 1H, Ph-CH_2), 4.35 (s, 1H, H4), 4.62 (d, ^4J = 2.1 Hz, 1H, H6), 4.98 (d, ^2J = 15.3 Hz, 1H, Ph-CH_2), 7.20–7.38 (m, 5H, Ph) ppm; ^{13}C NMR: δ = 23.8 (C8), 24.0 (CH_3), 27.5 (CH_3), 28.4 (CH), 35.9 (C9-*C*), 37.3 (CH_2), 38.6 (CH_2), 48.1 (Ph-CH_2), 54.2 (C5), 72.8 (C9), 84.3 (C4), 109.1 (C6), 127.9 (CH), 128.6 (2 × CH), 129.0 (2 × CH), 136.1 (C, Ph), 150.6 (C7), 165.4 (C2) ppm; IR: $\bar{\nu}$ = 2,964, 2,947, 2,857, 1,716 (C=O), 1,496, 1,455, 1,405, 1,362, 1,280, 1,252, 1,200, 1,180, 1,158, 1,119, 1,026 cm^{-1}; MS: *m/z* (%) = 403 (M^+, 96), 388 (21), 285 (69), 135 (84), 108 (16), 91 (100), 79 (30), 67 (15).

(4R,9R*)-9-(1-Adamantyl)-3-benzyl-5,5-dimethyl-1,3,10-triazatricyclo[5.2.1.0^{4,10}]dec-6-ene-2-thione* (**6m**, $C_{26}H_{33}N_3S$)

Yield 25 % (5 h); m.p.: 197.0–200.5 °C; ^{1}H NMR: δ = 1.20 (s, 3H, CH_3), 1.26 (s, 3H, CH_3), 1.60–1.74 (m, 12H, Ad), 2.00–2.05 (m, 3H, Ad), 2.40 (dd, ^2J = 15.5 Hz, ^3J = 8.8 Hz, 1H, H8), 2.56 (ddd, ^2J = 15.5 Hz, ^3J = 5.5 Hz, ^4J = 2.3 Hz, 1H, H8), 4.25 (d, ^2J = 15.3 Hz, 1H, Ph-CH_2), 4.34 (dd, ^3J = 8.8 Hz, ^3J = 5.5 Hz, 1H, H9), 4.45 (s, 1H, H4), 4.62 (d, ^4J = 2.3 Hz, 1H, H6), 5.84 (d, ^2J = 15.3 Hz, 1H, Ph-CH_2), 7.27–7.38 (m, 5H, Ph) ppm; ^{13}C NMR: δ = 23.8 (C8), 24.2 (CH_3), 28.1 (CH_3), 28.4 (CH), 36.3 (C9-*C*), 37.2 (CH_2), 39.0 (CH_2), 51.3 (Ph-CH_2), 55.5 (C5), 75.2 (C9), 87.3 (C4), 108.9 (C6), 128.1 (CH), 128.5 (2 × CH), 129.1 (2 × CH), 135.3 (C, Ph), 149.5 (C7), 189.1 (C2) ppm; IR: $\bar{\nu}$ = 3,018, 2,963, 2,906, 2,850, 1,681, 1,604, 1,495, 1,448, 1,423, 1,314, 1,216, 1,150,

1,050 cm^{-1}; MS: *m/z* (%) = 419 (M^+, 55), 271 (18), 135 (100), 106 (21), 91 (90), 79 (26); CCDC number 875430.

(4R,9R*)-9-(1-Adamantyl)-3-benzyl-5,5,6-trimethyl-1,3,10-triazatricyclo[5.2.1.0^{4,10}]dec-6-en-2-one*
(**6n**, $C_{27}H_{35}N_3O$)
Yield 53 % (2.5 h); m.p.: 168.0–169.0 °C; ^{1}H NMR: $\delta = 1.09$ (s, 3H, CH_3), 1.13 (s, 3H, CH_3), 1.49 (d, $^5J = 1.6$ Hz, 3H, C6-CH_3), 1.52–1.58 (m, 3H, Ad), 1.62–1.74 (m, 9H, Ad), 1.99–2.03 (m, 3H, Ad), 2.32 (dd, $^2J = 14.9$ Hz, $^3J = 8.6$ Hz, 1H, H8), 2.39 (ddm, $^2J = 14.9$ Hz, $^3J = 6.5$ Hz, 1H, H8), 3.65 (dd, $^3J = 8.6$ Hz, $^3J = 6.5$ Hz, 1H, H9), 3.99 (d, $^2J = 15.3$ Hz, 1H, Ph-CH_2), 4.36 (s, 1H, H4), 4.98 (d, $^2J = 15.3$ Hz, 1H, Ph-CH_2), 7.21–7.37 (m, 5H, Ph) ppm; ^{13}C NMR: $\delta = 8.5$ (C6-*C*H_3), 21.8 (CH_3), 22.5 (C8), 25.6 (CH_3), 28.4 (CH), 35.9 (C9-*C*), 37.3 (CH_2), 38.7 (CH_2), 48.2 (Ph-CH_2), 54.7 (C5), 72.3 (C9), 83.8 (C4), 115.0 (C6), 127.9 (CH), 128.6 (2 × CH), 129.0 (2 × CH), 136.2 (C, Ph), 144.0 (C7), 165.8 (C2) ppm; IR: $\bar{\nu} = 3{,}065$, 3,016, 2,961, 2,905, 2,850, 1,694 (C=O), 1,446, 1,409, 1,361, 1,248, 1,216, 1,121, 1,012 cm^{-1}; MS: *m/z* (%) = 417 (M^+, 100), 322 (47), 299 (23), 149 (17), 135 (34), 91 (41), 69 (18); HRMS: *m/z* calcd. for $C_{27}H_{36}N_3O^+$ 418.2853, found 418.2859.

(4R,9R*)-9-(1-Adamantyl)-3-benzyl-5,5,6-trimethyl-1,3,10-triazatricyclo[5.2.1.0^{4,10}]dec-6-ene-2-thione*
(**6o**, $C_{27}H_{35}N_3S$)
Yield 10 % (2.5 h); m.p.: 163.0–164.0 °C; ^{1}H NMR: $\delta = 1.12$ (s, 3H, CH_3), 1.19 (s, 3H, CH_3), 1.48 (d, $^5J = 1.5$ Hz, 3H, C6-CH_3), 1.61–1.74 (m, 12H, Ad), 2.00–2.05 (m, 3H, Ad), 2.37 (dd, $^2J = 15.1$ Hz, $^3J = 8.8$ Hz, 1H, H8), 2.47 (ddm, $^2J = 15.1$ Hz, $^3J = 5.5$ Hz, 1H, H8), 4.23 (d, $^2J = 15.3$ Hz, 1H, Ph-CH_2), 4.29 (dd, $^3J = 8.8$ Hz, $^3J = 5.5$ Hz, 1H, H9), 4.46 (s, 1H, H4), 5.84 (d, $^2J = 15.3$ Hz, 1H, Ph-CH_2), 7.26–7.41 (m, 5H, Ph) ppm; ^{13}C NMR: $\delta = 8.2$ (C6-*C*H_3), 21.9 (CH_3), 22.6 (C8), 26.3 (CH_3), 28.4 (CH), 36.3 (C9-*C*), 37.2 (CH_2), 39.0 (CH_2), 51.4 (Ph-CH_2), 55.8 (C5), 74.7 (C9), 86.9 (C4), 114.7 (C6), 128.1 (CH), 128.5 (2 × CH), 129.0 (2 × CH), 135.4 (C, Ph), 143.0 (C7), 189.3 (C2) ppm; IR: $\bar{\nu} = 2{,}959$, 2,909, 2,843, 1,708, 1,599, 1,496, 1,447, 1,420, 1,385, 1,362, 1,305, 1,231, 1,159, 1,121, 1,080 cm^{-1}; MS: *m/z* (%) = 433 (M^+, 35), 285 (19), 269 (28), 149 (95), 135 (53), 122 (19), 107 (18), 91 (100), 79 (30), 67 (15); HRMS: *m/z* calcd. for $C_{27}H_{36}N_3S^+$ 434.2624, found 434.2631; CCDC number 875431.

Acknowledgments The research was supported by the Grant Agency of the Czech Republic, grant no. 203/09/1345. We are grateful to Marek Nečas for crystallographic measurements and to Lukáš Maier for NMR measurements on the Bruker Avance 500.

References

1. Potáček M, Marek R, Žák Z, Trottier J, Janoušek Z, Viehe HG (1993) Tetrahedron Lett 34:8341
2. Zachová H, Man S, Nečas M, Potáček M (2005) Eur J Org Chem 2548
3. Man S, Kulhánek P, Potáček M, Nečas M (2002) Tetrahedron Lett 43:6431
4. Galeta J, Man S, Potáček M (2009) Arkivoc vi:245
5. Kulhánek P, Potáček M, Koča J (2004) Collect Czech Chem Commun 69:231
6. Man S, Bouillon JP, Nečas M, Potáček M (2004) Tetrahedron Lett 45:9419
7. Man S, Nečas M, Bouillon JP, Baillia H, Harakat D, Potáček M (2005) Tetrahedron 61:2387
8. Galeta J, Man S, Bouillon JP, Potáček M (2011) Eur J Org Chem 392
9. Man S, Nečas M, Bouillon JP, Portella C, Potáček M (2006) Eur J Org Chem 3473
10. Galeta J, Man S, Valoušková A, Potáček M (2013) Chem Pap 67:40
11. Henkel JG, Hane JT, Gianutsos G (1982) J Med Chem 25:51
12. Zah J, Terre'Blanche G, Erasmus E, Malan SF (2003) Bioorg Med Chem 11:3569
13. Blanpied TA, Clarke RJ, Johnson JW (2005) J Neurosci 25:3312
14. Furber M, Alcaraz L, Bent JE, Beyerbach A, Bowers K, Braddock M, Caffrey MV, Cladingboel D, Collington J, Donald DK, Fagura M, Ince F, Kinchin EC, Laurent C, Lawson M, Luker TJ, Mortimore MMP, Pimm AD, Riley RJ, Roberts N, Robertson M, Theaker J, Thorne PV, Weaver R, Webborn P, Willis P (2007) J Med Chem 50:5882
15. Miyazaki A, Tsuda Y, Fukushima S, Yokoi T, Vántus T, Bökönyi G, Szabó E, Horváth A, Kéri G, Okada Y (2008) J Med Chem 51:5121
16. Cady SD, Wang J, Wu Y, DeGrado WF, Hong M (2011) J Am Chem Soc 133:4274
17. Fort RC, Schleyer P von R (1964) Chem Rev 64:277
18. van Bommel KJC, Metselaar GA, Verboom W, Reinhoudt DN (2001) J Org Chem 66:5405
19. Jeong HY (2002) Thin Solid Films 417:171
20. Morcombe CR, Zilm KW (2003) J Magn Reson 162:479
21. Lenzke K, Landt L, Hoener M, Thomas H, Dahl JE, Liu SG, Carlson RMK, Möller T, Bostedt C (2007) J Chem Phys 127:084320
22. Tominaga M, Masu H, Azumaya I (2009) J Org Chem 74:8754
23. Lim H, Chang JY (2010) Macromolecules 43:6943
24. Tiwari RN, Tiwari JN, Chang L (2010) Chem Eng J 158:641
25. SHELXTL version 5.10 (1997) Bruker AXS. Madison, WI