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PCl_3-Mediated Cyclization: Synthesis at Room Temperature of *N*-Alkenyl Derivatives of Perhydro-1,4,5-Oxa(and Thia)diazepine-3,6-dione and of 6,7-Diazaspiro[3.4]octane-5,8-dione

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ABSTRACT: *The use of the PCl_3/hydrazone/dicarboxylic acid combination can be applied in an efficient one-pot procedure for the synthesis at room temperature of the seven-membered ring compounds,* **6** *(perhydro-1,4,5-oxadiazepine-3,6-diones) and* **7** *(perhydro-1,4,5-thiadiazepine-3,6-diones), and of the first reported derivatives of the heterocycle 6,7-diazaspiro[3.4]octane-5,8-dione* **8**. *Compounds* **6** *and* **7**, *containing an N-alkenyl group, were obtained in good yields using diglycolic and thiadiglycolic acids with PCl_3 and methylhydrazone* **1**, *with use of a high concentration (0.5 M) of the reagents. N-alkenyl derivatives* **8** *were obtained in the same manner using 1,1-cyclobutanedicarboxylic acid. Changing the order of addition of the reagents gave almost identical results. In the case in which the exocyclic double bond can give E,Z-isomers, the exclusive or prevalent formation of the E-isomer was always observed.* © 1999 John Wiley & Sons, Inc. Heteroatom Chem 10: 615–621, 1999

INTRODUCTION

1,4,5-Oxadiazepines and 1,4,5-thiadiazepines [1a,b], which are relatively rare heterocycles, have interesting applications as photofading preventing agents for inks [1c,d] or as drugs. The fully saturated monocyclic 1,4,5-oxadiazepines are prepared [1a,b,e,f] by the reaction of 2,2′-dichloromethyl ether with various symmetrical substituted hydrazines. The first and, to our knowledge, unique, example of 1,4,5-oxadiazepine-3,6-diones is a perfluoroderivative obtained by reaction of tetrafluoroformaldehyde azine with perfluoro-diglycolyl fluoride, in the presence of cesium fluoride, but it was obtained only in small amount, and it was only tentatively identified [1g]. 2,7-Dihydro-1,4,5-thiadiazepines can be prepared by the reaction of 3-thiapentane-1,5-diones with hydrazines under reflux in ethanol [1a,b]. To our knowledge, no examples of perhydro-1,4,5-thiadiazepine-3,6-diones are noted in the literature. Only one derivative of 2,3,4,7-tetrahydro-1,4,5-thiadiazepine-3-one is reported [1h].

Unsubstituted 6,7-diazaspiro[3.4]octane-5,8-dione is the unique reported example of this hetero-

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cyclic system, and it is prepared by reaction of 1,1-cyclobutanedicarboxylic acid diethyl ester with hydrazine in refluxing ethanol [1i].

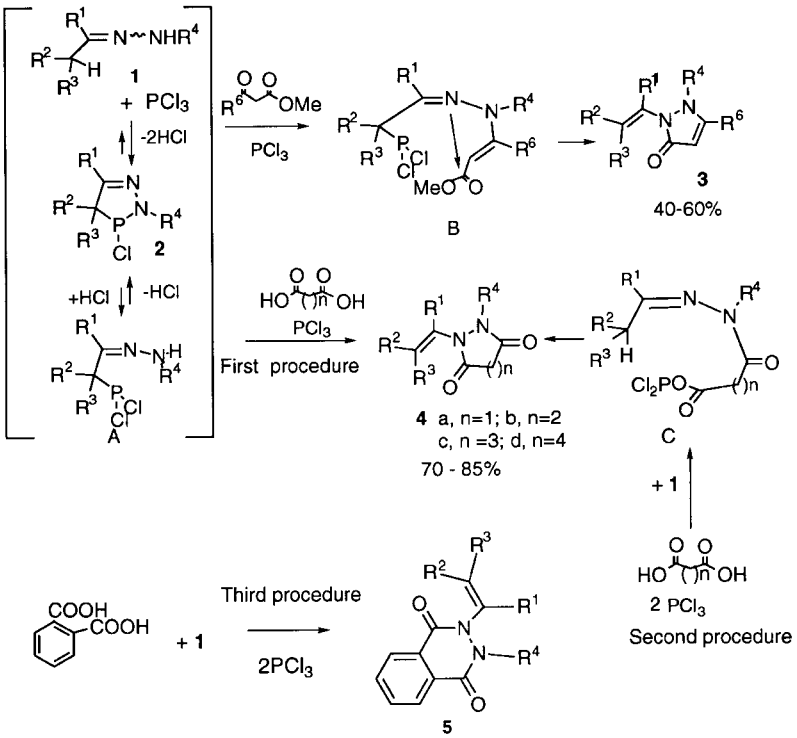
Now we describe a convenient one-pot synthesis at room temperature of the title compounds **6, 7**, and **8** using a combination of PCl_3, hydrazones and diglycolic acids, and thiadiglycolic and 1,1-cyclobutanedicarboxylic acids, respectively. Compounds **6** and **7** represent two unknown, to date, series of stable enamines [2] of 1,4,5-oxa (or thia) diazepine-3,6-diones. In addition, compounds **8** represent the first examples of substituted 6,7-diazaspiro[3.4]octane-5,8-dione.

Some years ago, we reported [3] that the reaction between arylhydrazones **1** (R^4 = Ph) and PCl_3 gives 2,3-disubstituted indoles in good yields after a few minutes at room temperature. Subsequently, we discovered that a reaction between chlorodiazaphospholines **2** (R^4 = Me), an enolizable ketone and additional PCl_3 gives, at room temperature, unsymmetrically substituted pyrroles [4,5]. Still later, we demonstrated that, on treating the reaction mixture containing **2** with a *β*-keto ester, a 1,2-dihydro-2-alkenyl-3*H*-pyrazol-3-one **3** was obtained at room temperature (see Scheme 1) [6]. From these results, it was clear that a new type of cyclization mediated by PCl_3 was discovered, which permits us to obtain diazaheterocycles, bearing an enamine group, which are probably very difficult to prepare by classical methods.

Recently, we found that a similar and more rapid cyclization occurs using free dicarboxylic acids in combination with PCl_3 and hydrazones giving the corresponding 1,2-diazaheterocycles that contain two carbonyl groups near the two nitrogen atoms [8]. In this manner, using malonic, succinic, glutaric, and adipic acids, we obtained, at room temperature and in good yields, new *N*-alkenyl five[7]- six-, seven- and eight-membered 1,2-diazaheterocycles **4** [8]. By use of these dicarboxylic acids, two additional interesting results were also observed. First, changing the order of addition of the reagents (hydrazone, $2PCl_3$, dicarboxylic acids) gave identical results. Second, the facile synthesis at room temperature of seven- and eight-membered rings occurs by use a high concentration of the reagents (0.2–0.5 M).

It should be noted that dicarboxylic acid derivatives such as esters, acyl chlorides, and anhydrides, under the same reaction conditions, did not give the corresponding diazaheterocycles; these facts established the fact that acyl chlorides or anhydrides cannot be the intermediates of this cyclization.

Recently, we reported [9] that it was necessary to use a third procedure, in which PCl_3 is added in a



SCHEME 1

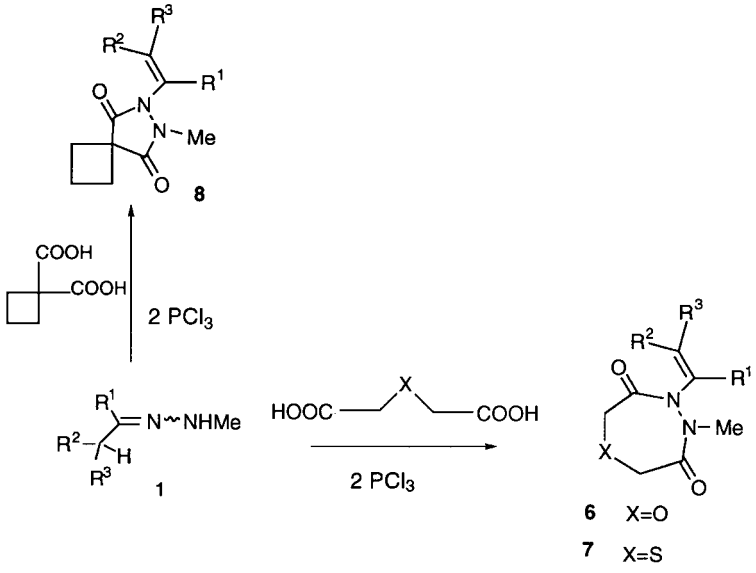
last step to a mixture of hydrazone and phthalic acid to obtain phthalazinediones **5** in good yields; in this manner, the formation of phthalic anhydride is minimized.

RESULTS AND DISCUSSION

In order to verify if this cyclocondensation might be extended to obtain seven-membered diazarings containing another nonadjacent heteroatom such as O or S, we have used diglycolic and thiadiglycolic acids (see Scheme 2). Also, in these cases, the reactions are always carried out at room temperature, good yields being obtained with reaction times of 6 to 10 hours for oxadiazepine-3,6-diones **6** and of 10 to 15 hours for the thiadiazepines-3,6-diones **7**. In all cases, the exclusive formation of the *E*-isomer, when an *E,Z*-configuration (a,b cases) is possible, was observed. Traces of *Z* isomers were obtained only after workup, indicating a slow isomerization in acidic medium.

As reported previously [8], the explanation of this facile formation of medium-sized rings without the use of high-dilution techniques is probably due to the different nature of the two nitrogen atoms in **1**. The amine nitrogen in **1** is more prone to react with the activated carboxylic acid than the less-nucleophilic imine nitrogen. Consequently, only after the first attack, which gives intermediates such as **C** in Scheme 1, the imine nitrogen is activated to give the second attack with consequent cyclization. In this manner, the intramolecular cyclization is favored more than a possible polymerization.

It is interesting to note that, in the case of the



	R^1	R^2	R^3		R^1	R^2	R^3
1 a	Ph	H	Ph	*E* -**6 a**	Ph	H	Ph
				E -**7 a**	Ph	H	Ph
				E -**8 a**	Ph	H	Ph
1 b	Ph	H	Me	*E*-**6 b**	Ph	H	Me
				E-**7 b**	Ph	H	Me
				E-**8 b**	Ph	H	Me
1 c	Me	Ph	Ph	**6 c**	Me	Ph	Ph
				7 c	Me	Ph	Ph
				7 A c	$CHPh_2$	H	H
				8 c	Me	Ph	Ph
1 d	Me	H	Ph	*E* -**8 d**	Me	H	Ph
1 e	Ph	H	H	**8 e**	Ph	H	H

SCHEME 2

thiadiazepine-3,6-dione obtained from the methyl ketone hydrazone **1c**, which bears hydrogen atoms in both α positions, two structurally isomeric thiadiazepine-3,6-diones, **7c** and **7Ac**, in a ratio that favors the latter isomer, were obtained.

This behavior was not observed in the formation of the corresponding oxadiazepine-3,6-dione, while it was previously observed [9] in the analogous synthesis of phthalazine-1,4-dione derivatives.

This difference can be due to a greater rigidity of the thiadiazepinedione ring compared with the oxadiazepinedione one, that may influence the conformational freedom of the transition state preceding the cyclization step, thus favoring the formation of the product with the minor degree of crowding.

In order to obtain further evidence about the differences in structural features between oxadiazepine-3,6-dione and thiadiazepine-3,6-dione rings, we analyzed the ^{1}H NMR spectra of compounds **6** and **7**.

At 25°C, oxadiazepine-3,6-diones **6** show two broad singlets, corresponding to the methylenic groups adjacent to the oxygen atom, whereas the spectra of thiadiazepine-3,6-diones **7** show two doublets of doublets, one for each methylene group α to sulfur, as a result of spin–spin coupling between the two nonequivalent axial and equatorial hydrogens.

This difference prompted us to perform several experiments at different temperatures, both on the oxadiazepine derivative **6a** and on thiadiazepine derivative **7a**.

Increasing the temperature of a deuterochloroform solution of **6a** to 55°C caused a sharpening of the two methylenic broad singlets centered at 4.01 and 4.35 ppm, whereas a gradual decrease of the temperature caused first their coalescence, then a splitting to give the appearance of a four doublet system, similar to that observed at 25°C for **7a**, as expected.

This permitted us to calculate, from the Eyring equation [10], the energy barrier for the interconversion process of **6a**, namely $\Delta G^{\neq} \sim 13.5$ kcal/mol.

When the thiadiazepine-3,6-dione **7a**, dissolved in DMSO-d_6, was gradually heated, even at 170°C, the coalescence was not observed.

This fact confirms that **7a** is a much more rigid system than the corresponding oxadiazepine-3,6-dione.

Finally, we wanted to determine whether similar spiro-1,2-diazaheterocycles can be obtained with use of the PCl_3/hydrazone/dicarboxylic acid combination.

For this purpose, we have used 1,1-cyclobutanedicarboxylic acid, obtaining compounds **8** in good yields, with reaction times of 2 to 3 hours. Also, in the cases of compounds **8a,b,d**, we have observed prevalent formation of the *E*-isomer, indicating that this stereoselectivity is a characteristic of this cyclization reaction, activated by PCl_3.

CONCLUSION

With these results and those reported in previous studies, we can affirm that the PCl_3/hydrazone/dicarboxylic acid combination can be used efficiently for a one-pot synthesis at room temperature of several five-, six-, seven-, and eight-membered 1,2-diazaheterocycles such as pyrazolidine-3,5-diones [7], pyridazine-3,6-diones, perhydro-1,2-diazepine-3,7-diones, perhydro-1,2-diazocin-3,8-diones [8], 2,3-dihydro-phthalazine-1,4-diones [9], perhydro-1,4,5-oxadiazepine-3,6-diones **6**, perhydro-1,4,5-thiadiazepine-3,6-diones **7**, and 6,7-diazaspiro[3.4]octane-5,8-diones **8**. All these compounds, which contain an *N*-alkenyl group, are stable enamines that are presumably stabilized by the adjacent carbonyl groups. In addition, all of the above compounds are new to the literature; this may be due to the difficulty in obtaining these enamine derivatives by other procedures.

Thus, we can conclude that presumably any other dicarboxylic acid can give this cyclocondensation and that the knowledge of the factors that regulate this reaction might be useful, with respect to other bifunctional reagents, to produce other new *N*-alkenyl-1,2-diaza-heterocycles.

EXPERIMENTAL

All chemicals and solvents were of reagent grade. ^{1}H-NMR spectra were recorded at 200 and 300 MHz in $CDCl_3$ solution. Chemical shift values are referred to Me_4Si. Mass spectra were recorded with a VG 7070 spectrometer or with an HP-5890 gas-chromatograph equipped with a methyl silicone capillary column and by an HP-5970 mass detector. IR spectra were obtained in CH_2Cl_2 solution by use of a Perkin Elmer 1600 spectrophotometer. Melting points were determined with a Buchi apparatus. The purity of all of the products was checked by thin-layer chromatography (TLC), gas chromatography–mass spectrometry (GC–MS) and ^{1}H-NMR spectra. Commercial PCl_3 was used without further purification. Yields are based on starting quantities of the dicarboxylic acid. Flash chromatography was performed in a Gilson apparatus.

Hydrazones

Hydrazones were obtained by heating the respective hydrazine and ketone together in equivalent

amounts in benzene solution at reflux for ca. 2 hours under Dean-Stark acid catalytic conditions. After drying and removal of the solvent, the crude products were first crystallized or used immediately to avoid their decomposition.

Typical Procedure

To a THF solution (15 mL) of dicarboxylic acid (10 mmol) was added PCl_3 (20 mmol); after a few minutes, a THF solution (50 mL) of hydrazone **1** (10 mmol) was added, and the reaction mixture was allowed to react at room temperature for about 2 to 15 hours. The course of the reaction was followed by GC–MS and TLC analyses. After evaporation under reduced pressure of THF, the residual crude oil was dissolved in dichloromethane, treated with triethylamine, aqueous saturated sodium carbonate, water, and finally it was dried over sodium sulfate. The solvent was removed to give crude products **6, 7**, and **8**, which were purified by crystallization or by silica gel column chromatography. It should be noted that the concentration of the reagents can vary within a range of 0.2 to 0.5 M, depending on the solubility of the dicarboxylic acid being used.

Compounds **6, 7**, and **8** were characterized essentially by ^{1}H-NMR spectroscopy, mass spectrometry, and microanalysis. All compounds exhibited a very strong C=O absorbtion in the IR: oxadiazepines **6** and thiadiazepines **7** at ca. 1675–1680 cm^{-1}, spirocyclobutanediones **8** at ca. 1675–1695 cm^{-1}. The *E*-configuration of the exocyclic double bond was deduced from some NOE experiments performed on an *E,Z*-mixture obtained by isomerization of the *E*-isomer.

E-5-(1,2-Diphenylvinyl)4-methylperhydro-1,4,5-oxadiazepine-3,6-dione (**E-6a**)

After 6 hours of reaction, ***E*-6a** was obtained (50% yield) as white crystals, m.p. 141°C, R_F 0.54 (diethyl ether-dichloromethane-*n*-hexane 1:1:1 as eluent). Found: C, 70.7; H, 5.6; N, 8.5%; HRMS (EI) *m/z* 322.1302 (M^+); $C_{19}H_{18}N_2O_3$ requires C, 70.8; H, 5.6; N, 8.7%; M^+, 322.1317. δ_H, 3.30 (3H, s, N-CH_3), 4.01 (2H, bs, O-CH_2-), 4.35 (2H, bs, O-CH_2-), 6.81 (1H, s, =C*H*), 6.90–7.40 (10H, m, Ph). At −60°C : δ_H, 3.35 (3H, s, N-CH_3), 4.07 (1H, d, J = 11.9 Hz, C_2H*H* or C_7H*H*), 4.30 (1H, d, J = 11.5 Hz, C_2H*H* or C_7H*H*), 4.35 (1H, d, J = 11.9 Hz, C_2*H*H or C_7*H*H), 4.50 (1H, d, J = 11.5 Hz, C_2 *H*H or C_7*H*H), 6.80 (1H, s, = *CH*), 6.90–7.60 (10H, m, Ph).

E-4-Methyl-5-(1-phenylprop-1-enyl)perhydro-1,4,5-oxadiazepine-3,6-dione (**E-6b**)

After 7 hours of reaction, ***E*-6b** was obtained (60% yield) as colorless crystals, m.p. 143°C, R_F 0.48 (diethyl ether-dichloromethane 1:2 as eluent). Found: C, 64.4; H, 6.2; N, 10.7%; HRMS (EI) *m/z* 260.1122 (M^+); $C_{14}H_{16}N_2O_3$ requires C, 64.6; H, 6.2; N, 10.8%; M^+, 260.1161. $^\circ_H$, 1.77 (3H, d, J = 7,1 Hz, =CHCH_3), 3,23 (3H, s, N-CH_3), 4.04 (2H, bs, O-CH_2-), 4.08 (2H, bs, O-CH_2-), 6.02 (1H, q, J = 7,1 Hz, =C*H*), 7.27–7.40 (5H, m, Ph).

*E-4-Methyl-5-(1-methyl-2,2-diphenylvinyl)*perhydro-1,4,5-oxadiazepine-3,6-dione (**E-6c**)

After 10 hours of reaction, ***E*-6b** was obtained (40% yield) as white crystals, m.p. 176°C, R_F 0.48 (diethyl ether-dichloromethane 1:2 as eluent). Found: C, 71.2; H, 5.9; N, 8.2% HRMS (EI) *m/z* 336.1450 (M^+); $C_{20}H_{20}N_2O_3$ requires C, 71.4; H, 6.0; N, 8.3%; M^+, 336.1474. δ_H, 2.09 (3H, s, =C-CH_3), 3.17 (3H, s, N-CH_3), 3.70 (2H, bs, O-CH_2), 4.15 (2H, bs, O-CH_2), 6.98 (1H, s, =C*H*), 7.20–7.31 (5H, m, Ph).

E-5-(1,2-Diphenylvinyl)4-methylperhydro-1,4,5-thiadiazepine-3,6-dione (**E-7a**)

***E*-7a** was obtained after 10 hours of reaction as white crystals (40%), m.p. 155–157°C, R_F = 0.56 (diethyl ether-dichloromethane 1:2 as eluent). Found: C, 67.6 H, 5.3; N, 8.3%; HRMS (EI) *m/z* 338.1090; $C_{19}H_{18}N_2O_2S$ requires C, 67.4; H, 5.4; N, 8.3%; M^+, 338.1089. δ_H, 2.72 (1H, d, J = 12.4 Hz, C_2H*H* or C_7H*H*), 3.07 (1H, d, J= 11.8 Hz, C_2H*H* or C_7H*H*), 3.32 (3H, s, N-CH_3), 3.51 (1H, d, J = 12.4 Hz, C_2*H*H or C_7*H*H), 3.75 (1H, d, J = 11.8 Hz, C_2*H*H or C_7*H*H), 6.71 (1H, s, =*CH*), 6.90–7.45 (10H, m, Ph).

E-4-Methyl-5-(1-phenylprop-1-enyl)perhydro-1,4,5-thiadiazepine-3,6-dione (**E-7b**)

After 12 hours, ***E*-7b** was obtained as a solid (45%), m.p. 150–152°C, R_F = 0.48 (diethyl ether-dichloromethane 1:2 as eluent). Found: C, 60.7; H, 5.7; N, 10.0%; HRMS (EI) *m/z* 276.0934; $C_{14}H_{16}N_2O_2S$ requires C, 60.85; H, 5.8; N, 10.1%; M^+, 276.0932. δ_H, 1.71 (3H, d, J = 7.2 HZ, CH_3C=), 2.68 (1H, d, J = 12.3 Hz, C_2H*H* or C_7H*H*), 3.02 (1H, d, J = 11.7 Hz, C_2H*H* or C_7H*H*), 3.23 (3H, s, N-CH_3), 3.45 (1H, d, J = 12.3 Hz, C_2*H*H or C_7*H*H), 3.70 (1H, d, J = 11.7 Hz, C_2*H*H or C_7*H*H), 5.93 (1H, q, J = 7.2 Hz, =*CH*), 7.20–7.45 (5H, m, Ph).

4-Methyl-5-(1-methyl-2,2-diphenylvinyl) perhydro-1,4,5-thiadiazepine-3,6-dione (**7c**) *and 4-Methyl-5-(1-diphenylmethyl-vinyl)perhydro-1,4,5-thiadiazepine-3,6-dione* (**7Ac**)

After 15 hours, the reaction with **1c** gave **7c** and **7Ac** in the ratio of ca. 2:8. After flash chromatography, **7c**

(contaminated with **7Ac**) was obtained in 8% yield R_F = 0.74 (diethyl ether-dichloromethane 1:2 as eluent). Found: HRMS (EI) *m/z* 352.1232; $C_{20}H_{20}N_2O_2S$ requires M^+, 352.1246. δ_H, 2.05 (3H, s, C*H*$_3$C=), 2.57 (1H, d, *J* = 12.4 Hz, C_2H*H* or C_7H*H*), 2.92 (1H, d, *J* = 11.5 Hz, C_2H*H* or C_7H*H*), 3.13 (3H, s, N-C*H*$_3$), 3.16 (1H, d, *J* = 12.4 Hz, C_2*H*H or C_7*H*H), 3.50 (1H, d, *J* = 11.5 Hz, C_2*H*H or C_7*H*H), 7.05–7.42 (10H, m, Ph).

7Ac (contaminated with **7c**) was obtained in 32% yield R_F = 0.58 (diethyl ether-dichloromethane 1:2 as eluent). Found: C, 68.4; H, 5.6; N, 7.8%; HRMS (EI) *m/z* 352.1250; $C_{20}H_{20}N_2O_2S$ requires C, 68.2; H, 5.7; N, 7.95%; M^+, 352.1246. *gd*$_H$, 2.46 (1H, d, *J* = 12.2 Hz, C_2H*H* or C_7H*H*), 2.72 (1H, d, *J* = 12.2 Hz, C_2*H*H or C_7*H*H), 2.98 (1H, d, *J* = 11.9 Hz, C_2H*H* or C_7H*H*), 3.19 (3H, s, N-C*H*$_3$), 3.56 (1H, d, *J* = 11.9 Hz, C_2*H*H or C_7*H*H), 4.94–4.99 (2H, m, *H*C= and *H*C-C=), 5.52–5.55 (1H, m, *H*C=), 7.00–7.40 (10H, m, Ph).

6-[(E)-1,2-Diphenylethenyl]-7-methyl-6,7-diazaspiro[3.4]octane-5,8-dione (**E-8a**)

After 3 hours, *E*-**8a** was obtained as colorless crystals (40% yield), m.p. 139°C, R_F = 0.65 (petroleum light-diethyl ether 1:1 as eluent). Found: C, 75.6; H, 6.0; N, 8.2%; HRMS (EI) *m/z* 332.1499 (M^+); $C_{21}H_{20}N_2O_2$ requires C, 75.9; H, 6.1; N, 8.4%; M^+, 332.1525. δ_H, 2.20–2.32 (2H, m, C*H*$_2$CH$_2$CCO), 2.40–2.70 (4H, m, C*H*$_2$CCO), 2.92 (3H, s, N-CH$_3$), 6.80 (1H, s, HC=), 7.15–7.32 (10H, m, Ph).

6-Methyl-7[(E)-1-phenyl-1-propenyl]-6,7-diazaspiro[3.4]octane-5,8-dione (**E-8b**)

After 3 hours of reaction, *E*-**8b**, contaminated with the *Z*-isomer, was obtained in 60% yield, R_F = 0.54 (petroleum light-diethyl ether 1:1 as eluent). Found: C, 71.0; H, 6.7; N, 10.4%; HRMS (EI) *m/z* 270.1344 (M^+); $C_{16}H_{18}N_2O_2$ requires C, 71.1; H, 6.7; N, 10.4%; M^+, 270.1368. δ_H, 1.93 (3H, d, *J* = 7.3 Hz, C*H*$_3$CH=), 2.18–2.35 (2H, m, C*H*$_2$CH$_2$CCO), 2.48–2.67 (4H, m, C*H*$_2$CCO), 2.90 (3H, s, N-CH$_3$), 6.11 (1H, q, *J* = 7.3 Hz, HC=), 7.15–7.37 (5H, m, Ph).

6-Methyl-7-(1-methyl-2,2-diphenylvinyl)-6,7-diazaspiro[3.4]octane-5,8-dione (**8c**)

After 2.5 hours of reaction, **8c** was obtained as colorless crystals (40% yield) m.p. 120°C, R_F = 0.70 (petroleum light-diethyl ether 3:7 as eluent). Found: C, 76.2; H, 6.4; N, 8.1%; HRMS (EI) *m/z* 346.1693 (M^+); $C_{22}H_{22}N_2O_2$ requires C, 76.3; H, 6.4; N, 8.1%; M^+, 346.1681. δ_H, 2.00 (3H, s, CH$_3$C=), 2.14–2.25 (2H, m, C*H*$_2$CH$_2$CCO), 2.27–2.53 (4H, m, C*H*$_2$CCO), 2.99 (3H, s, N-CH$_3$), 7.20–7.33 (10H, m, Ph).

6-Methyl-7-[(E)-1-methyl-2-phenylethenyl]-6,7-diazaspiro[3.4]octane-5,8-dione (**E-8d**)

After 2.0 hours, *E*-**8d**, containing some *Z*-isomer (5%), was obtained in 30% yield, R_F = 0.53 (petroleum light-diethyl ether 1:4 as eluent). Found: C, 71.0; H, 6.6; N, 10.3%; HRMS (EI) *m/z* 270.1331; $C_{16}H_{18}N_2O_2$ requires C, 71.1; H, 6.7; N, 10.4%; M^+, 270.1368. δ_H, 2.02 (3H, d, *J* = 1.2 Hz, C*H*$_3$C=), 2.12–2.33 (2H, m, C*H*$_2$C*H*$_2$CCO), 2.49–2.58 (4H, m, C*H*$_2$CCO), 2.92 (3H, s, NCH$_3$), 6.68 (1H, q, *J* = 1.2 Hz, HC=), 7.27–7.40 (5H, m, Ph).

6-Methyl-7-(1-phenylvinyl)-6,7-diazaspiro[3.4]octane-5,8-dione (**8e**)

After 3 hours, **8e** was obtained as a yellow oil in 50% yield, R_F = 0.48 (diethyl ether-dichloromethane-*n*-hexane 1:1:1 as eluent). Found: C, 70.2; H, 6.3; N, 10.8%; HRMS (EI) *m/z* 256.1216; $C_{15}H_{16}N_2O_2$ requires C, 70.3; H, 6.3; N, 10.9%; M^+, 256.1212. δ_H, 2.26–2.35 (2H, m, C*H*$_2$CH$_2$CCO), 2.58–2.63 (4H, m, C*H*$_2$CCO), 2.92 (3H, s, N-CH$_3$), 5.44 (1H, d, *J* = 0.5 Hz, HC=), 5.77 (1H, d, *J* = 0.5 Hz, HC=), 7.27–7.38 (5H, m, Ph).

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