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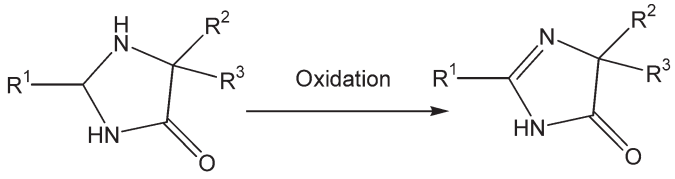

1, 2a–i **a**: $R^1 = CH_3(CH_2)_3$; **b**: $R^1 = C_6H_5$; **c**: $R^1 = 4\text{-}CH_3OC_6H_4$; **d**: $R^1 = 4\text{-}NO_2C_6H_4$; **e**: $R^1 = 2\text{-}HOC_6H_4$; **f**: 2-pyridyl; for $R^2 = R^3 = (CH_2)_4$ and **g**: R^1 = 2-pyridyl; for $R^2 = CH_3$; $R^3 = CH(CH_3)_2$

The reaction of aldehydes (pentanal, benzaldehyde, 4-methoxybenzaldehyde, 4-nitrobenzaldehyde, salicylaldehyde, pyridin-2-carbaldehyde) with 1-aminocyclopentancarboxamide or (*S*)-2-amino-2,3-dimethylbutanamide has been used to prepare substituted imidazolidin-4-ones **1a–g** (**a**: $R^1 = CH_3(CH_2)_3$; **b**: $R^1 = C_6H_5$; **c**: $R^1 = 4\text{-}CH_3OC_6H_4$; **d**: $R^1 = 4\text{-}NO_2C_6H_4$; **e**: $R^1 = 2\text{-}HOC_6H_4$; **f**: R^1 = 2-pyridyl; for $R^2 = R^3 = (CH_2)_4$), and **g**: R^1 = 2-pyridyl; for $R^2 = CH_3$; $R^3 = CH(CH_3)_2$) in the yields of 53–83%. Subsequent oxidations with various reagents gave the corresponding 4,5-dihydro-1*H*-imidazol-5-ones **2a–g**: Pd/C (72–93%), DDQ (25–80%), and MnO_2 (30–77%). Structure of the prepared compounds **1a–g** and **2a–g** was verified by ^{1}H NMR and ^{13}C NMR spectroscopy, EI-MS and elemental analysis. X-ray diffraction was performed in the case of compounds **1e** and **2e**.

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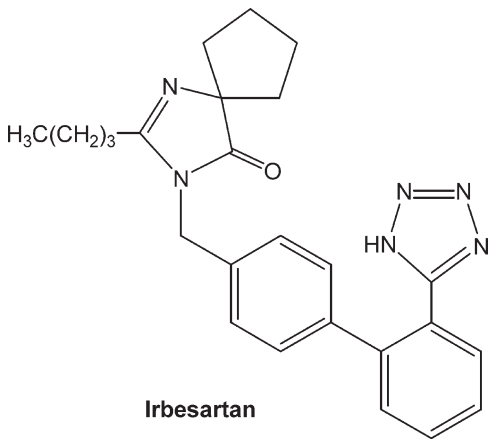
INTRODUCTION

A number of substituted 4,5-dihydro-1*H*-imidazol-5-ones belong among still applied selective and non-toxic herbicides [1]. Our previous articles dealt with their synthesis, characterisation, and study of mechanism of their formation [2]. Other possible applications of 4,5-dihydro-1*H*-imidazol-5-ones lie in their use as ligands that form coordination compounds with selected metal ions [3]. Some of such complexes have been successfully adopted as catalysts of deallylation reactions of diallyl malonates [3b,f] in the Henry reaction [3c,e], or in allyl oxidation [3i]. Another example of application of this heterocyclic system is represented by 2-butyl-1,3-diazaspiro[4.4]non-1-en-4-one, which is an important starting compound for the synthesis of medical drug Irbesartan (2-butyl-3-[[2′-(1*H*-tetrazol-5-yl)-[1,1′-biphenyl]-4-yl]methyl]-1,3-diazaspiro[4.4]-nonen-4-on). Irbesartan is an antagonist of angiotensin II and is clinically applied in the treatment of hypertension [4].



The existing methods of synthesis of 2-butyl-1,3-diazaspiro[4.4]non-1-en-4-one use the acylation of amide or nitrile of 1-aminocyclopentancarboxylic acid with pentanoic acid chloride followed by ring closure reaction [5]. Another method of preparation of 2-butyl-1,3-

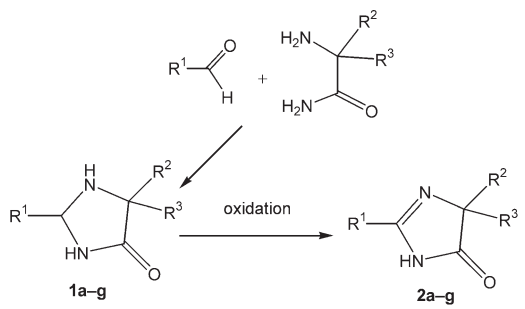
diazaspiro[4.4]non-1-en-4-one consists in acid catalyse condensation of ethyl 1-aminocyclopentancarboxylate with ethyl pentanimidate [6]. The third synthetic way described is based on the reaction of 1-aminocyclopentanecarboxamide with trimethyl orthopentanoate [7]. The described variant of synthesis of 2-butyl-1,3-diazaspiro[4.4]non-1-en-4-one is the reaction of pentanoic acid with 1-aminocyclopentannitrile [8]. The aim of the research described here is to elaborate a new alternative synthetic method for 2-butyl-1,3-diazaspiro[4.4]non-1-en-4-one and other substituted 4,5-dihydro-1*H*-imidazol-5-ones. This alternative adopts oxidation of substituted imidazolidin-4-ones to give 4,5-dihydro-1*H*-imidazol-5-ones.

RESULTS AND DISCUSSION

The reaction of aldehydes (pentanal, benzaldehyde, 4-methoxybenzaldehyde, 4-nitrobenzaldehyde, salicylaldehyde, pyridin-2-carbaldehyde) with 1-aminocyclopentancarboxamide [5] or (*S*)-2-amino-2,3-dimethylbutanamide [1] was used to prepare cyclic aminals, *i.e.*, the corresponding imidazolidin-4-ones **1a–g** (**a**: $R^1 = CH_3(CH_2)_3$; **b**: $R^1 = C_6H_5$; **c**: $R^1 = 4\text{-}CH_3OC_6H_4$; **d**: $R^1 = 4\text{-}NO_2C_6H_4$; **e**: $R^1 = 2\text{-}HOC_6H_4$; **f**: $R^1 = 2$-pyridyl; for $R^2 = R^3 = (CH_2)_4$) and **g**: $R^1 = 2$-pyridyl; for $R^2 = CH_3$; $R^3 = CH(CH_3)_2$) (Scheme 1). The ring closure reaction was performed with acid catalysis (acetic acid) by heating the starting substances in methanol. Recrystallization gave the respective imidazolidin-4-ones **1a–i** in the yields of 53–83%. In the case of (5*S*)-4-isopropyl-4-methyl-2-(pyridin-2-yl)imidazolidine-4-one (**1g**), the reaction creates another chiral centre at the carbon atom at 2-position of the imidazolidin-4-one cycle. In this case, the reaction produces a diastereomeric mixture with the configurations 2*S*, 5*S* and 2*R*, 5*S*, in the ratio of 1:1, which resulted in doubling of signals in the NMR spectra.

The second reaction step leading to the substituted 4,5-dihydro-1*H*-imidazol-5-ones **2a-g** was the oxidation of the prepared imidazolidin-4-ones **1a–g** (Scheme 1). The following oxidizing agents were used for this oxidation reaction: palladium on carbon carrier (Pd/C), 2,3-dichloro-5,6-dicyano-1,4-benzoquinone (DDQ), and activated manganese (IV) oxide (MnO_2). The results presented in the following table show that the first method (Pd/C) gives the highest yields; however, in most cases the other two (cheaper) variants are also applicable (Table 1).

Scheme 1



1, 2a–i **a**: $R^1 = CH_3(CH_2)_3$; **b**: $R^1 = C_6H_5$; **c**: $R^1 = 4\text{-}CH_3OC_6H_4$; **d**: $R^1 = 4\text{-}NO_2C_6H_4$; **e**: $R^1 = 2\text{-}HOC_6H_4$; **f**: 2-pyridyl; for $R^2 = R^3 = (CH_2)_4$ and **g**: $R^1 = 2$-pyridyl; for $R^2 = CH_3$; $R^3 = CH(CH_3)_2$

Table 1

Oxidations 1 → 2, yields obtained with individual reagents.

		Catalyst/yield [%]		
Entry	Product	Pd/C	DDQ	MnO_2
1	**2a**	80	25	65
2	**2b**	87	40	75
3	**2c**	83	73	77
4	**2d**	93	80	30
5	**2e**	72	77	67
6	**2f**	90	75	70
7	**2g**	72	38	64

Structures of the prepared products **1a–i and 2a–i** were verified by ^{1}H NMR and ^{13}C NMR spectroscopy, EI-MS and elemental analysis. In the case of 2-(4-nitrophenyl)-1,3-diazaspiro[4.4]non-1-en-4-one (**2d**), the NMR spectra revealed the presence of two tautomeric forms; a similar case was described and discussed in Ref. 2b,c. The structure of product 2-(2-hydroxyphenyl)-1,3-diazaspiro[4.4]nonan-4-one (**1e**) and its oxidation product 2-(2-hydroxyphenyl)-1,3-diazaspiro[4.4]non-1-en-4-one (**2e**) was also verified using X-ray diffraction. In molecule **1e** (Fig. 1), the bond distances in the central heterocyclic ring clearly show that all of them are single bonds. The only shortening of bond length is found in the case of N3—C1 bond, which can be attributed to the

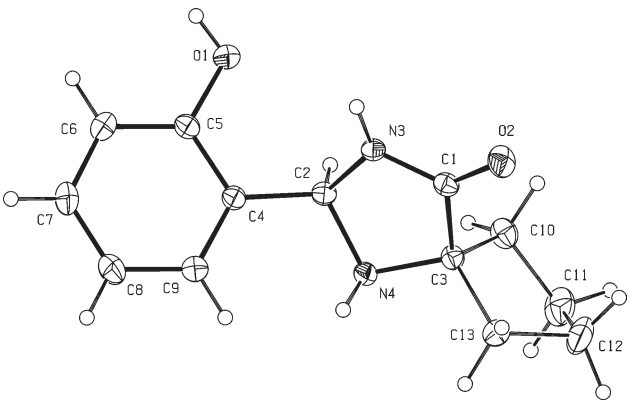


Figure 1. Molecular structure of **1e**, ORTEP 30% probability level. Selected interatomic distances [Å] and angles [°]: O(2)—C(1) 1.242(2), C(1)—C(3) 1.516(3), C(3)—N(4) 1.483(3), N(4)—C(2) 1.465(3), C(2)—N(3) 1.475(2), N(3)—C(1) 1.323(3), O(2)—C(1)—C(3) 124.91(19), C(1)—C(3)—N(4) 102.51(15), C(3)—N(4)—C(2) 105.38(14), N(4)—C(2)—N(3) 102.97(16), C(2)—N(3)—C(1) 111.82(17), N(3)—C(1)—C(3) 108.12(17), N(3)—C(1)—O(2) 126.94(18).

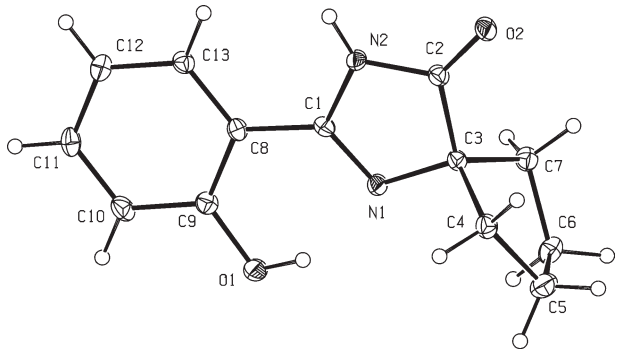


Figure 2. Molecular structure of **2e**, ORTEP 30% probability level. Selected interatomic distances [Å] and angles [°]:O(2)—C(2) 1.222(2), C(2)—C(3) 1.522(3), C(3)—N(1) 1.476(3), N(1)—C(1) 1.285(3), C(1)—N(2) 1.392(3), N(2)—C(2) 1.369(3), O(2)—C(2)—C(3) 128.50(19), C(2)—C(3)—N(1) 103,75(16), C(3)—N(1)—C(1) 107.77(17), N(1)—C(1)—N(2) 114.03(18), C(1)—N(2)—C(2) 108,72(17), N(2)—C(2)—C(3) 105.73(17), N(2)—C(2)—O(2) 125.8(2).

amido-character of the whole NH—C=O group. Also the C1—O2 interatomic distance corresponds to this character. From the values of bond angles and interplanar angles in this molecule is seen that the central ring is fairly deformed by a distortion of N4 atom from the ring core, and only five atoms (C1, C2, C3, N3, and O2) tend to lie in a plane.

Both molecules **1e** and **2e** are mutually similar. The main difference between them consists in the significant shortening of N1—C1 distance in the case of **2e** (Fig. 2), which corresponds to a typical double bond [9]. This fact the absence of the hydrogen atom at N1 atom and high degree of planarity of the central heterocyclic ring in this molecule are a proof of the oxidation of **1e**–**2e**.

The molecules of compound **1e** are interconnected to the layered supramolecular structure *via* H-bonding (Fig. 3). In the case of compound **2e**, two independent molecules were found in the crystal unit cell. The H-bonding in compound **2e** is slightly less extensive,

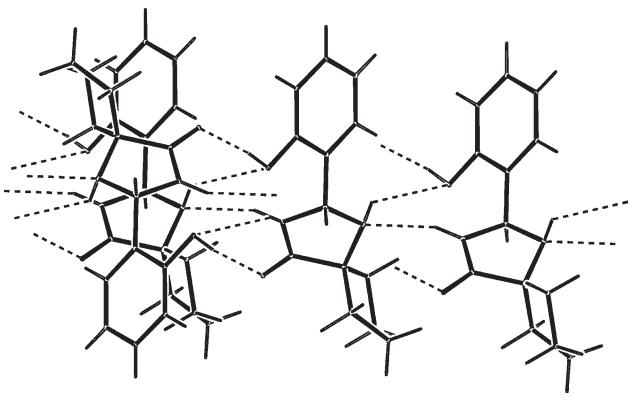


Figure 3. Crystal packing diagram of **1e** with hydrogen bonding system.

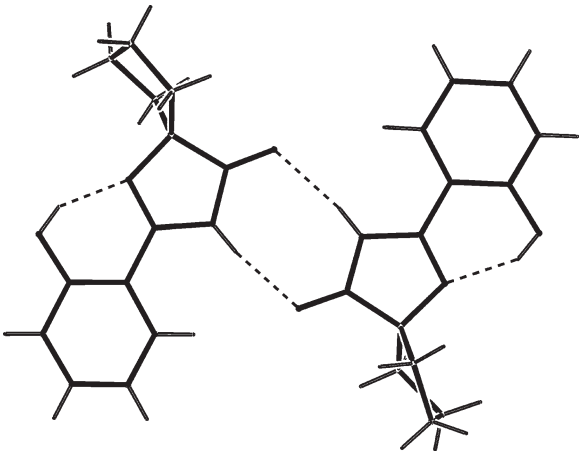


Figure 4. Crystal packing diagram of **2e** with hydrogen bonding system.

and only dimers are formed by the connection of amido group, and the imidazole nitrogen atom is connected to the O—H group *via* the intramolecular H-bond which fixed up the coplanarity of the aromatic ring (Fig. 4).

EXPERIMENTAL

If not stated otherwise, the starting substances were purchased from Sigma-Aldrich. The melting point temperatures have not been corrected. ^{1}H NMR and ^{13}C NMR spectra were recorded on a Bruker Avance 500 instrument (500.13 MHz for ^{1}H, and 125.77 MHz for ^{13}C). Chemical shifts δ are referenced to solvent residual peak (2.50 ppm ^{1}H, 39.43 ppm ^{13}C for DMSO–d_6, and 7.26 ppm ^{1}H, 77.00 ppm ^{13}C for $CDCl_3$). The mass spectra were measured with a set of Agilent Technologies (gas chromatograph 6890 N with mass detector 5973 Network); (the samples were dissolved in dichloromethane or acetone). The elemental microanalysis was carried out using an apparatus of FISONS Instruments EA 1108 CHN. The optical rotation was measured on a Perkin–Elmer 341 instrument; the concentration *c* was given in g/100 mL (Optical rotatory power determination).

Crystallography. The X-ray data for colorless crystals of **1e** and **2e** were obtained at 150 K using an Oxford Cryostream low-temperature device on a Nonius KappaCCD diffractometer with Mo K_α radiation ($\lambda = 0.71073$ Å), a graphite monochromator, and the ϕ and χ scan mode. Data reductions were performed with DENZO-SMN [10]. The absorption was corrected by integration methods [11]. Structures were solved by direct methods (Sir92) [12] and refined by full matrix least-square based on F^2 (SHELXL97) [13]. Hydrogen atoms were mostly localized on a difference Fourier map; however, to ensure uniformity of treatment of crystal, all the hydrogen atoms were recalculated into idealized positions (riding model) and assigned temperature factors H_{iso} (H) = 1.2 U_{eq}(pivot atom) or of 1.5 U_{eq} for the methyl moiety with C—H = 0.96, 0.97, 0.98, and 0.93 Å for methyl, methylene, methane, and aromatic-ring hydrogen atoms, respectively; 0.86 Å or 0.93 Å for N—H, and 0.82 Å for O—H bonds. The crystallographic data for structural analysis have been deposited with the Cambridge Crystallographic Data Centre, CCDC no. 757,260 and 757,259

for **1e** and **2e**, respectively. [(Copies of this information may be obtained free of charge from The Director, CCDC, 12 Union Road, Cambridge CB2 1EY, UK (fax: +44-1223-336033; e-mail: deposit@ccdc.cam.ac.uk or www: http://www.ccdc.cam.ac.uk.)] In Figure 2, there is a disordered cyclopentane ring. The disorder was treated by splitting of carbon atoms into two positions with similar occupancy.

General method of preparation of imidazolidin-4-ones (1a–g). A mixture of 1-aminocyclopentancarboxamide [5a] (4.35 g; 34 mmol) or (*S*)-2-amino-2,3-dimethylbutanamide [1] (4.40 g; 34 mmol) and the respective aldehyde (37 mmol), in methanol (20 mL) with a drop of acetic acid was refluxed 12 h. The mixture was evaporated, and the residue was recrystallized from the solvent given.

2-Butyl-1,3-diazaspiro[4.4]nonan-4-one (1a). Yield: 6.3 g (96%); mp 72–74°C (hexane). ^{1}H NMR ($CDCl_3$): δ 0.85–0.87 (m; 3H, CH_3), 1.25–1.32 (m; 4H, $(CH_2)_2$), 1.36–1.54 (m; 2H, CH_2), 1.55–1.64 (m; 6H, $(CH_2)_3$), 1.82–1.88 (m; 2H, CH_2), 4.23 (t; 1H; J = 6 Hz; CH), 8.13 (s; 1H; NH). ^{13}C NMR ($CDCl_3$, ppm): δ 13.7, 22.4, 25.1, 25.2, 26.7; 36.1; 36.5; 37.5; 68.5; 69.2; 182.0. Anal. Calcd. for $C_{11}H_{20}N_2O$ (196) (%): C, 67.31; H, 10.27; N, 14.27; found: C, 67.22; H, 10.38; N, 14.58.

2-Phenyl-1,3-diazaspiro[4.4]nonan-4-one (1b). Yield 2.49 g (79%); mp 136–138°C (ethyl acetate/hexane); ^{1}H NMR ($CDCl_3$): δ 1.49–1.76 (m, 7H), 1.81–1.90 (m, 1H), 3.13 (d, J = 8.0 Hz, 1H, NH), 5.35 (d, J = 8.0 Hz, 1H, CH), 7.30–7.44 (m, 5H, Ar), 8,55 (s, 1H, NHCO).^{13}C NMR ($CDCl_3$): δ: 25.1, 25.2, 36.4, 37.2, 68.9, 69.7, 127.0, 128.4, 128.5, 142.1, 180.3. EI-MS: *m/z* 216, 187, 173 (100%), 144, 106, 84. Anal. Calcd. for $C_{13}H_{16}N_2O_2$ (216) (%): C, 72.19; H, 7.46; N, 12.95; found: C, 72.01; H, 7.59; N, 13.12.

2-(4-Methoxyphenyl)-1,3-diazaspiro[4.4]nonan-4-one (1c). Yield 1.47 g (81%); mp 182–183°C (ethyl acetate); ^{1}H NMR ($CDCl_3$): δ 1.47–1.70 (m, 7H), 1.82–1.87 (m, 1H), 3.71 (s, 3H, OCH_3), 5.27 (s, 1H, CH), 6.88–6.90 (m, 2H, Ar), 7.29–7.31 (m, 2H, Ar), 8.44 (s, 1H, NHCO). ^{13}C NMR ($CDCl_3$, ppm): δ: 24.9, 36.1, 36.7, 55.2, 68.7, 69.1, 113.7, 128.1, 133.7, 159.4, 180.0; EI-MS: *m/z* 246, 217, 203 (100%), 134, 121, 84. Anal. Calcd. for $C_{14}H_{18}N_2O_2$ (246) (%): C, 68.27; H, 7.37; N, 11.37; found: C, 68.45; H, 7.51; N, 11.50.

2-(4-Nitrophenyl)-1,3-diazaspiro[4.4]nonan-4-one (1d). Yield 0.92 g (53%); mp 178–180°C (ethyl acetate); ^{1}H NMR ($CDCl_3$): δ 1.39–1.42 (m, 1H), 1.58–1.76 (m, 7H), 3.54 (d, J = 7.5 Hz, 1H, NH), 5.46 (d, J = 7.5 Hz, 1H, CH), 7.64–7.66 (m, 2H, Ar), 8.21–8.22 (m, 2H, Ar), 8.71 (s, 1H, NHCO). ^{13}C NMR ($CDCl_3$): δ 24.9, 25.0, 36.5, 37.6, 68.4, 68.5, 123.6, 128.2, 147.4, 150.0, 180.0; EI-MS: *m/z* 261, 232, 218 (100%), 151, 105, 84. Anal. Calcd. for $C_{13}H_{15}N_3O_3$ (261) (%): C, 59.76; H, 5.79; N, 16.08; found: C, 60.02; H, 5.95; N, 16.25.

2-(2-Hydroxyphenyl)-1,3-diazaspiro[4.4]nonan-4-one (1e). Yield 3.15 g (83%); mp 179–181°C (ethyl acetate); ^{1}H NMR($CDCl_3$) δ 4.48–1.56 (m, 1H), 1.59–1.80 (m, 6H), 1.85–1.90 (m, 1H), 5.60 (s, 1H, CH), 6.75–6.80 (m, 2H, Ar), 7.14 (t, J = 7.5 Hz, 1H, Ar), 7.23 (d, J = 7.5 Hz, 1H, Ar), 8.51 (s, 1H, NHCO), 10.96 (br, 1H, OH). ^{13}C NMR ($CDCl_3$) δ 24.6, 24.8, 35.6, 36.8, 66.3, 67.9, 115.9, 118.6, 125.1, 127.7, 129.2, 156.4, 178.5. EI-MS: *m/z* 232, 188, 171 (100%), 113, 77, 44. Anal. Calcd. for $C_{13}H_{16}N_2O_2$ (232) (%): C, 67.22; H, 6.94; N, 12.06; found: C, 67.35; H, 7.11; N, 12.31.

2-(2-Pyridyl)-1,3-diazaspiro[4.4]nonan-4-one (1f). Yield 1.62 g (80%); mp 109–111°C (ethyl acetate/hexane); ^{1}H NMR ($CDCl_3$) δ 1.48–1.55 (m, 1H), 1.62–1.72 (m, 6H), 1.87–1.91 (m, 1H), 5.38 (s, 1H, CH), 7.34–7.37 (m, 1H, ArH), 7.49 (d, J = 7.69 Hz, 2H, Py), 7.82–7.85 (m, 1H, Py), 8.54–8.56 (m, 2H, Py + NH). ^{13}C NMR ($CDCl_3$) δ 24.9, 36.7, 37.5, 68.4, 70.4, 121.7, 123.7, 137.3, 149.0, 159.9, 179.9; EI-MS: *m/z* 217, 188, 174 (100%), 145, 107, 79. Anal. Calcd. for $C_{12}H_{15}N_3O$ (217) (%): C, 66.34; H, 6.96; N, 13.34. Found: C, 66.21; H, 6.85; N, 13.22.

(E + 2)(5S)-4-Isopropyl-4-methyl-2-(pyridin-2-yl)imidazolidin-4-one (1g). Yield 1.51 g (74%); mp 113–118°C (ethyl acetate/hexane); $[\alpha]_D$ −14.2 (c 1, CH_3OH) ^{1}H NMR ($CDCl_3$) δ 0.80–0.99 (m, 12H, 2 × *i*.Pr), 1.20 (s, 3H, CH_3), 1.26 (s, 3H, CH_3), 1.83–1.91 (m, 2H, 2 × CH), 2.95 (br, 2H, NH), 5.48 (s, 1H, CH), 5.56 (s, 1H, CH), 7.15–7.18 (m, 2H, Py), 7.28 (d, J = 7.6 Hz, 1H, Py), 7.43 (d, J = 7.6 Hz, 1H, Py), 7.62–7.65 (m, 2H, Py), 8.25 (s, 1H, NHCO), 8.37 (s, 1H, NHCO), 8.45–8.48 (m, 2H, Py). ^{13}C NMR ($CDCl_3$) δ 16.6, 16.7, 17.5, 17.6, 21.6, 23.2, 33.1, 34.5, 64.6, 64.7, 69.6, 71.1, 121.0, 123.3, 123.4, 136.8, 136.9, 148.9, 149.1, 158.7, 158.9, 180.5, 180.8. EI-MS: *m/z* 219, 204, 176 (100%), 133, 107, 92, 42. Anal. Calcd. for $C_{12}H_{17}N_3O$ (219) (%): C, 65.73; H, 7.81; N, 19.16; found: C, 65.38; H, 7.56; N, 19.51.

General methods of preparation of 4,5-dihydro-1*H*-imidazol-5-ones (2a–g)

Method A (Pd/C). A mixture of the respective imidazolidin-4-one (5 mmol) and Pd/C (5%, 0.2 g) in methanol (50 mL) was refluxed 24 h. The final product was isolated after filtration, evaporation, and (sometimes) recrystallisation from the solvent given. In the case of isolation of compound **2d** the reaction mixture was evaporated, the residue was dissolved in NaOH solution (5%, 25 mL), the solution was filtered and the filtrate acidified to pH ∼ 7–8. The separated crystals of compound **2d** were collected by filtration and dried. The final product was recrystallized from DMF.

Method B (DDQ). A mixture of the respective imidazolidin-4-one (5 mmol) and 2,3-dichloro-5,6-dicyano-1,4-benzoquinone (DDQ) (1.3 g, 5.7 mmol) in dioxane (50 mL) was refluxed 10 min. The reaction mixture was filtered through a silica gel layer (2 cm), evaporated and (sometimes) recrystallized from the solvent given. In the case of isolation of compound **2d** the reaction mixture was evaporated, the residue was dissolved in NaOH solution (5%, 25 mL), the solution was filtered and the filtrate acidified to pH ∼ 7–8. The separated crystals of compound **2d** were collected by filtration and dried. The final product was recrystallized from DMF.

Method C (MnO_2). A mixture of the respective imidazolidin-4-one (5 mmol) and activated manganese (IV) oxide (5 g, 91 mmol) in acetone (100 mL) was refluxed 24 h. The final product was isolated after filtration with kieselguhr, evaporation, and (sometimes) recrystallization from the solvent given. In the case of isolation of compound **2d,** the reaction mixture was evaporated, the residue was dissolved in NaOH solution (5%, 25 mL), the solution was filtered and the filtrate acidified to pH ∼ 7–8. The separated crystals of compound **2d** were collected by filtration and dried. The final product was recrystallized from DMF. The yields of individual compounds are presented in Table 1.

2-Butyl-1,3-diazaspiro[4.4]non-1-en-4-one (2a). Colorless oil, TLC: (silika gel plates, Merck), chloroform/methanol 10:1, R_F = 0.51; ^{1}H NMR ($CDCl_3$) δ 0.90 (t, 3H, CH_3, J = 7.3 Hz); 1.31–1.40 (m, 2H, CH_2); 1.58–1.66 (m, 2H, CH_2); 1.72–1.80 (m, 3H); 1.83–1.93 (m, 5H, CH_2); 2.42 (t, 2H, CH_2, J = 7,4 Hz); 8.83 (bs, 1H, NHCO). ^{13}C NMR ($CDCl_3$) δ 13.7; 23.1; 25.9; 27.9; 30.0; 37.2; 77.5; 190.2. Anal. Calcd. for

$C_{11}H_{18}N_2O$ (194) (%): C 68.01; H 9.34; N 14.42; Found: C 67.89; H 9.46; N 14.68.

2-Phenyl-1,3-diazaspiro[4.4]non-1-en-4-one (2b). mp 202–203°C. ^{1}H NMR (DMSO-d_6) δ 1.78–1.89 (m, 8H), 7.52–7.55 (m, 2H, Ar), 7.58–7.62 (m, 1H, Ar), 7.97–7.99 (m, 2H, Ar), 11.41 (br, 1H, NHCO). ^{13}C NMR (DMSO-d_6) δ 25.6, 37.2, 77.6, 126.9, 128.7, 128.9, 131.5, 157.6, 188.1. EI-MS: *m/z* 214, 185, 171 (100%) 104, 83, 77, 54. Anal. Calcd. for $C_{13}H_{14}N_2O$ (214) (%): C, 72.87; H, 6.59; N, 13.07. Found: C, 72.81; H, 6.52; N, 13.12.

2-(4-Methoxyphenyl)-1,3-diazaspiro[4.4]non-1-en-4-one (2c). mp 236–237°C. ^{1}H NMR ($CDCl_3$) δ 1.92–2.09 (m, 8H), 3.87 (s, 3H, OCH_3), 6.98–7.00 (m, 2H, Ar), 7.86–7.88 (m, 2H, Ar), 10.20 (br, 1H, NHCO). ^{13}C NMR ($CDCl_3$) δ 25.6, 37.3, 55.6, 75.3, 114.3, 120.2, 129.6, 162.5, 162.7, 189.0. EI-MS: *m/z* 244, 215, 201, 134 (100%), 91, 83, 54. Anal. Calcd. for $C_{14}H_{16}N_2O_2$ (244) (%): C, 68.83; H, 6.60; N, 11.47. Found: C, 68.78; H, 6.52; N, 11.55.

2-(4-Nitrophenyl)-1,3-diazaspiro[4.4]non-1-en-4-one (2d). mp >300°C (dec.); ^{1}H NMR (DMSO-d_6) δ 1.72–1.96 (m, 16H), 8.09–8.49 (m, 8H, 2 × 2Ar), 11.48 (s, 1H, NHCO), 11.58 (s, 1H, NHCO). ^{13}C NMR (TFA + DMSO-d_6) δ 28.9, 41.0, 77.4, 77.7, 124.0, 127.5, 130.0, 133.5, 133.9, 153.4, 156.5, 169.4, 169.7, 181.9, 182.1. Anal. Calcd. for $C_{13}H_{13}N_3O_3$ (259) (%): C, 60.23; H, 5.05; N, 16.21. Found: C, 60.15; H, 4.98; N, 16.29.

2-(2-Hydroxyphenyl)-1,3-diazaspiro[4.4]non-1-en-4-one (2e). mp 232–233°C. ^{1}H NMR ($CDCl_3$) δ 1.90–2.09 (m, 8H), 6.91 (t, J = 7.50 Hz, 1H, Ar), 7.01 (d, J = 8.00 Hz, 1H, Ar), 7.35 (t, J = 8.00 Hz, 1H, Ar), 7.49 (d, J = 7.50 Hz, 1H, Ar), 10.46 (vbs, 1H, NHCO), 12.46 (vbs, 1H, OH). ^{13}C NMR ($CDCl_3$) δ 25.4 37.4, 76.1, 110.7, 117.3, 118.9, 127.7, 133.5, 160.3, 161.3, 185.5. EI-MS: *m/z* 230, 189, 173 (100%), 120, 102, 84, 54. Anal. Calcd. for $C_{13}H_{14}N_2O_2$ (230) (%): C, 60.81; H, 6.13; N, 12.17. Found: C, 60.78; H, 6.09; N, 12.24.

2-(1,3-Diazaspiro[4.4]non-1-en-4-one-2-yl)pyridine (2f). mp 120–122°C. ^{1}H NMR (DMSO-d_6 + TFA) δ 1.96–2.12 (m, 8H), 7.45 (t, J = 5.5 Hz, 1H, Py), 7.85 (t, J = 7.5 Hz, 1H, Py), 8.27 (d, J = 7.50 Hz, 1H, Py), 8.67 (d, J = 5.5 Hz, 1H, Py), 10.12 (s, 1H, NHCO).^{13}C NMR (DMSO-d_6 + TFA) δ 25.6, 37.1, 76.8, 122.7, 126.9, 137.6, 146.4, 149.4, 161.3, 187.4. EI-MS: *m/z* 215, 187 (100%), 159, 105, 78, 41. Anal. Calcd. for $C_{12}H_{13}N_3O$ (215) (%): C, 66.96; H, 6.09; N, 19.52. Found: C, 66.87; H, 6.02; N, 19.65.

(S)-2-(4-Isopropyl-4-methyl-4,5-dihydro-1H-imidazol-5-one-2-yl)pyridine (2g). Colorless oil; $[\alpha]_D$ −17.4 (c 2, CH_3OH). ^{1}H NMR (DMSO-d_6 + TFA) δ 0.85 (d, 3H, J = 6.8 Hz *i*-PrCH_3), 0.92 (d, 3H, J = 6.8 Hz *i*-PrCH_3), 1.23 (s, 3H, CH_3), 1.91 (m, 1H, *i*-Pr*CH*), 7.57 (m, 1H, Py), 7.87 (m, 1H, Py), 8.09 (d, 1H, J = 7.4 Hz, Py), 8.18 (d, 1H, J = 7.4 Hz, Py), 10.87 (bs, 1H, NHCO).^{13}C NMR (DMSO-d_6 + TFA) δ 16.8, 17.0, 21.4, 34.2, 74.6, 121.5, 126.5, 137.6, 147.4, 149.1, 159.0, 186.7. EI-MS: *m/z* 217, 202, 189, 174 (100%), 146, 105, 78. Anal. Calcd. for $C_{12}H_{15}N_3O$ (217) (%): C, 66.34; H, 6.96; N, 19.34. Found: C, 66.15; H, 6.85; N, 19.30.

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REFERENCES AND NOTES

[1] (a) Wepplo, P. J. Pestic Sci 1990, 31, 293; (b) Harris, J. E.; Gagne, J. A.; Fischer, J. E.; Sharma, R. R.; Traul, K. A.; Scot, J. D.; Hess, F. G. In The Imidazole Herbicides; Shaner, D. L.; O'Connor, S. L., Eds.; CRC Press: Boca Raton, FL, 1991; p 179.

[2] (a) Sedlák, M.; Halama, A.; Kaválek, J.; Macháček, V.; Štěrba, V. Collect Czech Chem Commun 1995, 60, 150; (b) Sedlák, M.; Halama, A.; Kaválek, J.; Macháček, V.; Mitaš, P.; Štěrba, V. Collect Czech Chem Commun 1996, 61, 910; (c) Sedlák, M.; Halama, A.; Mitaš, P.; Kaválek, J.; Macháček, V. J Heterocycl Chem 1997, 34, 1227; (d) Mitaš, P.; Sedlák, M.; Kaválek, J. Collect Czech Chem Commun 1998, 63, 85; (e) Sedlák, M.; Kaválek, J.; Mitaš, P.; Macháček, V. Collect Czech Chem Commun 1998, 63, 394; (f) Sedlák, M.; Hanusek, J.; Bína, R.; Kaválek, J.; Macháček, V. Collect Czech Chem Commun 1999, 64, 1629; (g) Sedlák, M.; Hanusek, J. Molecules 2000, 5, M177; (h) Sedlák, M.; Drabina, P.; Hanusek, J. Heterocycl Commun 2003, 9, 129.

[3] (a) Sedlák, M.; Drabina, P.; Císařová, I.; Růžička, A.; Hanusek, J.; Macháček, V. Tetrahedron Lett 2004, 45, 7723; (b) Turský, M.; Nečas, D.; Drabina, P.; Sedlák, M.; Kotora, M. Organometallics 2006, 25, 901; (c) Sedlák, M.; Drabina, P.; Keder, R.; Hanusek, J.; Císařová, I.; Růžička, A. J Organomet Chem 2006, 691, 2623; (d) Drabina, P.; Hanusek, J.; Jirásko, R.; Sedlák, M. Transition Met Chem 2006, 31, 1052; (e) Keder, R.; Drabina, P.; Hanusek, J.; Sedlák, M. Chem Pap 2006, 60, 324; (f) Nečas, D.; Drabina, P.; Sedlák, M.; Kotora, M. Tetrahedron Lett 2007, 45, 4539; (g) Mikysek, T.; Švancara, I.; Bartoš, M.; Vytřas, K.; Drabina, P.; Sedlák, M.; Klíma, J.; Urban, J.; Ludvík, J. Electroanalysis 2007, 19, 2529; (h) Sedlák, M.; Drabina, P.; Lánský, V.; Svoboda, J. J Heterocycl Chem 2008, 45, 859; (i) Drabina, P.; Sedlák, M.; Růžička, A.; Malkov, A.; Kočovský, P. Tetrahedron Asymmetry 2008, 19, 384.

[4] O'Neil, M. J. In The Merck Index—An Encyclopedia of Chemicals, Drugs, and Biologicals, 13th ed.; O'Neil, M. J.; Smith, A.; Hackelman, P. E., Eds.; Merck & Co.: Rahway, NJ, 2001; p 914.

[5] (a) Kavitha, C. V.; Gaonkar, S. L.; Narendra Sharath Chandra, J. N.; Sadashiva, C. T.; Rangappa, K. S. Bioorg Med Chem 2007, 15, 7391; (b) Cousaert, N.; Willand, N.; Gesquière, J.-C.; Tartar, A.; Deprez, B.; Deprez-Poulain, R. Tetrahedron Lett 2008, 49, 2743.

[6] Xu, J.-Y.; Li, N.-G.; Wu, X.-M.; Hua, W.-Y.; Zhang, J.; Wang, Q.-J. Zhongguo Yaowu Huxae Zazhi 2003, 13, 311;Chem Abstr 2005, 144, 88216.

[7] Huszar, C.; Kis-Tamas, A.; Nemeth, A.; Gajary, A.; Pali, L. PCT Int Appl, WO 9905118, 1999; Chem Abstr 1999, 130, 168371.

[8] Huszar, C.; Kis-Tama, A.; Nemeth, A.; Gajary, A.; Kollar, E.; Aranyosi, P.; Gyure, K.; Meszaros, I.; Csetrine, H. Z.; Supic, A.; Dervalicsne, Z. I.; Dubovszki, K.; Pali, L.; Kunsztne, K. A.; Bognar, E. PCT Int Appl, WO 9905120 A1 19990204, 1999; Chem Abstr 1999, 130, 139344.

[9] Allen, F. H.; Kennard, O.; Watson, D. G.; Brammer, L.; Orpen, A. G.; Taylor, R. J Chem Soc Perkin Trans 1987, 2, S1.

[10] Otwinowski, Z.; Minor, W. Methods Enzymol 1997, 276, 307.

[11] Coppens, P. In Crystallographic Computing; Ahmed, F. R.; Hall, S. R.; Huber, C. P., Eds.; Munksgaard: Copenhagen, 1970; p 255.

[12] Altomare, A.; Cascarano, G.; Giacovazzo, C.; Guagliardi, A. J Appl Crystallogr 1993, 26, 343.

[13] Sheldrick, G. M. SHELXL-97; University of Göttingen: Göttingen, 1997.