Stereospecific formation of polycyclic ferrocenyldihydropyrazoles based on *Z*- and *E*-isomeric ferrocenyl-substituted α,β-unsaturated ketones of the heterocyclic series

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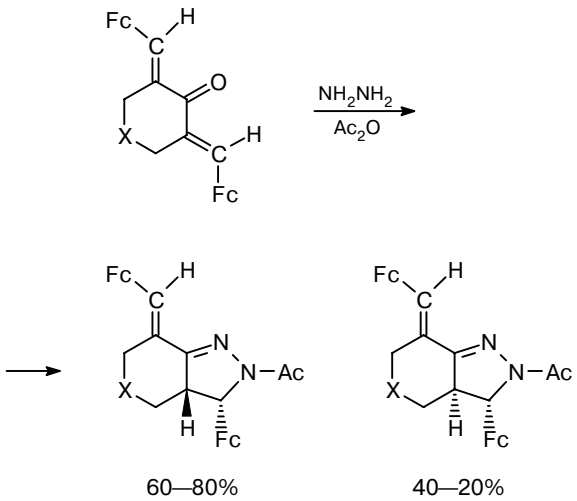
The reactions of *E*- and *Z*-isomeric 2-(ferrocenylmethylidene)quinuclidin-3-one, 1-methyl-3-(ferrocenylmethylidene)piperidin-4-one, and 2-(ferrocenylmethylidene)tropinone with hydrazine proceed stereospecifically to form the same diastereomeric polycyclic ferrocenyldihydropyrazoles regardless of the geometrical configuration of the starting α,β-unsaturated ketones. The structure of the *trans*-diastereomer of 4-acetyl-3-ferrocenyl-1,4,5-triazatricyclo[5.2.2.0^{2,6}]undec-5-ene was established by X-ray diffraction analysis.

Key words: ferrocene, dihydropyrazole, asymmetric induction, stereospecificity, X-ray diffraction analysis.

The ferrocenyl substituent in organic molecules can induce 'chiral plane—chiral center,' 'chiral center—chiral plane,' or 'chiral center—chiral center' asymmetry.[1—4]

The stereochemical aspects of the synthesis of ferrocene-containing heterocyclic systems were studied based on a few examples. Thus, 1,1- and 1,3-asymmetric induction of a chiral center by a chiral plane or vice versa was observed[5] in the synthesis of 4,5-dihydropyrazoles bearing the ferrocene and phenylbutadienyltricarbonyliron substituents at positions 3 and 5 of the heterocyclic system. It was mentioned that these reactions proceeded with high diastereomeric selectivity in different synthetic procedures. The high degree of 1,2-asymmetric induction of a chiral center by a chiral center was also observed[6,7] in the synthesis of bicyclic ferrocenylpyrazolines starting from *E*,*E*-bis(ferrocenylmethylidene)cycloalkanones (Scheme 1).

Scheme 1



Interest in the diastereoselective synthesis of biologically active heterocyclic compounds is associated with the requirements of pharmacology. Compounds of the ferrocene series also exhibit biological activities. It is known that ferrocenyl-substituted pyrazolines, cyclopropanes, cyclohexenes, tetrahydrophthalates, and ferrocenyl(alkyl)azoles possess antiinflammatory,[8—10] analgesic,[8—10] antiviral,[11] and antitumor[12] activities. The diastereomers of the same compound may differ in activity. The aim of the present work was to study the stereochemistry of formation of ferrocenyl-substituted dihydropyrazoles.

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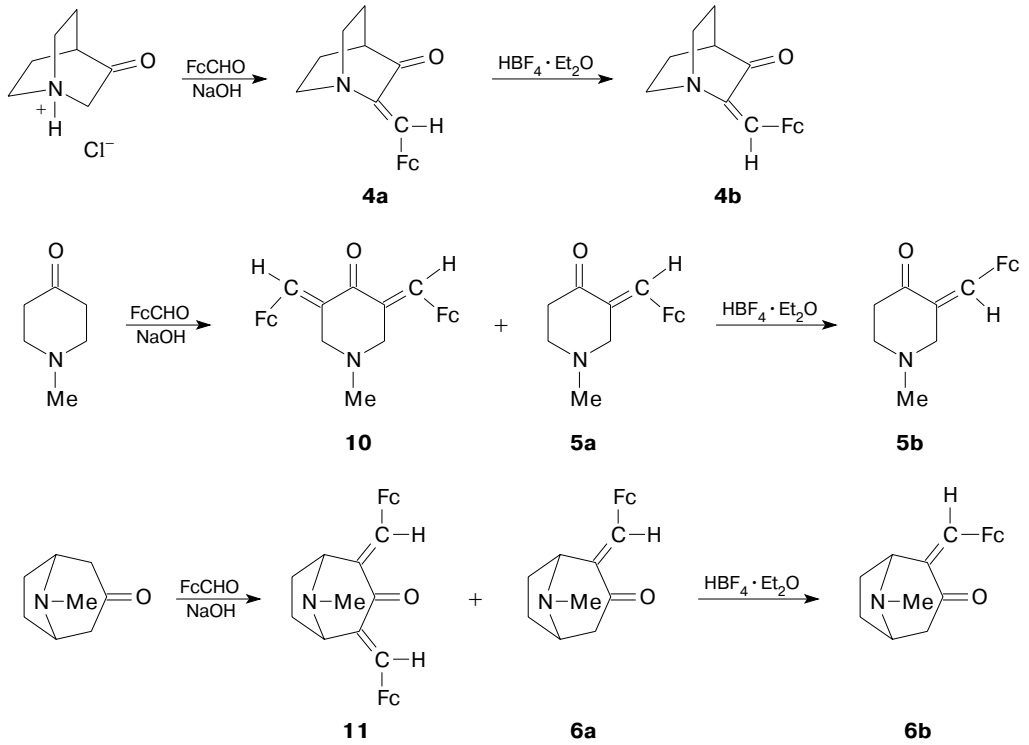
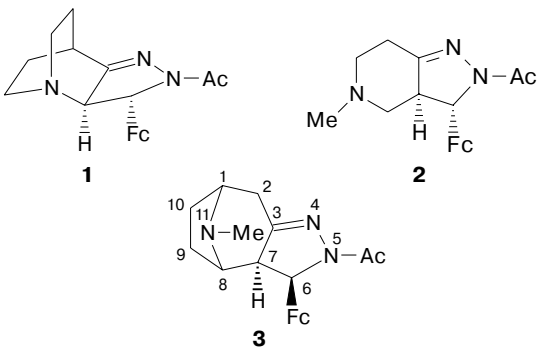
Scheme 2



Results and Discussion

As part of continuing studies of dihydropyrazoles, we investigated 1,2-asymmetric induction of a chiral center by a chiral center in the synthesis of polycyclic ferrocenylpyrazoles **1—3**:

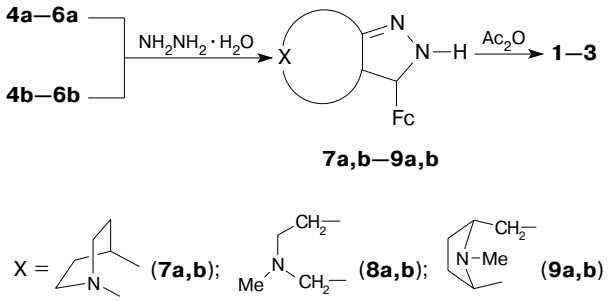


We used α,β-unsaturated carbonyl compounds **4—6**, which were prepared by condensation of ferrocenylcarbaldehyde with heterocyclic ketones in aqueous-alcoholic NaOH (Scheme 2), as the starting compounds.[7]

According to the data from ^{1}H NMR spectroscopy, chalcones **4a—6a** were formed as the only configurational isomers with the "external" arrangement of the bulky ferrocenyl substituent with respect to the *s-cis*-diene systems (*Z*-**4a**, *E*-**5a**, and *E*-**6a**).[6,13,14] The geometrical isomers with the "internal" arrangement of the ferrocenyl group (*E*-**4b**, *Z*-**5b**, and *Z*-**6b**) were prepared by isomerization of chalcones **4a—6a** under the action of $HBF_4 \cdot Et_2O$ as described previously.[15,16]

N-Acetyldihydropyrazoles **1—3** were synthesized by acylation of 1-unsubstituted dihydropyrazoles **7a,b—9a,b**. The latter, in turn, were prepared by addition of hydrazine[17] to α,β-unsaturated carbonyl compounds **4a,b—6a,b** (Scheme 3).

Scheme 3



Dihydropyrazoles isolated from chalcones **4a—6a** are arbitrarily denoted as **7a—9a**, whereas compounds isolated from isomeric enones **4b—6b** are denoted as **7b—9b**.

Dry compounds **7a,b—9a,b** are rather stable and remain unchanged upon storage under normal conditions for ~1—1.5 months. Since these compounds rapidly decompose in solutions, they were not character-

ized by NMR spectra. However, the pairs of dihydropyrazoles **7a** and **7b**, **8a** and **8b**, and **9a** and **9b** have identical melting points, which is indirect evidence in favor of the identity of the structures denoted as **a** and **b**.

Actually, the ^{1}H and ^{13}C NMR spectral studies of stable *N*-acetyl-substituted dihydropyrazoles **1—3** confirmed the conclusion that these compounds exist exclusively as the only diastereomeric form regardless of the configurational structure of the initial α,β-unsaturated ketone as evidenced by the identity of the corresponding ^{1}H and ^{13}C NMR spectral parameters and the melting points of acetyl(ferrocenyl)dihydropyrazoles **1—3** synthesized from the *Z*- and *E*-isomeric chalcones (see the Experimental section).

The ^{1}H NMR spectra of compounds **1** and **2** have signals for the H(3) protons of the pyrazole fragments at δ 4.86 and 5.51 with $^3J_{H(3a),H(3)}$ of 8.6 and 9.9 Hz, respectively. The signal for the analogous proton in compound **3** is observed at higher field (δ 4.76) and is characterized by the smaller spin-spin coupling constant ($^3J_{H(3a),H(3)}$ = 5.0 Hz).

Ferrocenylmethylidene-substituted bicyclic dihydropyrazoles have been identified previously by ^{1}H NMR spectroscopy and X-ray diffraction analysis.[6,7] It has been demonstrated that the *trans* or *cis* orientations of the ferrocenylpyrazole fragments with respect to the H(3a) atom can be established from the chemical shifts and the spin-spin coupling constants for the H(3) protons (Fig. 1). Thus, the signals for the H(3) protons in the *trans* isomers are observed at lower field and are characterized by larger spin-spin coupling constants than those in the *cis* isomers. Based on comparison of the ^{1}H NMR spectra of compounds **1**, **2**, and **3** with the spectra of the compounds identified previously,[6,7] the *trans* structures with the pseudoaxial orientations of the H(3a) and H(3) atoms and the pseudoequatorial position of the ferrocene fragment can be assigned to diastereomers **1** and **2**. In compound **3**, the H(3a) and H(3) protons are, apparently, in the *cis* orientation. However, the ^{1}H NMR spectral data for dihydropyrazole **3** (in the absence of the second diastereomer) did not allow us to unambiguously determine its spatial structure.

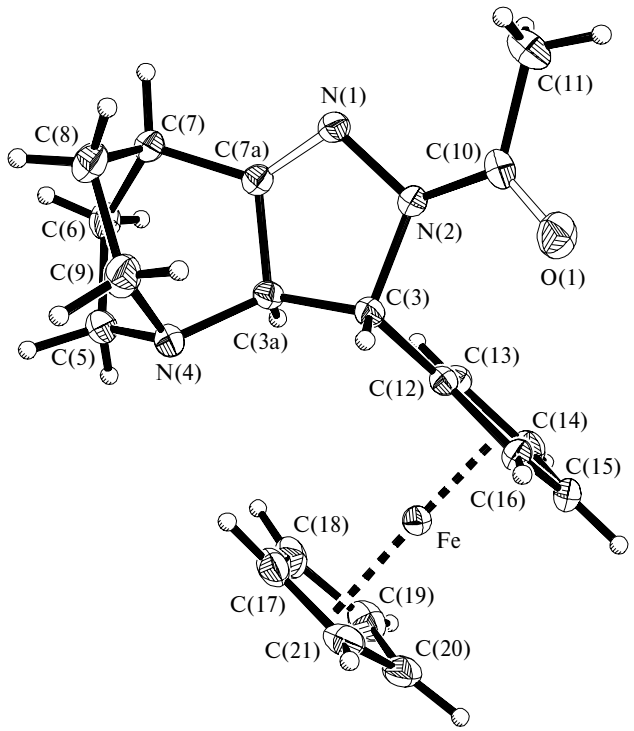


Fig. 1. Molecular structure of compound **1**.

With the aim of establishing the structure of one of the ferrocenyldihydropyrazoles synthesized, we performed X-ray diffraction study of a single crystal of compound **1** prepared by crystallization from $CHCl_3$ (see Fig. 1, Tables 1 and 2).

The central tricyclic core is the key fragment of compound **1**. The bicyclic system of quinuclidine is fused with the five-membered dihydropyrazole ring adopting a flattened envelope conformation. The ferrocenyl substituent has a pseudoequatorial orientation. The H(3a) and H(3) atoms at the C(3a) and C(3) atoms, respectively, are in the *trans* orientation. In the dihydropyrazole ring, the N(1)=C(7a) bond length (1.276 Å) is virtually identical to the analogous bond lengths in ferrocenyl-substituted pyrazolines (lit. data: *d*(C=N) = 1.285 Å [5] and 1.289 Å [18]), whereas the N(1)—N(2) bond length (1.421 Å) is somewhat larger than the values found previously (lit. data: *d*(N—N) = 1.392 Å [5] and 1.387 Å [18]). The C—C and C—N bond lengths in the quinuclidine fragment as well as the Fe—C and C—C bond lengths and the geometric parameters of the ferrocenyl group have standard values.[19]

The conclusion that the hydrogen atoms at positions 3a and 3 of the pyrazole ring in compound **1** are in the *trans* orientations, which have been made previously based on the ^{1}H NMR spectral data, was confirmed by the results of X-ray diffraction analysis. Apparently, compound **2** has an analogous structure. The structure of pyrazole **3** remains to be established.

To summarize, the synthesis of ferrocenyldihydropyrazoles from *Z*- and *E*-isomeric *s-cis*-fused enones proceeds stereospecifically to give the same diastereo-

Table 1. Principal bond lengths (*d*) and bond angles (ω) in the structure of compound **1**

Bond	*d*/Å	Angle	ω/deg
N(1)—N(2)	1.421(4)	C(7a)—N(1)—N(2)	106.7(3)
N(1)—C(7a)	1.276(4)	N(1)—N(2)—C(3)	112.0(2)
C(3a)—C(7a)	1.500(4)	N(2)—C(3)—C(3a)	100.6(2)
N(2)—C(3)	1.508(4)	N(4)—C(3a)—C(7a)	108.2(3)
C(3)—C(3a)	1.529(4)	C(3a)—N(4)—C(5)	105.1(3)
C(3a)—N(4)	1.479(4)	C(9)—N(4)—C(5)	107.3(3)
N(4)—C(5)	1.481(5)	C(7a)—C(7)—C(8)	103.3(3)
N(4)—C(9)	1.494(5)	N(1)—C(7a)—C(3a)	115.8(3)
C(5)—C(6)	1.540(6)	C(7a)—C(3a)—C(3)	103.0(3)
C(3)—C(12)	1.506(5)		

Table 2. Crystallographic data and details of X-ray diffraction analysis of compound **1**

Parameters	Characteristic
Molecular formula	$C_{20}H_{23}FeN_3O$
Molecular weight/g mol^{-1}	377.26
T/K	293
Crystal system	Orthorhombic
Space group	*Pbca*
a/Å	18.174(3)
b/Å	9.034(1)
c/Å	20.853(2)
α/deg	90.0
β/deg	90.0
γ/deg	90.0
V/Å^3	3423.7(8)
Z	8
d_{calc}/g cm^{-3}	1.464
Absorption coefficient/mm^{-1}	0.894
F(000)	1584
Radiation, λ/Å	Mo-Kα, 0.71073
Monochromator	Graphite
θ/2θ scanning range/deg	1.50—25.00
Number of reflections	3845
Number of independent reflections	3012
R_{int}	0.0434
Number of parameters in the refinement	296
Goodness-of-fit	1.023 (full-matrix least-squares based on F^2)
Residual electron density/e · Å^{-3}, ρ_{min}/ρ_{max}	−0.327/0.441
Weighting scheme	$w^{-1} = \sigma^2(F_0^2) + (0.0735P)^2$, where $P = (F_0^2 + 2Fc^2)/3$

meric products regardless of the configuration of the starting α-ferrocenylmethylidene-substituted ketone of the heterocyclic series.

Experimental

The ^{1}H and ^{13}C NMR spectra were recorded on a Varian Unity Inova spectrometer (300 and 75 MHz, respectively) in $CDCl_3$ with $SiMe_4$ as the internal standard. Column chromatography was carried out with the use of Al_2O_3 (Brockmann III).

The unit cell parameters and the intensities of reflections were measured on a Siemens P4/PC diffractometer at 293 K.

Ferrocenylcarbaldehyde (98%), quinuclidin-3-one hydrochloride (99%), tropinone (99%), and 1-methyl-4-piperidone (97%) were purchased from Aldrich; $HBF_4 \cdot Et_2O$ (50—52%) was purchased from Alfa AESAR. Dichloromethane was dried by washing successively with concentrated H_2SO_4, H_2O, a 10% solution of NaOH, and H_2O, dried over calcinated K_2CO_3, and distilled over 4 Å molecular sieves.

***Z*-2-(Ferrocenylmethylidene)quinuclidin-3-one (4a)** was prepared according to a standard procedure[11] from ferrocenylcarbaldehyde and quinuclidin-3-one hydrochloride in aqueous-alcoholic alkali as dark-red crystals in 76% yield, m.p. 122—123 °C (lit. data:[11] m.p. 122—123 °C).

***E*-3-(Ferrocenylmethylidene)-1-methylpiperidin-4-one (5a).** Ferrocenylcarbaldehyde (2.14 g, 10 mmol) and 1-methylpiperidin-4-one (2.0 mL) were added to a solution of NaOH (1.0 g) in water (20 mL) and EtOH (20 mL). The reaction mixture was stirred at 20 °C for 24 h and then mixed with benzene (100 mL). The organic layer was separated from the aqueous layer and then washed with water. The solvent was distilled off *in vacuo*. The residue was chromatographed on Al_2O_3 (a 3 : 1 hexane—benzene mixture as the eluent). Compound **5a** and 3,5-bis(ferrocenylmethylidene)-1-methylpiperidin-4-one (**10**) were obtained in yields of 1.98 g (64%) and 0.5 g (21%), respectively.

Compound **5a** was obtained as red-violet crystals, m.p. 117—118 °C. Found (%): C, 65.88; H, 6.11; Fe, 18.17; N, 4.39. $C_{17}H_{19}FeNO$. Calculated (%): C, 66.04; H, 6.19; Fe, 18.06; N, 4.53. ^{1}H NMR, δ: 2.49 (s, 3 H, Me); 2.60 (t, 2 H, CH_2, J = 6.0 Hz); 2.78 (t, 2 H, CH_2, J = 6.0 Hz); 3.49 (d, 2 H, CH_2, J = 2.0 Hz); 4.16 (s, 5 H, C_5H_5); 4.18 (m, 2 H, C_5H_4); 4.45 (m, 2 H, C_5H_4); 7.46 (t, 1 H, CH=, J = 2.0 Hz). ^{13}C NMR, δ: 38.8 (Me); 46.3, 52.5, 57.7 (3 CH_2); 69.5 (C_5H_5); 71.2, 71.4 (C_5H_4); 78.6 (C_{ipsoFc}); 128.5 (CH=); 129.6 (C); 198.4 (C=O).

Compound **10** was obtained as violet crystals, m.p. 197—198 °C (lit. data:[20] m.p. 197—198 °C).

***E*-2-(Ferrocenylmethylidene)-8-azabicyclo[3.2.1]octan-3-one (6a)** was synthesized analogously from ferrocenylcarbaldehyde (2.14 g) and tropinone (2.19 g, 15 mmol). The mixture was treated as described above and chromatographed on Al_2O_3 (a 3 : 1 hexane—$CHCl_3$ mixture as the eluent) to obtain monochalcone **6a** and 2,7-bis(ferrocenylmethylidene)-8-azabicyclo[3.2.4]octan-3-one (**11**) in yields of 2.02 g (60%) and 0.51 g (23%), respectively.

Compound **6a** was obtained as violet crystals, m.p. 110—111 °C. Found (%): C, 67.93; H, 6.44; Fe, 16.71; N, 4.07. $C_{19}H_{21}FeNO$. Calculated (%): C, 68.07; H, 6.32; Fe, 16.66; N, 4.18. ^{1}H NMR, δ: 2.49 (s, 3 H, HMe); 2.60 (t, 2 H, CH_2, J = 6.0 Hz); 2.78 (t, 2 H, CH_2, J = 6.0 Hz); 3.49 (d, 2 H, CH_2, J = 2.0 Hz); 4.16 (s, 5 H, C_5H_5); 4.18 (m, 2 H, C_5H_4); 4.45 (m, 2 H, C_5H_4); 7.46 (t, 1 H, CH=, J = 2.0 Hz).

Compound **11** was obtained as red crystals, m.p. 235—236 °C. Found (%): C, 67.68; H, 5.73; Fe, 20.93; N, 2.48. $C_{30}H_{29}Fe_2NO$. Calculated (%): C, 67.82; H, 5.50; Fe, 21.02; N, 2.65. ^{1}H NMR, δ: 1.86 (m, 2 H, CH_2); 2.39 (s, 3 H, Me); 2.54 (m, 2 H, CH_2); 4.19 (s, 10 H, 2 C_5H_5); 4.38 (m, 2 H, 2 CH); 4.44 (m, 2 H, C_5H_4); 4.49 (m, 4 H, C_5H_4); 4.54 (m, 2 H, C_5H_4); 7.62 (s, 2 H, 2 CH=). ^{13}C NMR, δ: 30.2 (2 CH_2); 35.9 (Me); 61.0 (2 CH); 69.5 (2 C_5H_5); 69.0, 71.0, 71.1, 73.2 (2 C_5H_4); 78.5 (2 C_{ipsoFc}); 134.5 (2 C); 137.1 (2 CH=); 185.5 (C=O).

***E*-2-(Ferrocenylmethylidene)quinuclidin-3-one (4b).** A mixture of chalcone **4a** (0.96 g, 3 mmol) and $HBF_4 \cdot Et_2O$ (1 mL) in anhydrous CH_2Cl_2 (100 mL) was stirred under an atmosphere of dry argon at 30—33 °C for 6 h. Then the reaction mixture was cooled to ~20 °C and washed with a 5% aqueous solution of Na_2CO_3. The organic layer was separated and dried with Na_2SO_4. The solvent was distilled off and the residue was chromatographed on Al_2O_3. The starting compound **4a** (hexane as the eluent) was obtained in a yield of 0.11 g (11%), m.p. 121—123 °C;[11] *E* isomer **4b** (benzene as the eluent) was obtained as violet crystals in a yield of 0.75 g (75%), m.p. 114—115 °C (lit. data:[15] m.p. 113—114 °C).

***Z*-3-(Ferrocenylmethylidene)-1-methylpiperidin-4-one (5b)** was prepared by isomerization of *E* isomer **5a** (1.5 g, 5 mmol) under the action of $HBF_4 \cdot Et_2O$ as described above. Chroma-

tography afforded the starting compound **5a** in a yield of 0.6 g (40%), m.p. 116—117 °C, and *Z* isomer **5b** (a 2 : 1 hexane—benzene mixture as the eluent) as violet crystals in a yield of 0.66 g (44%), m.p. 103—104 °C. Found (%): C, 66.16; H, 6.03; Fe, 17.93; N, 4.65. $C_{17}H_{19}FeNO$. Calculated (%): C, 66.04; H, 6.19; Fe, 18.06; N, 4.53. ^{1}H NMR, δ: 2.46 (s, 3 H, Me); 2.73 (t, 2 H, CH_2, J = 5.8 Hz); 2.94 (t, 2 H, CH_2, J = 5.8 Hz); 3.69 (d, 2 H, CH_2, J = 1.6 Hz); 4.19 (s, 5 H, C_5H_5); 4.21 (m, 2 H, C_5H_4); 4.78 (m, 2 H, C_5H_4); 7.35 (t, 1 H, CH=, J = 1.6 Hz).

***Z*-2-(Ferrocenylmethylidene)-8-azabicyclo[3.2.1]octan-3-one (6b)** was prepared by isomerization of chalcone **6a** (1.67 g, 5 mmol) as described above. After the corresponding workup and chromatography (a 2 : 1 hexane—benzene mixture as the eluent), the starting compound **6a** was isolated in a yield of 0.4 g (24%), m.p. 110—111 °C, and *Z* isomer **6b** was obtained as violet crystals in a yield of 1.04 g (62%), m.p. 98—99 °C. Found (%): C, 68.19; H, 6.16; Fe, 16.83; N, 4.25. $C_{19}H_{21}FeNO$. Calculated (%): C, 68.07; H, 6.32; Fe, 16.66; N, 4.18. ^{1}H NMR, δ: 1.87 (m, 2 H, CH_2); 2.34 (s, 3 H, Me); 2.57 (m, 2 H, CH_2); 3.41 (m, 2 H, CH_2); 4.15 (s, 5 H, C_5H_5); 4.27 (m, 2 H, CH); 4.42 (m, 2 H, C_5H_4); 4.60 (m, 2 H, C_5H_4); 7.30 (s, 1 H, CH=).

3-Ferrocenyl-1,4,5-triazatricyclo[5.2.2.0^{2,6}]undec-5-ene (7). $N_2H_4 \cdot H_2O$ (5 mL) was added to a solution of compound *Z*-**4a** (1.07 g, 3.3 mmol) in 95% EtOH (40 mL). The reaction mixture was stirred at ~70 °C for 3 h and then cooled. The yellow crystals that formed were filtered off, washed with aqueous EtOH, and dried over P_4O_{10}. Dihydropyrazole **7a** was obtained in a yield of 0.80 g (72%), m.p. 263—265 °C (lit. data:[11] m.p. 263—265 °C).

Pyrazole **7b** was obtained analogously from chalcone *E*-**4b** (1.07 g) as yellow crystals in a yield of 0.84 g (76%), m.p. 264—265 °C.

9-Ferrocenyl-3-methyl-3,7,8-triazabicyclo[4.3.0]non-6-ene (8) Analogously, compound **8a** was prepared from chalcone *E*-**5a** (1.03 g, 3.3 mmol) as a yellow powder in a yield of 0.81 g (75%), m.p. 188—190 °C.

Pyrazole **8b** was obtained from *Z*-**5b** (1.03 g) in a yield of 0.75 g (70%), m.p. 187—189 °C.

6-Ferrocenyl-11-methyl-4,5,11-triazatricyclo[6.2.1.0^{3,7}]undec-3-ene (9). Compound **9a** was prepared from chalcone *E*-**6a** (1.11 g, 3.3 mmol) as a yellow powder in a yield of 0.83 g (71%), m.p. 239—241 °C.

Analogously, pyrazole **9b** was obtained from *Z*-**6b** (1.11 g) in a yield 0.84 g (73%), m.p. 240—241 °C.

***N*-Acetyldihydropyrazoles 1—3** were synthesized according to a standard procedure.[17] Dry dihydropyrazoles (**7a**, **8a**, **9a**,**7b**, **8b**, and **9b**) (3.3 mmol) were dissolved in Ac_2O (2 mL) and the reaction mixtures were treated with a 5% solution of Na_2CO_3. The yellow crystals that precipitated were filtered off, washed with aqueous EtOH, and dried over P_4O_{10}.

4-Acetyl-3-ferrocenyl-1,4,5-triazatricyclo[5.2.2.0^{2,6}]undec-5-ene (1). Compound **1** was prepared from dihydropyrazole **7a** (1.12 g, 3.3 mmol) in a yield of 0.88 g (70%), m.p. 201 °C (from 95% EtOH; lit. data:[11] m.p. 200—201 °C.) Acetyldihydropyrazole **1** was prepared analogously from dihydropyrazole **7b** (1.12 g) in a yield of 0.91 g (72%), m.p. 201 °C. Found (%): C, 63.56; H, 6.27; Fe, 14.99; N, 11.05. $C_{20}H_{23}FeN_3O$. Calculated (%): C, 63.67; H, 6.15; Fe, 14.81; N, 11.13. ^{1}H NMR, δ: 1.97 (m, 4 H, 2 CH_2); 2.25 (s, 3 H, Me); 2.85 (m, 2 H, CH_2); 3.07 (m, 2 H, CH_2); 3.29 (m, 1 H, CH); 4.26 (s, 5 H, C_5H_5); 4.05 (m, 1 H, C_5H_4); 4.16 (m, 2 H, C_5H_4); 4.46 (m, 1 H, C_5H_4); 4.36 (d, 1 H, CH, J = 8.6 Hz); 4.86 (d, 1 H, CH, J = 8.6 Hz). ^{13}C NMR, δ: 22.6 (Me); 28.4 (CH_2); 35.5 (CH_2); 43.3 (CH_2); 48.5 (CH_2); 58.9, 65.7, 67.7 (3 CH); 68.3 (C_5H_5); 68.1, 68.3, 68.3, 71.8 (C_5H_4); 87.0 (C_{ipsoFc}); 167.3 (C=N); 170.7 (C=O).

8-Acetyl-9-ferrocenyl-3-methyl-3,7,8-triazabicyclo[4.3.0]non-6-ene (2). Compound **2** was obtained from dihydropyrazole **8a** (1.08 g) in a yield of 0.92 g (75%), m.p. 135—136 °C (from 95% EtOH). Found (%): C, 62.57; H, 6.17; Fe, 15.41; N, 11.28. $C_{19}H_{23}FeN_3O$. Calculated (%): C, 62.48; H, 6.35; Fe, 15.30; N, 11.50. ^{1}H NMR, δ: 1.80 (m, 1 H, CH_2); 2.17 (m, 1 H, CH_2); 2.21 (s, 3 H, Me); 2.36 (s, 3 H, Me); 2.49 (m, 1 H, CH_2) 2.70 (m, 1 H, CH_2); 2.90 (m, 1 H, CH_2); 3.20 (m, 1 H, CH_2); 3.31 (m, 1 H, CH); 4.23 (s, 5 H, C_5H_5); 3.85 (m, 1 H, C_5H_4); 3.96 (m, 1 H, C_5H_4); 4.13 (m, 2 H, C_5H_4); 5.51 (d, 1 H, CH, J = 9.9 Hz). ^{13}C NMR, δ: 22.1 (Me); 27.1 (Me); 45.7 (CH_2); 48.8 (CH_2); 53.7 (CH_2); 56.1, 56.3 (2 CH); 69.4 (C_5H_5); 65.3, 65.8, 67.0, 67.6 (C_5H_4); 86.2 (C_{ipsoFc}); 159.0 (C=N); 168.2 (C=O).

Compound **2** was prepared analogously from dihydropyrazole **8b** (1.08 g) in a yield of 0.87 g (71%), m.p. 135—136 °C. ^{1}H NMR, δ: 1.78 (m, 1 H, CH_2); 2.16 (m, 1 H, CH_2); 2.23 (s, 3 H, Me); 2.35 (s, 3 H, Me); 2.50 (m, 1 H, CH_2); 2.67 (m, 1 H, CH_2); 2.88 (m, 1 H, CH_2); 3.20 (m, 1 H, CH_2); 3.29 (m, 1 H, CH); 4.23 (s, 5 H, C_5H_5); 3.83 (m, 1 H, C_5H_4); 3.95 (m, 1 H, C_5H_4); 4.13 (m, 2 H, C_5H_4); 5.50 (d, 1 H, CH, J = 10.0 Hz).

5-Acetyl-6-ferrocenyl-11-methyl-4,5,11-triazatricyclo[6.2.1.0^{3,7}]undec-3-ene (3). Compound **3** was prepared from dihydropyrazole **9a** (1.15 g) in a yield of 0.90 g (69%), m.p. 114—115 °C (from benzene). Found (%): C, 64.59; H, 6.27; Fe, 14.38; N, 10.68. $C_{21}H_{25}FeN_3O$. Calculated (%): C, 64.46; H, 6.44; Fe, 14.27; N, 10.73. ^{1}H NMR, δ: 1.44 (m, 1 H, CH_2); 1.59 (m, 1 H, CH_2); 1.98 (m, 1 H, CH_2); 2.10 (m, 1 H, CH_2); 2.23 (s, 3 H, Me); 2.34 (dd, 1 H, CH_2, J = 2.4 and 13.2 Hz); 2.51 (s, 3 H, Me); 2.79 (dd, 1 H, CH_2, J = 3.6 and 13.2 Hz); 3.41 (dd, 1 H, CH_2, J = 3.6 and 6.0 Hz); 3.51 (t, 1 H, CH, J = 3.6 Hz); 3.75 (t, 1 H, CH, J = 5.0 Hz); 4.17 (s, 5 H, C_5H_5); 4.02 (m, 1 H, C_5H_4); 4.15 (m, 2 H, C_5H_4); 4.41 (m, 1 H, C_5H_4); 4.76 (d, 1 H, CH, J = 5.0 Hz). ^{13}C NMR, δ: 22.2 (Me); 23.2 (Me); 26.9 (CH_2); 34.6 (CH_2); 39.2 (CH_2); 57.1, 58.7, 62.7, 66.0 (4 CH); 68.2 (C_5H_5); 66.2, 68.0, 68.2, 70.3 (C_5H_4); 87.7 (C_{ipsoFc}); 157.1 (C=N); 168.7 (C=O).

Acetylpyrazole **3** was prepared analogously from dihydropyrazole **9b** (1.15 g) in a yield of 0.91 g (70%), m.p. 114—115 °C. ^{1}H NMR, δ: 1.42 (m, 1 H, CH_2); 1.60 (m, 1 H, CH_2); 1.99 (m, 1 H, CH_2); 2.12 (m, 1 H, CH_2); 2.23 (s, 3 H, Me); 2.32 (dd, 1 H, CH_2, J = 2.3 and 13.3 Hz); 2.50 (s, 3 H, Me); 2.81 (dd, 1 H, CH_2, J = 3.7 and 13.3 Hz); 3.41 (dd, 1 H, CH_2, J = 3.7 and 6.0 Hz); 3.50 (t, 1 H, CH, J = 3.6 Hz); 3.77 (t, 1 H, CH, J = 5.1 Hz); 4.17 (s, 5 H, C_5H_5); 4.03 (m, 1 H, C_5H_4); 4.15 (m, 2 H, C_5H_4); 4.42 (m, 1 H, C_5H_4); 4.77 (d, 1 H, CH, J = 5.1 Hz).

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References

1. V. I. Sokolov, *Vvedenie v teoreticheskuyu stereokhimiyu* [*Introduction to Theoretical Stereochemistry*], Nauka, Moscow, 1979, 243 pp. (in Russian).

2. T. Hayashi, *Pure Appl. Chem.*, 1998, **60**, 7.
3. M. Sawamura and Y. Ito, *Chem. Rev.*, 1992, **92**, 857.
4. J. Spencer, V. Cramlich, R. Hausel, and A. Togni, *Tetrahedron Asymmetry*, 1996, **7**, 41.
5. V. N. Postnov, V. G. Andrianov, Yu. T. Struchkov, A. M. Baran, and V. A. Sazonova, *J. Organomet. Chem.*, 1984, **262**, 201.
6. E. I. Klimova, M. Martinez Garcia, T. Klimova-Berestneva, L. Ruiz Ramirez, C. Alvarez Toledano, and R. A. Toscano, *Izv. Akad. Nauk, Ser. Khim.*, 1999, 765 [*Russ. Chem. Bull.*, 1999, **48**, 761 (Engl. Transl.)].
7. E. I. Klimova, M. Martinez Garcia, T. Klimova-Berestneva, C. Alvarez Toledano, R. A. Toskano, and L. Ruiz Ramirez, *J. Organomet. Chem.*, 1999, **585**, 106.
8. E. I. Klimova, V. N. Postnov, N. N. Meleshonkova, A. S. Zaks, and V. V. Yushkov, *Khim.-farm. Zh.*, 1992, **26**, 69 [*Pharm. Chem. J.*, 1992, **26** (Engl. Transl.)].
9. E. I. Klimova, V. N. Postnov, N. N. Meleshonkova, A. S. Zaks, and E. M. Chukichev, *Khim.-farm. Zh.*, 1992, **26**, 34 [*Pharm. Chem. J.*, 1992, **26** (Engl. Transl.)].
10. E. I. Klimova, V. N. Postnov, N. N. Meleshonkova, M. Martinez Garcia, and A. S. Zaks, *Khim.-farm. Zh.*, 1994, **28**, 33 [*Pharm. Chem. J.*, 1994, **28** (Engl. Transl.)].
11. E. I. Klimova, L. Ruiz Ramirez, M. Martinez Garcia, R. G. Espinosa, and N. N. Meleshonkova, *Izv. Akad. Nauk, Ser. Khim.*, 1996, 2743 [*Russ. Chem. Bull.*, 1996, **45**, 2602 (Engl. Transl.)].
12. L. V. Snegur, V. I. Boev, Yu. S. Nekrasov, M. M. Ilyin, V. A. Davankov, Z. A. Starikova, A. I. Yanovsky, A. F. Kolomiets, and V. N. Babin, *J. Organomet. Chem.*, 1999, **580**, 26.
13. V. N. Postnov, E. I. Klimova, M. Martinez Garcia, N. N. Meleshonkova, V. V. Rybakov, and L. A. Aslanov, *J. Organomet. Chem.*, 1994, **476**, 189.
14. E. J. Warawa and J. R. Campbell, *J. Org. Chem.*, 1974, **39**, 3511.
15. E. I. Klimova, L. Ruiz Ramirez, T. Klimova, and M. Martinez Garcia, *J. Organomet. Chem.*, 1998, **559**, 43.
16. E. I. Klimova, T. Klimova, M. Martinez Garcia, and N. N. Meleshonkova, *Mendeleev Commun.*, 1997, 233.
17. A. N. Nesmeyanov, V. N. Postnov, E. I. Klimova, and V. A. Sazonova, *Izv. Akad. Nauk SSSR, Ser. Khim.*, 1979, 239 [*Bull. Acad. Sci. USSR, Div. Chem. Sci.*, 1979, **28** (Engl. Transl.)].
18. V. G. Andrianov, Yu. T. Struchkov, V. N. Postnov, E. I. Klimova, and V. A. Sazonova, *J. Organomet. Chem.*, 1984, **272**, 81.
19. *Structure Correlation*, Eds. H.-B. Bürgi and J. D. Dunitz, VCH, Weinheim—New York, 1994, **2**.
20. E. I. Klimova, M. Martinez Garcia, T. Klimova, L. Ruiz Ramirez, J. M. Mendez Stivalet, and N. N. Meleshonkova, *Izv. Akad. Nauk, Ser. Khim.*, 2000, 511 [*Russ. Chem. Bull., Int. Ed.*, 2000, **49**, 514].

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