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Ene Synthesis of Bicyclic Arylmethylenedihydropyrazoles Using 4-Phenyl-4,5-dihydro-3*H*-1,2,4-triazole-3,5-dione

M. G. Martinez, T. Klimova-Berestneva, K. Damian-Zea,
N. N. Meleshonkova, and E. I. Klimova

Institute of Chemistry, National Autonomous University of Mexico, Mexico City, Mexico
National Autonomous University of Mexico, Mexico City, Mexico
Moscow State University, Moscow, Russia

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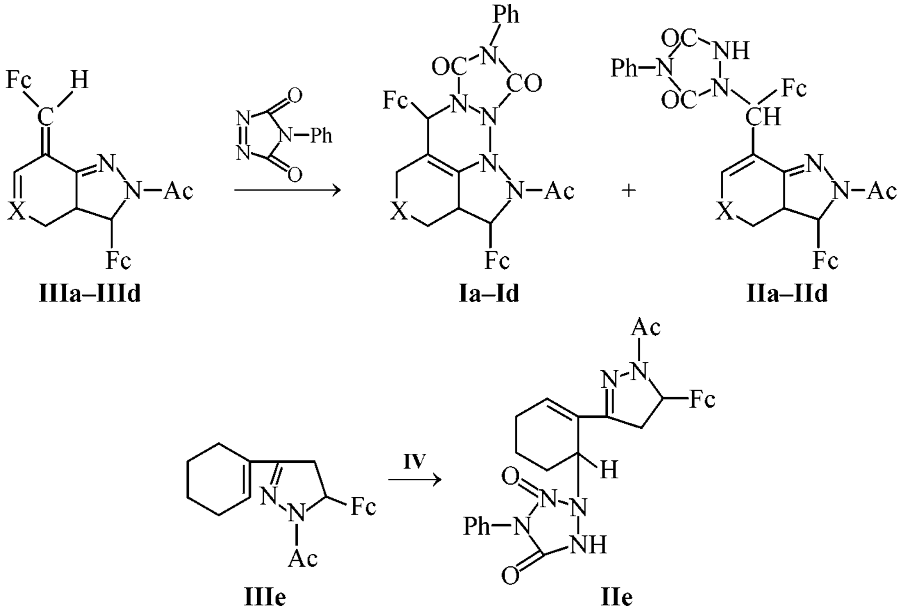
Abstract—8-Acetyl-7-aryl-2-arylmethylene-8,9-diaza- and 4,8,9-triazabicyclo[4.3.0]non-9-enes react with 4-phenyl-4,5-dihydro-3*H*-1,2,4-triazole-3,5-dione, following the ene addition pattern. Under similar conditons 7-aryl-2-arylmethylene-8-methyl-8,9-diazabicyclo[4.3.0]non-9-enes give rise to both mono- and polyaddition products. The product structures were studied by ^{1}H and ^{13}C NMR, IR, and UV spectroscopy and single crystal X-ray diffraction.

α,β-Unsaturated ketones react with hydrazine to give unstable 4,5-dihydropyrazoles having no substituent in position 1; acylation of these compounds yields stable 1-acetyl derivatives [1–5]. It is known that many biologically active substances contain pyrazole fragments. Relatively high pharmacological activity was reported [6–8] for bicyclic acetyldihydropyrazoles which were synthesized from mono- and bis(arylmethylene)cycloalkanones [5]. Ferrocenyl-substituted dihydropyrazoles also exhibit biological activity. In particular, 4-acetyl-3-ferrocenyl-1,4,5-triazatricyclo[5.2.2.0^{2,6}]undec-5-ene showed a high antiviral activity [9]. Introduction of additional nitrogen-containing fragments into dihydropyrazole ring [1] is expected to extend the range of biological activity of the products. In this respect, recently reported [10, 11] diene (**I**) and monoene adducts (**II**) of bi- and monocyclic ferrocenyldihydropyrazoles **IIIa**–**IIIe** with *N*-phenylazodicarboximide **IV** attract interest. Adducts **Ia**–**Id** and **IIa**–**IIe** are polynitrogen-containing organic substances which show antiviral activity.



IIIa–IIId **Ia–Id** **IIa–IId**

IIIe **IIe**

Fc = $C_5H_5FeC_5H_4$; X = CH_2 (**a**), $(CH_2)_2$ (**b**), NCH_3 (**c**), NPh (**d**).

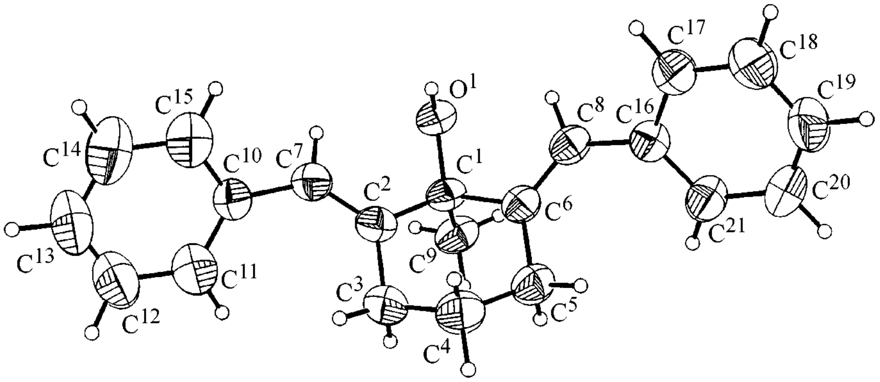
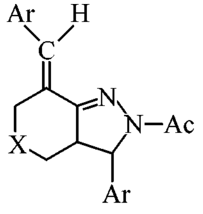
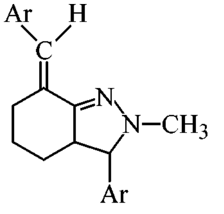


Fig. 1. Molecular structure of **X**. Principal bond lengths, Å: $C^2–C^7$ 1.327(6), $C^6–C^8$ 1.326(6), $C^1–C^2$ 1.527(6), $C^1–C^6$ 1.544(6), $C^5–C^6$ 1.495(6), $C^2–C^3$ 1.517(7). Principal bond angles, deg: $C^1C^6C^8$ 120.3(4), $C^1C^2C^7$ 120.5(4), $C^2C^1C^6$ 110.9(3).

However, these compounds are poorly soluble in many solvents. Therefore, it seemed reasonable to develop methods of synthesis of structurally related compounds having aryl or alkyl substituents and to study their chemical and pharmacological properties. Proceeding with studies on the chemistry of dihydropyrazoles, we have examined the condensation of bicyclic arylmethylene-substituted dihydropyrazoles **Va**–**Vc**, **VIa**, and **VIb** with 4-phenyl-4,5-dihydro-3*H*-1,2,4-triazole-3,5-dione (**IV**).



Va–Vc

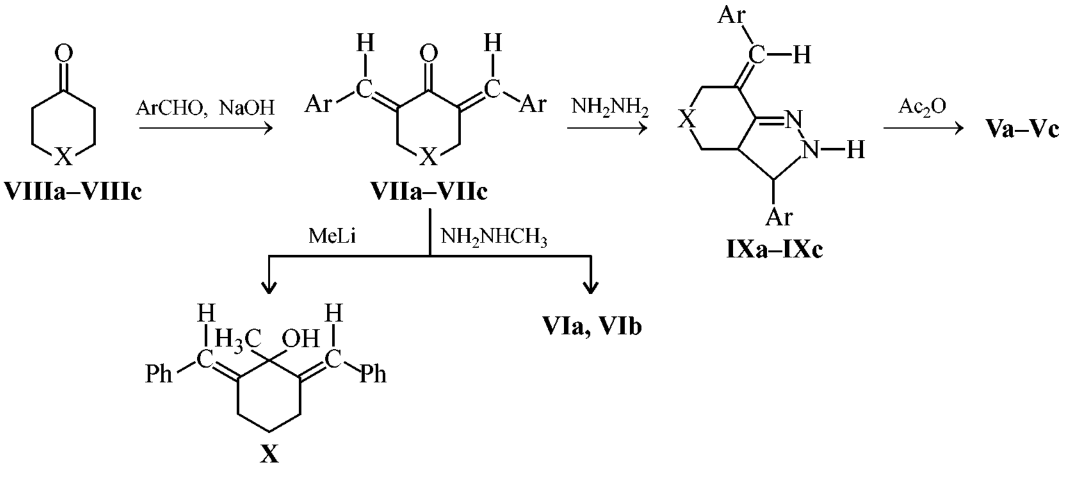


VIa, VIb

V, X = CH_2, Ar = Ph (**a**); X = CH_2, Ar = *p*-$CH_3OC_6H_4$ (**b**); X = NCH_3, Ar = *p*-$CH_3OC_6H_4$ (**c**); **VI**, Ar = Ph (**a**), *p*-$CH_3OC_6H_4$ (**b**).

Pyrazoles **V** and **VI** were prepared from α,β-unsaturated ketones **VIIa**–**VIIc** which were synthesized by condensation of benzaldehyde or *p*-methoxybenzaldehyde with cyclohexanone (**VIIIa**) or 1-methyl-4-piperidinone (**VIIIc**) in aqueous-alcoholic alkali [5].

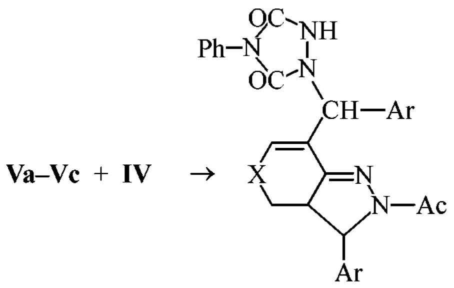
Compounds **VIIa**–**VIIc** were isolated as single isomers having *E,E* configuration of the arylmethylene fragments. We failed to obtain crystals suitable for X-ray analysis. Therefore, the structure of **VIIa**–**VIIc** was indirectly proved by the X-ray diffraction study of single crystals of methylcarbinols which were obtained by addition of methyllithium, e.g., of 2,6-bis(phenylmethylene)-1-methylcyclohexanol (**X**). The structure of molecule **X** and its principal geometric parameters are given in Fig. 1, and they do not require special comments. The X-ray diffraction data indicate that the arylmethylene fragments in the initial α,β-unsaturated ketones **VIIa**–**VIIc**, as well as in the corresponding methylcarbinols, have *E,E* configuration.



X = CH_2, Ar = Ph (**a**); X = CH_2, Ar = *p*-$CH_3OC_6H_4$ (**b**); X = NCH_3, Ar = *p*-$CH_3OC_6H_4$ (**c**).

N-Acetyldihydropyrazoles **Va**–**Vc** were synthesized by addition of hydrazine [5] to ketones **VIIa**–**VIIc** and subsequent acylation of bicyclic compounds **IX** at N^8. *N*-Methyldihydropyrazoles **VIa** and **VIb** were obtained by addition of methylhydrazine to compounds **VIIa** and **VIIb**, respectively. The yields of the products, both 8-unsubstituted and 8-acetyl and 8-methyl derivatives, were fairly high; their physical properties and elemental analyses are given in the Experimental. Dihydropyrazoles **Va**–**Vc**, **VIa**, and **VIb** are formed with high stereoselectivity. In all cases compounds **V** and **VI** were isolated as a single diastereoisomer with *trans* arrangement of protons in positions 6 and 7 of the dihydropyrazole ring, as follows from the ^{1}H and ^{13}C NMR data. The 7-H signal in the ^{1}H NMR spectra of pyrazoles **Va**–**Vc**, **VIa**, and **VIb** is located at δ 4.93, 4.86, 5.63, 3.65, and 3.58 ppm, respectively ($^3J_{6,7}$ = 9.3, 9.5, 11.2, 13.8, 14.0 Hz), which is typical of *trans* isomers [5]. *cis* Isomers are characterized by smaller coupling constants $^3J_{6,7}$ (~5.0–2.0 Hz) [12].

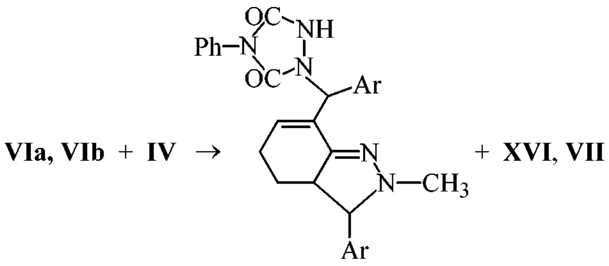
Dihydropyrazoles **V** and **VI** contain a double C=C bond which is conjugated with the C=N bond of the dihydropyrazole ring. Therefore, they are capable of acting as *s*-*cis*-hetero-1,3-dienes in reactions with active dienophiles. The presence in molecules **V** and **VI** of allyl hydrogen atoms provides the possibility for monoene addition, as was reported in [11] for ferrocenyl-substituted analogs. We have found that pyrazoles **V** and **VI** do not react with *N*-phenylazodicarboximide (**IV**) according to Diels–Alder scheme but give rise exclusively to ene addition products. From compounds **Va**–**Vc**, monoadducts **XI**–**XIII** were obtained.



XIa–XIIIa, XIb–XIIIb

X = NCH_3, Ar = *p*-$CH_3OC_6H_4$ (**XI**); X = CH_2, Ar = Ph (**XII**); X = CH_2, Ar = *p*-$CH_3OC_6H_4$ (**XIII**).

N-Methyl-substituted analogs **VIa** and **VIb** are capable of taking up one to seven molecules of enophile **IV** per molecule of the initial dihydropyrazole.



XIVa, XIVb, XVa, XVb

XIVa, **XIVb**, **XVI**, Ar = Ph; **XVa**, **XVb**, **XVII**, Ar = *p*-$CH_3OC_6H_4$.

When the reaction was carried out at –5 to 0°C with equimolar amounts of the reactants, monoene adducts **XIV** and **XV** were obtained in satisfactory yields. However, the formation of polyadducts cannot be avoided. According to the TLC and ^{1}H NMR data, up to 20–25% of polyene addition products **XVI** and **XVII** is formed. Monoadducts **XIV** and **XV** were separated from polyadducts **XVI** and **XVII** by chromatography on Al_2O_3. Compounds **XVI** and **XVII** are likely to be mixtures of di-, tri-, and polyaddition products, from which we failed to isolate individual compounds because of their low solubility in organic solvents. According to the ^{1}H NMR data, they were also mixtures of various diastereomers which could not be separated by TLC. Their ^{1}H NMR spectra were difficult to interpret, for signals from different diastereoisomers overlap with each other in all regions of the spectrum. The NMR and mass spectral data allowed us to only roughly estimate the number of enophile molecules that had reacted with one dihydropyrazole molecule. Studies in this line are now in progress, and it is firmly established that, on successive addition of enophile (in 1-equiv portions) to a solution of *N*-methyldihydropyrazole, up to seven moles of the enophile adds to one mole of the ene component.

The structure of **XI**–**XV** was proved by ^{1}H and ^{13}C NMR spectroscopy. According to the ^{1}H NMR data, compounds **XI**–**XV** are formed as mixtures of two diastereoisomers in a ratio of ~2 : 1, 2.5 : 1, or 3 : 1. The major isomer is denoted with the index “**a**,” and the minor, with “**b**.” In the ^{1}H NMR spectra of **XI**–**XV**, we observed a broadened singlet from the NH proton (δ 9.5–9.9 ppm), a singlet from one methine proton of the substituent in position *2* of the bicyclic system, and a singlet from one olefinic proton in **XIa** and **XIb** or a triplet from analogous olefinic protons in **XIIa**–**XVa** and **XIIb**–**XVb**. Dia-

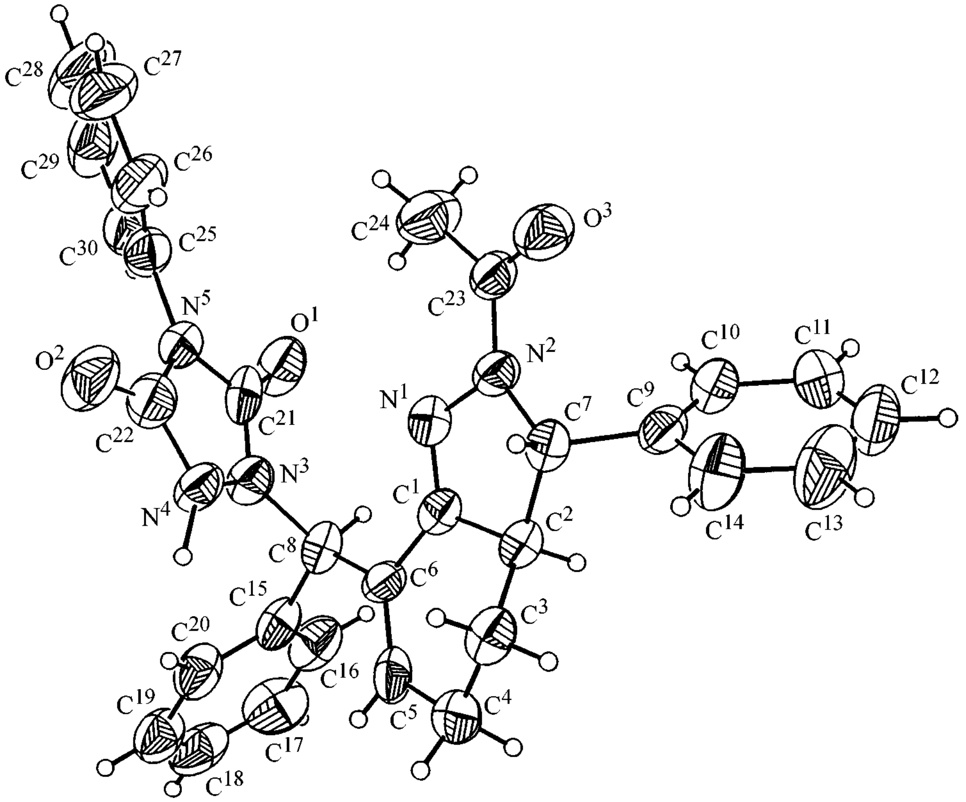


Fig. 2. Molecular structure of compound **XIIa**. Principal bond lengths, Å: N^1-N^2 1.408(5), N^1-C^1 1.260(6), N^2-C^7 1.487(6), N^3-N^4 1.391(6), N^3-C^{21} 1.352(7), N^4-C^{22} 1.373(7), C^1-C^2 1.499(7), and C^2-C^7 1.545(7). Principal bond angles, deg: $C^1N^1N^2$ 108.3(5), $N^1C^1C^2$ 115.1(6), $C^1C^2C^7$ 101.4(5), $N^2C^7C^2$ 101.0(4), $C^5C^6C^1$ 118.5(6), $C^1C^6C^8$ 117.8(5), and $C^5C^6C^8$ 123.7(6).

stereoisomers **XIIa** and **XIIb** were separated by preparative thin-layer chromatography on SiO_2. Their physical properties are given in the Experimental. The steric structure of **XIIa** was studied by X-ray diffraction. A single crystal of **XIIa** was obtained by crystallization from 96% methanol.

According to the X-ray diffraction data, crystals of **XIIa** are orthorhombic; a unit cell includes coupled asymmetric molecules of monoene adducts corresponding to *R*- and *S*-enantiomers which are linked together through molecules of crystallization water. The water molecules form hydrogen bonds with the NH and $C^5{=}O$ groups of the 4-phenylurazole moiety. The structure of molecule **XIIa** is shown in Fig. 2, and the crystal packing, in Fig. 3. The five-membered ring in the central bicyclic fragment has a *flattened envelope* conformation. The phenyl group on C^7 is oriented pseudoequatorially. The hydrogen atoms at C^7 and C^2 are arranged *trans* with respect to each other. The N^1-C^1 bond in the dihydropyrazole fragment is slightly longer [d = 1.260(6) Å], while the N^1-N^2 bond is slightly shorter [d = 1.408(5) Å] than the standard C=N (1.23 Å [12]) and N–N bonds (1.45 Å [13]). The geometric parameters of the cyclohexene and benzene fragments have their standard values.

Thus, arylmethylene-substituted bicyclic dihydropyrazoles react with active dienophiles and enophiles

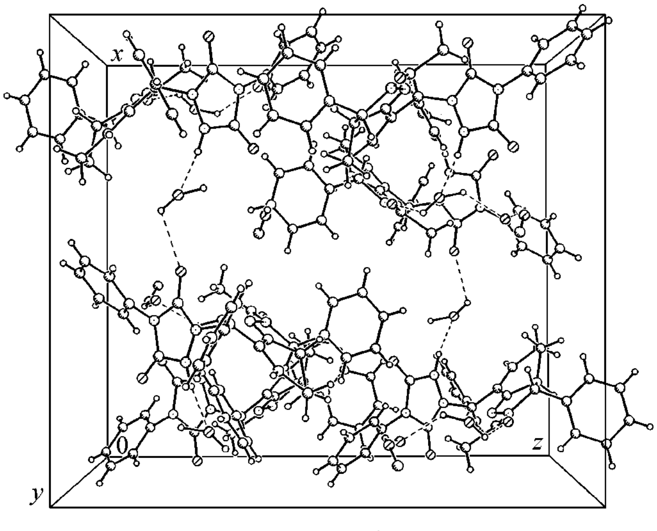


Fig. 3. Crystal packing of molecules **XIIa**.

Crystallographic parameters and parameters of X-ray diffraction experiment for **X** and **XIIa**

Parameter	**X**	**XIIa**
Formula	$C_{21}H_{22}O$	$C_{30}H_{27}N_5O_3$
Molecular weight, g mol^{-1}	290.40	505.52
Temperature, K	293	293
Crystal system	Tetragonal	Orthorhombic
Space group	$I4_1/a$	$Pbca$
a, Å	22.057 (1)	17.721 (6)
b, Å	–	16.558 (5)
c, Å	14.365 (3)	20.048 (6)
α, deg	–	90.0
β, deg	–	90.0
γ, deg	–	90.0
V, Å^3	6989 (2)	5883 (3)
Z	8	8
Calculated density, g cm^{-3}	1.104	1.266
Absorption coefficient, mm^{-1}	0.505	0.089
$F(000)$	2496	2360
Irradiation, λ, Å	CuK_α, 1.54178	MoK_α, 0.71073
Monochromator	Graphite	
θ-Range, deg	1.50–55.00	1.97–25.01
Total reflection number	2857	5190
Unique reflection number	2192	5190
R_{int}	0.0162	0.0000
Scan mode	2θ	$\omega = 2\theta$
Goodness-of-fit	1.51	0.653
	Full-matrix least squares on F^2	
Residual electron density, e Å^{-3}, ρ_{min}/ρ_{max}	–0.31/0.39	–0.189/0.164
Weight scheme	$w^{-1} = \sigma^2(F) + 0.0030F^2$	$w^{-1} = [\sigma^2(Fo^2) + (0.0479P)^2 + 0.00P]$, where $P = (Fo^2 + 2Fc^2)/3$

following the ene addition pattern. When an acetyl group is present on N^8, monoene adducts are formed. Replacement of the acceptor acetyl group by donor methyl group increases the reactivity of the ene component, so that the latter becomes capable of taking up in a stepwise mode several enophile molecules, depending on the number of allyl hydrogen atoms formed as a result of each addition step. We have found no published data on such processes. The effect of various factors on the stepwise polyene addition and isolation of products formed in each addition step deserve a separate study.

EXPERIMENTAL

The UV spectra were measured on a Specord UV-Vis spectrophotometer. The IR spectra were recorded on a Specord IR-75 spectrometer in KBr. The ^1H and ^{13}C NMR spectra were obtained on a Varian Unity Inova instrument at 300 and 75 MHz, respectively; $CDCl_3$ was used as solvent, and TMS, as internal reference. The mass spectra (70 eV) were run on a Varian-MAT CH-6 mass spectrometer. Column chromatography was performed on Al_2O_3 (Brockmann activity grade III); plates with a fixed layer of silica gel were used for thin-layer chromatography. The unit cell parameters and reflection intensities for single crystals of **X** and **XIIa** were determined on a Siemens P4/PC diffractometer. The crystallographic parameters and parameters of X-ray diffraction experiment and refinement are given in the table. The structures of **X** and **XIIa** were solved by the direct method and were refined by the least-squares procedure in full-matrix anisotropic approximation for non-hydrogen atoms.

2,6-Bis(arylmethylene)cyclohexanones VIIa and VIIb were synthesized by standard procedure from cyclohexanone and benzaldehyde or *p*-methoxybenzaldehyde in aqueous-alcoholic alkali [5]. Compounds **VIIa** and **VIIb** were purified by chromatography on Al_2O_3 using hexane–chloroform (3 : 1) as eluent.

Compound VIIa. Yield 68%. Pale yellow powder. mp 120–121°C; published data [5]: mp 121–122°C. ^{13}C NMR spectrum, δ_C, ppm: 22.92 (CH_2); 28.36 ($2CH_2$); 128.29 (2CH=); 128.51, 130.28, 136.85 ($2C_6H_5$); 128.69 (2C); 135.88, 136.10 ($2C^{ipso}$); 190.26 (C=O).

Compound VIIb. Yield 65%. Pale yellow powder, mp 153–154°C; published data [5]: mp 155°C. ^{13}C NMR spectrum, δ_C, ppm: 22.96 (CH_2); 28.46 ($2CH_2$); 55.23 ($2CH_3$); 113.83 (2CH=); 132.15, 136.41 ($2C_6H_4$); 128.67 (2C); 134.28 ($2C^{ipso}$); 159.84 (2C–O); 190.08 (C=O).

3,5-Bis(*p*-methoxybenzylidene)-1-methyl-4-piperidinone (VIIc) was synthesized similarly. Yield 71%. Pale yellow powder, mp 210–211°C. IR spectrum, ν, cm^{-1}: 1620, 1678, 2826, 3040. UV spectrum, λ_{max}, nm: 205.5, 356.4. ^1H NMR spectrum, δ, ppm (*J*, Hz): 2.48 s (3H, CH_3), 3.76 d (4H, CH_2, $J = 1.2$), 3.84 s (6H, CH_3), 6.95 d (4H, C_6H_4, $J = 9.0$), 7.37 d (4H, C_6H_4, $J = 9.0$), 7.77 s (2H, CH=). ^{13}C NMR spectrum, δ_C, ppm: 45.88 (CH_3); 55.29 ($2CH_2$); 57.13 ($2CH_3$); 114.01 (2CH=); 132.25, 135.93 ($2C_6H_4$); 127.94 (2C); 131.22 ($2C^{ipso}$); 160.16 (2C–O); 186.75 (C=O). Found, %: C 75.53; H 6.75; N 3.87. $C_{22}H_{23}NO_3$. Calculated, %: C 75.62; H 6.63; N 4.01.

Dihydropyrazoles IXa–IXc were synthesized by the standard procedure [5] from ketones **VIIa–VIIc** and hydrazine hydrate in ethanol. The precipitate was filtered off, washed with ethanol on a filter, and dried over P_4O_{10}.

7-Phenyl-2-phenylmethylene-8,9-diazabicyclo[4.3.0]non-9-ene (IXa). Yield 74%. Colorless powder, mp 84–86°C; published data [5]: mp 84–86°C.

7-*p*-Methoxyphenyl-2-*p*-methoxyphenylmethylene-8,9-diazabicyclo[4.3.0]non-9-ene (IXb). Yield 72%. Colorless powder, mp 94–95°C; published data [5]: mp 93–95°C.

7-*p*-Methoxyphenyl-2-*p*-methoxyphenylmethylene-4,8,9-triazabicyclo[4.3.0]non-9-ene (IXc). Yield 67%. Colorless crystals, mp 169–171°C.

***N*-Acetyldihydropyrazoles Va–Vc** were obtained by treatment of dry compounds **IXa–IXc** with acetic anhydride and were recrystallized from ethanol.

Compound Va. Yield 73%. Colorless crystals, mp 168–169°C; published data [5]: mp 168–169°C. ^{1}H NMR spectrum, δ, ppm (J, Hz): 1.50 m (1H, CH_2), 1.71 m (1H, CH_2), 1.93 m (1H, CH_2), 2.21 m (1H, CH_2), 2.43 m (1H, CH_2), 2.98 m (1H, CH_2), 2.38 s (3H, CH_3), 3.05 m (1H, CH, J = 9.3), 4.93 d (1H, CH, J = 9.3), 7.18 d (1H, CH=, J = 2.0), 7.24–7.40 m (10H, $2C_6H_5$). ^{13}C NMR spectrum, δ_C, ppm: 22.25 (CH_3); 24.30, 29.06, 30.07 ($3CH_2$); 57.25, 67.78 (2CH); 125.55 (CH=); 127.32 (C); 127.59, 127.94, 128.24, 128.77, 129.58, 130.60 ($2C_6H_5$); 135.96, 141.83 ($2C^{ipso}$); 158.68 (C=N); 170.19 (C=O). Mass spectrum: m/z 330 $[M]^+$.

Compound Vb. Yield 71%. Colorless crystals, mp 162–163°C; published data [5]: mp 162–163°C. ^{1}H NMR spectrum, δ, ppm (J, Hz): 1.49 m (1H, CH_2), 1.63 m (1H, CH_2), 1.93 m (1H, CH_2), 2.16 m (1H, CH_2), 2.42 m (1H, CH_2), 2.97 m (1H, CH_2), 2.35 s (3H, CH_3), 3.04 m (1H, CH, J = 9.5), 3.78 s (3H, CH_3), 3.83 s (3H, CH_3), 4.86 d (1H, CH, J = 9.5), 6.89 m (4H, C_6H_4), 7.14 d (1H, CH=, J = 2.6), 7.22 m (4H, C_6H_4). ^{13}C NMR spectrum, δ_C, ppm: 22.27 (CH_3); 24.34, 29.06, 30.01 ($3CH_2$); 55.26 ($2CH_3$); 57.22, 67.34 (2CH); 126.95 (CH=); 127.61 (C); 113.77, 114.23, 131.14 ($2C_6H_4$); 128.80, 144.13 ($2C^{ipso}$); 158.89 (2C–O); 159.11 (C=N); 170.29 (C=O). Mass spectrum: m/z 390 $[M]^+$.

Compound Vc. Yield 69%. Colorless crystals, mp 232–233°C. IR spectrum, ν, cm^{-1}: 1024, 1150, 1609, 1628, 1679, 2846, 2984. UV spectrum: λ_{max} 313.2 nm. ^{1}H NMR spectrum, δ, ppm (J, Hz): 2.27 s (3H, CH_3), 2.42 s (3H, CH_3), 2.74 d.d (1H, CH_2, J = 6.0, 10.2), 2.86 d.d (1H, CH_2, J = 2.54, 10.2), 3.64 m (2H, CH_2, J = 1.5), 3.78 s (3H, CH_3), 3.83 s (3H, CH_3), 3.90 d.m (1H, CH, J = 11.2), 5.63 d (1H, CH, J = 11.2), 6.82–7.25 m (8H, $2C_6H_4$), 7.34 br.s (1H, CH=). Found, %: C 70.93; H 6.89; N 10.47. $C_{24}H_{27}N_3O_3$. Calculated, %: C 71.09; H 6.71; N 10.36. Mass spectrum: m/z 405 $[M]^+$.

***N*-Methyldihydropyrazoles VIa and VIb.** A mixture of 5 mmol of ketone **VIIa** or **VIIb**, 2 ml of methylhydrazine, and 30 ml of methanol was refluxed for 1 h under stirring. It was then cooled to 0°C, and the precipitate was filtered off, washed with aqueous methanol, and recrystallized from methanol.

Compound VIa. Yield 72%. Yellow crystals, mp 120–121°C. ^{1}H NMR spectrum, δ, ppm (J, Hz): 1.40 m (1H, CH_2), 1.52 m (1H, CH_2), 1.88 m (1H, CH_2), 2.02 m (1H, CH_2), 2.40 m (1H, CH_2), 2.86 m (1H, CH_2), 2.80 s (3H, CH_3), 3.01 d.m (1H, CH, J = 13.8), 3.65 d (1H, CH, J = 13.8), 7.20 d (1H, CH=, J = 1.8), 7.22–7.46 m (10H, $2C_6H_5$). ^{13}C NMR spectrum, δ_C, ppm: 24.32 (CH_2); 26.70 ($2CH_2$); 42.08 (CH_3); 55.27, 81.47 (2CH); 127.04 (CH=); 127.18 (C); 127.35, 127.79, 128.07, 128.63, 128.61 ($2C_6H_5$); 130.89, 136.69 ($2C^{ipso}$); 155.29 (C=N). Found, %: C 84.53; H 7.21; N 9.33. $C_{21}H_{22}N_2$. Calculated, %: C 83.41; H 7.33; N 9.26.

Compound VIb. Yield 69%. Yellow crystals, mp 105–106°C. ^{1}H NMR spectrum, δ, ppm (J, Hz): 1.48 m (1H, CH_2), 1.88 m (1H, CH_2), 1.98 m (1H, CH_2), 2.39 m (1H, CH_2), 2.83 m (1H, CH_2), 2.87 m (1H, CH_2), 2.77 s (3H, CH_3), 2.99 d.m (1H, CH, J = 14.0), 3.58 d (1H, CH, J = 14.0), 3.81 s (3H, CH_3), 3.82 s (3H, CH_3), 7.15 d (1H, CH=, J = 1.8), 6.85–6.94 m (4H, C_6H_4), 7.27–7.38 m (4H, C_6H_4). ^{13}C NMR spectrum, δ_C, ppm: 24.27, 28.58, 28.66 ($3CH_2$); 41.95, 55.18, 55.24 ($3CH_3$); 54.97, 80.97 (2CH); 128.52 (CH=); 129.91 (C); 113.77, 114.23, 130.14 ($2C_6H_4$); 130.41, 130.53 ($2C^{ipso}$); 156.03 (C=N); 158.60, 159.26 (2C–O). Found, %: C 76.38; H 7.09; N 7.84. $C_{23}H_{26}N_2O_2$. Calculated, %: C 76.21; H 7.23; N 7.73.

Reaction of dihydropyrazoles Va–Vc, VIa, and VIb with *N*-phenylazodicarboximide (IV). *a*. Imide **IV**, 1 mmol, was added at 20°C with stirring to a solution of 1 mmol of pyrazole **Va–Vc**, **VIa**, or **VIb** in 20 ml of chloroform. When the original bright red color disappeared (~5 min), the solvent was distilled off under reduced pressure, and the residue was subjected to chromatography on Al_2O_3 using benzene–ethyl acetate (4 : 1) as eluent. The following products were isolated.

(1) **8-Acetyl-7-*p*-methoxyphenyl-2-[*p*-methoxyphenyl(4-phenyl-1-urazolyl)methyl]-4-methyl-4,8,9-triazabicyclo[4.3.0]nona-2,9-diene** (**XI**), 0.42 g (73%), a mixture of two diastereoisomers **XIa** and **XIb** in a ratio of ~2 : 1). Pale yellow powder, mp 268–269°C. Mass spectrum: *m*/*z* 580 $[M]^+$. Found, %: C 66.08; H 5.71; N 14.63. $C_{32}H_{32}N_6O_5$. Calculated, %: C 66.20; H 5.55; N 14.47.

Isomer XIa. ^{1}H NMR spectrum, δ, ppm (*J*, Hz): 2.24 s (3H, CH_3), 2.89 s (3H, CH_3), 3.34 m (2H, CH_2), 3.52 t.d (1H, CH, *J* = 6.5, 11.7), 3.77 s (3H, CH_3), 3.78 s (3H, CH_3), 4.84 d (1H, CH, *J* = 11.7), 6.15 s (1H, CH), 6.59 s (1H, CH=), 6.84–7.84 m (13H, H_{arom}), 9.87 br.s (1H, NH).

Isomer XIb. ^{1}H NMR spectrum, δ, ppm (*J*, Hz): 2.39 s (3H, CH_3), 2.89 s (3H, CH_3), 3.16 m (2H, CH_2), 3.55 t.d (1H, CH, *J* = 6.0, 12.1), 3.82 s (3H, CH_3), 3.83 s (3H, CH_3), 4.88 d (1H, CH, *J* = 12.1), 6.21 s (1H, CH), 6.39 s (1H, CH=), 6.84–7.67 m (13H, H_{arom}), 9.80 br.s (1H, NH).

(2) A mixture of isomers **XIIa** and **XIIb** (~2 : 1), 0.32 g. Pale yellow powder, mp 178–179°C. IR spectrum, ν, cm^{-1}: 1230, 1426, 1599, 1643, 1700, 2900, 3063, 3460. UV spectrum: λ_{max} 210.5 nm. Found, %: C 71.38; H 5.22; N 13.94. $C_{30}H_{27}N_5O_3$. Calculated, %: C 71.27; H 5.38; N 13.85.

Isomer XIIa was isolated by repeated crystallization from methanol, mp 192–193°C. IR spectrum, ν, cm^{-1}: 1227, 1423, 1601, 1640, 1707, 1771, 3061, 3430. UV spectrum: λ_{max} 210.2 nm. ^{1}H NMR spectrum, δ, ppm (*J*, Hz): 1.38 m (1H, CH_2), 1.87 m (1H, CH_2), 2.43 m (1H, CH_2), 3.13 m (1H, CH_2), 2.19 s (3H, CH_3), 3.19 m (1H, CH, *J* = 10.5), 4.85 d (1H, CH, *J* = 10.5), 6.38 t (1H, CH=, *J* = 4.8), 6.45 s (1H, CH), 7.27–7.56 m (15H, $3C_6H_5$), 8.60 br.s (1H, NH). ^{13}C NMR spectrum, δ_C, ppm: 22.47 (CH_3); 26.10, 26.62 ($2CH_2$); 55.17, 60.36, 67.25 (3CH); 125.38 (CH=); 125.67 (C); 127.84, 128.14, 128.52, 128.64, 128.86, 128.90, 128.92, 129.13, 129.16 ($3C_6H_5$); 131.41, 136.03, 140.82 ($3C^{ipso}$), 141.84 (C=N); 152.66, 154.60 (3C=O). Found, %: C 71.20; H 5.41; N 13.76. $C_{30}H_{27}N_5O_3$. Calculated, %: C 71.27; H 5.38; N 13.85.

Isomer XIIb. ^{1}H NMR spectrum, δ, ppm (*J*, Hz): 1.25 m (1H, CH_2), 1.87 m (1H, CH_2), 2.41 m (1H, CH_2), 3.10 m (1H, CH_2), 2.35 s (3H, CH_3), 3.16 m (1H, CH, *J* = 9.6), 4.60 d (1H, CH, *J* = 9.6), 6.33 t (1H, CH=, *J* = 4.5), 6.40 s (1H, CH), 7.16–7.55 m (15H, $3C_6H_5$), 8.50–8.60 br.s (1H, NH). ^{13}C NMR spectrum, δ_C, ppm: 22.37 (CH_3); 26.10, 26.90 ($2CH_2$); 54.95, 60.36, 67.07 (3CH); 125.71 (CH=); 127.40 (C); 127.69, 127.84, 128.16, 128.50, 128.64, 128.92, 128.92, 129.30, 129.46 ($3C_6H_5$); 131.25, 134.86, 140.80 ($3C^{ipso}$); 142.20 (C=N); 153.15, 154.20 (3C=O).

(3) Adduct **XIII** as a mixture of two diastereoisomers **XIIIa** and **XIIIb** (~2.5 : 1), 0.4 g (70%). Pale yellow powder, mp 202–203°C. IR spectrum, ν, cm^{-1}: 1284, 1377, 1559, 1656, 1699, 2830, 3226, 3331. UV spectrum: λ_{max} 208.2 nm. Mass spectrum: *m*/*z* 565 $[M]^+$. Found, %: C 68.03; H 5.37; N 12.51. $C_{32}H_{31}N_5O_5$. Calculated, %: C 67.95; H 5.53; N 12.38.

Compound XIIIa. ^{1}H NMR spectrum, δ, ppm (*J*, Hz): 1.77 m (1H, CH_2), 2.07 m (1H, CH_2), 2.36 m (1H, CH_2), 2.91 m (1H, CH_2), 2.20 s (3H, CH_3), 3.18 m (1H, CH, *J* = 9.6), 3.78 s (3H, CH_3), 3.82 s (3H, CH_3), 4.78 d (1H, CH, *J* = 9.6), 6.31 t (1H, CH=, *J* = 4.6), 6.40 s (1H, CH), 6.78–6.83 m (4H, C_6H_4), 7.16–7.25 m (4H, C_6H_4), 7.29–7.40 m (5H, C_6H_5), 9.20 br.s (1H, NH). ^{13}C NMR spectrum, δ_C, ppm: 21.75, 54.68, 54.90 ($3CH_3$); 26.03, 26.65 ($2CH_2$); 59.54, 65.83, 66.20 (3CH); 125.34 (CH=); 127.07 (C); 114.30, 114.60, 127.64, 128.05, 128.84, 129.04 (C_{arom}); 130.44, 132.92, 140.49 ($3C^{ipso}$); 151.69, 152.76 (2C−O); 158.97 (C=N); 168.08, 169.12, 169.28 (3C=O).

Compound XIIIb. ^{1}H NMR spectrum, δ, ppm (*J*, Hz): 1.79 m (1H, CH_2), 2.11 m (1H, CH_2), 2.34 m (1H, CH_2), 2.75 m (1H, CH_2), 2.18 s (3H, CH_3), 3.20 m (1H, CH, *J* = 9.6), 3.77 s (3H, CH_3), 3.83 s (3H, CH_3), 4.80 d (1H, CH, *J* = 9.6), 6.22 t (1H, CH=, *J* = 5.1), 6.34 s (1H, CH), 6.83–6.93 m (4H, C_6H_4), 7.14–7.23 m (4H, C_6H_4), 7.41–7.49 m (5H, C_6H_5), 9.48 br.s (1H, NH). ^{13}C NMR spectrum, δ_C, ppm: 22.61, 55.30, 55.36 ($3CH_3$); 26.03, 26.95 ($2CH_2$); 59.54, 65.49, 66.62 (3CH); 125.36 (CH=); 127.10 (C); 114.22, 114.38, 127.64, 128.00, 128.83, 129.20 (C_{arom}); 131.27, 133.37, 141.54 ($3C^{ipso}$); 152.99, 154.59 (2C−O); 159.52 (C=N); 169.90 (2C=O); 170.08 (C=O).

(4) Adduct **XIV**, 0.29 g (60%), and polyadduct **XVI**, 0.10 g. Compound **XIV** was a mixture of two diastereoisomers **XIVa** and **XIVb** (~2.5 : 1); pale yellow powder, mp 174–175°C. IR spectrum, ν, cm^{-1}: 1284, 1357, 1423, 1601, 1656, 1699, 3206, 3364.

UV spectrum: λ_{max} 213.2 nm. Mass spectrum: *m*/*z* 477 $[M]^+$. Found, %: C 73.07; H 5.93; N 14.39. $C_{29}H_{27}N_5O_2$. Calculated, %: C 72.95; H 5.70; N 14.65. Polyadduct **XVI**; colorless powder, mp ~250°C (with decomp.). Mass spectrum, *m*/*z*: 652, 827, 1050 $[M]^+$.

Compound XIVa. ^{1}H NMR spectrum, δ, ppm (*J*, Hz): 1.80–2.21 m (2H, CH_2), 2.43 m (2H, CH_2), 2.75 s (3H, CH_3), 3.10 t.d (1H, CH, *J* = 4.8, 14.1), 3.68 d (1H, CH, *J* = 14.1), 6.35 s (1H, CH), 7.23 t (1H, CH=, *J* = 7.18), 7.32–7.60 m (15H, $3C_6H_5$), 9.99 br.s (1H, NH). ^{13}C NMR spectrum, δ_C, ppm: 25.62 ($2CH_2$); 41.76 (CH_3); 54.45, 61.76, 79.60 (3CH); 125.64 (CH=); 127.42 (C); 127.31, 127.82, 128.17, 128.20, 128.58, 128.83, 128.90, 128.96, 129.03 ($3C_6H_5$); 136.66, 138.47, 138.56 ($3C^{ipso}$); 139.42 (C=N); 151.92, 152.17 (3C=O).

Compound XIVb. ^{1}H NMR spectrum, δ, ppm (*J*, Hz): 1.58–2.08 m (2H, CH_2), 2.35 m (2H, CH_2), 2.77 s (3H, CH_3), 2.95 t.d (1H, CH, *J* = 5.8, 13.6), 3.65 d (1H, CH, *J* = 13.6), 6.32 s (1H, CH), 7.09 t (1H, CH=, *J* = 7.02), 7.20–7.60 m (15H, $3C_6H_5$), 9.59 br.s (1H, NH). ^{13}C NMR spectrum, δ_C, ppm: 25.48 ($2CH_2$); 41.51 (CH_3); 53.92, 61.18, 79.90 (3CH); 125.58 (CH=); 126.28 (C); 127.42, 127.87, 127.92, 128.22, 128.38, 128.69, 128.80, 129.00, 129.17 ($3C_6H_5$); 131.66, 132.47, 136.11 ($3C^{ipso}$); 140.28 (C=N); 151.82, 152.27 (3C=O).

(5) Adduct **XV**, 0.31 g (58%), and polyadducts **XVII**, 0.13 g. Compound **XV** was a mixture of two diastereoisomers **XVa** and **XVb** (~3 : 1); pale yellow powder, mp 179–181°C. IR spectrum, ν, cm^{-1}: 1268, 1382, 1562, 1670, 1701, 2827, 3219, 3341. UV spectrum: λ_{max} 209.0 nm. Mass spectrum: *m*/*z* 537 $[M]^+$. Found, %: C 69.38; H 5.74; N 12.94. $C_{31}H_{31}N_5O_4$. Calculated, %: C 69.26; H 5.81; N 13.02. Polyadduct **XVII**: colorless powder, mp ~245–265°C (with decomp.). Mass spectrum: *m*/*z* 702, 887, 1063 $[M]^+$.

Compound XVa. ^{1}H NMR spectrum, δ, ppm (*J*, Hz): 1.76–2.00 m (2H, CH_2), 2.40 m (2H, CH_2), 2.74 s (3H, CH_3), 3.06 t.d (1H, CH, *J* = 5.1, 13.8), 3.65 d (1H, CH, *J* = 13.8), 3.82 s (3H, CH_3), 3.83 s (3H, CH_3), 6.29 s (1H, CH), 6.79 t (1H, CH=, *J* = 7.6), 6.88 d (2H, C_6H_4, *J* = 8.7), 6.93 d (2H, C_6H_4, *J* = 8.7), 7.35 d (2H, C_6H_4, *J* = 8.7), 7.54 d (2H, C_6H_4, *J* = 8.7), 7.38–7.50 m (5H, C_6H_5), 9.99 br.s (1H, NH). ^{13}C NMR spectrum, δ_C, ppm: 25.54, 25.61 ($2CH_2$); 41.65, 55.28, 55.30 ($3CH_3$); 54.26, 61.54, 79.16 (3CH); 125.62 (CH=); 126.25 (C); 113.90, 114.19, 127.88, 128.47, 128.99, 129.02, 129.17 (C_{arom}); 131.67, 138.25, 139.10 ($3C^{ipso}$); 151.93, 152.36 (2C–O); 159.18 (C=N); 159.38, 159.52, 159.79 (3C=O).

Compound XVb. ^{1}H NMR spectrum, δ, ppm (*J*, Hz): 1.56–1.78 m (2H, CH_2), 2.06 m (2H, CH_2), 2.75 s (3H, CH_3), 2.93 t.d (1H, CH, *J* = 5.1, 14.4), 3.62 d (1H, CH, *J* = 14.4), 3.81 s (3H, CH_3), 3.82 s (3H, CH_3), 6.31 s (1H, CH), 6.76 t (1H, CH=, *J* = 8.0), 6.86 d (2H, C_6H_4, *J* = 8.4), 6.91 d (2H, C_6H_4, *J* = 8.4), 7.44 d (2H, C_6H_4, *J* = 8.4), 7.70 d (2H, C_6H_4, *J* = 8.4), 7.22–7.35 m (5H, C_6H_5), 10.12 br.s (1H, NH). ^{13}C NMR spectrum, δ_C, ppm: 25.46, 25.48 ($2CH_2$); 41.38, 55.21, 55.34 ($3CH_3$); 53.76, 61.04, 79.46 (3CH); 125.55 (CH=); 125.69 (C); 114.03, 114.15, 127.99, 128.19, 128.71, 128.77, 129.09 (C_{arom}); 131.56, 138.25, 139.90 ($3C^{ipso}$); 151.76, 152.27 (2C–O); 159.07 (C=N); 159.79, 159.91, 160.25 (3C=O).

Polyene addition of imide IV to dihydropyrazole VIa. *N*-Phenylimide **IV** was added in 17.5-mg portions while stirring at 20°C to 30 mg of **VIa** in 20 ml of chloroform. Each next portion was added as the reaction mixture lost its bright color. The color changes almost instantaneously after addition of the first two portions, and longer time was necessary for decolorization of the mixture after addition of each subsequent portion of the enophile. The addition of the seventh equivalent of the enophile required about 3 h. The mixture was then diluted with 100 ml of ether, and the colorless precipitate was filtered off and washed with ether. Yield 0.124 g (82%), mp ~345–350°C (with decomp.). IR spectrum, ν, cm^{-1}: 1228, 1415, 1597, 1654, 1700, 2900, 3063, 3400–3575. Mass spectrum: *m*/*z* 1531 $[M]^+$.

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