Chemistry of Heterocyclic Compounds, Vol. 48, No. 4, July, 2012 (Russian Original Vol. 48, No. 4, April, 2012)

CARBO[3+3] CYCLOCONDENSATION REACTIONS. A NEW METHOD FOR THE SYNTHESIS OF TETRAHYDRO-PYRAZOLO[1,5-*b*]QUINAZOLINES AND TETRAHYDRO-PYRAZOLO[4,5-*b*]QUINOLINES

V. D. Orlov[1]* and D. Yu. Sidorenko[1]

The cyclocondensation of substituted 5-aminopyrazoles with benzylidene acetone leads to the regioselective synthesis of dihydropyrazolo[1,5-a]pyrimidines and dihydropyrazolo[3,4-b]pyridines containing a methyl group in the six-membered heterocycle. Compounds of both these groups readily undergo carbo[3+3] cyclo-condensation with chalcones in butanol under alkaline catalysis conditions and upon heating to give aryl-substituted tetrahydropyrazolo[1,5-b]quinazolines and tetrahydropyrazolo[4,5-b]quinolines. Ultrasonic initiation of these reactions leads to enhanced rate and higher yield of the desired products.

Keywords: 3-R-aminopyrazoles, chalcones, partially hydrogenated pyrazolo[3,4-*b*]pyridines, partially hydrogenated pyrazolo[1,5-*a*]pyrimidines, partially hydrogenated pyrazolo[1,5-*b*]quinazolines, partially hydrogenated pyrazolo[4,5-*b*]quinolines, carbo[3+3] cyclocondensation, domino reaction, regio-selective synthesis.

Carbo[3+3] cyclization (or carbo[3+3] cyclocondensation) reactions proceeding with the formation of a six-membered carbocycle are quite rare in organic chemistry. Recently, a new carbo[3+3] cyclocondensation reaction was discovered in a study of the reactions of 5-R-7-aryl-4,7-dihydrotriazolo[1,5-*a*]pyrimidines with chalcones under sodium methylate catalysis [1]. It turned out that when R = Ar, the reaction terminates upon formation of the Michael adduct, but when R = Me, the adduct is not even detected and the reaction terminates with cyclization of the adduct to give triazoloquinazoline derivatives. We later showed that similar cyclocondensation reactions also take place for a series of other dihydrogenated azolopyrimidines with a 5- or 7-methyl group in the six-membered ring [2-6]. Thus, we have discovered a rather general group of new carbo[3+3] cyclocondensation reactions.

In the present work, we have continued our investigation of this group of reactions using 3-substituted 5-aminopyrazoles. The 3-R^3-5-aminopyrazole molecule has four potential nucleophilic sites: the amino group, two endocyclic nitrogen atoms, and C-4 atom. The participation of all three nitrogen sites was demonstrated in the reaction of 5-amino-3-methylpyrazole with (2*E*)-3-phenylacryloyl chloride [7], but cyclization was not observed in this case. As the gained experience shows, the nucleophilic sites belonging to the enamine or

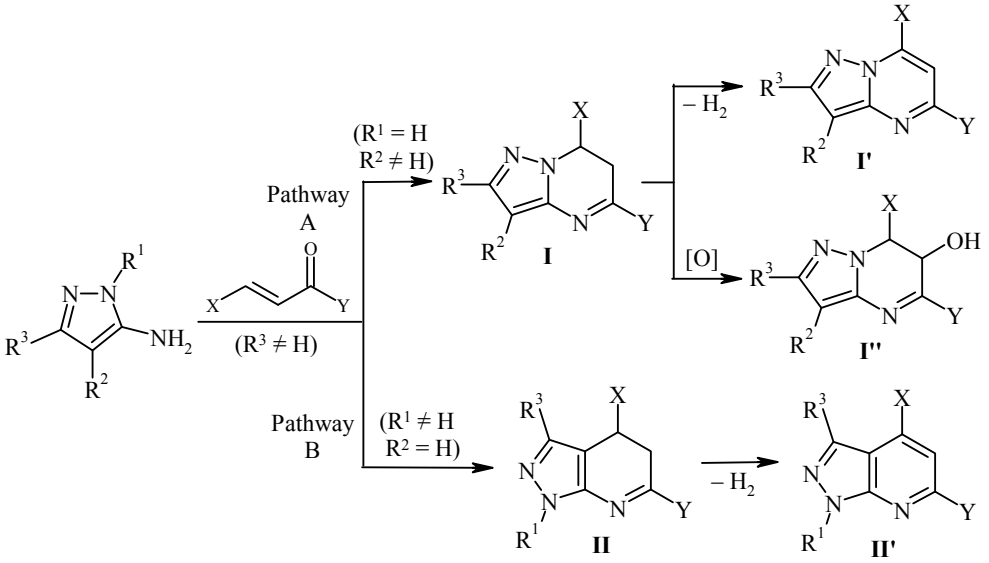
*To whom correspondence should be addressed, e-mail: orlov@univer.kharkov.ua.

[1] V. N. Karazin Kharkiv National University, 4 Svobody Sq., Kharkiv 61022, Ukraine.

Translated from Khimiya Geterotsiklicheskikh Soedinenii, No. 4, pp. 698-705, April, 2012. Original article submitted February 3, 2012.

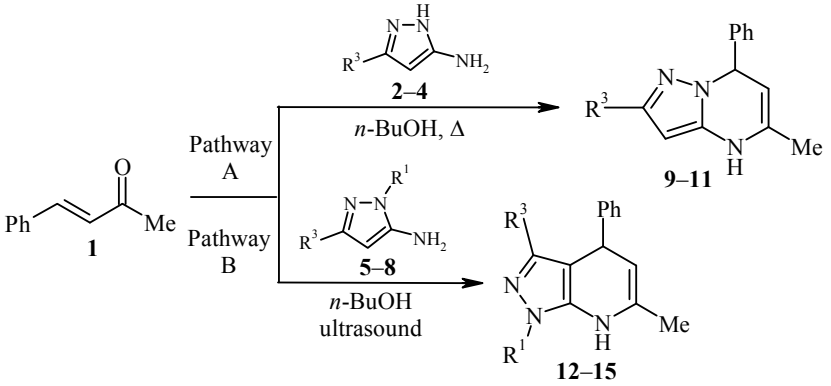
amidine fragments may participate in this cyclocondensation to give, correspondingly, either bicyclic dihydropyra-zolo[1,5-*a*]pyrimidine (**I**) or dihydropyrazolo[3,4-*b*]pyridine products (**II**) [8].

The unambiguous direction of this reaction may be easily achieved by introducing an additional substituent into the 5-aminopyrazole molecule. Bicyclic product **I** is formed if the substituent is at position C-4 [9-11], while bicyclic product **II** is formed if the substituent is at position N-1 [11-13]. If, on the other hand, both positions are unoccupied, the situation becomes much more complicated with the possible formation of both individual products **I** and **II** as well as their mixtures. Thus, 3-R^3-5-NH_2-pyrazoles (R^3 = Ar, Me) with chalcones [14, 15] in DMF and with 3-formylchromones in absolute ethanol give pyrazolo[1,5-*a*]pyrimidine derivatives (pathway A) [16]. At the same time, one of these amines (with R^3 = Ph) reacts with chalcones in ethanol but in the presence of toluenesulfonic acid gives pyrazolo[3,4-*b*]pyridine derivatives (pathway B) [13].



The heterocyclization reactions are also complicated by dehydrogenation leading to the formation of products **I'** and **II'**, and, in the case of 5-aminopyrazoles, also by oxidation to give 6-hydroxy-6,7-dihydro-pyrazolo[1,5-*a*]pyrimidine derivatives **I''**, which are resistant to dehydration [14].

The reaction of benzylidene acetone **1** with aminopyrazoles must initially be carried out in order to synthesize the desired compounds. Unsubstituted (**2-4**) and 1-substituted 3-R^3-5-NH_2-pyrazoles (**5-8**) were selected as the starting amines taking account of the literature results given above. The reaction was carried out by heating a mixture of the reagents in *n*-butanol at reflux since it became clear that the yields are lower in DMF, which was previously the most commonly used solvent. As expected, amines **2-4** under these conditions



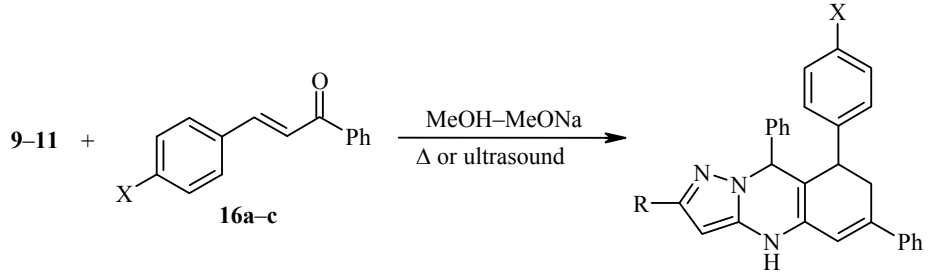
2, **9** R^3 = Me; **3**, **10** R^3 = Ph; **4**, **11** R^3 = 4-MeC_6H_4; **5**, **12** R^3 = Me, R^1 = Ph;
6, **13** R^3 = Ph, R^1 = Me; **7**, **14** R^3 = Ph, R^1 = Ph; **8**, **15** R^3 = 4-MeC_6H_4, R^1 = Ph

give exclusively 2-R-5-Me-7-Ph-4,7-dihydropyrazolo[1,5-*a*]pyrimidines **9-11**, while amines **5-8** give 1-R^1-3-R-4-Ph-6-Me-4,7-dihydropyrazolo[3,4-*b*]pyridines **12-15**. The composition and structure of the products obtained are in good accord with the elemental analysis data and the ^{1}H NMR and mass spectra given in the Experimental, as well as with the results of Desenko et al. [14, 17], who described aryl derivatives of these bicyclic compounds.

In previous work [5], we reported that ultrasonic activation of this reaction enhances the rate of cyclocondensation, reduces the probability of dehydrogenation, and facilitates higher yields of the desired products. Thus, all the experiments were carried out in duplicate using both heating and ultrasound. Under these conditions, the reactions proceed in 15-20 min and the yields are close to quantitative. In the case of either thermal or ultrasonic activation, pure compounds crystallize out of the reaction mixtures. These compounds are not contaminated by possible oxidation or dehydrogenation products described above. In the case of products **9-11**, there are also no products of alternative reaction B.

There are no data in the literature on products **9-15**. Thus, it was entirely unexpected that these compounds, as indicated by their ^{1}H NMR spectra taken in DMSO-d_6 solution, exist exclusively in the enamine tautomeric form. This assignment is supported by the signal found at 9.8-10.1 ppm, which disappears upon the addition of CD_3OD, and the absence of signals characteristic for protons of a CH-CH_2 fragment. These results are in contradiction to previous data [9, 13], according to which, in the case of two aromatic substituents in the six-membered heterocycle in the corresponding dihydropyrazolopyrimidines or dihydropyrazolopyridines, the product is found predominantly in the imine tautomer form. This finding can be explained only assuming that the imine form is more favorable than the enamine form for π-conjugation of the aromatic substituent at C-5 with the pyrazole ring. By the way, this is externally evident since the yellow color of the imino tautomer is more profound than the beige color of the enamine tautomer. There is no such conjugation for the methyl group.

Products **9-11** react efficiently with chalcones **16a-c** in a solution of sodium methylate in methanol upon brief heating at reflux for 10-15 min in an argon atmosphere in order to avoid oxidation. Crystalline precipitates of compounds **17a-c**, **18a**, and **19a** separate out from the reaction mixtures at reflux. This permits us to control the reaction time. Carrying out the reaction in an ultrasonic bath permits us to reduce the reaction time to 1-2 min, carry out the reaction not only in argon, but also in the air and, concurrently, raise the yields of the desired products to close to quantitative.



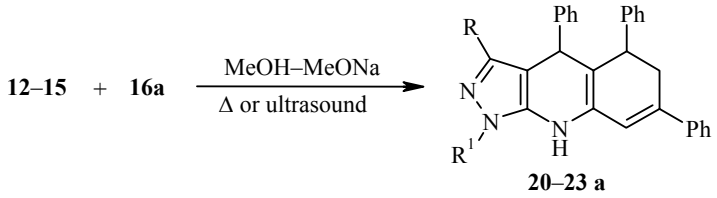
17a–c, **18a**, **19a**

17a–c R = Me; **18a** R = Ph; **19a** R = 4-MeC_6H_4;
16–19 a X = H; **16**, **17 b** X = OMe; **16**, **17 c** X = Br

The formation of a tricyclic 4,7,8,9-tetrahydropyrazolo[5,1-*b*]quinazoline in this reaction was primarily confirmed by the ^{1}H NMR spectra of compounds **17-19**. The signals for the NH group proton, cyclohexadiene ring AMX proton system, H-5, and H-9 in these spectra are extremely characteristic. The finding of NH group signals in the spectra indicates that enamine tautomer structure is retained in compounds **17-19**. The mass spectra of compounds **17-19** show a molecular ion peaks corresponding to the proposed structures.

It is known that in similar reactions under the same conditions, 5,7-diaryldihydroazolopyrimidines react with chalcones to give exclusively Michael β-adducts at position C-6 in the pyrimidine ring [1-4]. 2-Methyl-5,7-diphenyl-6,7-dihydropyrazolo[1,5-*a*]pyrimidine behaves identically [17], indicating the strong nucleophilicity of C-6 atom. Such adducts are usually readily identified using the characteristic $\nu_{C=O}$ IR band. However, these bands could not be detected in our studies.

Pyrazolopyridines **12-15** upon brief heating under the same conditions of alkaline hydrolysis (methanol, sodium methylate, argon, brief heating) also efficiently react with chalcone **16a** to give tetrahydropyrazolo-[3,4-*b*]quinolines **20-23a** with high yields.



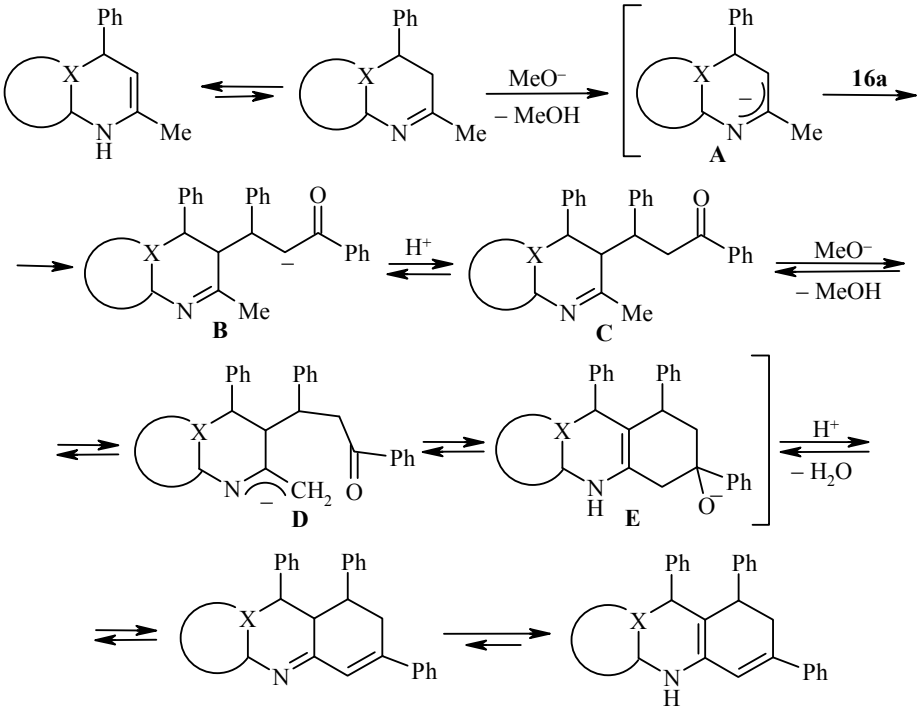
20a R = Me, R^1 = Ph; **21a** R = Ph, R^1 = Me; **22a** R = Ph, R^1 = Ph; **23a** R = 4-MeC_6H_4, R^1 = Ph

The formation of these quinoline products was confirmed primarily using the ^{1}H NMR spectra, in which very characteristic signals are seen for the cyclohexadiene fragment AMX system protons, H-4 and H-8 protons as well as a broad NH group singlet, which confirms enamine structure for compounds **20-23**. Signals are also observed for the protons of the aromatic rings and substituents. The elemental analysis and mass spectra data also support the assigned structure of products **20-23**.

Ultrasonic initiation of the reaction is as efficient for the synthesis of compounds **20-23** as for that of compounds **17-19**: the reaction time is shortened and the yield increased.

As in the case of azolopyrimidines, the formation of β-adducts could not be detected in this reaction. On the other hand, there is a basis for assuming that such adducts are formed in the first step, but then undergo cyclocondensation due to subsequent deprotonation of the methyl group and its spatial proximity to the carbonyl group. The latter factor probably is fundamentally important since the methyl group in compounds **9-15** by itself does not undergo condensation even with very active aldehydes, as we have found repeatedly. This rigid interrelationship of the two steps, Michael addition and cyclocondensation, permits us to regard these syntheses as domino reactions.

In our opinion, a possible mechanism for both the reactions studied may entail the following steps:



Michael adduct **C** is formed in the first step, as indicated by X-ray structural analysis for the analogous product of the reaction of 5,7-diphenyl-4,7-dihydro-1,2,4-triazolo[1,5-*a*]pyrimidine with chalcone [1]. The electron-withdrawing effect of the nitrogen atom enhanced by the electron-deficient azole ring, facilitates deprotonation of the methyl group in intermediate **D**, while its spatial proximity to the carbonyl group favors formation of an unstrained six-membered carbocycle in intermediate **E**, which converts to the desired product upon subsequent dehydration.

This mechanism satisfactorily accounts for regioselectivity in the formation of compounds **17-23** and the carbo[3+3] cyclocondensation reactions described previously for other azolopyrimidines [1-6].

In conclusion, we note that these regioselective reactions of substituted 5-aminopyrazoles with benzylidene acetone give dihydropyrazolo[1,5-*a*]pyrimidine and dihydropyrazolo[3,4-*b*]pyridine derivatives with a methyl group in the dihydroazine ring. In strongly alkaline media, these compounds undergo [3+3] cyclo-condensation with chalcones to give a new fused six-membered carbocycle. In our opinion, this process is a domino reaction.

EXPERIMENTAL

The ^{1}H NMR spectra were recorded on a Varian-VX200R Mercury spectrometer at 200 MHz in DMSO-d_6 with TMS as internal standard. The mass spectra were recorded on a Finnigan MAT 4651P mass spectrometer with direct sample inlet. The electron impact ionization was 70 eV. The melting points were determined on a Koefler hot bench and were not corrected. The elemental analysis was carried out on a Vario MICRO cube analyzer. The purity of the products was monitored by thin-layer chromatography on Silufol UV-254 plates with chloroform or acetone (for compounds **9-15)** and 1:1 EtOAc–hexane or 1:1 EtOAc–toluene as the eluent (for compounds **17-23**). Commercial samples of the aminopyrazoles and α,β-unsaturated ketones were used.

2,5-Dimethyl-7-phenyl-4,7-dihydropyrazolo[1,5-*a*]pyrimidine (9). A (heating at reflux). A solution of benzylidene acetone (**1**) (8.76 g, 0.06 mol) and 5-amino-3-methylpyrazole (**2**) (4.85 g, 0.05 mol) in butanol (20 ml) was heated at reflux for 1.0-1.5 h in an argon atmosphere. Then, 12-15 ml of butanol was distilled off at reduced pressure and the residue was diluted with acetone (10 ml). The white precipitate of product **9** was filtered off and crystallized from 2-propanol to give final product. Yield 6.98 g (62%); mp 286-288°C.

B. (ultrasound). A solution of benzylidene acetone (**1**) (8.76 g, 0.06) and 5-amino-3-methylpyrazole (**2**) (4.85 g, 0.05 mol) in butanol or 2-propanol (20 ml) was placed in an ultrasonic bath with water temperature 70-75°C for 15-25 min. The reaction mixture was then treated as in method A. Yield 9.56 g (85%); mp 286-288°C (without purification). ^{1}H NMR spectrum, δ, ppm (*J*, Hz): 2.31 (3H, s, CH_3); 2.53 (3H, s, CH_3); 5.50 (1H, d, *J* = 7.2, H-7); 6.12 (1H, d, *J* = 7.2, H-6); 6.73 (1H, s, H-3); 7.10–7.25 (3H, m, H Ph); 7.42 (2H, t, *J* = 8.0, H Ph); 9.90 (1H, s, NH). Found, %: C 74.61; H 6.69; N 18.67. $C_{14}H_{15}N_3$. Calculated, %: C 74.64; H 6.71; N 18.65.

Products **10-15** were obtained analogously.

5-Methyl-2,7-diphenyl-4,7-dihydropyrazolo[1,5-*a*]pyrimidine (10). Yield 8.41 g (67%, method A), 11.55 g (92%, method B); mp >300°C. ^{1}H NMR spectrum, δ, ppm (*J*, Hz): 2.31 (3H, s, CH_3); 5.63 (1H, d, *J* = 7.1, H-7); 6.23 (1H, d, *J* = 7.1, H-6); 6.81 (1H, s, H-3), 6.80-7.43 (10H, m, H Ph); 10.02 (1H, s, NH). Found, %: C 79.49; H 6.02; N 14.67. $C_{19}H_{17}N_3$. Calculated, %: C 79.41; H 5.96; N 14.62.

5-Methyl-2-(4-methylphenyl)-7-phenyl-4,7-dihydropyrazolo[1,5-*a*]pyrimidine (11). Yield 9.78 g (65%, method A), 13.39 g (89%, method B); mp 292-294°C. ^{1}H NMR spectrum, δ, ppm (*J*, Hz): 2.33 (3H, s, CH_3); 2.41 (3H, s, CH_3); 5.30 (1H, d, *J* = 8.2, H-7); 5.91 (1H, d, *J* = 8.2, H-6); 6.72 (1H, s, H-3); 7.12-7.44 (9H, m, H Ar); 10.12 (1H, s, NH). Found, %: C 79.61; H 6.39; N 13.87. $C_{20}H_{19}N_3$. Calculated, %: C 79.70; H 6.35; N 13.94.

3,6-Dimethyl-1,4-diphenyl-4,7-dihydro-1*H*-pyrazolo[3,4-*b*]pyridine (12). Yield 10.23 g (68%, method A), 13.09 g (87%, method B); mp 288-290°C. ^{1}H NMR spectrum, δ, ppm (*J*, Hz): 2.30 (3H, s, CH_3); 3.32 (3H, s, CH_3); 5.41 (1H, d, *J* = 7.0, H-4); 6.02 (1H, d, *J* = 7.0, H-5); 7.02-7.50 (10H, m, H Ph); 9.91 (1H, s, NH). Found, %: C 79.73; H 6.28; N 13.97. $C_{20}H_{19}N_3$. Calculated, %: C 79.70; H 6.35; N 13.94

1,6-Dimethyl-3,4-diphenyl-4,7-dihydro-1*H*-pyrazolo[3,4-*b*]pyridine (13). Yield 10.68 g (71%, method A), 12.79 g (85%, method B); mp 278-280°C. ^{1}H NMR spectrum, δ, ppm (*J*, Hz): 2.43 (3H, s, CH_3); 3.21 (3H, s, CH_3); 5.10 (1H, d, *J* = 6.2, H-4); 5.71 (1H, d, *J* = 6.2, H-5); 7.10-7.42 (10H, m, H Ar); 10.00 (1H, s, NH). Found, %: C 79.68; H 6.29; N 13.96; $C_{20}H_{19}N_3$; Calculated, %: C 79.70; H 6.35; N 13.94.

6-Methyl-1,3,4-triphenyl-4,7-dihydro-1*H*-pyrazolo[3,4-*b*]pyridine (14). Yield 13.43 g (74%, method A), 17.24 g (95%, method B); mp >300 °C. ^{1}H NMR spectrum, δ, ppm (*J*, Hz): 2.41 (3H, s, CH_3); 5.20 (1H, d, *J* = 7.2, H-4); 6.02 (1H, d, *J* = 7.2, H-5); 6.70-7.30 (15H, m, H Ar); 10.10 (1H, s, NH). Found, %: C 82.65; H 5.79; N 11.62. $C_{25}H_{21}N_3$. Calculated, %: C 82.62; H 5.82; N 11.56.

6-Methyl-3-(4-methylphenyl)-1,4-diphenyl-4,7-dihydro-1*H*-pyrazolo[3,4-*b*]pyridine (15). Yield 14.71 g (78%, method A), 17.53 (93%, method B); mp >300°C. ^{1}H NMR spectrum, δ, ppm (*J*, Hz): 2.30 (3H, s, CH_3); 2.82 (3H, s, CH_3); 5.31 (1H, d, *J* = 8.2, H-4); 5.92 (1H, d, *J* = 8.2, H-5); 6.80-7.40 (14H, m, H Ar); 9.82 (1H, s, NH). Found, %: C 82.71; H 6.09; N 11.16. $C_{26}H_{23}N_3$. Calculated, %: C 82.73; H 6.14; N 11.13.

2-Methyl-6,8,9-triphenyl-4,7,8,9-tetrahydropyrazolo[5,1-*b*]quinazoline (17a). A (heating at reflux). A mixture of chalcone **16a** (0.42 g, 2 mmol) and pyrazolopyrimidine **9** (0.45 g, 2 mmol) was dissolved in NaOMe solution (25 mg Na in 10 ml MeOH), refluxed for 15 min in an argon atmosphere in a flask with a reflux condencer. The precipitate formed was filtered off, washed with MeOH, then acetone. Pale-yellow substance **17a** was crystallized from 2-PrOH supplemented with 10% DMF. Yield 0.71 g (85%); mp 202-204°C.

B (ultrasound). A mixture of chalcone **16a** (0.42 g, 2 mmol) and pyrazolopyrimidine **9** (0.45 g, 2 mmol) was dissolved in NaOMe solution (25 mg Na in 10 ml MeOH), placed in an ultrasonic bath with a water temperature of 70 to 75° C for 1-2 min. The white precipitate was filtered off. Yield 0.76 g (92%); mp 202-204°C (without purification). ^{1}H NMR spectrum, δ, ppm (*J*, Hz): 2.30 (3H, s, CH_3); 2.51 (1H, dd, *J* = 12.3, *J* = 5.1) and 3.52 (1H, dd, *J* = 12.2, *J* = 6.2, 7-CH_2); 4.60 (1H, dd, *J* = 6.2, *J* = 5.0, H-8); 5.71 (1H, s, H-9); 6.32 (1H, d, *J* = 2.0, H-5); 6.74 (1H, s, H-3); 6.80-7.42 (15H, m, H Ph); 10.21 (1H, s, NH). Mass spectrum, *m/z* (I_{rel}, %): 415 $[M]^+$ (100), 414 (94), 338 (70), 261 (32), 209 (24), 206 (21), 77 (46). Found, %: C 83.79; H 6.09; N 10.07. $C_{29}H_{25}N_3$. Calculated, %: C 83.82; H 6.06; N 10.11.

Products **17b,c** and **18-23** were obtained analogously.

8-(4-Methoxyphenyl)-2-methyl-6,9-diphenyl-4,7,8,9-tetrahydropyrazolo[5,1-*b*]quinazoline (17b). Yield 0.73 g (82%, method A), 0.83 g (93%, method B); mp 198-200°C. ^{1}H NMR spectrum, δ, ppm (*J*, Hz): 2.32 (3H, s, CH_3); 2.60 (1H, dd, *J* = 12.4, *J* = 5.2) and 3.71 (1H, dd, *J* = 12.4, *J* = 6.4, 7-CH_2); 3.81 (3H, s, OCH_3); 4.50 (1H, dd, *J* = 6.4, *J* = 5.2, H-8); 5.58 (1H, s, H-9); 6.19 (1H, d, *J* = 1.8, H-5); 6.71 (1H, s, H-3); 6.70-7.52 (14H, m, H Ar); 10.10 (1H, s, NH). Mass spectrum, *m/z* (I_{rel}, %): 445 $[M]^+$ (100), 444 (78), 368 (56), 338 (26), 209 (36), 132 (45), 77 (63). Found, %: C 80.81; H 6.13; N 9.47. $C_{30}H_{27}N_3O$. Calculated, %: C 80.87; H 6.11; N 9.43.

8-(4-Bromophenyl)-2-methyl-6,9-diphenyl-4,7,8,9-tetrahydropyrazolo[5,1-*b*]quinazoline (17c). Yield 0.84 g (85%, method A), 0.94 g (95%, method B); mp 220-222°C. ^{1}H NMR spectrum , δ, ppm (*J*, Hz): 2.28 (3H, s, CH_3); 2.67 (1H, dd, *J* = 14.4, *J* = 5.8) and 3.45 (1H, dd, *J* = 14.4, *J* = 6.3, 7-CH_2); 4.57 (1H, dd, *J* = 6.3, *J* = 5.8, H-8); 5.73 (1H, s, H-9); 6.31 (1H, d, *J* = 2.1, H-5); 6.70 (1H, s, H-3); 6.70-7.55 (14H, m, H Ar); 10.21 (1H, s, NH). Mass spectrum, *m/z* (I_{rel}, %): 495/493 $[M]^+$ (^{81}Br/^{79}Br) (100), 494 (88), 493 $[M]^+$ (98), 492 (85), 338 (42), 286 (56), 284 (54), 209 (30), 156 (34), 154 (33), 77 (42). Found, %: C 70.41; H 4.91; Br 16.14; N 8.47. $C_{29}H_{24}BrN_3$. Calculated, %: C 70.45; H 4.89; Br 16.16; N 8.50.

2,6,8,9-Tetraphenyl-4,7,8,9-tetrahydropyrazolo[5,1-*b*]quinazoline (18a). Yield 0.84 g (88%, method A), 0.92 g (96%, method B); mp 302-304°C. ^{1}H NMR spectrum, δ, ppm (*J*, Hz): 2.72 (1H, dd, *J* = 14.2, *J* = 5.9) and 3.40 (1H, dd, *J* = 14.1, *J* = 7.0, 7-CH_2); 4.89 (1H, dd, *J* = 7.0, *J* = 6.0, H-8); 5.76 (1H, s, H-9); 6.51 (1H, d, *J* = 2.2, H-5); 6.70 (1H, s, H-3); 7.05–7.85 (20H, m, H Ph); 10.51 (1H, s, NH). Mass spectrum, *m/z* (I_{rel}, %): 477 $[M]^+$ (100), 476 (89), 400 (75), 271 (43), 194 (32), 77 (45). Found, %: C 85.52; H 5.69; N 8.78. $C_{34}H_{27}N_3$. Calculated, %: C 85.50; H 5.70; N 8.80.

2-(4-Methylphenyl)-6,8,9-triphenyl-4,7,8,9-tetrahydropyrazolo[5,1-*b*]quinazoline (19a). Yield 0.83 g (85%, method A), 0.92 g (94%, method B); mp 286-288°C. ^{1}H NMR spectrum, δ, ppm (*J*, Hz): 2.43 (3H, s, CH_3); 2.81 (1H, dd, *J* = 13.2, *J* = 6.1) and 3.60 (1H, dd, *J* = 13.2, *J* = 7.4, 7-CH_2); 4.53 (1H, dd, *J* = 7.4, *J* = 6.1, H-8); 6.10 (1H, c, H-9); 6.42 (1H, d, *J* = 2.0, H-5); 6.68 (1H, s, H-3); 7.00-7.75 (19H, m, H Ar); 10.7 (1H, s, NH). Mass spectrum, *m/z* (I_{rel}, %): 491 $[M]^+$ (100), 490 (95), 414 (53), 400 (15), 337 (26), 285 (29), 91 (23), 77 (43). Found, %: C 85.53; H 5.93; N 8.57. $C_{35}H_{29}N_3$. Calculated, %: C 85.51; H 5.95; N 8.55.

3-Methyl-1,4,5,7-tetraphenyl-4,5,6,9-tetrahydro-1*H*-pyrazolo[3,4-*b*]quinoline (20a). Yield 0.81 g (82%, method A), 0.91 g (92%, method B); mp 264-266°C. ^{1}H NMR spectrum, δ, ppm (*J*, Hz): 2.40 (1H, dd, *J* = 14.5, *J* = 7.6) and 3.70 (1H, dd, *J* = 14.5, *J* = 6.4, 6-CH_2); 2.81 (3H, s, CH_3); 4.53 (1H, dd, *J* = 7.6, *J* = 6.4, H-5); 5.92 (1H, s, H-4); 6.65 (1H, d, *J* = 1.8, H-8); 6.80-7.50 (20H, m, H Ph); 10.11 (1H, s, NH). Mass spectrum, *m/z* (I_{rel}, %): 491 $[M]^+$ (100), 490 (85), 414 (84), 386 (27), 337 (42), 285 (36), 180 (23), 77 (42). Found, %: C 85.50; H 5.96; N 8.57. $C_{35}H_{29}N_3$. Calculated, %: C 85.51; H 5.95; N 8.55.

1-Methyl-3,4,5,7-tetraphenyl-4,5,6,9-tetrahydro-1*H*-pyrazolo[3,4-*b*]quinoline (21a). Yield 0.79 g (80%, method A), 0.91 g (92%, method B); mp 240-242°C. ^{1}H NMR spectrum, δ, ppm (*J*, Hz): 2.53 (1H, dd, *J* = 14.3, *J* = 5.2) and 3.78 (1H, dd, *J* = 14.2, *J* = 6.0, 6-CH_2); 3.71 (3H, s, NCH_3); 4.42 (1H, dd, *J* = 6.0, *J* = 5.2, H-5); 5.83 (1H, s, H-4); 6.56 (1H, d, *J* = 1.9, H-8); 6.65-7.55 (20H, m, H Ph); 10.00 (1H, s, NH). Mass spectrum, *m/z* (I_{rel}, %): 491 $[M]^+$ (100), 490 (90), 448 (23), 414 (74), 337 (42), 285 (26), 208 (34), 131 (21), 77 (53). Found, %: C 85.52; H 5.94; N 8.54. $C_{35}H_{29}N_3$. Calculated, %: C 85.51; H 5.95; N 8.55.

1,3,4,5,7-Pentaphenyl-4,5,6,9-tetrahydro-1*H*-pyrazolo[3,4-*b*]quinoline (22a). Yield 0.97 g (88%, method A), 1.08 g (92%, method B); mp 282-284°C. ^{1}H NMR spectrum, δ, ppm (*J*, Hz): 2.72 (1H, dd, *J* = 14.4, *J* = 6.5) and 3.50 (1H, dd, *J* = 14.4, *J* = 5.0, 6-CH_2); 4.90 (1H, dd, *J* = 6.5, *J* = 5.0, H-5); 5.89 (1H, s, H-4); 6.67 (1H, d, *J* = 1.9, H-8); 6.80-7.90 (25H, m, H Ph); 10.50 (1H, s, NH). Mass spectrum, *m/z* (I_{rel}, %): 553 $[M]^+$ (100), 552 (95), 476 (73), 399 (41), 347 (34), 270 (41), 242 (35), 165 (26), 77 (65). Found, %: C 86.73; H 5.69; N 7.57. $C_{40}H_{31}N_3$. Calculated, %: C 86.77; H 5.64; N 7.59.

3-(4-Methylphenyl)-1,4,5,7-tetraphenyl-4,5,6,9-tetrahydro-1*H*-pyrazolo[3,4-*b*]quinoline (23a). Yield 0.96 g (85%, method A), 1.09 g (92%, method B); mp 274-276°C. NMR spectrum ^{1}H, δ, ppm (*J*, Hz): 2.42 (3H, s, CH_3); 2.61 (1H, dd, *J* = 14.0, *J* = 6.3) and 3.60 (1H, dd, *J* = 14.0, *J* = 7.1, 6-CH_2); 4.82 (1H, dd, *J* = 7.1, *J* = 6.3, H-5); 6.05 (1H, s, H-4); 6.78 (1H, d, *J* = 2.0, H-8); 6.90-7.95 (24H, m, H Ar); 10.40 (1H, s, NH). Mass spectrum, *m/z* (I_{rel}, %): 567 $[M]^+$ (100), 566 (92), 490 (72), 476 (28), 361 (43), 256 (31), 153 (32), 104 (41), 91 (25), 77 (68). Found, %: C 86.71; H 5.89; N 7.43. $C_{41}H_{33}N_3$. Calculated, %: C 86.74; H 5.86; N 7.40.

REFERENCES

1. V. V. Lipson, I. V. Ignatenko, S. M. Desenko, S. V. Shishkina, O. V. Shishkin, S. A. Komykhov, N. V. Logvinenko, V. D. Orlov, and H. Meier, *J. Heterocycl. Chem.*, **40**, 1081 (2003).
2. D. Yu. Sidorenko and V. D. Orlov, in: *Fourth All-Russian Conference on Enamines in Organic Synthesis* [in Russian], Perm, Russia (2007), p. 215.
3. V. D. Orlov, D. Yu. Sidorenko, and M. A. Kolosov, in: *Proceedings of the International Conference on New Directions in the Chemistry of Heterocyclic Compounds* [in Russian], Kislovodsk, Russia (2009), p. 84.
4. D. Yu. Sidorenko and V. D. Orlov, *Izv. Akad. Nauk, Ser. Khim.*, **57**, 1971 (2008) [*Russ. Chem. Bull.*, **57**, 2005 (2008)].
5. D. Yu. Sidorenko and V. D. Orlov, *Ultrason. Sonochem.*, **18**, 300 (2011).
6. D. Yu. Sidorenko and V. D. Orlov, *Mendeleev Commun.*, **20**, 170 (2010).
7. V. V. Lipson, T. M. Karnozhitskaya, S. V. Shishkina, O. V. Shishkin, and A. V. Turov, *Zh. Org. Khim.*, **44**, 1717 (2008).
8. V. A. Chebanov, K. A. Gura, and S. M. Desenko, *Top. Heterocycl. Chem.*, **23**, 41 (2010).

9. V. D. Orlov, J. Quiroga, V. N. Kolos, and S. M. Desenko, *Khim. Geterotsikl. Soedin.*, 962 (1988). [*Chem. Heterocycl. Compd.*, **24**, 1008 (1988)].
10. V. V. Lipson, N. V. Svetlichnaya, V. V. Borodina, M. G. Shirobokova, S. V. Shishkina, O. V. Shishkin, and V. I. Musatov, *Zh. Org. Khim.*, **46**, 1385 (2010).
11. V. A. Chebanov, Ya. I. Sakhno, S. M. Desenko, V. N. Chernenko, V. I. Musatov, S. V. Shishkina, O. V. Shishkin, and C. O. Kappe, *Tetrahedron*, **63**, 1229 (2007).
12. V. D. Orlov, J. Quiroga, and V. N. Kolos, *Khim. Geterotsikl. Soedin.*, 363 (1987). [*Chem. Heterocycl. Compd.*, **23**, 304 (1987)].
13. T. S. Saleh, T. M. A. Eldebss, and H. M. Albishri, *Ultrason. Sonochem.*, **19**, 49 (2012).
14. S. M. Desenko, V. D. Orlov, V. V. Lipson, O. V. Shishkin, L. A. Potekhin, and Yu. T. Struchkov, *Khim. Geterotsikl. Soedin.*, 109 (1993). [*Chem. Heterocycl. Compd.*, **29**, 95 (1993)].
15. J. Quiroga, B. Insuasty, R. Rincon, M. Larrahondo, N. Hanold, and H. Meier, *J. Heterocycl. Chem.*, **31**, 1333 (1994).
16. J. Quiroga, D. Mejia, B. Insuasty, R. Abonia, M. Nogueras, A. Sanchez, J. Cobo, and J. N. Low, *J. Heterocycl. Chem.*, **39**, 51 (2002).
17. V. V. Lipson, S. M. Desenko, M. G. Shirobokova, V. V. Borodina, and V. I. Musatov, *Khim. Geterotsikl. Soedin.*, 577 (2005). [*Chem. Heterocycl. Compd.*, **41**, 492 (2005)].