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Tautomerism of Aza Cycles: IV.[1] Tautomeric Structure of 4,5-Dihydropyrazol-5-one Annelated on Bond C^3–C^4 with Piperidine Cycle, and Its Three Hydrochlorides

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Abstract—5-Methyl-2-phenyl-3,3a,4,5,6,7-hexahydro-2*H*-pyrazolo[4,3-*c*]pyridin-3-one has been synthesized and shown to exist in crystal as zwitterionic structure with the proton localized on the nitrogen atom in the piperidine ring and negative charge delocalized over the pyrazololate fragment. The structure of 2 : 1, 1 : 2, and 2 : 3 hydrochlorides derived from the title compound has been determined by X-ray analysis.

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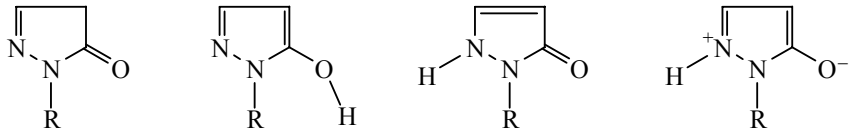
Among prototropic tautomeric systems, pyrazol-5-one derivatives have been studied in most detail. Apart from ketone (**A**) and enol tautomers (**B**), NH tautomer (**C**) was detected for some pyrazol-5-one derivatives [2–4]. This may be interpreted assuming concurrent keto–enol and imine–enamine tautomerism. In addition, NH tautomer (**C**) may be presumed to result from proton transfer from the OH group of tautomer **B** to produce zwitterionic structure **D** (an orbital isomer of **C** [5–7]). The properties of the NH tautomer should be determined by a large contribution of canonical structure **D** to the ground states, which should be reflected in its spectral and structural parameters. For instance, IR absorption bands typical of ammonium ions (2700–2400 cm^{-1}) should appear, whereas no bands typical of carbonyl stretching vibrations (1700–1650 cm^{-1}) should be observed [8]. These assumptions are consistent with numerous IR spectral data for pyrazol-5-ones (for detailed analysis of published data, see [9]). However, the possibility for easy π-electron delocalization [10] in tautomer **D** considerably reduces its energy preference over orbital isomer **C**, whereas the observed reduction of the OH, NH, and C=O stretching vibration frequencies is usually attributed to hydrogen bonding [9]. It should be noted that both these structures are capable of forming hydrogen bonds; therefore, additional experiments are necessary to confirm the ability of the OH group in tautomer **B** to act as intramolecular proton donor with respect to the nitrogen atom.

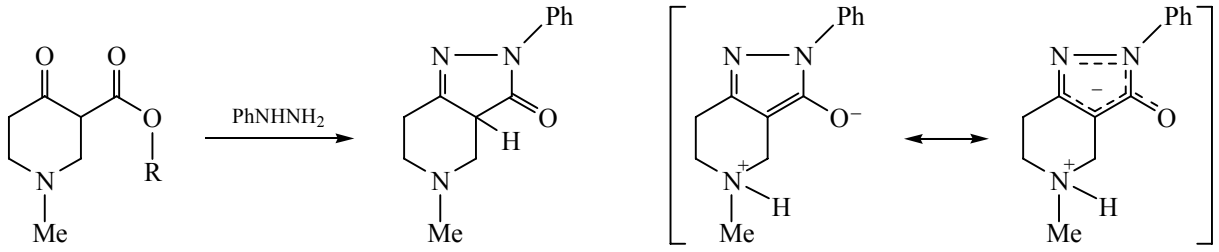


A **B** **C** **D**

Taking into account that the stability of different tautomers is determined by their acid–base properties (the most stable tautomer is the weakest acid) [11, 12], we presumed that fusion of a piperidine [13], dihydropyrrole, or other highly basic heterocycle to pyrazol-5-one should lead to labile proton localization on the most basic nitrogen atom. For this purpose, we have synthesized piperidine-fused pyrazol-5-one from 1-methyl-4-oxopiperidine-3-carboxylate **Ia** and phenylhydrazine [14]. The resulting 5-methyl-2-phenyl-

[1] For communication III, see [1].

Scheme 1.



R = Me or Et.

3,3a,4,5,6,7-hexahydro-2*H*-pyrazolo[4,3-*c*]pyridin-3-one (**IIa**) should exist as a zwitterionic structure **III** or **IV** with protonated nitrogen atom of the piperidine fragment rather than traditional CH-, OH-, or NH-pyrazole tautomers. Depending on the nature of substituents in different molecular fragments, such pyrazolopiperidines could be expected to exist as zwitterionic orbital isomers [5–7] with the anionic center either localized on the pyrazole nitrogen or oxygen atom or, more probably, essentially delocalized over the pyrazololate fragment (structure **IV**, Scheme 1).

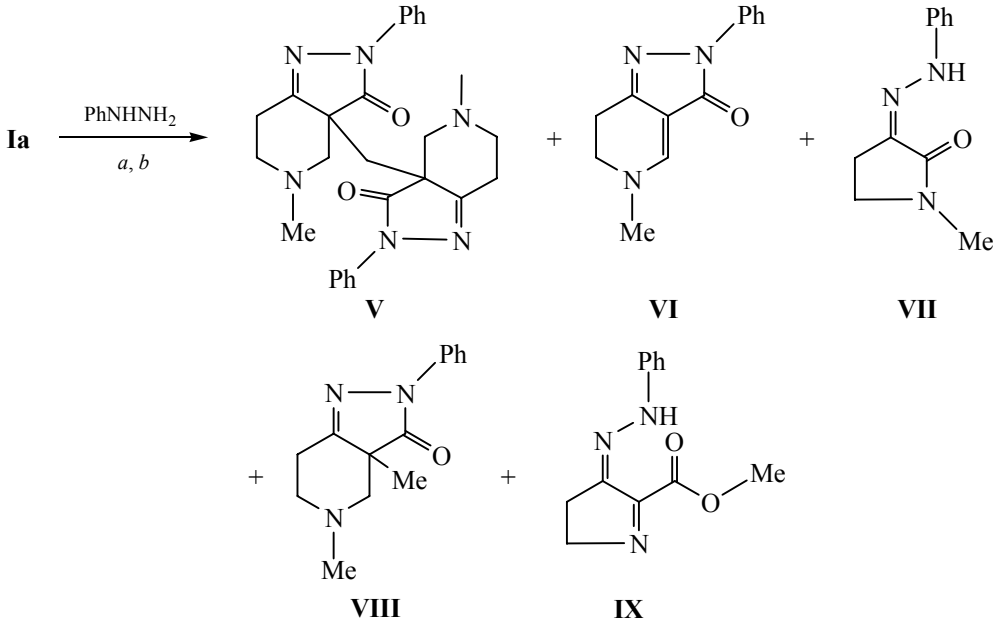
5-Acyl, 5-aryl, and 5-pyridinylmethyl analogs of pyrazolopiperidine **IIa** have been successfully synthesized [15–19] and even proposed for use as biologically active compounds and medicinal agents. The synthesis of 5-methyl-6-phenyl derivatives was also reported [19], and these compounds were assigned (without rigorous substantiation) the structures of all three known CH [13, 15, 16, 19], NH [4, 15–18, 20], and OH tautomers [15, 19, 21]. In view of ambiguity of published data on the structure of hexahydropyrazolo[4,3-*c*]pyridinone derivatives, in the present work we examined the condensation of keto ester **Ia** with phenylhydrazine in more detail.

The reaction of phenylhydrazine with keto ester **Ia** under standard conditions of synthesis of pyrazol-5-ones (heating in boiling alcohols or benzene) resulted in the formation of a complex mixture consisting of 5–7 products among which no pyrazolopiperidine **IIa** was detected [14, 22–24]. When a mixture of **Ia** (R = Me) and phenylhydrazine was heated for 5 min in boiling methanol, propan-2-ol, or benzene, the products were bis{5-methyl-3-oxo-2phenyl-3,3a,4,5,6,7-hexahydro-2*H*-pyrazolo[4,3-*c*]pyridin-3-yl}methane (**V**), 5-methyl-2-phenyl-3,5,6,7-tetrahydro-2*H*-pyrazolo[4,3-*c*]pyridin-3-one (**VI**), (3*Z*)-1-methyl-3-(2-phenylhydrazinylidene)pyrrolidin-2one (**VII**), and some other compounds which were detected by TLC. Compounds **V** and **VI** predominated among the products, and the yield of hydrazone **VII** was considerably lower. We succeeded in isolating compounds **V**–**VII** in the pure state [14, 22–24]; in addition, 3a,5-dimethyl-2-phenyl-3,3a,4,5,6,7-hexahydro-2*H*-pyrazolo[4,3-*c*]pyridin-3-one (**VIII**) and methyl (4*Z*)-4-(2-phenylhydrazono)-3,4-dihydro-2*H*-pyrrole-5-carboxylate (**IX**) [25] were identified by spectral methods. The other products were detected only by thin-layer chromatography. The structure of **V**–**IX** will be the subject of the next communication of this series.

Pyrazolopiperidine **IIa** was isolated as finely crystalline material when ester **Ia** (R = Me or Et) was carefully mixed with phenylhydrazine in methanol or benzene and the mixture was then kept at room or lower temperature. Compound **IIa** is soluble in water and acetic and trifluoroacetic acids, very poorly soluble in methanol and other alcohols, and insoluble in nonpolar solvents. Crystalline compound **IIa** can be stored for many years without appreciable decomposition (according to the IR data). It reacts with acids to form the corresponding salts; in particular, three hydrochlorides **X**–**XII** with different compositions were obtained from **IIa** and HCl (Scheme 2).

The IR spectra of a crystalline sample of **IIa** (in KBr or mineral oil) lacked absorption bands assignable to carbonyl stretching vibrations and absorption above 3000 cm^{-1}, but a strong hump was observed in the region 2100–2600 cm^{-1} typical of ^{+}N–H stretching vibrations. Analogous absorption was observed in the spectra of hydrochlorides **X**–**XII** and ester **Ia** hydrochloride (**XIII**); the structure of the latter was unambiguously determined by X-ray analysis (Fig. 1). Hydrochloride **XIII** in crystal has enol structure with the intramolecular hydrogen bond $OH\cdots O{=}C$ [$H^4\cdots O^8$ 1.86 Å, $\angle O^4H^4O^8$ 150(3)°]. The C^3–C^4 and C^4–O^4

Scheme 2.



a, MeOH, 65°C; *b*, *i*-PrOH, 80°C.

bond lengths in **XIII** indicate a classical version of keto–enol tautomerism (C=C 1.340 Å, C–O 1.333 Å [26]). The acidic proton is localized on the pyramidal nitrogen atom in the piperidine ring, the degree of pyramidality [27] being C_P^N 0.595.

Molecules **XIII** in crystal are linked through hydrogen bonds of different types. The hydrogen bond N–H···Cl links the N^1 atom and chloride counterion. Non-classical hydrogen bonds C–H···O between H^9 in the methoxy group and O^4 in the hydroxy group, as well as between H^7 and O^8 carbonyl oxygen atom, give rise to layers parallel to the *a*0*c* plane (Fig. 2). The layers are linked to form three-dimensional network through C–H···Cl bonds between methylene hydrogen atoms in the piperidine ring and Cl^1.

In the ^{1}H NMR spectra of pyrazolopiperidine **IIa** in D_2O and CD_3OD, only signals from aromatic and methyl protons were observed clearly, presumably as a result of exchange processes and conformational transformations. Signals from methylene protons appeared as broadened singlets, which were sometimes poorly resolved into triplets. No labile proton signal was detected. The above IR and ^{1}H NMR data suggest that compound **IIa** in crystal and in solution (D_2O, CD_3OD) exists as zwitterion **IV**. We failed to obtain crystals of **IIa** suitable for X-ray analysis by crystallization from D_2O or CD_3OD.

By reacting phenylhydrazine hydrochloride with ester **Ia** hydrochloride we obtained pyrazolopiperidine **IIa** salt with the same melting point (mp 225–227°C). However, this salt was not a simple 1 : 1 hydro-

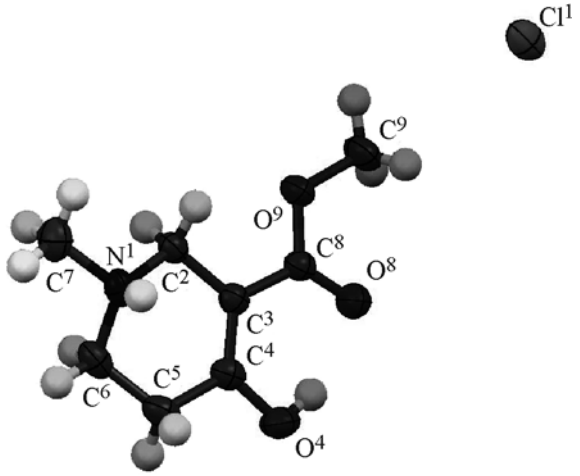


Fig. 1. Structure of hydrochloride **XIII** in crystal according to the X-ray diffraction data. Non-hydrogen atoms are shown as thermal vibration ellipsoids with a probability of 50%; hydrogen atoms are shown by spheres of arbitrary fixed radius. Principal bond lengths and bond (Å) and torsion angles (deg): O^4–H^4 0.85(4), O^4–C^4 1.339(3), N^1–H^1 0.81(2), N–C 1.485(3), C^3–C^4 1.345(3), C^3–C^8 1.450(3), O^8–C^8 1.226 (3), O^9–C^8 1.340(2); $C^2N^1C^6$ 112.7(2), $C^2N^1C^7$ 111.5(2), $C^6N^1C^7$ 112.0(2), $C^5C^4O^4$ 125.0(2), $C^8O^9C^9$ 116.4(2), $C^4O^4H^4$ 103(2); $C^3C^4O^4H^4$ –9(2), $C^4C^3C^8O^8$ –1.3(3), $C^4C^3C^2N^1$ 15.7 (3), $C^4C^5C^6N^1$ –47.9(2).

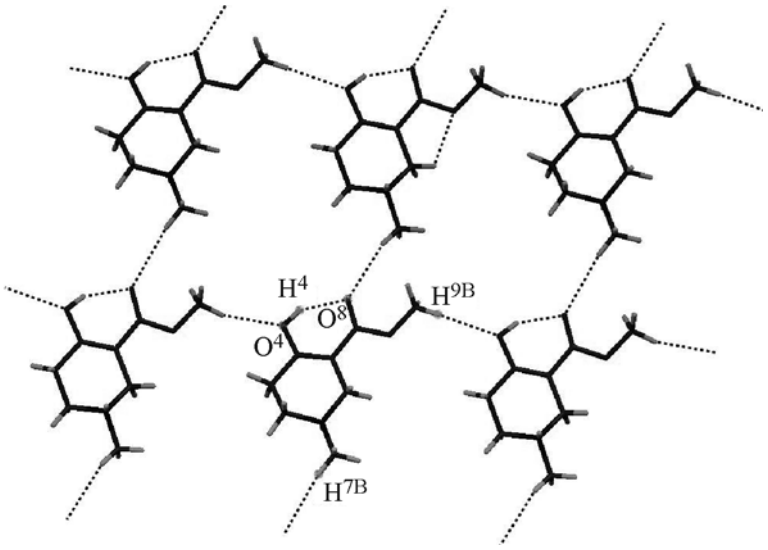
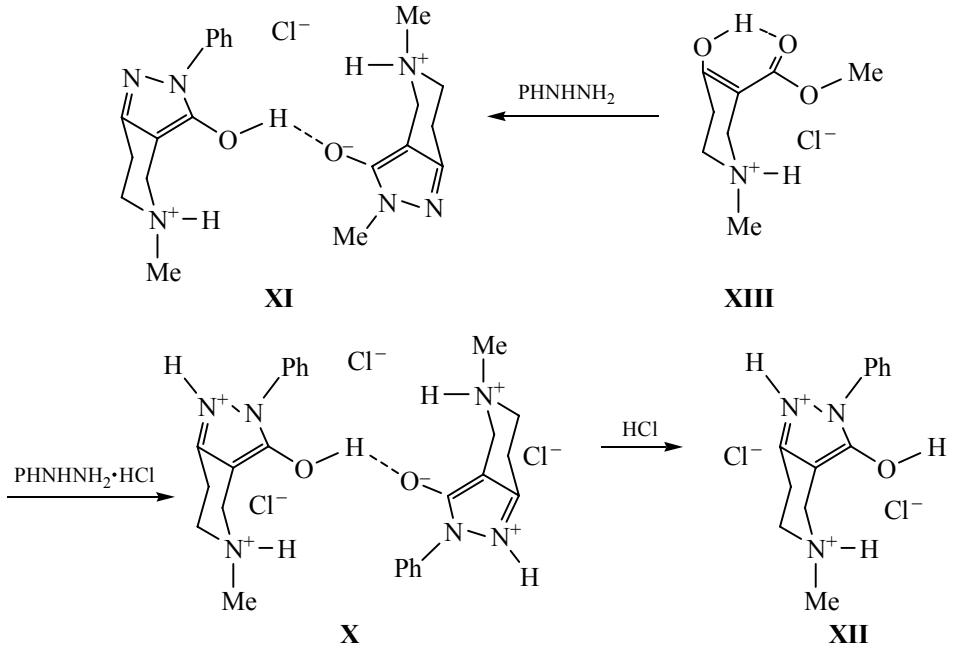


Fig. 2. Layered structure formed by molecules of hydrochloride **XIII** in crystal via C–H···O hydrogen bonding (view along the 0*b* crystallographic axis; hydrogen bonds are shown as dotted lines; chloride ions are not shown).

chloride as reported in [13]. According to the results of our X-ray diffraction study, it has a composition of 2 : 3 (hydrochloride **X**) [28]. The reaction of **Ia**·HCl with phenylhydrazine gave a different salt whose decomposition was estimated at 2 : 1 (**XI**, mp 173–175°C). Dissolution of **X** in concentrated aqueous HCl, followed by removal of the acid, afforded one more salt **XII** with a composition of 1 : 2, mp 163–165°C (Scheme 3).

All three hydrochlorides **X**–**XII** are stable crystalline compounds readily soluble in water, DMSO, and acetic and trifluoroacetic acids. Determination of the melting points of **X**–**XII** by the capillary method gave different values: **X**, 220–221°C; **XI**, 173–175°C; **XII**, 225–227°C (each with decomposition), whereas all three salts melted almost in the same temperature range (160–165°C) on a Boëtius hot stage. Presumably, in the latter case, excess HCl is removed

Scheme 3.



from crystalline samples of **X** and **XII** at a temperature lower than the melting point.

Like hydrochloride **XIII**, the IR spectra of **X**–**XII** displayed a broadened absorption band in the region 2700–2500 cm^{-1}, which corresponds to N^+–H stretching vibrations. The IR and ^1H NMR spectra of **X**–**XII** are fairly similar. Unfortunately, the salt character of compounds **X**–**XII** restricts the range of solvents suitable for recording their ^1H NMR spectra, whereas protic solvents initiate exchange processes, which reduces informativeness of the spectra.

Judging by the ^{13}C NMR spectra of freshly prepared solutions of pyrazolopiperidine **IIa** in trifluoroacetic acid [δ_C, ppm: 19.0 (C^8, CH_2), 43.2 (NMe), 48.9 (C^4, CH_2), 51.3 (C^7, CH_2), 95.6 (C^{3a}), 124.6 (C^m, Ph), 130.1 (C^o, Ph), 131.2 (C^p, Ph), 131.7 (C^{8a}), 141.9 (C^i, Ph), 153.2 (C^3)], this compound in acid solution is represented by dication with protons attached to the N^1, N^6, and O^3 atoms; such dication was identified in crystalline hydrochloride **X**.

The site of protonation of multicenter bases is determined by a number of factors, including the nature of substituents in the basic fragment and predominant tautomer structure. As a rule, it is difficult to identify the site of protonation in such compounds by spectral methods. Therefore, the structure of hydrochlorides **X**–**XII** in crystal was unambiguously assigned only by X-ray analysis. The position of hydrogen atoms attached to heteroatoms in molecules **X**–**XII** was determined independently from the difference electron density series.

The N^6 nitrogen atom in five pyrazolopiperidinium cations of three hydrochlorides **X**–**XII** always bears a proton, which confirms our assumption that N^6 is more basic than the other basic centers in molecule **IIa**.

The independent part of a unit cell of 2 : 3 hydrochloride **X** includes zwitterion **IV** protonated at the N^1 atom (molecule **XA**), dication **XB** with three protons attached to N^1, N^6, and O^3, and three chloride ions as counterions (Fig. 3). Both cations **XA** and **XB** are linked to each other through the classical intermolecular $O^3_BH^3_B\cdots O^{3-}_A$ hydrogen bond, so that the distances $O^3_B\cdots H^3_B$ and $O^3_A\cdots H^3_B$ become fairly leveled [O^3_B–H^3_B 1.10(9), $O^3_B\cdots O^3_A$ 2.406(6), $H^3_B\cdots O^3_A$ 1.32(8) Å; $\angle O^3_BH^3_BO^3_A$ 168(8)°].

Despite steric hindrances induced by closely located H^1_A in the pyrazole fragment and H^{11}_A in the benzene ring the dihedral angle between the planes of

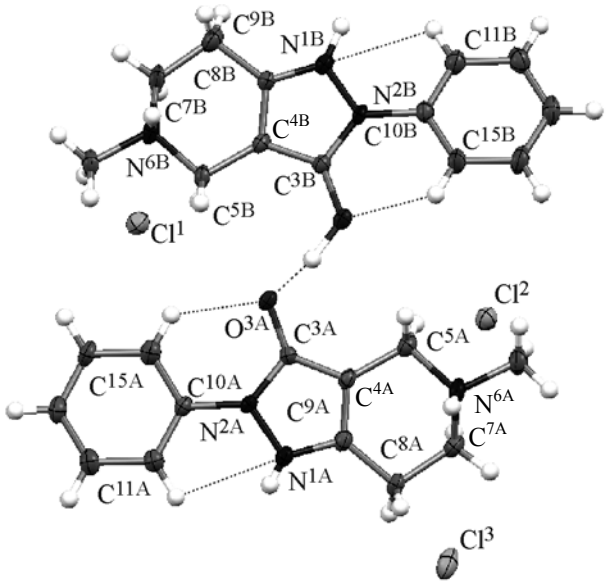


Fig. 3. Structure of independent molecules of hydrochloride **X** in crystal. Non-hydrogen atoms are shown as thermal vibration ellipsoids with a probability of 50%; hydrogen atoms are shown by spheres of arbitrary fixed radius. Hydrogen bonds are shown with dotted lines.

the pyrazole and benzene rings in molecule **XA** is 9.0°. This may be due to formation of two intramolecular hydrogen bonds between H^{11}_A and N^1_A ($N^{11}_A\cdots N^1_A$ 2.53 Å, $\angle C^{11}_AH^{11}_A\cdots N^1_A$ 101°) and between H^{15}_A and O^3_A ($H^{15}_A\cdots O^3_A$ 2.18 Å, $\angle C^{15}_AH^{15}_AO^3_A$ 126°) (Fig. 3), as well as due to conjugation between the electron systems of both fragments. The dihedral angle between the corresponding planes in the second cation of **X** is 15.8°.

Cations **XA** and **XB** in crystal are linked to the counterions through N–H···Cl hydrogen bonds involving hydrogen atoms on the nitrogen atoms in both pyrazole and piperidine rings [$N^1_AH^1_A\cdots Cl^2$ 2.46(8) Å, $\angle N^1_AH^1_ACl^2$ 150(7)°, (1/2 + *x*, 1/2 – *y*, 1/2 + *z*); $N^1_BH^1_B\cdots Cl^1$ 2.15(7)Å, $\angle N^1_BH^1_BCl^1$ 160(5)°, (1/2 + *x*, 1/2 – *y*, –1/2 + *z*); N^6_A–$H^6_A\cdots Cl^3$ 2.05(5) Å, $\angle N^6_AH^6_ACl^3$ 174(2)°, (3/2 – *x*, 1/2 + *y*, 1/2 – *z*); N^6_B–$H^6_B\cdots Cl^2$ 2.19(6) Å, $\angle N^6_BH^6_BCl^2$ 163(2)°, (1/2 – *x*, 1/2 + *y*, 1/2 – *z*)].

Chloride ions in the crystal of sesquihydrochloride **X** also form hydrogen bonds C–H···Cl with hydrogen atoms of the methyl group and benzene and piperidine ring with the distances ranging from 2.73 to 2.86 Å and angles ranging from 140° to 160°; these bonds in turn give rise to bilayers parallel to the *a*0*c* plane. The π···π contacts between the pyrazole and benzene rings

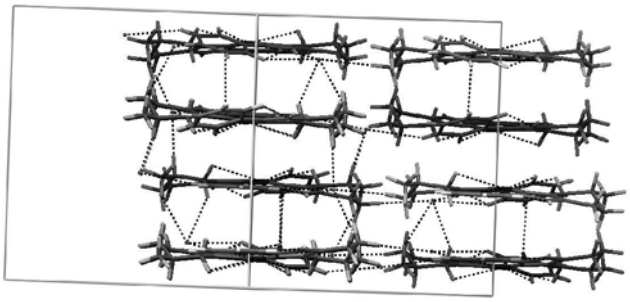


Fig. 4. A fragment of three-dimensional network formed by molecules of hydrochloride **X** (rod representation) in crystal. Intermolecular interactions are shown with dotted lines.

in the symmetry-related ions **XA** and **XV** provide additional stabilization of the bilayers. The set of the aforesaid intermolecular interactions is responsible for the formation of three-dimensional network in the crystal structure of hydrochloride **XB** (Fig. 4).

The independent part of a unit cell of 2 : 1 hydrochloride **XI** comprises a chloride ion and two molecules **XIA** and **XIB** that are linked to each other through the intermolecular hydrogen bond O^3_A–$H^3_A\cdots O^3_B$ with the following parameters: $H^3_A\cdots O^3_B$ 1.56(5) Å, $\angle O^3_A H^3_A O^3_B$ 151(7)° (1 + *x*, *y*, *z*) (Fig. 5). Molecule **XIB** has zwitterionic structure **IV**, and molecule **XIA** is zwitterion **IV** protonated at the oxygen atom.

The benzene ring plane in both **XIA** and **XIV** is turned with respect to the pyrazole ring plane through dihedral angles of 22.5° and –19.7°, respectively. These angles are larger by almost 10° than those in the corresponding (with account taken of protonation) molecules **XB** and **XA**. As in the latter, the observed arrangement of the benzene and pyrazole rings may be rationalized by the formation of hydrogen bonds $O^3\cdots H^{15}$ [$H^{15}_A\cdots O^3_A$ 2.26 Å, $\angle C^{15}_A H^{15}_A O^3_A$ 120°; $H^{15}_B\cdots O^3_B$ 2.38 Å, $\angle C^{15}_B H^{15}_B O^3_B$ 118°] and $N^1\cdots H^{11}$ [$C^{11}_A H^{11}_A\cdots N^1_A$ 2.41 Å, $\angle C^{11}_A H^{11}_A N^1_A$ 100°; $H^{11}_B\cdots N^1_B$ 2.46 Å, $\angle C^{11}_B H^{11}_B N^1_B$ 102°] (Fig. 5).

Unlike hydrochloride **X**, chloride ion in the crystal structure of **XI** is involved only in hydrogen bonds N^6–$H^6\cdots Cl$ [$H^6_A\cdots Cl^1$ 1.94(2) Å, $\angle N^6_A H^6_A Cl^1$ 164(2)°, (1 + *x*, *y*, 1 + *z*); $H^6_B\cdots Cl^1$, 1.97(2) Å, $\angle N^6_B H^6_B Cl^1$ 173(2)°]. These bonds are orthogonal to the intermolecular O^3_A–$H^3_A\cdots O^3_B$ bonds which link molecules **XIA** and **XIB** together. A combination of intermolecular hydrogen bonds N–H···Cl and O–H···O leads to formation of zigzag chains of molecules **XI** in crystal (Fig. 6). These zigzag chains are linked in turn to produce three-dimensional network through the following C–H···N and C–H···O hydrogen bonds: $H^{14}_A\cdots N^1_B$ 2.74 Å, $\angle C^{14}_A H^{14} N^1_B$ 133°, (2 – *x*, 1/2 + *y*, 1 – *z*); $C^{14}_B H^{14}_B\cdots N^1_A$ 2.64 Å, $\angle C^{14}_B H^{14}_B N^1_A$ 137°, (1 – *x*, –1/2 + *y*, 2 – *z*); $H^{51}_B\cdots N^2_A$ 2.70 Å, $\angle C^5_B H^{51}_B N^2_A$ 162°; $H^{52}_B\cdots O^3_A$ 2.41 Å, $\angle C^5_B H^{52}_B O^3_A$ 122°, (–1 + *x*, *y*, *z*); $H^{52}_A\cdots O^3_B$ 2.53 Å, $\angle C^5_A H^{52}_A O^3_B$ 116°, (1 + *x*, *y*, *z*); $H^{71}_A\cdots O^3_B$ 2.58 Å, $\angle C^7{}_A H^7{}_A{}^1 O^3_B$ 151°; $H^{71}_B\cdots O^3_A$ 2.69 Å, $\angle C^7_B H^{71}_B O^3_A$ 148°. Additional stabilization of the three-dimensional network is achieved via C–H···π interactions between the H^{163} atom of the methyl group and benzene ring (Ph_B), between H^{166} in the methyl group of the second independent molecule and Ph_A, and between H^{51} in the tetrahydropyridine ring and pyrazole ring (N^1_A–C^9_A).

The crystal structure of dihydrochloride **XII** is represented by one pyrazolopiperidine **IIa** dication and two chloride ions as external counterions (Fig. 7). Here, the asymmetric part of the unit cell contains only one independent molecule. The three protons in the dication are attached to different heteroatoms (N^1, N^6, and O^3), which indicates that no $C^{3a}H$ tautomer is formed in the crystal structure of **IIa**. The dihedral angle between the benzene and pyrazole ring planes in dication **XII** is 31.5° and is the largest among the examined pyrazolopiperidine **IIa** salts. As in the above cases, the formation of weak intramolecular hydrogen bond C^{15}–$H^{15}\cdots O^3$ (H···O 2.37 Å, $\angle C^{15}H^{15}O^3$ 113°) hinders rotation by a larger angle.

Analysis of intermolecular interactions in the crystal of dihydrochloride **XII** also revealed various hydrogen bonds (OH···Cl, NH···Cl, CH···Cl) and π···π contacts. The dication is linked to one chloride ion (Cl^2) by the hydrogen bond with the hydroxy hydrogen atom (H^3) [$H^3\cdots Cl^2$ 2.00(4) Å, $\angle O^3H^3Cl^2$ 174(4)°]. The second chloride ion (Cl^1) is involved in hydrogen bonds with both H^1 in the

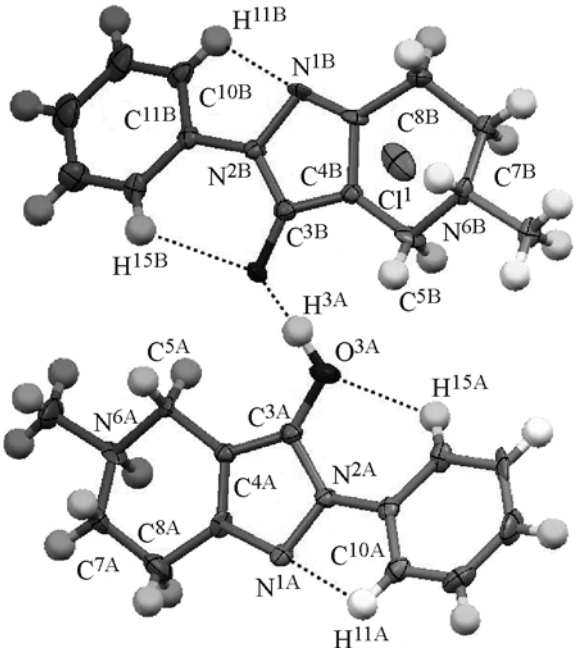


Fig. 5. Structure of hemihydrochloride **XI** in crystal according to the X-ray diffraction data. Non-hydrogen atoms are shown as thermal vibration ellipsoids with a probability of 50%; hydrogen atoms are shown by spheres of arbitrary fixed radius. Hydrogen bonds are shown with

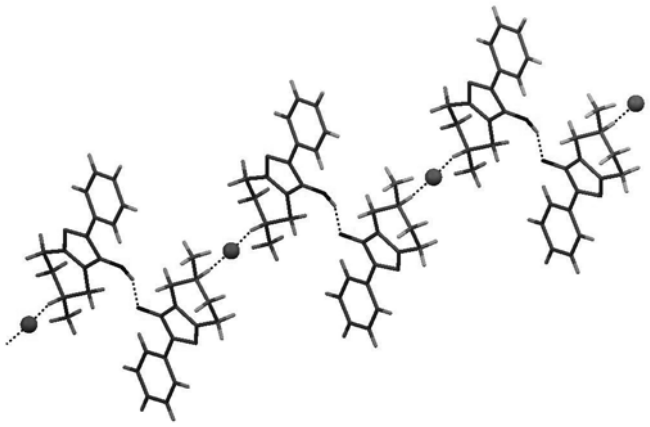


Fig. 6. Zigzag chains formed by hemihydrochloride **XI** molecules in crystal via N–H···Cl and O–H···O hydrogen bonds (view approximately along the 0*a* crystallographic axis). Hydrogen bonds are shown with dotted lines.

pyrazole fragment and H^6 (N^+H) in the tetrahydropyridine ring [$H^1\cdots Cl^1$ 2.16(4) Å, $\angle N^1H^1Cl^1$ 170(4)°, (1/2 – *x*, 1/2 + *y*, 1/2 – *z*); $H^6\cdots Cl^1$ 2.11(4) Å, $\angle N^6H^6Cl^1$ 163(3)°]. Stacks formed by dications **XII** are linked to each other through hydrogen bonds C–H···Cl with participation of both chloride ions (Cl^1 and Cl^2). Insofar as the number of chlorine atoms in crystals of **XII** is fairly large, hydrogen bonds formed by chloride ions (in combination with other intermolecular interactions) give rise to three-dimensional H-bond network (Fig. 8). In addition, stacking interactions between the pyrazole (N^1–C^9) and benzene rings (C^{10}–C^{15}) of the symmetry-related dications are observed.

The geometric parameters of the cations in hydrochlorides **X**–**XII** are given in Table 1. It is seen that the bond lengths and bond angles in the cations of salts **X**–**XII** differ insignificantly. The bond lengths indicate essential electron density delocalization in the pyrazole ring, as well as conjugation with the O^3 oxygen atom and even with the benzene ring. The C^3–O^3 bond in all cations is considerably shorter than the C–O bond in alcohols (1.413 Å) and even somewhat shorter than in phenol (1.362 Å) and enols (1.333 Å); on the other hand, it is considerably longer than the standard C=O bond (1.210 Å) [26]. The N^1–N^2 bond in all cations is similar or only slightly longer than the standard N–N bond in pyrazole (1.366 Å; bond order 1.5) [26]. Protonation of the pyrazole ring does not lead to significant extension of that bond, though its length attains the maximum value in cation **XIB** having no N^+H group. The bond lengths in the benzene ring are similar to those typical of benzene derivatives containing electron-withdrawing groups [26].

The bond angles in the pyrazole rings of **X**–**XII** approach the corresponding standard values for azoles. However, the $N^2N^1C^9$ angle in cations **XIA** and **XIB** is appreciably smaller, and the $N^1N^2C^3$ angle is larger, than in cations **X** and **XII** where the pyrazole ring is not protonated. The $O^3C^3N^2$ angle in all cations **X**–**XII** is larger than $O^3C^3C^4$, which may be due to intramolecular hydrogen bonding between O^3 and H^{15} in the benzene ring. The bond angles in the benzene rings differ insignificantly both within each benzene fragment and in different pyrazolopiperidinone cations **X**–**XII**.

Apart from rotation of the benzene ring with respect to the pyrazole ring plane, acoplanarity of cations **X**–**XII** is determined by conformation of the tetrahydropyridine ring which adopts a flattened *chair* structure. The C^5, C^4, C^9, and C^8 atoms of the tetrahydropyridine ring lie almost in the pyrazole ring plane, while the C^7 and N^6 atoms deviate from that plane in opposite directions. The methyl group always occupies equatorial position, and the hydrogen atom on N^6 is axial. The configuration of bonds at the N^2 atom

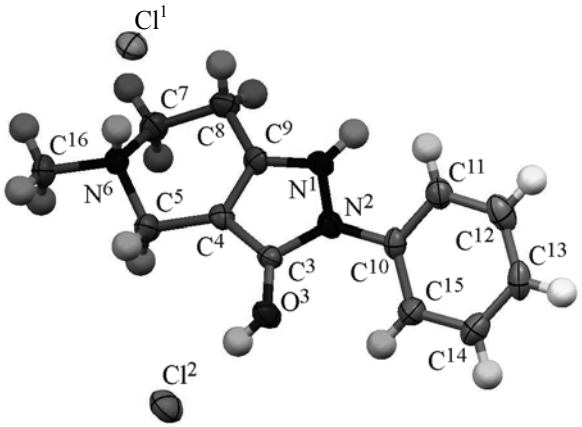


Fig. 7. Structure of dihydrochloride **XII** in crystal according to the X-ray diffraction data. Non-hydrogen atoms are shown as thermal vibration ellipsoids with a probability of 50%; hydrogen atoms are shown by spheres of arbitrary fixed radius.

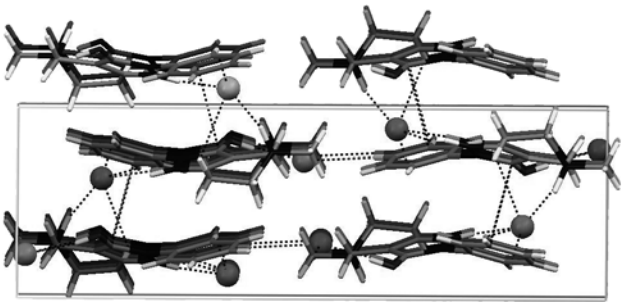


Fig. 8. Packing of the dications and chloride ions in the crystal structure of dihydrochloride **XII** (view along the 0*a* crystallographic axis). Intermolecular interactions are shown with dotted lines.

in the pyrazole ring is planar in all cations **X**–**XII**, and the N^6 atom in the piperidine fragment is characterized by pyramidal bond configuration with the degree of pyramidality C_P^N [27] ranging from 0.477 to 0.695.

As already noted, hydrochlorides **X**–**XII** are stable crystalline substances. Attempts to isolate free base **IIa** from hydrochlorides **X**–**XII** were unsuccessful. As a result, only complex mixtures containing compounds **V**–**IX** and some others were obtained [14, 22, 23], whose ratio depended on the isolation conditions. The isolation procedures and structures of the transformation products of pyrazolopiperidine **IIa** will be reported in detail in the next communication of this series.

EXPERIMENTAL

The ^{1}H and ^{13}C NMR spectra were recorded on Bruker Avance-600 (600 MHz for ^{1}H) and Bruker Avance-400 spectrometers (400 MHz) using the solvent signals as reference. The IR spectra were measured on a Bruker Vector-22 instrument from samples dispersed in mineral oil or pelleted with KBr (the difference in the positions of bands did not exceed ±2 cm^{-1}). The melting points were determined using a Boëtius hot stage and a standard PTP melting point apparatus. The mass spectra (electron impact) were obtained on a Trace MS instrument. Samples were injected as solutions in ethanol.

The X-ray analyses of single crystals of **X**–**XIII** were carried out at the Federal Joint Spectral Analytical Center (Arbuzov Institute of Organic and Physical Chemistry) on an Enraf–Nonius CAD-4 automatic X-ray diffractometer (graphite monochromator, 20°C). No drop in the intensity of three control reflections was observed during data acquisition. A correction for absorption was applied. The crystallographic data and parameters of X-ray diffraction experiments and structure refinement are given in Table 2.

The structures were solved by the direct method using SIR program [29] and were refined by the least-squares procedure first in isotropic and then in anisotropic approximation for all non-hydrogen atoms using SHELXL software package [30]. Hydrogen atoms in the hydroxy and ammonium groups in all structures were visualized from the difference electron density maps, and their positions were refined in isotropic approximation. The coordinates of the other hydrogen atoms were calculated on the basis of stereochemical considerations and were refined according to the riding model.

All calculations were performed with the aid of MolEN [31] and WinGX [32], intermolecular interactions were analyzed using PLATON [33], and the structures were plotted using Mercury program [34, 35].

The coordinates and temperature factors of atoms in the crystal structures of **X**–**XIII** were deposited to the Cambridge Crystallographic Data Centre.

5-Methyl-2-phenyl-3,3a,4,5,6,7-hexahydro-2*H*-pyrazolo[4,3-*c*]pyridin-3-one (IIa). Keto eester **Ia** (R = Me, Et), 0.292 mol, was gradually added to a solution of 3.16 g (0.292 mol) of freshly distilled phenylhydrazine in 25 mL of anhydrous propan-2-ol, and the mixture was left to stand overnight. The finely crystalline solid was filtered off, washed with propan-2-ol and (repeatedly) with methylene chloride, and dried at room temperature. Yield 3.6 g (53%), light

Table 1. Bond lengths and bond and torsion angles in the molecules of pyrazolopiperidinone hydrochlorides **X**–**XII**

Parameter	X		XI		XII
	A	B	A	B	
Bond lengths, Å					
O^3–H^3	–	1.10(8)	0.941(19)	–	0.85(4)
O^3–C^3	1.280(6)	1.297(6)	1.319(10)	1.310(10)	1.305(4)
N^1–N^2	1.390(6)	1.368(5)	1.381(10)	1.419(10)	1.371(4)
N^1–H^1	0.70(7)	0.94(6)	–	–	0.90(4)
N^1–C^9	1.338(6)	1.313(6)	1.388(15)	1.222(15)	1.334(4)
N^2–C^3	1.368(6)	1.359(6)	1.419(14)	1.341(14)	1.352(4)
N^2–C^{10}	1.434(6)	1.425(6)	1.382(11)	1.439(11)	1.438(4)
C^3–C^4	1.392(6)	1.405(6)	1.374(16)	1.377(16)	1.395(4)
C^4–C^5	1.494(7)	1.477(7)	1.530(14)	1.421(14)	1.500(4)
C^4–C^9	1.355(7)	1.377(7)	1.351(16)	1.452(15)	1.369(4)
N^6–C^5	1.496(6)	1.495(6)	1.489(13)	1.522(14)	1.495(4)
N^6–C^7	1.504(7)	1.428(8)	1.536(19)	1.445(17)	1.485(5)
N^6–C^{16}	1.489(6)	1.489(6)	1.450(13)	1.525(13)	1.495(4)
N^6–H^6	1.00(6)	1.00(6)	1.06(2)	1.06(2)	1.03(4)
C^7–C^8	1.536(7)	1.507(7)	1.460(12)	1.563(10)	1.535(4)
C^8–C^9	1.505(7)	1.496(6)	1.486(14)	1.505(14)	1.477(4)
Bond angles, deg					
$C^3O^3H^3$	–	122(4)	117(4)	–	112(3)
$N^2N^1C^9$	108.1(4)	109.1(4)	102.1(7)	105.4(7)	107.9(3)
$N^2N^1H^1$	119(6)	121.3(13)	–	–	124(3)
$C^9N^1H^1$	133(6)	128.4(13)	–	–	128(3)
$N^1N^2C^{10}$	121.2(4)	122.8(4)	116.8(7)	119.0(7)	121.7(3)
$N^1N^2C^3$	107.5(4)	107.5(4)	111.1(7)	110.0(8)	108.3(3)
$C^3N^2C^{10}$	131.3(4)	129.6(4)	130.5(8)	130.9(8)	130.0(3)
$C^5N^6C^7$	112.9(4)	116.0(4)	110.3(13)	114.4(15)	111.9(3)
$C^5N^6C^{16}$	110.4(4)	110.7(5)	110.9(7)	113.0(7)	109.7(3)
$C^7N^6C^{16}$	110.5(4)	114.2(5)	113.1(9)	110.1(8)	110.5(3)
$C^5N^6H^6$	107.7(10)	103.4(11)	107.9(13)	104.6(12)	110(2)
$C^7N^6H^6$	106.8(11)	106.5(11)	104.5(12)	109.9(12)	108(2)
$C^{16}N^6H^6$	108.2(11)	104.7(11)	109.8(18)	104.1(18)	107(2)
$O^3C^3N^2$	121.0(4)	122.1(5)	118.9(10)	122.6(11)	118.5(3)
$O^3C^3C^4$	131.7(5)	129.8(5)	135.1(11)	129.2(10)	133.4(3)
$N^2C^3C^4$	107.3(4)	108.1(4)	105.9(9)	107.8(9)	108.0(3)
$C^3C^4C^9$	107.6(5)	105.0(4)	106.6(10)	102.4(10)	105.8(3)
$C^3C^4C^5$	129.3(5)	131.3(5)	129.3(9)	132.2(10)	130.8(3)
$C^5C^4C^9$	123.0(4)	123.7(4)	124.1(9)	124.8(9)	123.4(3)

Table 1. (Contd.)

Parameter	X		XI		XII
	A	B	A	B	
Bond angles, deg					
$N^6C^5C^4$	109.1(4)	109.3(4)	109.0(7)	109.4(8)	107.9(3)
$N^6C^7C^8$	111.7(4)	114.1(5)	114.9(11)	110.1(9)	110.9(3)
$C^7C^8C^9$	106.9(5)	109.5(5)	108.4(8)	111.5(8)	108.9(3)
$N^1C^9C^4$	109.5(4)	110.3(4)	114.0(9)	114.2(9)	110.0(3)
$N^1C^9C^8$	124.2(5)	126.2(5)	121.7(9)	126.1(8)	125.6(3)
$C^4C^9C^8$	126.3(5)	123.5(5)	124.3(11)	119.5(11)	124.5(3)
$N^2C^{10}C^{11}$	120.6(4)	120.4(5)	120.4(6)	117.9(6)	119.5(3)
$N^2C^{10}C^{15}$	119.2(5)	119.3(5)	119.5(6)	121.9(5)	119.2(5)
Torsion angles, deg					
$H^3O^3C^3N^2$	–	–172(4)	–166(6)	–	–148(3)
$H^3O^3C^3C^4$	–	6(4)	19(6)	–	36(3)
$C^9N^1N^2C^3$	0.8(6)	0.4(5)	4.8(15)	3.9(17)	–1.9(4)
$C^9N^1N^2C^{10}$	178.9(5)	178.7(5)	171.5(11)	–173.6(12)	179.9(3)
$N^2N^1C^9C^4$	0.2(7)	0.8(6)	–2.6(18)	–3.7(19)	2.4(4)
$N^2N^1C^9C^8$	–179.0(5)	–178.1(5)	178.6(15)	–178.8(15)	–178.2(4)
$H^1N^1N^2C^3$	–179(7)	–168(4)	–	–	–180(3)
$N^1N^2C^3O^3$	177.0(5)	177.4(4)	178.0(13)	–174.9(13)	–176.5(3)
$N^1N^2C^3C^4$	–1.5(6)	–1.3(5)	–5.4(16)	–2.4(16)	0.7(5)
$C^{10}N^2C^3O^3$	–0.8(9)	–0.8(8)	14(2)	2(2)	1.5(6)
$C^{10}N^2C^3C^4$	–179.3(5)	–179.4(5)	–169.7(13)	174.7(12)	178.8(4)
$N^1N^2C^{10}C^{11}$	9.8(8)	–16.1(8)	–14.9(14)	19.2(14)	30.2(6)
$N^1N^2C^{10}C^{15}$	–169.9(5)	164.9(5)	168.3(9)	–166.3(10)	–149.9(4)
$C^3N^2C^{10}C^{11}$	–172.7(5)	161.9(5)	148.7(12)	–157.6(12)	–147.6(4)
$C^3N^2C^{10}C^{15}$	7.6(8)	–17.2(8)	–28.1(17)	16.9(18)	32.3(6)
$C^7N^6C^5C^4$	46.7(6)	42.3(6)	43.6(14)	–51.3(16)	50.8(4)
$C^5N^6C^7C^8$	–65.8(6)	–60.2(7)	–65.5(18)	63.9(17)	–67.8(4)
$H^6N^6C^7C^8$	52.6(16)	54.3(15)	51(2)	–53(2)	53(2)
$C^{16}N^6C^5C^4$	171.0(4)	174.5(4)	169.5(13)	–178.3(13)	173.8(4)
$C^{16}N^6C^7C^8$	170.1(5)	169.3(5)	169.9(15)	–167.7(14)	169.5(3)
$O^3C^3C^4C^5$	0.5(10)	1.7(8)	–1(3)	0(3)	–2.8(8)
$O^3C^3C^4C^9$	–176.6(6)	–176.9(5)	179.3(18)	172.1(16)	177.4(4)
$N^2C^3C^4C^5$	178.8(5)	–179.7(5)	–176.5(15)	–171.5(17)	–179.5(4)
$N^2C^3C^4C^9$	1.7(6)	1.7(5)	3.5(18)	0.3(17)	0.7(5)
$C^3C^4C^5N^6$	167.8(5)	169.6(5)	165.9(16)	–166.6(17)	162.7(4)
$C^9C^4C^5N^6$	–15.5(7)	–12.0(7)	–14(2)	23(2)	–17.5(6)
$C^3C^4C^9N^1$	–1.2(7)	–1.5(6)	–1(2)	2(2)	–1.9(5)

Table 1. (Contd.)

Parameter	X		XI		XII
	A	B	A	B	
Torsion angles, deg					
$C^3C^4C^9C^8$	178.0(5)	177.4(5)	178.1(16)	177.8(15)	178.6(4)
$C^5C^4C^9N^1$	–178.5(5)	179.8(4)	179.4(14)	174.9(16)	178.2(4)
$C^5C^4C^9C^8$	0.7(9)	–1.4(8)	–2(3)	–10(3)	–1.2(6)
$N^6C^7C^8C^9$	45.5(6)	41.5(7)	47(2)	–45(2)	44.4(4)
$C^7C^8C^9N^1$	163.6(5)	166.3(5)	164.4(16)	–166.0(17)	168.6(4)
$C^7C^8C^9C^4$	–15.5(8)	–12.4(7)	–14(2)	19(2)	–12.0(5)

beige powder, mp 143–145°C (decomp., PTP), 138–143°C (decomp., Boëtius). The product was insoluble in benzene, chloroform, carbon tetrachloride, methylene chloride, diethyl ether, and acetonitrile, very poorly soluble in DMSO, methanol, and propan-2-ol, and soluble in water. IR spectrum (KBr), ν, cm^{-1}: 3056, 3030, 2974, 2936, 2895, 2859, 2743 2685, 2576, 2474, 2341, 1609, 1588, 1579, 1537, 1493, 1453, 1420, 1380, 1351, 1318, 1275, 1240, 1161, 1152, 1128, 1084, 1067, 1051, 1032, 1011, 996, 972. ^{1}H NMR spectrum, δ, ppm (*J*, Hz): in D_2O: 7.50 d (2H, *o*-H, ^3J = 7.7), 7.41 t (2H, *m*-H, ^3J = 7.3), 7.24 t (1H, *p*-H, ^3J = 7.3), 3.91 br.s (2H, CH_2), 3.31 br.s (2H, CH_2), 2.81 s (3H, NCH_3), 2.77 t (2H, CH_2, ^3J = 6.2); in CD_3OD): 7.73 d (2H, *o*-H, ^3J = 7.8), 7.38 t (2H, *m*-H, ^3J = 7.6), 7.18 t (2H, *p*-H, ^3J = 7.6), 3.88 br.s (2H, CH_2), 3.40–3.27 m $(CH_2)^2$, 2.85 t (2H, CH_2, ^3J = 6.6), 2.82 s (3H, NCH_3). Found, %: C 67.93; H 7.01; N 18.45. *m*/*z* 229 $[M]^+$. $C_{13}H_{15}N_3O$. Calculated, %: C 68.11; H 6.50; N 18.32. *M* 229.26.

The filtrate was combined with the washings and evaporated, and the residue was recrystallized from carbon tetrachloride to isolate 0.75 g of compound **V**.

5-Methyl-2-phenyl-3,3a,4,5,6,7-hexahydro-2*H*-pyrazolo[4,3-*c*]pyridin-3-one sesquihydrochloride (X). A mixture of 2.16 g (0.015 mol) of phenylhydrazine hydrochloride and 3.1 g (0.015 mol) of methyl 1-methyl-4-oxopiperidine-3-carboxylate hydrochloride (**XIII**) in 50 mL of anhydrous methanol was heated at 50–60°C until it became homogeneous and was then heated for 10 min under reflux. The solution was filtered while hot, and the filtrate was left overnight at room temperature. The precipitate (1.6 g) was filtered off and washed on a filter with cold methanol. White crystalline powder, mp 219–221°C (PTP). The filtrate was evaporated by half, and colorless needles separated from the residue on storage were filtered off, washed with methanol, and dried in air. An additional portion of **X**, 1.25 g with mp 220–222°C (decomp., PTP) was thus isolated. The two portions of the product were combined and recrystallized from a mixture of ethanol with water and diethyl ether to obtain 1.8 g (42.4%) of **X** as colorless needles with mp 220–222°C (decomp., PTP) or 164–166°C (decomp., Boëtius); published data [13]: mp 224–225°C for 1 : 1 hydrochloride **IIa**·HCl. IR spectrum (KBr), ν, cm^{-1}: 3134, 3056, 3016, 2989, 2944, 2682, 2623, 2584, 2540, 2460, 2424, 2391, 2350, 1616, 1596, 1548, 1501, 1459, 1422, 1411, 1356, 1306, 1288, 1243, 1221, 1188, 1178, 1144, 1085, 1046, 1008, 958, 913. ^{1}H NMR spectrum, δ, ppm (*J*, Hz): in D_2O: 7.45–7.24 m (5H, C_6H_5), 4.15 d (1H, *J* = 14.2), 3.78 d (1H, *J* = 14.6), 3.71–3.58 m (1H), 3.38–3.21 m (1H), 3.07–2.76 m (5H, CH_2, NCH_3); in DMSO-d_6–CCl_4: 7.71 d (2H, *o*-H, *J* = 8.0), 7.42 t (2H, *m*-H, *J* = 7.5), 7.23 t (1H, *p*-H, *J* = 7.5), 4.30 d.d (1H, 4-H, *J* = 2.6, 14.2), 3.95 d.d (1H, 4-H, *J* = 6.1, 14.2), 3.62–3.54 m (1H, CH_2), 3.44–3.27 m (1H, CH_2), 3.15–2.96 m (1H, CH_2), 2.92–2.78 d (4H, NMe, CH_2). Mass spectrum: *m*/*z* 229.12056 $[M]^+$. Found, %: C 54.85; H 6.79; N 14.88; Cl 19.20. $C_{26}H_{33}Cl_3N_6O_2$. Calculated, %: C 54.98; H 5.86; N 14.80; Cl 18.73. *M* 229.12151 (for free base **IIa**).

5-Methyl-2-phenyl-3,3a,4,5,6,7-hexahydro-2*H*-pyrazolo[4,3-*c*]pyridin-3-one hemihydrochloride (XI). Compound **XIII**, 3.0 g (0.0144 mol) was dissolved in 40 mL of anhydrous methanol on heating, the solution was cooled to 30°C and added to a solution of 1.56 g (0.0144 mol) of phenylhydrazine, and the mixture was stirred, allowing it to cool down to room temperature, and was left to stand overnight (15 h). The light brown

[2] The signal is obscured by the solvent.

Table 2. Crystallographic parameters of hydrochlorides **X–XIII** and conditions of X-ray diffraction experiments

Parameter	**X**	**XI**	**XII**	**XIII**
Color, habit	Colorless, prisms			
Space group	$P2_1/n$	$P2_1$	$P2_1/n$	$P2_1/n$
Formula	$C_{13}H_{17}N_3O^+\cdot C_{13}H_{16}N_3O^+\cdot 3Cl^-$	$C_{13}H_{16}N_3O^+\cdot C_{13}H_{15}N_3O^+\cdot Cl^-$	$C_{13}H_{17}N_3O\cdot 2Cl^-$	$C_8H_{14}NO_3^+\cdot Cl^-$
Unit cell parameters, Å	*a* 13.924(6), *b* 13.770(4), *c* 15.293(3), β 115.50(3)°	*a* 6.037(3), *b* 18.926(6), *c* 11.020(5), β 99.57(3)°	*a* 9.181(2), *b* 6.984(1), *c* 22.116(5), β 101.31(2)°	*a* 11.121(7), *b* 6.867(2), *c* 13.523(4), β 98.02(4)°
Volume, Å^3	2647(1)	1241.6(9)	1390.5(5)	1022.6(8)
Z	4	2	4	4
Molecular weight	567.93	495.02	302.20	207.65
d_{calc}, g/cm^3	1.425	1.324	1.443	1.349
Absorption coefficient, mm^{-1}	3.435	1.650	0.462	3.150
F(000)	1192	524	632	440
Radiation source, λ, Å	CuK_α, λ 1.54184	CuK_α, λ 1.54184	MoK_α, λ 0.71073	CuK_α, λ 1.54184
Range of θ	$3.60 \le \theta \le 64.86$	$4.07 \le \theta \le 71.40$	$2.61 \le \theta \le 26.29$	$4.83 \le \theta \le 64.83$
Spherical segments	$-15 \le h \le 0$, $-16 \le k \le 0$, $-16 \le l \le 16$	$0 \le h \le 7$, $-22 \le k \le 23$, $-12 \le l \le 0$	$-11 \le h \le 0$, $-2 \le k \le 8$, $-27 \le l \le 27$	$-12 \le h \le 12$, $-7 \le k \le 0$, $-14 \le l \le 0$
Total number of reflections	3958	2161	3226	1449
R_{int}	0.0771	0.0525	0.0518	0.0692
Number of independent reflections with $I > 2\sigma(I)$	1702	1427	1034	1282
Divergence factor for reflections with $I > 2\sigma(I)$	*R* 0.0528, R_w 0.1018	*R* 0.0251, R_w 0.0588	*R* 0.0477, R_w 0.0616	*R* 0.0360, R_w 0.0949
Goodness of fit	0.916	0.982	0.890	0.997
Number of variables	349	260	185	129
Maximum and minimum residual electron density peaks, e^-/Å^3	0.245, –0.236	0.058, –0.068	0.272, –0.352	0.354, –0.293

solution was diluted with an equal volume of diethyl ether, the mixture was filtered, and the filtrate was left to stand at room temperature. The precipitate was filtered off and washed with methanol–diethyl ether. Yield 2.1 g (58.8%), light yellow needles, mp 173–175°C (decomp., PTP), 160–164°C (decomp., Boëtius). IR spectrum (KBr), ν, cm^{-1}: 3114, 3039, 2959. 2934, 2904, 2852, 2807, 2653, 2590, 2569, 2467, 1663, 1624, 1589, 1557, 1489, 1456, 1431, 1416, 1350, 1326, 1243, 1202, 1177, 1120, 1089, 1061, 1042, 1021. ^{1}H NMR spectrum (250 MHz, D_2O), δ, ppm: 7.59–7.41 m (4H, *o*-H, *m*-H), 7.40–7.28 m (1H, *p*-H), 4.01 br.s (1H), 3.49 br.s (1H), 2.99 s (3H, NMe), 2.95–2.78 m (2H). Found, %: C 62.76; H 7.44; N 16.94; Cl 7.10. $C_{26}H_{31}ClN_6O_2$. Calculated, %: C 63.08; H 6.31; N 16.98; Cl 7.16.

5-Methyl-2-phenyl-3,3a,4,5,6,7-hexahydro-2*H*-pyrazolo[4,3-*c*]pyridin-3-one dihydrochloride (XII). A solution of 0.5 g of hydrochloride **X** in 2 mL of

concentrated aqueous HCl was left to stand in an open beaker at room temperature until water evaporated. The residue was recrystallized from aqueous methanol to isolate 0.35 g of **XII** as colorless prisms, mp 225–227°C (decomp., PTP), 163–165°C (decomp. Boëtius). IR spectrum (mineral oil), ν, cm^{-1}: 3064, 3014, 2698, 2615, 2568, 2107, 1598, 1556, 1502, 1451, 1414, 1357, 1313, 1287, 1272, 1225, 1189, 1159, 1141, 1087, 1046, 1021, 1008, 971, 953, 810, 771, 722, 697. ^{1}H NMR spectrum (DMSO-d_6), δ, ppm (*J*, Hz): 11.55 s (0.85H, N^+H), 7.70 d (2H, *o*-H, *J* = 8.0), 7.35 t (2H, *m*-H, *J* = 7.5), 7.06 t (1H, *p*-H, *J* = 7.5), 4.35 d (2H, *J* = 14.1), 4.00–3.91 m (1H), 3.61–3.50 m (1H), 3.34 s (1H), 3.00–2.89 m (1H), 2.88 s (3H, NMe), 2.73–2.68 m (1H). Found, %: C 51.57; H 5.49; Cl 23.67; N 13.78. $C_{13}H_{17}Cl_2N_3O$. Calculated, %: C 51.63; H 5.63; Cl 23.49; N 13.90.

Methyl 1-methyl-4-oxopiperidine-3-carboxylate hydrochloride (XIII) was synthesized by cyclocondensation of dimethyl 3,3′-(methylimino)dipropanoate according to [36]. Recrystallization from methanol–diethyl ether (10 : 1) gave colorless crystals with mp 174–176°C (PTP), 170.5–172°C (Boëtius); published data: mp 168°C [36], 172°C [37]). IR spectrum (KBr), ν, cm^{-1}: 3136, 3006, 2994, 2956, 2700–2170, 1677, 1617, 1554, 1485, 1474, 1417, 1401, 1378, 1365, 1328, 1296, 1257, 1227, 1183, 1145, 1132, 1102, 1061, 1028, 981, 944, 878, 821, 791, 767, 702. ^{1}H NMR spectrum (DMSO-d_6), δ, ppm: 12.2 br.s (1H, NH), 11.9 s (1H, OH), 3.80 s (3H, OMe), 3.75–3.65 m and 3.50–3.15 m (6H, CH_2), 2.85 s (3H, NMe). Mass spectrum, *m*/*z* (I_{rel}, %): 172 (3), 171 (18) $[M]^+$, 172 (7), 156 (12) $[M - Me]^+$, 138 (100) $[M - MeOH]^+$, 128 (6), 112 (29).

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