Synthesis of *N*-unsubstituted 2-arylpyrazolo[1,5-*a*]benzimidazoles from 1-benzylideneamino-2-methylbenzimidazole and the role of acylotropic and acylotropic-prototropic isomerization

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2-Aryl-4*H*-pyrazolo[1,5-*a*]benzimidazoles were synthesized for the first time from 1-benzylideneamino-2-methylbenzimidazole by the benzoylation of the methyl group followed by the cyclization of the resulting vinyl acylates in concentrated HCl. The key steps of the process were studied by quantum chemical methods for model systems. It was shown that the concerted intramolecular acylotropic and acylotropic-prototropic transformations play an important role in this process.

Key words: 1-benzylideneamino-2-methylbenzimidazole, 4*H*-pyrazolo[1,5-*a*]benzimidazole, quantum chemical calculations, density functional theory, B3LYP density functional, transition states, acylotropic and acylotropic-prototropic isomerization.

Compounds of the 4*H*-pyrazolo[1,5-*a*]benzimidazole series have found wide use in color photography.[1,2] They are also used in the synthesis of various dye composites[3,4] and organic electronic materials.[5] Methods for the synthesis of 4*H*-pyrazolo[1,5-*a*]benzimidazoles have been extensively developed (see, for example, the review[6]). Nevertheless, investigations in this field are still important.

There are two general approaches to the synthesis of the fused system under consideration. In the chronologically first approach, which has been most well elaborated, pyrazole derivatives (pyrazolones, aminopyrazolones, chloropyrazoles) are used as the starting reagents.[6—8] In another, more recent approach, the pyrazole ring annulated to the benzimidazole ring is formed in 1,2-diamino- or 2-acetyl-1-aminomethylthiobenzimidazoles,[9,10] which became available only after the development of methods for the direct *N*-amination of benzimidazoles.[11]

Earlier,[12] *N*(4)-alkylpyrazolo[1,5-*a*]benzimidazoles have been successfully synthesized by the reactions of 1-amino-2-methyl-3R-benzimidazolium salts with acid anhydrides in the presence of K_2CO_3. It was hypothesized that these reactions afford methylene bases as intermediates, which undergo *C*-acylation and cyclization. However, *N*-unsubstituted pyrazolo[1,5-*a*]benzimidazoles are not generated from 1-amino-2-methylbenzimidazole under these conditions; instead, the bis-acylation of the amino groups occurs.[12]

In the present study, 2-aryl-4*H*-pyrazolo[1,5-*a*]benzimidazoles **1a—d** were synthesized for the first time starting from 1-benzylideneamino-2-methylbenzimidazole (**2**)[13] by the benzoylation at the methyl group followed by the cyclization of the resulting vinyl benzoates **3a—d** in concentrated HCl.

Results and Discussion

Our investigations showed that benzylideneamino derivative **2**, like its 1*H* and 1-Et analogs,[14,15] easily undergoes benzoylation with aroyl chlorides in the presence of Et_3N to form *C*,*O*-dibenzoylation products **3a—d** (Scheme 1). The reaction occurs in THF with 2 moles of aroyl chloride at 20—25 °C to give products in virtually quantitative yield.

Vinyl benzoates **3a—d** are crystalline pale yellow compounds with a very labile *O*-benzoylic bond. In particular, it was shown by an example of esters **3a**,**d** that these compounds easily undergo morpholinolysis to form 2-phenacyl derivatives **4** (*cf.* lit. data[16]).

According to the ^{1}H NMR data, compounds **4**, like their 1*H* analogs,[16] exist in solution in equilibrium with enamino ketone form **4´**. The signals for the methylene and methine protons of both tautomeric forms, from which it is convenient to determine the ratio of tautomers **4** and **4´**, are observed at δ 4.75—4.80 and 6.45—6.53, respectively. For compound **4a** (Ar = Ph) in $CDCl_3$, this ratio is ~1 : 1. An increase in the electron-donating ability of the aryl substituent (Ar = *p*-$MeOC_6H_4$) leads to an increase in the fraction of tautomer **4** to ~75%.

Esters **3a—d** undergo cyclization to 4*H*-pyrazolobenzimidazoles **1a—d** in 60—65% yields under reflux in con-

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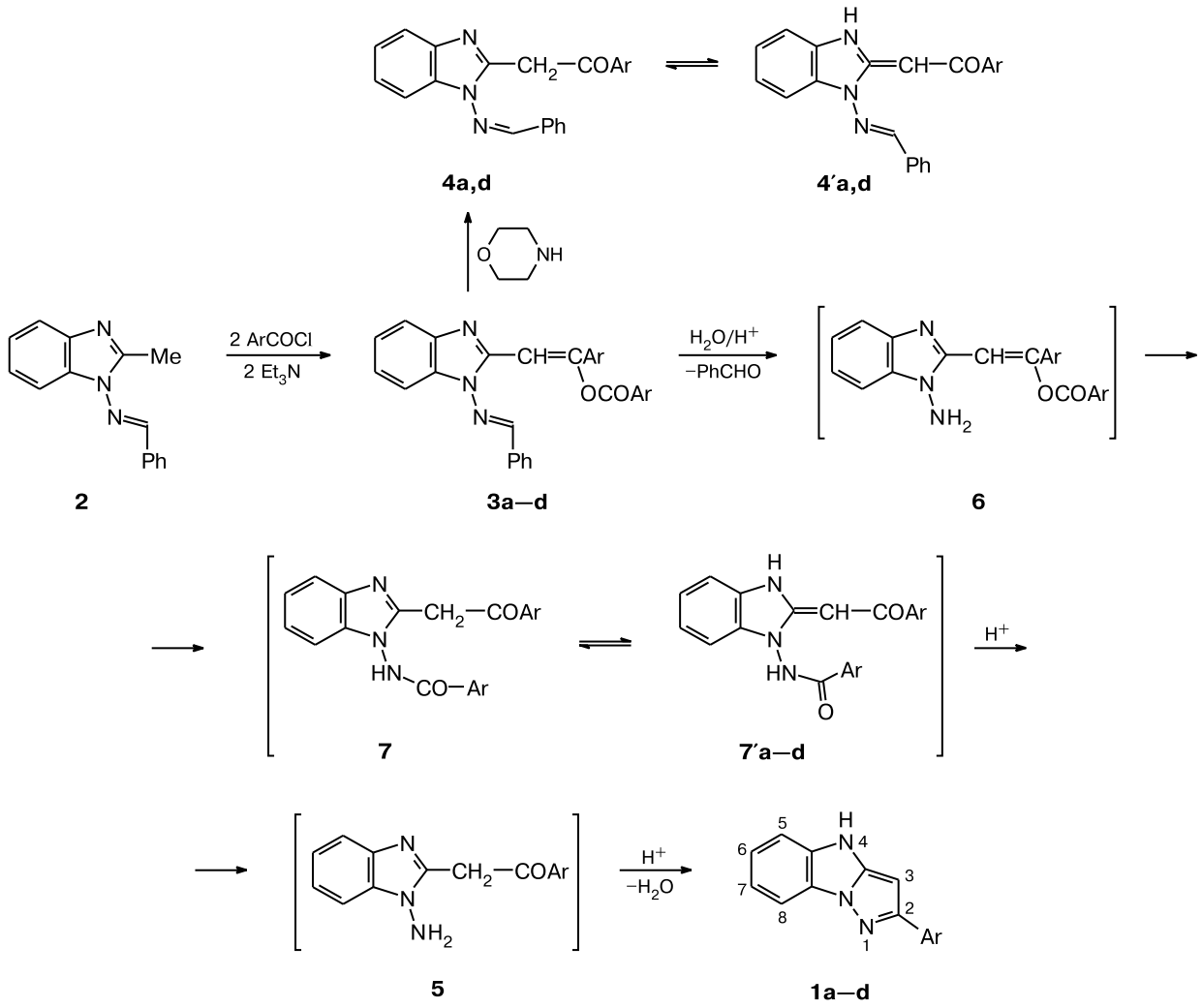
Scheme 1



Ar = Ph (**a**), *p*-MeC_6H_4 (**b**), *p*-ClC_6H_4 (**c**), *p*-$MeOC_6H_4$ (**d**)

centrated HCl for 1.5 h. To exclude undesired side transformations, the reaction was performed during the first 15 min with azeotropic removal of benzaldehyde that formed. The ^{1}H NMR spectra of compounds **1** show signals for aromatic protons of the aryl substituent and the benzimidazole moiety at δ 7.0—7.8 along with singlets for the proton H(3) of the pyrazole ring at δ 6.0 and the proton of the NH group at δ 11.

Undoubtedly, pyrazolobenzimidazoles **1** are directly formed from 1-amino-2-phenacylbenzimidazoles **5**, which we failed to detect and which were assumed to be products of the hydrolytic C=N and ArCO—O bond cleavage in benzoates **3**. However, we unexpectedly found that the transition **3** → **5** occurs in a more complex way through the intermediate aroylation of the *N*-amino group in 1-amino derivatives **6** and the formation of amides **7**. Compounds **7c,d** were isolated and identified. According to the TLC data, amides **7** were virtually the only transformation products of vinyl benzoates **3** within 15—20 min after the beginning of the reaction.

Unlike compounds **3**, amides **7** are colorless substances of low chromatographic mobility ($R_f \approx 0.05$). The IR spectra of these compounds show a strong common absorption band of two carbonyl groups at 1665 cm^{-1} and a low-intensity band of the secondary amino group at 3254 cm^{-1}. The structure of acyl derivatives **7** was confirmed by the mass spectrum of product **7d** (*m*/*z* 415 $[M]^+$) and the ^{1}H NMR spectra of compounds **7c**,**d**, which are superpositions of the spectra of ketone **7** and enamino ketone **7′** tautomeric forms similar to those formed by acetophenones **4**.

To study the chemism of a series of key steps in the synthesis of pyrazolobenzimidazoles **1**, we performed quantum chemical calculations. Based on the results of

the calculations, the mechanism of the acylation of 2-methylbenzimidazoles at the methyl group in the presence of bases, which has been very poorly covered in the literature, was characterized and the unusual concerted mechanism of the intramolecular isomerization of esters **6** to amides **7** was shown to occur.

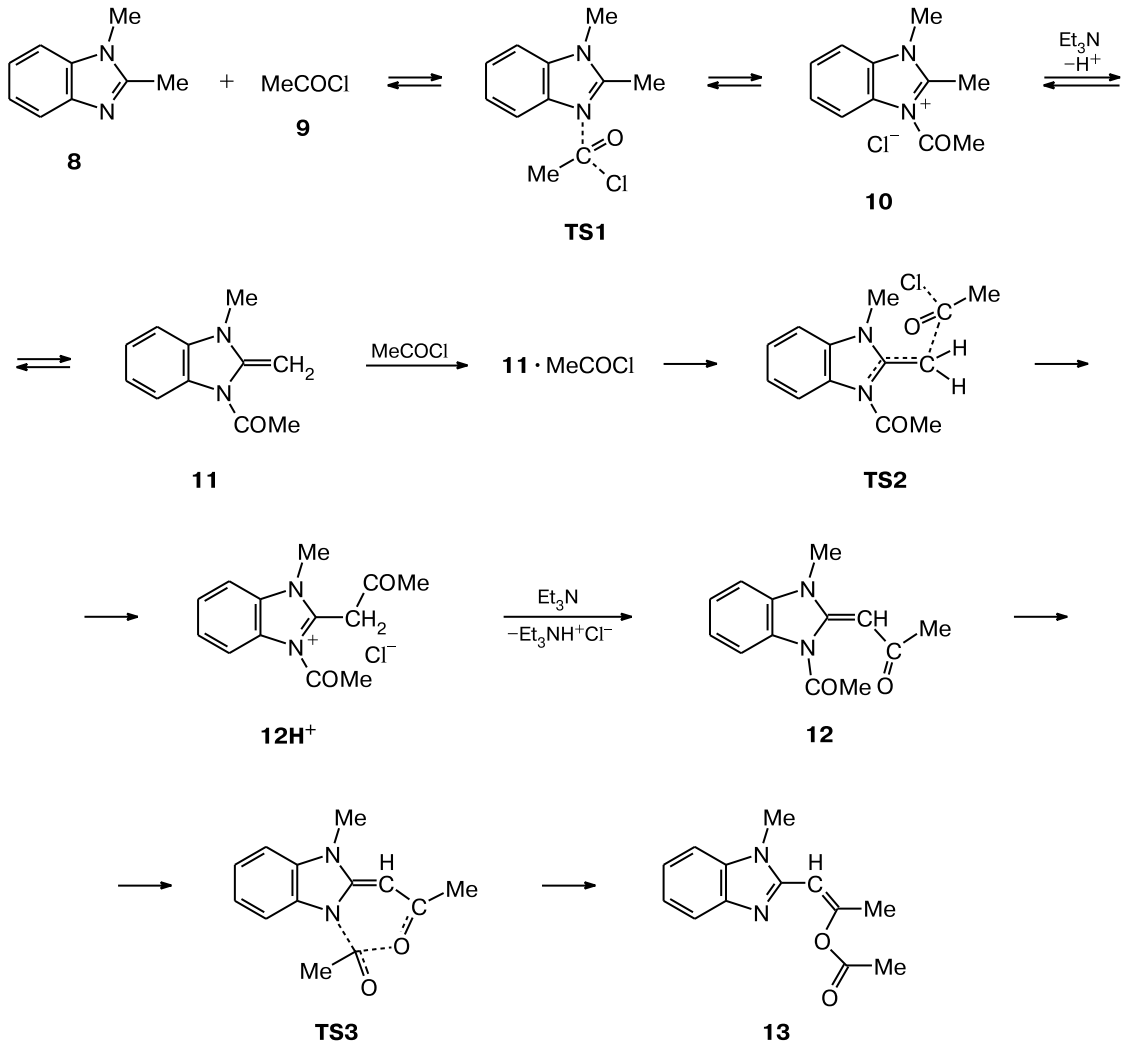
Results of quantum chemical study of acylotropic processes occurring in the synthesis of pyrazolobenzimidazoles 1. We studied the acylation at the methyl group in position 2 of benzimidazoles by an example of the model reaction of 1,2-dimethylbenzimidazole (**8**) with acetyl chloride (**9**) by the density functional theory method with the use of the B3LYP functional and the standard 6-31G** basis set.

According to the results of calculations, the acylation of benzimidazole **8** with acid chloride **9** occurs *via* a four-step mechanism involving the bimolecular nucleophilic substitution of the chlorine atom in AcCl (see Refs 17—19) to form *N*-acetylbenzimidazolium salt **10** as the initial step (Scheme 2).

The *N*-acylation involves the formation of a weakly-bound collision complex of the reagents followed by the formation of a highly polar (μ_{calc} = 10.1 D) transition state (TS) of the reaction **TS1** (Fig. 1, Table 1). The **TS1** contains the tetragonal-coordinated carbon atom of the CO group. This atom forms loosened N—C and C—Cl bonds with the entering and leaving groups, which have almost equal Mulliken bond orders (BO) (0.47 and 0.55, respectively).

The Gibbs free energy of activation $\Delta^{\neq}G^{\circ}_{calc}$ of the gas-phase *N*-acylation is 21.3 kcal mol^{-1}, which is unexpectedly high for the highly reactive starting compounds. However, this energy should sharply decrease in the liquid phase

Scheme 2



TS is the transition state, **11** · MeCOCl is the collision complex.

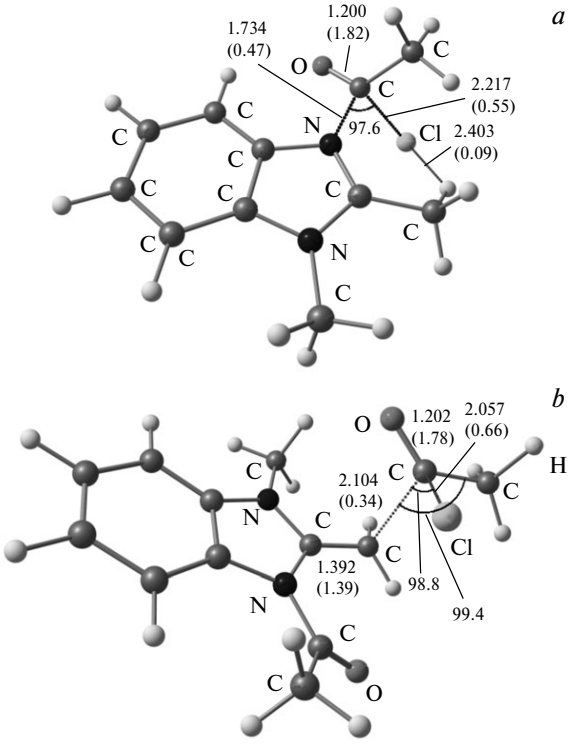


Fig. 1. Structures of the transitions states **TS1** (*a*) and **TS2** (*b*) of the N- and C-acylation, respectively. Here and in Figs 2 and 3, the bond lengths (Å), the Mulliken bond orders (in parentheses), and the N—C—Cl angles at the carbon atoms, at which the nucleophilic *N*-substitution occurs, are given.

and, in particular, in polar media, and the reaction rate should be substantially higher due to the solvation stabilization of the highly polar TS of the reaction typical also for the S_N2 substitution of the halogen atom at the sp^3-hybridized carbon atom.[20]

N-Acylium salt **10** is very unstable and readily decomposes to the starting reagents **8** and **9** because of the fact that the N—Ac bond is relatively weak (BO = 0.70, d_{C-N} = 1.538 Å) and is easily cleaved after the S_N2 attack by the chloride counterion. In the absence of solvation, the dissociation of salt **10** is nearly barrierless ($\Delta^{\neq}G^{\circ}_{dis} \approx$ $\approx$ 1 kcal mol^{-1}). Hence, it is not surprising that *N*-acylbenzimidazolium salts only with such a weakly nucleophilic anion as $SbCl_6^-$ were preparatively isolated.[21]

In the next step, salt **10** containing the CH-acidic 2-methyl group is deprotonated with triethylamine to give methylene base **11**, which is acylated with acid chloride **9** at the strongly nucleophilic methylene group to form C,N-diacyl derivative **12**. The latter is the structural analog of esters **3**. This unusual reactivity of the CH_2 group is evidently associated with the fact that the binding of an electrophile is very energetically favorable due to aromatization of the five-membered heterocyclic moiety. Like the electrophilic aromatic substitution, the reaction under consideration involves the axial attack of the π system of the substrate, which is favorable for the efficient interaction between the frontier molecular orbitals of the reagents. In the weakly endoergic starting collision complex that formed, the substrate and the electrophile are arranged in parallel planes, AcCl being located directly above the methylene group of base **11**. The electrophilic and nucleophilic centers of the reacting molecules are at a large distance from each other (3.48 Å). Then the collision complex is transformed into TS of *C*-acylation **TS2** (see Fig. 1). The latter is trans-

Table 1. Physicochemical characteristics of intermediates, reagents, final products, and transition states of the acylation of 1,2-dimethylbenzimidazole at 25 °C

Structure	$-G^{\circ}$/au	$\Delta^{\neq}G^{\circ}$ /kcal mol^{-1}	μ_{calc}/D	$-\bar{\nu}_i$/cm^{-1}
8	458.3837124	—	3.8	—
9	613.43224228	—	2.9	—
C*	1071.8091743	—	6.6	—
Σ**	1071.81595468	—	—	—
TS1	1071.7752721	21.3	10.1	160
10	1071.7765613	0.8	12.1	—
11	610.9723634	—	3.3	—
TS2	1224.367600	23.2	5.6	314
12	763.5938398	—	4.7	—
TS3	763.58236587	7.2	4.9	272
13	763.6067507	—	3.7	—
6e	779.616047	—	—	—
TS4	779.56065570	34.7	6.4	306
7″e	779.6111424	—	5.2	—
6eH$^+$	780.010164735	—	—	—
TS5	779.96144401	30.6	—	204

* The collision complex.

** The sum of the energies of the reagents.

formed into the protonated form of the diacyl derivative **12H**$^+$, which is the formal analog of the σ complex of the usual aromatic electrophilic substitution. The further deprotonation with triethylamine affords free base **12**. The activation energy of *C*-acylation $\Delta G^{\neq}_{calc}$ is 23.2 kcal mol^{-1}.

The concerted intramolecular 1,5-N→O acylotropic isomerization of compound **12** is the final step in the acylation of benzimidazole **8** giving the final product, *viz.*, vinyl acetate **13**. This transformation occurs through the moderately polar (μ_{calc} = 4.9 D) **TS3** (Fig. 2), which has a structure with the tetragonal carbon atom of the CO group classical for the intramolecular acylotropy.[22] This carbon atom is bound to two nucleophilic centers by the Ac—O and Ac—N bonds, which are loosened to approximately the same degree. The orders of these bonds and of the C=O bond are 0.53, 0.45, and 1.86, respectively. The acetyl group of **TS3** is involved in the nonpolar six-membered cyclic reaction unit and deviates from the common plane passing through the other nonhydrogen atoms. Since the N→O acylotropy under consideration is accompanied by the aromatization of the imidazole ring, it is very fast. This is evident from the energy $\Delta^{\neq}G^{\circ}_{calc}$ = 7.2 kcal mol^{-1}, which is very low for acylotropic processes.

As follows from the aforesaid, either the acylation of the methylene base or a particular deprotonation process is the rate-determining step of the bis-acylation of *N*-substituted 2-methylbenzimidazoles.

It should be emphasized that the bis-acylation, contrary to the reasonable, at the first glance, opposite hypothesis, occurs without the intermediate formation of *C*-monoacylation products, *viz.*, 1-R-2-$CH_2COR´$-benzimidazoles and their tautomeric forms.

Using model structure **6e**, we also showed that the isomerization of esters **6** to amides **7** in the route to pyrazolobenzimidazoles **1** occurs *via* an unusual intramolecular concerted mechanism.

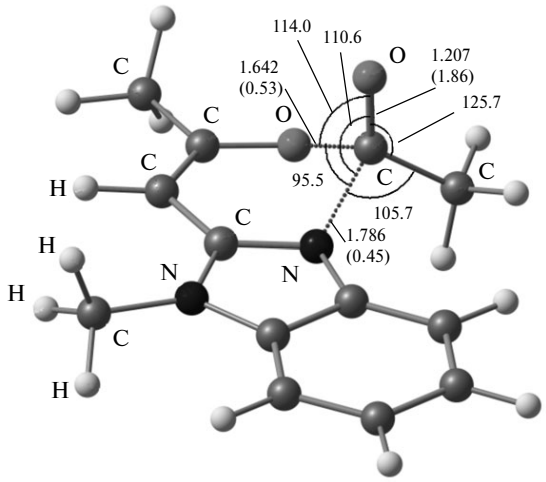


Fig. 2. Structure of the transitions state **TS3** of the intramolecular acylotropic O→N isomerization of vinyl acetate **12**.

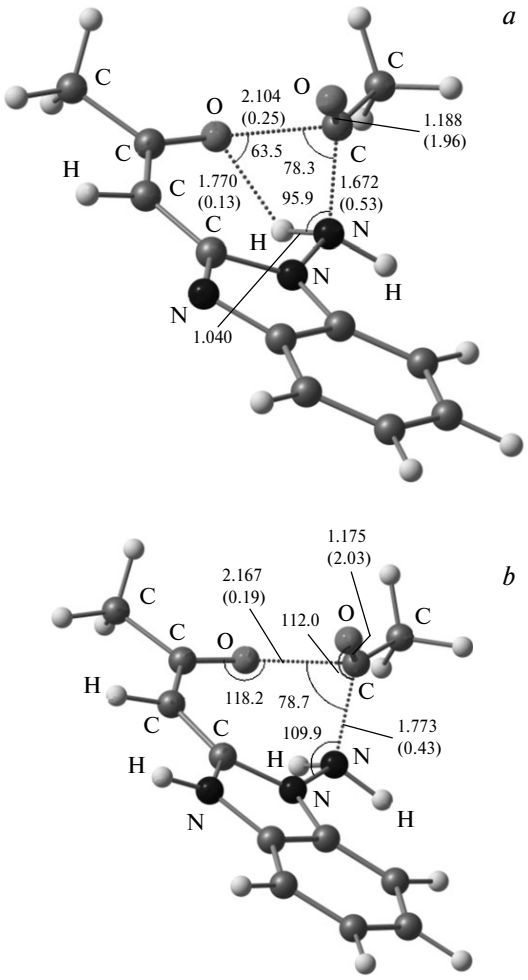
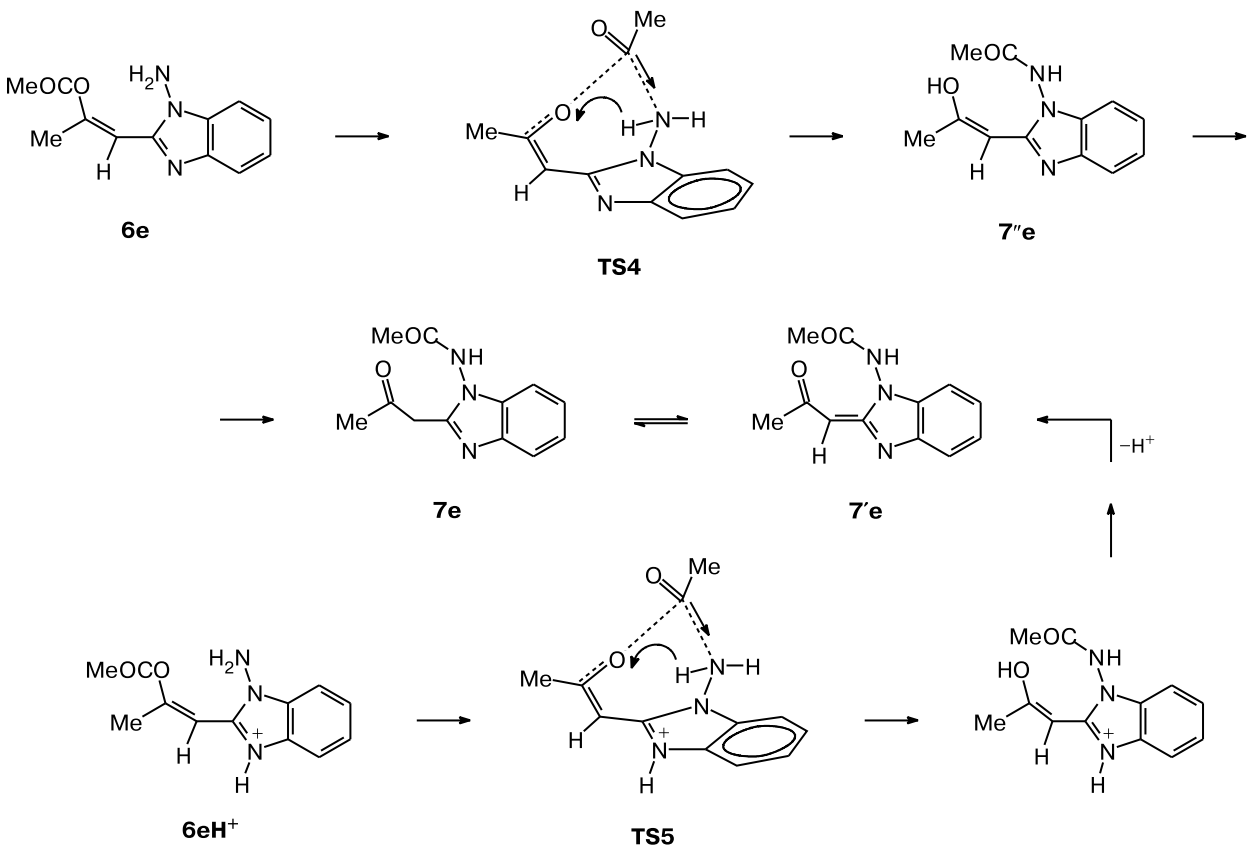


Fig. 3. Structures of the transitions states **TS4** (*a*) and **TS5** (*b*) of the dyotropic (acylotropic-prototropic) intramolecular isomerization of compound **6e** and its protonated form **6eH**$^+$, respectively.

As can be seen from the structures of compounds **6**, they are not acylotropic isomers of amides **7** and, consequently, they cannot, even theoretically, undergo pure acylotropic isomerization to amides **7** or their enol tautomeric forms **7″** (Scheme 3). At the same time, compounds **6** can undergo isomerization to enols **7″** *via* a more complex intramolecular acylotropic-prototropic mechanism through the concerted exchange of the acetyl group and the proton between the sp^3-hybridized N and O atoms. This is confirmed by the existence of the corresponding **TS4** for compound **6e** (Fig. 3). The reaction is a special case of concerted dyotropic[23] processes* accompanied by the double group transfer[25] (in the case under consideration, of the acetyl group and the proton). Therefore,

* Apparently, the double proton transfer, which can occur both in an inter- and intramolecular fashion, is the most well-known representative of dyotropic processes (see, for example, Ref. 24).

Scheme 3



compounds **6e** and **7″e** can be considered as a pair of dyotropomers (*cf.* Ref. 26).

The dyotropic transition state **TS4** has a seven-membered cyclic reaction unit, which, like that in **TS3**, contains the tetragonal-coordinated carbon atom of the CO group (see Fig. 3). The acylotropic group of TS, that migrates toward O→N in the course of the reaction, substantially deviates from the common plane passing through the other atoms of the heterocyclic core and the reaction unit. As opposed to the purely acylotropic **TS1** and **TS3**, this group in **TS4** is bound to two nucleophilic centers in quiet different ways. Thus, the bond with the *N*-amino group (the Ac—N bond order is 0.53, the bond length is 1.671 Å) is stronger, whereas the bond with the O-nucleophilic center is much weaker (BO_{Ac-O} = 0.25, d_{Ac-O} = = 2.104 Å). The fact that the transition state **TS4** relates compound **6e** not to ketoamide **7e** but to its enol form **7″e** (see Scheme 3) is confirmed by the character of the transformation of compound **6e** as it moves along the reaction coordinate that includes the above-mentioned TS.

The dyotropic reaction occurs *via* a concerted mechanism, as opposed to the known two-step dyotropic isomerization of *S*-acetyl-2-aminoethanethiol, in which the sulfur and nitrogen atoms are also exchanged with the acetyl group and a proton but *via* a two-step mechanism to form a tetrahedral intermediate.[27]

The acylotropic-prototropic isomerization of compound **6e** is evidently asynchronous. The initial step involves the migration exclusively of the acetyl group, whereas the migration of the proton of the NH group begins only after the reaction system reaches the transition state **TS4**. At this moment, the ratio between the acidity of the N—H bond and the nucleophilicity of the proton-accepting oxygen atom becomes favorable for the prototropy. In the structure of TS, the asynchronous character of the dyotropy is reflected in the fact that the prototropic hydrogen atom forms only one strong bond with the nitrogen atom, whereas the oxygen atom is involved only in a relatively weak hydrogen bond (the length is 2.408 Å; the N—H···O angle is 115.5°).

The dyotropic transformation under consideration is characterized by the relatively high activation energy $\Delta^{\neq}G^{\circ}_{calc}$ = 34.7 kcal mol^{-1}, which is much higher than that for the isomerization of ketone **12**. This difference is not surprising taking into account that the double group transfer should occur in the course of isomerization of vinyl acetate **6e** and that the seven-membered reaction unit is much more strained compared

to the six-membered reaction unit that is present in ketone **12**.

The strongly acidic medium used for the synthesis of pyrazolobenzimidazoles **1** would seem to substantially hinder or even completely prevent the acylotropic-prototropic isomerization of intermediates **6** as a result of the *N*-protonation and a decrease in the nucleophilicity of the *N*-amino group. Nevertheless, the study of compound **6e** showed that the protonated forms of diacyl derivatives **6** also undergo this isomerization (see Scheme 3). Moreover, it was found that the protonation of compounds **6** at the imidazole ring should even accelerate the dyotropic process, which, consequently, should be acid-catalyzed. The transition state **TS5** (see Fig. 3) of the acylotropic-protoropic isomerization of the protonated form of compound **6e**, *viz.*, the cation **6eH**$^+$ (see Scheme 3), is structurally very similar to the transition state **TS4**. It should be noted that the prototropic hydrogen atom in **TS5** does not form a hydrogen bond, and the Ac—N and Ac—O bonds are much more loosened (their BO are 0.43 and 0.19, respectively). The activation energy $\Delta^{\neq}G^{\circ}_{calc}$ of the reaction is 30.6 kcal mol^{-1}, which is 4.1 kcal mol^{-1} lower than that for the isomerization of the main form **6e**.

The above data show that the decrease in the rate of the dyotropic process due to a decrease in the nucleophilicity of the *N*-amino group in the cationic form is relatively small because the protonation occurs not at this group but at the N atom of the imidazole ring, which is non-conjugated with the *N*-amino group. Under these conditions, it is apparently more important that the additional total positive charge on the acyl group necessary for the acylotropy[28] is much more easily accumulated of the cation **6eH**$^+$. In the electroneutral TS, this process is hindered because the separation of the opposite charges is electrostatically unfavorable, whereas the charge localization in the cationic TS is favorable because it facilitates the delocalization of the positive charge over a larger number of atoms.

The above-considered data provide evidence that the method developed for the preparation of *N*-unsubstituted 2-arylpyrazolo[1,5-*a*]benzimidazoles has considerable synthetic potential and that the mono- and dyotropic processes accompanied by the intermolecular and intramolecular acyl group transfer play an important role in this approach. These transformations belong to a large and very important class of chemical and biochemical acylotropic reactions, whose kinetics and mechanism have been earlier studied in detail in the Institute of Physical and Organic Chemistry of the Southern Federal University, where the intramolecular degenerate acylotropic tautomerism was discovered.[22]

Experimental

The solid-state IR spectra were recorded on a Varian Excalibur 3100 FT-IR instrument. The ^{1}H NMR spectra (Table 2) were measured on a Varian Unity-300 spectrometer (300 MHz) with internal stabilization of the polar-resonance ^{2}H line of the deuterated solvent. The mass spectra were obtained on a Finnigan MAT INCOS-50 instrument (70 eV, direct inlet). The course of the reactions was monitored and the purity of the compounds was checked by TLC on Al_2O_3 plates (Brockmann activity III) using $CHCl_3$ as the eluent; the spots were visualized with iodine vapor.

The standard Gibbs free energies G° corresponding to T = 298.15 °C and p = 1 atm (10^5 Pa) were calculated with the use of the PC Gamess program package[29] in an ideal gas approximation assuming the harmonic mode of vibrations of atoms and the absence of thermally accessible excited electronic states for the systems under consideration. The zero-point energy (ZPE)

Table 2. Yields, melting points, and the results of elemental analysis and ^{1}H NMR spectroscopy for pyrazolo[1,5-*a*]benzimidazoles **1b—d**

Compound	Yield (%)	M.p./°C (solvent)	Found / Calculated (%)			Molecular formula	^{1}H NMR spectrum (DMSO-d_6, δ, *J*/Hz)
			C	H	N		
1b	64	256—258 (EtOH)	77.90 / 77.71	5.24 / 5.30	17.25 / 16.99	$C_{16}H_{13}N_3$	2.37 (s, 3 H, Me); 6.08 (s, 1 H, H(3)); 7.08—7.24 (m, 4 H, H(6), H(7) + 2 H(3´)); 7.35 (d, 1 H, H(5), *J* = 8.4); 7.67—7.79 (m, 3 H, H(8) + 2 H(2´)); 11.24 (s, 1 H, NH)
1c	63	290—292 (EtOH)	67.15 / 67.30	3.98 / 3.77	15.82 / 15.70	$C_{15}H_{10}ClN_3$*	6.17 (s, 1 H, H(3)); 7.06—7.28 (m, 2 H, H(6), H(7)); 7.38 (d, 2 H, H(3´), *J* = 8.6); 7.50—7.61 (m, 1 H, H(5)); 7.74 (d, 1 H, H(8), *J* = 7.5); 7.89 (d, 2 H, H(2´), *J* = 8.2); 11.37 (s, 1 H, NH)
1d	67	202—203 (PhH)	73.21 / 72.99	5.17 / 4.98	15.87 / 15.96	$C_{16}H_{13}N_3O$	3.82 (s, 3 H, OMe); 6.05 (s, 1 H, H (3)); 6.91 (d, 2 H, H(3´), *J* = 8.5); 7.03—7.24 (m, 2 H, H(6), H(7)); 7.35 (d, 1 H, H(5), *J* = 8.0); 7.65 (d, 1 H, H(8), *J* = 8.0); 7.72 (d, 1 H, H(2´), *J* = 7.8); 11.20 (s, 1 H, NH)

* Found (%): Cl, 13.01. Calculated (%): Cl, 13.24.

correction at $T = 0$ was calculated with the use of the scale factor equal to 0.961.[30] The stationary points on the potential energy surfaces for the molecules under consideration and the reactions systems were identified as minima or transition states by calculating the corresponding force-constant matrices with the use of the same basis set as that for the final geometry optimization. The assignment of TS to a particular reaction was confirmed by the study of the behavior of the reaction system by their movement along the reaction coordinate.

2-(2-Benzoyloxy-2-phenylvinyl)-1-benzylideneaminobenzimidazole (3a). Benzoyl chloride (0.45 mL, 4 mmol) was added dropwise with stirring to a solution of 1-benzylideneamino-2-methylbenzimidazole (**2**)[13] (0.47 g, 2 mmol) and triethylamine (0.58 mL, 4 mmol) in anhydrous THF (10 mL) cooled on an ice bath for 5 min. The reaction mixture was stirred for 30 min and then kept at 20—25 °C for 12 h. The solvent was evaporated, the residue was treated with water (10 mL), and the precipitate was filtered off. The yield was 0.88 g (99%). Pale-yellow crystals, m.p. 201—202 °C (with decomp., from MeCN), R_f 0.9 (R_f of the starting compound was 0.5). Found (%): C, 78.72; H, 4.51; N, 9.63. $C_{29}H_{21}N_3O_2$. Calculated (%): C, 78.54; H, 4.77; N, 9.47. ^{1}H NMR ($CDCl_3$), δ: 7.14—7.30 (m, 2 H, H(5), H(6) of the benzimidazole moiety); 7.35—7.48 (m, 4 H, H arom.); 7.51 (s, 1 H, CH=C—O); 7.52—7.72 (m, 7 H, H arom.); 7.76—7.82 (m, 2 H, *o*-H, Ph); 7.90—7.98 (m, 2 H, *o*-H, PhCH=); 8.32—8.36 (m, 2 H, *o*-H, Bz); 8.90 (s, 1 H, CH=N).

Esters **3b—d** were synthesized according to the same procedure. Chromatographically individual pale-yellow crystals with R_f 0.9, which were difficultly soluble in boiling MeOH and MeCN, were obtained. The recrystallization from butanol led to the decomposition of the crystals. Hence, compounds **3b**, **3c**, and **3d**, with m.p. 191—192 (with decomp.), 222—224 (with decomp.), and 187—189 °C (with decomp.), respectively, were introduced into further transformations without additional purification.

1-Benzylideneamino-2-phenacylbenzimidazole (4a). A solution of compound **3a** (0.88 g, 2 mmol) and morpholine (0.55 mL, 6 mmol) in MeOH (15 mL) was refluxed for 10 min, diluted with water (5 mL), and cooled. The precipitate that formed was filtered off. The yield was 0.62 g (92%). Yellow crystals, m.p. 159—160 °C (from MeCN), R_f 0,5. Found (%): C, 77.68; H, 4.91; N, 12.52. $C_{22}H_{17}N_3O$. Calculated (%): C, 77.86; H, 5.05; N, 12.38. ^{1}H NMR ($CDCl_3$), δ: 4.81 (s, 2 H, CH_2, **4a**); 6.56 (s, 1 H, CH=C, **4´a**); 7.32—8.00 (m, superimposed signals for the protons of the *o*-phenylene and phenyl groups, except for *o*-H (OCOPh), of tautomer **4a** (12 H) and signals for the protons of the *o*-phenylene and phenyl groups of tautomer **4´a** (14 H)); 8.06 (d, 2 H, *o*-H, Bz, **4a**, J = 7.7 Hz); 8.95 and 9.05 (both s, 1 H each, CH=N, **4a**, **4´a**). The ratio of the forms **4a** and **4´a** in $CDCl_3$ and DMSO-d_6 is ~1 : 1 and 1 : 3, respectively.

1-Benzylideneamino-2-(4-methoxyphenacyl)benzimidazole (4d). A solution of ester **3d** (1.00 g, 2 mmol) and morpholine (0.55 mL, 6 mmol) in DMF (2 mL) was heated on a boiling water bath for 10 min, diluted with H_2O (2 mL), and slowly cooled. The pale-yellow precipitate that formed was filtered off. The yield was 0.70 g (94%), m.p. 161—163 °C (from EtOH), R_f 0.5. Found (%): C, 74.85; H, 5.30; N, 11.51. $C_{23}H_{19}N_3O_2$. Calculated (%): C, 74.78; H, 5.18; N, 11.37. ^{1}H NMR ($CDCl_3$), δ: 3.80 (s, 3 H, OMe, **4´d**); 3.87 (s, 3 H, OMe, **4d**); 4.78 (s, 2 H, CH_2, **4d**); 6.45 (s, 1 H, C=CH, **4´d**); 6.93 (d, 2 H, H(2´), **4d**, J = 8.5 Hz); 6.97 (d, 2 H, H(2´), **4´d**, J = 8.7 Hz); 7.23—8.00 (m, 20 H, superposition of multiplets for arom. H of forms **4d** (9 H) and **4´d** (11 H)); 8.06 (d, 2 H, H(3´), **4d**, J = 8.5 Hz); 8.92 and 8.95 (both s, 1 H each, CH=N, **4d**, **4´d**); the ratio of the forms **4d** : **4´d** ≈ 3 : 1.

1-(4-Chlorobenzoylamino)-2-(4-chlorophenacyl)benzimidazole (7c). A suspension of ester **3c** (1.02 g, 2 mmol) in concentrated HCl (15 mL) was refluxed for 15 min with azeotropic removal of benzaldehyde that formed and then cooled. The precipitate was filtered off and washed with water. The yield was 0.73 g (87%). Colorless crystals, m.p. 228—229 °C (from EtOH), R_f 0.05. Found (%): C, 62.47; H, 3.28; Cl, 16.50; N, 9.72. $C_{22}H_{15}Cl_2N_3O_2$. Calculated (%): C, 62.26; H, 3.54; Cl, 16.74; N, 9.91. ^{1}H NMR ($CDCl_3$), δ: 5.55 (s, 2 H, CH_2, **7c**); 6.06 (s, 1 H, C=CHCO, **7´c**); 7.15—7.29 (m, superposition of multiplets for the protons H(4)—H(7) of form **7´c** (4 H) and for the protons H(5), H(6) of form **7c** (2 H)); 7.37 (d, 2 H, H(3´), **7´c**, J = 8.6 Hz); 7.47 (d, 2 H, H(3´), **7c**, J = 8.5 Hz); 7.52 (d, 2 H, H(3´), **7c**, J = 8.5 Hz); 7.59 (d, 2 H, H(3´), J = 8.6 Hz); 7.71—7.76 (m, 2 H, H(4), H(7), **7c**); 7.86 (d, 2 H, H(2´), **7´c**, J = 8.6 Hz); 7.99 (d, 2 H, H(2´), **7c**, J = 8.7 Hz); 8.05 (d, 2 H, H(2´), **7c**, J = 8.6 Hz); 8.11 (d, 2 H, H(2´), **7c,** J = 8.6 Hz); 11.91 and 11.95 (both s, 1 H each, NH, **7c, 7´c**).

1-(4-Methoxybenzoylamino)-2-(4-methoxyphenacyl)benzimidazole (7d) was synthesized by analogy with compound **7c**. The yield was 74%, colorless crystals, m.p. 154—155 °C (from EtOH), R_f 0.05. Found (%): C, 69.27; H, 5.12; N, 10.31. $C_{24}H_{21}Cl_2N_3O_4$. Calculated (%): C, 69.40; H, 5.00; N, 10.12. IR, ν/cm^{-1}: 1665 (CO), 3254 (NH). ^{1}H NMR (DMSO-d_6), δ: 3.81 and 3.90 (both s, 3 H each, 2 MeO, **7d** + **7´d**); 4.36 (strongly br.d, 2 H, CH_2 **7d**); 4.53 (strongly br.dd, 2 H, CH_2, **7d**); 5.94 (s, 1 H, CH=C, **7´d**); 6.90 (d, 2 H, H(2´), **7´d**, J = 8.8 Hz); 6.94 (d, 2 H, H(2´), **7d**, J = 8.8 Hz); 6.98 (d, 2 H, H(2´), **7d**, J = 8.8 Hz); 7.06 (d, 2 H, H(2´), **7´d**, J = 8.5 Hz); 7.11—7.31 (m, 2 H, H(5), H(6), **7d**, and 4 H, H(4)—H(7), **7´d**); 7.58 (d, 2 H, H(4), H(7), **7d**, J = 7.1 Hz); 7.78 (d, 2 H, H(3´), **7´d**, J = 8.8); 7.94 (d, 2 H, H(3´), **7d**, J = 8.5 Hz); 8.01 (d, 2 H, H(3´), **7d**, J = 8.8 Hz); 8.06 (d, 2 H, H(3´), **7´d**, J = 8.5 Hz); 11.56 and 11.74 (both s, 1 H each, 2 NH, **7d**, **7´d**). MS, m/z (I_{rel} (%)): 415 $[M]^+$ (3), 387 $[M - CO]^+$ (1), 135 $[p\text{-}MeOC_6H_4CO]^+$ (100), 107 $[C_7H_7O]^+$ (17), 92 $[C_6H_4O]^+$ (27), 77 $[C_6H_5]^+$ (41), 76 $[C_6H_4]^+$ (5), 64 $[C_5H_4]^+$ (10), 63 $[CH_3O_3, C_5H_3]$ (7), *etc*. Analogous intense peaks at m/z = 63, 64, 77, 107, and 135 (100%) are characteristic also of *p*,*p*´-dimethoxybenzyl.[31]

2-Phenyl-4*H*-pyrazolo[1,5-*a*]benzimidazole (1a). A suspension of dibenzoyl derivative **3a** (1.33 g, 3 mmol) in concentrated HCl (20 mL) was refluxed for 20 min with azeotropic removal of benzaldehyde that formed and then boiled with a reflux condenser for 1 h. The caramel-like reaction mixture gradually solidified. After cooling, the precipitate of hydrochloride of compound **1a** was filtered off. The base was isolated by treating the precipitate of the salt with concentrated NH_4OH. The yield was 0.47 g (67%). Colorless crystals, m.p. 256—257 °C (with decomp., from EtOH)[7]. ^{1}H NMR (DMSO-d_6), δ: 6.13 (s, 1 H, H(3)); 7.10—7.30 (m, 3 H, H(6), H(7) + H(4´) arom.); 7.30—7.41 (m, 3 H, H(5) + 2 H(3´) arom.); 7.73 (d, 1 H, H(8), J = 7.7 Hz); 7.87 (d, 2 H, H(2´) arom., J = 7.4 Hz); 11.27 (s, 1 H, NH).

Pyrazolobenzimidazoles **1b—d** (see Table 2) were synthesized according to the same procedure.

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