Aroyl[bis(4-hydroxycoumarin-3-yl)]methanes in reactions with 1,2-diaminobenzenes

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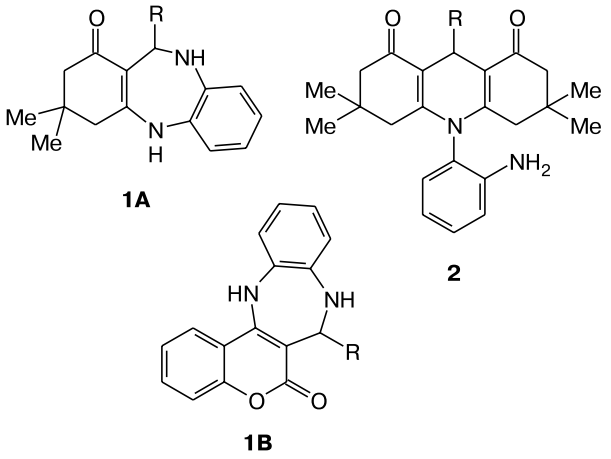
The reaction of aroyl[bis(4-hydroxycoumarin-3-yl)]methanes with 1,2-phenylenediamines in Pr^iOH is accompanied by the recyclization to 8-R- or 7-R-4-(2-hydroxyphenyl)-1,5-benzodiazepin-2-ones, whereas the reaction with *o*-phenylenediamine and its 4-methyl-substituted derivatives in MeOH produces organic ionic salts of the bis-coumarin anion with monoprotonated *o*-phenylenediamine as the cation.

Key words: aroyl[bis(4-hydroxycoumarin-3-yl)]methanes, 4-R-1,2-diaminobenzenes, 8-R-(7-R)-4-(2-hydroxyphenyl)-1,5-benzodiazepin-2-ones, recyclization, ionic salts, X-ray diffraction study.

Various 4-hydroxycoumarin derivatives have found use as drugs.[1—5] Among these is neodicoumarin (ethyl di(4-hydroxycoumarin-3-yl)acetate), which is used in medicine as an anticoagulant.[6] These bis-adducts based on heterocyclic CH acids and active carbonyl compounds (aldehydes or glyoxals) have attracted interest because their molecules contain several electrophilic centers, thus giving promise that various heterocyclization pathways are possible in the reactions with binucleophilic reagents.

Earlier,[7] we have demonstrated that the reaction of aryl(aroyl)[bis(5,5-dimethyl-1,3-dioxocyclohexan-2-yl)]methanes with *o*-phenylenediamine (*o*-PDA) produces hexahydrobenzo[*b*,*e*]-1,4-diazepin-1-one derivatives **1A** or 9-aryl(aroyl)-10-(2-aminophenyl)decahydroacridine-1,8-dione derivatives **2** depending on the electronic character of the substituent in the aryl or aroyl fragments. Electron-withdrawing substituents in the aromatic moiety facilitate the formation of the diazepine ring, whereas the formation of acridones is typical of the starting polyketones containing electron-releasing substituents in the benzene ring.

In the present study, we investigated the reaction of 4-R-benzoyl[bis(4-hydroxycoumarin-3-yl)]methanes **3a—c** with *o*-PDA (**4a**) and its substituted derivatives **4b—d**



R = Ar, COAr

with the aim of synthesizing diazepines **1B**, which are structurally similar to diazepines **1A** and in which the diazepine fragment is annulated with the coumarin ring. The starting ketones **3a—c** were synthesized in good yields by heating 4-hydroxycoumarin with *p*-substituted arylglyoxals in AcOH for a short period of time. Their structures were confirmed by ^{1}H NMR spectra, which show singlets for the methine protons at δ 6.2—6.4 and multi-

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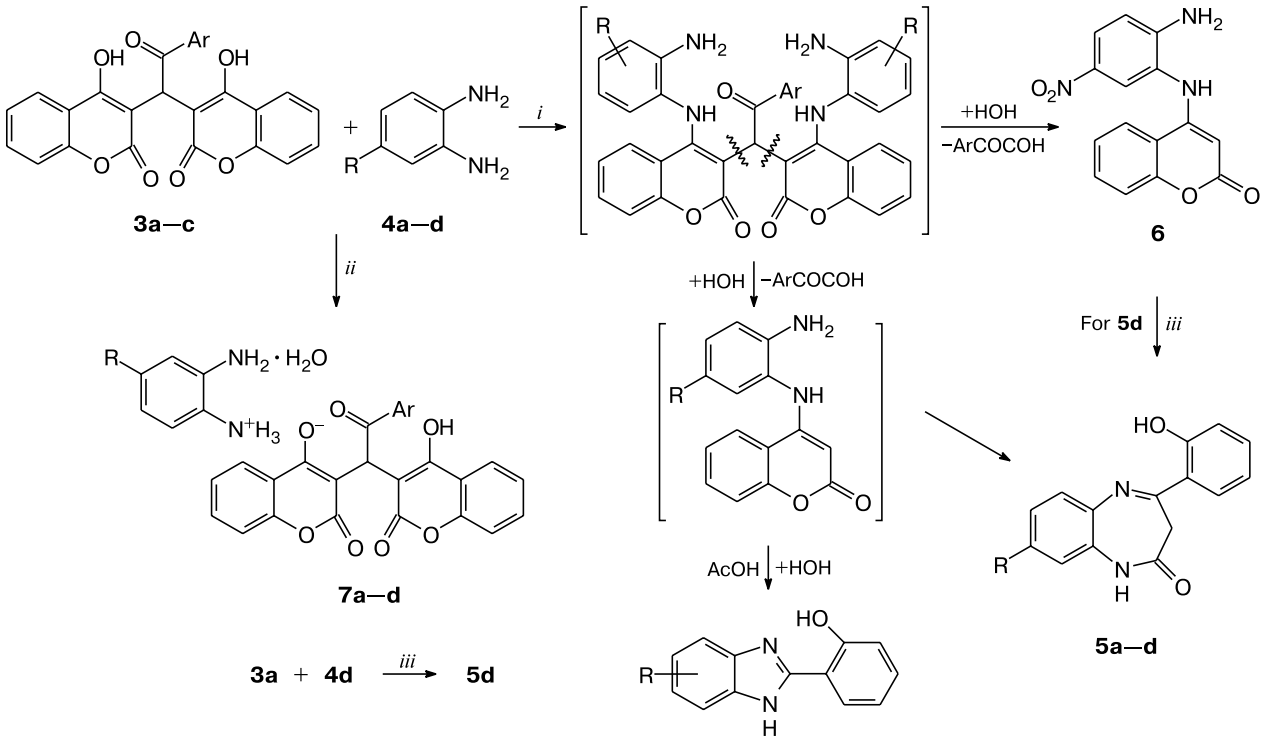
plets for the aromatic protons of two coumarin moieties and the substituted benzoyl fragment (see the Experimental section).

We found that heating of bis-adducts **3a—c** with diamines **4a—c** in Pr^iOH affords 4-(2-hydroxyphenyl)-2,3-dihydro-1*H*-1,5-benzodiazepin-2-ones **5a—c** (Scheme 1) with a small impurity of 2-(*o*-hydroxyphenyl)benzimidazoles, whose formation was confirmed by TLC based on a comparison with authentic samples prepared according to a known procedure.[8] Under these experimental conditions, diazepinone **5d** was not synthesized; instead, a product with a lower melting point compared to compounds **5** was isolated from the reaction mixture. The ^{1}H NMR spectrum of this product shows one-proton singlets at δ 5.56 and 9.18 and a two-proton singlet at δ 6.02. The latter two signals disappear after deuterium exchange. In the aromatic proton region, signals for the protons of the coumarin ring and the 4-nitro-*o*-phenylenediamine fragment are observed, which is indicative of the formation of 4-(2-amino-5-nitrophenylamino)coumarin (**6**). Diazepinone **5d** was synthesized in 75% yield by the reaction of adduct **3a** with diamine **4d** (or by refluxing enamine **6**) in *m*-xylene. The structure of compound **5** was confirmed by the ^{1}H NMR spectra, which show singlets for the methylene groups at δ 3.6—3.7, multiplets for aromatic protons, and singlets at δ 10.75 and 13.7—14.2, which disappear after deuterium exchange. In addition, the spectroscopic and physicochemical characteristics of diazepinone **5a** are consistent with the data from the study,[9] where this compound was synthesized from 4-hydroxycoumarin and *o*-PDA.

The chemical shifts of the hydroxy protons depend on the nature of the substituent in the *o*-phenylenediamine fragment. Electron-releasing substituents cause an increase in the electron density on the azomethine group of the seven-membered ring, resulting in strengthening of the intramolecular hydrogen bonding and a downfield shift of the signals. In the presence of electron-withdrawing substituents (compounds **5c,d**), the signals of the OH groups are shifted upfield.

It should be noted that the reactions of 4-substituted diamines **4b,c** produced the 8-R isomers (compound **5d** is the 7-nitro isomer; based on the ^{1}H NMR spectra, the impurity of the 8-nitro isomer in the crude product was at most 10%). This corresponds to the involvement of the more basic amino group in the formation of enamine. Earlier,[9] the structure of the 8-nitro isomer has been assigned to the reaction product of 4-hydroxycoumarin with

Scheme 1



3: Ar = Ph (**a**), 4-BrC_6H_4 (**b**), 4-$NO_2C_6H_4$ (**c**); **4**, **5:** R = H (**a**), Me (**b**), Br (**c**), NO_2 (**d**);
7: Ar = Ph, R = H (**a**); Ar = 4-BrC_6H_4, R = H (**b**); Ar = 4-BrC_6H_4, R = Me (**c**); Ar = 4-$NO_2C_6H_4$, R = H (**d**)

Reagents and conditions: *i*. Pr^iOH, Δ; *ii*. MeOH, Δ; *iii*. *m*-Xylene, Δ.

diamine **4d**. However, the chemical shifts and multiplicities of the signals for the protons of two aromatic nuclei were not discussed, which casts doubt on this assignment. As evidenced by the ^{1}H NMR spectra, products **5a—d** in DMSO-d_6 exist exclusively in the imine tautomeric form. We found no additional signals for the vinylene (δ 5.6) and enamine (δ 12.6) protons in the spectra of these compounds, which have been reported in the study.[10] At the same time, the minor enamine tautomeric form is quite possible for benzodiazepin-2-ones containing the tetrafluorinated 2-hydroxyphenyl substituent at position 4.[11]

The recyclization of 4-hydroxycoumarin to benzodiazepin-2-one derivatives in the presence of *o*-PDA was described in the studies[9—12] and involves the formation of enamine at the 4-hydroxy group followed by the lactone ring opening and heterocyclization. An alternative heterocyclization pathway involves the nucleophilic addition of the free amino group at the activated double bond and gives 2-(*o*-hydroxyphenyl)benzimidazoles in trace amounts. Analogous processes are well known.[13] The reactions of adducts **3a—c** with *o*-PDA proceed analogously, as evidenced by the elimination of enamine **6**. The elimination of the arylglyoxal molecule is, most likely, the second reaction step, because the retro cleavage of adducts **3a—c** upon heating in Pr^{i}OH was not observed.

Precipitates of diazepinones **5a—c** are formed by refluxing the starting components in Pr^{i}OH for 1 h, whereas the partial transformation of 4-hydroxycoumarin into diazepinone **5a** in 15% yield (according to our data, which are consistent with the data published in the literature[9]) was observed only after refluxing in Pr^{i}OH for 2 h. It appeared that the yield of compound **5a** substantially increases in the presence of a twofold excess of diamine **4a** with respect to adduct **3a**.

By contrast, the reactions of 4-hydroxycoumarinylmethanes **3a—c** with diamines **4a,b** in MeOH do not lead to the coumarin ring opening. These reactions produce readily crystallizable pale-yellow compounds **7a—d**. For *o*-PDA containing electron-withdrawing substituents, no reaction products with ketones **3** in MeOH were found. The ^{1}H NMR spectra of compounds **7a—d** are similar to those of bis-adducts **3a—c**. However, all signals in these spectra are shifted upfield; in addition, these spectra show signals for the protons of the *o*-phenylenediamine moiety, but signals for the NH_2 and N^+H_3 protons of the *o*-phenylenediamine fragment are absent. The assignment of the signals in the ^{1}H NMR spectrum of compound **7d** was made based on the results of the ^{1}H—^{1}H COSY experiment. The structures of products **7** were conclusively established based on the X-ray diffraction data for complex **7d** (Fig. 1, Table 1), which is an organic salt of the anion of the bis-coumarin adduct with monoprotonated

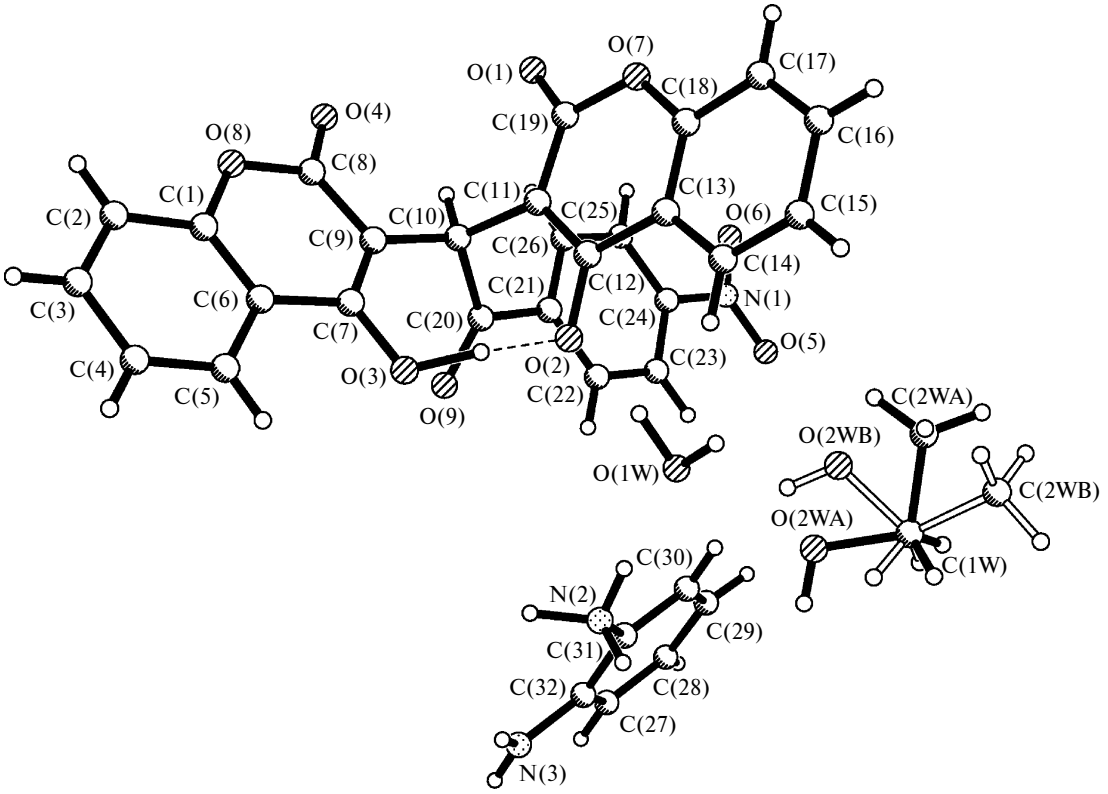


Fig. 1. X-ray diffraction structure of complex **7d** containing one disordered ethanol molecule.

Table 1. Selected bond lengths (*d*) in compound **7d**

Bond	*d*/Å	Bond	*d*/Å
O(1)—C(19)	1.217(2)	O(2)—C(12)	1.286(2)
O(3)—C(7)	1.332(2)	O(4)—C(8)	1.227(2)
O(7)—C(18)	1.365(3)	O(7)—C(19)	1.380(2)
O(8)—C(8)	1.362(2)	O(8)—C(1)	1.374(2)
O(9)—C(20)	1.211(2)	N(2)—C(31)	1.469(2)
N(3)—C(32)	1.410(2)	C(7)—C(9)	1.368(3)
C(8)—C(9)	1.429(2)	C(9)—C(10)	1.517(2)
C(10)—C(11)	1.517(2)	C(11)—C(19)	1.420(3)
C(10)—C(20)	1.527(2)	C(11)—C(12)	1.391(3)

o-PDA linked together by the bridging water molecule. The positions of the hydrogen atoms of the hydroxy and amino groups and the H atoms of the water molecule were located in difference electron density maps. It should be noted that the hydrogen atom was not found at the O(2) atom. The C(12)—O(2) bond (1.286(2) Å) is substantially shorter than that of the formally equivalent C(7)—O(3) bond (1.332(2) Å) and its length is smaller than the average C—O bond length in hydroxy groups[14] (1.333 Å). At the same time, the C(12)—O(2) bond length is similar to the C—O bond lengths in phenolate anions (1.280 Å). These data suggest that the negative charge of the anion is located on the O(2) atom.

The protonation of one of the amino groups in *o*-PDA is confirmed by the nonequivalence of the C—N bond lengths. The N(3)—C(31) bond is slightly elongated compared to the N(2)—C(32) bond and its length corresponds to N—C(sp^3) bonds. The protonated *o*-PDA molecule is linked to the anion through the water molecule by the rather strong intermolecular N(2)—H(2Nb)...O(1w) (H...O, 1.78 Å; N—H...O, 175°) and O(1w)—H(1Oa)...O(2) (H...O, 1.63 Å; O—H...O, 170°) hydrogen bonds.

In the crystal structure, the monohydrate of the organic salt exists as the solvate with an ethanol molecule in a ratio of 1 : 1. The ethanol molecule is disordered over two positions (A and B) with equal occupancies and is linked to the anion and the water molecule by the intermolecular O(2wa)—H(1wg)...O(1)′ (1 + *x*, *y*, *z*) (H...O, 2.09 Å; O—H...O, 159°), O(1W)—H(1Ob)...O(2wb)′ (H...O, 1.91 Å; O—H...O, 135°), and O(2wb)—H(2wh)...O(1w)′ (H...O, 2.08 Å; O—H...O, 143°) hydrogen bonds.

The bicyclic fragments of the anion are planar within 0.02 Å and are twisted with respect to the C(10)—C(20) bond (the C(20)—C(10)—C(9)—C(7) and C(20)—C(10)—C(11)—C(12) torsion angles are 55.5(2) and 55.3(2)°, respectively). This orientation is stabilized, on the one hand, by the very strong intramolecular O(3)—H(3O)...O(2) hydrogen bond (H...O, 1.33 Å; O—H...O, 174°) and, on the other hand, by the H(10)...O(4) (2.26 Å) (the sum of the van der Waals radii is 2.45 Å)[15] and H(10)...O(1) (2.37 Å) attractive interactions. This gives rise to a rather strong steric strain (the intramolecular shortened contacts: H(3O)...C(10), 2.62 Å (2.87 Å); H(3O)...C(11), 2.69 Å; H(3O)...C(20), 2.79 Å).

The nitrophenyl substituent is twisted with respect to the C(10)—C(20) bond (the C(10)—C(20)—C(21)—C(26) torsion angle is 33.9(2)°), which is, apparently, a consequence, of the repulsion between this substituent and the methine group C(10)H (the intramolecular shortened contacts: H(10)...C(26), 2.71 Å (2.87 Å); H(10)...H(26), 2.16 Å (2.34 Å); H(26)...C(10), 2.75 Å). The nitro group is virtually coplanar to the plane of the benzene ring (the C(23)—C(24)—N(1)—O(5) torsion angle is 3.0(3)°).

In the crystal structure, the molecules of the monohydrate of the organic salt are linked to each other to form infinite chains along the (1 0 0) crystallographic direction through the intermolecular N(3)—H(3Nb)...O(4)′ (1 − *x*, 1 − *y*, 1 − *z*) (H...O, 2.18 Å; N—H...O, 150°), N(2)—H(2Na)...O(1)′ (1 − *x*, 1 − *y*, 1 − *z*) (H...O, 2.00 Å; N—H...O, 147°), N(2)—H(2Na)...O(4)′ (1 − *x*, 1 − *y*, 1 − *z*) (H...O, 2.41 Å; N—H...O, 116°), and N(2)—H(2Nc)...N(3)′ (2 − *x*, −*y*, 1 − *z*) (H...N, 1.91 Å; N—H...N, 164°) hydrogen bonds.

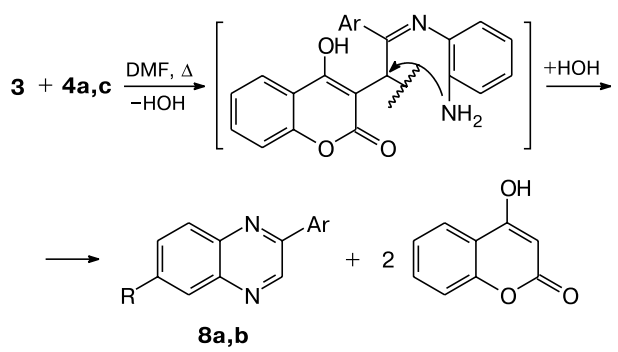
Consequently, the absence of the signals for the protons of the amino groups of the *o*-phenylenediamine fragment in the ^{1}H NMR spectra of compounds **7a—d** is associated with the presence of a system of hydrogen bonds, which is favorable for the exchange of these protons with residual water in DMSO-d_6.

The yield of benzodiazepin-2-ones in the reaction of 4-hydroxycoumarin with *o*-PDA is known[9] to be sharply increased in going from EtOH (15%) to *m*-xylene (80%) or an AcOH—EtOH mixture (75%). Under the reaction conditions used in the present study, the formation of the thermodynamically controlled reaction products, *viz.*, 1,5-benzodiazepin-2-ones, is observed in Pr^{i}OH, whereas stable salts of bis-adducts **3a—c** with diamines **4a,b** are formed in MeOH. Further heating of product **7d** in a 1 : 1 AcOH—Pr^{i}OH mixture does not give rise to diazepinone **5a**. In addition to salt **7d** that remained intact, the starting bis-adduct **3c** was isolated from the reaction mixture.

The reactions of compounds **3** with diamines **4a,c** in DMF (Scheme 2) are accompanied by the retro cleavage of the adducts to give 2-arylquinoxalines **8a,b** as the major products. The physicochemical characteristics of these products are consistent with the data published in the literature.[16] 4-Hydroxycoumarin was isolated from the reaction mixture, and traces of diazepinones **5a,c** were found in the solution (TLC monitoring).

Hence, the pathway of the reaction of coumarinylmethanes **3** with diamines **4** depends on the reaction con-

Scheme 2



8: Ar = Ph, R = H (**a**); Ar = 4-BrC_6H_4, R = Br (**b**)

ditions. The formation of enamine is the slowest and reversible step of the transformation of adducts **3** into diazepinones **5** in protic polar solvents. The rate of lactone ring opening depends on the temperature, which accounts for the formation of stable salts **7** rather than diazepinones **5** in MeOH. The reaction in DMF proceeds at the hard reaction center, the carbonyl group of the aroyl fragment, to give quinoxalines **8**.

Experimental

The progress of the reactions and the purity of the compounds were monitored by TLC on Silufol UV-254 plates in toluene—hexane (1 : 1) or toluene—AcOEt (1 : 2) systems or in chloroform (spots were visualized by exposure to iodine vapor or UV radiation). The ^{1}H NMR spectra were recorded on a Varian Mercury VX-200 instrument in DMSO-d_6 with Me_4Si as the internal standard. The ^{13}C NMR spectra were measured in a DMSO-d_6—CCl_4 mixture on a Bruker DRX-400 instrument. The elemental analysis was carried out on a LECO CHNS-900 instrument. The melting points were determined on a Kofler hot-stage apparatus.

Benzoyl[bis(4-hydroxy-2-oxo-2*H*-chromen-3-yl)]methane (3a). Phenylglyoxal monohydrate (0.15 g, 1 mmol) was added to a solution of 4-hydroxycoumarin (0.32 g, 2 mmol) in AcOH (20 mL). The reaction mixture was heated for 30 min. Then the yellow mixture was poured onto ice, and the white precipitate that formed was filtered off and thoroughly washed with water. Compound **3a** was obtained in a yield of 0.65 g (74%), m.p. 200—202 °C (from toluene). Found (%): C, 70.87; H, 3.60. $C_{26}H_{16}O_7$. Calculated (%): C, 70.91; H, 3.64. ^{1}H NMR, δ: 6.13 (s, 1 H, CH); 7.16—7.42 (m, 6 H, H(6)—H(8)); 7.61 (m, 3 H, *m*-H_{Ph}, *p*-H_{Ph}); 7.83 (d, 2 H, H(5), J = 7.6 Hz); 8.06 (d, 2 H, *o*-H_{Ph}, J = 8.2 Hz); 11.25 (s, 2 H, OH).

Compounds **3b,c** were synthesized analogously. They exist as stable solvates with 1 mole of AcOH (**3b**) and 0.25 mole of AcOH (**3c**).

4-Bromobenzoyl[bis(4-hydroxy-2-oxo-2*H*-chromen-3-yl)]methane (3b). The yield was 79%, m.p. 236—238 °C (from AcOH). Found (%): C, 58.11; H, 3.30. $C_{26}H_{15}BrO_7 \cdot AcOH$. Calculated (%): C, 58.05; H, 3.31. ^{1}H NMR, δ: 1.91 (s, 3 H, Me); 6.38 (s, 1 H, CH); 7.20—7.24 (m, 4 H, H(6), H(8)); 7.49 (t, 2 H, H(7), J = 7.2 Hz); 7.76 (d, 2 H, H(5), J = 8.7 Hz); 7.92 (d, 2 H, *m*-H arom., J = 8.7 Hz); 8.20 (d, 2 H, *o*-H arom., J = 7.7 Hz).

4-Nitrobenzoyl[bis(4-hydroxy-2-oxo-2*H*-chromen-3-yl)]methane (3c). The yield was 76%, m.p. 240—242 °C (from EtOH). Found (%): C, 63.47; H, 3.17; N, 2.80. $C_{26}H_{15}NO_9 \cdot 0.25AcOH$. Calculated (%): C, 63.55; H, 3.19; N, 2.79. ^{1}H NMR, δ: 1.93 (s, 1 H, Me); 6.43 (s, 1 H, CH); 7.29—7.42 (m, 4 H, H(6), H(8)); 7.55 (t, 2 H, H(7), J = 7.4 Hz); 7.83 (d, 2 H, H(5), J = 8.1 Hz); 7.99 (d, 2 H, *m*-H arom., J = 8.7 Hz); 8.27 (d, 2 H, *o*-H arom., J = 8.7 Hz).

4-(2-Hydroxyphenyl)-2,3-dihydro-1*H*-1,5-benzodiazepin-2-one (5a). ***A.*** A mixture of adduct **3a** (0.44 g, 1 mmol) and diamine **4a** (0.11 g, 1 mmol) in Pr^{i}OH (15 mL) was refluxed for 1 h. The bright-yellow precipitate that formed upon cooling was recrystallized from EtOH. Product **5a** was obtained in a yield of 0.13 g (53%), m.p. 268—269 °C (*cf.* lit. data[9]: m.p. 267—268 °C; *cf.* lit. data[10]: m.p. 160 °C).

B. Compound **5a** was synthesized in 68% yield under analogous conditions with the use of the reagents in a ratio of 1 : 2. ^{1}H NMR, δ: 3.60 (s, 2 H, CH_2); 6.94—7.00 (m, 2 H, *o*-H arom., *p*-H arom.); 7.20—7.34 (m, 3 H, *m*-H arom., H(9)); 7.41—7.47 (m, 2 H, H(7), H(8)); 7.90 (d, 1 H, H(6), J = 8.5 Hz); 10.74 (s, 1 H, NH); 14.08 (s, 1 H, OH).

Compounds **5b,c** were synthesized analogously. The reactions mixtures were refluxed for 1 and 1.5 h, respectively.

The chromatograms of the mother liquors in the synthesis of compounds **5a—c** ($CHCl_3$ as the eluent) showed blue luminescence of 2-(*o*-hydroxyphenyl)benzimidazole with R_f 0.18 (**5a**), 2-(*o*-hydroxyphenyl)-6-methylbenzimidazole with R_f 0.15 (**5b**), and 2-(*o*-hydroxyphenyl)-6-bromobenzimidazole with R_f 0.11 (**5c**).

4-(2-Hydroxyphenyl)-8-methyl-2,3-dihydro-1*H*-1,5-benzodiazepin-2-one (5b). The yield was 53%, m.p. 280—282 °C (from EtOH) (*cf.* lit. data[9]: m.p. 305—306 °C). ^{1}H NMR, δ: 2.38 (s, 3 H, Me); 3.57 (s, 2 H, CH_2); 6.94—7.02 (m, 2 H, *o*-H arom., *p*-H arom.); 7.08—7.18 (m, 2 H, *m*-H arom.); 7.27 (s, 1 H, H(9)); 7.38—7.48 (m, 1 H, H(7)); 7.87—7.93 (d, 1 H, H(6), J = 8.5 Hz); 10.58 (s, 1 H, NH); 14.21 (s, 1 H, OH).

8-Bromo-4-(2-hydroxyphenyl)-2,3-dihydro-1*H*-1,5-benzodiazepin-2-one (5c). The yield was 58%, m.p. 270—272 °C (from EtOH). Found (%): C, 54.34; H, 3.30; N, 8.52. $C_{15}H_{11}BrN_2O_2$. Calculated (%): C, 54.40; H, 3.35; N, 8.46. ^{1}H NMR, δ: 3.62 (s, 2 H, CH_2); 6.95—7.05 (m, 2 H, *o*-H arom., *p*-H arom.); 7.14—7.19 (m, 1 H, H(7)); 7.40—7.50 (m, 2 H, *m*-H arom.); 7.73 (s, 1 H, H(9)); 7.92 (d, 1 H, H(6), J = 8.2 Hz); 10.58 (s, 1 H, NH); 13.55 (s, 1 H, OH).

4-(2-Amino-5-nitrophenylamino)-2-oxo-2*H*-chromene (6). Diamine **4d** (0.15 g, 1 mmol) was added to a solution of bis-adduct **3a** (0.44 g, 1 mmol) in ethanol (10 mL). The reaction mixture was refluxed for 1.5 h. After cooling, a precipitate (0.16 g) was obtained. The yield was 55%, m.p. 182—183 °C (from EtOH). Found (%): C, 60.58; H, 3.70; N, 14.10. $C_{15}H_{11}N_3O_4$. Calculated (%): C, 60.61; H, 3.73; N, 14.14. ^{1}H NMR, δ: 5.56 (s, 1 H, H(3)); 6.02 (s, 2 H, NH_2); 6.51 (d, 1 H, H(3′), *o*-PDA, J = 8.0 Hz); 7.35—7.45 (m, 4 H, H(6), H(8), H(4′), H(6′), *o*-PDA); 7.59—7.68 (t, 1 H, H(7), J = 7.6 Hz); 7.80 (d, 1 H, H(5), J = 8.2 Hz); 9.18 (s, 1 H, NH).

4-(2-Hydroxyphenyl)-7-nitro-2,3-dihydro-1*H*-1,5-benzodiazepin-2-one (5d). ***A.*** A mixture of adduct **3a** (0.44 g, 1 mmol)

and diamine **4d** (0.15 g, 1 mmol) in *m*-xylene (30 mL) was refluxed for 6 h. The solution was concentrated to 2/3 of the initial volume on a rotary evaporator. The precipitate that formed was purified by reprecipitation from an ethanolic NaOH solution. The yield of diazepinone **5d** was obtained in a yield of 0.22 g (75%), m.p. 241—242 °C.

B. Enamine **6** (0.15 g, 0.5 mmol) in *m*-xylene (15 mL) was refluxed for 3.5 h. Then the solution was concentrated to 1/2 of the initial volume on a rotary evaporator. The precipitate that formed was purified by reprecipitation from an ethanolic NaOH solution. The yield was 64%. Diazepine **5d** synthesized by the method ***A*** and the product prepared by the method ***B*** showed no melting point depression. Found (%): C, 70.38; H, 4.70; N, 11.20. $C_{15}H_{11}N_3O_4$. Calculated (%): C, 70.18; H, 4.77; N, 11.69. ^{1}H NMR, δ: 3.74 (s, 2 H, CH_2); 6.97—7.02 (m, 2 H, *o*-H arom., *p*-H arom.); 7.38—7.49 (m, 2 H, *m*-H arom.); 7.70 (d, 1 H, H(9), J = 8.0 Hz); 7.93 (d, 1 H, H(8), J = 8.0 Hz); 8.32 (d, 1 H, H(6), J = 8.0 Hz); 11.12 (s, 1 H, NH); 13.35 (s, 1 H, OH).

Earlier,[9] compound **5d** was characterized as the 8-nitro isomer, m.p. 199—200 °C.

Salt of [bis(4-hydroxy-2-oxo-2*H*-chromen-3-yl)]-4-nitrobenzoylmethane with *o*-phenylenediamine (7d). A mixture of adduct **3c** (0.485 g, 1 mmol) and diamine **4a** (0.11 g, 1 mmol) in MeOH (10—12 mL) was refluxed for 1.25 h. After cooling, yellow crystals of salt **7d** were isolated in a yield of 0.38 g (63%); no additional purification was required, m.p. 161—162 °C. Found (%): C, 62.85; H, 3.76; N, 6.87. $C_{26}H_{15}O_7^-C_6H_8O_2N_3^+ \cdot H_2O$. Calculated (%): C, 62.64; H, 3.52; N, 6.98. ^{1}H NMR, δ: 6.35 (s, 1 H, CH); 6.80—6.85 and 6.90—6.96 (both m, 2 H each, *o*-PDA); 7.16—7.22 (m, 4 H, H(6), H(8)); 7.40—7.47 (t, 2 H, H(7), J = 7.0 Hz); 7.73 (d, 2 H, H(5), J = 7.6 Hz); 7.90 and 8.17 (both d, 2 H each, Ar, J = 8.9 Hz). ^{13}C NMR, δ: 49.06 (C(1″), C(sp^3)); 61.52 (C(3), C(3′), coumarin); 105.68 (C(3), C(6), *o*-PDA); 120.98 (C(4), C(5), *o*-PDA); 124.55 (C(5), C(5′), coumarin); 125.58 (C(9), C(9′), coumarin); 128.18 (C(7), C(7′), coumarin); 128.45 (C(6), C(6′), coumarin); 128.55 (C(8), C(8′), coumarin); 129.40 (C(2), C(2′), 4-$NO_2C_6H_4$); 133.70 (C(3), C(3′), 4-$NO_2C_6H_4$); 136.62 (C(1), C(2), *o*-PDA); 148.03 (C(4), 4-$NO_2C_6H_4$); 154.37 (C(10), C(10′), coumarin); 157.72 (C(1), 4-$NO_2C_6H_4$); 168.95 (C(4), C(4′), coumarin); 173.36 (C(2), C(2′), coumarin); 202.58 (C(2″), C=O).

Compounds **7a—c** were synthesized analogously.

Salt of benzoyl[bis(4-hydroxy-2-oxo-2*H*-chromen-3-yl)]methane with *o*-phenylenediamine (7a). The yield was 57%, m.p. 155—156 °C. Found (%): C, 67.80; H, 4.60; N, 5.00. $C_{26}H_{15}O_7^-C_6H_9N_2^+ \cdot H_2O$. Calculated (%): C, 67.84; H, 4.63; N, 4.94. ^{1}H NMR, δ: 6.33 (s, 1 H, CH); 6.78—6.86 and 6.90—6.98 (both m, 2 H each, *o*-PDA); 7.18—7.24 (m, 4 H, H(6), H(8)); 7.26—7.32 (m, 3 H, Ar); 7.46 (t, 2 H, H(7), J = 7.3 Hz); 7.70—7.75 (m, 4 H, H(5), 2 H_{Ar}).

Salt of 4-bromobenzoyl[bis(4-hydroxy-2-oxo-2*H*-chromen-3-yl)]methane with *o*-phenylenediamine (7b). The yield was 60%, m.p. 176—177 °C. Found (%): C, 59.50; H, 3.86; N, 4.40. $C_{26}H_{14}BrO_7^-C_6H_9N_2^+ \cdot H_2O$. Calculated (%): C, 59.55; H, 3.90; N, 4.34. ^{1}H NMR, δ: 6.28 (s, 1 H, CH); 6.80—6.86 and 6.90—6.95 (both m, 2 H each, *o*-PDA); 7.20—7.28 (m, 4 H, H(6), H(8)); 7.48 (t, 2 H, H(7), J = 7.0 Hz); 7.53 and 7.65 (both d, 2 H each, Ar, J = 8.8 Hz); 7.72 (d, 2 H, H(5), J = 7.7 Hz).

Salt of 4-bromobenzoyl[bis(4-hydroxy-2-oxo-2*H*-chromen-3-yl)]methane with 4-methyl-*o*-phenylenediamine (7c). The yield was 59%, m.p. 212—214 °C. Found (%): C, 60.07; H, 4.17; N, 4.30. $C_{26}H_{14}BrO_7^-C_7H_{11}N_2^+ \cdot H_2O$. Calculated (%): C, 60.10; H, 4.13; N, 4.25. ^{1}H NMR, δ: 2.18 (s, 3 H, Me); 6.27 (s, 1 H, CH); 6.45 (d, 1 H, *o*-PDA, J = 8.0 Hz); 6.67 (s, 1 H, *o*-PDA); 6.88 (d, 1 H, *o*-PDA, J = 8.0 Hz); 7.20—7.24 (m, 4 H, H(6), H(8)); 7.46 (t, 2 H, H(7), J = 7.3 Hz); 7.55 and 7.65 (both d, 2 H each, Ar, J = 8.8 Hz); 7.75 (d, 2 H, H(5), J = 8.1 Hz).

2-Phenylquinoxaline (8a). A mixture of adduct **3a** (0.44 g, 1 mmol) and diamine **4a** (0.11 g, 1 mmol) in DMF (10 mL) was refluxed for 20 min. Then the reaction mixture was cooled and benzene (5 mL) was added. Product **8a** was obtained in a yield of 0.14 g (68%), m.p. 76 °C (from EtOH) (*cf.* lit. data[14]: m.p. 77—78 °C).

2-(4-Bromophenyl)-6-bromoquinoxaline (8b) was synthesized analogously. The yield was 65%, m.p. 148 °C (from EtOH) (*cf.* lit. data[14]: m.p. 148—149 °C). ^{1}H NMR, δ: 7.82 (d, 2 H, *o*-H arom., J = 8.6 Hz); 7.95—8.05 (m, 2 H, H(7), H(8)); 8.30 (d, 2 H, *m*-H arom., J = 8.6 Hz); 8.38 (s, 1 H, H(5)); 9.63 (s, 1 H, H(3)).

X-ray diffraction study. Triclinic crystals of **7d** were prepared by crystallization from EtOH, $C_{26}H_{14}NO_9^-C_6H_9N_2^+ \cdot C_2H_5OH \cdot H_2O$, at 20 °C a = 10.515(6) Å, b = 11.264(3) Å, c = 15.508(5) Å, α = 93.04(2)°, β = 104.90(4)°, γ = 116.18(4)°, V = 1563(1) Å^3, M_r = 657.62, Z = 2, space group $P\bar{1}$, d_{calc} = 1.397 g cm^{-3}, μ(Mo-Kα) = 0.106 mm^{-1}, F(000) = 688. The unit cell parameters and the intensities of 8656 reflections (5154 independent reflections, R_{int} = 0.032) were measured on a Xcalibur-3 diffractometer (Mo-Kα radiation, CCD detector, graphite monochromator, ω scanning technique, $2\theta_{max}$ = 50°). The hydrogen atoms were located in difference electron density maps and refined using a riding model with $U_{iso} = nU_{eq}$ of the parent nonhydrogen atoms (n = 1.5 for the hydroxy groups and n = 1.2 for the other hydrogen atoms). The hydrogen atoms of the protonated amino group and the hydroxy group O(3)H were refined isotropically. The structure was refined by the full-matrix-least-squares method based on F^2 with anisotropic displacement parameters for nonhydrogen atoms to wR_2 = 0.101 based on 5062 reflections (R_1 = 0.046 based on 2190 reflections with $F > 4\sigma(F)$, S = 0.766). The atomic coordinates and complete tables of the bond lengths and bond angles were deposited with the Cambridge Structural Database.

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