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A New Class of Benzoin Condensation Catalysts: *N,N′*-Disubstituted *o*-Phenylenediamines

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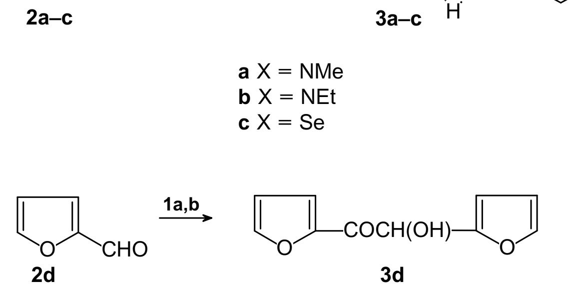
N,N′-Dialkyl(diaralkyl)-*o*-phenylenediamines may act as effective catalysts in the benzoin condensation of heterocyclic aldehydes.

Only a few types of benzion condensation catalysts are known. Among the organic catalysts quaternary azolium salts[1] and bis(1,3-dialkylimidazolidine-2-ylidenes)[2] are of greatest interest. The mechanism of condensation usually involves formation of an *O*-anionic adduct between aldehyde and ionic or uncharged nucleophile, which is produced by dissociation or deprotonation of the catalyst.[1–3]

In the present communication we report on a new class of organic benzoin condensation catalysts, *viz.* *N,N′*-disubstituted *o*-phenylenediamines **1a–d**. The catalytic properties of these amines were demonstrated for heterocyclic aldehydes **2a–d** (Scheme 1).

Condensation of **2a–d** by means of compounds **1a–d** occurs easily on heating the reaction components in dimethylformamide (DMF) or without solvent and results in formation of the products **3a–d**, which exist in a ketonic or enediolic form (see Table 1). The lowest reactivity as compared with other aldehydes investigated is of furfural **2d**. Its reaction therefore proceeds under significantly more rigorous conditions (160–190 °C) than the condensation of aldehydes **2a–c** (130–150 °C).



Scheme 1

Table 1 Conversions of heterocyclic aldehydes by action of diamines **1a–d**.

Aldehyde[a]	Catalyst or reagent (mol% in mixture with aldehyde)	Reaction conditions, *T*/°C (*t*/min)	Product yield (%)	M.p./°C (solvent for recrystallization)
2a	**1a** (11)	130(5)	**3a** (55)[b]	240–241 (DMF)
	1b (11)	130(5)	**3a** (80)[b]	
	1b (11)	130(5)	**3a** (72)	
	1d (36)	150(10)	**3a** (68)	
	1a (100)	100(10)	**4a** (61)[c]	147–150 (MeCN)
	4a (100)	130(5)	**3a** (64)	
2b	**1b** (11)	130(5)	**3b** (75)[b]	247–249 (DMF)
2c	**1c** (11)	140(5)	**3c** (45)	272–273 (DMF)[7]
2d	**1a** (7)	160–190(15)	**3d** (43)[b]	134–135 (EtOH)
	1b (7)	160–190(15)	**3d** (54)[b]	

[a] The quantity of aldehyde was 1 g in all experiments. [b] The reaction was carried out without solvent. [c] The reaction was carried out by heating equimolar amounts of aldehyde and amine in the presence of 0.02 ml AcOH for 5 min.

In a typical experiment 1-methyl-2-formylbenzimidazole **2a** (1.0 g) and freshly distilled diamine **1a** (0.1 g, 11 mol%) were kept at 130 °C for 5 min. The reaction mixture was then cooled and treated with 5 ml of DMF. The precipitate of **3a** was filtered off, washed with 10 ml of ethanol and recrystallised from DMF.

Compounds **3a–c** are orange-coloured due to their enediolic structure. The enediolic character of **3a–c** is confirmed by the absence of CO group absorption in their IR spectra and by ^{1}H NMR data for compound **3a** as well as

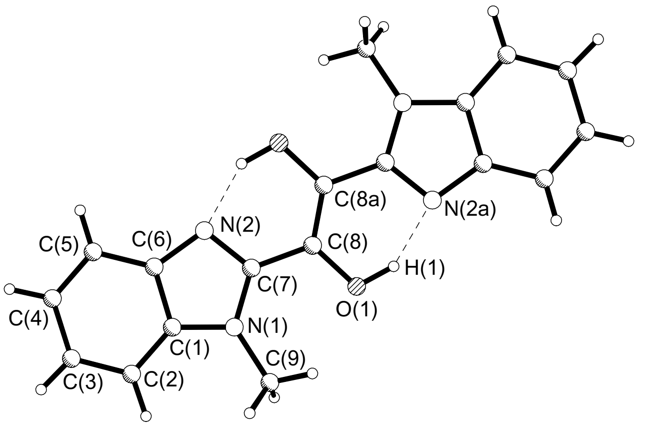
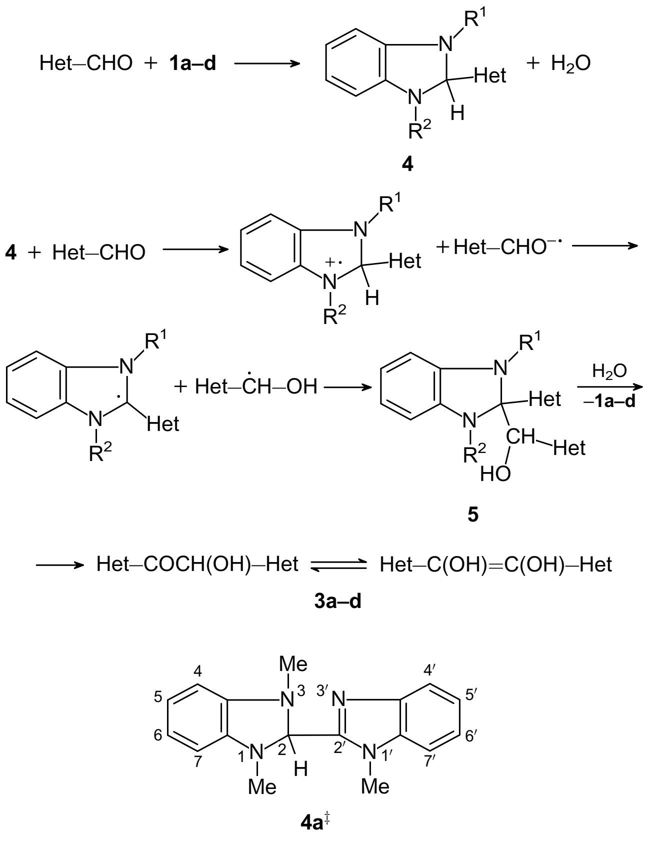


Fig. 1 The molecular structure of **3a**. Main geometric parameters: bond lengths (Å): C(1)–C(2) 1.388(2), C(2)–C(3) 1.386(3), C(3)–C(4) 1.405(3), C(4)–C(5) 1.383(3), C(5)–C(6) 1.399(2), C(1)–C(6) 1.405(6), C(7)–C(8) 1.451(2), C(8)–C(8a) 1.368(3), C(8)–O(1) 1.366(2), O(1)–H(1) 0.94(2), N(1)–C(1) 1.386(2), N(1)–C(7) 1.371(2), N(1)–C(9) 1.461(2), N(2)–C(6) 1.382(2), N(2)–C(7) 1.337(2); bond anlgles (°): C(1)–N(1)–C(7) 106.5(1), C(1)–N(1)–C(9) 123.0(1), C(7)–N(1)–C(9) 130.1(1), C(6)–N(2)–C(7) 105.6(1), N(1)–C(1)–C(2) 131.3(2), N(1)–C(1)–C(6) 106.2(1), C(2)–C(1)–C(6) 122.5(1), C(1)–C(2)–C(3) 116.6(2), C(2)–C(3)–C(4) 121.6(2), C(3)–C(4)–C(5) 121.6(2), C(4)–C(5)–C(6) 117.4(2), N(2)–C(6)–C(1) 109.4(1), N(2)–C(6)–C(5) 130.3(1), C(1)–C(6)–C(5) 120.3(1), N(1)–C(7)–N(2) 112.4(1), N(1)–C(7)—-C(8) 126.6(1), N(2)–C(7)–C(8) 121.1(1), O(1)–C(8)–C(7) 116.4(1), O(1)–C(8)–C(8a) 122.9(2), C(7)–C(8)–C(8a) 120.7(2), C(8)–O(1)–H(1) 107(1); parameters of hydrogen bond: O(1)...N(2a) 2.570(4), H(1)...N(2a) 1.72(2) A, O(1)–H(1)...N(2a) 148(1).

a crystallographic study of **3a** (Fig. 1) (*cf.* ref. 4).[†]

The catalytic activity of diamines **1a–d** is probably connected with their ability to form benzimidazolines by action of aldehydes.[5] Being very strong reductants (*cf.*, for example, ref. 6), these compounds may donate one electron to aldehyde molecules at elevated temperatures. In its turn, the electron transfer may initiate benzoin condensation by formation of 2-(α-hydroxyheteroarylmethyl)-substituted benzimidazoline **5** and hydrolysis of the latter with regeneration of the catalyst (Scheme 2).

Scheme 2 is confirmed by a preparative synthesis of 1,3-dimethyl-2-(1-methylbenzimidazol-2-yl)benzimidazoline **4a** from compounds **1a** and **2a** under relatively mild temperature conditions and the ability of **4a** to yield enediol **3a** by interaction with aldehyde **2a** (Table 1).



Scheme 2

In accordance with the proposed scheme *N*-methylaniline, which is structurally similar to the diamines **1a–d**, does not catalyse benzoin condensation of the aldehydes investigated.

In contrast to heterocyclic aldehydes **2a–d**, aromatic aldehydes, such as benzaldehyde and its simplest derivatives, are not condensed by means of diamines **1a–d**. This may be explained by hindrance to formation in this case of the corresponding benzimidazolinic alcohols, similar to compounds **5**.

References

1 T. Ukai, R. Tanaka and T. Kokawa, *J. Pharm. Soc. Jpn.*, 1943, **63**, 296; R. Breslow, *J. Am. Chem. Soc.*, 1958, **80**, 3719; H. Stetter, R. Y. Ramsch and H. Kuhlmann, *Synthesis*, 1976, 733.
2 M. F. Lappert and R. K. Maskell, *J. Chem. Soc., Chem. Commun.*, 1982, 580.
3 J. P. Kuebrich, R. L. Schowen, M. Wang and M. E. Lupes, *J. Am. Chem. Soc.*, 1971, **93**, 1214.
4 C. A. Buehler, *Chem. Rev.*, 1964, **64**, 7.
5 *Benzimidazoles and Congeneric Tricyclic Compounds*, eds. P. N. Preston and G. Tennant, Wiley Interscience, New York, 1971, p. 140.
6 N. T. Berberova, E. P. Ivakhnenko, A. S. Morkovnik and O. Yu. Okhlobystin, *Khim. Geterotsikl. Soedin.*, 1979, 1696 [*Chem. Heterocycl. Compd. (Engl. Transl.)*, 1979, 1372]; A. S. Morkovnik, E. S. Klimov, A. N. Suslov, E. P. Ivakhnenko, O. Yu. Okhlobystin and B. A. Tertov, *Khim. Geterotsikl. Soedin.*, 1987, 634 [*Chem. Heterocycl. Compd. (Engl. Transl.)*, 1987, 525]; A. S. Morkovnik, A. N. Suslov, Z. S. Morkovnik and B. A. Tertov, *Zh. Obshch. Khim.*, 1988, **58**, 446 (in Russian).
7 T. Ukai and S. Kanahara, *J. Pharm. Soc. Jpn.*, 1955, **75**, 31.

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Cambridge, 26th October 1994; Com. 4/05668J

[†] *Spectroscopic data for* **3a**: ^{1}H NMR (300 MHz, [^{2}H$_7$]DMF) δ 4.31 (s, 12H, 2 NMe), 7.27 (br.s, 2H, 2 OH), 7.35–7.47 (m, 4H, arom.), 7.71–7.82 (m, 4H, arom.).

Crystal data for **3a**: $C_{18}H_{16}N_4O_2$, $M = 320.36$, monoclinic, space group $P2_1/c$, $T = -92\,°C$, $a = 8.163(2),_3$ $b = 6.649(3)$, $c = 13.871(4)$ A, $\beta = 102.08(2)°$, $V = 736.2(0.8)$ A , $D_c = 1.454$ g cm^{-3}, $Z = 2$, μ(MoKα) = 0.92 cm^{-1}. Data were measured on a Siemens P3/PC diffractometer with Mo-Kα radiation (λ = 0.71069 Å, graphite monochromator) using θ/2θ scan, $\theta_{max} = 27°$. The structure was solved by direct methods (MULTAN program) and refined anisotropically by a full-matrix least-squares procedure. The hydrogen atoms were placed in calculated positions (except the hydrogen atoms of the methyl and hydroxyl groups, which were located in a difference Fourier synthesis) and refined isotropically. The final discrepancy factors were $R = 0.043$, $R_w = 0.052$ on 1363 independent reflections with $I > 3\sigma$. Atomic coordinates, bond lengths and angles and thermal parameters have been deposited at the Cambridge Crystallographic Data Centre, see Notice to Authors, *Mendeleev Commun.*, 1995, Issue 1.

[‡] *Spectroscopic data for* **4a**: ^{1}H NMR (300 MHz, C_6D_6, δ) 2.48 (s, 6H, 2 NMe), 3.62 (s, 3H, NMe), 5.62 (s, 1H, 2-H), 6.48–6.53 (m, 2H, 4-H, 7-H), 6.97–7.03 (m, 2H, 5-H, 6-H), 7.12–7.16 (m, 1H, 4′-H), 7.31–7.41 (m, 2H, 5′-H, 6′-H), 8.16–8.21 (m, 1H, 7′-H).