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LETTERS TO THE EDITOR

Synthesis of 4-(Hydroxyphenyl)-1,2,4-triazoles

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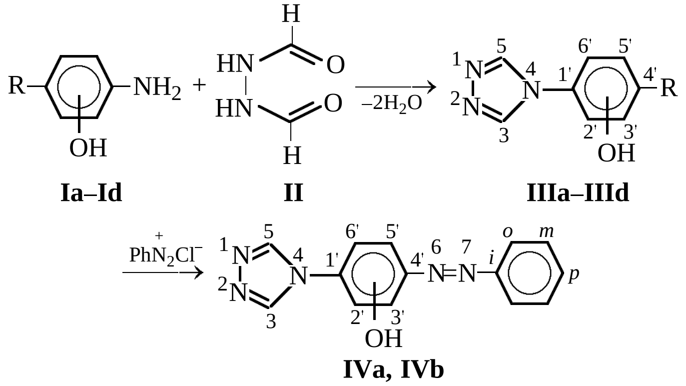
Derivatives of 1,2,4-triazole are potential ligands for the synthesis of magnetoactive coordination compounds possessing optoelectronic, electrochemical, electrophysical, and thermochemical properties [1–7]. Certain 1,2,4-triazoles are applied as drugs [8–10], herbicides, pesticides, and growth regulators [11–13], while 4-substituted 1,2,4-triiazoles exhibit radioprotective activity [14, 15].

In the present work we developed a procedure for preparing previously unknown 4-substituted 1,2,4-triazoles, specifically 4-(*o*-,*m*-,*p*-hydroxyphenyl)-1,2,4-triazoles, and studied their azo coupling with phenyldiazonium chloride.



2-OH (**Ia, IIIa, IVa**), 3-OH (**Ib, IIIb, IVb**), 4-OH (**Ic, IIIc**); R = H (**Ia–Ic, IIIa–IIIc**); 2-OH; R = $NO_2$3 (**Id, IIId**).

4-Substituted 1,2,4-triazoles were prepared by fusing diformylhydrazine (**II**) with amino phenols **I** at 114–170°C. Triazoles **III** are stable crystalline substances with high melting points and soluble in ethanol, DMSO, and aqueous ethanol (1 : 1).

Treatment of solutions of compounds **IIIa** and **IIIb** in methanol (aniline, $NaNO_2$, conc. HCl) gave azo derivatives **IVa** and **IVb**, respectively.

4-(*o*-Hydroxyphenyl)-1,2,4-triazole (IIIa). A mixture of 8.8 g of diformylhydrazone (**II**), 10.9 g of *o*-aminophenol (**Ia**), and a little hydroquinone was heated at 145–150°C for 0.5 h under argon and then cooled to 70°C, and 20 ml of ethanol. The mixture was stirred for 5 min, cooled to 20°C, diluted with 100 ml of absolute ether, and left to stand overnight in a refrigerator. The precipitate that formed was filtered off and recrystallized from aqueous ethanol (1:1). Yield 6.65 g (46%), grayish yellow crystals, mp 214–216°C. IR spectrum, ν, cm^{-1}: 3400 (OH), 3100

(CH), 1600 (C=N), 1520, 1475, 1440 ($C=C_{arom}$), 1285 (C–N). ^{1}H NMR spectrum, ν, ppm: 7.32–7.81m (CH_{arom}), 9.20 s (2H, $C^{3,5}H$), 10.92 br.s (1H, OH). ^{13}C NMR spectrum, δ_C, ppm: 150.53 ($C^{2'}$), 143.17 ($C^{3,5}$), 129.79 ($C^{5'}$), 125.63 ($C^{4'}$), 121.71 ($C^{1'}$), 119.70 ($C^{3'}$), 119.95 ($C^{6'}$). ^{15}N NMR spectrim, δ_N, ppm: –203.5 (N^4), –62.0 ($N^{1,2}$). Found, %: C 59.62; H 3.95; N 26.12. $C_8H_7N_3O$. Calculated, %: C 59.63; H 4.38; N 26.07.

4-(*m*-Hydroxyphenyl)-1,2,4-triazole (IIIb) was prepared similarly to **IIIa** from 4.4 g of compound **II** and 5.5 g of *m*-aminophenol at 114–115°C, reaction temperature 1 h. Yield 4.37 g (54%), grayish yellow crystals, mp 230–231°C (from ethanol). IR spectrum, ν, cm^{-1}: 3410 (OH), 3100 (CH), 1605 (C=N), 1520, 1490, 1440 ($C=C_{arom}$), 1220 (C–N). ^{1}H NMR spectrum, δ, ppm: 6.85–7.33 m (CH_{arom}), 9.05 s (2H, $C^{3,5}H$), 10.01 s (1H, OH). ^{13}C NMR spetrum, δ_C, ppm: 158.87 ($C^{3'}$), 141.71 ($C^{3,5'}$), 135.19 ($C^{1'}$), 131.25 ($C^{5'}$), 115.42 (C^6), 112.02 ($C^{4'}$), 108.60 ($C^{2'}$). ^{15}N NMR spectrum, δ_N, ppm: –193.8 (N^4), –59.7 ($N^{1,2}$). Found, %: C 59.58; H 4.30; N 25.92. $C_8H_7N_3O$. Calculated, %: C 59.63; H 4.38; N 26.07.

4-(*p*-Hydroxyphenyl)-1,2,4-triazole (IIIc) was prepared similarly to **IIIc** from 4.4 g of compound **II** and 5.5 g *p*-aminophenol at 165–170°C, reaction time 0.5 h. Yield 4.82 g (64%), grayish yellow crystals, mp 285–286°C (from ethanol). IR spectrum, ν, cm^{-1}: 3400 (OH), 3090 (CH), 1590 (C=N), 1520, 1480 ($C=C_{arom}$), 1230 (C–N). ^{1}H NMR spectrum, δ, ppm: 6.90–17.45 m (C_{arom}), 8.92 s (2H, $C^{3,5}$), 9.85 s (1H, OH). ^{13}C NMR spectrum, δ_C, ppm: 157.43 ($C^{4'}$), 141.82 ($C^{3,5}$), 125.85 ($C^{1'}$), 123.33 ($C^{2',}$ 6'), 116.30 ($C^{3',5'}$). ^{15}N NMR spectrum, δ_N, ppm: –194.4 (N^4), –59.7 ($N^{1,2}$). Found, %: C 59.48; H 4.25; N 26.02. $C_8H_7N_3O$. Calculated, %: C 59.63; H 4,38; N 26.07.

4-(2-Hydroxy-4-nitrophenyl)-1,2,4-triazole (IIId) was prepared similarly to **IIIa** from 4.4 g of compound **II** and 7.7 g of 2-amino-5-nitrophenol at 175–180°C, reaction time 1 h. Yield 6.68 g (68%), black crystals, mp 360–365°C. IR spectrum, ν, cm^{-1}: 3410 (OH), 3105 (CH), 1590 (C=N), 1520, 1495, 1425 ($C=C_{arom}$), 1360, 865 (NO_2), 1210 (C–N). ^{1}H NMR spectrum, δ, ppm: 7.72–7.83 m (3H, C_6H_3), 8.95 s (2H, $C^{3,5}H$), 14.33 br.s (1H, OH). ^{13}C NMR spectrum, δ_C, ppm: 151.36 ($C^{2'}$), 147.93 ($C^{4'}$), 143.41 ($C^{3,5}$), 127.69 ($C^{1'}$), 126.55 ($C^{6'}$), 115.29 ($C^{5'}$), 111.92 ($C^{3'}$). ^{15}N NMR spectrum, δ_N, ppm: –200.4 (N^4), –59.9 ($N^{1,2}$), –7.2 (NO_2). Found, %: C 46.85; H 2.71; N 26.95. $C_8H_6N_4O_3$. Calculated, %: C 46.60; H 2.91; N 27.18.

4-(2-Hydroxy-4-phenylazophenyl)-1,2,4-triazole (IVa). To a cold (0°C) solution of 1.61 g of 4-(*o*-hydroxyphenyl)-1,2,4-triazole (**IIIa**) in 20 ml of methanol, a cold (0°C) solution of phenyldiazonium chloride (2 g of aniline and 1.65 g of $NaNO_2$ in 6 ml of conc. HCl and 50 ml of water) was added. After 5-min stirring, a saturated solution of sodium acetate was added until turbidity, and the mixture was left to stand overnight. The precipitate that formed was filtered off, washed on the filter with cold water, and dried in a vacuum. Yield 1.56 g (60%), bright yellow crystals, mp 235–237°C (from DMF). IR spectrum, ν, cm^{-1}: 3440 (OH), 3100 (CH), 1610, 1595 (N=N, C=N), 1530, 1500, 1425 ($C=C_{arom}$), 1205 (C–N). ^{1}H NMR spectrum, δ, ppm: 7.27–8.01 m (3H, C_6H_3), 7.54–7.85 m (5H, C_6H_5), 8.93 (2H, $C^{3,5}H$). ^{13}C NMR spectrum, δ_C, ppm: 153.81 ($C^{6'}$), 151.81 (C_i), 144.88 ($C^{3'}$), 143.00 ($C^{3,5}$), 131.05 (C_p), 129.40 (C_m), 124.38 ($C^{4'}$), 122.27 ($C^{1'}$, C_o), 120.21 ($C^{2'}$), 117.22 ($C^{5'}$). ^{15}N NMR spectrum, δ_N, ppm: –200.8 (N^4), –125.5 (N^6), –121.5 (N^7), –57.7 ($N^{1,2}$). Found, %: C 63.25; H 4.29; N 26.18. $C_{14}H_{11}N_5O$. Calculated, %: C 63.38; H 4.17; N 26. 40.

4-(3-Hydroxy-4-phenylazophenyl)-1,2,4-triazole (IVb) was prepared similarly to **IVa** from 1.73 g of 4-(*m*-hydroxyphenyl)-1,2,4-triazole (**Ib**), 2.0 g of aniline, 1.65 g of $NaNO_2$, 1.65 g of sodium acetate at 0°C. Yield 1.51 g (58%), bright yellow crystals, mp 274–276°C. IR spectrum, ν, cm^{-1}: 3430 (OH), 3105 (CH), 1610, 1585 (N=N, C=N), 1535, 1510, 1410 ($C=C_{arom}$), 1205 (C-N). 1H NMR spectrum, δ, ppm: 7.00–7.66 m (3H, C_6H_3), 7.48–7.85 m (5H, C_6H_5), 8.85 s ($C^{3,5}H$), 10.96 br.s (1H, OH). ^{13}C NMR spectrum, δ_C, ppm: 162.26 ($C^{3'}$), 152.38 (C_i), 144.30 ($C^{3,5}$), 137.49 ($C^{4'}$), 135.17 ($C^{1'}$), 131.32 (C_p), 129.55 (C_m), 122.75 (C_o), 118.27 ($C^{5'}$), 117.04 ($C^{6'}$), 112.12 ($C^{2'}$). ^{15}N NMR spectrum, δ_N, ppm: –199.3 (N^4), –120.4 (N^7), –116.0 (N^6), –58.1 ($N^{1,2}$). Found, %: C 63.38; H 4.22; N 26.12. $C_{14}H_{11}N_5O$. Calculated, %: C 63.38; H 4.17; N 26.40.

The IR spectra were obtained on a Specord IR-75 instrument in KBr. The ^{1}H and ^{13}C NMR spectra were recorded at 20°C on a Bruker-400 spectrometer (400.13 and 100.62 MHz, respectively) in DMSO-d_6, internal reference HMDS.

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