

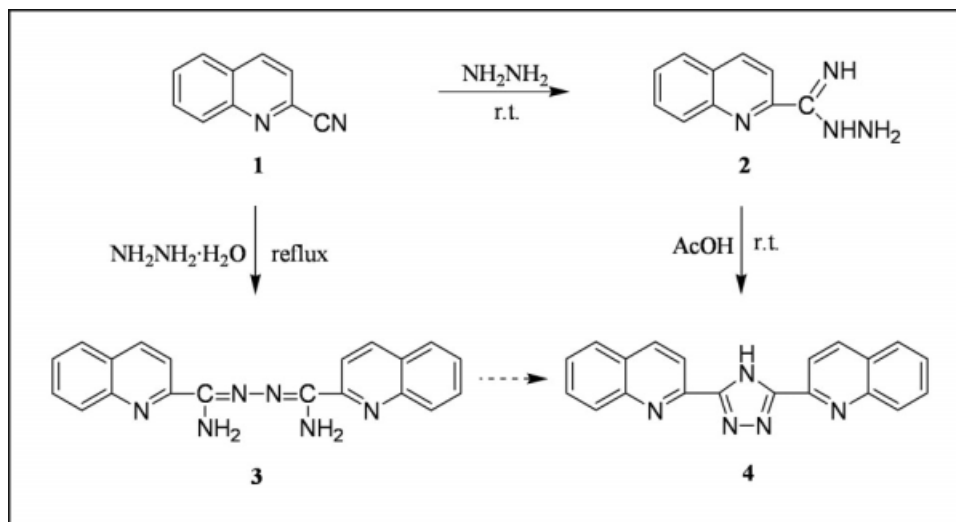
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The first quinolyl substituted 1,2,4-triazole, 3,5-bis(2-quinoly)-1,2,4-triazole (**4**), was synthesized from 2-cyanoquinoline (**1**) through an intermediate 2-quinolyldiazidene (**2**) with 60.4% yield in a simple way. In the synthetic process of **4**, another new intermediate, 1,4-diamino-1,4-bis(2-quinoly)-2,3-diaza-1,3-butadiene (**3**) was obtained in a yield of 81.5%. Additionally, the absolute configurations of both **3** and **4** were determined by X-ray crystallography.

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INTRODUCTION

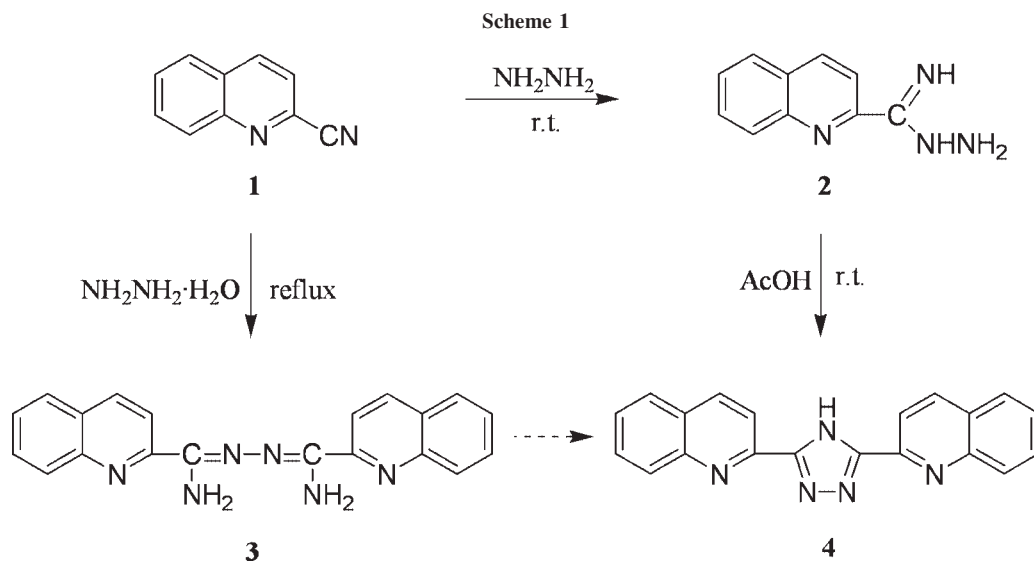
Over recent years, heterocyclic compounds containing 1,2,4-triazole rings have attracted widespread attention because of their broad applications as antifungus, antitumor, fungicide, weedicide, and so on [1]. Moreover, substituted 1,2,4-triazoles are very useful ligands in coordination chemistry [2–4]. This is mainly because of that they can act as bridging ligands between transition metal ions thus providing rich and versatile coordination modes. More interestingly, their ligand strength is in the right region to give iron(II) spin-crossover complexes, which could be used as molecular-based memory devices, displays and switching materials [5,6].

Although a lot of 1,2,4-triazole compounds with substituted alkyl, phenyl or pyridyl groups [3,7] have been synthesized successfully, substituted 1,2,4-triazoles with quinolyl group, an important alkaloid with stronger conjugated system, have never been reported so far. Recently, we have prepared some new triaryltriazole

compounds [8,9] and their complexes [10–16]. As a continuation of our investigation on the substituted 1,2,4-triazoles, herein, we present the first synthesis of 3,5-bis(2-quinoly)-1,2,4-triazole (**4**) through the nucleophilic addition of hydrazine to 2-cyanoquinoline (**1**) (Scheme 1). The product **4** was characterized by UV, FTIR, ¹H NMR, TOF-MS spectra, elemental analysis and single crystal X-ray diffraction. In addition, another new intermediate, 1,4-diamino-1,4-bis(2-quinoly)-2,3-diaza-1,3-butadiene (**3**), has also been obtained and its crystal structure was described [17].

RESULTS AND DISCUSSION

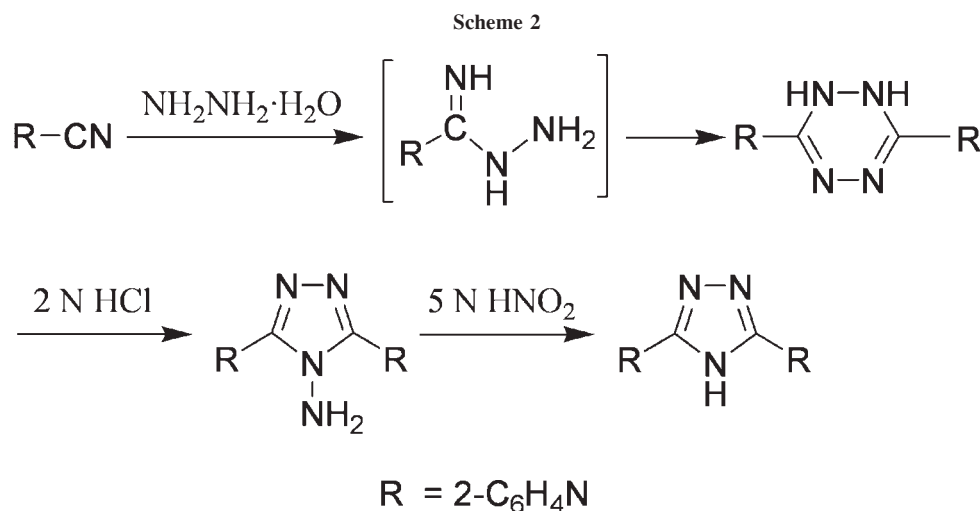
Several methods have been reported for the syntheses of 3,5-diaryl-substituted 1,2,4-triazoles [18–24]. However, following the method (Scheme 2) reported by Gellard and Lions [23] using 2-cyanoquinoline (**1**) instead of 2-cyanopyridine as starting material for the synthesis



of **4**, we did not obtain the corresponding 1,2,4,5-tetrazine. The corresponding 1,2,4,5-tetrazine was also not obtained, though we changed the reaction conditions such as the molar ratios of the 2-cyanoquinoline and hydrazine hydrate, reaction temperature, and replacing hydrazine hydrate with anhydrous hydrazine. Instead, two different intermediates were identified. One is 1,4-diamino-1,4-bis(2-quinoly)-2,3-diaza-1,3-butadiene (**3**) with 81.5% yield after refluxing **1** and hydrazine hydrate (molar ratios 1:2) for 2 h at 110°C [24]. The other is 2-quinolyhydrazidine (**2**) in a yield of 94.6% by stirring **1** and anhydrous hydrazine (molar ratios 1:33) in anhydrous ethanol for 3 h at room temperature [25]. The structure of **3** has been determined by X-ray crystallography (Fig. 1). When **3** was heated to 200°C in argon atmosphere, only trace amounts of compound **4** was formed. In contrast, when **2** was mixed in acetic acid at room temperature, **4** was obtained in a yield of 60.4%

[26]. To our knowledge, this is the first report to synthesize 3,5-diaryl-substituted 1,2,4-triazoles without involving the corresponding 1,2,4,5-tetrazine and 1,2,4-triazoline intermediates compared with the other methods [23,24].

The molecular structure of **4** was also confirmed by X-ray crystallography. Single crystals of **4** were obtained by slow evaporation of its ethanol solution at ambient temperature. A structural view with atom-numbering scheme is shown in Figure 2 and selected bond lengths and bond angles are listed in Table 1. The X-ray structure analysis indicates that **4** consists of two quinolyl rings and one triazole ring. These rings do not share a common plane. The quinolyl ring with N1 atom makes a dihedral angle of 10.1(4)° with the triazole ring, whereas the quinolyl ring with N5 atom makes a dihedral angle of 35.5(4)° with respect to the triazole plane. The dihedral angle between two quinolyl groups is



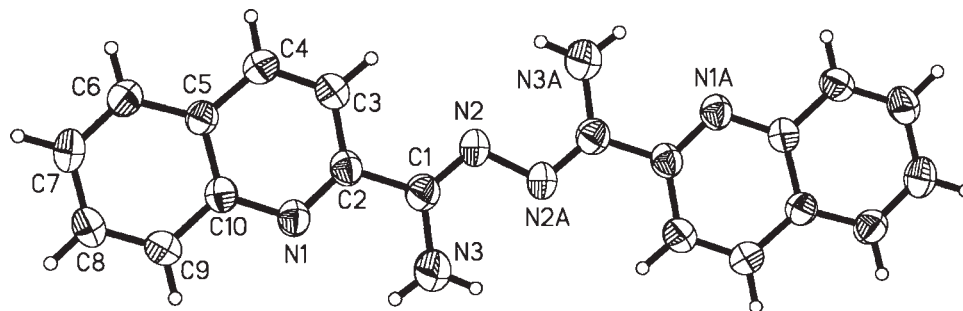


Figure 1. A view of **3** showing the atom-numbering scheme. Thermal ellipsoids are shown at the 50% probability level.

37.7(4)°. The bond lengths and bond angles in the structure of **4** are in the usual ranges. In the crystal, the possibility of N—H...N hydrogen bonds is reduced due to the presence of the bulky quinolyl groups. However, the molecules of **4** are further stabilized by C—H... π interactions involving C19—H19 and the phenyl ring at $(-1/2 + x, 1/2 - y, 1/2 + z)$ [C19... π = 3.588(5) Å and C19—H19... π = 136.6(4)°] [8].

EXPERIMENTAL

Melting points were determined with an X-4 digital microscope melting-point apparatus (Beijing) and are uncorrected. UV-vis spectra were recorded on a Perkin-Elmer Lambda 35 spectrophotometer at room temperature. FT-IR spectra were recorded on a Nicolet 380 FT-IR instrument using KBr disks. ¹H NMR spectra were measured on a Bruker AM 500 MHz spectrometer. Chemical shifts are reported in parts per million (ppm) downfield from tetramethylsilane (TMS). Mass spectra were recorded on an Autoflex II TOF/TOF. Elemental analyses of compounds were performed with an Elementer Varian EL III instrument. Commercial reagents were used without further purification unless otherwise stated. 2-Cyanoquinoline (**1**) was synthesized according to literature method [27].

2-Quinolylhydrazidine (2). A mixture of **1** (1.54 g, 10 mmol) and anhydrous hydrazine (10.2 mL, 321 mmol) was stirred in anhydrous ethanol (6.3 mL) at ambient temperature for 2 h. The solid was collected and washed with cold water. Then the crude product was recrystallized from anhydrous ethanol to give yellow needles 1.76 g (94.6%), mp 191–192°C

(lit. mp 191–192°C [25]); IR (v, cm⁻¹): 3436, 3290, 3178, 3061, 3012, 1636, 1599, 1561, 1507, 831, 747, 625, 477. ¹H NMR (CDCl₃, ppm): δ 4.74 (s, 2H, NH), 5.38 (s, 2H, NH₂), 7.51–7.54 (t, 1H, ArH), 7.68–7.71 (t, 1H, ArH), 7.79–7.81 (d, 1H, ArH), 8.05–8.07 (d, 1H, ArH), 8.10–8.15 (m, 2H, ArH).

1,4-Diamino-1,4-bis(2-quinolyl)-2,3-diaza-1,3-butadiene (3). A mixture of **1** (1.2 g, 7.8 mmol) and hydrazine hydrate (1.2 mL) was stirred at 110°C for 2 h. Upon cooling to ambient temperature, the solid was collected and recrystallized from ethyl acetate to give yellow needles 1.08 g (81.5%), mp 178–180°C; UV (EtOH, nm): 209 (1.32), 240 (1.70), 296 (0.53), 308 (0.51), 332 (0.47, sh). IR (v, cm⁻¹): 3436, 3289, 3180, 3058, 1637, 1598, 1561, 1507, 831, 747, 625, 477. ¹H NMR (CDCl₃, ppm): δ 5.47 (s, 2H, NH₂), 7.54–7.58 (t, 1H, ArH), 7.62–7.76 (t, 1H, ArH), 7.82–7.85 (d, 1H, ArH), 8.07–8.10 (d, 1H, ArH), 8.16–8.17 (t, 2H, ArH). Anal. Calcd. for C₂₀H₁₆N₆: C, 70.57; H, 4.74; N, 24.69. Found: C, 70.68; H, 4.99; N, 24.54.

3,5-Bis(2-quinolyl)-1,2,4-triazole (4). At 0°C, **2** (2.44 g, 13.1 mmol) was mixed with glacial acetic acid (7.5 mL, 131 mmol) and then stirred for 3 h at room temperature. After the removal of unreacted acid under vacuum, the crude product was recrystallized from anhydrous ethanol to yield colorless crystals 1.28 g (60.4%), mp 226–227°C; UV (EtOH, nm): 213 (2.04), 248 (2.27), 306 (0.71), 320 (0.83), 335 (1.00). IR (v, cm⁻¹): 3174, 3056, 1698, 1615, 1598, 1567, 1502, 836, 769, 615, 476. ¹H NMR (CDCl₃, ppm): δ 7.66 (s, 1H, ArH), 7.84 (s, 1H, ArH), 7.93 (s, 1H, ArH), 8.36 (s, 1H, ArH), 8.43 (s, 1H, ArH), 8.56 (s, 1H, ArH). MS: *m/z* 324.1 (M⁺ + 1), 323.1 (M⁺), 295.1 (M⁺ + 1 - N₂), 294.1 (M⁺ - N₂). Anal. Calcd. for C₂₀H₁₃N₅: C, 74.28; H, 4.05; N, 21.66. Found: C, 74.42; H, 4.18; N, 21.52.

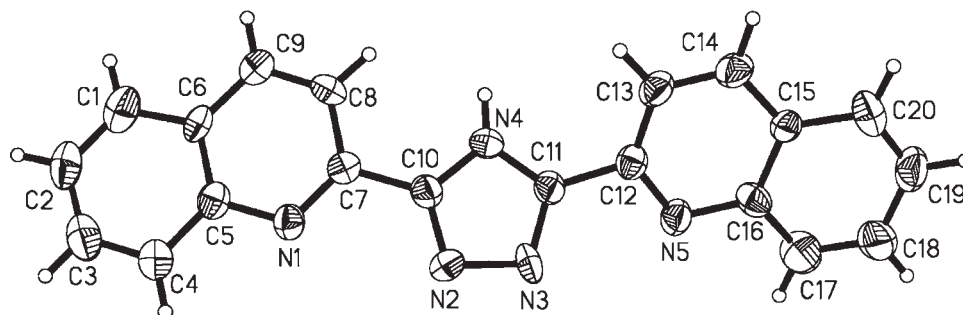


Figure 2. A view of **4** showing the atom-numbering scheme. Thermal ellipsoids are shown at the 50% probability level.

Table 1

Selected bond lengths and angles for **4**.

Bond length (Å)		Bond angle (°)	
N1—C7	1.308 (5)	C7—N1—C5	118.1 (4)
N1—C5	1.383 (5)	C10—N2—N3	103.6 (3)
N2—C10	1.321 (5)	C11—N3—N2	106.9 (3)
N2—N3	1.387 (4)	C11—N4—C10	104.5 (3)
N3—C11	1.359 (5)	C12—N5—C16	116.1 (4)
N4—C10	1.330 (5)	N1—C7—C10	118.6 (4)
N4—C11	1.319 (5)	C8—C7—C10	118.4 (4)
N5—C12	1.316 (5)	N5—C12—C11	113.2 (4)
N5—C16	1.385 (5)	C13—C12—C11	121.0 (4)
C7—C10	1.470 (5)		
C11—C12	1.482 (6)		

Single-crystal X-ray diffraction analysis of **4.** C₂₀H₁₃N₅, $M_r = 323.35$, monoclinic, $P2_1/c$, $a = 14.306(3)$ Å, $b = 7.0990(14)$ Å, $c = 15.372(3)$ Å, $\beta = 95.85(3)^\circ$, $V = 1553.0(5)$ Å³, $Z = 4$, $\rho = 1.383$ mg/m³, $\mu = 0.087$ mm⁻¹, $F(000) = 672$, $R_1 = 0.0775$ for 1248 observed ($I > 2\sigma(I)$) reflections and 0.1822 for all 2939 reflections, Goodness-of-fit = 1.003, 226 parameters.

A colorless block crystal of **4** with dimensions $0.06 \times 0.10 \times 0.10$ mm³ was selected for lattice parameter determination and collection of intensity data at 293 K on a FR590 CAD4 four-circle diffractometer with monochromated Mo K_α radiation ($\lambda = 0.71073$ Å) using a $\theta/2\theta$ scan mode. The data was corrected for Lorentz and polarization effects during data reduction. An empirical absorption correction based on ψ scans was applied. The structure was solved by the direct methods and refined on F^2 by full-matrix least-squares methods using the SHELXL version 5.10 [28]. All nonhydrogen atoms were refined anisotropically. Hydrogen atoms for C—H and N—H were placed in calculated positions (0.96 Å), assigned fixed isotropic thermal parameters at 1.2 times the equivalent isotropic U of the atoms to which they are attached, and allowed to ride on their respective parent atoms.

CCDC 736135 contains the supplementary crystallographic data for this article. These data can be obtained free of charge from the Cambridge Crystallographic Data Centre via www.ccdc.cam.ac.uk/data_request/cif.

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