Available online at www.sciencedirect.com
ScienceDirect
Mendeleev Commun., 2009, **19**, 42–44

Mendeleev Communications

(*Z*)-1-Organyl-2-(2,4-dicyano-1,3-diphenyl-1,3-butadienyl)imidazoles from 1-substituted imidazoles with phenylcyanoacetylene

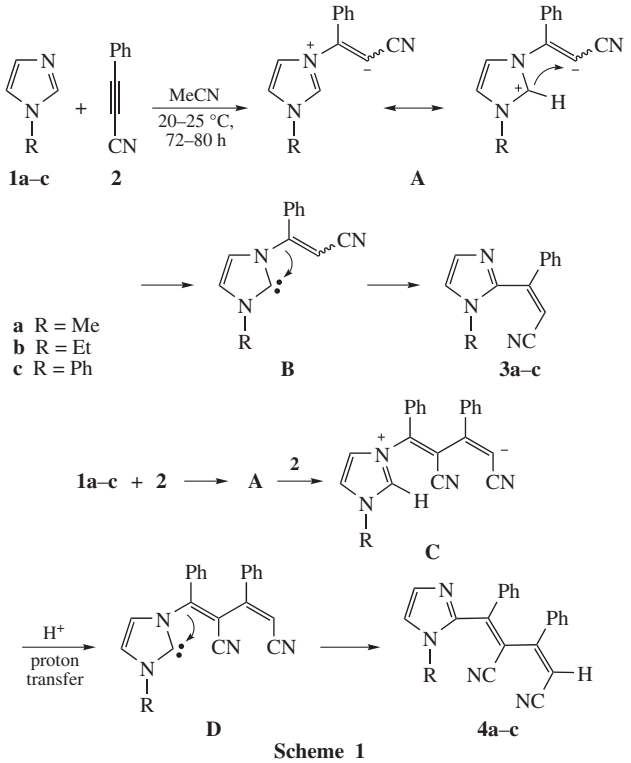
Boris A. Trofimov,* Lyudmila V. Andriyankova, Kseniya V. Belyaeva, Anastasiya G. Mal'kina, Lina P. Nikitina, Andrei V. Afonin and Igor A. Ushakov

A. E. Favorsky Irkutsk Institute of Chemistry, Siberian Branch of the Russian Academy of Sciences, 664033 Irkutsk, Russian Federation. Fax: +7 395 241 9346; e-mail: boris_trofimov@irioch.irk.ru

DOI: 10.1016/j.mencom.2009.01.017

1-Substituted imidazoles (R = Me, Et, Ph) react (20–25 °C) with phenylcyanoacetylene to afford the 1:2 adducts, (*Z*)-1-organyl-2-(2,4-dicyano-1,3-diphenyl-1,3-butadienyl)imidazoles, in 10–20% yields, along with the 1:1 adducts, (*Z*)-1-organyl-2-(2-cyano-1-phenylethenyl)imidazoles.

2-(1,3-Butadienyl)imidazoles particularly those having functional groups in the unsaturated moieties are of interest as potent building blocks for the synthesis of imidazole derivatives. Recently, we have found that the reaction of 1-substituted imidazoles with α,β-acetylenic γ-hydroxynitriles proceeds as an unusual exchange of the substituent at the 1-position of the imidazole ring (Me, Et and vinyl group) for functionalized vinyl moiety, thus implying an easy substituent migration in zwitterionic intermediates.[1] Similar zwitterionic adducts are common for the reactions of α,β-acetylenic γ-hydroxynitriles with pyridines,[2] quinoline and quinoxaline,[3] phenanthridines,[4] and natural alkaloid (anabazine).[5] Therefore, it may be anticipated that 1-substituted imidazoles could form with electron-deficient acetylenes having no proton-donor function, the zwitterions, which further can be converted to 2-ethenylimidazoles (1:1 adducts) and 2-(1,3-butadienyl)imidazoles (1:2 adducts), if the second molecule of phenylcyanoacetylene intercepts the intermediate carbanion.



Scheme 1

Indeed, in this work we found that when 1-substituted imidazoles **1a–c** are allowed to react with phenylcyanoacetylene **2** (20–25 °C, MeCN, 72–80 h) a mixture of 2-ethenylimidazoles **3a–c**† (8–25% yield) and 2-(1,3-butadienyl)imidazoles **4a–c** (10–20% yield) is formed (Scheme 1).‡

Adducts (1:2) **4a–c** are likely resulted from the primary zwitterionic intermediates **A** added by its carbanionic site to the second molecules of acetylene **2** thus furnishing intermediate **C**. The latter abstracts a proton from the 2-position of

† Isolation and characterization of imidazoles **3a–c** will be published elsewhere.

‡ IR spectra were recorded on an IFS 25 instrument. NMR spectra were run on a Bruker DPX-400 (400.13 MHz, ^{1}H; 100.62 MHz, ^{13}C; 40.55 MHz, ^{15}N) spectrometer in $CDCl_3$ with HMDS as an internal standard. 1-Substituted imidazoles **1a–c** were prepared according to the known procedures.[8] Phenylcyanoacetylene **2** was obtained by the published procedure.[9] Column and thin-layer chromatography was carried out on neutral Al_2O_3 with chloroform/benzene/ethanol (20:4:1) mixture as eluent. The reaction was controlled by disappearance of spot of the initial phenylcyanoacetylene **2** on fine layer of Al_2O_3.

(Z)-1-Methyl-2-(2-cyano-1-phenylethenyl)imidazole **3a** *and (Z)-1-methyl-2-(2,4-dicyano-1,3-diphenyl-1,3-butadienyl)imidazole* **4a**: (**1a**:**2**, 1:1). A mixture of 1-methylimidazole **1a** (82 mg, 1 mmol) and acetylene **2** (127 mg, 1 mmol) in MeCN (1 ml) was stirred at 20–25 °C for 72 h. The solvent was removed and column chromatography gave 35 mg of crimson oil containing imidazoles **3a** (8%) and **4a** (10%) in 1:1 ratio (^{1}H NMR). IR (microlayer of **3a** and **4a** mixture, ν/cm^{-1}): 407, 423, 643, 663, 695, 763, 832, 902, 924, 1001, 1030, 1080, 1139, 1160, 1186, 1259, 1282, 1406, 1447, 1474, 1492, 1517, 1574, 1597, 1622, 1679, 2215, 2954, 3020, 3060, 3108, 3141.

4a: ^{1}H NMR, δ: 3.11 (s, 3H, NMe), 5.62 (s, 1H, H^9), 6.93 (d, 1H, H^5, $^3J_{5,4}$ 1.2 Hz), 7.03 (d, 1H, H^4, $^3J_{4,5}$ 1.2 Hz), 7.48 (m, 1H, H$^{14'}$), 7.48 (m, 2H, H$^{13',15'}$), 7.49 (m, 1H, H^{14}), 7.51 (m, 2H, H^{13,15}), 7.57 (m, 2H, H^{12,16}), 7.66 (m, 2H, H$^{12',16'}$). ^{13}C NMR, δ: 34.76 (NMe), 96.99 (C^9), 110.68 (C^7), 116.70 (C$^{10'}$), 116.90 (C^{10}), 125.16 (C^5), 126.90 (C^{14}), 128.27 (C$^{12',16'}$), 129.00 (C$^{13',15'}$), 129.40 (C^{12,16}), 129.70 (C^{13,15}), 129.84 (C^4), 131.30 (C$^{14'}$), 134.96 (C$^{11'}$), 135.50 (C^{11}), 142.72 (C^2), 152.10 (C^6), 157.40 (C^8). ^{15}N NMR, δ: –217.60 (N^1), –116.90 (C$^{10'}$N), –107.10 (N^3).

(Z)-1-Ethyl-2-(2-cyano-1-phenylethenyl)imidazole **3b** *and (Z)-1-ethyl-2-(2,4-dicyano-1,3-diphenyl-1,3-butadienyl)imidazole* **4b**: (**1b**:**2**, 1:1, 72 h). Analogously, from 1-ethylimidazole **1b** (96 mg, 1 mmol) and acetylene **2** (127 mg, 1 mmol) in MeCN (1 ml), 80 mg of crimson oil containing imidazoles **3b** (25%) and **4b** (14%) in the ratio of 7:3 (^{1}H NMR), were prepared. IR (microlayer of **3b** and **4b** mixture, ν/cm^{-1}): 466, 648, 697, 734, 765, 835, 920, 967, 1001, 1035, 1064, 1099, 1139, 1159, 1185, 1213, 1280, 1352, 1388, 1425, 1447, 1476, 1492, 1519, 1574, 1596, 1625, 1675, 2216, 2937, 2983, 3060, 3107.

the imidazole ring, finally giving carbene intermediate **D** (the stable imidazole carbenes of such a type are well known[6]). The 3,2-migration of the functionalized 1,3-butadienyl group in these intermediates affords 2-(1,3-butadienyl)imidazoles **4a–c**.

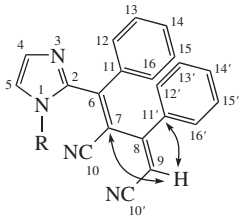
Note that zwitterions of the type **A** are well-established intermediates in the reactions of nucleophiles with electron-deficient systems.[7]

In one case (R = Me), molar ratio **1a**:**2** = 1:2 (20–25 °C, Et_2O, 120 h), imidazole **4a** has been isolated as an individual compound (10% yield).

Apparently, no limitations for further elongation of the conjugation polyene chain at the 2-position of the imidazole nucleus using excess acetylene **2** are envisaged.

Imidazoles **4a–c** have been identified and exhaustively characterized in the mixture with imidazoles **3** by ^{1}H, ^{13}C, ^{15}N NMR spectroscopy and using ^{1}H–^{1}H homonuclear and ^{1}H–^{13}C heteronuclear 2D (COSY, NOESY, HSQC and HMBC) techniques.

In the ^{1}H NMR spectrum of compounds **4a–c**, the singlets of the H^9 protons appear at 5.60–5.72 ppm. In the ^{13}C NMR spectra of the mixtures **3** + **4**, along with the signals of vinylimidazoles **3a–c**, there are signals of two other olefinic moieties at 151.60–152.10 (C^6), 110.09–111.03 (C^7), 157.04–157.43 (C^8), 96.99–97.45 ppm (C^9) as well as those of two CN groups



Z-**4a–c**

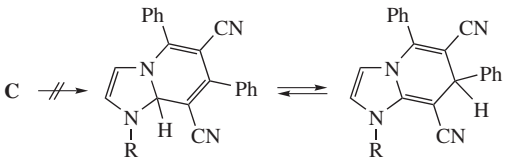
Figure 1 Labeling hydrogen and carbon atoms in adducts **4**.

belonging to adducts **4a–c**. This conclusion follows from that the proton H^9 is spin-coupled over three bonds not with imidazole C^2, but with carbon C^7 of the second double bond (Figure 1).

The configuration of imidazoles **4a–c** has been assigned based on the vicinal $^3J_{CH}$ values for the proton H^9 and carbon C^7 ($^3J_{C^7,H^9}$ 10.1–10.3 Hz) as well as $C^{11'}$ of phenyl substituents ($^3J_{C^{11'},H^9}$ 4.8–5.0 Hz). As is evident from the $^3J_{CH}$ values, the proton H^9 is in the *trans* position with respect to the imidazole cycle and, consequently, in the *cis* position relative to the phenyl group, that corresponds to the (*Z*)-configuration of this olefinic moiety (Figure 1).

The ^{1}H NMR spectra of adducts **4a–c** show the signals of protons H^4 and H^5 of the imidazole ring, whereas the signals of protons H^2 are absent. In the ^{13}C NMR spectra the signals of carbons C^4 and C^5 remain unchanged, while the signal of carbon atom C^2 is shifted low-field from 136–137 ppm to 142–143 ppm. In addition, in the ^{15}N NMR spectra the nitrogen atoms N^1 and N^3 resonate in different regions (from –195 to –220 ppm and from –109 to –111 ppm, respectively). These facts are indicative of substitution of the hydrogen atom at C^2 and confirm that 1,3-butadienyl fragment is located at second carbon atom of the imidazole ring.

Alternatively, zwitterionic 1:2 intermediate **C** could undergo cyclization to yield fused heterocyclic system **5** (two tautomers) (Scheme 2).



5

Scheme 2

However, no cyclic adducts have been detected (NMR) in the reaction mixtures. First, this is proved by the ^{15}N NMR spectra of compounds **3a–c** and **4a–c**, where there are both 'pyrrole' (N^1) and 'pyridinic' (N^3) nitrogen atoms (from –195 to –220 and from –107 to –111 ppm, respectively), while in cyclic adducts **5**, both nitrogen atoms (N^1 and N^3) should have a similar character.

Second, the vicinal $^3J_{CH}$ values between the proton H^9 and *ipso*-carbon $C^{11'}$ in compounds **4a–c** are discernible over three bonds ($^3J_{C^{11'},H^9}$ 4.8–5.0 Hz), whereas in the cyclic six-membered structures **5** the $^3J_{CH}$ values between H^2 atom and *ipso*-carbon of the phenyl group would be transmitted over four bonds and are to be expected lesser than 1 Hz.

Third, practically equal values of *cis*- and *trans*-vicinal $^3J_{CH}$ in compounds **3a–c** and **4a–c** (4.8–5.4 and 10.1–11.0 Hz, respectively) are also indicative of their similar structure.

The absence of cyclic adducts **5** from the reaction mixtures is in agreement with the configuration of intermediate zwitterions **C** (Scheme 1), where carbanionic site is *trans*-position with respect to the imidazolic cycle, that is unfavourable for the ring closing.

4b: ^{1}H NMR, δ: 1.13 (t, 3H, N–CH_2*Me*, $^3J_{MeCH_2}$ 7.1 Hz), 3.50 (q, 2H, N–CH_2, $^3J_{MeCH_2}$ 7.1 Hz), 5.65 (s, 1H, H^9), 7.00 (d, 1H, H^5, $^3J_{5,4}$ 1.1 Hz), 7.06 (d, 1H, H^4, $^3J_{4,5}$ 1.1 Hz), 7.47 (m, 1H, $H^{14'}$), 7.50 (m, 1H, H^{14}), 7.50 (m, 2H, $H^{13',15'}$), 7.52 (m, 2H, $H^{13,15}$), 7.55 (m, 2H, $H^{12,16}$), 7.65 (m, 2H, $H^{12',16'}$). ^{13}C NMR, δ: 14.64 (N–CH_2*Me*), 42.42 (N–CH_2), 97.36 (C^9), 111.03 (C^7), 116.52 ($C^{10'}$), 116.71 (C^{10}), 121.92 (C^5), 127.40 (C^{14}), 128.15 ($C^{12',16'}$), 129.18 ($C^{13',15'}$), 129.50 ($C^{12,16}$), 129.70 ($C^{13,15}$), 130.29 (C^4), 131.50 ($C^{14'}$), 135.27 ($C^{11'}$), 135.92 (C^{11}), 142.46 (C^2), 151.70 (C^6), 157.24 (C^8). ^{15}N NMR, δ: –203.40 (N^1), –116.70 ($C^{10'}N$), –108.50 (N^3).

(Z)-1-Phenyl-2-(2-cyano-1-phenylethenyl)imidazole **3c** *and (Z)-1-phenyl-2-(2,4-dicyano-1,3-diphenyl-1,3-butadienyl)imidazole* **4c**: (**1c**:**2**, 1:1, 80 h). Analogously, from 1-phenylimidazole **1c** (144 mg, 1 mmol) and acetylene **2** (127 mg, 1 mmol) in MeCN (1 ml), 101 mg of crimson oil containing imidazoles **3c** (22%) and **4c** (20%) in the ratio of 3:2 (^{1}H NMR), were prepared. IR (microlayer of **3c** and **4c** mixture, ν/cm^{-1}): 534, 647, 673, 697, 732, 764, 833, 906, 1003, 1030, 1059, 1078, 1108, 1160, 1180, 1263, 1295, 1365, 1389, 1402, 1446, 1492, 1509, 1570, 1596, 1656, 1686, 2217, 2894, 2923, 3061, 3155.

4c: ^{1}H NMR, δ: 5.72 (s, 1H, H^7), 7.36 (m, 2H, $H^{12,16}$), 7.41 (d, 1H, H^5, $^3J_{5,4}$ 1.0 Hz), 7.41 (m, 2H, $H^{13,15}$), 7.41 (m, 1H, $H^{14'}$), 7.43 (m, 1H, H^{14}), 7.45 (m, 2H, *o*-H from N–Ph), 7.45 (m, 2H, $H^{13',15'}$), 7.48 (m, 2H, $H^{12',16'}$), 7.50 (m, 1H, *p*-H from N–Ph), 7.53 (d, 1H, H^4, $^3J_{4,5}$ 1.0 Hz), 7.62 (m, 2H, *m*-H from N–Ph). ^{13}C NMR, δ: 97.29 (C^9), 110.09 (C^7), 116.50 ($C^{10'}$), 116.89 (C^{10}), 123.05 (C^5), 124.90 (*o*-C from N–Ph), 126.62 (C^{14}), 128.07 ($C^{12',16'}$), 128.21 (*p*-C from N–Ph), 128.77 (*m*-C from N–Ph), 129.00 ($C^{13',15'}$), 129.51 ($C^{12,16}$), 129.74 ($C^{13,15}$), 130.24 (C^4), 131.48 ($C^{14'}$), 135.10 ($C^{11'}$), 135.62 (C^{11}), 136.00 (*i*-C from N–Ph), 142.03 (C^2), 151.60 (C^6), 157.43 (C^8). ^{15}N NMR, δ: –205.90 (N^1), –115.70 ($C^{10'}N$), –108.20 (N^3).

(Z)-1-Methyl-2-(2,4-dicyano-1,3-diphenyl-1,3-butadienyl)imidazole **4a**: A mixture of 1-methylimidazole **1a** (42 mg, 0.5 mmol) and acetylene **2** (127 mg, 1 mmol) in dry diethyl ether (0.3 ml) was stirred at 20–25 °C for 120 h. The solvent was removed, viscous residue was passed through a column (40×1 cm) and 1,3-butadienylimidazole **4a** (17 mg, 10%) was isolated, mp 166–168 °C (acetone). IR (KBr, ν/cm^{-1}): 461, 499, 584, 642, 694, 732, 765, 827, 893, 929, 1030, 1077, 1152, 1183, 1281, 1329, 1436, 1471, 1578, 1632, 2205, 2852, 2920, 2954, 3058, 3096, 3136. ^{1}H NMR, δ: 3.11 (s, 3H, N–Me), 5.62 (s, 1H, H^9), 6.93 (d, 1H, H^5, $^3J_{5,4}$ 1.2 Hz), 7.03 (d, 1H, H^4, $^3J_{4,5}$ 1.2 Hz), 7.48 (m, 1H, $H^{14'}$), 7.48 (m, 2H, $H^{13',15'}$), 7.49 (m, 1H, H^{14}), 7.51 (m, 2H, $H^{13,15}$), 7.57 (m, 2H, $H^{12,16}$), 7.66 (m, 2H, $H^{12',16'}$). ^{13}C NMR, δ: 34.76 (N–Me), 96.99 (C^9), 110.68 (C^7), 116.70 ($C^{10'}$), 116.90 (C^{10}), 125.16 (C^5), 126.90 (C^{14}), 128.27 ($C^{12',16'}$), 129.00 ($C^{13',15}$), 129.40 ($C^{12,16}$), 129.70 ($C^{13,15}$), 129.84 (C^4), 131.30 ($C^{14'}$), 134.96 ($C^{11'}$), 135.50 (C^{11}), 142.72 (C^2), 152.10 (C^6), 157.40 (C^8). ^{15}N NMR, δ: –217.60 (N^1), –116.90 ($C^{10'}N$), –107.10 (N^3). Found (%): C, 78.20; H, 4.62; N, 16.54. Calc. for $C_{22}H_{16}N_4$ (%): C, 78.55; H, 4.79; N, 16.66.

In summary, the zwitterionic adducts of 1-substituted imidazoles **1a**–**c** with electron-deficient acetylenes (represented by phenylcyanoacetylene **2**) are capable of furnishing 2-(1,3-butadienyl)imidazoles **4a**–**c** (1:2 adducts) along with corresponding 2-ethenylimidazoles **3a**–**c** (1:1 adducts). Thus, an unprecedented one-pot strategy for introduction of 1,3-butadienyl moieties at the 2-position of the imidazole nucleus is under way.

The formation of the 1:2 adducts implies the further oligomerization of phenylcyanoacetylene **2** in the presence of imidazole **1**, *i.e.*, the assembling of the 1:3 adducts and longer functionalized polyene oligomers terminated by imidazole ring, could be predicted.

This work was supported by the Russian Foundation for Basic Research (grant no. 08-03-00156), the Presidium of the Russian Academy of Sciences (Programme 18) and the Division of Chemistry and Materials Science of the RAS (grant no. 5.1.8.).

References

1 B. A. Trofimov, L. V. Andriyankova, A. G. Mal'kina, K. V. Belyaeva, L. P. Nikitina and L. V. Baikalova, *Mendeleev Commun*., 2007, **17**, 237.

2 (*a*) B. A. Trofimov, L. V. Andriyankova, S. A. Zhivet'ev, A. G. Mal'kina and V. K. Voronov, *Tetrahedron Lett*., 2002, **43**, 1093; (*b*) B. A. Trofimov, L. V. Andriyankova, S. I. Shaikhudinova, T. I. Kazantseva, A. G. Mal'kina and A. V. Afonin, *Synthesis*, 2002, 853.

3 L. V. Andriyankova, A. G. Mal'kina, A. V. Afonin and B. A. Trofimov, *Mendeleev Commun*., 2003, 186.

4 L. V. Andriyankova, A. G. Mal'kina, L. P. Nikitina, K. V. Belyaeva, I. A. Ushakov, A. V. Afonin, M. V. Nikitin and B. A. Trofimov, *Tetrahedron*, 2005, **61**, 8031.

5 B. A. Trofimov, L. V. Andriyankova, R. T. Tlegenov, A. G. Mal'kina, A. V. Afonin, L. N. Il'icheva and L. P. Nikitina, *Mendeleev Commun*., 2005, 33.

6 (*a*) A. J. Arduengo, R. L. Harlow and M. Kline, *J. Am. Chem. Soc*., 1991, 113, 361; (*b*) D. Bourissou, O. Guerret, F. P. Gabai and G. Bertrand, *Chem. Rev*., 2000, **100**, 39.

7 V. Nair, R. S. Menon, A. R. Sreekanth, N. Abhilash and A. T. Biju, *Acc. Chem. Res*., 2006, **39**, 520.

8 A. F. Pozharskii and A. M. Simonov, *Zh. Obshch. Khim*., 1963, **33**, 179 (in Russian).

9 Yu. M. Skvortsov, A. G. Mal'kina, A. N. Volkov, B. A. Trofimov, E. B. Oleinikova, I. V. Kazin and V. V. Gedymin, *Izv. Akad. Nauk SSSR, Ser. Khim*., 1978, 872 (*Bull. Acad. Sci. USSR, Div. Chem. Sci.*, 1978, **27**, 754).

Received: 3rd July 2008; Com. 08/3166