

SHORT
COMMUNICATIONS

Efficient Synthesis of 1-(2-Propynyl)pyrrole

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Recent interest in 1-(2-propynyl)pyrrole (**I**) is explained by wide synthetic application of diacetylene pyrrole derivatives which are promising for preparation of highly ordered polymeric structures possessing specific optical, electronic, and magnetic properties [1, 2]. Nevertheless, no efficient and selective procedure for synthesizing 1-(2-propynyl)pyrrole (**I**) was so far reported. We were interested in this compound as a model of heteroaromatic alkyne. Carbanions derived therefrom were not studied in heterocyclizations with isothiocyanates [3], which stimulated the present work.

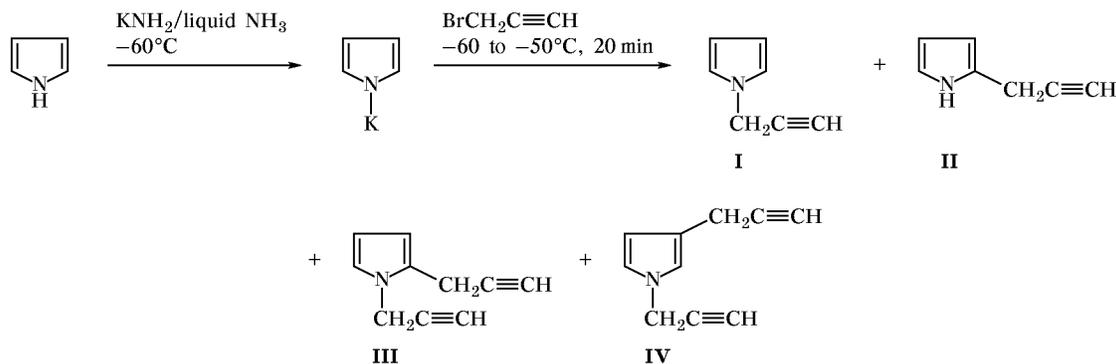
The known procedures for preparation of pyrrole **I** [1, 2, 4] are based on the reaction of potassium or sodium pyrrolate with 2-propynyl bromide and are characterized by different modes of generation of pyrrolate anion. The largest yield of the product (57%) containing 10% of the allene isomer was obtained by treatment of pyrrole with potassium hydroxide in toluene in the presence of 18-crown-6 [1]. In the other cases, when pyrrole was treated with metallic potassium in diethyl ether [2] or with the

system sodium amide–liquid ammonia [4], the yield of pyrrole **I** was as low as 30 and 15%, respectively, and the reaction time was more than 12 h.

Taking into account that pyrrolate ion is capable of undergoing alkylation at both nitrogen and carbon atoms [5, 6] and that *N*-(2-propynyl) group is readily converted into allenyl moiety (for example, 1-allenylpyrrole can be synthesized in 68% yield from pyrrole and 2-propynyl bromide in the superbasic KOH–DMSO system [7]), we have found that the best results are obtained using the system KNH₂–liquid ammonia. In order to avoid formation of 2-, 3-, and poly(2-propynyl)pyrroles and also the transformation of 2-propynyl bromide into 2-propynylamine [8], the reaction of potassium pyrrolate with 2-propynyl bromide was carried out at –60 to –50°C, and the reaction time was shortened to 20 min (Scheme 1).

Under these conditions we obtained 1-(2-propynyl)pyrrole in 70% yield, and its purity (after distillation) was 99%. The overall concentration of by-products did not exceed 12.2%. By preparative gas–liquid chromatography we isolated and identified previously

Scheme 1.



unknown 2-(2-propynyl)pyrrole (**II**), 1,2-bis(2-propynyl)pyrrole (**III**), and 1,3-bis(2-propynyl)pyrrole (**IV**). When lithium amide was used instead of potassium amide, other conditions being equal, the yield of pyrrole **I** was only 48% (purity of the crude product 82%), whereas with sodium amide (reaction time 1 h) we obtained 43% of a mixture of 1-(2-propynyl)pyrrole (**I**) and its allene isomer at a ratio of 10:1.

Synthesis of 1-(2-propynyl)pyrrole (I) from pyrrole and 2-propynyl bromide in the system potassium amide–liquid ammonia. To 300 ml of liquid ammonia (containing less than 0.1% of water) we added 19.5 g (0.5 mol) of metallic potassium cut in ~0.5-g pieces and 0.1 g of $\text{Fe}(\text{NO}_3)_3$. After 10 min, the solution turned grey, and 35.1 g (0.52 mol) of pyrrole was added under stirring in a stream of nitrogen at -60 to -40°C over a period of 1–2 min, and 60 g (0.53 mol) of 2-propynyl bromide was then added at -60 to -50°C over a period of 5 min. The mixture was stirred for 5 min at -50 to -35°C , the ammonia was evaporated on a water bath in 20 min, and the liquid organic phase was separated using a glass filter. The solid residue which contained KBr and unreacted potassium was washed with ether in a continuous stream of nitrogen. The ether washings were combined with the organic phase. According to the GLC data, there were 87.8% of 1-(2-propynyl)pyrrole (**I**), 2.6% of 2-(2-propynyl)pyrrole (**II**), 6.0 and 2.7%, respectively, of isomeric bis(2-propynyl)pyrroles **III** and **IV**, and 0.9% of unidentified compounds. The solvent was removed in a slight vacuum, and the residue was subjected to fractional distillation under reduced pressure in the presence of hydroquinone to isolate 36.8 g of pyrrole **I** (yield 70% with respect to potassium), purity 99%, bp 60°C (15 mm), $n_{\text{D}}^{23} = 1.5122$. ^1H NMR spectrum, δ , ppm: 6.71 t (2H, 2-H, 5-H), 6.15 t (2H, 3-H, 4-H, $^3J_{\text{H,H}} = 2.15$ Hz), 4.59 d (2H, CH_2), 2.35 t (1H, $\equiv\text{CH}$, $^4J(\text{CH}_2\text{C}\equiv\text{CH}) = 2.56$ Hz). ^{13}C NMR spectrum, δ_{C} , ppm: 120.44 (C^2 , C^5), 108.95 (C^3 , C^4), 78.18 ($-\text{C}\equiv$), 73.61 ($\equiv\text{CH}$), 38.54 (CH_2). The ^1H and ^{13}C NMR spectra of product **I** were similar to those reported in [1]. IR spectrum, ν , cm^{-1} : 604, 654, 728 s, 825 w, 935, 973, 1015 w, 1058, 1070, 1090 s, 1281 s, 1314, 1341, 1399, 1431, 1497 s, 1532 sh, 1559, 1688 w, 1733 w, 2126 w ($\text{C}\equiv\text{C}$), 2786 w, 2916, 3102, 3125, 3296 s ($\equiv\text{C}-\text{H}$), 3409. Mass spectrum, m/z (I_{rel} , %): 105 M^+ (96), 104 (100), 79 (39), 78 (65), 77 (54), 67 (15), 52 (47), 51 (52), 50 (17), 39 (69), 38 (27), 32 (51), 28 (81).

Distillation of the still residue gave 5 g of a fraction with bp 40 – 80°C (0.8 mm), which contained pyrroles **II**–**IV**. They were separated by preparative gas–liquid chromatography.

2-(2-Propynyl)pyrrole (II). Yield 2.1%, purity 90%. ^1H NMR spectrum, δ , ppm: 8.28 br.s (1H, NH), 6.70 d.t (1H, 5-H), 6.15 q (1H, 4-H), 6.02 m (1H, 3-H, $^3J_{3,4} = 3.0$, $^3J_{4,5} = 2.7$, $^4J_{3,5} = 1.6$ Hz), 3.61 d.d (2H, CH_2), 2.17 t [1H, $\equiv\text{CH}$, $^4J(\text{CH}_2\text{C}\equiv\text{CH}) = 2.74$ Hz, $^4J(\text{CH}=\text{CCH}_2) = 0.73$ Hz]. Mass spectrum, m/z (I_{rel} , %): 105 M^+ (93), 104 (100), 79 (22), 78 (40), 77 (37), 52 (25), 51 (42), 50 (20), 43 (5), 39 (19), 28 (14).

1,2-Bis(2-propynyl)pyrrole (III). Yield 3.5%, purity 92%, $n_{\text{D}}^{25} = 1.5302$. ^1H NMR spectrum, δ , ppm: 6.70 d.d (1H, 5-H), 6.06 t (1H, 4-H), 6.04 m (1H, 3-H, $^3J_{3,4} = 3.0$, $^3J_{5,4} = 2.3$ Hz), 4.64 d (2H, NCH_2), 2.34 t [1H, $\text{NCH}_2\text{C}\equiv\text{CH}$, $^4J(\text{NCH}_2\text{C}\equiv\text{CH}) = 2.65$ Hz], 3.56 d.d (2H, CCH_2), 2.09 t [1H, $\text{CCH}_2\text{C}\equiv\text{CH}$, $^4J(\text{CCH}_2\text{C}\equiv\text{CH}) = 2.65$, $^4J(\text{CH}=\text{CCH}_2) = 0.64$ Hz]. ^{13}C NMR spectrum, δ_{C} , ppm: 126.31 (C^2), 121.30 (C^5), 108.28 and 107.75 (C^4 , C^3), 80.30 ($\text{NCH}_2\text{C}\equiv$), 78.13 ($\text{CCH}_2\text{C}\equiv$), 73.50 ($\text{NCH}_2\text{C}\equiv\text{CH}$), 69.90 ($\text{CCH}_2\text{C}\equiv\text{CH}$), 36.30 (NCH_2), 16.76 (CCH_2). IR spectrum, ν , cm^{-1} : 646 s, 716 s, 778, 884 w, 934, 1020, 1072 s, 1119, 1206 w, 1287 s, 1312, 1344, 1424, 1484 s, 1549 w, 1670 w, 1710 w, 2122 ($\text{C}\equiv\text{C}$), 2827 w, 2909, 2951 w, 3095, 3110 w, 3292 s ($\equiv\text{CH}$), 3405–3439. Mass spectrum, m/z (I_{rel} , %): 143 M^+ (100), 142 (98), 141 (42), 117 (26), 105 (26), 104 (77), 89 (16), 78 (24), 77 (40), 70 (16), 63 (16), 51 (55), 50 (22), 43 (5), 39 (63), 38 (9), 28 (5).

1,3-Bis(2-propynyl)pyrrole (IV). Yield 1.6%, purity 95%, $n_{\text{D}}^{25} = 1.5327$. ^1H NMR spectrum, δ , ppm: 6.69 m (1H, 2-H), 6.67 t (1H, 5-H), 6.11 t (1H, 4-H, $^3J_{4,5} = 2.52$ Hz), 4.60 d (2H, NCH_2), 2.41 t [1H, $\text{NCH}_2\text{C}\equiv\text{CH}$, $^4J(\text{NCH}_2\text{C}\equiv\text{CH}) = 2.58$ Hz], 3.42 d (2H, CCH_2), 2.08 t [1H, $\text{CCH}_2\text{C}\equiv\text{CH}$, $^4J(\text{CCH}_2\text{C}\equiv\text{CH}) = 2.72$ Hz]. ^{13}C NMR spectrum, δ_{C} , ppm: 120.76 (C^2), 119.23 (C^3), 118.39 (C^5), 108.82 (C^4), 83.29 ($\text{NCH}_2\text{C}\equiv$), 78.13 ($\text{CCH}_2\text{C}\equiv$), 73.63 ($\text{NCH}_2\text{C}\equiv\text{CH}$), 68.47 ($\text{CCH}_2\text{C}\equiv\text{CH}$), 38.60 (NCH_2), 16.82 (CCH_2). IR spectrum, ν , cm^{-1} : 601, 644 s, 712, 749, 775, 933, 985 w, 1002 w, 1071, 1155 s, 1187 w, 1291, 1343, 1403, 1427, 1498 s, 1530 w, 1553 w, 1710, 2119 ($\text{C}\equiv\text{C}$), 2830 w, 2913, 2947 sh, 3292 s ($\equiv\text{C}-\text{H}$). Mass spectrum, m/z (I_{rel} , %): 143 M^+ (100), 142 (100), 141 (25), 118 (20), 115 (44), 104 (56), 89 (10), 78 (13), 77 (28), 63 (5), 58 (6), 51 (39), 50 (11), 43 (27), 39 (25), 28 (6).

Pyrroles **II**–**IV** were separated using a PAKhV-07 preparative chromatograph equipped with a thermal conductivity detector; 5-m \times 10-mm column packed with 5% of XE-60 on Chromaton N-AW-HMDS; carrier gas helium; oven temperature 150°C ; injector

and detector temperature 200°C. The NMR spectra were obtained on a Bruker DPX-400 instrument at 400.13 MHz for ^1H and 100.69 MHz for ^{13}C ; CDCl_3 was used as solvent, and HMDS, as internal reference. The IR spectra were recorded on a Bruker IFS-25 spectrometer from samples prepared as thin films. The mass spectra (electron impact, 60 eV) were run on an LKB-2091 GC-MS system (38-m SE-54 capillary column, injector temperature 250°C, oven temperature programming from 70 to 200°C at a rate of 10 deg/min, ion source temperature 240°C).

REFERENCES

1. Van Eyk, S.J., Naarmann, H., and Walker, N.P.C., *Synthetic Metals*, 1992, vol. 48, no. 3, pp. 295–300.
2. Paley, M.S., Frasier, D.O., Abeledeyem, H., McManus, S.P., and Zutaut, S.E., *J. Am. Chem. Soc.*, 1992, vol. 114, no. 9, pp. 3247–3251.
3. Brandsma, L., Nedolya, N.A., Tarasova, O.A., and Trofimov, B.A., *Khim. Geterotsikl. Soedin.*, 2000, no. 11, pp. 1443–1463.
4. Hubert, A.J. and Reimlinger, H., *J. Chem. Soc. C*, 1968, no. 5, pp. 606–608.
5. Pozharskii, A.F., *Teoreticheskie osnovy khimii geterotsiklov* (Theoretical Foundations of the Chemistry of Heterocyclic Compounds), Moscow: Khimiya, 1985, pp. 145–146.
6. Tarasova, O.A., Shmidt, E.Yu., Albanov, A.I., Mikhaleva, A.I., Brandsma, L., and Trofimov, B.A., *Russ. J. Org. Chem.*, 1999, vol. 35, no. 10, pp. 1499–1502.
7. Tarasova, O.A., Shmidt, E.Yu., Klyba, L.V., Sinegovskaya, L.M., Mikhaleva, A.I., Krivdin, L.B., and Trofimov, B.A., *Russ. J. Org. Chem.*, 1998, vol. 34, no. 5, pp. 688–692.
8. Brandsma, L., *Preparative Acetylenic Chemistry*, Amsterdam: Elsevier, 1988, p. 274.