

Facile Synthesis of 2-Aryl- and 2-Heteroarylpyrroles from *N*-Allylcarboxamides

By Norbert Engel and Wolfgang Steglich^[*]

2-Aryl- and 2-heteroarylpyrroles are of interest as precursors for the synthesis of chemotherapeutics^[1]. The syntheses hitherto described in the literature, however, are laborious and afford only moderate yields^[2]. We have found that the pyrroles (5), R¹ = aryl, heteroaryl, *tert*-alkyl, can be prepared in high yields from the imidoyl chlorides (2)^[3]—readily available from *N*-allylcarboxamides (1)—by cyclization with potassium *tert*-butoxide in an inert solvent (Table 1)^[4].

Special purification of (2) is not essential. Hence, this method provides convenient access to 2-(2-furyl)pyrrole (5*b*) and 2-(2-thienyl)pyrrole (5*c*)^[5].

The cyclization to the pyrrole ring can be interpreted in terms of a 1,5 dipolar ring closure of the nitrile ylide (3)^[6] formed by elimination of HCl from (2), the primary product (4) subsequently isomerizing to (5)^[7]. In the case of *N*-allylimidochlorides of the aliphatic acids bases promote elimination of HCl to give the ketenimines, which subsequently rearrange into γ,δ -unsaturated nitriles^[8]. This novel method for the synthesis of pyrroles is therefore limited to allylamides of carboxylic acids which do not contain an H atom in the α -position.

and then extracted with ether. After removal of solvent the extract is purified by steam distillation and/or recrystallization.

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(1*a*), 10283-95-1; (1*b*), 63122-36-1; (1*c*), 63122-31-2; (1*d*), 63122-38-3; (1*e*), 109-25-1; (1*f*), 63163-3; (2*a*), 39887-72-4; (2*b*), 63122-39-4; (2*c*), 63122-40-7; (2*d*), 63122-41-8; (2*e*), 63148-39-0; (2*f*), 63122-42-9; (5*a*), 3042-22-6; (5*b*), 63122-43-0; (5*c*), 52101-46-7; (5*d*), 5398-58-3; (5*e*), 20055-04-3; (5*f*), 26093-30-1.

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Table 1. Pyrroles (5) from *N*-allylcarboxamides (1) [a].

$$\text{R}^1-\overset{\text{O}}{\parallel}{\text{C}}-\text{NH}-\text{CH}_2-\overset{\text{R}^2}{\text{C}}=\text{CH}-\text{R}^3 \xrightarrow{\text{COCl}_2} \text{R}^1-\overset{\text{Cl}}{\text{C}}=\text{N}-\text{CH}_2-\overset{\text{R}^2}{\text{C}}=\text{CH}-\text{R}^3 \xrightarrow[\text{(-HCl)}]{\text{KORBu}} \left[\text{R}^1-\text{C}(\text{N}^-\text{R}^3)=\text{C}(\text{R}^2)=\text{CH}-\text{R}^3 \right] \rightarrow \left[\text{R}^1-\text{C}(\text{N}^-\text{R}^3)=\text{C}(\text{R}^2)=\text{CH}-\text{R}^3 \right] \rightarrow \text{R}^1-\text{C}_4\text{H}_3\text{NR}^3$$

(1) (2) (3) (4) (5)

(1)	R ¹	R ²	R ³	Yield [b] [%]	M.p. [°C], B.p. [°C/torr]	(5)	Yield [c] [%]	M.p. [°C], B.p. [°C/torr]
(1a)	C ₆ H ₅	H	H	91	113—115/0.05	(5a)	86 A	130 (cyclohexane)
(1b)	2-Furyl	H	H	93	87 (bath temp.)/0.05	(5b)	86 B	44 (subl. in vac.)
(1c)	2-Thienyl	H	H	86	65 (ether)	(5c)	86 A	78 (subl. in vac.)
(1d)	(CH ₃) ₃ C	H	H	92	108/17	(5d)	87 B	65—66/17
(1e)	C ₆ H ₅	CH ₃	H	81	86 (toluene/petroleum ether)	(5e)	61 B	154 (cyclohexane)
(1f)	C ₆ H ₅	H	C ₆ H ₅	87	94 (toluene/petroleum ether)	(5f)	60 A	129 (cyclohexane)

[a] (1*a*), (1*e*), (1*f*), (5*a*), (5*d*), (5*e*), (5*f*) are well documented in the literature. The remaining compounds gave correct elemental analyses and spectroscopic data consistent with the given structures.

[b] Prepared from amine and acyl chloride in aqueous hydrogen carbonate at 0—5°C.

[c] A: referred to (1); B referred to distilled imidoyl chloride: (2*a*), yield 91%, b.p. 71°C/0.05 torr; (2*b*), 84%, b.p. 68°C (bath temperature)/0.05 torr; (2*d*), 74%, b.p. 53°C/17 torr.

General procedure

Synthesis of (2): A mixture of (1) (10 mmol), a 20 % solution of phosgene in toluene (20 ml), and 2 drops of dimethylformamide is stirred for *ca.* 15 h at room temperature. The solution is then heated to 40—50°C and the toluene removed *in vacuo* simultaneously. The residue is distilled *in vacuo* and stored, or used directly for further syntheses.

Synthesis of (5): A solution of (2) (10 mmol) in tetrahydrofuran (10 ml) is added dropwise at 5—10°C under N₂ to a solution of potassium *tert*-butoxide (30 mmol) in dimethylformamide (15 ml) [in the case of (2*f*) dimethyl sulfoxide and 90°C]. 10 minutes after completion of addition the violet to black reaction solution is poured into a 20-fold amount of ice-water

cyclo-Triarsenic as μ,η -Ligand in Transition-Metal Complexes

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On reaction of white phosphorus P₄ with hydrated cobalt(II) and nickel(II) salts in the presence of 1,1,1-tris(diphenylphosphinomethyl)ethane, CH₃C(CH₂PPh₂)₃ (triphos), we recently obtained the first metal complexes containing *cyclo*-triphosphorus (δ -P₃) as a ligand^[1]. This finding prompted us to

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try to synthesize the corresponding complexes of *cyclo*-triarsenic (δ -As₃) by an analogous procedure using yellow arsenic (As₄). Elementary As₄ is extremely unstable and readily converts into the gray form, particularly on exposure to light. To overcome this difficulty we have employed a THF solution of yellow arsenic prepared by an improved method based on that described by Erdmann *et al.*^[12]

This As₄ solution reacts smoothly with Co^{II} or Ni^{II} aquo-ions and the triphosphane in THF/ethanol/acetone solution to give the As₃ complexes of general composition [(triphos)M- μ -(η -As₃)M(triphos)]X₂ (M = Co, Ni; X = BF₄, BPh₄). The new compounds have a triple-decker sandwich structure containing the bridging *cyclo*-triarsenic entity as an internal layer. The salts behave as 1:2 electrolytes and are exceptionally air stable, both in the solid state and in solution (acetone, nitroethane, *etc.*). The magnetic moments of both the cobalt and the nickel dinuclear units correspond to the existence of one unpaired electron for each unit.

An X-ray structural investigation has been undertaken on the compound [(triphos)Co- μ -(η -As₃)Co(triphos)](BPh₄)₂, which crystallizes with two molecules of acetone^[3]. The complex cation possesses a triple-decker sandwich structure in which the *cyclo*-triarsenic unit forms the internal slice

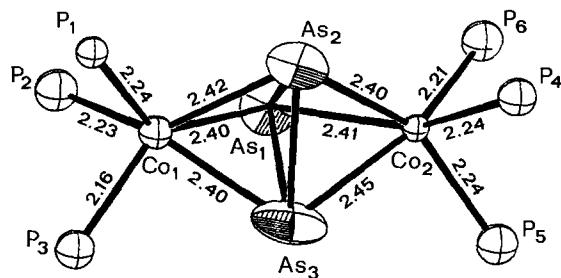


Fig. 1. Structure of the [(triphos)Co(As₃)Co(triphos)]²⁺ dication with bond lengths [Å]. Bond angles: P—Co—P = 90—93°, As—Co—As = 60—61°.

(Figure 1). Each cobalt atom is six-coordinated by the three phosphorus atoms of one triphos ligand and by the three arsenic atoms of the bridging *cyclo*-triarsenic group.

The magnetic moments of these cobalt and nickel complexes, both correspond to a doublet ground state; in a qualitative MO model^[4], the highest-occupied orbital (*e*, C₃-symmetry) contains one and 3 electrons, respectively. The two compounds are classified as 31 and 33-electron triple-decker complexes, 12 electrons being supplied by the donor atoms of the two triphos ligands, 3 by the *cyclo*-triarsenic ligand, the other electrons in the valence shell being provided by the two metal atoms. A mononuclear cobalt complex containing the As₃ ring as ligand, As₃Co(CO)₃, had already been synthesized by Dahl *et al.*^[5] by reaction of Co₂(CO)₈ with (AsCH₃)₅.

Procedure

7 g of gray arsenic is heated for *ca.* 90 min at 560—580°C (*cf.* [12]). The vapor of yellow arsenic is absorbed at *ca.* 0°C in 250 ml of THF, the solution filtered and then concentrated to 150 ml in the dark, in a nitrogen stream, at room temperature. To this solution is added 0.680 g (2 mmol) of Co(BF₄)₂·6H₂O in 20 ml of ethanol and 1.25 g (2 mmol) of "triphos" in 30 ml of acetone. The resulting mixture is heated in the dark on a water-bath under a stream of nitrogen for 20 min, then concentrated in the light to *ca.* 30 ml by passage of nitrogen. The dark-green crystals which separate are filtered off and then dissolved in 50 ml acetone. To this solution is added 0.680 g (2 mmol) of NaBPh₄ in 20 ml ethanol. On concentration of the solution, black-green crystals precipitate.

These are filtered off, washed with THF and ethanol, and dried in *vacuo*. Yield 75 %.

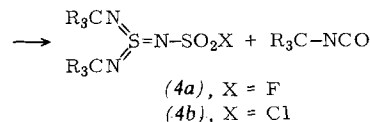
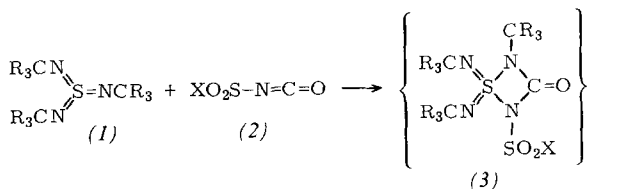
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Synthesis of 1 λ ⁶,2,4-Thiadiazetidin-3-ones from Tris(imido)sulfur(VI) Derivatives and Sulfonyl Isocyanates^[**]

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Characteristic reactions of sulfur compounds belonging to the "Y-triene" type (RN=)₃S^{IV} involve an increase in the coordination number of the central S^{VI} atom^[2]. We expected the reaction of the *tert*-butyl derivative (1), R = CH₃, with sulfonyl isocyanates (2) to yield the cycloaddition products (3).



However, thiadiazetidinones (3) bearing a strongly electronegative substituent on the ring nitrogen are unstable; like their S^{IV} analogs^[3] they decompose with elimination of alkyl isocyanate. On reaction of (1) with an only slight excess of (2), X = F, Cl, the corresponding monosulfonylimidosulfur(vi) compounds (4) can be isolated in good yields. The colorless solids (4a), m. p. 55°C, and (4b), m. p. 91°C, are stable for a long time at 0°C. Thus the possible syntheses of "Y-trienes" (RN=)₃S are not restricted to derivatives with bulky groups R.

An excess of (2) reacts further with (4) to give the symmetrical thiadiazetidinones (8).

The formation of (6) rather than (5) as the next addition product follows from the structure of the final product (8).

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