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1,3-Dipolar cycloaddition of diaryldiazomethanes across *N*-ethoxy-carbonyl-*N*-(2,2,2-trichloroethylidene)amine and reactivity of the resulting 2-azabutadienes towards thiolates and cyclic amides

Rodolphe Kinghat [a], Gérard Schmitt [a], Kabula Ciamala [a], Abderrahim Khatyr [a, *], Michael Knorr [a, *], Sandrine Jacquot-Rousseau [a], Yoann Rousselin [b], Marek M. Kubicki [b, *]

[a] *Institut UTINAM UMR CNRS 6213, Université de Franche-Comté, 16 Route de Gray, 25030 Besançon, France*
[b] *Institut de Chimie Moléculaire de l'Université de Bourgogne UMR 6302, Université de Bourgogne, 9 Avenue A. Savary, 21078 Dijon, France*

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Dedicated to the memory of
Prof. Bernard Laude, deceased in 2015

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ABSTRACT

1,3-dipolar cycloaddition of diaryldiazomethanes $Ar_2C{=}N_2$ across $Cl_3C{-}CH{=}N{-}CO_2Et$ **1** yields Δ^3-1,2,4-triazolines **2**. Thermolysis of **2** leads, *via* transient azomethine ylides **3**, to diaryldichloroazabutadienes $[Ar(Ar')C{=}N{-}CH{=}CCl_2]$ **4**. Treatment of **4a** (Ar = Ar' = C_6H_5) and **4c** (Ar = Ar' = *p*-ClC_6H_4) with NaSR in DMF yields 2-azabutadienes $[Ar_2C{=}N{-}C(H){=}C(SR)_2]$ **5**. In contrast, nucleophilic attack of NaS*t*Bu on **4** affords azadienic dithioethers $[Ar_2C{=}N{-}C(S^tBu){=}C(H)(S^tBu)]$ (**7a** Ar = C_6H_5; **7b** Ar' = *p*-ClC_6H_4). The reaction of **4a** with NaSEt conducted in neat EtSH produces $[Ph_2C{=}N{-}C(H)(SEt){-}CCl_2H]$ **8**, which after dehydrochloration by NaOMe and subsequent addition of NaSEt is converted to $[Ph_2C{=}N{-}C(SEt){=}C(H)(SEt)]$ **7c**. Upon the reaction of **4c** with NaS^iPr, the intermediate dithioether $[(p\text{-}ClC_6H_4)_2C{=}N{-}CH{=}C(S^iPr)_2]$ **5k** is converted to tetrakisthioether $[(p\text{-}^iPrSC_6H_4)_2C{=}N{-}CH{=}C(S^iPr)_2]$ **6**. Treatment of **4a** with the sodium salt of piperidine leads to $[Ph_2C{=}N{-}CH{=}C(NC_5H_{10})_2]$ **10**. The coordination of **6** on CuBr affords the macrocyclic dinuclear Cu(I) complex **11**. The crystal structures of **5i**, **7a**,**b**, **10** and **11** have been determined by X-ray diffraction.

1. Introduction

The reactive imine ethoxycarbonyl-*N*-(2,2,2-trichloroethylidene)amine (**1**) (also named anhydrochloral-urethane), first described by Feist and Ulrich *et al.* [1,2], has been used in the past by several groups as a versatile starting material for a number of transformations. For example, treatment of $Cl_3C{-}CH{=}N{-}CO_2Et$ (**1**) with Grignard reagents gives $Cl_3C{-}CHRNHCO_2Et$ (R = Me, Et, Pr, Bu, $PhCH_2$, $CH_2{=}CHCH_2$), which after hydrolysis and decarboxylation leads to α-amino acids [3]. Hetero-Michael addition of pyrazolinones to $Cl_3CCH{=}NCO_2R$ is reported to yield novel 1,3,4-substituted 2-pyrazolin-5-ones [4]. The synthesis of 5,6,7-substituted 1,2,4-triazolo[1,5-*a*]pyrimidines was achieved by the treatment of triazolopyrimidinols with **1** [5]. Several papers deal also with the utilisation of this imine as a heterodienophile for [4 + 2] Diels-Alder cycloadditions [6–9].

Our laboratory investigated in the late 90s the potential of the title compound as a reagent for the synthesis of heterocycles via 1,3-dipolar cycloaddition [10–12]. In this

* Corresponding authors.
E-mail addresses: michael.knorr@univ-fcomte.fr (M. Knorr), marek.kubicki@u-bourgogne.fr (M.M. Kubicki).

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context we have described and discussed the unexpected formation of 4,4-dichloro-1,1-diphenyl-2-azabuta-1,3-diene [$Ph_2C{=}N{-}CH{=}CCl_2$] (**4a**) by cycloaddition of diphenyldiazomethane across the imine function of **1** at 65 °C in toluene [12]. We have demonstrated that the first step of the process consists of a dipolar 1,3-cycloaddition of the diazo-compound across the imine, leading to the Δ^3-1,2,4-triazoline **2a**. Then, extrusion of dinitrogen gives the transient azomethine ylide **3a**. Subsequent elimination of ethyl chloroformate produces the 2-azadiene **4a** in 70% yield (Scheme 1). Investigating the electronic structure and chemical properties of **4a**, we have found that it presents an interesting reactivity towards various nucleophiles, such as alkoxides, thiolates, and the sodium salt of pyrrole or the cyanide anion [13–17]. More recently, some of these compounds were reacted as *S,N*-chelators with transition metal derivatives and allowed us to access new organometallic products *via* oxidative addition and cyclometallation reaction [18,19].

In order to modulate the electronic properties of this reactive 2-azadienic array, we now have investigated two different strategies to prepare functionalized derivatives of **4a** to have a feedstock for further organic or organometallic transformations:

(i) introduction of electron-pushing or withdrawing substituents at the *para*-positions of the phenyl rings.
(ii) systematic investigation of the reactivity towards a wide series of thiolates SR^- and amides NR_2^- to obtain functional ligands possessing both *S,N* or *N,N* donor sites for complexation studies.

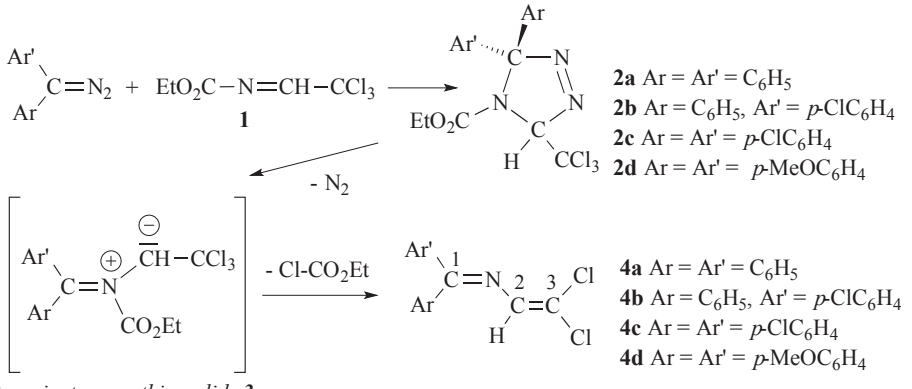
We report herein the preparation of some new functionalized 1,1-diaryl-4,4-dichloro-2-azabutadienes and the rich reactivity of these π-conjugated compounds [20] towards various thiolate nucleophiles of the type NaSR. The molecular structures of some azadienic dithioethers resulting from the unpredictable attack of thiolates have been determined by means of X-ray diffraction studies. This investigation includes also a reactivity study of **4a** toward the sodium salt of piperidine and the structural characterization of the resulting substitution product.

2. Results and discussion

2.1. Cycloaddition of diaryldiazomethanes $Ar_2C{=}N_2$ across $Cl_3C{-}CH{=}N{-}CO_2Et$

In analogy to the protocol using diphenyldiazomethane as a dipole, the cyloaddition of di(*p*-chlorophenyl)diazomethane, (*p*-chlorophenyl)phenyldiazomethane and di(*p*-methoxyphenyl)-diazomethane produces at 20 °C in toluene as solvent, the expected Δ^3-1,2,4-triazolines **2b–d** as colourless powders (see Scheme 1). Subsequent thermolysis of these heterocyclic compounds in toluene at 60° leads to (most probably *via* the transient azomethine ylides **3** [21]) the corresponding 1,1-diaryl-4,4-dichloro-2-azabutadienes **4b–d** as pale-yellow stable solids. However, it is not necessary to isolate first the heterocyclic intermediates **2**. If the imine **1** is treated with $Ar_2C{=}N_2$ in warm toluene, *in situ* transformation affords straightforwardly the 2-azadienes **4**. The crude residue of **4c** is contaminated by 10–15% of tetrakis(*p*-chlorophenyl)diazine $(p\text{-}ClC_6H_4)_2C{=}N{-}N{=}C(p\text{-}ClC_6H_4)_2$ as a minor product, which can be separated by fractional crystallisation from hot ethanol [22].

As observed in the proton NMR spectrum of **4a**, the vinylic hydrogen resonances of **4c** and **4d** are quite low-field shifted and appear as singlets at δ 7.07. Furthermore, two distinct singlets due to the methoxy groups are found at δ 3.83 and δ 3.87 in the spectrum of **4d**. In the case of **4b**, two singlets in a 2:1 ratio are detected at δ 7.03 and δ 7.01 in $CDCl_3$ solution, respectively. Two singlets, attributed to the C=N resonance, are also observed in the $^{13}C\{^1H\}$ spectrum at δ 167.0 and 166.9 in an approximate 2:1 ratio. Initially, we rationalized this finding by formation of two stereoisomers resulting from different approaches of the dissymmetric diaryldiazoalkane across the C=N bond of imine **1** in the transition state. A careful examination under an optical microscope confirmed that the morphology of all crystals of **4b** within this batch was quite homogenous, the melting point being sharp between 64–66 °C. Surprisingly, dissolving a single crystal in $CDCl_3$ again gave rise to two sets of signals in the 2:1 ratio. A survey of the literature revealed that this phenomenon is most probably due to a hindered inversion at the imine nitrogen. For example,



Scheme 1. Reaction of diaryldiazomethanes with imine **1**.

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