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Trapping and Analysing Wheland–Meisenheimer σ Complexes, Usually Labile and Escaping Intermediates

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The reactions between 2,4-dipyrrolidin-1-yl-1,3-thiazole, a supernucleophilic reagent, and 4,6-dinitrobenzofuroxan (DNBF) or 4,6-dinitrotetrazolopyridine (DNTP), two superelectrophilic reagents, afforded new covalent complexes that are contemporaneously intermediates of an S_NAr reaction (a Meisenheimer complex) and of an S_EAr reaction (a Wheland complex). These compounds belong to a new class of covalent complexes, which we have named Wheland–Meisenheimer complexes (WM). The high stability of the complexes reported herein allowed the first X-ray diffraction analyses of WM complexes. In addition, the reactions are diastereoselective, probably because of the specific approach of the two starting partners. The WM complex obtained with DNBF unexpectedly evolved to a neutral substitution product, a furazan derivative. Probably, the protons bonded to two sp^3 carbon atoms are lost together with the oxygen atom of the furoxan moiety to form water. This represents a unique example of the formation of a neutral substitution compound from a C–C WM complex. Finally, exchange of the DNBF moiety in **WM8** with DNTP in a solution of CD_3CN was observed; the formation of the **WM9** complex provided further evidence for the reversibility of the formation of the WM complexes.

Introduction

Chemical reactions involving the neutral carbon atoms of strongly activated nucleophilic and electrophilic molecules allow the particular behaviour of the simple nucleophile/electrophile coupling reaction to be observed. This is the case with superelectrophilic species such as 4,6-dinitrobenzofuroxan (DNBF) or supernucleophilic species such as 1,3,5-tris(dialkylamino)benzenes.

σ-Anionic complexes (Meisenheimer complexes),[1] including a number of strongly activated electrophilic substrates, have been widely reported.[2] σ-Cationic complexes (Wheland complexes),[3] intermediates of electrophilic aromatic substitution reactions,[4–7] have been less investigated[8,9] owing to experimental difficulties in their isolation or observation by spectroscopic methods. Recently, we have focused our interest on Wheland complexes and have been able to isolate some and study their reactivity.[10]

Non-covalent complexes, such as π–π complexes, or, more generally, donor–acceptor complexes are also very interesting for elucidating both electrophilic and nucleophilic aromatic substitution reactions. We have reported evidence for the presence of non-covalent complexes on the reaction pathway of S_NAr reactions.[11,12]

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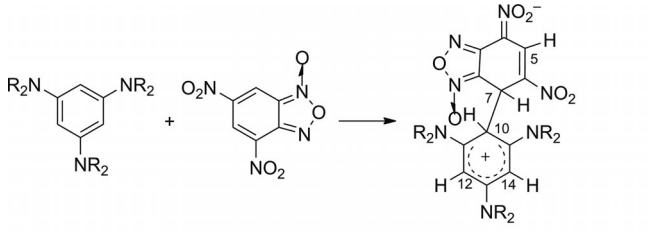
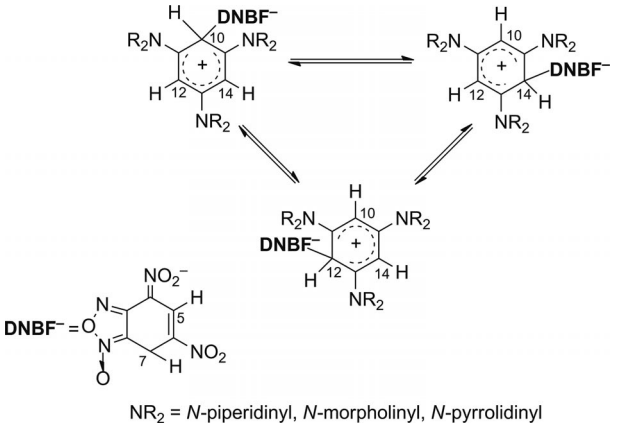
The reaction between superelectrophilic and supernucleophilic reagents afforded a new kind of σ complexes, zwitterionic in character, which we have called Wheland–Meisenheimer complexes (WM; Scheme 1).[13]



Scheme 1. Formation of Wheland–Meisenheimer complexes (WM) from 1,3,5-tris(dialkylamino)benzenes and 4,6-dinitrobenzofuroxan (DNBF).

Zwitterionic adducts **WM1**–**3** are moderately stable[14] and showed very peculiar and unexpected behaviour in variable-temperature ^1H NMR experiments. The signals arising from 10-H, 12-H and 14-H at low temperature are well separated, but they broaden until coalescence on raising the temperature. Thus, a dynamic process occurs that is reversible and has been explained by the existence of three rapidly exchanging homomeric structures of the Wheland–Meisenheimer complex, as depicted in Scheme 2.[13]



Scheme 2. Proposed mechanism for the reversible dynamic process observed for **WM1**–**3** in variable-temperature ^{1}H NMR experiments.

Recently, Lenoir and co-workers[15] reported a theoretically calculated comparison between the formation of a WM complex and the formation of a donor–acceptor complex (such as a π–π complex) in the reactions between DNBF and symmetrical triaminobenzenes: the π–π complex is thermodynamically more stable than the WM complex in the case of 1,3,5-triaminobenzene, whereas the WM complex is thermodynamically more stable than the donor–acceptor π–π complex in the case of the reaction between DNBF and 1,3,5-tris(dialkylamino)benzenes.

The high stabilization of the positive charge of the supernucleophiles 1,3,5-tris(dialkylamino)benzenes is due to the strong donating ability of the dialkylamino group, as reported by Effenberger and co-workers.[16]

Another superelectrophilic[17] carbon reagent, 4,6-dinitrotetrazolo[1,5-*a*]pyridine (DNTP), which, within the electrophilic scale developed by Mayr and co-workers,[18–20] is a considerably more powerful electrophile than DNBF,[21–23] reacts with 1,3,5-tris(dialkylamino)benzenes, to afford σ complexes[24] **WM4**–**6** (Scheme 3) similar to those reported in Scheme 1. These complexes behave similarly to **WM1**–**3** complexes in variable-temperature ^{1}H NMR experiments.

In addition, the results of some experiments strongly indicated that the formation of these kinds of complexes (by nucleophile/electrophile attack) is a reversible process.

The thiazole ring is reported to show borderline properties,[25] emphasized by the presence of particular substituents. 2-Aminothiazole readily reacts with electrophilic reagents, but nitrothiazoles afford moderately stable σ-anionic complexes (Meisenheimer complexes) with nucleophilic reagents.[26,27]

For a long time we have been interested in the properties of aminothiazoles, specifically in relation to the prototropic NH/CH equilibrium[28,29] and their chemical reactions with both nucleophilic[30,31] and electrophilic reagents.[32,33]

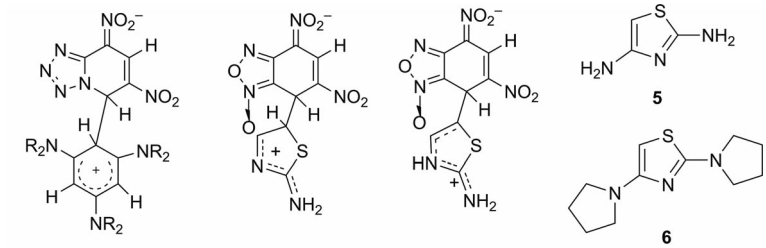
Recently, we attempted[34] to assess the nitrogen and carbon nucleophilicities of 2-aminothiazoles through coupling reactions with superelectrophilic DNBF.

Investigation of the DNBF/2-aminothiazole system[35] allowed us to detect the σ complex **WM7**. However, this complex proved to be very unstable, because it very quickly converted into **4** (Scheme 3), which is a usual Meisenheimer complex.

The very short life-time of the intermediate **WM7** prompted us to turn our attention towards more nucleophilic thiazole substrates, such as 2,4-diaminothiazole (**5**) and its derivatives.

It is known that 2,4-diaminothiazole (**5**) is an electron-rich molecule able to complex electrophilic species such as bromine: 2,4-diaminothiazole hydrotribromide is a bromine·**5** complex[36] that acts as a solid brominating reagent. However, 2,4-diaminothiazole derivatives exhibit other properties complicated by the tautomerism of the two amino groups. Clearly, in 2,4-bis(dialkylamino)thiazole derivatives this complication does not exist, and they could be promising candidates for carbon supernucleophiles owing to the high electron-releasing effect of the dialkylamino substituents, a fact previously exploited in 1,3,5-tris(dialkylamino)benzenes. The high carbon nucleophilicity of 2,4-diaminothiazole derivatives has also been confirmed by Gompper et al.,[37] who discussed the formation of a zwitterionic complex from 2,4-bis(dimethylamino)-1,3-thiazole and 1,3,5-trinitrobenzene.

On the basis of these considerations we realized that the presence on the thiazole ring of two pyrrolidinyl groups at the 2- and 4-positions, respectively, could enhance the nucleophilic power at the 5-position of the thiazole ring, and this might give a neutral carbon supernucleophile at least comparable to 1,3,5-tris(dialkylamino)benzenes. This might be the key substrate for obtaining a stable WM complex and its X-ray diffraction structure, as hoped by us and also other authors.[15] For this reason, we prepared 2,4-di-



Scheme 3.

pyrrolidin-1-yl-1,3-thiazole (**6**; Scheme 3) and studied its reactivity with DNBF and DNTP.

Results and Discussion

When 2,4-dipyrrolidin-1-yl-1,3-thiazole (**6**), dissolved in CH_3CN, was added (at 25 °C) to an equimolar amount of DNBF (or DNTP), the solution colour immediately changed, and a solid precipitated. The ^1H NMR spectrum of the solid obtained from the reaction of **6** and DNBF recorded in [D_6]DMSO shows two doublets centred at δ = 5.63 and 6.13 ppm (J = 2.7 Hz) and a singlet at δ = 8.63 ppm; the related ^{13}C NMR signals (correlated through g-HSQC experiments) appear at δ = 35.6, 59.6 and 132.7 ppm, respectively. The presence of two doublets with the same coupling constant in the region of protons bound to an sp^3 carbon atom, and the related chemical shifts in the ^{13}C NMR spectrum, confirmed the structure of the zwitterionic σ complex **WM8** (Scheme 4). ^1H NOE experiments permitted the assignment of the doublets at δ = 5.63 and 6.13 ppm to the proton bound to the sp^3 carbon atoms of the DNBF and thiazole moiety, respectively, whereas the singlet at δ = 8.63 ppm is related to the proton bound to the sp^2 carbon atom of the DNBF moiety. The ESI-MS analysis was also in agreement with the structure **WM8**.

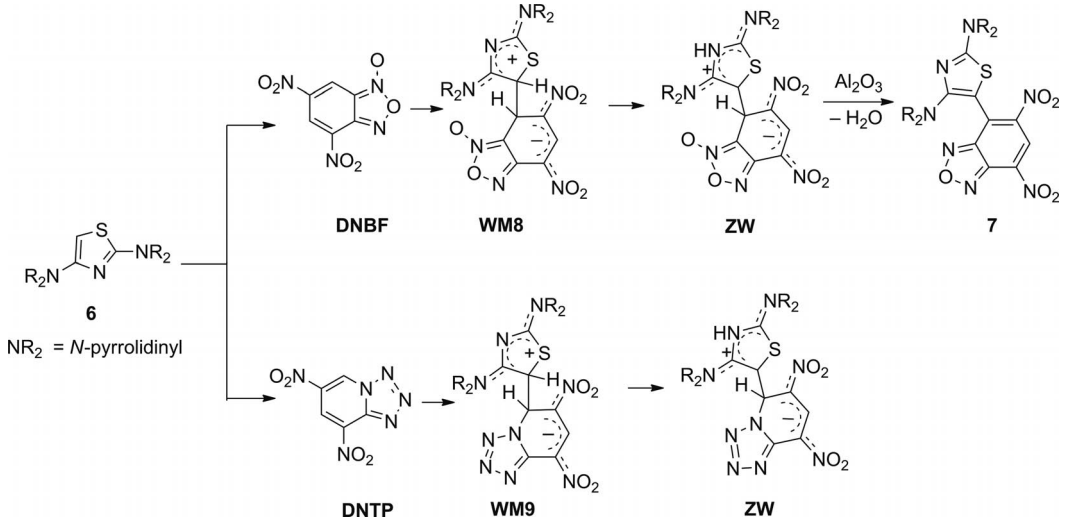
The NMR spectroscopic data of the solid obtained from the reaction of **6** and DNTP agree with structure **WM9** (Scheme 4). In particular, in the ^1H NMR spectrum recorded in [D_6]DMSO, signals at δ = 6.32 (br. s, 1 H), 7.23 (d, $^3J_{H,H}$ = 1.8 Hz, 1 H), and 8.65 (s, 1 H) ppm were found, and the related ^{13}C NMR signals are at δ = 61.9, 56.1, and 131.2 ppm.

Owing to the stability of complexes **WM8** and **WM9**, several attempts were made to obtain single crystals of these complexes, and we were able to obtain crystals suitable for X-ray diffraction analysis from a 1:1 (v/v) mixture of CH_3CN/CH_2Cl_2. The structures of **WM8** and **WM9** were confirmed by this technique, and we emphasize that these are the first examples of detailed structural X-ray diffraction analyses of stable crystalline intermediates of nucleophilic/electrophilic aromatic substitution reactions. Some details of the structures of **WM8** and **WM9** (Figure 1) are worthy of note.

The X-ray structure of the **WM8** complex shows that the C1–C7 distance (1.56 Å) is longer than a standard C–C distance (1.49 Å); the corresponding C1–C5 distance in **WM9** is also 1.56 Å. This confirms the weakness of the bond, which could be the cause of the dynamic process[13,24] observed in **WM1**–**6** (indicated in Scheme 2). Clearly, this process cannot occur in the present case. The relative spatial environment of the substituents around the C1–C7 bond corresponds to a gauche relationship, the torsion angle H1–C1–C7–H7 for **WM8** being 66.7° (the corresponding angle for **WM9** is 71.7°).

It is important to note the possible formation of different stereomeric forms in this reaction; as both the reactive carbon atoms of the starting materials are stereogenic centres we expected to obtain all four possible σ complexes and to observe two diastereomeric species in the NMR spectra and all the four stereoisomers by X-ray diffraction analysis. However, the NMR data showed the presence of only one diastereomer, a crystal of which, when analysed by X-ray diffraction analysis, revealed the presence of the (*R*,*R*) and (*S*,*S*) enantiomeric couple for **WM8** and of the (*R*,*S*) and (*S*,*R*) enantiomeric couple for **WM9**. A single crystal of each of **WM8** and **WM9**, after analysis by X-ray diffraction, were dissolved in CD_3CN and their ^1H NMR spectra showed the same signals as observed in the NMR spectra of the solutions from which the crystals were precipitated.

This diastereoselectivity can be explained by considering the spatial conformation of the complexes in the solid phase: as shown in Figure 1, the furoxan ring of DNBF (as well as the tetrazole ring of DNTP of **WM9**) faces the thi-



Scheme 4. Reactions between the thiazole derivative **6** and DNBF or DNTP with the formation of new Wheland–Meisenheimer complexes **WM8** and **WM9** and the conversion of **WM8** into benzofurazan derivative **7**.

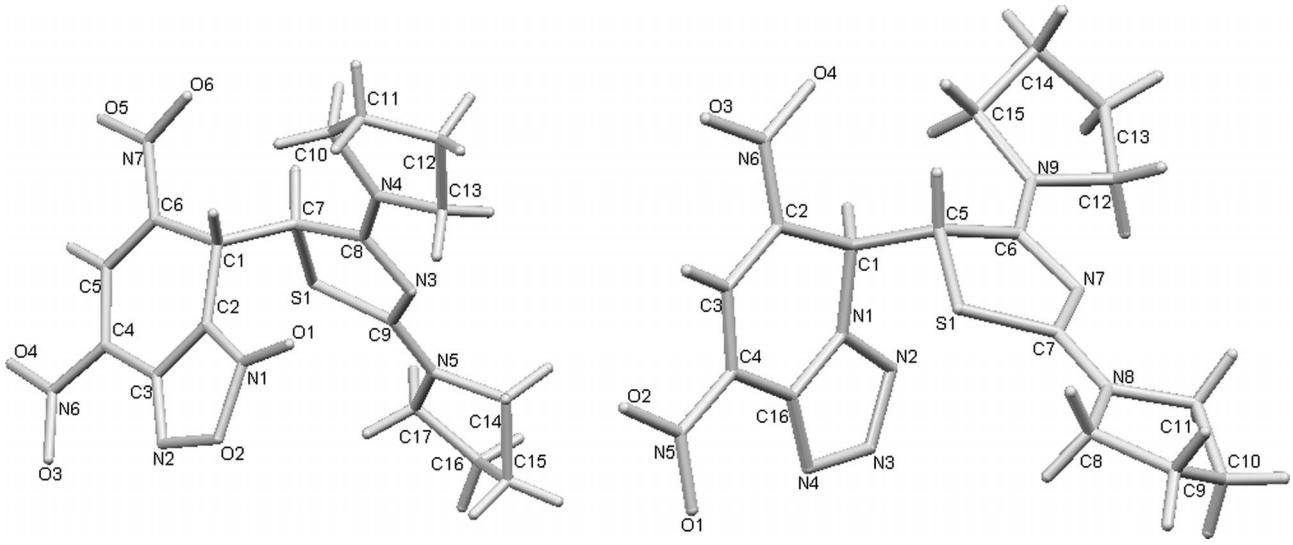
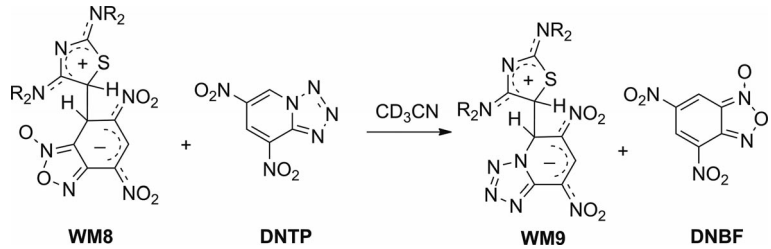


Figure 1. Graphic representation of the crystalline structures of **WM8** and **WM9**.

azole ring, and the medium distance between the two rings is close to the van der Waals radii for both enantiomeric forms. Thus, such an approach between the two reagents (see Figure S3 in the Supporting Information) might be responsible for the observed stereoselection.

From the data reported in the Supporting Information it is possible to see that the C9–N5 and C8–N4 (1.30 and 1.31 Å, respectively, for **WM8**) and the corresponding C7–N8 and C6–N9 (1.31 Å for **WM9**) exocyclic bonds are slightly shorter than the C9–N3 and C8–N3 (1.34 and 1.33 Å, respectively, for **WM8**) and C7–N7 and C6–N7 (1.33 Å for **WM9**) endocyclic bonds of the thiazole ring. One can deduce that the C–N exocyclic bonds have more π character than the C–N endocyclic bonds, in agreement with the strong electron-donating effect of the two amino groups bound to the thiazole ring. The thiazole ring and the furoxan ring are face-to-face, and the observed configuration agrees with the presence of an internal donor–acceptor interaction between the positively charged thiazole moiety and the negatively charged benzofuroxan or tetrazolopyridine moiety of **WM8** or **WM9**, respectively. For instance, the S1–C2, S1–C5 and S1–C3 distances are 3.144, 3.714 and 3.690 Å, respectively, for complex **WM8**, and the S1–N1, S1–C16 and S1–C3 distances are 3.04, 3.513 and 3.687, respectively, for complex **WM9**. The molecular packing shows no donor–acceptor intermolecular interactions. This structural situation is an indication that the two moieties are prone to a donor–acceptor interaction, which may be conceived between the starting reagents (see Figure S3 in the Supporting Information); however, we have no evidence of such an interaction (probably preceding the formation of the WM σ complex) in a π complex between the starting materials. In addition, the two nitro groups are almost co-planar with respect to the benzofuroxan or the tetrazolopyridine moiety, torsion angles C5–C6–N7–O5 and C3–C4–N6–O3 being 7.0 and 2.2° for **WM8**, whereas the torsion angles C16–C4–N5–O1 and C3–C2–N6–O3 in **WM9** are 7.0 and 1.6°, respectively. It is of interest to note that the NO_2 group is near to the N2 of the furoxan heterocycle, the N2–O3 distance being 2.72 Å in **WM8**. Accordingly, these compounds are prone[38] to the Boulton–Katritzky rearrangement.[39]

Even if it is reasonable to think that the first evolution of **WM8** is the shift of the proton from the C7 atom of the thiazole ring to a more basic centre, probably the N3 atom (and the corresponding shift of the proton bound to the C5 atom of the thiazole ring to the N7 atom in **WM9**), we have no evidence (in either case) for the presence of a zwitterionic σ complex **ZW**. Interestingly, in the reaction mixture containing the **WM8** complex, we observed the slow formation of the final C–C coupling product **7**, which may be obtained in almost quantitative yield by adding Al_2O_3 to



Scheme 5. Exchange of the electrophilic partner from **WM8** to **WM9**.

the reaction mixture in CH_2Cl_2 (Scheme 4). Note that this is the first example of the evolution of WM complexes to neutral products, probably favoured by the possibility, for **WM8**, of losing water.

Finally, when DNTP was added to a solution of **WM8** in CD_3CN, the **WM9** complex was formed in a slow process (about 2 weeks for quantitative conversion; Scheme 5), which confirmed our previous conclusion on the reversibility of the formation of WM complexes.

Conclusions

The reactions between 2,4-dipyrrolidin-1-yl-1,3-thiazole and 4,6-dinitrobenzofuroxan or 4,6-dinitrotetrazolopyridine quantitatively produced covalent complexes that are contemporaneously a Wheland and Meisenheimer intermediate of the two main reactions of the aromatic substrates: a nucleophilic and electrophilic substitution reaction. The reactions occur with high diastereoselectivity, and this is explained by considering the particular approach of the two partners. The particular stability at room temperature of these complexes allowed single crystals to be obtained that are suitable for X-ray diffraction analysis; the analyses confirmed their structures and revealed some interesting details that explain the behaviour of WM complexes. Furthermore, exchange of the electrophilic partner in **WM8** with DNTP led to **WM9**, which also confirmed our previous conclusion on the reversibility of the formation of WM complexes. Finally, the complex obtained with DNBF as the electrophilic partner easily eliminated water with re-aromatization of both rings to afford an unusual substitution product, a furazan derivative.

Experimental Section

Caution: 4,6-Dinitrobenzofuroxan (DNBF) is a powerful explosive with a sensitivity level comparable to that of dry picric acid. Consequently, all preparations and manipulations of compounds containing the DNBF moiety were carried out only on a small scale (<0.1 g) behind suitable protective shielding. 2,4-Dipyrrolidin-1-yl-1,3-thiazole[40](**6**), DNBF,[41] and 4,6-dinitrotetrazolopyridine[42] (DNTP) were prepared and purified as described in the literature.

Typical Procedure for the Synthesis of the σ Complexes WM8 and WM9: A solution of 2,4-dipyrrolidin-1-yl-1,3-thiazole (**6**; 49.1 mg, 0.22 mmol) in CH_3CN (5 mL) was added, at room temperature, to a solution of DNBF (49.7 mg, 0.22 mmol) in CH_3CN (5 mL). Immediately after mixing, the solution turned from pale yellow to a more intense orange-yellow and an orange solid formed (in the case of the reaction with DNTP the solution, immediately after mixing, turned from pale yellow to deep red and, after a few seconds, the solution became orange, and an orange solid precipitated). The solid was collected by filtration, washed with a small amount of cold CH_3CN and recrystallized from CH_3CN/CH_2Cl_2 (1:1, v/v). The melting-point analysis of this solid produced a gradually darkening above 178.8 °C (206.2 °C for the solid precipitated from the reaction with DNTP). The crystals were analysed by NMR, ESI-MS and X-ray diffraction. The reaction was also carried out in CD_3CN, and the solid was removed by filtration. The ^1H NMR spectrum of the solution showed the absence of signals from the starting materials and the presence of new signals that agree with those of structure **WM8**.

{[7-(2,4-Dipyrrolidin-1-yl-4,5-dihydro-1,3-thiazol-4-ylium-5-yl)-6-nitro-3-oxido-2,1,3-benzoxadiazol-4(7*H*)-ylidene](oxido)amino}oxidanide (WM8): Orange solid. Yield: 79 mg, 80%. M.p. >178.8 °C (dec.). TLC ($CHCl_3$/MeOH, 9:1, v/v): R_f = 0.44. UV/Vis (CH_2Cl_2): λ_{max} (ε) = 485 (33628 $M^{-1}cm^{-1}$) nm. ^1H NMR (600 MHz, $CDCl_3$, 25 °C): δ = 2.07–2.23 (m, 7 H), 2.31–2.38 (m, 1 H), 3.38–3.46 (m, 1 H), 3.50–3.58 (m, 1 H), 3.71–3.84 (m, 3 H), 3.87–3.95 (m, 1 H), 4.17–4.27 (m, 2 H), 5.52 (d, $^3J_{H,H}$ = 2.8 Hz, 1 H), 6.01 (d, $^3J_{H,H}$ = 2.8 Hz, 1 H), 9.02 (s, 1 H) ppm. ^1H NMR (600 MHz, CD_3CN, 25 °C): δ = 1.97–2.12 (m, 8 H), 3.42 (t, $J_{H,H}$ = 6.9 Hz, 2 H), 3.64–3.79 (m, 4 H), 4.14 (t, $J_{H,H}$ = 6.9 Hz, 2 H), 5.51 (d, $^3J_{H,H}$ = 2.7 Hz, 1 H), 5.92 (br. d, 1 H), 8.77 (s, 1 H) ppm. ^1H NMR (600 MHz, [D$_6$]DMSO, 25 °C): δ = 1.88–2.08 (m, 7 H), 2.14–2.21 (m,1 H), 3.33–3.39 (m, 1 H), 3.44–3.51 (m, 1 H), 3.61–3.73 (m, 4 H), 4.05–4.17 (m, 2 H), 5.63 (d, $^3J_{H,H}$ = 2.7 Hz, 1 H), 6.13 (d, $^3J_{H,H}$ = 2.7 Hz, 1 H), 8.63 (s, 1 H) ppm. ^{13}C NMR (100.57 MHz, [D$_6$]DMSO, 25 °C): δ = 174.5, 172.6, 149.9, 132.7, 122.0, 111.0, 109.6, 59.6, 51.8, 51.76, 51.3, 50.0, 35.6, 25.5, 24.8, 24.6, 23.9 ppm. MS (ESI$^+$): m/z = 450 [M + H]$^+$.

{[5-(2,4-Dipyrrolidin-1-yl-4,5-dihydro-1,3-thiazol-4-ylium-5-yl)-6-nitrotetrazolo[1,5-*a*]pyridin-8(5*H*)-ylidene](oxido)amino}oxidanide (WM9): Orange solid. Yield: 84 mg, 88%. M.p. >206.2 °C (dec.). TLC ($CHCl_3$/MeOH, 9:1, v/v): R_f = 0.42. UV/Vis (CH_2Cl_2): λ_{max} (ε) = 481 (14529 $M^{-1}cm^{-1}$) nm. ^1H NMR (600 MHz, $CDCl_3$, 25 °C): δ = 1.95–2.45 (m, 8 H), 3.33–3.40 (m, 2 H), 3.64–3.70 (m, 2 H), 3.79–3.88 (m, 1 H), 4.00–4.07 (m, 1 H), 4.26–4.33 (m, 2 H), 6.17 (br. s, 1 H), 7.00 (br. s, 1 H), 9.02 (s, 1 H) ppm. ^1H NMR (600 MHz, CD_3CN, 25 °C): δ = 2.10–2.20 [m, 7 H (partially eclipsed by water signal)], 2.26–2.32 (m, 1 H), 3.21–3.27 (m, 1 H), 3.32–3.39 (m, 1 H), 3.53–3.59 (m, 1 H), 3.62–3.69 (m, 1 H), 3.76–3.84 (m, 1 H), 3.85–3.91 (m, 1 H), 4.15–4.26 (m, 2 H), 6.05 (br. s, 1 H), 7.02 (d, $^3J_{H,H}$ = 2.1 Hz, 1 H), 8.79 (s, 1 H) ppm. ^1H NMR (600 MHz, [D$_6$]DMSO, 25 °C): δ = 1.80–1.97 (m, 4 H), 1.97–2.13 (m, 3 H), 2.17–2.28 (m, 1 H), 3.11–3.21 (m, 1 H), 3.37–3.45 (m, 1 H), 3.48–3.58 (m, 1 H), 3.58–3.68 (m, 1 H), 3.73–3.85 (m, 2 H), 4.13–4.22 (m, 1 H), 4.22–4.32 (m, 1 H), 6.32 (br. s, 1 H), 7.23 (d, $^3J_{H,H}$ = 1.8 Hz, 1 H), 8.65 (s, 1 H) ppm. ^{13}C NMR (150.82 MHz, [D$_6$]DMSO, 25 °C): δ = 174.6, 173.0, 148.0, 131.2, 118.7, 109.7, 61.9, 56.1, 52.2, 51.7, 51.2, 50.2, 25.5, 24.7, 24.5, 23.9 ppm. MS (ESI$^+$): m/z = 434 [M + H]$^+$, 456 [M + Na]$^+$.

Synthesis of 4-(2,4-Dipyrrolidin-1-yl-1,3-thiazol-5-yl)-5,7-dinitro-2,1,3-benzoxadiazole (7): Aluminium oxide (0.200 g) was added to a solution of complex **WM8** (20.0 mg, 0.045 mmol) in CH_2Cl_2 (15 mL). Immediately, the solution turned from an intense orange-yellow colour to violet. The reaction was monitored by TLC analysis (eluent: $CHCl_3$/MeOH, 9:1, v/v) and the mixture stirred with a magnetic stirring bar until disappearance of the starting reagent (about 10 min); then the mixture was filtered, and the aluminium oxide was washed with CH_2Cl_2 (3 × 10 mL). After removal of the solvent in vacuo, pure **7** was obtained (0.016 g, 77%). M.p. >300 °C (dec.). TLC ($CHCl_3$/MeOH, 9:1. v/v): R_f = 0.82. UV/Vis (CH_2Cl_2): λ_{max} (ε) = 585 (17125 $M^{-1}cm^{-1}$) nm. ^1H NMR (600 MHz, $CDCl_3$, 25 °C): δ = 1.72–1.82 (m, 1 H), 1.95–2.06 (m, 1 H), 2.06–2.24 (m, 6 H), 2.56–2.65 (m, 1 H), 2.78–2.89 (m, 1 H), 3.58 (t, J = 6.9 Hz, 2 H), 3.87 (t, J = 6.9 Hz, 2 H), 3.90–3.99 (m, 1 H), 4.07–4.15 (m, 1 H), 9.53 (s, 1 H) ppm. ^{13}C NMR (100.57 MHz, $CDCl_3$, 25 °C): δ = 170.2, 169.2, 151.8, 143.6, 132.6, 128.9, 121.7, 121.4, 111.2, 52.9, 50.4, 50.3, 49.9, 26.4, 25.7, 25.1, 24.2 ppm. MS (ESI$^+$): m/z = 432 [M + H]$^+$.

Crystal Data for WM8: Suitable crystals obtained from the concentration of a solution of CH_3CN/CH_2Cl_2 (1:1, v/v). $C_{17}H_{19}N_7O_6S$,

M_r = 449.45, monoclinic, space group $P2_1/c$ (No. 14), a = 11.922(3), b = 13.604(3), c = 12.995(3) Å, β = 112.261(2)°, V = 1950.5(7) Å^3, T = 298(2) K, Z = 4, ρ_c = 1.531 g cm^{-3}, $F(000)$ = 946, graphite-monochromated Mo-K_α radiation (λ = 0.71073 Å), μ(Mo-K_α) = 0.220 mm^{-1}, orange brick (0.20 × 0.15 × 0.15 mm), empirical absorption correction with SADABS (transmission factors 0.9678–0.9574), 2400 frames, exposure time 15 s, $1.99 \le \theta \le 27.50°$, $-14 \le h \le 14$, $-16 \le k \le 16$, $-15 \le l \le 15$, 18938 reflections collected, 3625 independent reflections (R_{int} = 0.0305), solution by direct methods (SHELXS97)[43] and subsequent Fourier syntheses, full-matrix least squares on F_o^2 (SHELX97),[44] hydrogen atoms refined with a riding model, data/restraints/parameters = 3625/18/270, $S(F^2)$ = 1.025, $R(F)$ = 0.0648 and $wR(F^2)$ = 0.1616 on all data, $R(F)$ = 0.0554 and $wR(F^2)$ = 0.1525 for 2962 reflections with $I > 2\sigma(I)$, weighting scheme $w = 1/[\sigma^2(F_o^2) + (0.1013P)^2 + 0.7373P]$ in which $P = (F_o^2 + 2F_c^2)/3$, largest difference peak and hole 0.438 and –0.281 e Å^{-3}. The two pentacycles (pyrrolidines) proved to be disordered and were split into two parts and isotropically refined by using different free variables for each ring. CCDC-807797 contains the supplementary crystallographic data for this paper. These data can be obtained free of charge from The Cambridge Crystallographic Data Centre via www.ccdc.cam.ac.uk/data_request/cif. For the structure of **WM8** with probability ellipsoids, see Figure S1 in the Supporting Information.

Crystal Data for WM9: Suitable crystals obtained from the concentration of a solution of CH_3CN/CH_2Cl_2 (1:1, v/v). $C_{16}H_{19}N_9O_4S$, M_r = 433.46, monoclinic, space group $P2_1/c$ (No. 14), a = 11.2926(13), b = 11.7694(13), c = 15.0824(17) Å, β = 106.9910(10)°, V = 1917.1(4) Å^3, T = 298(2) K, Z = 4, ρ_c = 1.502 g cm^{-3}, $F(000)$ = 904, graphite-monochromated Mo-K_α radiation (λ = 0.71073 Å), μ(Mo-K_α) = 0.216 mm^{-1}, orange brick (0.40 × 0.20 × 0.20 mm), empirical absorption correction with SADABS (transmission factors 0.9581–0.9186), 2400 frames, exposure time 10 s, $1.89 \le \theta \le 27.50°$, $-14 \le h \le 14$, $-15 \le k \le 15$, $-19 \le l \le 19$, 21305 reflections collected, 4381 independent reflections (R_{int} = 0.0223), solution by direct methods (SHELXS97)[43] and subsequent Fourier syntheses, full-matrix least squares on F_o^2 (SHELX97),[44] hydrogen atoms refined with a riding model, data/restraints/parameters = 4381/0/272, $S(F^2)$ = 1.046, $R(F)$ = 0.0412 and $wR(F^2)$ = 0.1079 on all data, $R(F)$ = 0.0378 and $wR(F^2)$ = 0.1041 for 3958 reflections with $I > 2\sigma(I)$, weighting scheme $w = 1/[\sigma^2(F_o^2) + (0.0626P)^2 + 0.5044P]$ in which $P = (F_o^2 + 2F_c^2)/3$, largest difference peak and hole 0.326 and –0.284 e Å^{-3}. CCDC-827059 contains the supplementary crystallographic data for this paper. These data can be obtained free of charge from The Cambridge Crystallographic Data Centre via www.ccdc.cam.ac.uk/data_request/cif. For the structure of **WM9** with probability ellipsoids, see Figure S2 in the Supporting Information.

Supporting Information (see footnote on the first page of this article): General experimental remarks, structures of **WM8** and **WM9** with probability ellipsoids, NMR spectra of the new compounds and selected bond lengths for **WM8** and **WM9**.

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