Studies with 2-(Arylhydrazono)aldehydes: Synthesis and Chemical Reactivity of Mesoxalaldehyde 2-Arylhydrazones and of Ethyl 2-Arylhydrazono-3-oxopropionates

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The coupling reaction of 3-(dimethylamino)acrolein (**2a**) and ethyl 3-(dimethylamino)acrylate (**2b**) with arenediazonium chlorides afforded the 2-(arylhydrazono)aldehydes **1a – e**. Compounds **1a, b** reacted with hydroxylamine hydrochloride to yield the oximes **4a, b**. The dioxime **5** was obtained from reaction of **1a** with an excess of hydroxylamine hydrochloride. This dioxime afforded the 1,2,3-triazole carbonitrile **6** when treated with acetic anhydride, while α-hydrazono propionitrile **8** was obtained when **5** was treated with acetic acid. Compounds **1a – e** could be utilized for the synthesis of a variety of pyrazoles and arylazolopyrimidines *via* reaction with hydrazines, haloketones and aminoazoles, respectively.

Key words: 2-Arylhydrazonopropane-1,3-dial, 2-Aryl-1,2,3-triazole-4-carbonitrile, Formazanes

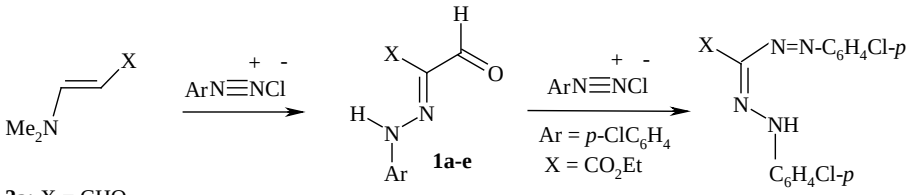
Introduction

2-(Arylhydrazono)aldehydes are versatile reagents and their chemistry is now receiving considerable attention [1 – 6]. A general route to arylhydrazonals is the coupling of arenediazonium salts with enamines [1 – 6]. However, recently it was reported that some enaminonitriles couple with diazonium tetrafluroborates to yield cyclic pyridazinones [7 – 11]. Anomalous behavior has also been reported for reactions of cyclic enaminones and enamino esters with arenediazonium salts [12, 13].

Results and Discussion

In conjunction with our interest in the chemistry of arylhydrazoates we report here results of our work aimed at exploring the potential utility of enaminals and enaminoesters as precursors to arylhydrazonals as well as some chemistry of the synthesized arylhydrazonals. Thus, the arylhydrazonals **1a – e** could be readily obtained upon coupling of the enaminoaldehyde **2a** and the enaminoester **2b** with arene diazonium salts. The behavior of **2a, b** toward arene diazonium salts thus parallels the reported behavior of enamines [14] and enaminones [1] toward the same reagents but differs from the reported behavior of **2b** toward arenediazonium tetrafluoroborates where cyclization into cinnolines has been observed [9 – 11]. Compounds **1a – e** were assigned the indicated hydrazone structure in preference to a potentially tautomeric enolazo structure. This assignement is based on ^{1}H NMR and ^{13}C NMR spectra which revealed signals for two formyl protons and carbons in **1a – d** and one such signal in the spectra of **1e**. The appearance of the hydrazone NH signal at $\delta \sim 12$ ppm in the ^{1}H NMR spectra of **1a – e** can be assumed to result from the existence of hydrogen bonding between the NH hydrogen and the formyl carbonyl group. Recent results have established that 2-arylhydrazonoketones prefer the *anti* form to fit stereoelectronic [15, 16] requirements. Thus, the low-field signals observed for hydrazone NH in **1a – e** are most likely due to delocalization of the lone pair at nitrogen over the adjacent imine and carbonyl moieties. Compound **1e** readily coupled further with 4-chlorobenzenediazonium salts to yield formazanes **3**. These were also isolated as byproducts of the reaction of **2a, b** with arenediazonium salts. The structure of **3** has been established by single crystal X-ray structure determination (Scheme 1, Fig. 1).

In Table 1 selected bond lengths and bond angles are summarized. It is clear that all nitrogens are sp^2 hybridized which may point to extensive delocaliza-



2a: X = CHO
b: X = CO_2Et

1a: X = CHO, Ar = *p*-ClC_6H_4; **b:** X = CHO, Ar = C_6H_5
c: X = CHO, Ar = *p*-$CH_3OC_6H_4$; **d:** X = CHO, Ar = *m*-ClC_6H_4
e: X = CO_2Et, Ar = *p*-ClC_6H_4

Scheme 1.

Table 1: Selected bond lengths (Å) and angles (deg) of compound **3**.

N3–N5	1.301(4)	N5–N3–C11	117.6(3)
N5–C20	1.332(4)	N3–N5–C20	119.4(3)
N6–C8	1.422(5)	C8–N6–N17	117.6(3)
N6–N17	1.326(5)	N6–N17–C20	120.3(4)
C9–C20	1.487(5)		
N17–C20	1.438(5)		

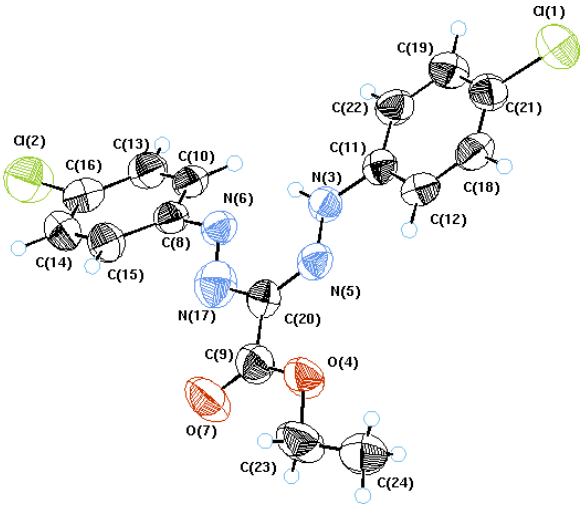


Fig. 1. Molecular structure of **3** in the crystal.

tion of nitrogen lone pairs of N(3) and N(5). It is also important to note that the *trans* relationship of the NH and formyl substituents of the C=N function indicates that stabilization by stereoelectronic effects supersedes a possible fixation by hydrogen bonding.

Compounds **1a**, **b** reacted with equimolar amounts of hydroxylamine hydrochloride to yield the oximes **4a**, **b**. When **1a** was reacted with an excess of hydroxylamine hydrochloride in ethanolic sodium acetate, dioxime **5** was formed. Treatment of dioxime **5** with acetic anhydride afforded 1,2,3-trizazole-4-carbonitrile **6**. Experiments to isolate oxime **7**, as reported earlier [17], failed. On the other hand, dioxime **5** afforded α-hydrazonopropionitrile **8** when treated with acetic acid (Scheme 2).

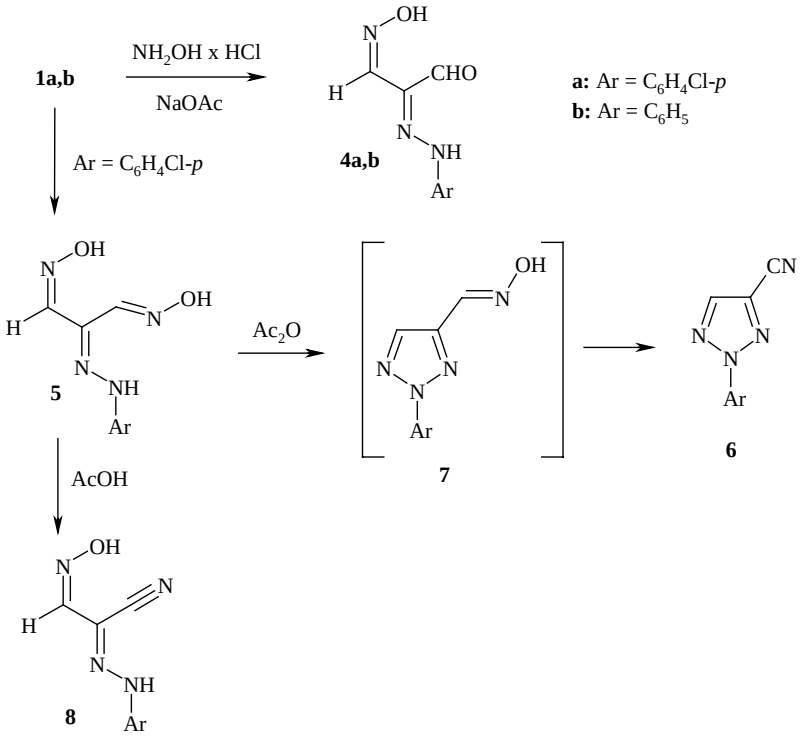
Treatment of **1c** with hydroxylamine hydrochloride resulted in the formation of ethyl 1,2,3-triazole-4-carboxylate **10**. Intermediate oxime **9** could also be isolated and readily cyclized to **10** on reflux in acetic anhydride. Compounds **1a**, **c** reacted with hydrazines to yield the arylazopyrazoles **11a**, **b** and **12a**, **b** (Scheme 3).

Compound **1a**, **e** reacted with chloroacetone to yield condensation products *via* elimination of one molecule of hydrogen chloride and one molecule of water. These were formulated as **14a**, **b** and were assumed to be formed *via* the intermediates **13a**, **b** (Scheme 4). These reactions parallel a recently reported pyrazole synthesis from the reaction of 2-arylhydrazonals with chloroacetone [18].

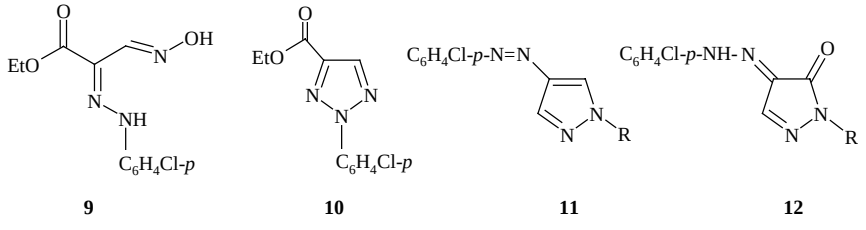
Compound **1e** reacted with ethyl 4-chloroacetoacetate to yield the 3-oxoester **16**, formed most likely *via* intermediacy of the acyclic compound **15** in a manner similar to that observed for the reaction of **1c** with chloroacetone. Although **16** may exist also in equilibrium with an enol form, the ^{1}H NMR spectrum revealed the absence of the latter as a signal for OH was absent and a CH_2 signal at δ = 4.54 ppm was observed. Unexpectedly, the reaction of **1a** with ethyl 4-chloroacetoacetate afforded a product of molecular formula $C_{15}H_{12}Cl_2N_2O_3$ corresponding to condensation of the ketoester with **1a** *via* elimination of two molecules of water. Structure **18** was concluded for this product based on spectral data, and its formation is assumed to proceed *via* intermediacy of **17** (Scheme 5).

Compounds **1a**, **c** also reacted with aminoazoles **19a**, **b** to yield the azolopyrimidines **20a**, **b** and **21a**, **b** (Scheme 6).

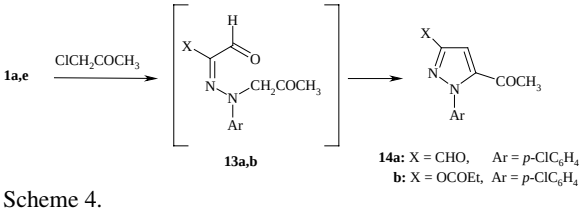
In conclusion we could show that the coupling reaction of substituted enamines with arenediazonium salts



Scheme 2.



Scheme 3.



Scheme 4.

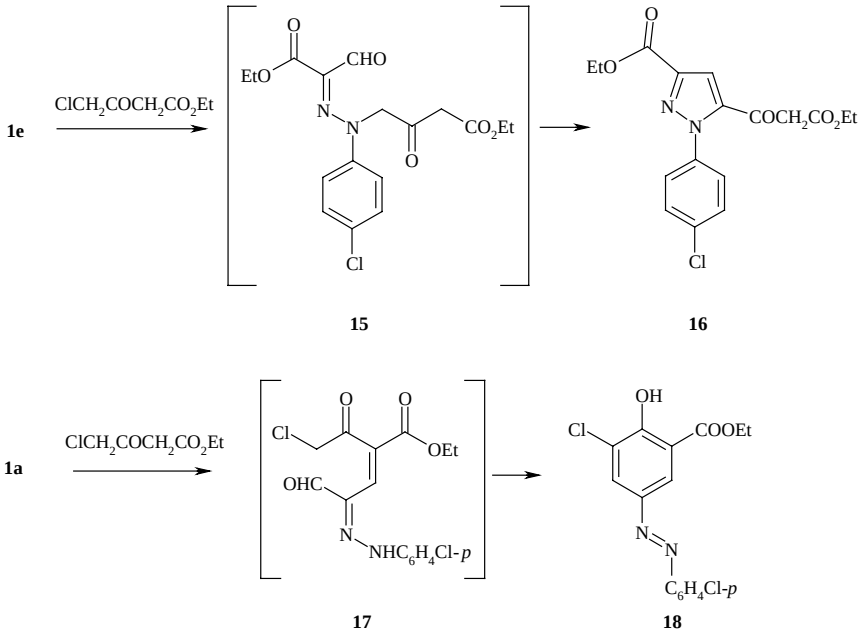
is a general route to arylhydrazonals that are versatile starting materials for the synthesis of polyfunctional azoles and condensed azoles.

Experimental Section

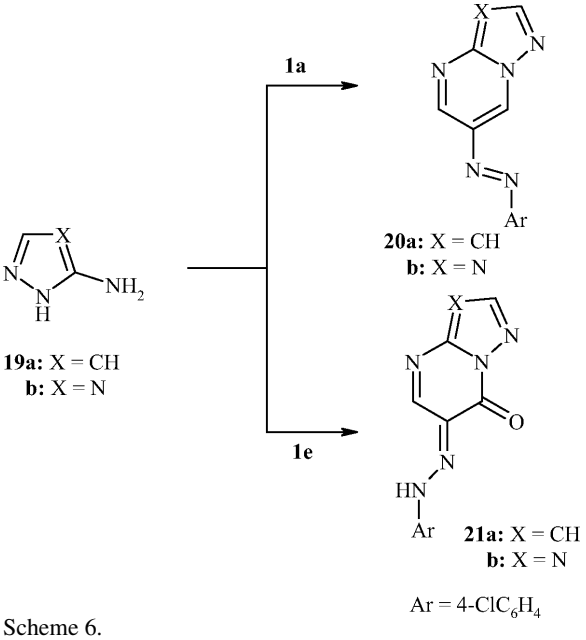
All melting points are uncorrected. IR spectra were recorded on KBr pellets with a Pye Unicam SP 1100 spectrophotometer. ^{1}H NMR and ^{13}C NMR spectra were recorded on a Varian EM-400 MHz spectrometer in [D_6]DMSO as a solvent and with TMS as internal standard; chemical shifts are reported in δ units (ppm). Mass spectra were measured on MS 30 and MS 9 (AEI) instruments at 70 eV. Microanalyses were performed with a LECO CHClNS-932 instrument.

Crystallographic analysis

The crystal was mounted on a glass fiber. All measurements were performed on an Enraf Nonius FR 590 diffractometer. The data were collected at a temperature of 20±1 °C using the ω scanning technique to θ_{max} = 26.02°. The structure was solved by Direct Methods using SIR 92 and refined by full-matrix least-squares [17]. Non-hydrogen atoms were refined anisotropically. Hydrogen atoms were located



Scheme 5.



Scheme 6.

geometrically and were refined isotropically. – *Crystal data*: $C_{16}H_{15}Cl_2N_4O_2$, M_r = 364.232, monoclinic space group $P2_1/c$, a = 7.9984(3), b = 10.6059(4), c = 20.4607(9) Å, β = 95.833(2)°, Z = 4, D_x = 1.401 Mg m^{-3}. 6153 reflections measured, wR = 0.126. Fig. 1 illustrates the molecular structure.

CCDC 611263 contains the supplementary crystallographic data for this paper. These data can be obtained free of charge from The Cambridge Crystallographic Data Centre *via* http://www.ccdc.cam.ac.uk/data_request/cif.

*General procedure for the preparation of compounds **1a – e** and **3***

A cold solution of the arenediazonium salt (10 mmol) was prepared by adding a solution of sodium nitrite (10 mmol in water) to a cold solution of the aromatic amine hydrochloride with stirring. The resulting solution of the diazonium salt was added to a cold solution of 3-(dimethylamino)acrolein (**2a**) (1.0 g, 10 mmol) in 30 mL of ethanol, ethyl 3-(dimethylamino)acrylate (**2b**) (1.43 g, 10 mmol) or **1e** (2.54g, 10 mmol), containing sodium acetate. The reaction mixture was stirred at r. t. for 30 min. The solid product formed was washed with water and crystallized from the proper solvent.

*2-[(4-Chlorophenyl)hydrazono]malonaldehyde (**1a**)*

M. p. 150 °C. – Yield: 1.47 g, 70 %. – IR (KBr): ν = 1676 (C=O); 3435 (NH) cm^{-1}. – ^{1}H NMR (400 MHz): δ = 7.53 (d, J = 8.0 Hz, 2H, Ar-H); 7.74 (d, J = 8.0 Hz, 2H, Ar-H); 9.53 (s, 1H, formyl); 9.83 (s, 1H, formyl); 14.04 (s, 1H, NH). – ^{13}C NMR (100 MHz): δ = 112.6, 121.89, 131.08, 142.32, 159.42, 189.88, 190.84. – MS (AEI, 70 eV): *m/z* (%) = 210 (90) [M]$^+$. – $C_9H_7ClN_2O_2$ (210.62): calcd. C 51.32, H 3.35, N 13.30; found C 51.30, H 3.34, N 13.29.

*2-[Phenylhydrazono]malonaldehyde (**1b**)*

M. p. 121 °C. – Yield: 1.16 g, 66 %. – IR (KBr): ν = 1673 (C=O); 3432 (NH) cm^{-1}. – ^{1}H NMR (400 MHz): δ = 7.29

(t, 1H, Ar-H); 7.48 (d, J = 8.0 Hz, 2H, Ar-H); 7.70 (d, J = 8.0 Hz, 2H, Ar-H); 9.54 (s, 1H, formyl); 9.84 (s, 1H, formyl); 14.15 (s, 1H, NH). – ^{13}C NMR (100 MHz): δ = 116.89, 127.75, 130.69, 134.10, 142.12, 190.58, 190.84. – MS (AEI, 70 eV): *m/z* (%) = 176 (85) $[M]^+$. – $C_9H_8N_2O_2$ (176.17): calcd. C 61.36, H 4.58, N 15.90; found C 61.32, H 4.58, N 15.88.

*2-[(4-Methoxyphenyl)hydrazono]malonaldehyde (**1c**)*

M. p. 173 °C. – Yield: 1.23 g, 60 %. – IR (KBr): ν = 1663 (C=O); 3435 (NH) cm^{-1}. – ^{1}H NMR (400 MHz): δ = 3.79 (s, 3H, OCH_3); 7.04 (m, 2H, Ar-H); 7.73 (m, 2H, Ar-H); 8.32 (s, 1H, formyl); 9.14 (br., 1H, formyl); 12.78 (br., 1H, NH). – MS (AEI, 70 eV): *m/z* (%) = 206 (86) $[M]^+$. – $C_{10}H_{10}N_2O_3$ (206.20): calcd. C 58.25, H 4.89, N 13.59. found C 58.11, H 4.88, N 13.57.

*2-[(3-Chlorophenyl)hydrazono]malonaldehyde (**1d**)*

M. p. 139 °C. – Yield: 1.45 g, 69 %. – IR (KBr): ν = 1683 (C=O); 3436 (NH) cm^{-1}. – ^{1}H NMR (400 MHz): δ = 7.32 (d, J = 7.8 Hz, 1H, Ar-H); 7.48 (t, J = 7.8 Hz, 1H, Ar-H); 7.68 (d, J = 8.0 Hz, 1H, Ar-H); 7.81 (s, 1H, Ar-H); 9.55 (s, 1H, formyl); 9.84 (s, 1H, formyl); 13.94 (s, 1H, NH). – ^{13}C NMR (100 MHz): δ = 116.9, 117.2, 127.0, 132.3, 134.5, 135.1, 143.9, 186.8, 191.0. – MS (AEI, 70 eV): *m/z* (%) = 210 (90) $[M]^+$. – $C_9H_7ClN_2O_2$ (210.62): calcd. C 51.32, H 3.35, N 13.30; found C 51.31, H 3.33, N 13.30.

*2-[(4-Chlorophenyl)hydrazono]-3-oxopropionic acid ethyl ester (**1e**)*

M. p. 88 °C. – Yield: 1.57 g, 62 %. – IR (KBr): ν = 1655, 1692 (2CO); 3446 (NH) cm^{-1}. – ^{1}H NMR (400 MHz): δ = 1.30 (t, J = 7.2 Hz, 3H); 4.30 (q, J = 7.2 Hz, 2H); 7.49 (d, J = 8.0 Hz, 2H, Ar-H); 7.62 (d, J = 8.0 Hz, 2H, Ar-H); 9.64 (s, 1H, formyl); 13.94 (s, 1H, NH). – ^{13}C NMR (100 MHz): δ = 14.86, 61.829, 119.20, 128.46, 130.02, 130.50, 141.69, 164.29, 187.89. – MS (AEI, 70 eV): *m/z* (%) = 254 (100) $[M]^+$. – $C_{11}H_{11}ClN_2O_3$ (254.67): calcd. C 51.88, H 4.35, N 11.00; found C 51.84, H 4.37, N 10.95.

*Ethyl 2-[2-(4-chlorophenyl)-1-diazenyl]-2-[2-(4-chlorophenyl)hydrazono]acetate (**3**)*

M. p. 175 °C. – Yield: 2.99 g, 82 %. – ^{1}H NMR (400 MHz): δ = 1.31 (t, J = 7.2 Hz, 3H); 4.27 (q, J = 7.2 Hz, 2H); 7.45 – 8.54 (m, 8H, Ar-H); 14.68 (s, 1H, NH). – $C_{16}H_{14}Cl_2N_4O_2$ (365.21): calcd. C 52.62, H 3.86, N 15.34; found C 52.58, H 3.80, N 15.29.

*General procedure for the preparation of compounds **4a, b** and **9***

A mixture of **1a**, **b** (10 mmol) or **1e** (2.54 g, 10 mmol); hydroxylamine hydrochloride (0.69 g, 10 mmol) and sodium acetate (3 g) in ethanol (20 mL) was heated under reflux for 30 min, and then poured onto water. The solid product was collected by filtration and crystallized from ethanol.

*2-[(4-Chlorophenyl)hydrazono]malonaldehyde monooxime (**4a**)*

M. p. 130 °C. – Yield: 1.66 g, 65 %. – IR (KBr): ν = 1660 (C=O); 3110 (NH); 3426 (OH) cm^{-1}. – ^{1}H NMR (400 MHz): δ = 7.39 (d, J = 8.0 Hz, 2H, J = 8.0 Hz, Ar-H); 7.51 (d, J = 8.0 Hz, 2H, Ar-H); 8.16 (s, 1H); 9.40 (s, 1H); 12.27 (s, 1H, NH); 12.61 (s, 1H, OH). – ^{13}C NMR (100 MHz): δ = 116.11, 126.43, 129.10, 129.98, 141.84, 143.75, 190.09. – MS (AEI, 70 eV): *m/z* (%) = 225 (30) $[M]^+$. – $C_9H_8ClN_2O_2$ (225.63): calcd. C 47.91, H 3.57, N 18.62; found C 47.89, H 3.55, N 18.60.

*2-[Phenylhydrazono]malonaldehyde monooxime (**4b**)*

M. p. 146 °C. – Yield: 1.22 g, 64 %. – ^{1}H NMR (400 MHz): δ = 7.16 (t, 1H, Ar-H); 7.33 – 7.46 (m, 4H, Ar-H); 8.18 (s, 1H); 9.43 (s, 1H); 12.23 (br., 1H, NH); 12.66 (br., 1H, OH). – ^{13}C NMR (100 MHz): δ = 116.28, 125.57, 131.07, 132.88, 142.81, 149.05, 190.114. – MS (AEI, 70 eV): *m/z* (%) = 191 (66) $[M]^+$. – $C_9H_9N_3O_2$ (191.19): calcd. C 56.54, H 4.74, N 21.98; found C 56.56, H 4.70, N 21.90.

*2-[(4-Chlorophenyl)hydrazono]malonaldehyde dioxime (**5**)*

A mixture of **1a** (2.10 g, 10 mmol); hydroxylamine hydrochloride (1.38 g, 20 mmol) and sodium acetate (3 g) in ethanol (20 mL) was heated under reflux for 30 min, then poured onto water. The solid product was collected by filtration and crystallized from ethanol.

M. p. 140 °C. – Yield: 1.61 g, 67 %. – ^{1}H NMR (400 MHz): δ = 7.20 (d, J = 8.0 Hz, 2H, Ar-H); 7.34 (d, J = 8.0 Hz, 2H, Ar-H); 7.76 (s, 1H); 8.24 (s, 1H); 12.13 (s, 1H, NH); 12.65 (s, 1H, OH); 12.68 (s, 1H, OH). – ^{13}C NMR (100 MHz): δ = 116.13, 126.31, 129.27, 129.49, 140.39, 142.15, 148.98. – MS (AEI, 70 eV): *m/z* (%) = 240 (45) $[M]^+$. – $C_9H_9ClN_4O_2$ (240.65): calcd. C 44.92, H 3.77, N 23.28; found C 44.90, H 3.72, N 23.22.

*2-(4-Chlorophenyl)-2H-[1,2,3]triazole-4-carbonitrile (**6**)*

A mixture of **5** (2.4 g, 10 mmol) and acetic anhydride (20 mL) was refluxed for 2 h, then poured into water. The solid formed was collected by filtration and crystallized from ethanol.

M. p. 130 °C. – Yield: 1.43 g, 70 %. – IR (KBr): ν = 2253 (CN) cm^{-1}. – ^{1}H NMR (400 MHz): δ = 7.69 (d, J = 8.0 Hz, 2H, Ar-H); 8.08 (d, J = 8.0 Hz, 2H, Ar-H); 8.90 (s, 1H). – ^{13}C NMR (100 MHz): δ = 112.66, 121.94, 123.38, 131.07, 135.02, 138.07, 142.32. – MS (AEI, 70 eV): *m/z* (%) = 204 (100) $[M]^+$. – $C_9H_5ClN_4$ (204.62): calcd. C 52.83, H 2.46, N 27.38; found C 52.85, H 2.40, N 27.33.

*2-[(4-Chlorophenyl)hydrazono]-3-hydroxyimino-propionitrile (**8**)*

A mixture of **5** (2.49 g, 10 mmol) and acetic acid (20 mL) was refluxed for 2 h, and then poured into water. The solid formed was collected by filtration and crystallized from ethanol.

M. p. 264 °C. – Yield: 1.46 g, 66 %. – IR (KBr): ν = 2212 (CN); 3349 (NH); 3498 (OH) cm^{-1}. – ^1H NMR (400 MHz): δ = 7.39 (d, J = 8.0 Hz, 2H, Ar-H); 7.50 (s, 1H, CH); 7.68 (d, J = 8.0 Hz, 2H, Ar-H); 7.88 (s, 1H, NH); 11.78 (s, 1H, OH). – MS (AEI, 70 eV): *m/z* (%) = 222 (100) $[M]^+$. – $C_9H_7ClN_4O$ (222.63): calcd. C 48.55, H 3.17, N 25.17; found C 48.53, H 3.12, N 25.05.

*Ethyl 2-[(4-chlorophenyl)hydrazono]-3-hydroxyimino-propionionate (**9**)*

M. p. 182 °C. – Yield: 1.94 g, 72 %. – IR (KBr): ν = 1699 (C=O); 3230 (NH); 3402 (OH) cm^{-1}. – ^1H NMR (400 MHz): δ = 1.29 (t, J = 7.2 Hz, 3H); 4.25 (q, J = 7.2 Hz, 2H); 7.29 (d, J = 8.0 Hz, 2H, Ar-H); 7.45 (d, J = 8.0 Hz, 2H, Ar-H); 8.29 (s, 1H); 12.23 (s, 1H, NH); 12.62 (s, 1H, OH). – MS (AEI, 70 eV): *m/z* (%) = 269 (85) $[M]^+$. – $C_{11}H_{12}ClN_3O_3$ (269.68): calcd. C 48.99, H 4.48, N 15.58; found C 48.95, H 4.43, N 15.35.

*Ethyl 2-(4-chlorophenyl)-1,2,3-triazole-4-carboxylate (**10**)*

A mixture of **9** (2.69 g, 10 mmol) and acetic anhydride (20 mL) was refluxed for 2 h, and then poured into water. The solid formed was collected by filtration and crystallized from ethanol.

M. p. 183 °C. – Yield: 1.83 g, 73 %. – IR (KBr): ν = 1728 (C=O) cm^{-1}. – ^1H NMR (400 MHz): δ = 1.34 (t, J = 7.2 Hz, 3H); 3.38 (q, J = 7.2 Hz, 2H); 7.68 (d, J = 8.0 Hz, 2H, Ar-H); 8.09 (d, J = 8.0 Hz, 2H, Ar-H); 8.63 (s, 1H). – MS (AEI, 70 eV): *m/z* (%) = 251 (100) $[M]^+$. – $C_{11}H_{10}ClN_3O_2$ (251.67): calcd. C 52.50, H 4.01, N 16.70; found C 52.51, H 4.00, N 16.72.

*General procedure for the preparation of compounds **11a, b** and **12a, b***

A mixture of **1a** (2.1 g, 10 mmol) or **1e** (2.54 g, 10 mmol) with hydrazine hydrate (0.5 g, 10 mmol) or phenylhydrazine (1.08 g, 10 mmol) was refluxed in ethanol for 1 h. The solid product obtained was collected by filtration and crystallized from the proper solvent.

*4-(4-Chlorophenylazo)-1H-pyrazole (**11a**)*

M. p. 170 °C. – Yield: 1.50 g, 73 %. – IR (KBr): ν = 3172 (NH) cm^{-1}. – ^1H NMR (400 MHz): δ = 7.60 (d, J = 8.0 Hz, 2H, Ar-H); 7.77 (d, J = 8.0 Hz, 2H, Ar-H); 8.30 (s, 2H); 12.60 (s, 1H, NH). – ^{13}C NMR (100 MHz): δ = 124.48, 126.14, 130.47, 135.64, 141.91, 151.96, 154.80. – MS (AEI, 70 eV): *m/z* (%) = 206 (60) $[M]^+$. – $C_9H_7ClN_4$ (206.63): calcd. C 52.31, H 3.41, N 27.11; found C 52.30, H 3.43, N 27.15.

*4-(4-Chlorophenylazo)-1-phenyl-1H-pyrazole (**11b**)*

M. p. 196 °C. – Yield: 1.98 g, 70 %. – ^1H NMR (400 MHz): δ = 7.40 (t, 1H, Ar-H); 7.57 (d, J = 8.0 Hz, 2H, Ar-H); 7.64 (d, J = 8.0 Hz, 2H, Ar-H); 7.83 (d, J = 8.0 Hz, 2H, Ar-H); 7.98 (d, J = 8.0 Hz, 2H, Ar-H); 8.29 (s, 1H); 9.40 (s, 1H). – ^{13}C NMR (100 MHz): δ = 119.86, 124.67, 127.65, 128.33, 130.61, 131.40, 143.39, 136.21, 140.06, 143.36, 151.91. – MS (AEI, 70 eV): *m/z* (%) = 282 (80) $[M]^+$. – $C_{15}H_{11}ClN_4$ (282.73): calcd. C 63.72, H 3.92, N 19.82; found C 63.70, H 3.90, N 19.80.

*4-[(4-Chlorophenyl)hydrazono]-2,4-dihydropyrazol-3-one (**12a**)*

M. p. 156 °C. – Yield: 1.65 g, 74 %. – IR (KBr): ν = 1667 (C=O); 3232, 3451 (2NH) cm^{-1}. – ^1H NMR (400 MHz): δ = 7.46 – 7.48 (m, 4H, Ar-H); 7.55 (s, 1H, NH); 7.95 (s, 1H); 11.95 (s, 1H, NH). – ^{13}C NMR (100 MHz): δ = 118.43, 119.15, 126.32, 129.60, 130.15, 130.79, 138.88, 141.29, 157.04, 165.74, 165.85. – MS (AEI, 70 eV): *m/z* (%) = 222 (100) $[M]^+$. – $C_9H_7ClN_4O$ (222.63): calcd. C 48.55, H 3.17, N 25.17; found C 48.54, H 3.15, N 25.14.

*4-[(4-Chlorophenyl)hydrazono]-2-phenyl-2,4-dihydropyrazol-3-one (**12b**)*

M. p. 190 °C. – Yield: 2.15 g, 72 %. – IR (KBr): ν = 1654 (C=O); 3432 (NH) cm^{-1}. – ^1H NMR (400 MHz): δ = 7.26 (t, 1H, Ar-H); 7.47 – 7.52 (m, 4H, Ar-H); 7.65 (d, J = 8.0 Hz, 2H, Ar-H); 7.91 (d, J = 8.0 Hz, 2H, Ar-H); 8.17 (s, 1H); 12.98 (s, 1H, NH). – ^{13}C NMR (100 MHz): δ = 118.44, 119.04, 119.15, 126.32, 129.60, 129.99, 130.58, 138.88, 141.29, 141.84, 157.04. – MS (AEI, 70 eV): *m/z* (%) = 298 (100) $[M]^+$. – $C_{15}H_{11}ClN_4O$ (298.73): calcd. C 60.31, H 3.71, N 18.76; found C 60.28, H 3.73, N 18.72.

*General procedure for the preparation of compounds **14a, b***

A mixture of **1a**, **e** (2.10 g, 10 mmol) or **1e**, **g** (2.54 g, 10 mmol) and chloroacetone (10 mmol) in ethanol (30 mL) containing triethylamine (10 mmol) was refluxed for 30 min, then left to cool. The solid products were collected by filtration and crystallized from dimethylformamide.

*5-Acetyl-1-(4-chlorophenyl)-1H-pyrazole-3-carbaldehyde (**14a**)*

M. p. 180 °C. – Yield: 1.64 g, 66 %. – IR (KBr): ν = 1654 (C=O); 3432 (NH) cm^{-1}. – ^1H NMR (400 MHz): δ = 2.58 (s,

3H); 7.57 – 7.61 (m, 4H, Ar-H); 7.86 (s, 1H); 10.00 (s, 1H). – MS (AEI, 70 eV): *m/z* (%) = 248 (80) $[M]^+$. – $C_{12}H_9ClN_2O_2$ (248.67): calcd. C 57.96, H 3.65, N 11.27; found C 57.65, H 3.63, N 11.23.

*Ethyl 5-acetyl-1-(4-chlorophenyl)-1H-pyrazole-3-carboxylate (**14b**)*

M. p. 170 °C. – Yield: 2.0 g, 69 %. – IR (KBr): ν = 1691 (C=O); 3446 (NH) cm^{-1}. – ^1H NMR (400 MHz): δ = 1.31 (t, *J* = 7.2 Hz, 3H); 2.57 (s, 3H,); 4.34 (q, *J* = 7.2 Hz, 2H); 7.51 (d, *J* = 8.0 Hz, 2H, Ar-H); 7.57 (d, *J* = 8.0 Hz, 2H, Ar-H); 7.81 (s, 1H); 10.08 (s, 1H). – MS (AEI, 70 eV): *m/z* (%) = 292 (85) $[M]^+$. – $C_{14}H_{13}ClN_2O_3$ (292.72): calcd. C 57.44, H 4.42, N 9.57; found C 57.40, H 4.42, N 9.52.

*General procedure for the preparation of compounds **16** and **18***

A mixture of **1a** (2.10 g, 10 mmol) or **1e** (2.54 g, 10 mmol); ethyl 4-chloroacetoacetate (10 mmol); and triethylamine (10 mmol) in ethanol (30 mL) was refluxed for 30 min, then left to cool. The solid product was collected by filtration and crystallized from a suitable solvent.

*Ethyl 1-(4-chlorophenyl)-5-(2-ethoxycarbonyl-acetyl)-1H-pyrazole-3-carboxylate (**16**)*

M. p. 186 °C. – Yield: 2.62 g, 72 %. – IR (KBr): ν = 1674, 1710, 1719 (3CO) cm^{-1}. – ^1H NMR (400 MHz): δ = 1.29 – 1.39 (m, 6H, $2CH_3$); 4.30 – 4.44 (m, 4H, $2CH_2$); 4.54 (s, 2H, CH_2); 7.35 (d, *J* = 8.0 Hz, 2H, Ar-H); 7.74 (s, 1H); 8.15 (d, *J* = 8.0 Hz, 2H, Ar-H); 9.04 (s, 1H, pyrrole H-4). – MS (AEI, 70 eV): *m/z* (%) = 364 (60) $[M]^+$. – $C_{17}H_{17}ClN_2O_5$ (364.78): calcd. C 55.97, H 4.70, N 7.68; found C 55.93, H 4.65, N 7.61.

*Ethyl 3-chloro-5-[2-(4-chlorophenyl)-1-diazenyl]-2-hydroxobenzoate (**18**)*

M. p. 146 °C. – Yield: 2.54 g, 75 %. – IR (KBr): ν = 1681 (C=O); 3432 (OH) cm^{-1}. – ^1H NMR (400 MHz): δ = 1.38 (t, *J* = 7.2 Hz, 3H); 4.45 (q, *J* = 7.2 Hz, 2H); 7.66 (d, *J* = 8.0 Hz, 2H, Ar-H); 790 (d, *J* = 8.0 Hz, 2H, Ar-H); 8.19 (d, 1H); 8.29 (d, 1H); 11.60 (br., 1H, OH). – MS (AEI, 70 eV): *m/z* (%) = 338 (20) $[M]^+$. – $C_{15}H_{12}Cl_2N_2O_3$ (339.17): calcd. C 53.12, H 3.57, N 8.26; found C 53.05, H 3.48, N 8.17.

*General procedure for the preparation of compounds **20a, b** and **21a, b***

Compound **1a** (2.10 g, 10 mmol) or **1e** (2.54 g, 10 mmol) in ethanol (30 mL) was heated with one of the heterocyclic amines **19a**, **b** (10 mmol) under reflux for 4 – 6 h and allowed to cool to r. t. The solid product was collected by filtration and crystallized from ethanol.

*(4-Chlorophenyl)-pyrazolo[1,5-a]pyrimidin-6-yl-diazene (**20a**)*

M. p. 269 °C. – Yield: 1.80 g, 70 %. – ^1H NMR (400 MHz): δ = 7.22 (d, 1H); 7.68 (d, *J* = 8.0 Hz, 2H, Ar-H); 7.94 (d, *J* = 8.0 Hz, 2H, Ar-H); 8.37 (d, 1H); 8.70 (d, 1H); 9.14 (d, 1H). – MS (AEI, 70 eV): *m/z* (%) = 257 (70) $[M]^+$. – $C_{12}H_8ClN_5$ (257.68): calcd. C 55.93, H 3.13, N 27.18; found C 55.85, H 3.06, N 27.11.

*(4-Chlorophenyl)-[1,2,4]triazolo[1,5-a]pyrimidin-6-yl-diazene (**20b**)*

M. p. 246 °C. – Yield: 1.76 g, 68 %. – ^1H NMR (400 MHz): δ = 7.75 (d, *J* = 8.0 Hz, 2H, Ar-H); 7.98 (d, *J* = 8.0 Hz, 2H, Ar-H); 8.86 (s, 1H); 9.42 (s, 1H); 10.16 (s, 1H). – MS (AEI, 70 eV): *m/z* (%) = 258 (100) $[M]^+$. – $C_{11}H_7ClN_6$ (258.67): calcd. C 51.08, H 2.73, N 32.49; found C 51.01, H 2.75, N 32.49.

*6-[(4-Chlorophenyl)hydrazono]-6H-pyrazolo[1,5-a]pyrimidin-7-one (**21a**)*

M. p. 191 °C. – Yield: 1.97 g, 72 %. – IR (KBr): ν = 1643 (C=O); 3132 (NH) cm^{-1}. – ^1H NMR (400 MHz): δ = 6.59 (d, 1H); 7.52 (d, *J* = 8.0 Hz, 2H, Ar-H); 7.57 (d, *J* = 8.0 Hz, 2H, Ar-H); 7.78 (d, 1H); 8.83 (s, 1H); 14.91 (s, 1H, NH). – ^{13}C NMR (100 MHz): δ = 98.35, 119.62, 124.77, 130.57, 131.81, 139.95, 144.70, 148.62, 154.97, 193.95. – MS (AEI, 70 eV): *m/z* (%) = 273 (100) $[M]^+$. – $C_{12}H_8ClN_5O$ (273.68): calcd. C 52.66, H 2.95, N 25.59; found C 52.66, H 2.95, N 25.59.

*6-[(4-Chlorophenyl)hydrazono]-6H-[1,2,4]triazolo-[1,5-a]pyrimidin-7-one (**21b**)*

M. p. 202 °C. – Yield: 1.92 g, 70 %. – IR (KBr): ν = 1645 (C=O); 3110 (NH) cm^{-1}. – ^1H NMR (400 MHz): δ = 7.52 (d, *J* = 8.0 Hz, 2H, Ar-H); 7.57 (d, *J* = 8.0 Hz, 2H, Ar-H); 8.33 (s, 1H); 8.78 (s, 1H); 15.11 (s, 1H, NH). – MS (AEI, 70 eV): *m/z* (%) = 274 (100) $[M]^+$. – $C_{11}H_7ClN_6O$ (274.67): calcd. C 48.10, H 2.57, N 30.60; found C 48.06, H 2.55, N 30.55.

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