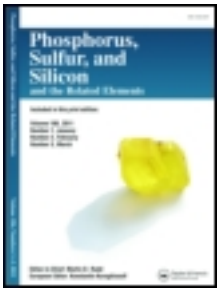


Phosphorus, Sulfur, and Silicon and the Related Elements
Publication details, including instructions for authors and subscription information:
http://www.tandfonline.com/loi/gpss20

The Behavior of 4-Azidocoumarin-3-carboxaldehyde Towards Certain Sulfur Reagents and Primary Amines

Nabila M. Ibrahim [a], Hisham Abdallah A. Yosef [a], El-Sayed M. A. Yakout [b] & Mohamed Refat H. Mahran [a]

[a] Department of Organometallic and Organometalloid Chemistry, National Research Centre, Dokki, Cairo, Egypt

[b] Department of Pesticide Chemistry, National Research Centre, Dokki, Cairo, Egypt

Published online: 28 Apr 2009.

To cite this article: Nabila M. Ibrahim, Hisham Abdallah A. Yosef, El-Sayed M. A. Yakout & Mohamed Refat H. Mahran (2009) The Behavior of 4-Azidocoumarin-3-carboxaldehyde Towards Certain Sulfur Reagents and Primary Amines, Phosphorus, Sulfur, and Silicon and the Related Elements, 184:5, 1124-1138, DOI: 10.1080/10426500902855133

To link to this article: http://dx.doi.org/10.1080/10426500902855133

Phosphorus, Sulfur, and Silicon, 184:1124–1138, 2009

ISSN: 1042-6507 print / 1563-5325 online
DOI: 10.1080/10426500902855133

Taylor & Francis
Taylor & Francis Group

The Behavior of 4-Azidocoumarin-3-carboxaldehyde Towards Certain Sulfur Reagents and Primary Amines

Nabila M. Ibrahim,[1] Hisham Abdallah A. Yosef,[1] El-Sayed M. A. Yakout,[2] and Mohamed Refat H. Mahran[1]
[1]Department of Organometallic and Organometalloid Chemistry, National Research Centre, Dokki, Cairo, Egypt
[2]Department of Pesticide Chemistry, National Research Centre, Dokki, Cairo, Egypt

*The behavior of 4-azidocoumarin-3-carboxaldehyde (**1**) towards certain sulfur reagents such as isothiocyanates (**2a–c**), thionyl chloride, Lawesson's reagent (LR, **3**), and phosphorus pentasulfide as well as towards primary amines such as glycine (**4**) and towards anthranilic acid (**5**) was investigated. The structures of the new products were attested by suitable analytical and spectroscopic measurements.*

Keywords 4-Azidocoumarin-3-carboxaldehyde; primary amines; reactions; structural elucidations; sulfur reagents

INTRODUCTION

Azides are very important building blocks due to their industrial as well as biological applications.[1–3] They are also applied in synthesis, particularly via 1,3-dipolar cycloaddition reactions.[4–7] Coumarins are of great interest, since they display a broad range of biological activities such as antimicrobial,[8] coronary vasodilating,[9] and anti-neoplastic[10–12] activity and can be also used for the treatment of retroviral infections against HIV-protease.[13,14] In response to our growing interest in the chemistry of coumarin derivatives,[15–20] we have now studied the behavior of 4-azidocoumarin-3-carboxaldehyde (**1**) towards a number of sulfur and nitrogen reagents: ethyl, cyclohexyl and ammonium isothiocyanates (**2a**–**c**), thionyl chloride, Lawesson's reagent (LR, **3**),

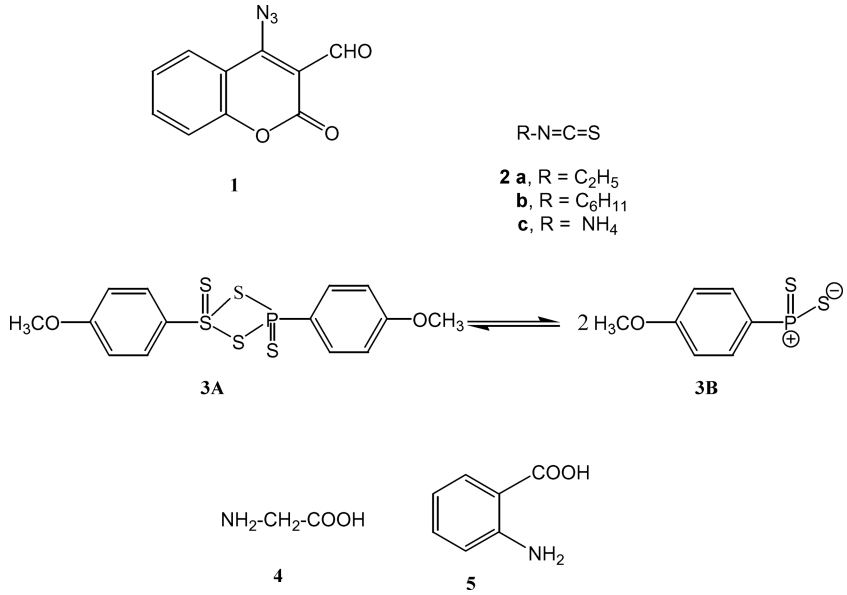
Received 21 November 2007; accepted 25 February 2008.

Dedicated to Professor Marian Mikołajczyk, CBMiM PAN in Łódź, Poland, on the occasion of his 70th birthday.

Address correspondence to Mohamed Refat H. Mahran, Department of Organometallic and Organometalloid Chemistry, National Research Centre, Dokki, Cairo 12622, Egypt. E-mail: mrh_mahran@yahoo.com

phosphorus pentasulfide, glycine (**4**), and anthranilic acid (**5**) (Scheme 1).

The azido-function in *ortho*-activated aryl azides is known to suffer attack by stabilized carbanions to produce interesting new heterocyclic systems.[19,21,22] Compound **1** is essentially prepared by reacting 4-hydroxycoumarin with DMF/$POCl_3$ (Vilsemeier)[23] followed by condensation of the resulting 4-chlorocoumarin-3-carboxaldehyde with sodium azide.[23]

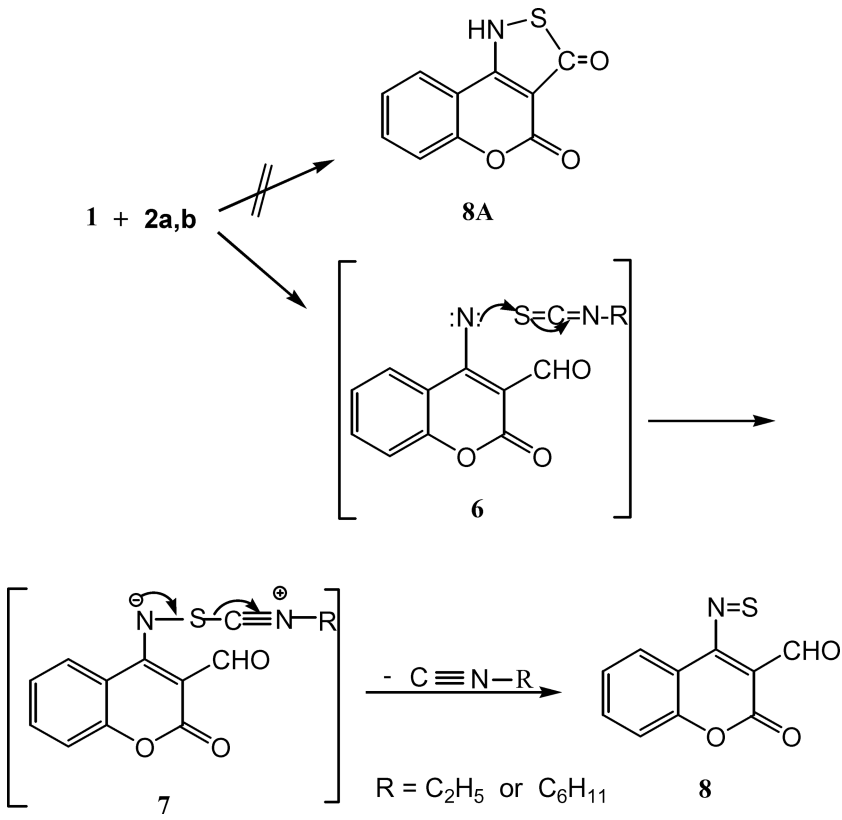


SCHEME 1

RESULTS AND DISCUSSION

When a mixture of 4-azidocoumarin-3-carboxaldehyde (known also as 4-azido-2-oxo-2*H*-chromene-3-carbaldehyde) (**1**) and ethyl isothiocyanate (**2a**) in THF was stirred at ambient temperature, a colorless crystalline substance was obtained and identified as 2-oxo-4-(thioxoamino)-2*H*-chromene-3-carbaldehyde (**8**) (Scheme 2) for the following reasons:

a. Correct elemental analysis and molecular weight determination (MS) for compound **8** corresponded to $C_{10}H_5NO_3S$.
b. The strong absorption band for the azido group present in the IR spectrum of **1** at 2176 cm^{-1} was absent in the spectrum of compound

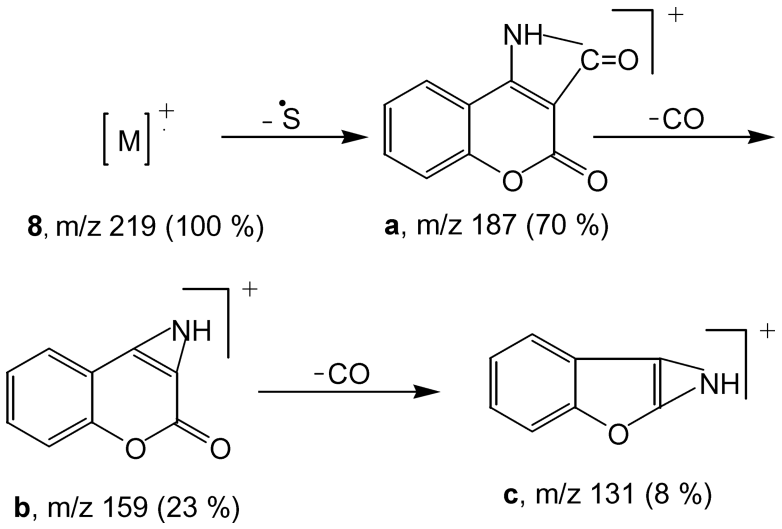


SCHEME 2

8. Strong absorption bands were observed at 3150 (CH, aromatic), 1760 (C=O, lactone), 1730 (C=O, aldehyde), 1600 (C=C, aromatic), and at 1380 (C—O, stretching) cm^{-1}.

c. The ^1H NMR spectrum of compound **8** (in d_6-DMSO) showed the signal of the proton of the CHO group at $\delta = 10.20$ (not exchangeable with D_2O). The aromatic protons gave signals at $\delta = 8.08$ (d, $J_{HH} =$ 7.8 Hz, 1H), 7.70 (dd, $J_{HH} = 8.4$, 8.7 Hz, 1H) and at 7.48 (m, 2H). These data exclude an alternative structure like **8A** for the product of the reaction of **1** with **2a** (or **2b**).

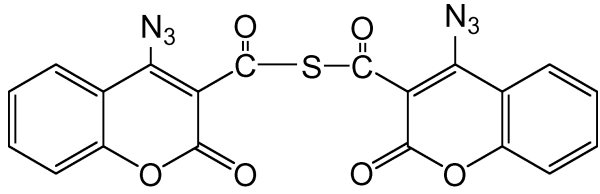
d. The mass spectrum of **8** showed the molecular ion peak at m/z 219 (100%). Loss of sulfur radical from M^+ yields cation **a** at m/z 187 (70%), which suffers further loss of two neutral CO molecules to afford cations **b** and **c** at m/z 159 (23%) and 131 (8%), respectively (Scheme 3).



SCHEME 3

Under similar conditions, compound **1** reacted with cyclohexyl isothiocyanate (**2b**) to give a colorless crystalline product proved to be **8** (mp, mmp, and IR data). Formation of **8** may be explained in terms of the initial formation of a nitrene species like **6** under the current reaction conditions. Attack by **6** on the isothiocyanate sulfur atom would produce a transient species like **7**, which undergoes molecular rearrangement via elimination of the corresponding alkyl isocyanide to give **8** (Scheme 2).

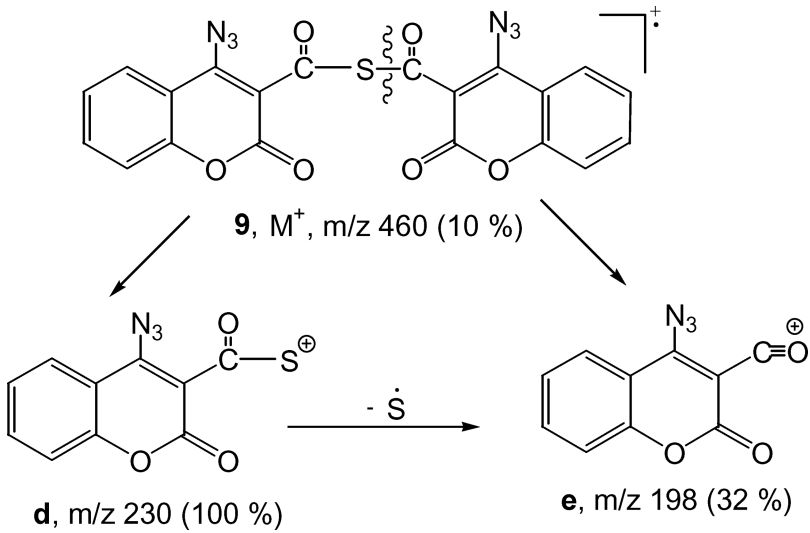
Upon reacting azide **1** with ammonium isothiocyanate (**2c**) in THF, a yellow crystalline material was obtained and identified as bis(3-carbonyl-4-azido-2-oxo-2*H*-chromeno)sulfide (**9**) for the following reasons (Figure 1):



9

FIGURE 1

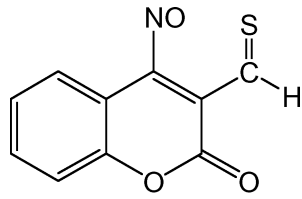
a. Correct elemental analysis and molecular weight determination (MS) for **9** corresponded to $C_{20}H_8N_6O_6S$ (m/z 460, M^+, 5%).
b. Strong absorption bands appeared in the IR spectrum of **9** (KBr) at 3112 (CH, aromatic), 2373 (N_3), 1731 (C=O, lactone and thioanhydride), 1609, 1557 (C=C, aromatic) and 1362 (C—O, stretching) cm^{-1}.
c. The ^1H NMR spectrum of compound **9** (DMSO) showed the absence of signals around $\delta = 10$ (CHO). The aromatic protons (10 H) appeared as a multiplet in the region 8.35–7.24 ppm.
d. The mass spectrum of compound **9** showed the base peak **d** at m/z 230 (100%), which is expected from the cleavage of M^+ (Scheme 4).



SCHEME 4

Cleavage at the same position also produces ion **e** at m/z 198 (32%). Loss of a sulfur radical from ion **d** can also produce ion **e**.

On the other hand, refluxing of **1** with thionyl chloride yielded a yellow material that is isomeric [$C_{10}H_5NO_3S$, MS: m/z 219, (M^+, 5%)] but not identical to compound **8**. It was identified as 4-nitroso-2-oxo-2*H*-chromeno-3-carbthialdehyde (**10**) (Figure 2). Its IR spectrum (KBr) revealed the presence of strong absorption bands at 3102 (CH, aromatic), 1766 (C=O, lactone), 1613 (C=C, aromatic), 1559 (C-NO, monomer), and 1407 (C—O, stretching) cm^{-1}. The ^1H NMR spectrum of compound **10** revealed the presence of signals at 10.26 (s, 1H, CHS) and 8.09–7.26 (m, 4H, arom-H).

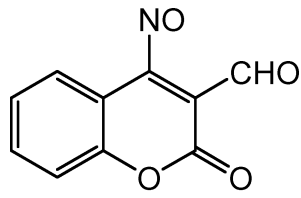


10

FIGURE 2

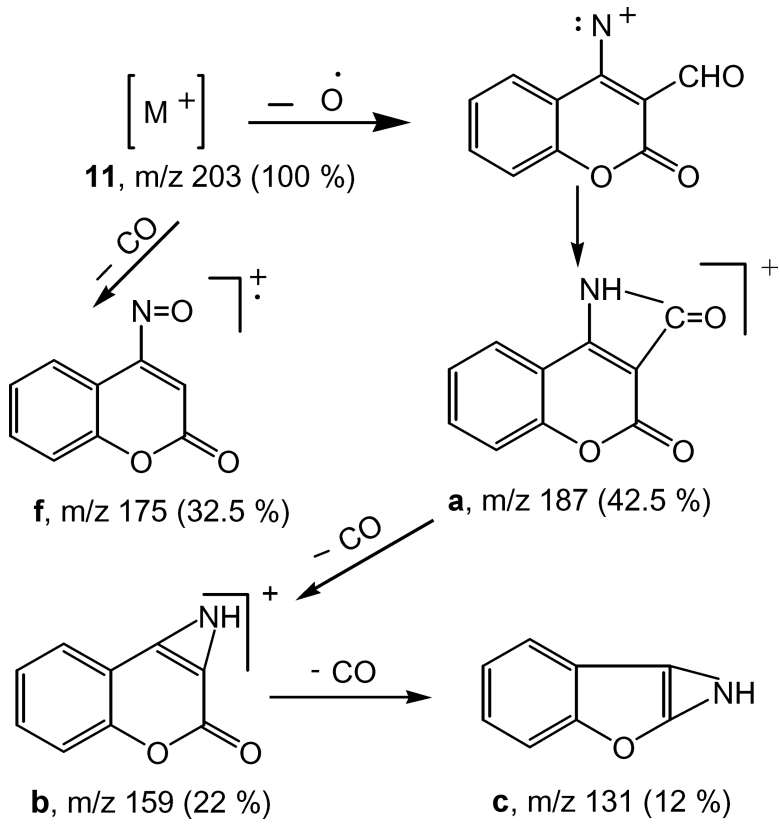
The reaction of **1** with Lawesson's reagent (LR, **3**) proceeded in dry toluene to give a mixture of two products. The first (major, 60%) was identified as 4-nitroso-2-oxo-2*H*-chromeno-3-carbaldehyde (**11**) (Figure 3) for the following reasons:

a. Correct elemental analysis and molecular weight determination (MS) for **11** corresponded to $C_{10}H_5NO_4$(m/z 203, M^+, 100%).
b. The IR spectrum (KBr) showed the presence of absorption bands at 3098 (CH, aromatic), 1763 (C=O, lactone), 1717 (C=O, aldehyde), 1611 (C=C, aromatic), 1533 (C-NO, monomer), and 1186 (C—O, stretching) cm^{-1}.
c. The ^1H NMR spectrum of compound **11** (DMSO, δ ppm) showed the signal of the CHO proton at $\delta = 10.22$. The aromatic protons gave signals at 8.18 (t, $J_{HH} = 7.02$ Hz, 1H) and 7.75–7.38 (m, 3H).
d. The mass spectrum of compound **11** showed the molecular ion peak at m/z 203 (100%). Loss of an oxygen radical from M^+ as expected for *N*-oxides[24] yields cation **a** at m/z 187 (42.5%). The latter ion suffers loss of two CO molecules to yield cations **b** and **c** at m/z 159 (22%) and 131 (12%), respectively, as in the fragmentation pattern of compound **8** vide supra. Loss of a neutral CO molecule from M^+ yields radical cation **f** at m/z 175 (32.5%) (Scheme 5).



11

FIGURE 3

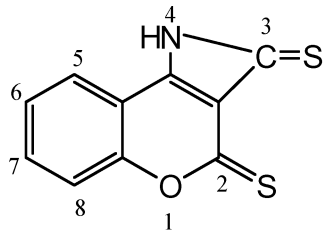


SCHEME 5

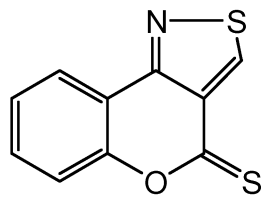
The second product (minor, 10%) resulting from the reaction of **1** with LR was proved to be 2-oxo-4-(thioxoamino)-2*H*-chromene-3-carbaldehyde (**8**) (mp, mmp, and IR and mass spectra).

The reaction of **1** with purified phosphorus pentasulfide proceeded in refluxing toluene to give two isomeric but not identical substances, which were separated by column chromatography. The first (major product, 55%) was identified as 2*H*-chromeno[4,3-*b*]azete-2,3(1*H*)-dithione (**12**) (Figure 4) for the following reasons:

a. Correct elemental analysis and molecular weight determination (MS) for **12** corresponded to $C_{10}H_5NOS_2$ (MS: m/z 219, M^+, 95%; 175, M—C=S, 100%).
b. The IR spectrum (KBr) revealed the presence of strong bands at 3428 (NH), 1597, 1517 (C=C, aromatic), and 1134 (C=S) cm^{-1}. The



12



13

FIGURE 4

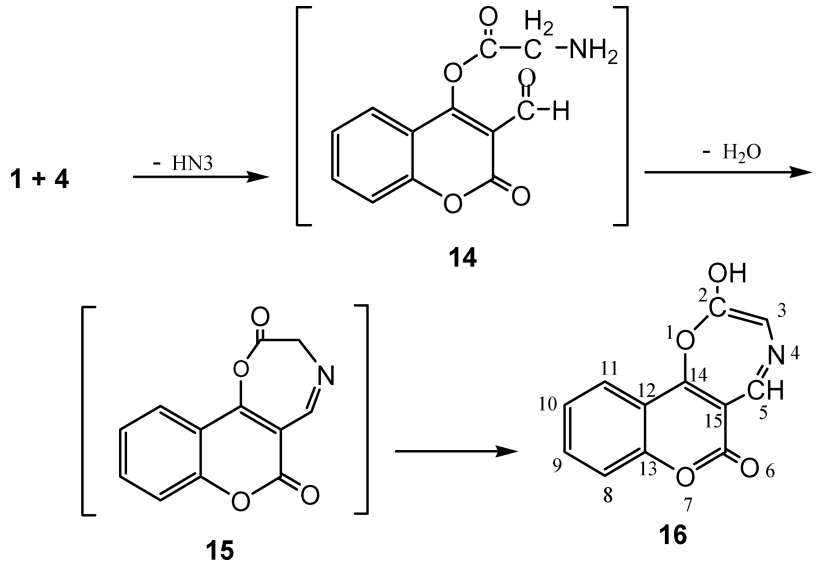
strong lactone–carbonyl band present in the spectrum of **1** at 1722 cm^{-1} was absent in the spectrum of **12**.

c. The ^1H NMR spectrum of **12** (d_6-DMSO) showed the signal of the NH proton as a singlet at 10.35 (exchangeable with D_2O). Signals were also observed at 8.05 (d, $J_{HH} = 7.8$ Hz, 1H, H-8), 7.75 (t, 1H, H-7), 7.65 (d, $J_{HH} = 8.2$ Hz, 1H, H-5), and 7.50 (t, 1H, H-6). According to the aforementioned spectral data, an alternative isothioxolene structure like **13**, can be excluded.

The second substance (minor product, 10%) was proved to be compound **8** (mp, mmp, and IR and mass spectra).

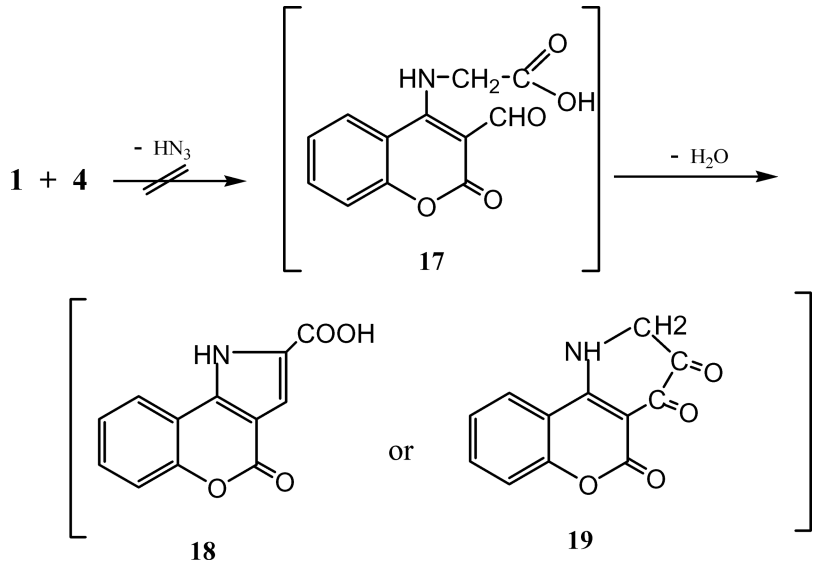
The presence of the formyl function in **1** prompted us to examine its behavior towards certain primary aminated aliphatic and aromatic carboxylic acids, namely, glycine (**4**), and anthranilic acid (**5**). Thus heating a mixture of **1** and **4** in dry toluene under reflux yielded a pale yellow crystalline product identified as 2-hydroxy-6*H*-chromeno[3,4-*f*][1,4]oxazepine-6-one (**16**) according to the following evidence: (a) Correct elemental analysis and molecular weight determination (MS) for **16** corresponded to a composition $C_{12}H_7NO_4$; (b) the IR spectrum of **16** (KBr) showed strong absorption bands at 3326 (OH), 1710 (C=O), 1594, 1555 (C=C aromatic, C=N) and 1230 (C–O, stretching) cm^{-1}; and (c) the ^{13}C NMR spectrum of compound **16** (DMSO-d_6) showed the presence of the following 12 signals caused by its carbon skeleton: $\delta = 189.6$ (C-2), 169.3 (C-6), 162.9 (C-14), 157.0 (C-5), 155.1 (C-13), 134.9 (C-9), 129.4 (C-11), 124.4 (C-10), 118.3 (C-8), 114.8 (C-12), 95.6 (C-15), and 69.1 (C-3).

It is evident that formation of **16** proceeds via initial deazidofication[19] of **1** through elimination of HN_3[19] to yield the intermediate **14**. Intramolecular cyclization of **14** via elimination of H_2O yields **15**, which is enolized to **16** (Scheme 6).

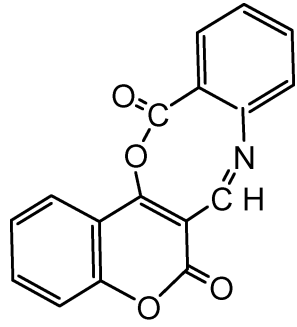


SCHEME 6

The alternative mechanism (Scheme 7) involving deazidofication[19] of **1** by **4** followed by dehydration of the resulting intermediate such as **17** to give **18** or **19** is thus overlooked.



SCHEME 7



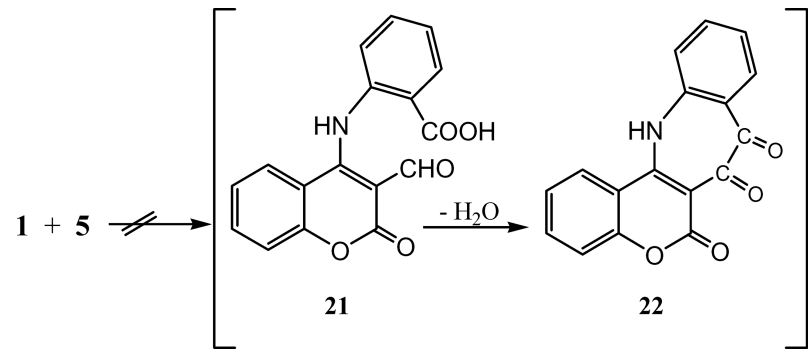
20

FIGURE 5

In the same sense, the reaction of **1** with anthranilic acid (**5**) proceeded in boiling toluene to yield a pale brown product identified as (5*Z*)-2*H*,7*H*-chromeno[4,3-*b*][5,1]benzoxazocine-2,9-dione (**20**) (Figure 5).

Correct elemental analysis and molecular weight determination for **20** (MS) corresponded to $C_{17}H_9NO_4$ [m/z 291 (M^+, 1.4%), m/z 262 (M-HCN, 5.02%), m/z 247 (M-CO_2, 100%)]. The IR spectrum (KBr, cm^{-1}) showed bands at 3124 (CH, aromatic), 1749 (C=O, lactone), 1611 (C=N), 1567, 1513, 1467 (C=C, aromatic), and 1152 (C–O, stretching) cm^{-1}. The ^1H NMR spectrum (d_6-DMSO) showed the signal of the azomethine proton as a singlet at $\delta = 9.40$. The aromatic protons (8H) gave signals at $\delta = 8.60$ (d, $J_{HH} = 6.48$, 1H), 8.30 (d, $J_{HH} = 6.48$, 1H), 8.07 (t, 1H), 7.75 (m, 1H), 7.55 (m, 1H), 7.10 (t, 1H), 6.65 (d, $J_{HH} = 7.29$, 1H), and 6.45 (t, 1H).

Based on these data, an alternative structure such as **22** for the reaction product of **1** with **5** can be excluded (Scheme 8).



21 **22**

SCHEME 8

CONCLUSION

Apparently, the azido-function in **1** seems to be the most vulnerable site for attack by alkyl isothiocyanates (**2a**,**b**), LR **3**, thionyl chloride, and phosphorus pentasulfide. The formyl function in **1**, on the other hand, is the only site for attack by ammonium isothiocyanate (**2c**). Both functions, however, are involved in the reaction of **1** with aminated derivatives of carboxylic acids (**4** and **5**) leading to polycyclic systems of types **16** and **20**, respectively. Although thionitroso compounds are known to be mostly unstable,[25,26] compound **8**, on the other hand, shows marked stability, and its spectral data are reproducible and concordant with the proposed structure. To the best of our knowledge, the results of the present study show new synthetic potentials for the azido function, either as such or coupled with a vicinal formyl group.

EXPERIMENTAL

Melting points were determined with an electrothermal digital melting point apparatus and are uncorrected. Elemental analytical data (in accord with the calculated values) were obtained at the analytical laboratory of the National Research Centre, Cairo, Egypt. The IR spectra were recorded in KBr disks on a Jasco Fourier Transform Infrared spectrophotometer model FT/IR-3000E. The ^{1}H NMR spectra were recorded in deuterated dimethylsulfoxide (d_6-DMSO) with a Varian Mercury VX-300 spectrometer (300 MHz), using tetramethylsilane (TMS) as internal reference. Mass spectra (EI-MS) were obtained at 70 eV with a Finnigan MAT SSQ 7000 spectrometer.

Reaction of 4-Azidocoumarin-3-carboxaldehyde (1) with Ethyl Isothiocyanate (2a) or Cyclohexyl Isothiocyanate (2b)

A mixture of 0.22 g **1** (1 mmol) and 0.09 g or 0.14 g of the isothiocyanate **2a** or **2b** (1 mmol), respectively, in 20 mL of dry THF was stirred at room temperature for 5–8 h (the progress of the reaction was controlled by TLC). The volatile materials were evaporated under reduced pressure, and the residue was chromatographed on silica gel using petroleum ether (bp 60–80°C) and acetone as eluent. Compound **8** could be isolated from both reactions (mp, mmp, and comparative IR spectra). Physical, analytical, and spectral data of compound **8** are presented in Tables I and II.

TABLE I Physical, Analytical, and IR Spectral Data of Compounds 8–12, 16, and 20

	Yield (%)	Mp. (°C)	Mol.formula (Mol. wt.)	M^+ m/z (%)+	Analysis Calcd/Found				IR (cm^{-1})								
					C%	H%	N%	S%	NH	OH	CH aromatic	N_3	C=O	C=C aromatic	C=N	C–O stretching	C=S
8	60	178	$C_{10}H_5NO_3S$	219	54.79	2.30	6.39	14.63	—	—	3150	—	1760 (lactone)	1600	—	1380	—
			(219.211)	(100)	54.51	2.11	6.12	14.40					1730 (aldehyde)				
9	65	320	$C_{20}H_8N_6O_6S$	460	52.17	1.75	18.26	6.96	—	—	3112	2373	1731 (lactone,	1609,	—	1362	—
			(460.378)	(5)	52.02	2.01	18.03	6.72					Thioanhydride)	1557			
10	55	305	$C_{10}H_5NO_3S$	219	54.79	2.30	6.39	14.63	—	—	3102	—	1766 (lactone)	1613	—	1407	1186
			(219.211)	(5)	54.91	2.08	6.22	14.39									
11	60	155	$C_{10}H_5NO_4$	203	59.12	2.48	6.90	—	—	—	3098	—	1763 (lactone)	1611,	—	1186	—
			(203.147)	(100)	58.85	2.25	6.67						1717 (aldehyde)	1533			
12	55	180–182	$C_{10}H_5NOS_2$	219	54.77	2.30	6.39	29.24	3428		3113,	—	—	1597,	—	1236	1134
			(219.267)	(95)	54.51	2.28	6.35	29.03			2923			1517			
16	75	215–217	$C_{12}H_7NO_4$	229	62.88	3.08	6.11	—	—	3326	3130	—	1710	1594	1555	1230	—
			(229.183)	(5)	63.10	3.21	6.24										
20	75	345	$C_{17}H_7NO_4$	291	70.10	3.11	4.81	—	—	—	3124	—	1749	1567,	1611	1152	—
			(291.249)	(1.4)	69.93	2.87	4.65						(lactone)	1513,			
														1467			

TABLE II ^{1}H NMR Spectral Data for Compounds 8–12 and 20

	^{1}H NMR (DMSO-d_6, δ ppm)
8	7.48 (m, 2H, arom-H), 7.70 (dd, J_{HH} = 8.4, 8.7 Hz, 1H, arom-H), 8.08 (d, J_{HH} = 7.8 Hz, 1H, arom-H), 10.20 (s, 1H, CHO)
9	7.24-8.35 (m, 8H, arom-H)
10	7.26-8.09 (m, 4H, arom-H), 10.26 (s, 1H, CHS)
11	7.38-7.75 (m, 3H, arom-H), 8.18 (t, J_{HH} = 7.0 Hz, 1H, arom-H), 10.22 (s, 1H, CHO)
12	7.50 (t, 1H, H-6), 7.65 (d, J_{HH} = 8.2 Hz, 1H, H-5), 7.75 (t, 1H, H-7), 8.05 (d, J_{HH} = 7.8 Hz, 1H, H-8), 10.35 (s, 1H, NH exchangeable with D_2O)
20	6.45 (t, 1H, arom-H), 6.65 (d, J_{HH} = 7.3 Hz, 1H, arom-H), 7.10 (t, 1H, arom-H), 7.55 (m, 1H, arom-H), 7.75 (m, 1H, arom-H), 8.07 (t, 1H, arom-H), 8.30 (d, J_{HH} = 6.5 Hz, 1H, arom-H), 8.60 (d, J_{HH} = 6.5 Hz, 1H, arom-H), 9.40 (s, 1H, azomethine proton)

Reaction of 4-Azidocoumarin-3-carboxaldehyde (1) with Ammonium Isothiocyanate (2c)

A mixture of **1** (0.22 g, 1 mmol) and ammonium isothiocyanate (0.08 g, 1 mmol) in 20 mL of dry THF was stirred at ambient temperature for 7 h. The volatile materials were evaporated under reduced pressure, and the residue was crystallized from DMF/H_2O to give compound **9**. Physical, analytical, and spectral data of compound **9** are presented in Tables I and II.

Reaction of 4-Azidocoumarin-3-carboxaldehyde (1) with Thionyl Chloride

A solution of **1** (0.44 g, 2 mmol) in 10 mL of thionyl chloride was refluxed in the absence of solvent on a steam bath for 8 h. After evaporation of the volatile materials under reduced pressure, the remaining solid material was collected and recrystallized from DMF/H_2O to give compound **10**. Physical, analytical, and spectral data of compound **10** are presented in Tables I and II.

Reaction of 4-Azidocoumarin-3-carboxaldehyde (1) with Lawesson's Reagent (3)

A mixture of **1** (0.44 g, 2 mmol) and **3** (0.61 g, 1.5 mmol) in 20 mL of dry toluene was refluxed for 7 h. The volatile materials were evaporated under reduced pressure, and the residue was chromatographed on silica gel using petroleum ether (bp 60–80°C) and acetone as eluent to give compounds **8** (mp, mmp, and comparative IR spectra) and **11**. Physical,

analytical, and spectral data of compound **11** are presented in Tables I and II.

Reaction of 4-Azidocoumarin-3-carboxaldehyde (1) with Phosphorus Pentasulfide $(P_2S_5)_x$

1 (0.44 g, 2 mmol) and $(P_2S_5)_x$ (1.0 g) purified by cautious extraction with CS_2 (Soxhlet) were mixed in 20 mL of dry toluene and refluxed for 10 h (TLC). The reaction mixture was filtered while hot, and the volatile materials were evaporated under reduced pressure. The residue was chromatographed on silica gel using petroleum ether (bp 60–80°C) and acetone as eluent to give compounds **8** (mp, mmp, and comparative IR spectra) and **12**. Physical, analytical, and spectral data of compound **12** are presented in Tables I and II.

Reaction of 4-Azidocoumarin-3-carboxaldehyde (1) with Glycine (4)

A mixture of **1** (0.44 g, 2 mmol), **4** (0.27 g, 2 mmol), and a few drops of piperidine was refluxed in 20 mL of dry toluene for 10 h. After evaporation of the volatile materials under reduced pressure, the remaining solid material was collected and recrystallized from DMF/H_2O to give compound **16**. Physical, analytical, and spectral data of compound **16** are presented in Tables I and II.

Reaction of 4-Azidocoumarin-3-carboxaldehyde (1) with Anthranilic acid (5)

A mixture of **1** (0.44 g, 2 mmol) and **5** (0.15 g, 2 mmol) in 20 mL of dry toluene was refluxed for 4 h. After evaporation of the volatile materials in vacuo, the remaining solid material was collected and recrystallized from DMF/H_2O to give compound **20**. Physical, analytical, and spectral data of compound **20** are presented in Tables I and II.

REFERENCES

[1] E. F. V. Scriven, *Azides and Nitrenes: Reactivity and Utility* (Academic Press, Orlando, 1984).
[2] C. Sander and F. J. Muehbour, *Environmental Exp. Bot.*, **17,** 43 (1977).
[3] W. Owais, J. L. Rosichan, R. C. Roland, A. Kleinhofs, and R. N. Nilan, *Mut. Res.*, **118,** 299 (1983).
[4] T. L. Gilchrist, G. E. Gymer, and A. R. Katritzky, *Boulton J. Adv. Heterocyclic Chem.*, **16,** 33 (1974).

[5] P. Purvisis, R. K. Smalley, H. Saschitsky, and M. A. Alkhader, *J. Chem. Soc., Perkin Trans, I*, 249 (1984).
[6] D. I. Patei and R. K. Smalley, *J. Chem. Soc., Perkin Trans I*, 2587 (1984).
[7] B. Loubinoux and J. L. Collin, *J. Heterocycl. Chem*., **21,** 1969 (1984).
[8] G. M. Cingolani, F. Gualtrieri, and M. Pigini, *J. Med. Chem.*, **12,** 531 (1969).
[9] D. S. Bariani, *J. Med. Chem*., **13,** 544 (1970).
[10] A. Shah, Y. Naliapara, D. Sureja, N. Motohashi, M. Kawas, C. Miskolei, D. Szabo, and J. Molnar, *Anticancer Res.*, **18,** 3001 (1998); *Chem. Abstr.*, **129,** 310494 (1998).
[11] M. Yamato, *Jpn. Kokai Tokkyo Koho JP* 61,215,341, (1987); *Chem. Abstr.*, **106,** 66807 (1986).
[12] C. C. Tzeng, K. H. Lee, Y. L. Chen, and B. R. Huang, *U.S.* 5,962,460 (1999); *Chem. Abstr.*, **131,** 243173 (1999).
[13] M. Kawano and T. Chiba, *Akita Kogyo Koto Senmon Kenkyu Kiyo*, **35,** 64 (2000).
[14] V. Hariprasad, T. T. Talele, and V. M. Kulkarni, *Pharm. Pharmacol. Commun*., **4,** 365 (1998); *Chem. Abstr.*, **129,** 275812 (1998).
[15] S. M. S. Atta, T. S. Hafez, and M. R. H. Mahran, *Phosphorus, Sulfur, and Silicon*, **80,** 109 (1993).
[16] E. M. A. Yakout, S. M. S. Atta, N. M. Ibrahim, R. S. Omar, and M. R. H. Mahran, *Egyptian J. Chem.*, **37,** 634 (1994).
[17] M. R. Mahran, Kh. M. Ghoneim, M. M. Sidky, R. S. Omar, E. M. A. Yakout, and N. M. Ibrahim, *Bull. Fac. Pharm. Cairo Univ*., **32,** 51 (1994).
[18] N. A. Ganoub and M. R. H. Mahran, *Heteroatom Chem*., **9,** 427 (1998).
[19] M. S. Mohamed, W. A. Zaghary, T. S. Hafez, N. M. Ibrahim, M. M. Abo El-Alamin, and M. R. H. Mahran, *Bull. Fac. Pharm. Cairo Univ.,* **40,** 175 (2002).
[20] N. M. Ibrahim, *Phosphorus, Sulfur, and Silicon*, **181,** 1773 (2006).
[21] D. R. Sutherland and G. J. Tennant, *J. Chem. Soc. Perkin Trans. I*, 534 (1974).
[22] T. C. Porter, R. K. Smalley, M. Teguiche, and B. Purwono, *Synthesis*, 773 (1997).
[23] T. H. Steinfuehrer, A. Hantschmann, M. Pietsch, and M. Weissenfels*, Liebigs Ann. Chem.*, 23 (1995).
[24] M. Hesse, H. Meier, and B. Zeeh, *Spektroskopische Methoden in der organischen Chemie* (G. Thieme, Stuttgart, 1979), p. 364.
[25] L. N. Markovsky, V. V. Penkovsky, and Yu. G. Shermolovich, *Rev. Heteroatom Chem*., **9,** 21 (1993).
[26] V. Penkovsky and Y. Shermolovich, *Phosphorus, Sulfur, and Silicon*, **95–96,** 317 (1994).