Available online at www.sciencedirect.com
ScienceDirect
Mendeleev Commun., 1991, **1**(**2**), 78–79

Mendeleev Communications

Synthesis and Structure of 3-formylquinoline-2(1*H*)-thione and -selone and the Corresponding Imines

A. L. Nivorozhkin, L. E. Nivorozhkin, L. E. Konstantinovsky and V. I. Minkin*

Institute of Physical and Organic Chemistry, Rostov University, 344711 Rostov on Don, USSR

3-Formylquinoline-2(1*H*)-thione and -selone have been prepared; based on ^{1}H, ^{13}C and ^{15}N NMR, UV and IR spectral studies the tautomeric form with a proton located at the heterocyclic nitrogen has been proved to be the most stable for the above aldehydes and their imines in both the solid state and in solution.

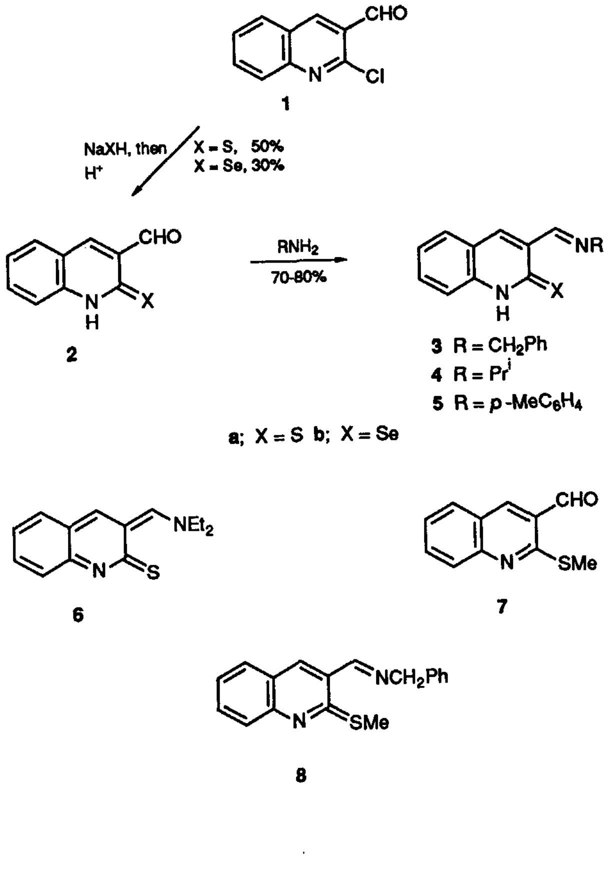
In recent years the reactions and the tautomerism of 3-formylpyridine-2(1*H*)-thiones, which are important in the synthesis of polycyclic pyridines,[1–3] have been widely studied. By contrast, information on the synthesis and structure of their benzoannelated derivatives is not available. In our search for new bidentate chelating ligands capable of forming fluxional metal–chelate complexes possessing MN_2S_2 and MN_2Se_2 coordination sites, similar to those of some metalloproteins, we developed a simple procedure for preparation of 3-formylquinoline-2(1*H*)-thione or -selone and the imines derived therefrom (Scheme 1).

Treatment of 3-formyl-2-chloroquinoline **1**[4] with 1.5 equiv. of sodium hydrosulphide (hydroselenide) in ethanol solution gave 3-formylquinoline-2(1*H*)-thione **2a** (yellow needles, m.p. > 300 °C, decomp.) and 3-formylquinoline-2(1*H*)-selone **2b** (reddish needles, m.p. 248–249 °C) in moderate yields. Unlike 3-formylpyridine-2(1*H*)-thiones, which afford imidodithiocine (5,11-dihydro-6,12-imino-6*H*-dipyrido[*b*,*f*][1,5]dithiocine) derivatives on reaction with amines,[5] compounds **2a** and **2b** readily produce the imines **3**–**5** (X = S or Se) on being heated with equimolar amounts of alkyl- and aryl-amines in ethanol solution; m.p.s: **3a**, 151–152; **3b**, 197–198, **4a**, 205–206; **5a**, 213–214; **5b**, 268–269 °C.

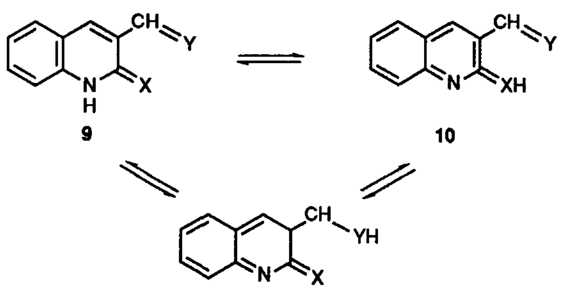
Since compounds **2**–**5** contain three basic centres, equilibrium between three prototropic tautomers is, in principle, possible (Scheme 2).

In the case of 3-formylpyridine-2(1*H*)-thiones, the conclusion has been drawn, based on thorough spectral studies[3] and semiempirical quantum mechanical calculations,[6] that the type **10** tautomeric form predominates in the gas phase whereas in solution the equilibrium is shifted towards type **9** tautomers. The latter form is also suggested to be energetically favoured for 3-formylquinoline-2(1*H*)-one **2** (X = O).[4]

We have found that the type **9** tautomeric form is strongly energetically preferred in solution (solvents with polarity from $CDCl_3$ to Me_2SO) for all compounds **2**–**5** studied. *S*-Methylation of **2a** with methyl iodide[7] gave the sulphide **7**



Scheme 1



11

X = S, Se; Y = O, NR

Scheme 2

(colourless needles, m.p. 103–104 °C), which models the tautomeric form **10**. The UV spectrum of **7** (λ_{max} 370 nm, ϵ 1700) is quite different from those of **2a** (λ_{max} 442 nm, ϵ 3200) and **2b** (λ_{max} 468 nm, ϵ 3900) in Me_2SO. This comparison indicates the insignificance of type **10** tautomers. The ^1H NMR spectra of **2a** and **2b** in $(CD_3)_2SO$ solution show slightly broadened singlet peaks due to the NH protons at δ 13.8 and 14.4, positions characteristic of relatively strong intramolecular NH···S hydrogen bonds.[8] The carbaldehyde methine protons are seen as sharp singlet peaks at δ 10.7 (**2a**) and 10.8 (**2b**). Such a spectral pattern is clear evidence for the preference of the type **9** (Y = S,Se) tautomeric form of compounds **2a** and **2b**. No one-bond ^{15}N–H coupling was observed in the ^1H NMR spectrum of the $^{15}N{=}CH$ labelled imine **3a** which is consistent with the assignment of its stable tautomeric form to a structure of type **9**. An additional splitting of the azomethine proton signal is caused by its two-bond coupling to ^{15}N ($^2J_{NH}$ 3.6 Hz).

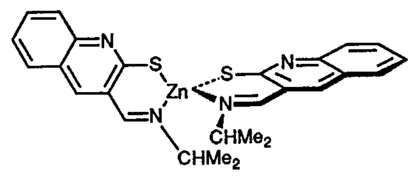
The absence of the CH–NH spin–spin coupling in the ^1H NMR spectra of the imines **3–5a, b** can also be tentatively rationalized as the consequence of fast proton exchange processes involving intermolecular hydrogen NH···S (Se) bonds possible in the *Z* (relating to the exocyclic C=CH bond) diastereoisomeric form of type **11** tautomers; see ref. 9 for an analogous example. However, conclusive evidence against such a possibility is afforded by the magnitude of the ^{15}N chemical shift (− 50.0 ppm relative to CD_3NO_2 as reference in $CDCl_3$ solution) of the azomethine nitrogen of **3a**, which is characteristic of a double bonded sp^2 nitrogen centre.[10]

A comparison of ^{13}C NMR and UV spectra of **3–5a** with those of compounds **6** (yellow plates, m.p. 286–287 °C) and **8** (colourless plates, m.p. 66–67 °C) which structurally model the tautomeric forms **11** and **10** respectively lends additional support to the conclusion on the predominance of the tautomers **9** in the equilibria depicted in Scheme 2. In the ^{13}C NMR spectrum of **3a** in $CDCl_3$ solution, the C(S) signal (δ 180.3) is shifted more than 20 ppm downfield with regard to that of **8** (δ 159.0) which clearly indicates that the CS bond has double bond character in the former compound. There is no close resemblance in the shape of the UV spectral curves and the long wavelength band positions for **3a** (λ_{max} 416 nm, ϵ 7100), **6** (λ_{max} 405 nm, ϵ 4100) and **8** (λ_{max} 354 nm, ϵ 3800) in ethanol solution. Therefore the stable tautomer of **3a** may not be assigned to the structural types of **10** or **11**.

Table 1 Relative heats of atomization ($\Delta\Delta H_a$/kcal mol^{-1}) of the tautomers involved in the $\mathbf{9} \rightleftharpoons \mathbf{10} \rightleftharpoons \mathbf{11}$ (Y = NH) equilibria[a]

	9		10		11	
	X = O	X = S	X = O	X = S	X = O	X = S
Gas phase	8	0	0	14	16	11
Me_2SO[b]	2	0	0	15	8	10

[a] PPP SCF MO method with ground state parametrization as in ref. 11. 1 cal = 4.184 J. [b] To account for the solvent effect the continual model[14] was used.



12

Scheme 3

This conclusion is in good agreement with the results of PPP SCF MO calculations on the relative stability of the tautomeric forms **9**, **10** and **11**. Dewar's ground state $\sigma\pi$-parametrization[11] was employed which was earlier found to reproduce well the experimental data on the benzenoid–quinonoid tautomeric equilibria of hydroxy and mercapto aromatic and heterocyclic imines.[12,13] As seen from the data in Table 1, the tautomeric form **9** (X = S) is predicted to be the most stable both in the gas phase and in solution, though in polar solvents the energy gap between the tautomers **9** and **10** is expected to narrow. Substitution of sulphur in compounds of type **3–5** (X = S) for oxygen results, according to the calculations, in a significant stabilization of the hydroxy–imine tautomeric form **10**.

The compounds **3–5a, b** readily form bis-chelate metal complexes in reactions with metal acetates in ethanol solution. The fluxional behaviour of the Zn^{II} complex **12** caused by the low energy barrier to inversion of the tetrahedral configuration at the metal centre has been shown by the diastereotopic averaging of the methyl groups in the prochiral isopropyl substituent, $\Delta G^{\ddagger}_{268}$ = 13.6 kcal mol^{-1} (solvent $CDCl_3$).

We thank Dr I. V. Dorogan for help with quantum mechanical calculations.

Received in USSR, 1st January 1991
Received in UK, 14th March 1991; *Com. 1/00182E*

References

1 J. Becher and C. E. Stidsen, *Sulfur Reports*, 1988, **8**, 105.
2 J. Elguero, C. Marzin, A. R. Katritzky and P. Linda, *The Tautomerism of Heterocycles*, Academic Press, New York, 1976, p. 278.
3 C. Dreier, J. Becher, E. G. Frandsen and L. Henriksen, *Tetrahedron*, 1981, **37**, 2663.
4 O. Meth-Cohn, B. Narine and B. Tarnowski, *J. Chem. Soc., Perkin Trans. 1*, 1981, 1520.
5 J. Becher, C. Dreier and O. Simonsen, *Tetrahedron*, 1979, **35**, 869.
6 V. I. Minkin, V. A. Kosobutskii and B. Ya. Simkin, *J. Mol. Struct.*, 1975, **24**, 237.
7 M. C. Christensen, C. Dreier and J. Becher, *Synthesis*, 1980, 405.
8 V. A. Bren, V. I. Usacheva, J. V. Bren, B. Ya. Simkin and V. I. Minkin, *Khim. Gerotsikl. Soedin.*, 1974, 631.
9 S. M. Aldoshin, L. O. Atovmyan, O. A. Diachenko, V. I. Minkin, V. A. Bren and G. D. Paluy, *Zh. Strukt. Khim.*, 1984, **26**, 106.
10 G. W. Buchanan, *Tetrahedron*, 1989, **45**, 581.
11 M. J. S. Dewar and A. J. Harget, *Proc. Roy. Soc. (London), Ser. A*, 1970, **315**, 443, 457.
12 N. Bodor, M. J. S. Dewar and A. J. Harget, *J. Am. Chem. Soc.*, 1970, **92**, 2929.
13 B. Ya. Simkin, V. A. Bren and V. I. Minkin, *Zh. Org. Khim.*, 1977, **13**, 1710.
14 S. Miertus, V. Frecer and M. Majekova, *J. Mol. Struct. (Theochem.)*, 1988, **179**, 353.