The Determination of the Azo–Hydrazono Tautomerism of Some 2-Pyrazolin-5-one Dyes by Means of Nuclear Magnetic Resonance Spectroscopy and ^{15}N-Labeled Compounds[1]

G. J. LESTINA AND T. H. REGAN

Research Laboratories, Eastman Kodak Company, Rochester, New York 14650

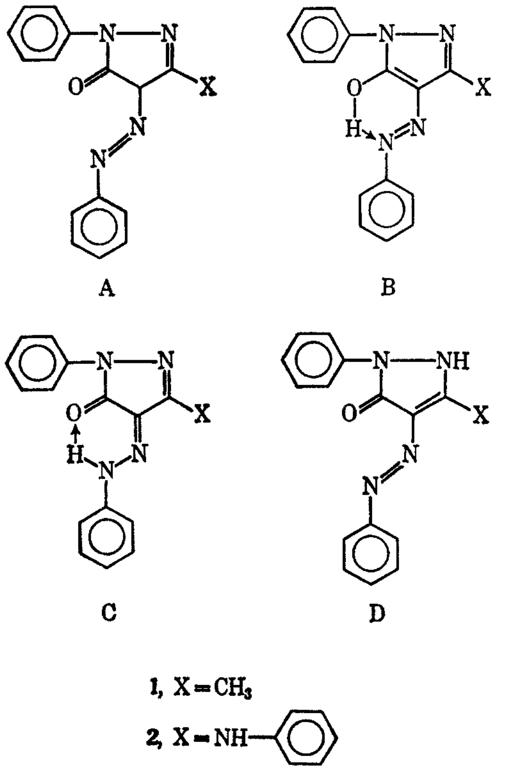
Received September 25, 1968

Through use of ^{15}N labeling and nmr spectroscopy we showed that 3-methyl-1-phenyl-4-phenylazo-2-pyrazolin-5-one (1) exists entirely in the hydrazone form in chloroform solution, in agreement with some of the earlier ir and nmr results with unlabeled compounds. In dimethyl sulfoxide (DMSO) and pyridine solutions a mixture of the hydrazono and the enol-azo forms is proposed. In a similar fashion we found that 3-anilino-1-phenyl-4-phenylazo-2-pyrazolin-5-one (2) exists entirely in the hydrazone form in chloroform and DMSO at 38° and in pyridine at −40°. At 38° in pyridine, however, a mixture of tautomeric forms is proposed.

The question of the tautomeric forms of 3-methyl-1-phenyl-4-phenylazo-2-pyrazolin-5-one (**1**) and of other 4-arylazo-2-pyrazolin-5-ones has stimulated much work in recent years.[2–7] The possible tautomeric forms of **1** and other 3-substituted 1-phenyl-4-arylazo-2-pyrazolin-5-ones are shown in Chart I. On the basis of spectroscopic studies, various authors have proposed **1** to exist in forms A,[2] B,[3] and C.[4–7] In our opinion the most persuasive arguments[5,6] have supported form C for compound **1** in chloroform.

CHART I

POSSIBLE TAUTOMERIC FORMS OF 3-SUBSTITUTED 1-PHENYL-4-PHENYLAZO-2-PYRAZOLIN-5-ONE



For our work we needed more conclusive proof and more extensive results than those reported in the literature. Since previous authors relied on similar spectroscopic techniques to arrive at quite varied conclusions, and since the tautomeric form of **1** could possibly change in going from chloroform to a more polar solvent such as DMSO, we reinvestigated the tautomerization of **1**.

In an earlier work[8] we observed marked differences in tautomeric ratios between 3-methyl-1-phenyl-2-pyrazolin-5-one and the 3-anilino analog in DMSO solution. In the current work compound **2** was included with **1** to see whether these differences in tautomeric ratios would persist in the 4-phenylazo derivatives of the 3-anilino-2-pyrazolin-5-ones.

The purpose of this work, then, was to (a) provide an unambiguous proof of the tautomeric form of **1** in chloroform and, if possible, in pyridine and DMSO; and (b) determine similarly the tautomeric form of **2**.

To do this we studied the tautomerization of **1** and **2** by using compounds labeled with ^{15}N adjacent to the 4-phenyl group. Since only the hydrazono form, form C, could exist with a hydrogen attached to the ^{15}N, a splitting of the proton resonance would be conclusive proof of the existence of the hydrazono form.

The labeled compounds, **1a** and **2a**, were prepared by diazotization of ^{15}N aniline followed by coupling with the appropriate pyrazolinone; the possibility of diazonium scrambling[9] under these mild conditions[10,11] is nil.

Table I summarizes the nmr data for **1a** and **2a**. In chloroform solution at 38 and 60° the unlabeled material **1** gave a broad singlet at 13.5 ppm, whereas compound **1a** showed a doublet with the center of gravity at 13.5 ppm, indicative of a proton attached to a ^{15}N. Since the ^{15}NH peak separation is so large[12] (96 Hz), and since the area of the ^{15}N proton peaks of **1a** relative to the aromatic protons was in a good 1:10 ratio, compound **1a** (and **1**) must exist entirely in the hydrazono form under these conditions. Furthermore, the high concentration of ^{15}N-bonded proton shows that little, if any, diazonium rearrangement[9] occurs during the synthesis of **1a**. The presence of only one ^{15}N-induced doublet in the spectrum of **1a** indicates that only one geometric isomer of the hydrazono form exists in this

---

[1] Presented before the Division of Organic Chemistry at the 156th National Meeting of the American Chemical Society, Atlantic City, N. J., Sept 1968.

[2] F. A. Snavely, W. S. Trahanovsky, and F. H. Suydam, *J. Org. Chem.*, **27**, 994 (1962).

[3] W. Pelz, W. Puschel, H. Schellenberger, and K. Loffler, *Angew. Chem.*, **72**, 967 (1960).

[4] S. Toda, *Nippon Kagaku Zasshi*, **80**, 402 (1959).

[5] R. Jones, A. J. Ryan, S. Sternhell, and S. E. Wright, *Tetrahedron*, **19**, 1497 (1963).

[6] J. Elguero, R. Jacquier, and G. Tarrago, *Bull. Soc. Chim. Fr.*, 2990 (1966).

[7] H. Yasuda and H. Midoridawa, *J. Org. Chem.*, **31**, 1722 (1966); F. A. Snavely and C. H. Yoder, *J. Org. Chem.*, **33**, 513 (1968).

[8] G. J. Lestina, G. Happ, D. Maier, and T. Regan, *ibid.*, **33**, 3336 (1968).

[9] J. M. Insole and E. S. Lewis, *J. Amer. Chem. Soc.*, **85**, 122 (1963); **86**, 32, 34 (1964).

[10] A. K. Bose and I. Kugajevsky, *Tetrahedron*, **23**, 1489 (1967).

[11] A. K. Bose and I. Kugajevsky, *J. Amer. Chem. Soc.*, **88**, 2325 (1966).

[12] (a) G. Binsch, J. B. Lambert, B. W. Roberts, and J. D. Roberts, *ibid.*, **86**, 5564 (1964); (b) G. Dudek and E. P. Dudek, *ibid.*, **86**, 4283 (1964).

TABLE I

THE NMR SPECTRAL DATA FOR ^{15}N-LABELED 3-SUBSTITUTED 1-PHENYL-4-PHENYLAZO-2-PYRAZOLIN-5-ONE

Compound **1a**

Solvent	Temp, °C	NH, δ (ppm)[a]	Rel area[b] of ^{15}NH peak	J, ^{15}NH, Hz
$CDCl_3$	38	13.5[c]	1.1	96 ± 1
	60	13.5 (broad doublet)	d	96 ± 1
DMSO-d_6	38			
	60	13.5 (broad singlet)	d	
Pyridine-d_5	38	13 (very broad singlet)	d	
	−40	13.5 (broad singlet)	d	

Compound **2a**

Solvent	Temp, °C	NH, δ (ppm)[a]	Rel area[b] of ^{15}NH peak	J, ^{15}NH, Hz	N'H,[e] ppm[a]
$CDCl_3$	38	13.1[c]	1.1	97 ± 1	6.54
DMSO-d_6	38	13.1 (broad doublet)	0.8[d]	96 ± 1	9.08
Pyridine-d_5	38	13 (broad singlet)	d		9.86
	−40	13.7	1.0	97 ± 1	10.8

[a] δ is given in parts per million downfield from internal tetramethylsilane. [b] Relative to the area of the aromatic protons. [c] "Center of gravity" positions unless otherwise indicated. [d] Peaks were too broad for reliable area measurements. [e] ^{14}NH resonance from the 3-anilino moiety.

solvent, while the far-downfield position of the NH peak suggests that the proton is involved in a strong intramolecular hydrogen bond.

The above data indicate that form C represents the sole detectable tautomer of **1a** (and **1**) in chloroform. This conclusion is consistent with some of those[4-6] drawn from ir and nmr studies on unlabeled compounds. In the DMSO solution of **1a** no NH resonance was present at 38°; warming the solution to 60° gave only a broad singlet at 13.5 ppm. In pyridine at 38° no NH signal was observed but at −40° a broad absorption appeared at 13.5 ppm. The areas of these broad peaks ($W_{1/2} \cong 100$ Hz) are not a reliable measure of concentration; they are consistently low. Nevertheless, the chemical shift of this singlet indicates that the proton is in a magnetic environment similar to that of **1a** in chloroform. This suggests that the collapse of the ^{15}NH doublet and the peak broadening are both the result of proton exchange between the ^{15}N and the carbonyl oxygen. This means that **1a** probably consists of a mixture of forms B and C in these solvents.

Compound **2a** showed the sharp doublet (center of gravity at 13.1 ppm), characteristic of the ^{15}N-induced spin splitting, both in chloroform and DMSO solutions; in contrast, the unlabeled compound **2** showed only a broad singlet at 13.2 ppm in chloroform and 13.1 ppm in DMSO. The large coupling constant (96–97 Hz) for the ^{15}NH spin splitting is indicative[12b] of the sole existence of the hydrazono form (form C) for **2a** and is consistent with what has been observed with hydrazones.[10] Integration of the peak areas of **2a** gave a good 1:15 ratio for the NH peaks relative to the aromatic proton peaks for the chloroform solution and a slightly poorer ratio for the broader doublet of the DMSO example.

In pyridine at 38° compound **2a** gave a broad singlet at about 13 ppm; cooling to −40° gave the ^{15}NH doublet at 13.7 ppm (center of gravity position). Therefore, compound **2a** exists entirely in form C at −40° but at 38° probably consists of forms B and C for the same reasons as cited for compound **1a** in DMSO and pyridine solution.

In these three solvents the chemical shift of the ^{14}NH resonance of the 3-anilino group varied with solvent change whereas the "center of gravity" position of the ^{15}NH doublet remained relatively constant. This apparent solvent insensitivity of the ^{15}NH doublet further supports the claim that this proton is tied up in a strong intramolecular hydrogen bond.

Experimental Section

The nmr spectra were recorded on the Varian Model A-60 spectrometer; the solutions were *ca.* 10% (w/v) in chloroform, DMSO, and pyridine. All melting points are uncorrected. ^{15}N-Aniline (96.8% isotopic purity) was purchased from Merck Sharp & Dohme of Canada.

Preparation of 3-Methyl-1-phenyl-4-phenylazo-2-pyrazolin-5-one (1 and 1a).—These compounds were prepared by low temperature diazotization of the appropriate anilines followed by coupling of the diazonium salts with 3-methyl-1-phenyl-2-pyrazolin-5-one. The physical properties of **1a** were identical[13] with those of the unlabeled compound (**1**).

Preparation of 3-Anilino-1-phenyl-4-phenylazo-2-pyrazolin-5-one (2 and 2a).—These compounds were prepared by coupling the appropriate diazonium salts with 3-anilino-1-phenyl-2-pyrazolin-5-one (Eastman Organic Chemicals No. 8297) in the same manner as that described for **1** and **1a**. Recrystallization from carbon tetrachloride gave 0.8 g of red solid, mp 195–196°.

Anal. Calcd for $C_{21}H_{17}N_5O$: C, 71.0; H, 4.8; N, 19.7. Found: C, 70.8; H, 4.7; N, 20.0.

Registry No.—**1** (form C), 19374-75-5; **1a**, 19374-76-6; **2** (form C), 19374-77-7; **2b**, 19374-78-8.

---

(13) L. Knorr, *Ann. Chem.*, **238**, 183 (1887).