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1,2,4-Triazoles. III.[1] The Tautomerism of 3-Phenyl-1,2,4-triazolin-5-one, 3-Phenyl-1,2,4-triazoline-5-thione and Their N-Methyl Derivatives

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On the basis of ultraviolet (UV) and infrared (IR) evidence, 3-phenyl-1,2,4-triazolin-5-one and its N-methyl derivatives were all shown to exist as the oxo forms, except the 2-methyl derivative which existed as the hydroxy form. Similarly, UV data showed the predominance of the thione forms of 3-phenyl-1,2,4-triazoline-5-thione and its N-methyl derivatives. The syntheses of the N-methyl derivatives of the triazolines used in the present study were described.

3-Phenyl-1,2,4-triazolin-5-one (I) and 3-phenyl-1,2,4-triazoline-5-thione (II) can exist in five tautomeric forms with hydrogen atoms in different positions in the molecules. The five possible tautomeric forms are the three hydroxy and two oxo forms of I, and the three thiol and two thione forms of II, as shown in Chart 1. However, since various investigators have assigned different structures to these compounds, there is considerable confusion in representation of their structures. This work was to clarify the structures of these compounds.

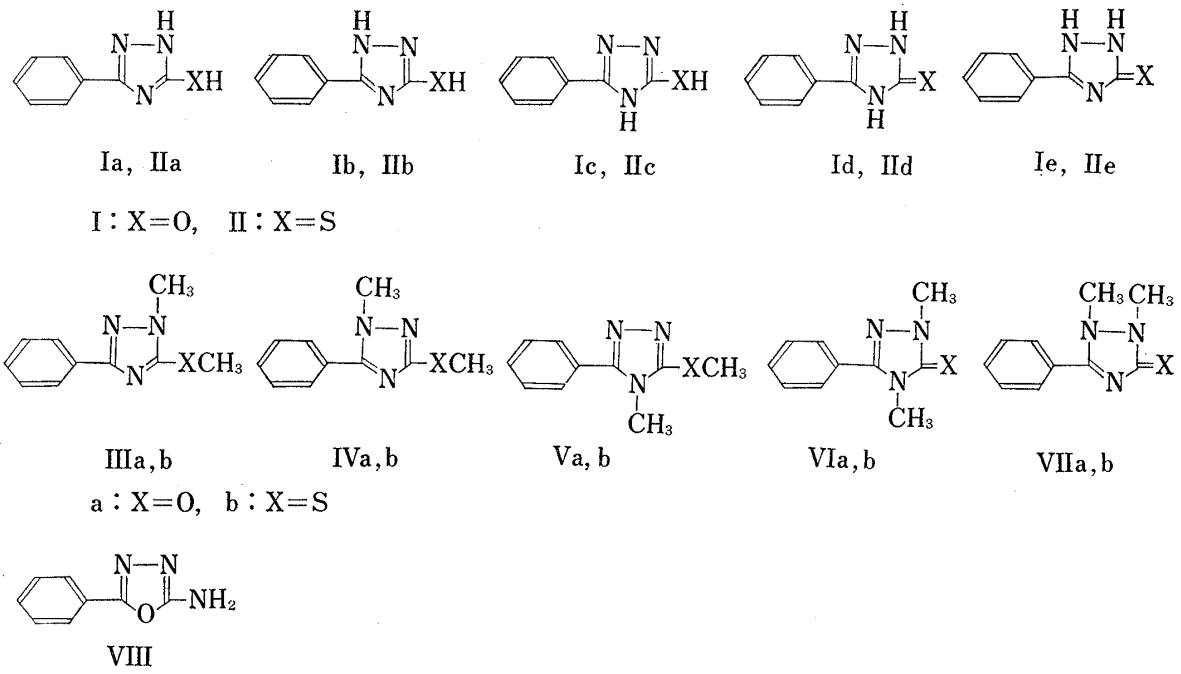


Chart 1

Compound (I) was first prepared by Young and Witham,[3] and was pictured as either Ia or Ib. The tautomeric structure Ia was also described by Hoggarth.[4] Goerdeler and Schenk[5]

1) Part II: S. Kubota and M. Uda, *Chem. Pharm. Bull.* (Tokyo), **20**, 2096 (1972).
2) Location: *Shomachi, Tokushima.*
3) G. Young and E. Witham, *J. Chem. Soc.*, **77**, 224 (1900).
4) E. Hoggarth, *J. Chem. Soc.*, **1949**, 1918.
5) J. Goerdeler and H. Schenk, *Chem. Ber.*, **99**, 782 (1966).

obtained I by the reaction of thiobenzoyl isocyanate with hydrazine hydrate and identified the product as 5-hydroxy-3-phenyl-1,2,4-triazole. Tsuge, *et al.*[6] initially assigned structure Id or Ie to compound I, obtained by the mothod of Goerdeler and Schenk from its infrared (IR) and nuclear magnetic resonance (NMR) spectra. Then, they concluded that compound (I) had the Id structure, since its IR and NMR spectra differed from those of the triazolone isomer, Ie, obtained by Bougault and Popovici[7] on reaction of the semicarbazone of phenylglyoxalic acid with iodine and sodium hydroxide. Mautner and Kumler[8] reported that the compound of Bougault and Popovici had the Ie structure, but later, this compound was found to be 2-amino-5-phenyl-1,3,4-oxadiazole (VIII), not Ie.[9–11] Thus, although various structures (Ia, Ib, Ic, Id, and Ie) have been proposed for I and many studies on the synthesis of this compound have been reported,[12–16] no unambiguous conclusion on its structure has been reached.

We prepared I by the procedures of Young and Witham,[3] Hoggarth,[4] and Tsuge, *et al.*,[6] and found that the products were identical. It was also obtained by heating an alkaline solution of 1-benzoylsemicarbazide (IX).[17]

To examine which structure of the tautomeric forms best represents compound I, we synthesized the N-methyl derivatives (IIIa, IVa, Va, VIa, and VIIa) of the tautomeric forms (Ia, Ib, Ic, Id, and Ie), respectively, and compared their IR and ultraviolet (UV) spectra with those of I.

Compound (I) seems to exist in a solid state as the oxo form, Id or Ie, since its IR spectrum in KBr disk showed a strong C=O stretching band at 1740 cm^{-1}. 1,4-Dimethyl-3-phenyl-1,2,4-triazolin-5-one (VIa), the model compound of Id, showed a C=O stretching band at 1700 cm^{-1}, while 1,2-dimethyl-3-phenyl-1,2,4-triazolin-5-one (VIIa), the model compound of Ie, showed absorption at 1660 cm^{-1}. This difference in the frequency of absorption is probably due to the fact that the C=O group of VIIa is conjugated with the C=N double bond, while that of VIa is not. Since the frequency of the C=O band of I was closer to that of VIa than to that of VIIa, I seemed to exist in the Id form. The IR spectra of the same compounds in tetrahydrofuran (THF) showed a similar tendency: that is, I and VIa showed C=O stretching bands at 1730 cm^{-1} and 1710 cm^{-1}, respectively, while the band of VIIa was at 1640 cm^{-1}. Moreover, the fact that I showed no OH stretching absorption either in the solid state or in THF indicated the absence of Ia, Ib, and Ic, which each has a hydroxyl group.

The UV spectra in THF supported the above conclusions. The UV spectrum of I showed a maximum at 274 nm and was similar to that of VIa, which had a maximum at 271 nm. These absorption bands are at longer wavelengths than those of the O-methyl derivatives (IIIa, IVa, and Va), which are at 252—255 nm, and are very different from those of VIIa, which has a strong absorption band at 234 nm with a broad band at about 280 nm. Similar conclusions were drawn from the UV spectra of I in ethanol (Fig. 1, 2 and Table 1).

The slight difference between the values of λ_{max} of I and VIa is due to the methyl groups at N-1 and N-4 of the triazole ring in the latter. Introduction of a methyl group at N-4 of the triazole ring in I is considered to influence the coplanarity of the phenyl and triazole rings

6) O. Tsuge, S. Kanemasa, and M. Tashiro, *Tetrahedron*, **24**, 5205 (1968).
7) T. Bougault and L. Popovici, *Compt. rend,*. **189**, 188 (1929).
8) H.G. Mautner and W.D. Kumler, *J. Am. Chem. Soc.*, **77**, 4076 (1955).
9) K. Futaki and S. Tosa, *Chem. Pharm. Bull.* (Tokyo), **8**, 908 (1960).
10) F. Maggio, G. Werber, and G. Lombardo, *Ann. Chim.* (Rome), **50**, 491 (1961).
11) J.C. Howard and H.A. Burch, *J. Org. Chem.*, **26**, 1651 (1961).
12) M. Pesson, S. Duppin, and M. Antoine, *Compt. rend.*, **253**, 992 (1961).
13) M. Ohta and H. Ueda, *Nippon Kagaku Zasshi*, **82**, 1525 (1961).
14) W. Ried and A. Czack, *Ann.*, **676**, 121 (1964).
15) R.G. Baccar and H. Mathis, *Compt. rend.*, **261**(1), 174 (1965).
16) R. Huisgen, H. Blaschke, and E. Brunn, *Tetrahedron Letters*, **1966**, 405.
17) A. Dornow and S. Lupfert, *Arch. Pharm.*, **288**, 311 (1955).

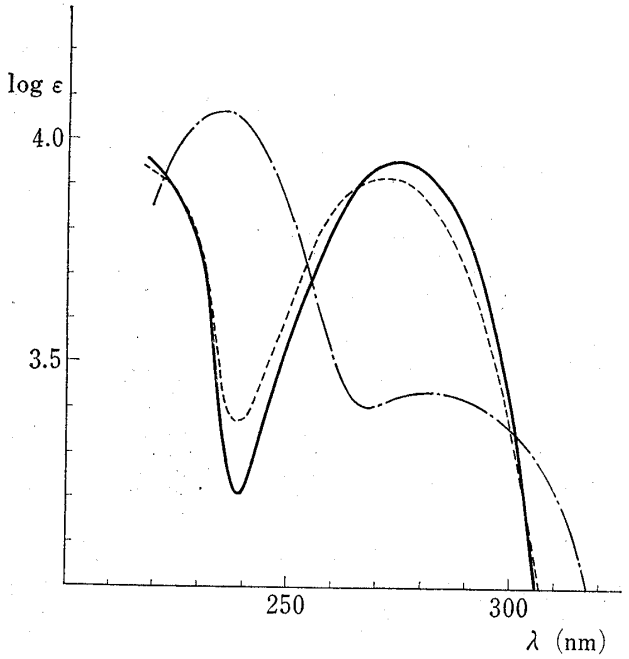


Fig. 1. Ultraviolet Spectra of —— I, ------ VIa, and -·-·- VIIa in Tetrahydrofuran

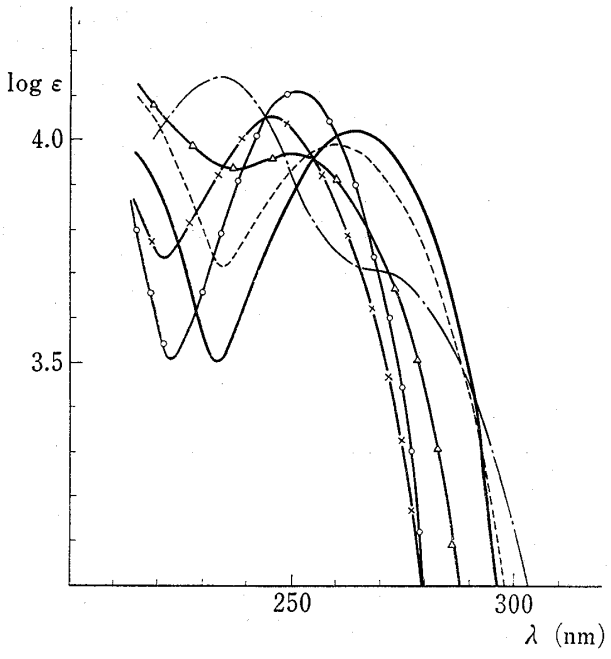


Fig. 2. Ultraviolet Spectra of —— I, -o- IIIa, -△- IVa, -×- Va, ------ VIa, and -·-·- VIIa in Ethanol

and shift the absorption maximum to a shorter wavelength, while the methyl group at N-1 causes a bathochromic shift (Table I). However, the hypsochromic effect of the N-4 methyl group seems to be larger than the bathochromic effect of the N-1 methyl group, so VIa has an absorption maximum at a shorter wavelength than I.

Table I. Ultraviolet Absorption Maxima of 3-Phenyl-1,2,4-triazolin-5-one and Its Methyl Derivatives

Compound No.	Substituents at positions				Ethanol		Tetrahydrofuran	
	1	2	4	5	λmax(nm)	log ε	λmax(nm)	log ε
I	H	—	H	—	264	4.03	274	3.95
IIIa	CH_3	—	—	OCH_3	251	4.11	252	4.19
IVa	—	CH_3	—	OCH_3	249	3.97	255	4.01
Va	—	—	CH_3	OCH_3	244	4.06	253	4.04
VIa	CH_3	—	CH_3	—	260	3.99	271	3.91
VIIa	CH_3	CH_3	—	—	233 275(sh)[a]	4.14 3.69	234 280	4.06 3.43
X	CH_3	—	H	—	268	4.05	279	4.10
XI	—	CH_3	—	H	253	3.96	257	3.97
XII	H	—	CH_3	—	254	3.92	267	3.98

a) sh: shoulder

The NMR spectrum of I in DMSO-d_6 showed broad singlets at 12.20 and 11.95 ppm, probably due to the NH groups. On the basis of these spectral data, it is considered that I exists in the Id form, 3-phenyl-1H,4H-1,2,4-triazolin-5-one, in the solid state and in both THF and ethanol.

There has been similar confusion over the structure of 3-phenyl-1,2,4-triazoline-5-thione (II). All five tautomeric structures, IIa,[18] IIb,[19] IIc,[20] IId,[21] and IIe,[22] have been reported

18) E. Hoggarth, *J. Chem. Soc.*, **1949**, 1160.
19) Yao-Tsu Chen and Tzi-I Chang, *Hua Hsueh Pao*, **30**, 10 (1964); *Chem. Abstr.*, **61**, 3065b (1964).
20) F. Kurzer, *J. Chem. Soc.* (*C*), **1970**, 1813.
21) J.F. Willems and A. Vandenberghe, *Bull. Soc. Chim. Belges*, **75**, 358 (1966).
22) G.J. Durant and S. Kline, *J. Chem. Soc.* (*C*), **1967**, 92.

for II, but the compounds which have been synthesized by various investigators using different methods[18–22] appear to be identical (Chart 1). The IR spectrum of II in KBr disk showed multiple combination bands in the 3200—2600 cm^{-1} region indicating strong intermolecular hydrogen bonding.

The NMR spectrum of II in DMSO-d_6 exhibited a broad peak at 11.7 ppm, corresponding to two protons and probably due to the NH groups.

The UV spectrum of II in ethanol was compared with those of IIIb, IVb, Vb, VIb, and VIIb, the compounds used as models of the five tautomeric forms of II. The UV spectrum of II showed maxima at 226 nm and 256 nm with a shoulder at 281 nm, which is presumably due to a thiocarbonyl group. This characteristic spectrum of II resembled that of VIb, which had maxima at 219 nm and 254 nm with a shoulder at about 280 nm, but not that of VIIb, which showed a strong maximum at 248 nm with a broad band at about 290 nm. The UV spectra of IIIb, IVb, and Vb, the compounds used as models of the thiol form of II, had no absorption maximum or shoulder near 280—290 nm and were essentially different from that of II. The same result was obtained when water was used as the solvent. These UV spectral data indicated that II exists predominantyl as the IId form, 3-phenyl-1H,4H-1,2,4-triazoline-5-thione, both in ethanol and in water. The predominance of the IId form of II was similar to the case of the 3-α-pyridyl derivative.[1]

N-Methylated 3-phenyl-1,2,4-triazolin-5-ones (X, XI, and XII) and N-methylated 3-phenyl-1,2,4-triazoline-5-thiones (XIII, XIV, and XV) can exist in the oxo-hydroxy and thione-thiol tautomeric forms, respectively, as shown in Chart 2.

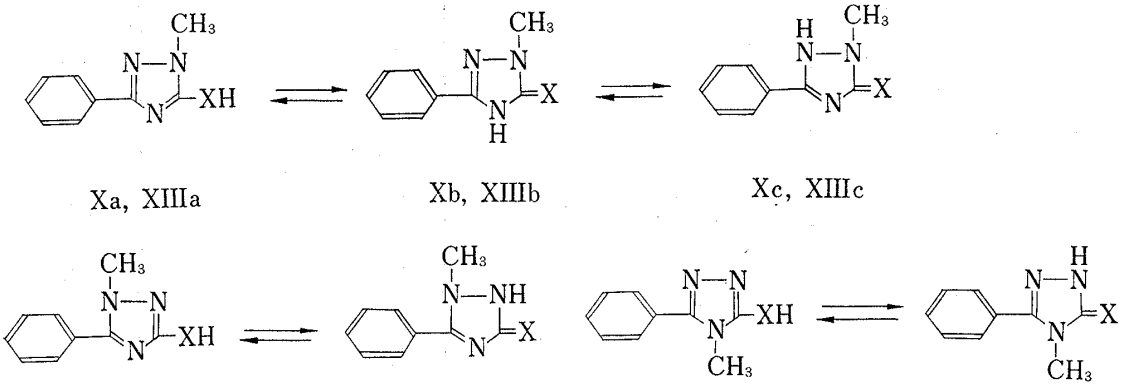


Chart 2

The IR spectrum of X showed a C=O stretching absorption band at 1700 cm^{-1} in the solid state and at 1695 cm^{-1} in THF. The positions of this band were almost the same as those of VIa and very different from those of VIIa under the same conditions. These facts suggest that X exists predominantly as Xb, not Xa or Xc. The C=O streching band of XII is at 1690 cm^{-1} in the solid state and at 1705 cm^{-1} in THF and no OH stretching band was observed. This compound has only two possible forms, the oxo form (XIIb) and hydroxy form (XIIa), and IR spectral data showed that the former was predominant. In contrast with these compounds, both in the solid state and in THF XI had a broad absorption band near 3480 cm^{-1}, characteristic of an associated OH group, but no C=O stretching band. This indicates that XI exists in the hydroxy form, XIa. The UV spectral data also supported the conclusion deduced from the IR spectra. Namely, the spectra of X and XII were similar to that of VIa, a model compound of the oxo forms. The slight difference between the spectra can be explained as follows; VIa absorbs at a shorter wavelength than X, since the 4-methyl

group influences the coplanarity of the phenyl and triazole rings and VIa absorbs at a longer wavelength than XII due to the bathochromic effect of the 1-methyl group. On the other hand, the spectrum of XI was similar to that of IVa, a model compound of the hydroxy form and very different from that of VIIa, a model compound of XIb. It is unknown why only XI can exist in the hydroxy form, but XIb seems to be more unstable sterically than Xb or XIIb.

Compound XIII, XIV, and XV can exist as the thione or thiol form (Chart 2). It has been reported that XV exists as the thione form in ethanol.[23] The UV spectra of XIII and XIV in ethanol showed a shoulder or a broad band at 288 nm and 310 nm, respectively, suggesting the presence of a thiocarbonyl group (Table II). Comparison of the UV spectra of XIII and XIV with those of the compounds (IIIb, IVb, VIb, and VIIb) used as models of the possible tautomeric forms, indicated that XIII and XIV exist predominantly in the thione forms, XIIIb and XIVb, respectively. These results were consistent with previous reports[1,24,25] that compounds which have thione-thiol tautomeric forms exist predominantly in the thione form.

Table II. Ultraviolet Absorption Maxima of 3-Phenyl-1,2,4-triazoline-5-thione and Its Methyl Derivatives

Compound No.	Substituents at positions				Ethanol		Tetrahydrofuran	
	1	2	4	5	λmax(nm)	log ε	λmax(nm)	log ε
II	H	—	H	—	226 256 281(sh)	4.17 4.27 3.99	225 251 275(sh)	4.09 4.21 4.04
IIIb	CH_3	—	—	SCH_3	223 252	4.20 4.16	227 242	4.14 4.13
IVb	—	CH_3	—	SCH_3	220 261(sh)	4.18 3.72	221 265(sh)	4.17 3.59
Vb	—	—	CH_3	SCH_3	253[a]	4.13	247	4.09
VIb	CH_3	—	CH_3	—	219[b] 254 280(sh)	4.11 4.27 3.81	230(sh) 247 275(sh)	4.04 4.21 3.73
VIIb	CH_3	CH_3	—	—	248 290	4.29 3.49	241 275(sh)	4.31 3.67
XIII	CH_3	—	H	—	227 255 288(sh)	4.21 4.28 3.99	—[c]	—
XIV	H	CH_3	—	—	242 310	4.22 3.33	236 278	4.25 3.52
XV	H	—	CH_3	—	217[d] 254 280(sh)	4.11 4.34 3.93	218(sh) 248	4.01 4.20

a) lit.,[23] 254 (11600) *b*) lit.,[23] 254.5 (18400), 280 (sh, 8200)
c) insoluble in water *d*) lit.,[23] 254.5 (18800), 280 (sh, 8000). sh: shoulder

The model compounds used in the present study were synthesized by the procedures given below and their structures were confirmed from their IR and NMR spectra.

1-Methyl-5-methoxy-3-phenyl-1,2,4-triazole (IIIa) was isolated from a mixture of equivalent amounts of IIIa and VIa, obtained by methylation of 1-methyl-3-phenyl-1,2,4-triazolin-5-one (X)[26] with diazomethane. Methylation of X with methyl iodide in alkaline solution gave only VIa.

23) J. Sandström and I. Wennerberk, *Acta Chem. Scand.*, **20**, 57 (1966).
24) A.R. Katritzky and J.M. Lagowski, *Adv. Heterocyclic Chem.*, Part 1, p. 396; Part 2, p. 60. Academic Press, New York, 1963.
25) A.J. Blackman and J.B. Polya, *J. Chem. Soc. (C)*, **1971**, 1016.
26) G. Young and W.H. Oates, *J. Chem. Soc.*, **79**, 659 (1901).

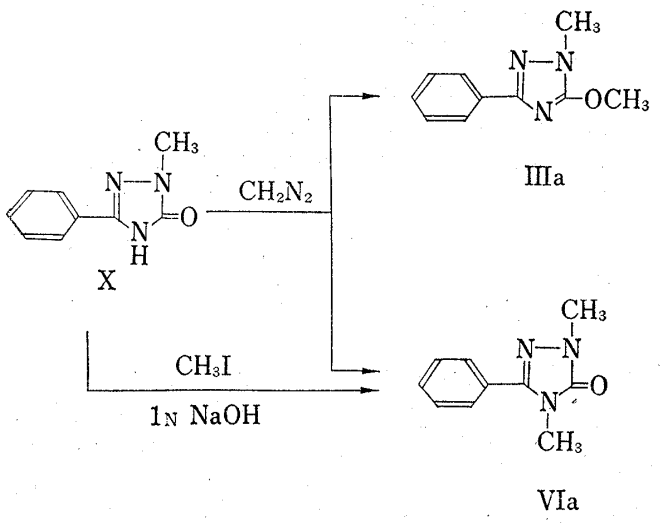


Chart 3

It was found that only 2-methyl-5-methoxy-3-phenyl-1,2,4-triazole (IVa) was produced by methylation of 5-hydroxy-2-methyl-3-phenyl-1,2,4-triazole (XI) with diazomethane. Compound XI was prepared by reaction of 1-benzoyl-1-methylhydrazine[27] with potassium isocyanate, followed by dehydrative ring closure of the resulting 1-benzoyl-1-methylsemicarbazide(XVI).

4-Methyl-5-methoxy-3-phenyl-1,2,-4-triazole (Va) and VIa were synthesized by the following steps. Reaction of benzoylhydrazine with methyl isocyanate following Pacilly's method[28] gave 1-benzoyl-4-methylsemicarbazide (XVII). This was cyclized to 4-methyl-3-phenyl-1,2,4-triazolin-5-one (XII) by heating in alkaline solution. Methylation of XII with methyl iodide in alkaline solution

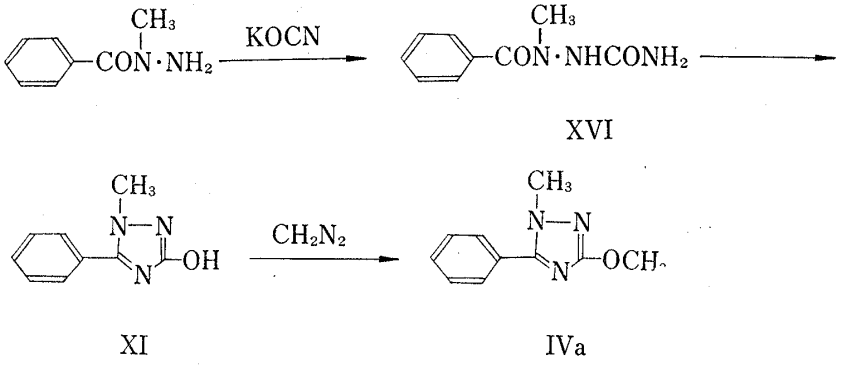


Chart 4

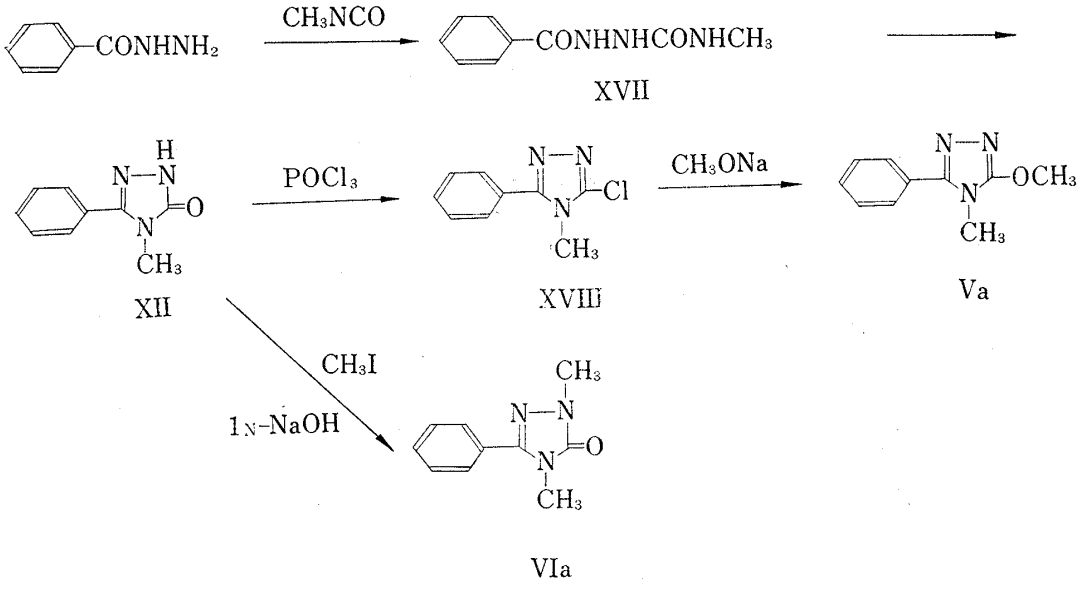


Chart 5

27) C. Ainsworth, *Canad. J. Chem.*, **43**, 1607 (1965).
28) Ch. C. Pacilly, *Rec. Trav. Chim.*, **55**, 101 (1963).

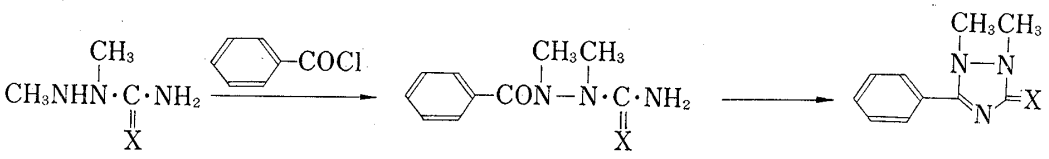
gave VIa. Scarcely any Va was obtained, even by methylation of XII with diazomethane, so Va was prepared by reaction of sodium methylate with 5-chloro-3-phenyl-1,2,4-triazole (XVIII), obtained by chlorination of XII with phosphorus oxychloride.

1,2-Dimethyl-3-phenyl-1,2,4-triazolin-5-one (VIIa) could not be synthesized by methylation of X or XI, so it was prepared by cyclization of 1-benzoyl-1,2-dimethylsemicarbazide (XIXa), which was obtained from 1,2-dimethylsemicarbazide[29] and benzoyl chloride.

1-Methyl-5-methylthio-3-phenyl-1,2,4-triazole (IIIb) was synthesized from 1-methyl-3-phenyl-1,2,4-triazoline-5-thione (XIII) by methylation with methyl iodide in alkaline solution. Compound (XIII) was obtained from 1-benzoyl-2-methylthiosemicarbazide by the procedure of Durant.[22]

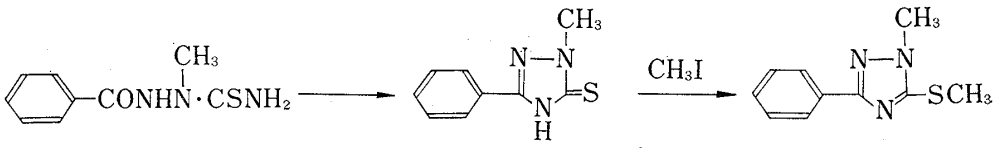
2-Methyl-5-methylthio-3-phenyl-1,2,4-triazole (IVb) was obtained by methylation of 2-methyl-3-phenyl-1,2,4-triazoline-5-thione (XIV) with methyl iodide in alkaline solution. Compound XIV has previously been synthesized by cyclization of 1,4-dibenzoyl-1-methylthiosemicarbazide in alkaline solution,[22] but it was also easily obtained by cyclization of 1-benzoyl-1-methylthiosemicarbazide (XX). The latter was prepared by reaction of 1-benzoyl-1-methylhydrazine[27] with potassium thiocyanate.

1,2-Dimethyl-1,2,4-triazoline-5-thione (VIIb) was prepared, in the same way as in the case of VIIa, by condensation of 1,2-dimethylthiosemicarbazide[30] with benzoyl chloride,



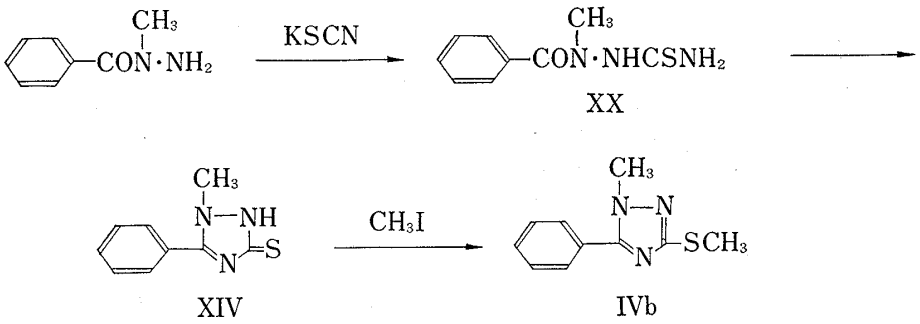
a : X=O, b : X=S XIXa,b VIIa,b

Chart 6



XIII IIIb

Chart 7



XX XIV IVb

Chart 8

29) C.F. Kroeger, P. Selditz, and M. Mutscher, *Chem. Ber.*, **98**, 3034 (1965).
30) J. Sandström and S. Sunner, *Acta Chem. Scand.*, **17**, 731 (1963).

and then cyclization of the resulting 1-benzoyl-1,2-dimethylthiosemicarbazide (XIXb) in alkaline solution (Chart 6).

Compound Vb and VIb were prepared as described in the literature.[23]

Experimental

All melting points were uncorrected. IR spectra were recorded on a Hitachi EPI-G_2 spectrometer. UV spectra were obtained using a Hitachi Model 124 spectrophotometer. NMR spectra were measured at 100 MHz with a JOEL PS-100 spectrometer using TMS as an internal standard.

3-Phenyl-1,2,4-triazolin-5-one (I)——A solution of 1-benzoylsemicarbazide (IX, 1.0 g) in 1N NaOH (15 ml) was heated under reflux at 130° for 3 hr, then allowed to come to room temperature and neutralized with 10% HCl. A colourless precipitate which separated was dissolved in 1N NaOH. After removal of a small amount of insoluble material by filtration, the filtrate was neutralized with 10% HCl giving a colourless precipitate. Repetition of this procedure gave colourless crystals (0.35 g), mp 318—319° (decomp.). *Anal.* Calcd. for $C_9H_7ON_3$: C, 59.62; H, 4.38; N, 26.07. Found: C, 59.40; H, 4.28; N, 25.98. IR ν_{max}^{KBr} cm^{-1}: 3200—2700 (NH), 1745 (C=O), 1730 (C=O, sh). NMR (DMSO-d_6) δ: 11.95 (1H, broad singlets, NH), 12.20 (1H, broad singlets, NH).

1-Methyl-5-methoxy-3-phenyl-1,2,4-triazole (IIIa)——An excess of diazomethane in ether was added to a solution of 1-methyl-3-phenyl-1,2,4-triazolin-5-one (X, 0.4 g) in EtOH (40 ml). The mixture was allowed to stand at room temperature over night. Removal of an excess of diazomethane and the solvent by evaporation gave a light brown oil, which was dissolved in EtOH (5 ml) and filtered. The filtrate was evaporated *in vacuo* to an oily residue. Thin layer chromatography of the oily product on silica gel (solvent: $CHCl_3$–MeOH (20: 1, v/v)) gave two spots with different fluorescence under UV light. The NMR spectra of this product showed that it consisted of IIIa and VIa. The residue was chromatographed on silica gel, and IIIa, which eluted first with $CHCl_3$, was recrystallized from EtOH to give colourless needles (0.12 g), mp 98—99°. *Anal.* Calcd. for $C_{10}H_{11}ON_3$: C, 63.48; H, 5.86; N, 22.21. Found: C, 63.49; H, 5.85; N, 22.31. NMR ($CDCl_3$) τ: 5.88 (3H, s, O-CH_3), 6.38 (3H, s, N-CH_3).

1-Benzoyl-1-methylsemicarbazide (XVI)——A mixture of 1-benzoyl-1-methylhydrazine (2.5 g), conc. HCl (2.5 ml), H_2O (8.5 ml), and potassium isocyanate (2.7 g) was refluxed for 5 hr, and cooled. A white precipitate which formed was recrystallized from EtOH to give a colourless fine needles (2.0 g), mp 217—218°. *Anal.* Calcd. for $C_9H_{11}O_2N_3$: C, 55.95; H, 5.74; N, 21.75. Found: C, 55.99; H, 5.77; N, 21.76.

5-Hydroxy-2-methyl-3-phenyl-1,2,4-triazole (XI)——A solution of XVI (1.5 g) in 1N NaOH (15 ml) was refluxed for 4 hr. After being cooled, the solution was neutralized with 10% HCl to give a white precipitate, which on recrystallization from EtOH afforded colourless fine needles (1.1 g), mp 195—196°. *Anal.* Calcd. for $C_9H_9ON_3$: C, 61.70; H, 5.18; N, 23.99. Found: C, 61.65; H, 5.14; N, 24.16. IR ν_{max}^{KBr} cm^{-1}: 3450 (OH). NMR ($CDCl_3$) τ: 6.13 (3H, s, N-CH_3).

2-Methyl-5-methoxy-3-phenyl-1,2,4-triazole (IVa)——To a solution of XI (0.3 g) in MeOH (15 ml) was added an excess of diazomethane in ether and the mixture was stirred at room temperature for 24 hr. After removal of the solvent by evaporation *in vacuo*, the remaining residue was dissolved in 1N NaOH (10 ml) and then extracted with $CHCl_3$ (10 ml). The extract was washed successively with 1N NaOH (5 ml×2), H_2O (5 ml), and then dried over anhyd. Na_2SO_4. After the solvent had been removed by evaporation, the residual oil was placed in a refrigerator over night. The solid which separated was recrystallized from isopropylether giving colourless fine rods (0.21 g), mp 85—86°. *Anal.* Calcd. for $C_{10}H_{11}ON_3$: C, 63.48; H, 5.86; N, 22.21. Found: C, 63.64; H, 5.82; N, 22.46. NMR ($CDCl_3$) τ: 6.00 (3H, s, O-CH_3), 6.15 (3H, s, N-CH_3).

4-Methyl-3-phenyl-1,2,4-triazolin-5-one (XII)——A solution of 1-benzoyl-4-methylsemicarbazide (XVII, 2.5 g) in 1N NaOH (15 ml) was heated at 130° for 3 hr. After the solution had been allowed to come to room temperature, it was neutralized with 10% HCl to give a colourless precipitate. The product was collected by filtration and washed with EtOH giving colourless needles (2.1 g), mp 179—180°. *Anal.* Calcd. for $C_9H_9ON_3$: C, 61.70; H, 5.18; N, 23.99. Found: C, 62.09; H, 5.16; N, 24.35. IR ν_{max}^{KBr} cm^{-1}: 1690 (C=O). NMR ($CDCl_3$) τ: 6.60 (3H, s, N-CH_3).

1,4-Dimethyl-3-phenyl-1,2,4-triazolin-5-one (VIa)——To a solution of XII (1.5 g) in 1N NaOH (8 ml) was added a solution of methyl iodide (2.0 g) in EtOH (2 ml). The mixture was stirred at room temperature for 5 hr. After being cooled, a colourless precipitate which separated was collected by filtration and crystallized from EtOH to give colourless needles (0.75 g), mp 144—145°. *Anal.* Calcd. for $C_{10}H_{11}ON_3$: C, 63.48; H, 5.86; N, 22.21. Found: C, 63.75; H, 5.84; N, 22.54. IR ν_{max}^{KBr} cm^{-1}: 1700 (C=O). NMR ($CDCl_3$) τ: 6.46 (3H, s, $N_{(1)}$-CH_3), 6.62 (3H, s, $N_{(4)}$-CH_3).

5-Chloro-4-methyl-3-phenyl-1,2,4-triazole (XVIII)——A mixture of XII (1.0 g), phosphorus oxychloride (5 ml) and N,N-dimethylformamide (0.15 ml) was refluxed at 120° for 12 hr. After the reaction mixture had been allowed to come to room temperature, it was poured on to the ice-water mixture and then evaporated under reduced pressure. The resulting oily residue was treated with 1N NaOH and filtered. The filtrate was extracted with $CHCl_3$ (8 ml) and the solvent was evaporated *in vacuo*. The remaining residue was recrystallized from EtOH–ether to give colourless needles (0.4 g), mp 166—167°. *Anal.* Calcd. for C_9H_8-

N_3Cl: C, 55.83; H, 4.16; N, 21.70. Found: C, 56.01; H, 4.29; N, 21.99. NMR ($CDCl_3$) τ: 6.33 (3H, s, N-CH_3).

4-Methyl-5-methoxy-3-phenyl-1,2,4-triazole (Va)——To a solution of sodium (0.3 g) in MeOH (15 ml) was added XVIII (0.3 g), and the mixture was refluxed for 6 hr. After removal of the solvent *in vacuo*, the remaining residue was dissolved in H_2O (15 ml) and extracted with $CHCl_3$ (15 ml). The extract was dried over anhyd. Na_2SO_4 and evaporated to dryness. The residue was crystallized from isopropylether to give colourless needles (0.12 g), mp 134—136°. *Anal.* Calcd. for $C_{10}H_{11}ON_3$: C, 63.48; H, 5.86; N, 22.21. Found: C, 63.68; H, 6.16; N, 22.14. NMR ($CDCl_3$) τ: 5.80 (3H, s, O-CH_3), 6.54 (3H, s, N-CH_3).

1-Benzoyl-1,2-dimethylsemicarbazide (XIXa)——A solution of benzoylchloride (0.69 g) in EtOH (1 ml) was added dropwise with stirring to a solution of 1,2-dimethylsemicarbazide (0.5 g) in 1N NaOH (2 ml). After the mixture had been stirred for 1 hr, the product which separated was collected by filtration and washed with boiling EtOH to give colourless fine needles (0.45 g), mp 209—210°. *Anal.* Calcd. for $C_{10}H_{13}O_2N_3$: C, 57.96; H, 6.32; N, 20.28. Found: C, 57.61; H, 6.29; N, 20.21.

1,2-Dimethyl-3-phenyl-1,2,4-triazolin-5-one (VIIa)——A solution of XIXa (0.3 g) in 1N NaOH (3 ml) was heated under reflux at 130° for 1 hr. After being cooled, a colourless precipitate which formed was collected and crystallized from EtOH to give colourless needles (0.22 g), mp 255—256°. *Anal.* Calcd. for $C_{10}H_{11}N_3O$: C, 63.48; H, 5.86; N, 22.21. Found: C, 63.45; H, 5.76; N, 21.82. IR ν_{max}^{KBr} cm^{-1}: 1660 (C=O). NMR ($CDCl_3$) τ: 6.42 (3H, s, $N_{(2)}$-CH_3), 6.52 (3H, s, $N_{(1)}$-CH_3).

1-Methyl-5-methylthio-3-phenyl-1,2,4-triazole (IIIb)——A solution of methyl iodide (0.2 g) in EtOH (0.3 ml) was added to a solution of 1-methyl-3-phenyl-1,2,4-triazoline-5-thione (XIII, 0.2 g) in 1N NaOH (5 ml). The mixture was stirred for 2 hr at room temperature and extracted with $CHCl_3$. After removal of the solvent by evaporation *in vacuo*, the residue was dissolved in isopropylether. Evaporation of the solvent *in cvauo* gave a colourless oil, which solidified slowly on cooling. The solid was recrystallized from isopropylether giving colourless crystals (0.12 g), mp 24—25°. *Anal.* Calcd. for $C_{10}H_{11}N_3S$: C, 58.54; H, 5.37; N, 20.49. Found: C, 58.72; H, 5.04; N, 20.17. NMR ($CDCl_3$) τ: 6.23 (3H, s, N-CH_3), 7.28 (3H, s, S-CH_3).

1-Benzoyl-1-methylthiosemicarbazide (XX)——A mixture of 1-benzoyl-1-methylhydrazine (3.0 g), conc. HCl (3 ml), H_2O (30 ml), and potassium thiocyanate (4.5 g) was refluxed for 1 hr, and cooled. The resulting solid was collected by filtration, washed twice with EtOH to give a colourless powder (3.8 g), mp 220—222°. *Anal.* Calcd. for $C_9H_{11}N_3OS$: C, 51.67; H, 5.26; N, 20.10. Found: C, 51.74; H, 5.25; N, 20.20.

2-Methyl-3-phenyl-1,2,4-triazoline-5-thione (XIV)——A solution of XX (3.0 g) in 1N NaOH (20 ml) was heated under reflux at 120° for 2 hr, and then cooled. The reaction mixture was neutralized with 10% HCl to give a precipitate, which was crystallized from boiling EtOH giving coloulress needles (2.6 g), mp 196—198°. *Anal.* Calcd. for $C_9H_9N_3S$: C, 56.54; H, 4.71; N, 21.99. Found: C, 56.26; H, 4.64; N, 21.99. NMR ($CDCl_3$) τ: 6.16 (3H, s, N-CH_3).

2-Methyl-5-methylthio-3-phenyl-1,2,4-triazole (IVb)——To a solution of XIV (2.0 g) in 1N NaOH (2 ml) was added a solution of methyl iodide (3.0 g) in EtOH (5 ml). The mixture was stirred at room temperature for 2 hr and extracted with $CHCl_3$ (10 ml × 5). The $CHCl_3$ layer was dried over anhyd. Na_2SO_4 and the solvent was removed by evaporation *in vacuo*. The resulting residue was dissolved in isopropylether and evaporated. The oily product was slowly solidified on cooling. Recrystallization from isopropylether gave colourless needles (0.19 g), mp 48—49°. *Anal.* Calcd. for $C_{10}H_{11}N_3S$: C, 58.54; H, 5.37; N, 20.49. Found: C, 58.89; H, 5.48; N, 20.90. NMR ($CDCl_3$) τ: 6.10 (3H, s, N-CH_3), 7.40 (3H, s, S-CH_3).

1-Benzoyl-1,2-dimethylthiosemicarbazide (XIXb)——A solution of benzoylchloride (0.81 g) in EtOH (2 ml) was added dropwise to a solution of 1,2-dimethylthiosemicarbazide (0.7 g) in 1N NaOH (5 ml). After the mixture had been stirred at room temperature for 7 hr, a precipitate which formed was collected by filtration. Recrystallization from EtOH gave colourless fine needles (0.85 g), mp 186—187°. *Anal.* Calcd. for $C_{10}H_{13}ON_3S$: C, 53.79; H, 5.87; N, 18.82. Found: C, 54.03; H, 5.97; N, 18.81.

1,2-Dimethyl-3-phenyl-1,2,4-triazoline-5-thione (VIIb)——A solution of XIXb (0.5 g) in 1N NaOH (6 ml) was heated under reflux at 120° for 2 hr. After being cooled, the reaction mixture was neutralized with 10% HCl. The solid which formed was collected by filtration and crystallized from EtOH to give colourless fine needles (0.3 g), mp 270—272° (decomp.). *Anal.* Calcd. for $C_{10}H_{11}N_3S$: C, 58.54; H, 5.37; N, 20.49. Found: C, 58.57; H, 5.53; N, 20.68. NMR (DMSO-d_6) τ: 6.21 (3H, s, $N_{(2)}$-CH_3), 6.76 (3H, s, $N_{(1)}$-CH_3).

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