than the one previously proposed[4,6] and given in formula III.

Similarities in the absorption spectra of 8-quinolinol in alkaline and "neutral" media (except for bathochromic shifts) support this view. The sodium derivative of 8-quinolinol is very soluble in water and insoluble in materials such as benzene or chloroform,[10] suggesting that it is a salt rather than a chelate. This evidence and the well-known fact that sodium ion does not commonly add complexing groups indicate that the appearance of a structure comparable to II in alkaline solutions of 8-quinolinol is most unlikely. A structure as is shown in formula IV is more probable. In neutral solvents, the absence of a structure comparable to II may be due to an enhanced tendency toward intermolecular hydrogen bonding rather than intramolecular. In such media, a structure like that given in IV with the proton on the oxygen alone would then seem reasonable.

Acknowledgment.—Support received from the Office of Naval Research and from the National Science Foundation is gratefully acknowledged.

(10) P. Süe and G. Wétroff, *Bull. soc. chim.*, [5] **2**, 1002 (1935).

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The Synthesis of Some *s*-Triazolo(4,3-b)-*as*-triazines[1]

BY E. C. TAYLOR, JR., W. H. GUMPRECHT AND R. F. VANCE

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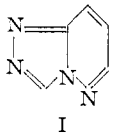
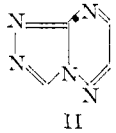
In view of the significant purine-inhibitory activity which has been observed for a number of derivatives of heterocyclic systems related to the purine ring system[2-6] it seemed of considerable interest to investigate the chemical and biological properties of heterocyclic systems retaining some gross structural similarity to the purines but less closely related than the majority of compounds previously studied. A few derivatives of one such system, *s*-triazolo(4,3-b)pyridazine (I), have been reported to be extremely toxic.[7] The present paper reports the preparation of several derivatives of a closely related ring system, *s*-triazolo(4,3-b)-*as*-triazine (II).



I



II

(1) Abstracted from part of the thesis presented by W. H. Gumprecht to the University of Illinois in partial fulfillment of the degree of Bachelor of Science in Chemistry.

(2) R. O. Roblin, Jr., J. O. Lampen, J. P. English, Q. P. Cole and J. R. Vaughan, Jr., THIS JOURNAL, **67**, 290 (1945).

(3) G. H. Hitchings, G. B. Elion, H. VanderWerff and E. A. Falco, *J. Biol. Chem.*, **174**, 765 (1948).

(4) G. H. Hitchings, G. B. Elion, E. A. Falco, P. B. Russell, M. B. Sherwood and H. VanderWerff, *ibid.*, **183**, 1 (1950).

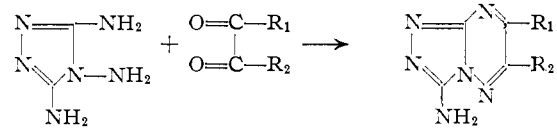
(5) R. L. Thompson, M. L. Wilkin, G. H. Hitchings, G. B. Elion, E. A. Falco and P. B. Russell, *Science*, **110**, 454 (1949).

(6) E. A. Falco, G. H. Hitchings, P. B. Russell and H. VanderWerff, *Nature*, **164**, 107 (1949).

(7) C. Bülow, *Ber.*, **42**, 2208 (1909). A reinvestigation of these compounds is in progress in these laboratories.

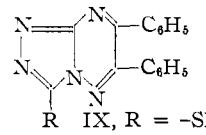
A few derivatives of *s*-triazolo(4,3-b)-*as*-triazine have been reported by Hoggarth,[8,9] who condensed several 3,4-diamino-1,2,4-triazoles with benzil and biacetyl to give the appropriately substituted triazolotriazines. However, the requisite triazoles had been prepared only in poor yield and often as only one of many products by the reaction of hydrazine with 1-benzoylmethylthioisothiosemicarbazide, 1,4-dibenzoylthiosemicarbazide, N,N'-dithiocarbamylhydrazine and similar compounds, and the condensation reactions were employed only for the purpose of furnishing confirmatory evidence for the vicinal diamino grouping in the triazoles concerned.

A more attractive approach leading directly to *s*-triazolo(4,3-b)-*as*-triazines more suitably substituted for possible biological activity has been found to involve the condensation of α,β-dicarbonyl compounds with guanazine (3,4,5-triamino-1,2,4-triazole) (III), readily available from the condensation of hydrazine with cyanogen bromide. Successful condensations with benzil, biacetyl, *p,p'*-dichlorobenzil, phenanthrenequinone and pyruvic acid to give the appropriately substituted 3-amino-*s*-triazolo(4,3-b)-*as*-triazines (IV–VIII) were carried out; unsuccessful attempts were made to effect condensation with glyoxal and alloxan.



III

IV, $R_1 = R_2 = -C_6H_5$
V, $R_1 = R_2 = -CH_3$
VI, $R_1 = R_2 = -C_6H_4Cl$-*p*
VII, $R_1 = R_2$ = phenanthro(9,10-e)
VIII, R_1 = -OH, $R_2 = -CH_3$



R IX, R = -SH; X, R = $-SCH_3$

Unsuccessful attempts were made to convert 3-mercapto- (IX) and 3-methylmercapto-6,7-diphenyl-*s*-triazolo(4,3-b)-*as*-triazine (X) to the 3-amino derivative IV with alcoholic ammonia or with potassium amide. This behavior is consistent with the reported failure of 3-methylmercapto-5-phenyl-1,2,4-triazole to react with ammonia[10] and parallels the observed unreactivity of numerous heterocyclic thioamides and S-alkylisothioamides with amines.[11]

Preliminary tests carried out with the organism *Leuconostoc mesenteroides* P-60 showed that compounds IV, V, VIII, IX and X were inactive either as purine substitutes or as antagonists at the concentrations employed. Compounds VI and VII were too insoluble to be tested under the conditions employed.

(8) E. Hoggarth, *J. Chem. Soc.*, 614 (1950).

(9) E. Hoggarth, *ibid.*, 4817 (1952).

(10) E. Hoggarth, *ibid.*, 1160 (1949).

(11) (a) F. H. S. Curd, M. I. Davis, E. C. Owen, F. L. Rose and G. A. P. Tuey, *ibid.*, 720 (1946); (b) F. H. S. Curd, J. K. Landquist and F. L. Rose, *ibid.*, 775 (1947); (c) A. F. Crowther, F. H. S. Curd, D. N. Richardson and F. L. Rose, *ibid.*, 1636 (1948); (d) R. de B. Ashworth, A. F. Crowther, F. H. S. Curd and F. L. Rose, *ibid.*, 581 (1948); (e) H. C. Carrington, *ibid.*, 684 (1947); (f) H. L. Wheeler and G. S. Jamieson, *Am. Chem. J.*, **33**, 342 (1904); (g) F. E. King and T. J. King, *J. Chem. Soc.*, 943 (1947); (h) P. B. Russell, G. B. Elion, E. A. Falco and G. H. Hitchings, THIS JOURNAL, **71**, 2279 (1949).

Acknowledgment.—The authors are indebted to Mrs. Katherine J. Sholtz for carrying out the microbiological tests.

Experimental[12]

Guanazine Hydrobromide (III).—This compound was prepared essentially by the procedure of Pellizzari and Cantoni.[13]

3-Amino-6,7-diphenyl-*s*-triazolo-(4,3-b)-*as*-triazine (IV).—To a mixture of 5.4 g. (0.028 mole) of guanazine hydrobromide and 5.8 g. (0.028 mole) of benzil in 40 ml. of water, 40 ml. of methyl ethyl ketone and 40 ml. of ethanol was added 1.4 g. (0.035 mole) of solid sodium hydroxide. The color of the reaction mixture turned instantly to blood-red. The resulting blood-red solution was heated under reflux for 30 minutes, cooled and water added until no more solid separated. After allowing the mixture to stand for several hours, the solid was separated, washed thoroughly with water and recrystallized from absolute ethanol. The yield of bright red needles was 4.2 g. (53%), m.p. 263–264°. The analytical sample was prepared by sublimation at 240° (0.1 mm.).

Anal. Calcd. for $C_{16}H_{12}N_6$: C, 66.6; H, 4.2; N, 29.1. Found: C, 66.6; H, 4.2; N, 29.1.

3-Amino-6,7-dimethyl-*s*-triazolo(4,3-b)-*as*-triazine (V).—A solution of 15.0 g. (0.077 mole) of guanazine hydrobromide and 6.8 g. (0.079 mole) of biacetyl in 130 ml. of boiling water was adjusted to *p*H 5 by the careful addition of ammonium hydroxide. An immediate separation of beautiful yellow platelets occurred. After cooling the mixture overnight at 0°, the crystals were filtered, washed thoroughly with water and recrystallized from 95% ethanol, yield 10.47 g. (83%), m.p. 299–300°.

Anal. Calcd. for $C_6H_8N_6$: C, 43.9; H, 4.9; N, 51.2. Found: C, 44.1; H, 4.9; N, 51.2.

3-Amino-6,7-bis-(*p*-chlorophenyl)-*s*-triazolo(4,3-b)-*as*-triazine (VI).—A solution of 5.0 g. (0.018 mole) of *p,p'*-dichlorobenzil in a mixture of 80 ml. of ethyl methyl ketone and 80 ml. of ethanol was added to a solution of 3.5 g. (0.018 mole) of guanazine hydrobromide in 80 ml. of hot water, 48 g. (0.12 mole) of solid sodium hydroxide added and the blood-red solution heated under reflux for one-half hour. Addition of the cooled reaction mixture to 400 ml. of water containing 10 g. of calcium chloride resulted in the separation of a red solid, yield 4.17 g. (65%), m.p. 228–230°. Recrystallization from methylene chloride–petroleum ether raised the melting point to 229–231°.

Anal. Calcd. for $C_{16}H_{10}N_6Cl_2$: C, 53.8; H, 2.8; N, 23.5. Found: C, 53.9; H, 3.0; N, 23.9.

3-Amino-*s*-triazolo(4,3-b)phenanthro(9,10-e)-*as*-triazine (VII).—A mixture of 5.0 g. (0.024 mole) of 9,10-phenanthrenequinone, 4.7 g. (0.024 mole) of guanazine hydrobromide, 100 ml. of ethanol, 40 ml. of water and 1.7 g. (0.043 mole) of solid sodium hydroxide was heated under reflux for one-half hour. The blood-red solution was then cooled and poured into 500 ml. of water. The precipitated red solid was collected by filtration, washed with water followed by warm benzene to remove any unreacted quinone and recrystallized from glacial acetic acid to give lustrous red prisms, yield 6.63 g. (96.5%), m.p. 334–336° dec.

Anal. Calcd. for $C_{16}H_{10}N_6$: C, 67.1; H, 3.5; N, 29.4. Found: C, 67.1; H, 3.7; N, 29.3.

3-Amino-6(or 7)-methyl-7(or 6)-hydroxy-*s*-triazolo(4,3-b)-*as*-triazine (VIII).—A mixture of 5.9 g. (0.03 mole) of guanazine hydrobromide, 2.8 g. (0.032 mole) of freshly-distilled pyruvic acid and 50 ml. of 2 *N* sulfuric acid was heated under reflux for two hours and then concentrated to approximately 5 ml. Careful neutralization of the solution to *p*H 6 with 3 *N* sodium hydroxide resulted in the separation of shiny, light tan crystals which were separated by filtration and recrystallized from water, yield 2.85 g. (57%), m.p. 317–318° dec.

Anal. Calcd. for $C_5H_6N_6O$: C, 36.1; H, 3.6; N, 50.6. Found: C, 36.0; H, 3.7; N, 50.8.

3-Mercapto-6,7-diphenyl-*s*-triazolo(4,3-b)-*as*-triazine (IX).—A solution of 6.0 g. (0.046 mole) of 3,4-diamino-5-mercapto-1,2,4-triazole,[9] 9.64 g. (0.046 mole) of benzil and 1.9 g. (0.047 mole) of solid sodium hydroxide in 45 ml. of water and 75 ml. of ethanol was heated under reflux for one hour. Cooling caused the separation of red-brown crystals which were separated by filtration and washed with cold ethanol to remove unreacted benzil. The crude yield of the sodium salt of 3-mercapto-6,7-diphenyl-*as*-triazolo(4,3-b)-*as*-triazine was 13.4 g. (89%).

Glacial acetic acid was added to a suspension of 1.5 g. of the above sodium salt in 10 ml. of hot water until the solution was strongly acid. Addition of water and cooling caused the separation of 0.90 g. of an orange solid which was collected by filtration, washed with cold ethanol and extracted in a Soxhlet extractor with 50 ml. of methylene chloride. The yellow solid which separated from the extract was recrystallized from aqueous dimethylformamide to give long orange needles, yield 0.50 g. (36%), m.p. 305.4–306.6° dec.

Anal. Calcd. for $C_{16}H_{11}N_5S$: C, 62.9; H, 3.6; N, 22.9. Found: C, 63.0; H, 3.5; N, 23.1.

3-Methylmercapto-6,7-diphenyl-*s*-triazolo(4,3-b)-*as*-triazine (X).[9]—A suspension of 3.35 g. (0.01 mole) of the above sodium salt of 3-mercapto-6,7-diphenyl-*s*-triazolo(4,3-b)-*as*-triazine in 150 ml. of water was treated with 1.45 g. (0.011 mole) of methyl iodide and the mixture stirred at room temperature for three hours. The resulting yellow solid was collected by filtration and recrystallized from aqueous dimethylformamide to give 1.78 g. (55%) of yellow needles, m.p. 201–203°.

Anal. Calcd. for $C_{17}H_{13}N_5S$: C, 63.9; H, 4.1; N, 21.9. Found: C, 64.2; H, 4.0; N, 21.9.

Attempts to convert IX or X to 3-amino-6,7-diphenyl-*s*-triazolo(4,3-b)-*as*-triazine (IV) by heating with saturated alcoholic ammonia at 180° for 20 hours or by heating under reflux for 48 hours with potassium amide in toluene were unsuccessful; only unreacted starting material was isolated in each instance.

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(12) All melting points are corrected. The microanalyses were carried out by Mrs. Esther Fett, Mrs. Katherine Pih and Mr. Joseph Nemeth.

(13) G. Pellizzari and C. Cantoni, *Gazz. chim. ital.*, **35**, I, 291 (1905).

Thermodynamic Functions of Paraffins

BY GEORGE W. THOMSON

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The direct calculation of the thermodynamic functions of complex molecules by the statistical methods which have been applied to simple molecules is not possible with our present knowledge. However, a number of useful approximation methods are available. Pitzer[1] showed that the functions for *n*-paraffins and some of the simpler branched compounds could be estimated by adding the contributions for the translational and over-all rotational motion (designated F_0), the C–C stretching vibrations and the C–C bending vibrations of the skeleton, the internal rotation of the skeleton, the internal rotation and vibrations of the CH_3 groups and the vibrations of the CH_2 groups. In addition a function was included to allow for the steric interaction energy associated with different possible equilibrium positions of the rigid molecule.

These calculations were later refined and extended by Person and Pimentel[2] who re-evaluated most of the contributions using newer data. Their tables were presented for 298.16°K. and for 300 to 1500°K. at 100°K. intervals. It is the purpose of the present note to extend these tables down to 200°K., using their methods and equations, and to

(1) K. S. Pitzer, *J. Chem. Phys.*, **8**, 711 (1940).

(2) W. S. Person and G. C. Pimentel, THIS JOURNAL, **75**, 532 (1953).