REFERENCES

(1) Brodie, B. B., Burns, J. J., Lowman, E. W., Chenkin, T., Lee, P., Weiner, M., and Steele, J. M., *Am. J. Med.*, **16**, 181(1954).
(2) Pulver, R., *Schweiz. Med. Wochschr.*, **80**, 308(1950).
(3) Moss, D. G., *J. Clin. Pathol.*, **1**, 344(1954).
(4) Tophøj, E. A., *Acta Med. Scand.*, **160**, 197(1958).
(5) Burns, J. J., Rose, R. K., Chenkin, T., Goldman, A., Schulbert, A., and Brodie, B. B., *J. Pharmacol. Exptl. Therap.*, **109**, 27(1953).
(6) Burns, J. J., Rose, R. K., Goodwin, S., Reichenthal, J., Horning, E. C., and Brodie, B. B., *ibid.*, **113**, 481(1955).
(7) Randall, H. M., Fowler, R. G., Fuson, N., and Dangel, J. R., "Infrared Determination of Organic Structures," Van Nostrand, New York, N. Y., 1949, p. 16.
(8) Kampmann, E., and Frey, H. H., *Nature*, **209**, 519 (1966).
(9) Beckman, H., "Pharmacology: The Nature, Action and Use of Drugs," W. B. Saunders, Philadelphia, Pa., 1961, p. 261.

Keyphrases

Phenylbutazone—analysis
Biologic specimens—phenylbutazone analysis
Sulfinpyrazone—analysis interference
IR spectrophotometry—identity
UV spectrophotometry—analysis

Synthesis of Some Iodopurine Derivatives

By R. T. KODA, J. A. BILES, and W. WOLF

Several new 6- and 8-iodopurine derivatives have been prepared. It was found that a nucleophilic displacement of a chloro- or mercapto- function by iodide ion was most successful for the introduction of iodine into the purine ring. The resultant iodopurine derivatives were also screened against the lymphoid leukemia L-1210 test system for biological activity.

RECENT STUDIES (1) indicate that the antitumor activity of purine and pyrimidine derivatives is associated with (*a*) their incorporation into DNA or RNA, thereby altering or terminating normal replication; (*b*) the blocking of the incorporation of normal nucleic acid bases into the structure of DNA or RNA; or (*c*) inhibition of the *de novo* synthesis of naturally occurring purine or pyrimidine bases.

Irrespective of the mechanism by which they act, many halogen and mercapto derivatives of purine and pyrimidine have been shown to possess antitumor activity (2–5). This activity has been generally correlated to both steric and electronic effects contributed by the substituent group.

An iodine substitution on various purine derivatives may exert both a steric effect, because of its large molecular diameter (van der Waals radius = 2.15 Å.), or an inductive effect, due to its electronegativity.

The synthesis of a number of iodopurine derivatives was attempted with an iodine atom residing in the three available positions—C-2, C-6, and C-8. The latter position is not normally involved in intermolecular hydrogen bonding in the polydeoxynucleotide strands but would contribute mainly by its inductive effect on the electron distribution in the purine ring. Iodo substitutions at both C-2 and C-6 are in close proximity to those regions on the purine ring at which intermolecular hydrogen bonding normally occurs and may exert both steric and inductive effects by a purine base which has been incorporated into a polydeoxynucleotide strand.

DISCUSSION

Previous synthetic routes for the preparation of iodopurine derivatives involved either the direct iodination of the purine ring (6–9) with various electrophilic agents or nucleophilic displacement reactions (10–16) of functional groups such as mercapto, alkylmercapto, or halogen by iodide ion. Since direct iodination procedures have proved to be only partially successful, the displacement of a mercapto function on various purine derivatives by iodide ion was attempted. The synthesis of mercaptopurines was usually carried out by the displacement of a hydroxy function at C-6 or C-8 by phosphorus pentasulfide in pyridine (10, 17–20) or

Received May 22, 1968, from the Department of Pharmaceutical Chemistry, School of Pharmacy, University of Southern California, Los Angeles, CA 90007
Accepted for publication August 22, 1968.
Abstracted from a portion of the dissertation submitted by R. T. Koda to the Graduate School, University of Southern California, in partial fulfillment of Doctor of Philosophy degree requirements.
The authors thank Allergan Pharmaceuticals, Santa Ana, Calif., for their financial assistance.

TABLE I—MERCAPTOPURINE DERIVATIVES

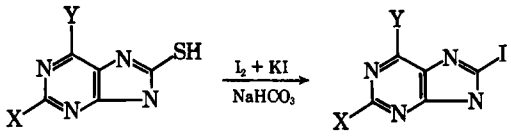
R_1	R_2	R_3	Method of Preparation[a]	Reference
NH_2	OH	SH	Fusion	—
H	NH_2	SH	Fusion	(21)
NH_2	H	SH	Fusion	(31)
H	OH	SH	Fusion	(22)
OH	H	SH	Fusion	(32, 33)
OH	NH_2	SH	Fusion	(30)
NH_2	SH	H	Displacement	(10)
H	SH	SH	Fusion	—
SH	NH_2	SH	Fusion	—
SH	NH_2	H	[b]	—
SH	OH	H	[b]	—

[a] Fusion indicates a condensation between thiourea and 4,5-diaminopyrimidine derivatives to yield the corresponding 8 mercaptopurine. Displacement indicates the substitution of a hydroxy function at C-6 and C-8 on purine derivatives using phosphorus pentasulfide in pyridine to yield the mercaptopurine. [b] Cyclo Chemical Corp.

the fusion of 4,5-diaminopyrimidine derivatives with thiourea (21, 22, 30–33) to yield the corresponding 8-mercaptopurine derivatives (Table I).

The displacement of an 8-mercapto function on purine nucleosides by iodide ion has previously been reported as successful (12). However, a corresponding study of the displacement of an 8-mercapto function on purine bases has not been previously reported.

As an example, when 6-amino-8-mercaptopurine (21) (8-mercaptoadenine) was treated with a mixture of iodine, potassium iodide, and sodium bicarbonate in aqueous solution, a good yield of 8-iodoadenine (I) was isolated. This reaction was subsequently found to be general for all 8-mercaptopurine derivatives having a single additional functional group (amino or hydroxy) at C-2 or C-6 (Scheme I) but not for those which were disubsti-



X = H when Y = NH_2 or OH
Y = H when X = NH_2 or OH

Scheme I

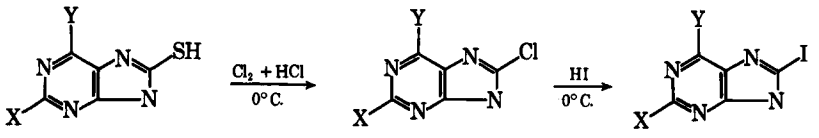
tuted in the pyrimidine ring as discussed below. Thus, the synthesis of 2-amino-8-iodopurine (II), 6-hydroxy-8-iodopurine (III), 2-hydroxy-8-iodopurine (IV), in addition to 8-iodoadenine (I), was attained in good yield using this procedure.

An alternate method for the synthesis of 8-iodopurine derivatives involved the initial displacement of the 8-mercapto function by chlorine, using a mixture of chlorine gas and hydrochloric acid at 0°, followed by the displacement of the 8-chloro function by treatment with hydriodic acid at 0° (Scheme II). The UV and IR spectra of the iodopurine product obtained by either synthetic route were identical.

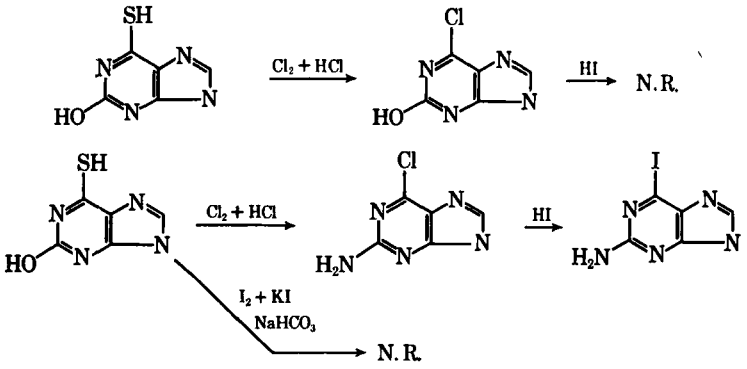
It is surprising that either displacement reaction described above did not operate on more heavily substituted purine derivatives. Attempts to selectively displace one of the mercapto functions on 6,8-dimercaptopurine (22) by iodide ion were not successful, and attempts to displace an 8-mercapto function by iodide ion on purine derivatives having simultaneous substitutions at C-2 and C-6 presented some unusual problems. While treatment of 6-amino-2-hydroxy-8-mercaptopurine (8-mercaptoisoguanine) with a mixture of iodine, potassium iodide, and sodium bicarbonate in water at room temperature resulted in the displacement of the 8-mercapto function to yield 8-iodoisoguanine (V), under similar reaction conditions, 8-mercaptoguanine or 2,8-dimercaptoadenine did not yield the corresponding 8-iodo derivatives.

It is possible that the presence of a hydroxy or mercapto function at C-2 and/or C-6, in addition to an amino substitution, increased the electron density at C-8 so that a stabilized carbonium ion intermediate cannot exist, making the usual displacement of the 8-mercapto function by iodide ion unsuccessful. It also has been reported that the thione tautomeric form at C-8 predominates in neutral or weakly acidic conditions (23).

The synthesis of several 6-iodopurine derivatives has previously been reported (24–28). The method for their synthesis generally involved a displacement of a 6-chloro function with hydriodic acid. However, attempts to extend this procedure to the displacement of a 6-mercapto function did not succeed. Thus, the authors were unable to displace the mercapto group on 2-amino-6-mercaptopurine (thioguanine) by iodide ion. However, 2-amino-6-iodopurine (VI) was successfully obtained by initially converting thioguanine to its 6-chloro derivative (using chlorine gas and hydrochloric acid), then treating the chloropurine derivative with hydriodic acid as shown in Scheme III.



Scheme II



Scheme III

A similar attempt to synthesize 2-hydroxy-6-iodopurine from 2-hydroxy-6-mercaptopurine did not succeed. Treatment of 2-hydroxy-6-mercaptopurine with a mixture of hydrochloric acid and chlorine gas gave a chlorinated product which when treated directly with hydriodic acid failed to yield the expected iodinated purine derivative. One may rationalize again that a hydroxy group at C-2 has increased the electron density at C-6 to such an extent that displacement cannot occur due to the lack of stabilization of the required carbonium ion intermediate.

The most serious problem encountered was the attempt to introduce an iodine at C-2. The authors have not been successful in this attempt. The 2-mercapto function of 6-amino-2-mercaptopurine and 6-hydroxy-2-mercaptopurine could not be displaced under any conditions used. This failure to displace a mercapto function at C-2 is in agreement with similar results obtained by Robins (15) who reported that treatment of 2-methylthiopurines with chlorine yielded only the 2-methylsulfonyl derivatives, while a similar reaction on 6- and 8-methylthiopurines resulted in a facile displacement reaction. This inability to displace a substituent at C-2 as opposed to the uncomplicated displacement at C-8, where both carbons appear to be equivalent (—N=CH—N) may be explained by the substantial difference that exists in the chemistry of the imidazole and pyrimidine ring systems.

It has been reported (6, 7) that several purine nucleosides—guanosine, xanthosine, and 2′-deoxyguanosine—could be directly iodinated with *N*-iodosuccinimide in dimethylsulfoxide using catalytic amounts of *n*-butyl disulfide. However, attempts to directly iodinate adenine and guanine using similar procedures to the above failed to yield any product other than the starting material. Further studies of the direct iodination of adenine or guanine with iodine monochloride in either glacial acetic acid or dimethylformamide, or with mixtures of iodine and nitric acid or iodine-iodic acid in glacial acetic acid also failed to lead to the iodinated derivatives.

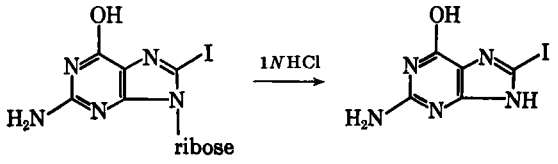
However, treatment of adenine with iodine monochloride in a mixture of *N*-ethylacetamide and dry carbon tetrachloride gave a product containing iodine whose UV and IR spectra varied considerably from that of the original material. Elemental analyses for carbon, hydrogen, and iodine did not agree with calculated values for iodoadenine. Favorable results were not achieved even after recrystallization from water. As it was observed that one of the characteristics of the substance was its ability to react with starch-iodide paper, it is likely that the product obtained was the *N*-iodo derivative of adenine at N-9. This would account for its oxidizing properties and may also explain the difficulty encountered in the purification of the product due to the relative instability of the *N*-iodo function.

As neither nucleophilic displacement or electrophilic substitution methods has allowed the synthesis of 8-iodoguanine (VII), this was finally accomplished by the hydrolysis of the iodinated nucleoside 8-iodoguanosine (6), under acidic conditions to yield the iodinated purine base (Scheme IV).

A summary of the results of the synthesis of iodopurines is shown in Table II.

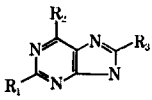
BIOLOGICAL EVALUATION OF IODOPURINES

The biological evaluation of the iodopurine derivatives was conducted under the auspices of the Cancer Chemotherapy National Service Center, National Cancer Institute, according to previously described protocols (29). The results of this study are shown in Table III. The results indicate that none of the compounds tested possessed any significant biological activity against the L-1210 lymphoid leukemia test system. All of the compounds, with the exception of 8-iodohypoxanthine (III) and 8-iodoisoguanine (V), possessed toxicity at elevated dosages. When the compounds were submitted for



Scheme IV

TABLE II—IODOPURINE DERIVATIVES



R_1	R_2	R_3	Calcd.	Found	pH	$\lambda_{max.}$	$\epsilon \times 10^{-3}$
NH_2	OH	I	C, 19.2 H, 1.59	C, 19.0 H, 1.83	1.3 11.9	275 279	8.60 7.37
OH	NH_2	I	C, 17.44 H, 2.03	C, 17.43 H, 2.39	1.0 14.0	299 296	15.2 13.3
H	NH_2	I	C, 19.6 H, 1.96 N, 22.5	C, 19.7 H, 2.3 N, 22.4	1.0 11.9	272 274	17.3 15.4
NH_2	H	I	C, 19.4 H, 1.61	C, 19.5 H, 2.14	1.0 12.85	222 309	30.0 9.44
H	OH	I	C, 22.9 H, 1.15	C, 22.85 H, 1.6	1.0 12.85	259 267	14.4 14.1
OH	H	I	C, 20.8 H, 2.08	C, 20.87 H, 2.21	1.0 12.85	306 223 299	7.18 17.95 6.77
NH_2	I	H	C, 23.0 H, 1.53	C, 23.2 H, 1.84	1.0 12.85	319 213 313 224	7.55 23.0 6.80 22.90
H	NH_2	H 9-iodo	C, 20.2 H, 2.69 I, 42.7 N, 23.6	C, 20.0 H, 2.68 I, 33.25 C, 18.69 H, 2.69 I, 38.56 N, 19.75			

evaluation, it was found that 2-amino-6-iodopurine had previously been submitted for testing under NSC No. 45254. The results showed that it also did not possess any significant antitumor activity against the L-1210 tumor test system.

Although the iodopurine derivatives did not show any significant biological activity against the L-1210 tumor test system, it is suggested that further evaluation against other tumor test systems be made in order to determine the complete antitumor spectrum for this group of compounds.

EXPERIMENTAL

Melting points were determined on a Fisher-Johns melting point apparatus and are given uncorrected. Microanalyses were conducted by Elek Microanalytical Laboratory, Torrance, Calif. All compounds were dried over phosphorus pentoxide at 2 mm. Hg and 100° for at least 12 hr. IR spectra were run as mineral oil mulls between sodium chloride windows on a spectrophotometer (Perkin Elmer 137 Infracord). UV spectra were run on a spectrophotometer (Beckman DB) using water as a solvent.

Preparation of 8-Iodoadenine Hydrochloride (I)—To a suspension of 0.160 g. (0.96 mmole) of 6-amino-8-mercaptopurine (23) and 0.90 g. of sodium bicarbonate in 5.0 ml. of water was added, over a 30-min. period, a solution of 0.90 g. of iodine and 0.60 g. (3.75 mmoles) of potassium iodide in 2.0 ml. of water. After the addition was completed, the mixture was allowed to stir for an additional 18 hr. at room temperature and filtered. The precipitate was washed with 5.0 ml. of 10% potassium iodide solution and finally with water. The yellow product was recrystallized from 5% hydrochloric acid to yield 0.120 g. (75%) of 6-amino-8-iodopurine hydrochloride (I), which darkened above 250°.

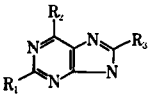
Anal.—Calcd. for $C_5H_5ClIN_5 \cdot 0.5H_2O$: C, 19.6; H, 1.96; N, 22.4. Found: C, 19.7; H, 2.3; N, 22.4. UV data: pH 1, $\lambda_{max.}$ 272 mμ (ϵ = 17,300); pH 7, $\lambda_{max.}$ 271 mμ (ϵ = 14,900); 215 mμ (ϵ = 20,300); pH 11.9, $\lambda_{max.}$ 274 mμ (ϵ = 15,400).

2-Amino-8-iodopurine Sulfate (II)—*Method A*—To a suspension of 0.165 g. (0.99 mmoles) of 2-amino-8-mercaptopurine (31) and 0.90 g. (3.75 mmoles) of sodium bicarbonate was added a solution of 0.90 g. of iodine and 0.60 g. potassium iodide in 2.0 ml. of water. The mixture was stirred for 18 hr. at room temperature and filtered. The precipitate was washed with water and recrystallized from 1 *N* sulfuric acid to yield 0.110 g. (36%) of 2-amino-8-iodopurine sulfate (II) which gradually decomposed above 160° when heated on a melting point block.

Anal.—Calcd. for $C_{10}H_{10}I_2N_{10}O_4S$: C, 19.4; H, 1.61. Found: C, 19.5: H, 2.14. UV data: pH 1, $\lambda_{max.}$ 222 mμ (ϵ = 30,000); pH 6.65 $\lambda_{max.}$ 312 mμ (ϵ = 9,000); $\lambda_{max.}$ 220 mμ (ϵ = 22,300); pH 12.85, $\lambda_{max.}$ 309 mμ (ϵ = 9,440).

Method B—To a mixture of 0.5 ml. of absolute methanol and 1.5 ml. of concentrated hydrochloric acid, previously cooled to −10°, was added 0.25 g. (1.5 mmoles) of 2-amino-8-mercaptopurine (31). Chlorine gas was passed into the mixture for 30 min., never allowing the temperature to rise above 0°. At the end of the reaction period, a white solid separated. The reaction mixture was neutralized with ammonium hydroxide, filtered, and washed with water. The white precipitate, without further purification, was added to 3.0 ml. of hydriodic acid (57%) which had been previously cooled to −10°. The suspension was stirred for 1.5 hr. at 0° then filtered. The precipitate was washed with water

TABLE III—ANTITUMOR ACTIVITY OF SOME IODOPURINE DERIVATIVES AGAINST LYMPHOID LEUKEMIA L-1210



R_1	R_2	R_3	Dose, mg./kg.	Survivors	Animal Weight Diff., T/C	Survival, Days—Test	Survival, Days—Control	% T/C
H	NH_2	I	400	0/4				
			200	4/4	−2.1	9.3	9.4	98
			100	4/4	−2.4	8.8	9.4	93
NH_2	H	I	400	0/4				
			200	0/4				
			100	0/4				
			80	0/6				
			40	0/6				
			20	3/6	−1.2	8.0	8.3	
			10	3/6	0.0	8.7	8.3	
			5	6/6	0.6	8.2	8.3	98
			5	6/6	−0.7	8.7	9.1	95
H	OH	I	400	4/4	−0.7	9.3	9.4	98
			200	4/4	1.0	9.3	9.4	98
			100	4/4	1.4	9.8	9.4	104
NH_2	OH	I	400	1/4	−4.3	10.0	9.4	
			200	1/4	−4.9	9.0	9.4	
			100	0/4				
			80	0/6				
			40	5/6	−0.9	8.6	8.3	103
			20	6/6	0.4	8.2	8.3	98
			20	6/6	−0.7	9.0	9.1	98
			10	6/6	0.1	8.5	8.3	102
			5	6/6	0.1	8.2	8.3	98
OH	H	I	400	2/6	−0.6	9.0	8.6	
			200	0/6				
			100	4/6	−0.1	8.3	8.6	96
			50	6/6	−0.2	9.8	10.1	97
OH	NH_2	I	400	5/6	−1.9	9.8	8.6	113
			200	5/6	−4.3	8.6	8.6	100
			100	5/6	−0.3	8.4	8.6	97
NH_2	I	H	112[a]	7/7	0.0	8.7	9.0	96

[a] Previously evaluated under NSC No. 45254, Oct. 14, 1962.

and recrystallized from 1 *N* sulfuric acid to yield 0.24 g. (51.5%) of 2-amino-8-iodopurine sulfate (II). UV and IR spectral evidence indicated that the compound was identical to that prepared by Method A.

6-Hydroxy-8-iodopurine (III)—To a suspension of 0.168 g. (1 mmole) of 6-hydroxy-8-mercaptopurine (24) and 0.90 g. of sodium bicarbonate in 5.0 ml. of water was added, over a 30-min. period, a solution of 0.60 g. of iodine and 0.60 g. (3.75 mmoles) of potassium iodide in 2.0 ml. of water. Stirring was continued for an additional 18 hr. at room temperature. The mixture was acidified to pH 5 with glacial acetic acid then filtered to yield a light yellow precipitate which was washed with 5.0 ml. of 10% potassium iodide solution, then with water. Recrystallization from water gave 0.150 g. (57%) of 6-hydroxy-8-iodopurine (III) which gradually darkened above 245°.

Anal.—Calcd. for $C_5H_3IN_4O \cdot 0.5H_2O$: C, 22.9; H, 1.15. Found: C, 22.85; H, 1.6. UV data: pH 1, $\lambda_{max.}$ 259 mμ (ϵ = 14,400); pH 6.65 $\lambda_{max.}$ 263 mμ, (ϵ = 13,800); pH 12.85, $\lambda_{max.}$ 267 mμ (ϵ = 14,100).

2-Hydroxy-8-iodopurine (IV)—To a suspension of 0.165 g. (1 mmole) of 2-hydroxy-8-mercaptopurine (32, 33) and 0.90 g. of sodium bicarbonate in 5.0 ml. of water was added a solution containing 0.60 g. of iodine and 0.90 g. of potassium iodide in 2.0 ml. of water. The dropwise addition of the iodine–potassium iodide solution was conducted over a 30-min. period. The reaction mixture was allowed to stir an additional 48 hr. at room temperature, then acidified with glacial acetic acid and filtered. The dark brown precipitate was washed with water and recrystallized from water to yield light yellow crystals of 2-hydroxy-8-iodopurine (IV) which decomposed above 250°. Yield: 0.130 g. (49.5%).

Anal.—Calcd. for $C_5H_3IN_4O \cdot 1.5H_2O$: C, 20.8; H, 2.08. Found: C, 20.87; H, 2.21. UV data: pH 1, $\lambda_{max.}$ 306 mμ (ϵ = 7180); $\lambda_{max.}$ 223 mμ (ϵ = 17,950); pH 6.65, $\lambda_{max.}$ 290 mμ (ϵ = 4260); pH 12.85, $\lambda_{max.}$ 299 mμ (ϵ = 6770).

6-Amino-2-hydroxy-8-iodopurine (V)—A solution of 0.60 g. iodine and 0.90 g. of potassium iodide in 2.0 ml. water was added dropwise, over a 30-min. period, to a suspension of 0.187 g. (1 mmole) of 6-amino-2-hydroxy-8-mercaptopurine and 0.90 g. of sodium bicarbonate in 5.0 ml. of water. Stirring was continued for an additional 24 hr. at room temperature. The mixture was filtered and the precipitate washed with 2 ml. of 10% potassium iodide solution, then with water. Recrystallization from 1 *N* sulfuric acid gave 0.135 g. (40.5%) of a

white crystalline product which gradually darkened above 235°.

Anal.—Calcd. for $C_5H_4IN_5O \cdot 0.5\ H_2O \cdot 0.5\ H_2SO_4$: C, 17.44; H, 2.03. Found: C, 17.43; H, 2.39. UV data: pH 1, $\lambda_{max.}$ 299 mμ (ϵ = 15,200); pH 6.65, $\lambda_{max.}$ 297 mμ (ϵ = 15,650); pH 12.85, $\lambda_{max.}$ 296 mμ (ϵ = 13,300).

2-Amino-6-iodopurine (VI)—To a mixture of 1.0 ml. of absolute methanol and 3.0 ml. of concentrated hydrochloric acid, previously cooled to −10° was added 0.50 g. (3 mmoles) of 2-amino-6-mercaptopurine (12). Chlorine gas was passed into the mixture for 30 min., never allowing the reaction temperature to rise above −5°. The mixture was neutralized with ammonium hydroxide and the white precipitate of 2-amino-6-chloropurine was filtered, washed with water, and dried.

To 5.0 ml. of hydriodic acid (57%), previously cooled to −10°, was added 0.50 g. (2.95 mmoles) of 2-amino-6-chloropurine. The mixture was stirred for 1.5 hr. at −10°, then filtered. The precipitate was suspended in water and the pH adjusted to neutrality with ammonium hydroxide. The mixture was filtered and the precipitate recrystallized from ethanol–water (1:1) to give 0.32 g. (25%, based upon 2-amino-6-chloropurine) of 2-amino-6-iodopurine (VI), which gradually darkened above 245°.

Anal.—Calcd. for $C_5H_4IN_5$: C, 23.0; H, 1.53. Found: C, 23.2; H, 1.84. UV data: pH 1, $\lambda_{max.}$ 319 mμ (ϵ = 7550), $\lambda_{max.}$ 213 mμ (ϵ = 23,000); pH 6.65, $\lambda_{max.}$ 314 mμ (ϵ = 8000), $\lambda_{max.}$ 240 mμ (ϵ = 9120); $\lambda_{max.}$ 217 mμ (ϵ = 27,900); pH 12.85, $\lambda_{max.}$ 313 mμ (ϵ = 6800), $\lambda_{max.}$ 224 mμ (ϵ = 22,900).

8-Iodoguanine Hydrochloride (VII)—A suspension of 0.50 g. (1.22 mmoles) of 8-iodoguanosine (8, 9) in 15.0 ml. of 1 *N* hydrochloric acid was heated on a steam bath for 2 hr. During the heating period, light yellow needles separated from solution. The reaction mixture was cooled in an ice bath and additional precipitation occurred. The crystals were filtered and washed with water. Recrystallization from 1 *N* hydrochloric acid gave 0.15 g. (40%) of 2-amino-6-hydroxy-8-iodopurine (VII).

Anal.—Calcd. for $C_5H_5ClIN_5O$: C, 19.2; H, 1.59. Found: C, 19.0; H, 1.83. UV spectral data: pH 1.3, $\lambda_{max.}$ 275 mμ (ϵ = 8600); pH 6.65, $\lambda_{max.}$ 252 mμ (ϵ = 9450); pH 11.9, $\lambda_{max.}$ 279 mμ (ϵ = 7370).

6,8-Dimercaptopurine (VIII)—One gram (7.05 mmoles) of 4,5-diamino-6-mercaptopyrimidine and 3.0 g. (39.5 mmoles) of thiourea were thoroughly mixed, then fused at 200–210° in an oil bath for 30 min. After cooling, the mass was dissolved in 30 ml. of 1 *N* potassium hydroxide, decolorized twice with charcoal, and filtered. The filtrate was acidified with acetic acid whereupon precipitation occurred. The yellow precipitate of 6,8-dimercaptopurine was filtered, washed with water, and dried. Purification was accomplished by reprecipitation from 1 *N* potassium hydroxide using glacial acetic acid. The UV spectral data at pH 1 and 11 were identical to that reported by Robins (14).

6-Amino-2,8-dimercaptopurine (IX)—A mixture of 2.0 g. (14.1 mmoles) of 2-mercapto-4,5,6-triaminopyrimidine sulfate and 8.0 g. (0.105 mole) of thiourea was heated at 200° for 60 min. in an oil bath. The fusion mixture was cooled and dissolved in 30 ml. of 1 *N* potassium hydroxide, decolorized with charcoal, and filtered. The filtrate was acidified with glacial acetic acid and a bright yellow precipitate separated. The precipitate was filtered and purified by reprecipitation from 1 *N* potassium hydroxide. Fine yellow microcrystals of 6-amino-2,8-dimercaptopurine (IX), which were slightly hygroscopic, were isolated and found to gradually darken above 240°.

Anal.—Calcd. for $C_5H_5N_5S_2$: C, 30.1; H, 2.51. Found: C, 29.9; H, 2.75. UV spectral data: pH 1, $\lambda_{max.}$ 302 mμ (ϵ = 15,900), $\lambda_{max.}$ 234 mμ (ϵ = 8730); pH 6.65, $\lambda_{max.}$ 238 mμ (ϵ = 12,100); pH 12.85, $\lambda_{max.}$ 313 mμ (ϵ = 16,200), $\lambda_{max.}$ 230 mμ (ϵ = 19,100).

REFERENCES

(1) Strauss, B. S., "An Outline of Chemical Genetics," Saunders, Philadelphia, Pa., 1960, pp. 85–102.
(2) Prusoff, W. H., *Cancer Res.*, **20**, 92(1960).
(3) *Ibid.*, **23**, 1246(1963).
(4) Le Page, G. A., *ibid.*, **23**, 1202(1963).
(5) Brockman, R. W., *ibid.*, **23**, 1191(1963).
(6) Lipkin, D., Howard, F. B., Nowotny, D., and Sano, M., *J. Biol. Chem.*, **238**, 2249(1963).
(7) Nowotny, D., and Lipkin, D., *Monatsh. Chem.*, **96**, 125(1965).
(8) Ascoli, F., and Hahan, F. M., *J. Biol. Chem.*, **241**, 428(1966).
(9) Brammer, K. W., *Biochim. Biophys. Acta*, **72**, 217 (1963).
(10) Daves, G. D., Jr., Noell, C. W., Robins, R. K., Koppel, H. C., and Beaman, A. G., *J. Am. Chem. Soc.*, **82**, 2633(1960).
(11) Beaman, A. G., Gerster, J. F., and Robins, R. K., *J. Org. Chem.*, **27**, 986(1962).
(12) Beaman, A. G., and Robins, R. K., *J. Appl. Chem.*, **12**, 432(1962).
(13) Koppel, H. C., and Robins, R. K., *J. Am. Chem. Soc.*, **80**, 2751(1958).
(14) Holmes, R. H., and Robins, R. K., *ibid.*, **86**, 1242 (1964).
(15) Noell, C. W., and Robins, R. K., *ibid.*, **81**, 5997 (1959).
(16) Usbeck, G. A., Jones, J. W., and Robins, R. K., *ibid.*, **83**, 113(1961).
(17) Hitchings, G. H., Elion, G. B., Galco, E. A., and Russell, P. B., *J. Biol. Chem.*, **177**, 357(1949).
(18) Elion, G. B., Burgi, E., and Hitchings, G. H., *J. Am. Chem. Soc.*, **74**, 411(1952).
(19) Elion, G. B., and Hitchings, G. H., *ibid.*, **77**, 1676 (1955).
(20) Bergmann, G., and Kalmus, A., *J. Chem. Soc.*, **1962**, 860.
(21) Jones, J. W., and Robins, R. K., *J. Am. Chem. Soc.*, **82**, 3773(1960).
(22) Robins, R. K., *ibid.*, **80**, 6671(1958).
(23) Brown, D. J., and Mason, S. F., *J. Chem. Soc.*, **1957**, 682.
(24) Ballweg, H., *Ann. Chem.*, **649**, 114(1961).
(25) Hitchings, G. H., Elion, G. B., and Goodman, I., U. S. pat. No. 3,132,144; through *Chem. Abstr.*, **61**, 43781*a* (1964).
(26) Ishido, Y., Kikuchi, Y., and Sato, T., *Nippon Kogaku Zasshi*, **86**, 246(1965).
(27) Ishikura, Y., Kanazawa, T., and Sato, T., *Bull. Chem. Soc. (Japan)*, **35**, 731(1962).
(28) Garkusha, G. A., *Zh. Obshch. Khim.*, **27**, 1712(1957).
(29) *Cancer Chemotherapy Rept.*, **25**, 1(1962).
(30) Elion, G. B., Goodman, I., Lang, W., and Hitchings, G. H., *J. Am. Chem. Soc.*, **81**, 1898(1959).
(31) Lewis, A. F., Beaman, A. G., and Robins, R. K., *Can. J. Chem.*, **41**, 1807(1963).
(32) Johns, C. O., *Am. Chem. J.*, **41**, 58(1909).
(33) Johns, C. O., *J. Biol. Chem.*, **21**, 319(1915).

Keyphrases

Iodopurine derivatives—synthesis
Antitumor activity—iodopurine derivatives
IR spectrophotometry—structure
UV spectrophotometry—structure