v/v). Crystallization of the first eluted compound from ethanol yielded 0.2 g (10%) of ethyl 2-chloro-3-(5-chloro-3-methyl-2-indolyl)propenoate (**20**) as yellow crystals, mp 155–157°.

Anal. Calcd for $C_{14}H_{13}Cl_2NO_2$: C, 56.40; H, 4.40; N, 4.70. Found: C, 56.26; H, 4.28; N, 4.65.

Uv λ_{max} 262 mμ (ε 9670), 355–357 (ε 33,200); ir (KBr) 3440 (NH), 1710 cm^{-1} (CO); nmr ($CDCl_3$) δ 1.4 (t, 3, J = 7 Hz, CH_3), 2.4 (s, 3, CH_3), 4.45 (q, 2, J = 7 Hz, CH_2), 7.28 (s with fine structure, 2, C_6 H and C_7 H), 7.55 (s with fine structure, 1, C_4 H), 7.99 (s, 1, β proton).

Crystallization of the later eluted second component from hexane yielded 0.9 g (39%) of ethyl 2-chloro-3-(5-chloro-3-methyl-2-indolyl)-3-ethoxypropanoate (**19**), mp 81–83°.

Anal. Calcd for $C_{16}H_{19}Cl_2NO_3$: C, 55.83; H, 5.56; N, 4.07. Found: C, 55.60; H, 5.48; N, 4.19.

Uv λ_{max} 230 mμ (ε 38,000), 286–287 (8100), 294 (8100), infl 304 (5850); ir ($CHCl_3$) 3470 (NH), 1750 cm^{-1} (CO); nmr ($CDCl_3$) δ 1.13 (t, 3, J = 7 Hz, CH_3), 1.3 (t, 3, J = 7 Hz, CH_2), 2.34 (s, 3, CH_3), 3.52 (q, 2, J = 7 Hz, OCH_2), 4.33 (q, 2, J = 7 Hz, $COOCH_2$–), 4.5 (d, 1, J = 9 Hz), and 5.05 (d, 1, J = 9 Hz) (AB system, α and β proton), 7–7.5 (m, 2, C_6 H and C_7 H), 7.53 (s with fine structure, 1, C_4 H), 8.33 (broad s, 1, NH).

Acknowledgment.—The authors wish to thank the following members of our Physical Chemistry Department: Mr. S. Traiman for the ir spectra, Dr. V. Toome for the uv spectra, Dr. T. Williams for the nmr spectra, and Dr. F. Scheidl for the microanalyses. We are indebted to Professor G. Buchi for valuable discussions.

Registry No.—**1g**, 40735-51-1; **1h**, 40735-52-2; **1i**, 40735-53-3; **1k**, 40735-54-4; **2c**, 40735-55-5; **2d**, 40735-56-6; **2f**, 40735-57-7; **3a**, 40735-58-8; **3c**, 40735-59-9; **3d**, 40735-60-2; **3f**, 40735-61-3; **3g**, 40735-62-4; **3h**, 40735-63-5; **3i**, 40735-64-6; **3k**, 40827-74-5; **5d**, 40731-34-8; **5f**, 16381-47-8; **5i**, 40731-36-0; **6b**, 40731-37-1; **6c**, 40731-38-2; **6d**, 24106-90-9; **6e**, 40730-98-1; **6f**, 40730-99-2; **6i**, 40731-00-8; **7d**, 40731-01-9; **7e**, 40731-02-0; **8b**, 40731-03-1; **8c**, 40731-04-2; **8d**, 40731-05-3; **8e**, 40731-06-4; **8i**, 40731-07-5; **9c**, 40731-08-6; **9f**, 40731-09-7; **10**, 40731-10-0; **11**, 40731-11-1; **12**, 15815-97-1; **13**, 40731-13-3; **14**, 40731-14-4; **15**, 40731-15-5; **16**, 40731-16-6; **17**, 40731-17-7; **18**, 40827-72-3; **19**, 40731-18-8; **20**, 40731-19-9; **21a**, 40731-20-2; **21c**, 40731-21-3; **21g**, 40827-73-4; **21h**, 40731-22-4; **21i**, 40731-23-5; **21k**, 40731-24-6; **23a**, 40731-25-7; **23c**, 40731-26-8; **23f**, 40731-27-9; **24a**, 40731-28-0; **24c**, 40731-29-1; **24f**, 40731-30-4; phosphorus pentachloride, 10026-13-8; methylene chloride, 75-09-2; thionyl chloride, 7719-09-7; *tert*-butyl hypochlorite, 507-40-4; ethyl 5-chloro-3-phenylindole-2-carboxylate, 21139-32-2; ethyl 3-phenylindole-2-carboxylate, 37129-23-0; 2-acetyl-3-phenylindole, 36015-23-3; trifluoroacetic acid, 76-05-1; ethanol, 64-17-5.

Supplementary Material Available.—Listings of structure factors coordinates, and thermal parameters for **21c** will appear following these pages in the microfilm edition of this volume of the journal. Photocopies of the supplementary material from this paper only or microfiche (105 × 148 mm, 20 × reduction, negatives) containing all of the supplementary material for the papers in this issue may be obtained from the Journals Department, American Chemical Society, 1155 16th St., N.W., Washington, D. C. 20036. Remit check or money order for $3.00 for photocopy or $2.00 for microfiche, referring to code number JOC-73-3077.

Synthesis of 1,2-Diaminobenzimidazole, 1*H*-*s*-Triazolo[1,5-*a*]benzimidazoles, and *as*-Triazino[2,3-*a*]benzimidazoles

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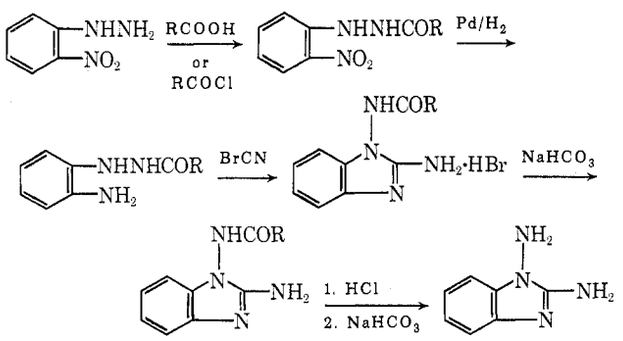
The preparations of 1,2-diaminobenzimidazole, a new compound, and of two new ring systems, 1*H*-*s*-triazolo[1,5-*a*]benzimidazole and *as*-triazino[2,3-*a*]benzimidazole, are reported.

Although 1-aminobenzimidazoles are relatively well-known compounds[1] and 2-aminobenzimidazoles have been known for a longer period of time,[2] nothing has been reported on 1,2-diaminobenzimidazole and its derivatives. The 1,2-diaminobenzimidazoles are readily obtained from *o*-acylhydrazidoanilines and cyanogen bromide.



The *o*-nitrophenylhydrazines were obtained from the corresponding *o*-nitroanilines by diazotization followed by reduction with sodium bisulfite.[3] The catalytic hydrogenation proceeded smoothly as long as the *o*-acylhydrazidonitrobenzene was pure. The ring-closure step was carried out by adding the cyanogen bromide to a suspension of the *o*-acylhydrazidoaniline in water. All of the ring compounds, isolated from the cyanogen bromide reactions, had the uv absorptions characteristic of benzimidazoles, namely 240–250 mμ for the amidine group and 280–300 mμ for the benzenoid portion.[4]

Heating the 1-acylamido-2-aminobenzimidazoles with acid anhydrides or acid chlorides produced 1*H*-*s*-triazolo[1,5-*a*]benzimidazoles (a new ring system). The R groups at positions 1 and 2 were always found to be identical with the R group of the acid anhydride or chloride.[1b] It would appear from this observation that ring closure is slow compared to the rate of trans acylation. It is interesting to note that the action of hydrochloric acid on the 1-acylamido-2-aminobenzimidazoles did not bring about the formation of the triazolo compound (Phillips method).[5]

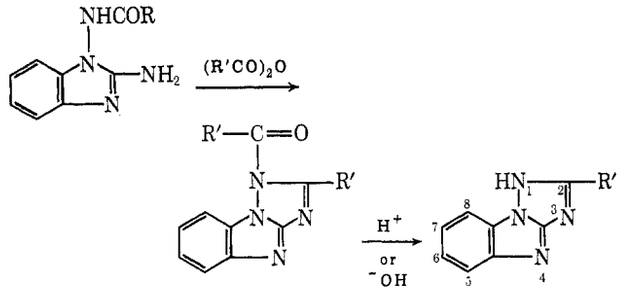
(1) (a) R. A. Abramovitch and K. Schofield, *J. Chem. Soc.*, 2326 (1955); (b) M. N. Sheng and A. R. Day, *J. Org. Chem.*, **28**, 736 (1963).

(2) N. J. Leondard, D. Y. Curtin, and K. M. Beck, *J. Amer. Chem. Soc.*, **69**, 2459 (1947).

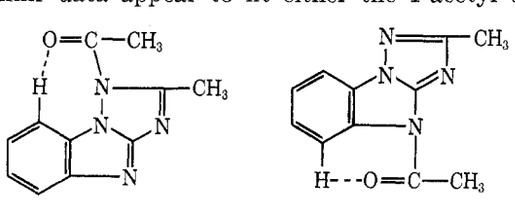
(3) W. Davis, *J. Chem. Soc.*, **121**, 720 (1922); C. Montigel and T. Reichstein, *Helv. Chim. Acta*, **20**, 1468 (1937).

(4) K. Hofmann, Ed., "Imidazole and Derivatives," part 1, Interscience, New York, N. Y., 1953, p 253; A. Mangini and F. Montanari, *Bull. Sci. Fac. Chim. Ind. Bologna*, **14**, 36 (1956).

(5) M. A. Phillips, *J. Chem. Soc.*, 3134 (1928); 2820 (1929); 1409 (1930).

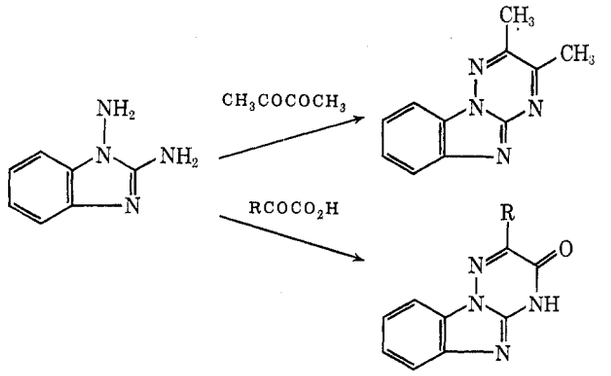


Owing to the tautomeric nature of 1*H*-*s*-triazolo[1,5-*a*]benzimidazole, there are three theoretically possible isomeric structures for the monoacyl derivatives. The assignment of the acyl group to the 1 position is therefore somewhat arbitrary. Only a single isomer was obtained by ring closure and the same isomer was obtained by acylation of 1*H*-*s*-triazolo[1,5-*a*]benzimidazole. The nmr spectrum ($CHCl_3$) for the acetyl derivative shows a singlet at δ 2.46 (3 H, CH_3CO), a singlet at 2.83 (3 H, CH_3), a multiplet centered at 7.4 (3 H, aromatic), and a multiplet centered at 8.5 (1 H, in 8 or 5 position). The unusual shift of one proton is probably due to a long-range anisotropic effect. This shift was noted only for the acyl derivatives and was not observed for 1*H*-*s*-triazolo[1,5-*s*]benzimidazole or its 2-alkyl derivatives. The nmr data appear to fit either the 1-acetyl or 4-



acetyl derivative. Benzylation of 1*H*-*s*-triazolo[1,5-*a*]benzimidazole also gave only one isomer.

1,2-Diaminobenzimidazole reacted with 2,3-butanedione to form 2,3-dimethyl-*as*-triazino[2,3-*a*]benzimidazole. Reactions with pyruvic acid and benzoylformic acid gave 2-methyl-*as*-triazino[2,3-*a*]benzimidazol-3(4*H*)-one and 2-phenyl-*as*-triazino[2,3-*a*]benzimidazol-3(4*H*)-one, respectively. The dialkyl derivatives were yellow solids while the derivatives of the α-keto acids were colorless solids which show an intense amide carbonyl at 1700 cm^{-1}.



Experimental Section

Melting points, up to 270°, were taken on a Thomas-Hoover capillary melting point apparatus. Above 270°, they were taken on a copper block melting point apparatus. The melting points are uncorrected. Ir spectra were obtained with a Perkin-Elmer Model 521 spectrophotometer and uv spectra were measured with a Cary 14 spectrophotometer. Nmr spectra were determined at 60 Mcps on a Varian Associates NMR Model HA-60.

1-Formamido-2-aminobenzimidazole Hydrobromide (1).—A solution of 1.5 g (0.0142 mol) of cyanogen bromide in a little water was added to a suspension of 2.12 g (0.0142 mol) of *o*-formylhydrazidoaniline[1b] in 30 ml of water. The mixture was stirred for 2 hr at 0° and then for 5 hr at room temperature. The solvent was removed under reduced pressure. The residual dark oil was triturated alternately with dry ethanol and dry benzene until it solidified, yield 85%. We were unable to purify this compound because of its hygroscopic nature. That it was at least 95% pure 1-formamido-2-aminobenzimidazole hydrobromide was shown by the fact that a 95% yield of monopicrate was obtained in methanol solution. This is the yield after recrystallization from water–dimethylformamide: mp 270–275°.

Anal. Calcd for $C_{14}H_{11}N_7O_8$: C, 41.50; H, 2.70; N, 24.10. Found: C, 41.31; H, 2.54; N, 24.23.

1-Acetamido-2-aminobenzimidazole Hydrobromide (2).—The acetamido derivative was prepared from *o*-acethydrazidoaniline[1b] by the procedure used for compound **1**. The residue from the evaporation of the solvent was washed with dry ether and dry acetone and recrystallized from acetonitrile: yield 90% mp 244–246°.

Anal. Calcd for $C_9H_{11}BrN_4O$: C, 39.86; H, 4.09; N, 20.66; Br, 29.47. Found: C, 39.61; H, 4.03; N, 20.43; Br, 29.27.

1-Acetamido-2-aminobenzimidazole Hydrate (3).—An aqueous solution of **2** was neutralized with sodium bicarbonate to precipitate the free base which was recrystallized from water. It was isolated as a monohydrate: yield 82%; mp 224–226°; ir (KBr) strong band at 1700 cm^{-1} (amide carbonyl); nmr (DMSO) singlet at δ 2.06 (3 H, CH_3), singlet at 6.45 (2 H, NH_2), multiplet centered at 7.0 (4 H, aromatic), singlet at 10.5 (1 H, HNC=O). The amide proton, being adjacent to two electron-withdrawing groups, absorbs more downfield than the phenyl protons. The 2-amino and 1-amido proton absorptions disappeared in the presence of D_2O.

Anal. Calcd for $C_9H_{12}N_4O_2$: C, 51.92; H, 5.77; N, 26.92. Found: C, 51.96; H, 5.97; N, 26.96.

The monopicrate, prepared in methanol solution, was recrystallized from acetonitrile: mp 276–283°.

Anal. Calcd for $C_{15}H_{13}N_7O_8$: C, 42.96; H, 3.10; N, 23.39. Found: C, 43.06; H, 3.24; N, 23.23.

1-Propionamido-2-aminobenzimidazole Hydrobromide (4).—Compound **4** was prepared from *o*-propionhydrazidoaniline[1b] by the procedure used for preparing compound **2**: yield 66%, mp 221–223°.

Anal. Calcd for $C_{10}H_{13}BrN_4O$: C, 42.28; H, 4.55; N, 19.66; Br, 28.04. Found: C, 42.18; H, 4.69; N, 19.49; Br, 28.02.

1-Propionamido-2-aminobenzimidazole (5).—Free base **5** was prepared from hydrobromide **4** by neutralization with sodium bicarbonate and recrystallization from ethyl acetate: yield 83%, mp 171–173°.

Anal. Calcd for $C_{10}H_{12}N_4O$: C, 58.82; H, 5.88; N, 27.42. Found: C, 59.01; H, 5.75; N, 27.25.

1-Benzamido-2-aminobenzimidazole Hydrobromide (6).—Compound **6** was prepared from *o*-benzoylhydrazidoaniline[1b] by the procedure used for preparing compound **2**: yield 80%, mp 245–247°.

Anal. Calcd for $C_{14}H_{13}BrN_4O$: C, 50.43; H, 3.93; N, 16.81; Br, 23.98. Found: C, 50.59; H, 4.01; N, 16.79; Br, 24.06.

The monopicrate, prepared in methanol solution, was recrystallized from acetonitrile: mp 270–280°.

Anal. Calcd for $C_{20}H_{15}N_7O_8$: C, 49.89; H, 3.13; N, 20.37. Found: C, 50.1; H, 3.29; N, 20.23.

1,2-Diaminobenzimidazole (7).—The 1,2-diamino compound may be prepared by hydrolyzing any of the 1-acylamido-2-aminobenzimidazoles or their hydrobromides. The following is an example. 1-Acetamido-2-aminobenzimidazole hydrobromide (0.5 g) was dissolved in 60 ml of 4 *N* hydrochloric acid and the solution was refluxed for 1 hr. On cooling the hydrochloride separated. The salt was dissolved in water and the solution was neutralized with sodium bicarbonate to precipitate the free base. The free base was recrystallized from ethanol: yield 70%; mp 256–259°; ir (KBr) showed no carbonyl absorption, strong N–H stretching absorptions at 3375 and 3500 cm^{-1};

nmr (DMSO) singlet at δ 5.52 (2 H, 1-NH_2), singlet at 6.15 (2 H, 2-NH_2), multiplet centered at 7.1 (4 H, aromatic protons).

Anal. Calcd for $C_7H_8N_4$: 56.75; H, 5.42; N, 37.92. Found: C, 56.80; H, 5.52; N, 37.76.

1-Acetyl-2-methyl-1*H*-*s*-triazolo[1,5-*a*]benzimidazole (8).—1-Acetamido-2-aminobenzimidazole hydrobromide (0.5 b, 0.0018 mol) was dissolved in 60 ml of acetic anhydride and the solution was refluxed for 5 hr. The solution was reduced to 5–10 ml under reduced pressure. An oil separated which solidified on cooling. The solid was recrystallized from acetonitrile: yield 71%; mp 154–155°; ir (KBr) strong band at 1700 cm^{-1} for amide carbonyl.

Anal. Calcd for $C_{11}H_{10}N_4O$: C, 61.70; H, 4.67; N, 26.17. Found: C, 61.67; H, 4.58; N, 25.98.

2-Methyl-1*H*-*s*-triazolo[1,5-*a*]benzimidazole (9).—1-Acetyl-2-methyl-1*H*-*s*-triazolo[1,5-*a*]benzimidazole (0.5 g) was dissolved in 80 ml of hydrochloric acid and the solution was refluxed for 2 hr. The solution was evaporated to 10–15 ml and neutralized with sodium bicarbonate. The precipitate was removed, washed with water, and recrystallized from acetonitrile: yield 80%; mp 258–259°; nmr (CD_3COOD) singlet at δ 2.5 (3 H, CH_3), multiplet centered at 7.5 (4 H, aromatic).

Anal. Calcd for $C_9H_8N_4$: C, 62.78; H, 4.65; N, 32.56. Found: C, 62.64; H, 4.53; N, 32.47.

1-Propionyl-2-ethyl-1*H*-*s*-triazolo[1,5-*a*]benzimidazole (10).—1-Propionamido-2-aminobenzimidazole hydrobromide was refluxed with propionic anhydride. The procedure for **8** was followed to obtain **10**: yield 71%; mp 111–113°; ir (KBr) 1700 cm^{-1} (amide carbonyl); nmr ($CDCl_3$) triplet at δ 1.37 (3 H, 2-CH_3), quartet at 2.9 (2 H, 2-CH_2), triplet at 1.42 (3 H, 1-CH_3), quartet at 3.4 (2 H, 1-CH_2), multiplet at 7.55 (3 H, aromatic protons 5, 6, 7), singlet at 8.55 (1 H, aromatic proton 8).

Anal. Calcd for $C_{13}H_{14}N_4O$: C, 64.47; H, 5.80; N, 23.14. Found: C, 64.34; H, 5.84; N, 23.00.

2-Ethyl-1*H*-*s*-triazolo[1,5-*a*]benzimidazole (11).—This compound was prepared from **10** by the procedure used for making **9**. The product was recrystallized from ethyl acetate: yield 66%; mp 198–200°: nmr (CD_3COOD) triplet at δ 1.4 (3 H, 2-CH_3), quartet at 2.85 (2 H, 2-CH_2), multiplet at 7.55 (4 H, aromatic protons).

Anal. Calcd for $C_{10}H_{10}N_4$: C, 64.45; H, 5.41; N, 30.00. Found: C, 64.51; H, 5.31; N, 30.19.

1-Benzoyl-2-phenyl-1-*H*-*s*-triazolo[1,5-*a*]benzimidazole (12).—1-Benzamido-2-aminobenzimidazole (0.5 g) was dissolved in 60 ml of benzoyl chloride and the solution was refluxed for 5 hr. The solution was distilled under reduced pressure to 5–10 ml and the resulting oil was cooled until it solidified. The product was washed with dry ether and recrystallized from acetonitrile: yield 83%; mp 230–232°; ir (KBr) 1700 cm^{-1} (amide carbonyl); nmr ($CDCl_3$) multiplet at δ 7.37 (3 H, protons 5, 6, 7), multiplet at 7.54 (5 H, C_6H_5), multiplet at 8.04 (5 H, $C_6H_5C{=}O$), multiplet at 8.43 (1 H, proton 8).

Anal. Calcd for $C_{20}H_{14}N_4$: C, 77.40; H, 4.54; N, 18.05. Found: C, 77.51; H, 4.65; N, 17.88.

2-Phenyl-1*H*-*s*-triazolo[1,5-*a*]benzimidazole (13).—1-Benzoyl-2-phenyl-1*H*-*s*-triazolo[1,5-*a*]benzimidazole (0.5 g) was dissolved in 40 ml of 10% sodium hydroxide and the solution was refluxed for 2 hr. The solution was evaporated almost to dryness and the residue was extracted with ethyl acetate. Distillation of the ethyl acetate left a colorless solid which was recrystallized from ethanol: yield 60%; mp 310–315°; nmr (CD_3COOD) multiplet at δ 7.54 (4 H, aromatic), multiplet at 8.00 (5 H, aromatic).

Anal. Calcd for $C_{14}H_{10}N_4$: C, 71.78; H, 4.27; N, 23.92. Found: C, 71.84; H, 4.15; N, 23.76.

1-Benzyl-2-phenyl-1*H*-*s*-triazolo[1,5-*a*]benzimidazole (14).—2-Phenyl-1*H*-*s*-triazolo[1,5-*a*]benzimidazole (0.63 g, 0027 mol) was dissolved in dry dimethylformamide. Sodium hydride (0.065 g, 0.0077 mol) was added gradually with stirring. The mixture was gently refluxed for 40 min and 0.38 g (0.003 mol) of benzyl chloride was added. Refluxing was continued for 2 hr and the solution was cooled to 5°. The addition of 10 ml of water precipitated a solid which was recrystallized from *n*-hexane: yield 50%; mp 130–132°; nmr (CCl_4) singlet at δ 5.38 (2 H, CH_2), multiplet at 7.20 (4 H, aromatic), multiplet at 7.30 (5 H, 2-phenyl group), multiplet at 7.82 (5 H, C_6H_5 of benzyl).

Anal. Calcd for $C_{21}H_{16}N_4$: C, 77.75; H, 4.97; N, 17.27. Found: C, 77.65; H, 5.10; N, 17.27.

2,3-Dimethyl-*as*-triazino[2,3-*a*]benzimidazole (15).—1,2-Diaminobenzimidazole (0.5 g, 0.0035 mol) was dissolved in 60 ml of methanol. A solution of 0.43 g (0.005 mol) of 2,3-butanedione in methanol was added and the solution was refluxed for 2 hr. The methanol was removed *in vacuo* and the residue was recrystallized from ethanol: yield 58%; yellow crystals; mp 236–239°; ir showed no carbonyl or NH absorption.

Anal. Calcd for $C_{11}H_{10}N_4$: C, 66.65; H, 5.09; N, 28.27. Found: C, 66.65; H, 5.08; N, 28.25.

2-Methyl-*as*-triazino[2,3-*a*]benzimidazol-3(4*H*)-one (16).—Pyruvic acid was used in place of 2,3-butanedione and ethanol was the solvent. The product was recrystallized from dimethylformamide: yield 72%, colorless crystals, mp 350–355°.

Anal. Calcd for $C_{10}H_8N_4O$: C, 59.99; H, 4.20; N, 27.82. Found: C, 59.80; H, 4.01; N, 27.76.

2-Phenyl-*as*-triazino[2,3-*a*]benzimidazol-3(4*H*)-one (17).—Benzoylformic acid was used in place of 2,3-butanedione and ethanol was the solvent. The product was recrystallized from dimethylformamide–water: yield 68%, colorless crystals, mp 355–358°.

Anal. Calcd for $C_{15}H_{10}N_4O$: C, 68.67; H, 3.84; N, 21.36. Found: C, 68.48; H, 3.84; N, 21.30.

Registry No.—**1**, 40697-60-7; **1** monopicrate, 40697-61-8; **2**, 40697-62-9; **3**, 40697-63-0; **3** monopicrate, 40697-64-1; **4**, 40697-65-2; **5**, 40697-66-3; **6**, 40697-67-4; **6** monopicrate, 40697-68-5; **7**, 29540-87-2; **8**, 40935-54-4; **8** 4-acetyl tautomer, 40697-70-9; **9**, 40697-71-0; **10**, 40697-72-1; **10** 4-propionyl tautomer, 40697-73-2; **11**, 40697-74-3; **12**, 40736-41-2; **12** 4-benzoyl tautomer, 40736-42-3; **13**, 40697-75-4; **14**, 40697-76-5; **15**, 40697-77-6; **16**, 40697-78-7; **17**, 40697-79-8; **18**, 40697-80-1; cyanogen bromide, 506-68-3; *o*-formhydrazidoaniline, 6299-89-4; *o*-acetylhydrazidoaniline, 6299-91-8; *o*-propionylhydrazidoaniline, 40697-83-4; *o*-benzoylhydrazidoaniline, 6299-88-3; acetic anhydride, 108-24-7; propionic anhydride, 123-62-6; benzoyl chloride, 98-88-4; 2,3-butanedione, 431-03-8; 2,3-pentanedione, 600-14-6; pyruvic acid, 127-17-3; benzoylformic acid, 611-73-4.