

1,2,3-Benzotriazines. IV.
The Chemical Reactivity of Benzimidazo[1,2-c][1,2,3]benzotriazine (1)

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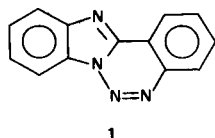
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Dedicated to Professor Allan R. Day

The reactions of benzimidazo[1,2-c][1,2,3]benzotriazine (1) with fluoroboric acid, potassium iodide and phenyl isothiocyanate are described. The structure of the phenyl isothiocyanate product is elucidated by chemical and spectroscopic techniques. The reaction of 1 with alcoholic potassium hydroxide is shown to proceed by a free radical mechanism. The structure of the compound formed from 1 and sodium diethyl malonate is investigated by spectroscopic methods. The reduction and photochemical reactivity of 1 are also discussed.

Although the 1,2,3-benzotriazine system has been known for a long time, the parent ring has never been prepared and the reactions of this class of heterocycles have not been thoroughly studied. The 1,2,3-triazine ring is easily opened and it is generally assumed that, in acid medium, the reactions of 1,2,3-benzotriazines are similar to those of benzenediazonium salts (3). 3-Amino-1,2,3-benzotriazin-4-one has been shown to generate a diazonium ion, in acidic solution. This ion was intercepted by β -naphthol (Bamberger-Goldberger test) (4). The reactions of 1,2,3-benzotriazines, in alkaline medium, have all been carried out on 4-oxo derivatives. The presence of an amide carbonyl in the ring alters the molecule sufficiently to prevent any conclusions as to the behavior of the 1,2,3-triazine ring under basic conditions.

While 1,2,3-benzotriazines are very stable and can be heated up to and sometimes above their melting point without decomposition, only the most stabilized diazonium salts can be handled at room temperature. Thus, the possibility of using 1,2,3-benzotriazines as potential diazonium salts is of interest. The present work was undertaken to explore this possibility in connection with the benzimidazo[1,2-c][1,2,3]benzotriazine system (1). This



condensed 1,2,3-triazine was chosen because of its ease of preparation and reactivity, as indicated by preliminary studies (5, 6, 7). To examine the similarity between the

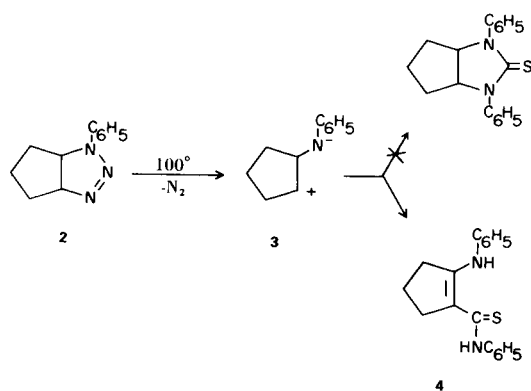
reactions of 1 and those of the corresponding diazonium ions, a general study of the reactivity of 1 was in order. The scope of this study was to clarify the modes of decomposition of 1 in acid and basic medium, and to study the ease of cleavage of the 1,2,3-triazine ring by various reducing agents and by light.

RESULTS AND DISCUSSION

In acid media, substituted benzimidazo[1,2-c][1,2,3]benzotriazines have been reported to undergo scission of the triazine ring, followed by elimination of nitrogen and formation of 2-(2'-substituted phenyl)benzimidazoles (7). These reactions were in every way similar to those of diazonium salts. The Sandmeyer reaction was also tried on 1 and found to occur very readily with little or no formation of by-products, unlike the corresponding reactions of benzenediazonium salts with cuprous halides (7). To further test the ability of 1 to undergo nucleophilic replacements typical of aromatic diazonium salts, the Balz-Schiemann reaction and the replacement with iodide were attempted. Both of these reactions were successful and they offer a better synthetic route to 2-(*o*-fluorophenyl)- and 2-(*o*-iodophenyl)benzimidazoles than the previous methods (8, 9).

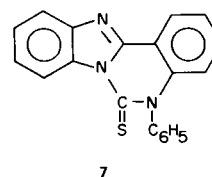
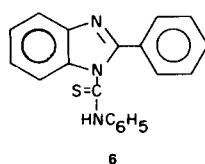
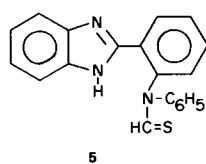
A more novel replacement was attempted with phenyl isothiocyanate. The thermolytic evolution of nitrogen from Δ^2 -1,2,3-triazolines such as 2 was held by Huisgen to form a 1,3-dipole (3) which could undergo a 1,3-dipolar cycloaddition with phenyl isocyanate or phenyl isothiocyanate to yield the corresponding symmetrical diphenyl urea or thiourea (10). The structure of the phenyl isothiocyanate product was later shown to be 2-anilino-cyclo-

pentene-1-thiocarbonyl (4) (11, 12). Although the

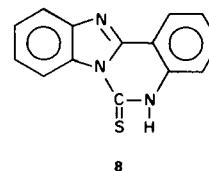


mechanistic path of these reactions is not completely settled, particularly in the case of the phenyl isocyanate product, the correct structural assignment of the products clearly indicates that caution must be used before reactions are said to occur by a presumed mechanistic scheme (11). The controversial nature of this reaction led us to investigate a similar thermal decomposition for 1. When 1 was heated in *o*-dichlorobenzene either with phenyl isocyanate or phenyl isothiocyanate, as reported for the Δ^2 -1,2,3-triazolines, it was recovered quantitatively. These results were not totally unexpected since 1 is quite stable at high temperatures. However, it had been previously observed that ring cleavage could occur at these temperatures in the presence of a trace of mineral acid. Therefore, an attempt was made to catalyze the ring opening by addition of a trace amount of acid to the hot solutions of 1 with phenyl isocyanate or isothiocyanate. It was hoped that ring cleavage could compete with the known dimerization of isocyanates and isothiocyanates under these conditions. When phenyl isocyanate was used, only carbanilide, the known dimerization product of phenyl isocyanate in aqueous mineral acid, and a trimer of phenyl isocyanate were isolated. However, with phenyl isothiocyanate a white solid was formed and shown to be the desired adduct. The success of this reaction can be attributed to the slower dimerization of phenyl isothiocyanate, in the presence of mineral acids, as compared to phenyl isocyanate.

The most probable structures which could be postulated for the adduct of 1 with phenyl isothiocyanate, are 5, 6, and 7. The analytical data indicated an empirical

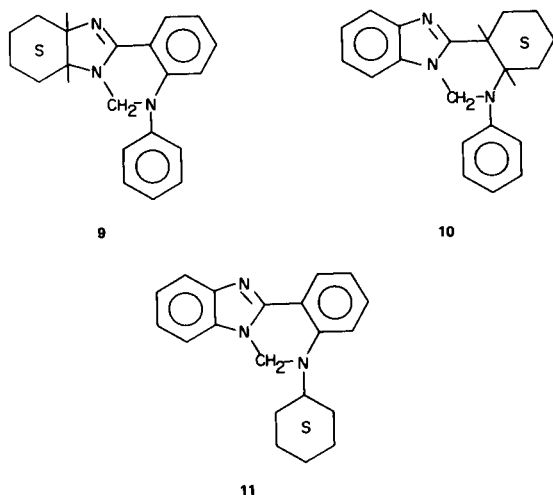


formula of C₂₀H₁₃N₃S and the mass spectrum showed a parent ion of 327 mass units. These results are in agreement with structure 7 only since 5 and 6 have two extra hydrogens. In addition, the ir spectrum of the adduct did not show a N-H absorption whether it was examined as a potassium bromide disc or as a Nujol mull or in chloroform solution. Such an absorption would have been expected for 5 or 6. The nmr spectrum showed only a phenyl multiplet at δ 7.2-9.5. The uv spectrum showed maxima at λ max (methanol) $m\mu$, (log ϵ): 239 (4.60), 297 (4.32), 310 (4.31), 323 (4.14), and 340 (4.07). The information pointed to 5-phenylbenzimidazo[1,2-*c*]quinazoline-6(5*H*)-thione (7) as the correct structure. To further characterize this compound its chemical reactivity was investigated. Compound 7 was inert to both benzenesulfonyl chloride and ethyl chloroformate, which would have been expected to react with a free NH group. Attempts to hydrolyze 7 with both dilute and concentrated hydrochloric or sulfuric acids led to a quantitative recovery of starting material. This behavior is consistent with that of the unsubstituted benzimidazo[1,2-*c*]quinazoline-6(5*H*)-thione (8). Compound 8 was prepared by



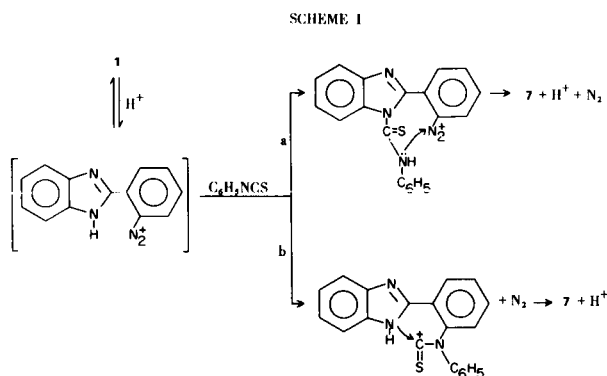
Niementowski from 2-(2'-aminophenyl)benzimidazole and carbon disulfide, and shown to be inert to acids and alkalis (13).

The desulfurization of 7 with W-4 Raney nickel yielded unexpected results. The empirical formula of the product was C₂₀H₂₁N₃ instead of the expected C₂₀H₁₅N₃. This could only be explained by the reduction of a benzene ring in addition to desulfurization. Similar reductions have been previously observed in desulfurizations with Raney nickel (14, 15). The appearance of cyclohexyl protons at δ 0.6-1.6, in addition to the expected methylene protons at δ 3.0, in the nmr spectrum, as well as the observed CH stretching absorptions at 2960 and 2850 cm⁻¹ in the ir spectrum, confirmed the presence of a reduced ring. Three possible structures, 9, 10, and 11 could be assigned to this product.

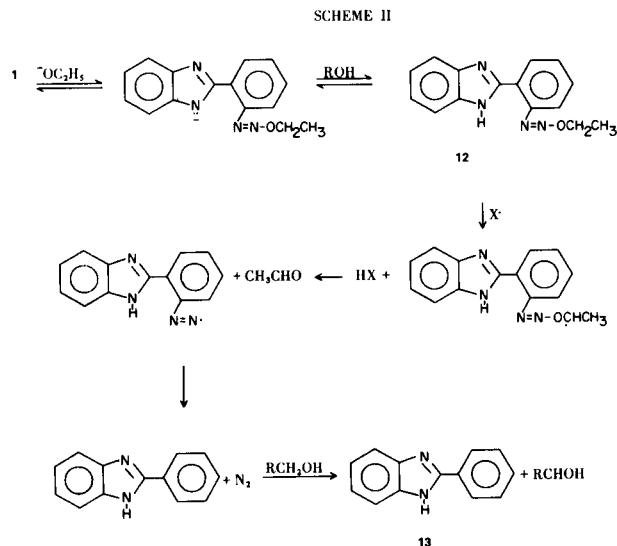


Structure **11** best fits the data since it does not involve the reduction of the stable 2-phenylbenzimidazole system. Although 2-phenylbenzimidazole has been shown to yield 2-cyclohexylbenzimidazole on catalytic reduction with platinum, the reduction of a benzimidazole ring is usually difficult (16). Furthermore, structure **11** is the only one consistent with the uv spectrum which shows maxima at λ_{max} (methanol) $m\mu$ ($\log \epsilon$): 243 (4.19), 275 (4.17), 281 (4.25), 290sh (4.23), 302 (4.25), 315sh (4.00). This spectrum shows the presence of the 2-phenylbenzimidazole chromophore which has maxima at λ_{max} , $m\mu$ ($\log \epsilon$): 250 (4.09), 294sh (4.33), 301 (4.36), 315sh (4.13). The long wavelength absorptions at 301 and 315 $m\mu$ are not present in the 2-phenylimidazole chromophore (17) which exists in **9** or in the benzimidazole chromophore (18) present in **10**.

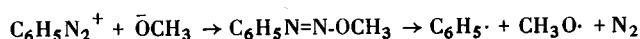
Thus, the replacement of the diazo group of **1** by phenyl isothiocyanate appears to be a characteristic reaction of this system to produce a six-membered ring. The mechanism of this reaction is probably similar to that of other acid-catalyzed replacements. Possible mechanistic paths (a or b) are shown in Scheme I.



The stability of **1** in basic medium had never been investigated. The reaction of **1** with ethanolic potassium hydroxide yielded 2-phenylbenzimidazole (**13**). A mechanism based on the data available for this reaction and consistent with current theories for the reactions of diazonium salt in basic media is postulated in Scheme II.



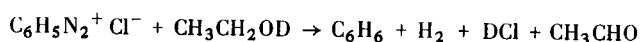
The first step is an ionic process which involves attack by the base on the triazine ring. Attempts to initiate the reaction with free radical initiators, in the absence of base, failed completely. The dependence of the reaction rate on the base concentration showed that the base was an integral part of the mechanism. The diazo ether formed (**12**) is shown to decompose subsequently by a radical induced chain reaction. The possibility that the diazo ether is decomposing spontaneously must also be considered. For instance, DeTar postulates the decomposition of diazonium salts in basic medium as follows (19):



The subsequent steps are a radical chain process. This process appears reasonable for aromatic diazonium salts since in the absence of oxygen the product mixture was almost colorless and 98% or more of the diazonium salt was converted to benzene. In the presence of oxygen, a dark brown mixture was obtained and the products formed, only accounted for 30-75% of the diazonium salt used (19). However, in the case of **1**, oxygen and other known radical inhibitors or trapping agents such as nitrogen dioxide or diphenylpicrylhydrazyl radical completely inhibited the reaction and **1** could be recovered quantitatively. More specifically, nitrogen dioxide should have produced a significant amount of 2-(2'-nitrophenyl)-benzimidazole by a spontaneous process, but in this case

also, **1** was the only product isolated. Thus, these trapping agents are behaving as scavengers. A small amount of azobisisobutyl nitrile, a known radical initiator, increased the reaction rate by a threefold factor. This may be explained by the ability of this compound to produce radicals to initiate the reaction. Finally, when the reaction was carried out in an ESR-3 spectrometer, a signal was produced at $g = 2.0$ with a line width of 21 gauss. This value is typical of an organic free radical.

Rekasheva and Miklukhim (20) have shown that where diazonium salts are reacted with ethanol, the abstracted hydrogen does not come from the OH bond but rather from the α -carbon. The formation of acetaldehyde is

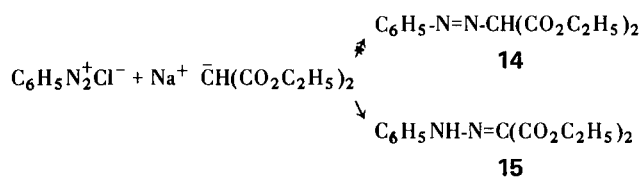


consistent with the postulated mechanism and has been observed by other investigators (21, 22). In the case of **1**, the small amount of acetaldehyde which would be formed would be hard to identify under the strongly basic conditions which prevailed. Thus, the formation of this product was not proved conclusively.

A variety of alkoxides were treated with **1**. Primary and secondary alkoxides such as *n*-amyl and isopropyl alkoxides gave **13** in yields comparable to those of the original reaction. When tertiary alkoxides such as *t*-butyl or *t*-amyl alkoxides were used, **1** was recovered quantitatively. This observation could be attributed to the absence of an α -hydrogen for oxidation or to steric inhibition of the initial rate determining step.

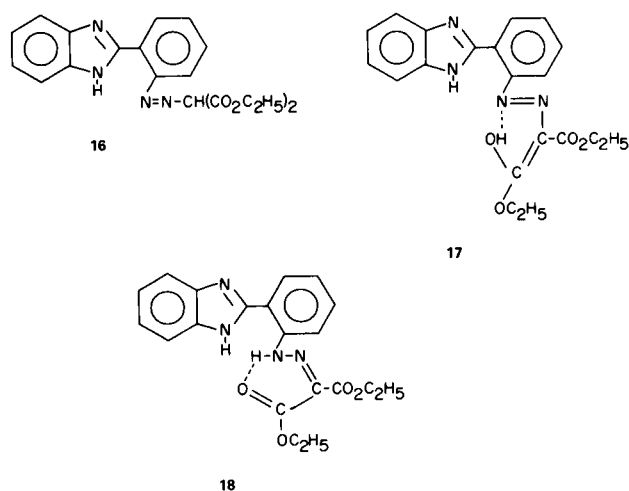
The use of other organic anions was attempted next, in order to determine the scope of this reaction and possibly to trap the diazo intermediate. The reaction of **1** with the acetate anion was attempted. *N,N*-Phenylnitrosoacetanilide and phenyldiazoic acid both react with ethanol to give benzene, nitrogen and acetaldehyde. It was shown that *N,N*-phenylnitrosoacetanilide first rearranges to the corresponding phenyldiazoacetate which then decomposes by a free radical mechanism (23). Thus, it was anticipated that the reaction of **1** with acetate would be similar to that of the ethoxide ion. In the case of the cyanide ion, it was hoped that a stable diazocyanide would be formed. Actually, both reactions resulted in a quantitative recovery of **1**, showing that cleavage of the triazine ring is not facile in a weakly basic medium. The use of a stronger basic anion such as sodium diethylmalonate resulted both in ring cleavage and in the formation of a stable intermediate.

When benzenediazonium chloride was treated with diethylmalonate the product obtained was found to have structure **15** rather than **14** (24). This observation started



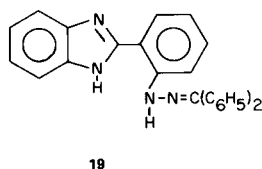
the controversial subject of the azo-hydrazone equilibrium which could not be solved satisfactorily before the advent of spectroscopic techniques.

The yellow solid obtained from **1** and sodium diethylmalonate had an empirical formula of $\text{C}_{20}\text{H}_{20}\text{N}_4\text{O}_4$ and a molecular weight of 380. Three possible structures could be considered for this product, **16**, **17**, or **18**.



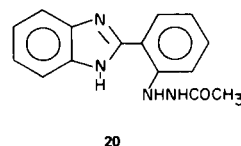
In structure **17**, the OH group could be hydrogen bonded to the azo group, as shown, or to the ester group. The nmr spectrum, in deuterated chloroform, showed the presence of two methylenes from the ethyl group at δ 4.5, eight protons at δ 6.8-7.8 as a multiplet from the phenyl groups and two exchangeable protons at δ 11.0 and 14.5, respectively. The coupling constant of the two ethyl groups is consistent with the reported values for diethylmalonate and derivatives (25). The absence of an absorption due to a methine proton eliminates **16**. The exchangeable proton at δ 11.0 could be assigned to the imidazole proton. Dilution studies indicated that the exchangeable proton at δ 14.5 was hydrogen-bonded. The mass spectrum gave, along with a molecular weight at 380, peaks at 335 (loss of OC_2H_5), 307 (loss of $-\text{C}(\text{O})\text{OC}_2\text{H}_5$), 261 (loss of $-\text{C}(\text{O})\text{OC}_2\text{H}_5 + \text{C}_2\text{H}_5\text{OH}$) and 187 (loss of 2-phenylbenzimidazole). These results appear more consistent with **18** than **17**. The ir spectrum was run as a potassium bromide disc, in chloroform, and in

carbon tetrachloride solution. In the solid phase, a weak band occurred at 1735 cm^{-1} and a strong band occurred at 1696 cm^{-1} . Only one band is observed above 3100 cm^{-1} at 3353 cm^{-1} . Since it is difficult to make correlations in this phase, solution studies were carried out. In carbon tetrachloride solution, the carbonyl bands occurred at 1719 and 1693 cm^{-1} respectively. In the same solution, bands were observed at 3476 and 3260 cm^{-1} . The ratios of $3476/3260\text{ cm}^{-1}$ and $1719/1693\text{ cm}^{-1}$ increase with dilution. These data suggest intermolecular hydrogen bonding in concentrated solution. Intramolecular hydrogen bonded carbonyl and non-bonded carbonyl are present in more dilute solutions. The band at 1693 cm^{-1} results from a hydrogen-bonded carbonyl while the band at 1719 cm^{-1} results from a non-bonded carbonyl group. The ester carbonyl stretching is lower than that reported for diethylmalonate (25) by $40\text{--}50\text{ cm}^{-1}$ and this may be ascribed to increased conjugation which would be present in either **17** or **18**. The peak at 3476 cm^{-1} was shown to be typical of an intramolecular hydrogen bond. An intramolecularly bonded N-H does not shift to lower frequencies to the extent of an O-H bond. The considerable overlap of these two regions (O-H and N-H) makes unequivocal assignment of the peak impossible. The presence of two carbonyl groups favor **18** since **17** should have only one carbonyl. The uv spectrum showed at $\lambda\text{ max}$ (methanol) $m\mu$, ($\log \epsilon$): 246 (4.26), 302 (4.44), and 362 (4.32). A similar chromophore, **19**, has a long wavelength absorption at $366\text{ m}\mu$ (4.39). Although the data presented did not



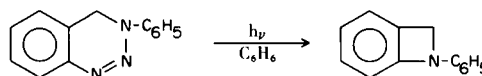
support **18** unequivocally, evidence against **17** may be found in the work of Abramovitch and co-workers who showed by ir (26) and nmr (25) studies that diethylmalonate and its derivatives do not exist in an enolic form such as the one shown in **17**.

The behavior of **1** towards a variety of reducing agents was examined. Catalytic reduction, Raney nickel, sodium and alcohol, ammonium sulfide, sodium sulfite and hydrochloric acid and sodium borohydride all yielded 2-phenylbenzimidazole (**13**). Reduction of **1** with stannous chloride and hydrochloric acid yielded 2-(2'-hydrazinophenyl)benzimidazole which although not obtained in pure form could be acetylated to yield the same product (**20**) which was formed from **1** and zinc in acetic acid. Although

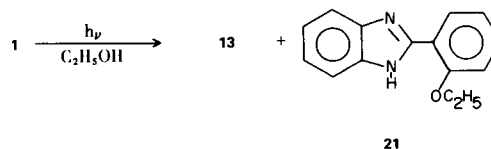


other structures could be postulated for **20**, the analytical and physical data support the structure shown. The nmr of this compound, in dimethylsulfoxide, shows three distinct NH absorptions at δ 10.2, 10.8, and 13.2.

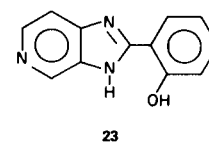
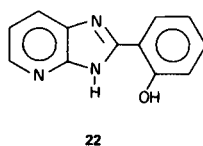
The photolysis of 3-phenyl-3,4-dihydro-1,2,3-benzotriazine, in benzene, was found to yield *N*-phenylazetidine as the major product (27).



It was thought of interest to irradiate **1** under these conditions to compare its behavior to that of this triazine. The irradiation of **1** in benzene yielded a mixture of at least five products which could not be separated. The photolysis of **1** was then tried in ethanol and two products were isolated, 2-phenylbenzimidazole (**13**) and 2-(2'-ethoxyphenyl)benzimidazole (**21**), the first one being the major product. This behavior is similar to that observed for the irradiation of *p*-nitrobenzenediazonium salts in ethanol (28). The major product formed was nitrobenzene accompanied by *p*-ethoxynitrobenzene and other products.



A preliminary investigation of the hydrolysis of some 1,2,3-triazines related to **1**, the corresponding 8- and 9-azabenzimidazobenzotriazines (29), showed that these systems behaved very much as **1**. With 6*N* sulfuric acid, these compounds yielded 2-(2'-hydroxyphenyl)imidazo[4,5-*b*]pyridine (**22**) and 2-(2'-hydroxyphenyl)imidazo[4,5-*c*]pyridine (**23**), respectively, as previously shown for **1** (7).



Thus, from the reactions investigated, we have shown that **1** and related systems behave as internal diazonium salts. Their reactions are more limited than those of a diazonium salt because of the greater stability of the 1,2,3-triazine ring but in many cases the triazines may be used advantageously in place of the corresponding diazonium salts since they are easier to handle and give better yields of products.

EXPERIMENTAL

Melting points were taken on a Thomas-Hoover apparatus. Microanalyses were carried out by Dr. Alfred Bernhardt, Max Planck Institute, 433 Mulheim, West Germany. Ir spectra were determined on a Perkin-Elmer double beam 521 recording spectrophotometer. Nmr spectra were determined on a Varian A-60 or HA-60 spectrometer as 5-10% solutions in appropriate solvents with tetramethylsilane as an internal standard. Chemical shifts are reported as δ values in parts per million. Ultraviolet spectra were recorded with a Cary Model 14 spectrophotometer using 1 cm quartz cells.

Reaction of **1** with Fluoroboric Acid.

A solution of **1** (8.4 g., 0.038 mole) and 140 ml. of 48-50% fluoroboric acid was heated at reflux for 3 hours and allowed to stand overnight. The solid which separated was collected by filtration, dissolved in water and this solution was neutralized with sodium bicarbonate. The solid obtained was then sublimed at 125-130° (2 mm.) to yield 3.2 g. (40%) of 2-(*o*-fluorophenyl)-benzimidazole, m.p. 206-207° (lit. m.p. (8) 207°). The ir spectrum of this compound showed ν max 1582, 1490, 1441, 1404, 1212, 1092, 968, 759, 745, and 735 cm^{-1} (potassium bromide). The uv spectrum exhibited λ max (methanol) $m\mu$ (log ϵ): 231 (4.16), 238 (4.13), 293 (4.28), 307 (4.30), 327 (3.97).

Anal. Calcd. for $\text{C}_{13}\text{H}_9\text{FN}_2$: C, 73.57; H, 4.27; N, 13.20; F, 8.95. Found: C, 73.43; H, 4.38; N, 13.29; F, 8.72.

Reaction of **1** with Potassium Iodide.

To a stirred solution of **1** (2.0 g., 0.0091 mole) in 100 ml. of glacial acetic acid was added dropwise, 20 ml. of 1 *M* potassium iodide. The reaction mixture was stirred at room temperature for 3 hours, the solid residue was removed by filtration, and the solution was neutralized with ammonium hydroxide. The solid was recrystallized from benzene to yield 1.9 g. (63.3%) of 2-(*o*-iodophenyl)benzimidazole as white needles, m.p. 236-238° (lit. m.p. (9) 258°). The ir spectrum of this compound showed ν max 1456, 1421, 1398, 1273, 1010, 969, 758, 748 and 737 cm^{-1} (potassium bromide). The uv spectrum exhibited λ max (methanol) $m\mu$ (log ϵ): 229 (4.26), 276 (4.06), 282 (4.11).

Anal. Calcd. for $\text{C}_{13}\text{H}_9\text{IN}_2$: C, 48.77; H, 2.83; N, 8.75; I, 39.64. Found: C, 48.92; H, 2.74; N, 8.65; I, 39.68.

Reaction of **1** with Phenyl Isothiocyanate.

A solution of **1** (6.1 g., 0.028 mole) and phenyl isothiocyanate (21.0 g., 0.17 mole) in *o*-dichlorobenzene was heated to 170°. Concentrated hydrochloric acid (1 ml.) was added dropwise, the solution was heated for an additional hour and allowed to stand overnight. The precipitate which formed was collected and recrystallized from carbon tetrachloride to yield 3.2 g. (36.6%) of benzimidazo[1,2-*c*]quinazoline-6(5*H*)-thione (**8**), m.p. 255-256.5°. The ir spectrum of **8** showed ν max 3049, 1618, 1587, 1438, 1356, 1337, 1152, 939, 751, 739, and 687 cm^{-1} (potassium

bromide). The uv spectrum exhibited λ max (methanol) $m\mu$ (log ϵ): 239 (4.60), 297 (4.32), 310 (4.31), 323 (4.14), 340 (4.07). The nmr spectrum of **8** in trifluoroacetic acid showed absorptions at δ 7.0-9.1 (complex, aromatic). The mass spectral molecular ion was at m/e 327.

Anal. Calcd. for $\text{C}_{20}\text{H}_{13}\text{N}_3\text{S}$: C, 73.37; H, 4.00; N, 12.83; S, 9.79. Found: C, 73.55; H, 3.92; N, 12.66; S, 9.61.

Desulfurization of **8**.

A slurry of **8** (2.0 g., 0.0061 mole) and W-4 Raney nickel (25 g.) in ethanol was refluxed for 2 hours. The Raney nickel was removed by filtration and the solvent was evaporated. The solid which formed was recrystallized from benzene to yield 0.9 g. (48.4%) of 5-cyclohexyl-5,6-dihydrobenzimidazo[1,2-*c*]quinazoline (**11**), as white needles, m.p. 248-250°. The ir spectrum of **11** (potassium bromide) showed ν max 3027, 2910, 2848, 1450, 1420, 1271, 984, 749, and 737 cm^{-1} . The uv spectrum exhibited λ max (methanol) $m\mu$ (log ϵ): 243 (4.19), 248sh (4.11), 275 (4.17), 281 (4.25), 290sh (4.23), 302 (4.25), 315sh (4.00). The nmr spectrum of **11** (dimethyl sulfoxide) showed absorptions at δ 0.6-1.6 (broad, cyclohexyl), 3.0 (singlet, methylene), 6.7-7.1 (complex, aromatic). Integration of this spectra was not possible.

Anal. Calcd. for $\text{C}_{20}\text{H}_{21}\text{N}_3$: C, 79.17; H, 6.97; N, 13.85. Found: C, 79.24; H, 6.91; N, 13.76.

Reaction of **1** with Ethanolic-Potassium Hydroxide.

A mixture of **1** (2.0 g., 0.0091 mole) and 1 *M* ethanolic potassium hydroxide (100 ml.) was heated at reflux for 8 hours. The solution was concentrated to approximately 30 ml. and 250 ml. of water was added. The solid which formed was collected by filtration and recrystallized from 65% ethanol to yield 1.35 g. (76.7%) of **13**, m.p. 294-296° (lit. m.p. (30) 294.5-295.5°).

Anal. Calcd. for $\text{C}_{13}\text{H}_{10}\text{N}_2$: C, 80.39; H, 5.19; N, 14.42. Found: C, 80.18; H, 5.10; N, 14.59.

Reaction of **1** with Sodium Diethylmalonate.

Sodium (4.6 g., 0.2 mole) was dissolved in 100 ml. of ethanol and diethylmalonate (32 g., 0.2 mole) was added dropwise. To this mixture was added compound **1** (1.0 g., 0.0045 mole) and the reaction was heated for 4 hours. After the excess sodium salt was removed from the cooled mixture, the solution was concentrated until it became viscous and then poured into water. The resulting yellow solid was collected and recrystallized from isopropyl alcohol to yield 1.5 g. (88%) of diethyl [*o*-(2-benzimidazolylphenyl)azo]malonate (**18**), m.p. 163-165°. The ir spectrum of **18** showed ν max 3344, 2970, 1698, 1580, 1495, 1455, 1437, 1318, 1204, 1190, 1157, 1094, 740, and 733 cm^{-1} (potassium bromide). The uv spectrum exhibited λ max (methanol) $m\mu$ (log ϵ): 220 (4.47), 246 (4.21), 302 (4.44), 362 (4.32). The nmr spectrum of **18** (deuteriochloroform) showed absorptions at δ 1.4 (6H) (triplet, methyl, $J = 7\text{Hz}$), 4.5 (4H) (quartet, methylene, $J = 7\text{Hz}$), 6.8-7.8 (8H) (complex, aromatic), 11.0 (1H) (broad, N-H), 14.5 (1H) (singlet, N-H). The mass spectral molecular ion was at m/e 380.

Anal. Calcd. for $\text{C}_{20}\text{H}_{20}\text{N}_4\text{O}_4$: C, 63.15; H, 5.30; N, 14.73; O, 16.82. Found: C, 63.02; H, 5.40; N, 14.51; O, 16.88.

Reaction of **1** with Alkoxides.

To a hot solution of alcohol in which sodium (6.0 g., 0.26 mole) had previously been dissolved, compound **1** (2.0 g., 0.0091 mole) was added in small portions. The solution was heated for 3 hours, cooled and reduced in volume to approximately 30 ml. Water was then added and the resulting solid was collected by filtration.

When the alcohol used was ethyl, *n*-amyl or isopropyl, the solid

isolated was identified as 2-phenylbenzimidazole (**13**). The yields from the corresponding alcohols were: ethyl (73.9%), *n*-amyl (79.5%), isopropyl (78.4%).

When the alcohol used was *t*-butyl or *t*-amyl the solid isolated was identified as **1**. The yields from the corresponding alcohols were: *t*-butyl (92%), *t*-amyl (88%). Both products were identified by comparison of their infrared spectra to that of an authentic sample of **1**, and by melting point determinations of various mixtures of the product with authentic samples of **1**.

Reduction of **1**.

A. Catalytic.

A suspension of **1** (2.0 g., 0.0091 mole) and 10% palladium on carbon in ethanol was reduced in a Parr hydrogenator until the hydrogen uptake had ceased. The catalyst was removed by filtration and the solvent was evaporated. The resulting solid was recrystallized from 65% ethanol to yield 1.2 g. (68.2%) of **13**, m.p. 294-296° (lit. m.p. (30) 294.5-295.5°).

Anal. Calcd. for $C_{13}H_{10}N_2$: C, 80.39; H, 5.19; N, 14.42. Found: C, 80.35; H, 5.17; N, 14.53.

B. Raney Nickel, W-4.

A slurry of Raney nickel, W-4 (25 g.) and **1** (1.0 g., 0.0045 mole) in ethanol was heated at reflux for 3 hours. The Raney nickel was removed by filtration and the filtrate was evaporated to dryness. The resulting solid was recrystallized from 65% ethanol to yield 0.65 g. (73.9%) of **13**, m.p. 294-296° (lit. m.p. (30) 294.5-295.5°).

C. Sodium Sulfite and Hydrochloric Acid.

A solution of sodium sulfite (3.4 g., 0.027 mole) in 15 ml. of water was added to a hot solution of **1** (1.0 g., 0.0045 mole) in ethanol. Concentrated hydrochloric acid (10 ml.) was added and the solution was heated for 24 hours. The excess sodium sulfite was removed by filtration and the solution was evaporated to dryness. The solid which formed was dissolved in water and the solution was neutralized with sodium hydroxide. The resulting precipitate was collected by filtration and recrystallized from 64% aqueous ethanol to yield 0.62 g. (70.4%) of **13**, m.p. 294-297° (lit. m.p. (30) 294.5-295.5°).

D. Ammonium Sulfide.

To a solution of **1** (2.0 g., 0.0091 mole) in 150 ml. of hot ethanol was added 10 ml. of 24% aqueous ammonium sulfide. The solution was heated on a steam bath until no more hydrogen sulfide was evolved, then allowed to cool. The solid which formed was collected by filtration and recrystallized from 65% aqueous ethanol to yield 1.2 g. (68.2%) of **13**, m.p. 293-295° (lit. m.p. (30) 294.5-295.5°).

E. Sodium Borohydride.

To a solution of **1** (1.0 g., 0.0045 mole) in ethanol was added sodium borohydride (0.5 g., 0.014 mole) in small portions. The solution was heated for 2 hours, cooled, filtered and evaporated to approximately one-half volume. Water was added and the solid which formed was collected by filtration. The solid was recrystallized from 65% ethanol to yield 0.55 g. (62.5%) of **13**, m.p. 293.5-295° (lit. m.p. (30) 294.5-295.5°).

The above compounds were identified by their ir spectra, which were identical to that of an authentic sample of **13** and also by a mixed melting point determination of the products with an authentic sample of **13**.

F. Stannous Chloride and Hydrochloric Acid.

A solution of **1** (2.0 g., 0.0091 mole) and anhydrous stannous chloride (8.0 g., 0.042 mole) was heated in 150 ml. of concentrated hydrochloric acid for 3 hours. The solution was cooled, the hydrochloric acid which formed was collected by filtration and re-dissolved in water. Hydrogen sulfide was then bubbled through this solution for 15 minutes and the inorganic salts were removed by filtration. The filtrate was neutralized with sodium hydroxide and the solid which formed was collected to yield 1.9 g. (93.1%) of crude 2-(*o*-hydrazinophenyl)benzimidazole.

G. Zinc.

A solution of **1** (2.0 g., 0.0091 mole) in 30 ml. of glacial acetic acid was warmed to 75-80°. Zinc dust (2.0 g., 0.03 mole) was added in small portions and the temperature was maintained at 80° for 5 minutes after the final addition. The excess zinc was removed by filtration, hydrogen sulfide gas was bubbled through the filtrate, and the procedure described in F was followed to give a solid which was collected and recrystallized from isopropyl alcohol to yield 1.3 g. (54.1%) of **20** as white needles, m.p. 289-291°. The ir spectrum of **20** showed ν max 3200, 1674, 1580, 1527, 1473, 1426, 1312, 1260, and 740 cm^{-1} (potassium bromide). The uv spectrum exhibited λ max (methanol) $m\mu$ (log ϵ): 240sh (4.15), 247sh (4.09), 291 (4.25), 298 (4.18), 314 (4.06), 328 (3.98). The nmr spectrum of **20** (dimethylsulfoxide) showed absorptions at δ 2.0 (3H) (singlet, CH_3), 7.1-8.3 (8H) (complex, aromatic), 10.2 (1H) (singlet, N-H), 10.8 (1H) (singlet N-H), 13.2 (1H) (singlet, N-H).

Anal. Calcd. for $C_{15}H_{14}N_4O$: C, 67.65; H, 5.30; N, 21.04; O, 6.01. Found: C, 67.53; H, 5.22; N, 21.05; O, 6.16.

The same product was obtained by heating a solution of 2-(*o*-hydrazinophenyl)benzimidazole (1.5 g., 0.0067 mole) in glacial acetic acid for 4 hours.

Photolysis of **1**.

A solution of **1** (0.5 g., 0.0023 mole) in ethanol was placed in a quartz vessel 220 mm. in length and having an inner diameter of 34 mm. Oxygen was removed from the solution by bubbling nitrogen through it for 30 minutes. The solution was irradiated with a 450 watt ultraviolet lamp for 3 hours. The solution was evaporated to dryness. The resulting solid was treated with chloroform and the insoluble material collected by filtration. This solid was recrystallized from 65% aqueous ethanol to yield 0.2 g. (49.8%) of **13**, m.p. 294-296° (lit. m.p. (28) 294.5-295.5°). An infrared spectrum of this product was identical to that of an authentic sample of **13**.

The chloroform filtrate was concentrated and then chromatographed using alumina as the absorbent and chloroform as the eluant. The first band was collected and the solvent was removed by evaporation. The resulting gummy solid was recrystallized from cyclohexane to yield colored crystals with a wide melting point range 115-121°. This solid was redissolved in a small amount of benzene and re-chromatographed using alumina as the absorbent and benzene as the eluant. The first band was collected and the solvent evaporated to yield a yellow solid. This solid was recrystallized from cyclohexane to yield 90 mg. (16.4%) of **21** as yellow plates, m.p. 121-122.5°. The ir spectrum of **21** showed ν max 3348, 2968, 1645, 1464, 1408, 1279, 1236, 1084, 762, and 749 cm^{-1} (potassium bromide). The uv spectrum exhibited λ max (methanol) $m\mu$ (log ϵ): 219 (4.42), 251sh (4.27), 294sh (3.57). The nmr spectrum of **21** (deuteriochloroform), showed absorptions at δ 1.4 (3H) (triplet, CH_3), 4.4 (2H) (quartet, CH_2), 5.0 (1H) (singlet, N-H), 6.5-7.7 (8H) (complex, aromatic).

Anal. Calcd. for $C_{15}H_{14}N_2O$: C, 75.61; H, 5.92; N, 11.76; O, 6.71. Found: C, 75.56; H, 6.04; N, 11.62; O, 6.87.

Hydrolysis of Pyrido[2',3'(3',2'):4,5]imidazo[1,2-c][1,2,3]benzotriazine and Pyrido[3',4'(4',3'):4,5]imidazo[1,2-c][1,2,3]benzotriazine with 6 *N* Sulfuric Acid.

These compounds (1.0 g., 0.0046 mole) were refluxed in 45 ml. of 6 *N* sulfuric acid for 5 hours. The cooled solutions were poured into 50 ml. of water and neutralized with 7 *M* ammonium hydroxide to yield yellow solids. 2-(*o*-Hydroxyphenyl)imidazo[4,5-*b*]pyridine (22) was formed in 88% yield, m.p. 330-333°.

Anal. Calcd. for C₁₂H₉N₃O: C, 68.23; H, 4.29; N, 19.90; O, 7.57. Found: C, 68.32; H, 4.48; N, 19.71; O, 7.74.

2-(*o*-Hydroxyphenyl)imidazo[4,5-*c*]pyridine (23) was formed in 82.5% yield, m.p. 223-225°.

Anal. Calcd. for C₁₂H₉N₃O: C, 68.23; H, 4.29; N, 19.90. Found: C, 68.04; H, 4.45; N, 19.72.

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