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Interaction of Imidazole Derivatives with Electron Acceptors. II.[1) Reaction Products of Imidazole with *p*-Benzoquinone

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The interaction between imidazole and *p*-benzoquinone in acetonitrile was investigated at both low temperature (below 0°) and room temperature. The step of formation of the charge-transfer complex between two intact molecules could not be detected. Instead, the two compounds were found to react with each other fairly quickly at room temperature to form 2,5-bis(imidazol-1-yl)hydroquinone, 2,3-bis(imidazol-1-yl)hydroquinone and hydroquinone.

Keywords——imidazole; *p*-benzoquinone; hydroquinone; ^{1}H-NMR; ^{13}C-NMR; 2,5-bis(imidazol-1-yl)hydroquinone; 2,3-bis(imidazol-1-yl)hydroquinone

Since imidazole can be expected to act as an electron donor, we have been studying the interaction of imidazole with electron acceptors. This time we investigated the interaction of this compound with *p*-benzoquinone.

Okamoto *et al.*2) reported that imidazole and *p*-benzoquinone form a charge-transfer complex showing an absorption maximum at 370 nm. They observed that the absorbance at this wavelength of a solution of these two compounds in acetonitrile increased remarkably on prolonged standing at room temperature. This phenomenon seems to us to indicate that the absorption band at 370 nm may not be the absorption band of the charge-transfer complex formed between the intact molecule of imidazole and that of *p*-benzoquinone, because the charge-transfer complex is known to be formed immediately after mixing of the two reactants. Hirohashi *et al.*3) also reported that two moles of 2-methylimidazole form a charge-transfer complex with one mol of *p*-benzoquinone, and the complex shows an absorption maximum at 500 nm in EtOH. However, they determined the molar ratio of the constituent molecules of the complex using a solution that had been left to stand for one day, which might therefore contain a large amount of reaction products.

Thus, the interaction of imidazole with *p*-benzoquinone was reinvestigated in detail.

Results and Discussion

In order to detect the presence of a charge-transfer complex in a solution containing both an electron donor and an electron acceptor, it sometimes necessary to observe the color development of the solution at fairly low temperature.4) For example, aniline and chloranil were reported to form a stable charge-transfer complex in a mixed solvent of ether–isopropyl alcohol (3:1) at temperatures below ~200° K,5) and the charge-transfer complex of imidazole with tetracyanoethylene was observed to decompose very rapidly at temperatures higher than 0°.1)

Thus, the interaction between imidazole and *p*-benzoquinone was reinvestigated in acetonitrile at below 0°. Owing to the decrease of the solubility of imidazole in acetonitrile on cooling to low temperature, a 0.1 M solution of imidazole was used instead of the 1.0 M solution employed by Okamoto *et al.*2) This solution was cooled to about −35° and mixed with an acetonitrile solution of 0.01 M *p*-benzoquinone which had also been cooled to about −35°.

The temperature of the mixture was allowed to rise gradually, and the time and temperature dependence of the visible absorption spectrum of the mixture was measured.

The initial spectrum measured one min after mixing the two solutions at −33° had only a feeble end absorption in the wavelength region shorter than 400 nm, and the absorbance of this absorption band was smaller than 0.01 throughout the whole wavelength region. This situation did not change appreciably until the temperature of the mixture had reached about −10° after an elapsed time of 60 min. As the temperature rose, the end absorption gradually became more intense; the absorbances at 350, the shortest wavelength measured, and 370 nm were both 0.02 at −5°, both 0.03 at 0° and both 0.06 at 6°. These measurements were made at elapsed times of 70, 90 and 125 min from the beginning of mixing of the two solutions, respectively. Thereafter, the end absorption became more and more intense and the mixture began to show a new absorption band having a maximum at 460 nm. When the temperature reached 20°, the absorbances at 370 and 460 nm were 0.38 and 0.43, respectively, after about four hr.

The time dependence of the visible absorption spectrum of an acetonitrile solution of imidazole and *p*-benzoquinone at the same molar concentrations as above was also measured at 26°. The time dependence was found to be larger than that at low temperature and much smaller than that of the spectrum of the mixture of 1.0 M imidazole and 0.01 M *p*-benzoquinone in acetonitrile reported by Okamoto *et al.*[2] The initial spectrum measured one min after mixing of the two solutions had only a weak end absorption in the wavelength region shorter than 400 nm, and the absorbances at 350 and 370 nm were 0.02 and 0.03, respectively. The end absorption became more and more intense fairly gradually as the standing time increased, and the mixture began to show a new absorption band having a maximum at 460 nm after an elapsed time of about 25 min. The absorbances at 370 and 460 nm were 0.38 and 0.46 at 60 min and 0.62 and 0.93 at 150 min. A faintly yellow substance began to precipitate after about three hr. The thin layer chromatogram (TLC) of the precipitates indicated that they consisted of the same kinds of compounds as those detected on TLC of the precipitates formed in a mixture of imidazole and *p*-benzoquinone at higher concentrations in acetonitrile, as mentioned in detail below.

The above-mentioned experimental results suggest that the absorption band in the wavelength region of 350—400 nm of the mixture of imidazole and *p*-benzoquinone in acetonitrile may not be the absorption band of the charge-transfer complex formed between two intact molecules. The step of formation of the charge-transfer complex between intact molecules of imidazole and *p*-benzoquinone could not be detected in dichloromethane at about −60°, either.

The faintly yellow substance that precipitated fairly quickly after mixing concentrated acetonitrile solutions of 0.02 mol of imidazole and 0.01 mol of *p*-benzoquinone consisted of at least five compounds, as judged by TLC. Two of the five spots detected were found to correspond to those of hydroquinone and imidazole from their *Rf* values. The results of purification of the precipitates by recrystallization from MeOH indicated that they consisted largely of two compounds. These two compounds will be designated as compound A, which is less soluble in MeOH than the other one, and compound B. The filtrate left after collection of the precipitates was found to contain about 0.01 mol of hydroquinone and about 0.01 mol of imidazole.

Thus, it was found that two moles of *p*-benzoquinone react with two moles of imidazole in acetonitrile at room temperature to give a mixture of A and B (one mol as a whole) and one mol of hydroquinone. Imidazole and *p*-benzoquinone were also found to react with each other quite similarly in both dichloromethane and acetone.

Structures of A and B

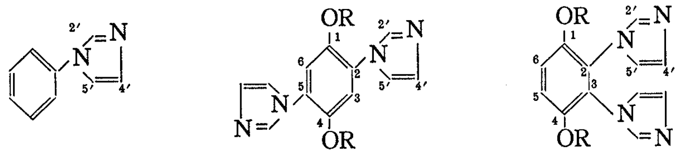
Elemental analyses and mass spectral measurements of molecular ions showed that A and

B have the same elemental composition, $C_{12}H_{10}N_4O_2$. Therefore, A and B were formed by the reaction of one mol of *p*-benzoquinone with two moles of imidazole.

Infrared spectra (IR) indicated that both A and B have no carbonyl group. A and B both dissolved in aqueous caustic alkaline solution and precipitated again on acidification of the alkaline solution. Therefore, A and B can be considered to have phenolic hydroxy groups.

Since both compounds, especially A, are barely soluble in most organic solvents but are comparatively easily soluble in DMF and DMSO, the proton magnetic resonance spectra(^{1}H-NMR) and carbon-13 magnetic resonance spectra(^{13}C-NMR) were measured in DMSO-d_6. The ^{1}H-NMR spectrum of A had only five peaks, as shown in Table I. This result indicated that ten hydrogen atoms of A can be divided into five pairs, each one of which consists of two magnetically equivalent atoms. The very broad peak at 9.92 ppm (δ, throughout this work, for both ^{1}H-NMR and ^{13}C-NMR) was found to disappear upon addition of D_2O to the solution. Thus, this peak can be assigned to the hydrogen atoms of phenolic hydroxy groups. This result showed that A has two phenolic hydroxy groups and does not have any NH group. Therefore, A probably has the hydroquinone skeleton. The peak at 6.97 ppm is a singlet, but all of the other peaks are multiplets. Accordingly, a pair of hydrogen atoms can be considered to be located fairly far from the other pairs of hydrogen atoms. Three pairs of hydrogen atoms which showed peaks at 7.92, 7.43 and 7.06 ppm were found to couple with each other by the double irradiation technique. Since the phenyl ring was already shown to have two hydroxy groups, these three pairs of hydrogen atoms must be those of two imidazole ring moieties of A. Accordingly, two hydrogen atoms forming a pair and showing a peak at 6.97 ppm are probably linked directly with the phenyl ring.

^{13}C-NMR of A measured by the complete decoupling technique had only six peaks, as shown in Table I. This indicated that twelve carbon atoms of A can be divided into six pairs,



A : R=H
A-M: R=CH_3

B : R=H
B-M: R=CH_3

Chart 1

Table I. ^{1}H-NMR and ^{13}C-NMR Data (in ppm, δ) for 1-Phenylimidazole, A, A-M, B and B-M measured in DMSO-d_6[a)]

	1-Phenyl imidazole	A	A-M	B	B-M
$C_{(1)}$		142.4	145.4	145.0	148.0
$C_{(2)}$		123.6	124.8	121.6	123.5
$C_{(3)}$		6.97(s, 2H) 113.1	7.33(s, 2H) 110.5		
$C_{(5)}$				6.99(s, 2H) 116.5	7.32(s, 2H) 112.8
$C_{(2')}$	8.25(m, 1H) 135.1	7.92(m, 2H) 136.9	7.98(m, 2H) 137.2	7.41(m, 2H) 137.7	7.42(m, 2H) 137.8
$C_{(4')}$	7.12(m, 1H) 129.4	7.06(m, 2H) 127.9	7.07(m, 2H) 127.9	6.82(m, 2H) 127.3	6.83(m, 2H) 127.6
$C_{(5')}$	7.72(m, 1H) 117.6	7.43(m, 2H) 119.7	7.51(m, 2H) 120.2	6.92(m, 2H) 120.7	6.93(m, 2H) 120.7
$\mathrm{O\underline{H}}$		9.92(b, 2H)		9.69(b, 2H)	
$\mathrm{O\underline{CH}_3}$			3.14(s, 6H) 56.6		3.74(s, 6H) 56.4

a) Numbering of atoms is shown in Chart 1. The following abbreviations are used: s, singlet; m, multiplet; b, broad.

each consisting of two magnetically equivalent atoms. This result and the finding that ten hydrogen atoms can be divided into five pairs indicate that A must have a symmetric structure. The ^{13}C-NMR spectrum measured by the partial decoupling technique indicated that two pairs of carbon atoms showing peaks at 142.4 and 123.6 ppm are not linked directly with any hydrogen atom and that all of the remaining four pairs of carbon atoms are directly linked with hydrogen atoms (*cf.* Table I). The peak at 142.4 ppm is easily assignable to the carbon atoms carrying the phenolic hydroxy groups, because of the magnitude of the chemical shift. The chemical shift value of 136.9 ppm is close to that of 135.0 ppm of the $C_{(2)}$ atom of imidazole measured in DMSO-d_6. This result suggests that A has two $-\overset{|}{N}-CH=N-$ groups.

If A is assumed to have the phenylimidazole type structure, it must resemble 1-phenylimidazole, because 2-phenylimidazole and 4(5)-phenylimidazole do not have three C–H bonds but have an N–H bond in their imidazole ring moieties. From all of the above-mentioned experimental results A was expected to have the bis(imidazol-1-yl)hydroquinone structure.

The ^{1}H-NMR and ^{13}C-NMR spectra of B gave very similar information (*cf.* Table I). Namely, it was shown that ten hydrogen atoms and twelve carbon atoms of B can be divided into five and six pairs, respectively. Accordingly, B must also have a symmetric structure. Next, B was shown to have two phenolic hydroxy groups and two $-\overset{|}{N}-CH=N-$ groups. B also appeared to have the bis(imidazol-1-yl)hydroquinone structure.

The structures of A and B were confirmed by direct comparison of A and B with authentic samples, after conversion to the dimethylether derivatives. The physical properties of both derivatives (abbreviated hereafter as A–M and B–M, respectively) are shown in Table I. As authentic samples, 2,3- (I) and 2,5-bis(imidazol-1-yl)hydroquinone dimethylether (II) were synthesized. Since the isomer of I and II, 2,6-bis(imidazol-1-yl)hydroquinone dimethylether, does not have a symmetrical structure as regards the $C_{(1)}$ and $C_{(4)}$ atoms and two methoxy groups, this compound was excluded.

All of the physical properties including IR spectra of A–M and B–M were identical with those of II and I, respectively. Therefore, it was concluded that A is 2,5-bis(imidazol-1-yl)-hydroquinine(III) and B is 2,3-bis(imidazol-1-yl)hydroquinone(IV).

Since the structures of A and B were thus established, all the peaks observed in the ^{1}H-NMR and ^{13}C-NMR spectra of A, A–M, B and B–M could be assigned as shown in Table I. The assignment was made by analogy with the data for 1-phenylimidazole, which are shown in the left-hand side column of Table I. In the case of 1-phenylimidazole, all the ^{13}C-NMR peaks have been assigned by Begtrup.⁶⁾ Three ^{1}H-NMR peaks of 1-phenylimidazole at 8.25, 7.72 and 7.12 ppm could be assigned to hydrogen atoms combined directly with $C_{(2')}$, $C_{(5')}$ and $C_{(4')}$, respectively, from the results of ^{13}C-NMR with selective proton decoupling.

Experimental

All melting points are uncorrected. Ultraviolet spectra (UV) were recorded on Union SM-401 and Hitachi 200-20 spectrometers. The visible absorption spectrum at low temperature was recorded on a Shimadzu MPS-50L spectrometer with an attached Dewar bottle having two windows that allowed the light to pass. IR spectra were recorded as KBr pellets on JASCO DS-301 and JASCO DS-701G spectrometers and ^{1}H-NMR and ^{13}C-NMR were recorded in DMSO-d_6 on JEOL PS-100 and JEOL FX-100 spectrometers, respectively, with TMS as an internal standard.

Chemicals——Imidazole and *p*-benzoquinone, both guaranteed reagent grade, were purchased from Tokyo Kasei Kogyo Co. Ltd. The former compound was recrystallized twice from benzene to give a pure compound of mp 90—91°. The latter compound was dissolved in $CHCl_3$ and the solution was passed through a column of silica gel in order to remove impurities. The residue left by concentration of the eluate was sublimed twice *in vacuo* to give a pure compound of mp 115—116°. Acetonitrile for spectroscopic analysis, EtOH of super special reagent grade and hydroquinone of guaranteed reagent grade were purchased from Hayashi Pure Chemical Ind. Ltd., Wako Pure Chemical Ind. Ltd. and Tokyo Kasei Kogyo Co. Ltd., respectively, and were used without any further purification. CH_2Cl_2 of guaranteed reagent grade was purchased from Wako Pure Chemical Ind. Ltd. and was purified by fractional distillation.

Measurement of the Time and Temperature Dependence of the Visible Absorption Spectrum of a Mixture of Imidazole and *p*-Benzoquinone in Acetonitrile——Acetonitrile solutions of 0.1 M imidazole and 0.01 M *p*-benzoquinone were cooled separately in an EtOH bath maintained at about $-40°$ by adding dry ice. Both solutions (1.5 ml each) were pipetted into an optical cell placed in an EtOH bath maintained at about $-35°$ in a Dewar bottle attached to the spectrometer. Just after the completion of pipetting, the mixture was stirred vigorously with a Yamato Touch-mixer, model MT-11, for a few seconds to complete the mixing and put back in the cold bath as quickly as possible. Thereafter, the visible absorption spectrum of the mixture was measured in the wavelength region of 350—650 nm at intervals of 2.5 min.

Measurement of the time dependence at room temperature was performed by a similar method except that cooling was not necessary. A faintly yellow substance began to precipitate about three hr after mixing. The mixture was left to stand overnight at room temperature and the precipitates were collected by filtration.

Thin Layer Chromatography——MeOH solutions of the substance to be examined, imidazole and hydroquinone were spotted on a silica gel plate (Yamato REPLATE-26; 25×75 mm^2) that had been activated at 110° for 1.5 hr, and the plate was developed with MeOH–$CHCl_3$ (1: 10). All spots were visualized with I_2 vapor.

Isolations of A and B——A solution of 1.36 g (0.02 mol) of imidazole in 35 ml of acetonitrile was added in small portions to a solution of 1.08 g (0.01 mol) of *p*-benzoquinone in 35 ml of the same solvent with stirring at room temperature. A faintly yellow substance began to precipitate about 20 min after mixing the two solutions. The mixture was left to stand overnight at room temperature, and the precipitates were collected by filtration. TLC of the precipitates showed five spots at *Rf* values of 0.13, 0.33, 0.55, 0.63 and 0.70. Authentic samples of imidazole and hydroquinone showed spots on the same TLC plate at *Rf* values of 0.70, and 0.63, respectively.

The precipitates obtained above (1.25 g) were ground to powder in a morter and dissolved in 300 ml of MeOH by refluxing. Very small amounts of insoluble material were filtered off and the filtrate was concentrated to about 50 ml. The solution was left to stand overnight, and the separated faintly brown needles (0.22 g) were collected by filtration. Recrystallization from DMF afforded faintly brown needles, mp 352—355° (dec.). This substance was found to be pure compound A by TLC. *Anal.* Calcd for $C_{12}H_{10}N_4O_2$: C, 59.50; H, 4.16; N, 23.13; Mol. wt., 242.23. Found: C, 59.32; H, 4.14; N, 22.90; Mol. wt.(M^+), 242. UV $\lambda_{\max}^{\mathrm{EtOH}}$ nm (log ε): 247 (4.12), 313 (4.04). Compound A was hardly soluble in most organic solvents usually employed, but was soluble in hot DMF and DMSO.

The filtrate left after the collection of compound A was further concentrated to about 10 ml and was left to stand at room temperature. The faintly brown prisms (0.30 g) that separated were collected by filtration. TLC showed that the crystals contain a small amount of A, so they were ground to powder in a mortar and dissolved in 50 ml of MeOH by refluxing. A very small amount of insoluble material was filtered off and the filtrate was concentrated to about 10 ml, and left to stand at room temperature. The faintly yellow prisms that separated (0.09 g), mp 302—305° (dec.), were collected by filtration. This substance was found to be pure compound B by TLC. *Anal.* Calcd for $C_{12}H_{10}N_4O_2$: C, 59.50; H, 4.16; N, 23.13; Mol. wt., 242.23. Found: C, 59.35; H, 4.14; N, 23.03; Mol. wt. (M^+), 242. UV $\lambda_{\max}^{\mathrm{EtOH}}$ nm (log ε): 306 (3.83). Compound B was slightly soluble in most organic solvents usually employed but was soluble in hot DMF and DMSO.

Isolation of Hydroquinone——The filtrate of the reaction mixture left after collection of the precipitates was evaporated to dryness. The residue (1.20 g) was dissolved in 1 ml of MeOH–AcOEt (1: 5) and was subjected to chromatographic separation on 50 g of silica gel. The early fractions eluted with the same solvent mixture left 0.49 g of colorless prisms on removal of the solvent by evaporation. The IR spectrum of the crystals coincided completely with that of hydroquinone.

The next fractions eluted with the same solvent mixture left 0.59 g of colorless prisms on removal of the solvent. The IR spectrum of the crystals coincided completely with that of imidazole.

Methylation of A and B——An excess of ethereal diazomethane was added in small portions to an ice-cold suspension of 0.5 g of A in 50 ml of MeOH with stirring. The stirring was continued at room temperature for a further 10 hr, then the solvent was removed by evaporation. The residue was dissolved in a mixture of THF and MeOH (5: 1) and subjected to chromatographic separation on Al_2O_3. The early fractions eluted with the same solvent mixture left faintly yellow crystals on removal of the solvent. Recrystallization from THF afforded 0.05 g of A-M as faintly yellow needles of mp 239—241° (dec.). *Anal.* Calcd for $C_{14}H_{14}N_4O_2$: C, 62.21; H, 5.22; N, 20.73. Found: C, 62.03; H, 5.28; N, 20.45. UV $\lambda_{\max}^{\mathrm{EtOH}}$ nm (log ε): 247 (4.11), 306 (4.03).

Methylation of B was performed by a similar procedure. The reaction product was also subjected to chromatographic separation on Al_2O_3. B-M was obtained from early fractions eluted with the same solvent mixture as that used in the case of methylation of A. Recrystallization from THF afforded pure B-M as colorless prisms of mp 253—254° (dec.). *Anal.* Calcd for $C_{14}H_{14}N_4O_2$: C, 62.21; H, 5.22; N, 20.73. Found: C, 62.19; H, 5.31; N, 20.62. UV $\lambda_{\max}^{\mathrm{EtOH}}$ nm (log ε): 304 (3.82).

Synthesis of 2,5-Bis(imidazol-1-yl)hydroquinone Dimethylether (II)——A solution of 1.75 g of acetalylthiocarbimide and 0.8 g of 2,5-dimethoxy-*p*-phenylenediamine[7] in 20 ml of EtOH was refluxed for 1 hr under an atmosphere of N_2, and evaporated to dryness. The residual colorless powder was recrystallized from $CHCl_3$ to afford 1.85 g of 2,5-bis[N′-(2,2-diethoxyethyl)thioureido]hydroquinone dimethylether (V) as colorless prisms of mp 205—208°. *Anal.* Calcd for $C_{22}H_{38}N_4O_6S_2$: C, 50.95; H, 7.39; N, 10.81. Found: C, 50.86; H, 7.36; N, 10.71. UV $\lambda_{\max}^{\mathrm{EtOH}}$ nm: 252, 318.

A suspension of 1.8 g of V in 50 ml of 10% aq. HCl solution was heated in a boiling water bath for 1 hr. The suspension became a clear solution and afterwards 2,5-bis(2-mercaptoimidazol-1-yl)hydroquinone dimethylether (VI) precipitated as colorless prisms. VI was collected by filtration, washed with H_2O, and dried in a desiccator over silica gel. It was used in the succeeding step of the reaction without further purification.

VI (0.12 g) was heated with 10 ml of 20% aq. HNO_3 solution in a boiling water bath for 5 min. The reaction proceeded with evolution of NO_2 gas. The reaction mixture was made slightly alkaline with 15% aq. NH_4OH solution and the reaction product was extracted with $CHCl_3$. The $CHCl_3$ layer was washed with H_2O, dried over anhyd. Na_2SO_4 and evaporated to dryness. Recrystallization of the residue from THF afforded 0.06 g of II as faintly yellow needles of mp 235—238° (dec.). *Anal.* Calcd for $C_{14}H_{14}N_4O_2$: C, 62.21; H, 5.22; N, 20.73. Found: C, 62.14; H, 5.42; N, 20.45.

Synthesis of 2,3-Bis(imidazol-1-yl)hydroquinone Dimethylether (I)——2-Amino-3-nitrohydroquinone dimethylether[8] (5.0 g) was added in small portions to a mixture of 3.8 g of thiophosgene and 10 ml of H_2O with continuous vigorous stirring for 1.5 hr. The stirring was continued for a further 1.5 hr. The reaction product was extracted with $CHCl_3$ and the $CHCl_3$ layer was washed with 10% aq. HCl solution and H_2O, dried over anhyd. Na_2SO_4 and evaporated to dryness *in vacuo*. The residue (6.2 g) was subjected to chromatographic separation on silica gel. The early fractions eluted with a mixture of $CHCl_3$ and *n*-hexane (1: 1) left yellow crystals on removal of the solvent. Recrystallization from acetone–H_2O afforded 1.7 g of 2-isothiocyanato-3-nitrohydroquinone dimethylether (VII) as yellow plates of mp 130—131°. *Anal.* Calcd for $C_9H_8N_2O_4S$: C, 45.01; H, 3.36; N, 11.67. Found: C, 44.95; H, 3.41; N, 11.62. UV $\lambda_{\max}^{\mathrm{EtOH}}$ nm (log ε): 273 (3.83), 325 (3.76).

Aminoacetal (0.85 g) was added to a solution of 1.4 g of VII in 20 ml of EtOH, and the solution was refluxed for 30 min. The oily residue left on removal of the solvent was heated with 20 ml of 10% aq. HCl solution in a boiling water bath for 40 min. The separated crystals were collected by filtration, washed with H_2O and dried in a desiccator over silica gel. Recrystallization from EtOH afforded 1.3 g of 3-(2-mercaptoimidazol-1-yl)-2-nitrohydroquinone dimethylether (VIII) as yellow prisms of mp 262—263° (dec.). *Anal.* Calcd for $C_{11}H_{11}N_3O_4S$: C, 46.98; H, 3.94; N, 14.94. Found: C, 46.83; H, 4.13; N, 14.73. UV $\lambda_{\max}^{\mathrm{EtOH}}$ nm (log ε): 263 (4.11).

VIII (1.18 g) was heated with 10 ml of 20% aq. HNO_3 solution in a boiling water bath for 5 min. The reaction mixture was made slightly alkaline with 15% aq. NH_4OH solution and the reaction product was extracted with $CHCl_3$. The $CHCl_3$ layer was washed with H_2O, dried over anhyd. Na_2SO_4 and evaporated to dryness. Recrystallization of the residue from a mixture of CH_2Cl_2 and *n*-hexane (1: 1) afforded 0.72 g of 3-(imidazol-1-yl)-2-nitrohydroquinone dimethylether (IX) as yellow prisms of mp 148—149°. *Anal.* Calcd for $C_{11}H_{11}N_3O_4$: C, 53.01; H, 4.45; N, 16.86. Found: C, 52.94; H, 4.64; N, 16.69. UV $\lambda_{\max}^{\mathrm{EtOH}}$ nm (log ε): 296 (3.55).

IX (0.64 g) was hydrogenated catalytically with 5% Pd-C in 50 ml of EtOH. When the uptake of H_2 gas had ceased, the catalyst was removed by filtration and the solvent was evaporated off. Recrystallization of the residue from a mixture of CH_2Cl_2 and *n*-hexane (1: 2) afforded 0.46 g of 2-amino-3-(imidazol-1-yl)-hydroquinone dimethylether (X) as colorless prisms of mp 124—125°. *Anal.* Calcd for $C_{11}H_{13}N_3O_2$: C, 60.26; H, 5.98; N, 19.15. Found: C, 59.92; H, 6.09; N, 19.04. UV $\lambda_{\max}^{\mathrm{EtOH}}$ nm (log ε): 300 (3.67).

Acetalylthiocarbimide (0.33 g) was added to a solution of 0.4 g of X in 12 ml of MeOH and the reaction mixture was heated under reflux in a boiling water bath for 1 hr. The oily residue left no removal of the solvent was heated with 10 ml of 10% aq. HCl solution in a boiling water bath for 30 min. The colorless crystalline substance that precipitated upon neutralization of the solution with 15% aq. NH_4OH solution was collected by filtration, washed with H_2O and dried in a desiccator over silica gel. Recrystallization from MeOH afforded 0.34 g of 3-(imidazol-1-yl)-2-(2-mercaptoimidazol-1-yl)hydroquinone dimethylether (XI) as colorless needles of mp 274—277° (dec.). XI was used in the succeeding step of the reaction without further purification.

XI (0.28 g) was heated with 10 ml of 20% aq. HNO_3 solution in a boiling water bath for 5 min. The reaction mixture was made slightly alkaline with 15% aq. NH_4OH solution and the reaction product was extracted with $CHCl_3$. The $CHCl_3$ layer was washed with H_2O, dried over anhyd. Na_2SO_4 and evaporated to dryness. Recrystallization of the residue from THF afforded 0.21 g of I as colorless prisms of mp 257—260° (dec.). *Anal.* Calcd for $C_{14}H_{14}N_4O_2$: C, 62.21; H, 5.22; N, 20.73. Found: C, 61.95; H, 5.29; N, 20.54.

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