(s, 1 H, H-5), 4.96 (d, 1 H, J = 13 Hz, H-19), 5.60 (d, 1 H, J = 10 Hz, H-7), 5.90 (br t 1 H, H-9), 6.60 (d, 1 H, J = 10 Hz, H-8), 6.66 (s, 2 H, H-1, H-2), 7.40 (d, 1 H, J = 13 Hz, H-18).

Acknowledgment. We thank the National Institute on Drug Abuse for a grant (DA-01674). A.S. thanks GNDU, Amritsar, India, for a grant of leave.

Registry No. 1, 18651-71-3; (±)-5, 83967-54-8; 6, 78923-43-0; 7, 83967-55-9; 8, 78914-30-4; 9, 78914-29-1; 10, 80410-25-9; 11, 84025-04-7; 12, 83967-56-0; 13, 80410-27-1; 14, 80410-26-0; 14 fumarate, 84025-05-8; 15, 83967-57-1; 16, 83967-58-2; 17, 83967-59-3; thebaine, 115-37-7; MP, 922-67-8; DMAD, 762-42-5; EP, 623-47-2; 3-butyn-2-one, 1423-60-5; THF, 109-99-9; MeOH, 67-56-1.

Synthesis and Reactions of *o*-Benzoquinone Monosulfonimides

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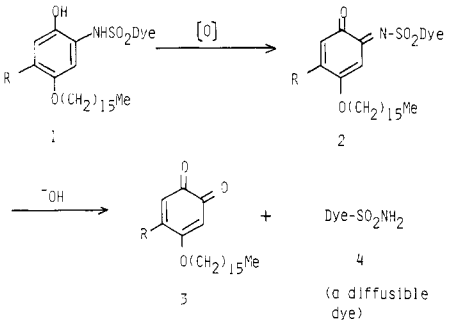
Received June 25, 1982

4-Alkoxy(R^2O)-5-alkyl(R^1)-*N*-[[2-(2-methoxyethoxy)-5-nitrophenyl]sulfonyl]-*o*-benzoquinone imines (**10a–d**: R^1, R^2; **a**, Me, Me; **b**, Me, *n*-$C_{16}H_{33}$; **c**, *t*-Bu, Me; **d**, *t*-Bu, *n*-$C_{16}H_{33}$) are synthesized by the oxidation of *o*-sulfonamidophenols **9a–d** with MnO_2. Reactions of **10a–d** with aqueous NaOH–MeOH result in 1,4-additions of MeO^- to the imide groups, affording *p*-benzoquinone monoacetals **12a–d**. The subsequent hydrolyses (1,2-additions of HO^- to **10** reproduced reversibly) give arenesulfonamides (**14**) in varying yields depending upon the 5-alkyl substituents. The formation rates ($t_{1/2}$) of **14** from **10b** and from **10d** are 1.3 and 0.4 h, respectively. Heterogeneous hydrolysis (aqueous NaOH–AcOEt) of **10b** affords 1,2-addition products [*o*-benzoquinone (**11b**) and **14**] and 1,4-addition products [*p*-benzoquinone imine (**15a**) and *p*-benzoquinone (**16a**)]. Similar compounds (**11d**, **14**, **15b**, and **16b**) are obtained by heterogeneous hydrolysis of **10d**, but the portion of 1,2-addition products (**11d** and **14**) is larger. While the redox and coupling reaction between **10b** and *N*-ethyl-*N*-(2-methanesulfonamidoethyl)-2-methylbenzene-1,4-diamine (**17**) gives the indoaniline dye **19**, no coupling reaction between the reduced **10d** and the oxidized **17** is observed.

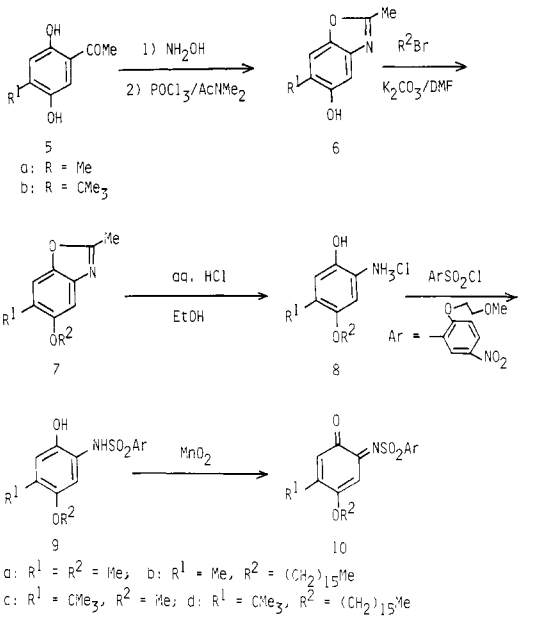
The chemistry of *p*-benzoquinone monosulfonimides was extensively studied by Adams[1] and recently revived with respect to their synthetic applications[2,3] and reaction mechanisms.[4] However, no reactions of the ortho analogues have ever been investigated. This is probably because they are so difficult to isolate. For example, Adams reported that, although he attempted the oxidation of 4- and 5-methyl-2-benzenesulfonamidophenol, he could not isolate the corresponding *o*-quinone monosulfonimides.[5]

o-Sulfonamidophenols **1** containing a dye moiety have been proposed as dye releasers for instant color photography.[6] Their main reactions have been presumed to be oxidation into the corresponding *o*-quinone monosulfonimides **2** and the subsequent hydrolysis to release the



diffusible dye **4**. However, the details of the dye-releasing processes have not been investigated so far. In this respect, studies on the behavior, particularly on the side reactions of the intermediates **2**, are significant in order to design dye-releasers of high efficiency.

Scheme I



The above-described organochemical and photographic interests prompted us to investigate the reaction of *o*-benzoquinone monosulfonimides. In this paper, we report the isolation and reactions of *o*-quinone monosulfonimides.[7] The isolation and structural determination of

(1) Adams, R.; Reifschneider, W. *Bull. Soc. Chim. Fr.* **1958**, 25 and references cited therein.
(2) Rutolo, D.; Lee, L.; Sheldon, R.; Moore, H. W. *J. Org. Chem.* **1978**, *43*, 2304.
(3) Ohnuma, T.; Sekine, Y.; Ban, Y. *Tetrahedron Lett.* **1979**, 2533.
(4) Shudo, K.; Orihara, Y.; Ohta, T.; Okamoto, T. *J. Am. Chem. Soc.* **1981**, *103*, 943.
(5) Adams, R.; Stewart, J. M. *J. Am. Chem. Soc.* **1952**, *74*, 5876.
(6) (a) Koyama, K.; Maekawa, Y.; Miyakawa, M. U.S. Patent 4055428, 1977. (b) Fujita, S. *Yuki Gosei Kagaku Kyokai-Shi* **1981**, *39*, 331.
(7) A preliminary report has appeared in: Fujita, S. *J. Chem. Soc., Chem. Commun.* **1981**, 425.

0022-3263/83/1948-0177$01.50/0

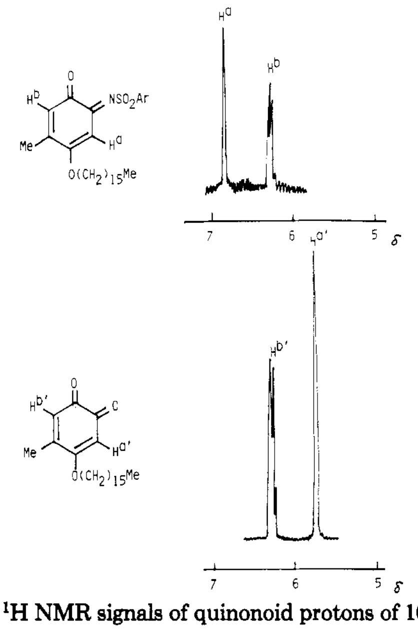


Figure 1. ^{1}H NMR signals of quinonoid protons of **10b** and **11b**.

the reaction products give information for designing improved dye-releasers. In particular, the reaction paths have been found to be affected by the alkyl substituents.

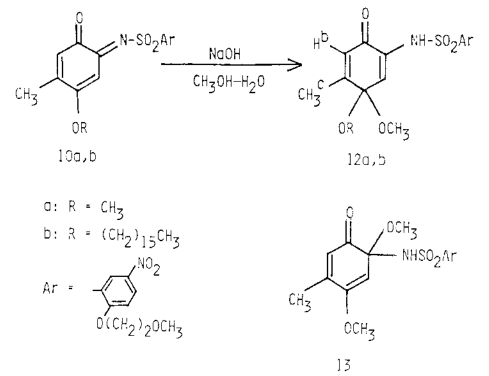
Results and Discussion

Synthesis of *o*-Quinone Monosulfonimides. A synthetic route to *o*-benzoquinone monosulfonimides is illustrated in Scheme I. The oximation and subsequent Beckmann rearrangement of acylhydroquinone **5** gave 5-hydroxy-2-methylbenzoxazoles **6**,[8] which were, in turn, alkylated into the corresponding alkyl ethers **7**. The acid-catalyzed hydrolysis of **7** and the condensation of the resulting *o*-aminophenols (**8**) with arenesulfonyl chloride[9] afforded *o*-sulfonamidophenols **9**. The compounds (**8a,d**) having a ballast group ($OC_{16}H_{33}$-*n*) could also be synthesized by the method reported.[6a]

The 4-alkoxy-5-alkyl-*N*-(arylsulfonyl)-*o*-benzoquinone imines (**10a–d**) were prepared by oxidation of the phenols **9** with manganese dioxide. They are the first examples of *o*-benzoquinone monosulfonimides isolated.[10] Both of the substituents attached to the 4- and 5-positions are presumed to block nucleophilic attacks (1,4-addition to the imide and carbonyl groups) or self-condensations during the preparations of **10a–d**.[11]

The compounds **10a–d** are acid-labile orange crystals which have visible absorption maxima (λ_{max}) at ca. 455 nm (ϵ ~4500). The signals of the protons at the 3-position (H^a) and 6-position (H^b) appear at δ 6.8–6.9 and 6.2–6.3, respectively. [The assignment was possible since the 5-methyl protons of **10a** (or **10b**) exhibited long-range coupling with H^b as shown in Figure 1.] On the other hand, the corresponding signals of the related *o*-benzoquinone **11** appear at δ 5.7–5.8 (for $H^{a'}$) and 6.2–6.3 (for $H^{b'}$), respectively. It is to be noted that the difference between the value of H^a and that of $H^{a'}$ is remarkable and can be ascribed to the larger electronegativity of the imide nitrogen than that of the carbonyl oxygen. The signals of H^b and $H^{b'}$ appear in approximately the same region.

Scheme II



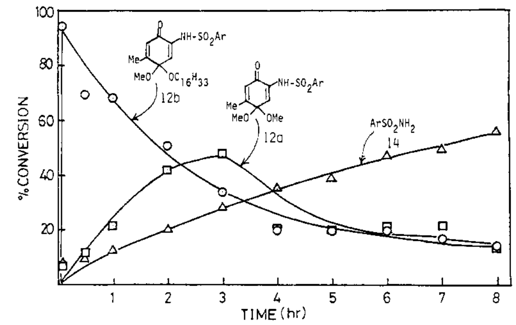


Figure 2. Rate of formation of the products from **10b**. A 1.61 × 10^{-2} M solution (10 mL) of **10b** in methanol and 1 N NaOH (0.5 mL) were mixed and stirred at 25 °C. The products isolated were **12b** (○), **12a** (□), and **14** (△).

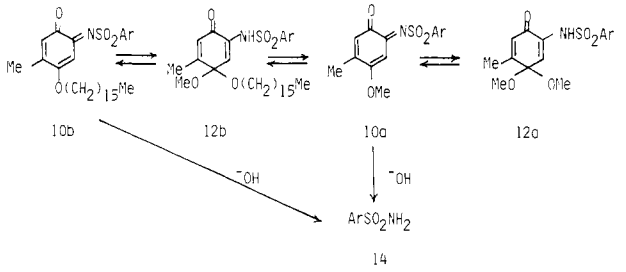
Alkaline Hydrolysis of 4-Alkoxy-*N*-(arylsulfonyl)-5-methyl-*o*-benzoquinone Imines (10a,b). A solution of **10a** in methanol was treated with 1 N aqueous sodium hydroxide, and the mixture was stirred for 40 min. Quenching with acetic acid and workup gave an acid-labile product (**12a**, Scheme II) whose mass spectral (*m/e* 442) and analytical data were in agreement with a methanol adduct. The ^{1}H NMR spectrum of **12a** exhibits a singlet (6 H) at δ 3.10 (2 × OMe), and the long-range coupling constant (J = 2 Hz) between Me^c (δ 1.90) and H^b (δ 6.10) was very similar to that for cross-conjugated dienones (1.6 Hz).[12] Moreover, the presence of a sulfonamide group in **12a** is shown by its ^{1}H NMR (δ 7.99) and IR spectra (ν_{max} 3380 cm^{-1}). These data show that the methanol adduct has the *p*-benzoquinone monoacetal structure (**12a**) and exclude the alternative conjugated structure **13**.

Similarly, the methanol adduct **12b** was obtained by solvolysis of **10b**. The ^{1}H NMR signal of the 4-methoxy group of **12b** appears at δ 3.06, which is in the same region as that for **12a**.

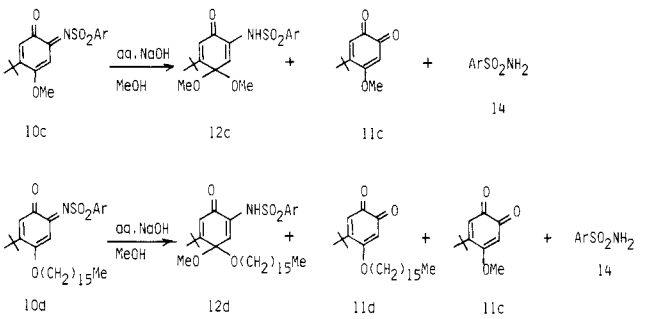
p-Benzoquinone monoacetals are useful synthetic intermediates[13] and are prepared by partial hydrolysis of the corresponding diacetals[14] or by oxidation of *p*-alkoxyphenols in the presence of alcohols.[15] The present method provides a new route for the preparation of amido-substituted *p*-benzoquinone monoacetals. The mixed mono-

(8) (a) Fujita, S.; Koyama, K.; Inagaki, Y. *Synthesis* **1982**, 68. (b) Fujita, S. *Yuki Gosei Kagaku Kyokai-Shi* **1982**, *40*, 176.
(9) Fujita, S. *Synthesis* **1982**, 423.
(10) We have reported another example of the *o*-quinone monosulfonimide and its reduction with *N,N*-diethylhydroxylamine. See: Fujita, S.; Sano, K. *J. Org. Chem.* **1979**, *44*, 2647.
(11) The self-condensation of *o*-benzoquinone monoimine was reported. See: Nogami, T.; Hishida, T.; Yamada, M.; Mikawa, H.; Shirota, Y. *Bull. Chem. Soc. Jpn.* **1975**, *48*, 3709.
(12) (a) Norris, R. K.; Sternhell, S. *Aust. J. Chem.* **1966**, *19*, 617. (b) Kropp, R. J. *J. Am. Chem. Soc.* **1964**, *44*, 2647.
(13) (a) Fujita, S. *Yuki Gosei Kagaku Kyokai-Shi* **1982**, *40*, 307. (b) Koelsch, P. M.; Tanis, S. P. *Kodak Lab. Chem. Bull.* **1981**, *52*, 1.
(14) Henton, D. R.; Chenard, B. L.; Swenton, J. S. *J. Chem. Soc., Chem. Commun.* **1979**, 326.
(15) (a) McKillop, A.; Perry, D. H.; Edwards, M.; Antus, S.; Farkas, L.; Magradi, M.; Taylor, E. C. *J. Org. Chem.* **1976**, *41*, 282. (b) Güchi, G.; Chun, P.-S.; Hoppmann, A.; Mak, C.-P.; Pearse, A. *J. Org. Chem.* **1978**, *43*, 3983.

Scheme III



Scheme IV



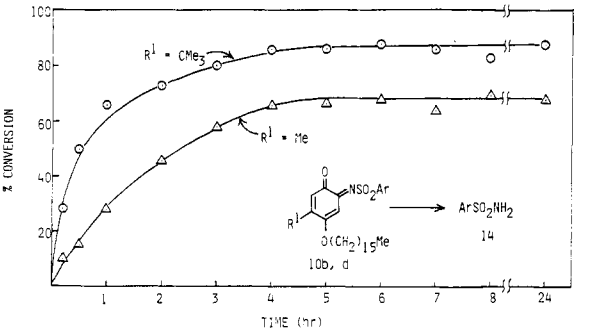
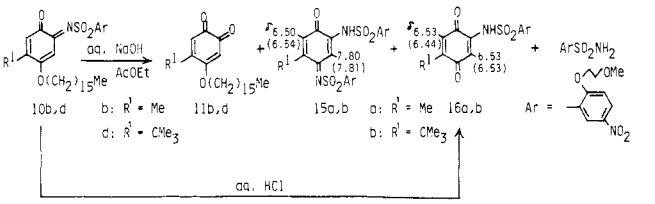


Figure 3. Rates of formation of **14** from **10b** (△) and from **10d** (○). A 1.34×10^{-2} M solution (24 mL) of **10b** or **10d** in methanol and 1 N NaOH (2.0 mL) were mixed and stirred at 30 °C.

Scheme V



acetal structure of **12b** is interesting, although it is expected to have less steric hindrance than the related compound reported.[15a]

In order to clarify the dye-releasing mechanism, the reaction of **10b** with methanolic sodium hydroxide was followed as a function of time (Figure 2). At first, the adduct **12b** was detected in an amount of 94%, and then it gradually disappeared, to be replaced by the adduct **12a**. The concentration of **12a** rose to a maximum and then diminished. As the amounts of **12b** and **12a** decreased, 2-(2-methoxyethoxy)-5-nitrobenzenesulfonamide (**14**, a model compound for diffusible dyes such as **4**) was increasingly formed. The *o*-quinones (**11b,a**) expected were not detected under these conditions. This is probably because further attacks of nucleophiles (such as ^-OH etc.) occurred at the 4-positions of **11b** and **11a** to give unidentified products.

On the basis of Figure 2, Scheme III is suggested, although further kinetic investigations will be necessary. While compound **10a** could not be detected in the actual reaction mixture from **10b**, its intermediacy is strongly supported by the formation of **12a**.

Alkaline Hydrolysis of 4-Alkoxy-*N*-(arylsulfonyl)-5-*tert*-butyl-*o*-benzoquinone Imines (10c,d). Hydrolysis of **10c** gave the methanol adduct **12c**, **14**, and quinone **11c** (Scheme IV). The compound **12c** (FDMS, *m/e* 484) was extremely unstable and decomposed to a complex mixture on NMR measurement with chloroform-*d*, dimethyl-d_6 sulfoxide, pyridine-d_5, or acetone-d_6 as a solvent. A partial exchange of the CH_3O group by CD_3O was observed with an NMR measurement in CD_3OD.

Hydrolysis of **10d** afforded a more complex mixture, from which the adduct **12d**, quinones **11d,c**, and **14** were isolated. The compound **12d** exhibits a molecular peak at *m/e* 694 in its FD mass spectrum. The signal pattern of the olefinic and aromatic protons of **12d** is similar to that of **12c**. A partial exchange of MeO by CD_3O was also observed in CD_3OD. The quinones **11d,c**, whose structures were determined by elemental analyses and NMR spectra, are stable enough to be isolated under the solvolytic conditions in contrast to the related compound **11b**.

The comparison of the solvolytic behavior of **10b** and **10d** indicate that alkyl substituents (methyl vs. *tert*-butyl) affected the reaction paths of the *o*-benzoquinone monosulfonimides. Figure 3 shows the yields of **14** from **10b** and from **10d** determined as a function of time. The ultimate yields of **14** from **10b** and from **10d**, which corresponded to the dye-releasing efficiency of 1, were found to be 68% and 88%, respectively. The formation rates ($t_{1/2}$) of **14** were 1.3 h for **10b** and 0.4 h for **10d**. These results indicate that the solvolysis of **10d** follows a reaction path similar to that described in Scheme III and that the imine **10d**, having a *tert*-butyl group, is superior to **10b**, having a methyl group, in the yield and the rate of formation of **14**. These effects of alkyl substituents can be ascribed to the steric hindrance of the *tert*-butyl group against the nucleophilic attack on the 4-carbon atom attached by an alkoxyl group.

Heterogeneous Hydrolysis of 10b and 10d. Heterogeneous hydrolysis of **10b** (aqueous NaOH/ethyl acetate) gave **11b**, **14**, and two new products (**15a** and **16a**, Scheme V). The FD and EI mass spectra of **15a** exhibit molecular peaks at *m/e* 655 (MH^+). The ^1H NMR spectrum shows that compound **15a** has two units of a 2-(2-methoxyethoxy)-5-nitrophenyl group and no hexadecyloxy group. The proton signal of the 5-methyl group (δ 2.03) coupled with that of the 6-proton (δ 6.50) in a long-range fashion. The signal of the 3-proton appears at δ 7.80 (Scheme V), which is lower than the corresponding value of **16a** (δ 6.53 for the 3-proton) by ca. 1.3 ppm. This difference is almost of the same order as the value (ca. 1.1) observed in the case of **10b** (H^a) vs. **11b** ($H^{a'}$) as shown in Figure 1 and is also ascribable to the difference of electronegativity between the imido group of **15a** and the carbonyl of **16a**. These data indicate that compound **15a** has the structure of a *p*-benzoquinone monosulfonimide.

Compound **16a** was also formed in the acid-catalyzed hydrolysis of **10b**. The ^1H NMR spectrum and analytical data show that compound **16a** has a 2-(2-methoxyethoxy)-5-nitrobenzenesulfonamido group but no hexadecyloxy group.

In a similar way, *o*-benzoquinone monosulfonimide **10d**, having a *tert*-butyl group, afforded **11d**, **14**, **15b**, and **16b** on hydrolysis (aqueous NaOH/ethyl acetate). The structures of **15b** and **16b** were determined in the same manner as those of **15a** and **16a**, respectively.

The products (**15a** and **15b**) are presumed to have come from a nucleophilic attack on **10b** and **10d**, respectively,

Scheme VI

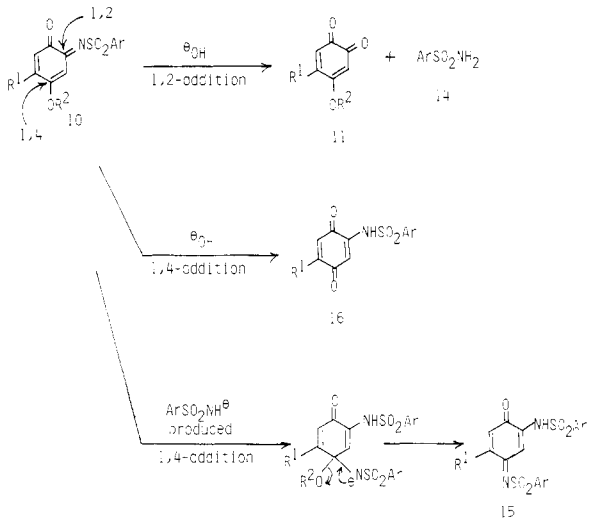


Table I. Heterogeneous Hydrolysis of 10b and 10d[a]

substrate	conditions	yield of product, % 11	14	15	16
10b	2 N NaOH/AcOEt	64	81	4	4
10b	4 N NaOH/AcOEt	0	63	12	2
9b	$K_3Fe(CN)_6$-2 N NaOH	53	63	12	3
10d	2 N NaOH/AcOEt	95	87	3	2
10d	4 N NaOH/AcOEt	52	83	5	8
9d	$K_3Fe(CN)_6$-2 N NaOH	93	84	6	0

[a] The yields were determined by the HPLC technique. See the Experimental Section.

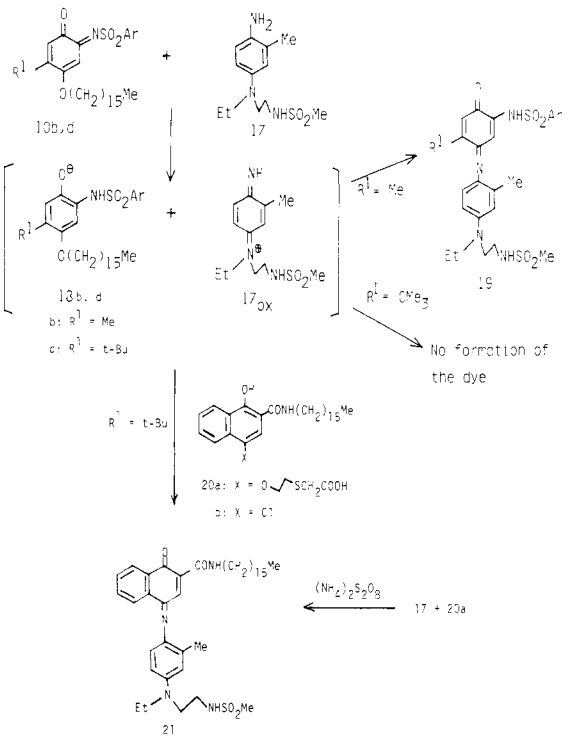
by the arenesulfonamide anion ($ArSO_2NH^-$) produced partially by the hydrolysis of **10b** and **10d** (Scheme VI). The control experiments revealed that compounds **15a** and **15b** were not produced by the reactions of quinones **16a** and **16b**, respectively, with the arenesulfonamide anion. The *p*-benzoquinones (**16a** and **16b**) are ascribed to the attack of hydroxide ion on the 4-carbons attached by an alkoxy group. In these pathways, the arenesulfonamido unit, which corresponds to a diffusible dye such as **4** from the dye releaser **1**, is quenched or becomes useless in the photographic sense.

Table I shows the yields of the products in the heterogeneous hydrolysis of **10b** and **10d**. The runs, which contain oxidation and hydrolysis of **9b** and **9d**, simulate the photographic processes more closely. The yield of **14** from **10d** (having a *tert*-butyl group) was found to be higher than that from **10b** (having methyl group) under each set of the conditions examined. These experiments indicate again the steric hindrance of the *tert*-butyl group against the nucleophilic attacks on the 4-position.

Reactions of 10b and 10d with a *p*-Phenylenediamine. The 5-methyl-substituted *o*-quinone monosulfonimide **10b** underwent a coupling reaction with a *p*-phenylenediamine (**17**), which is a color developer in conventional color photography, to afford an indoaniline dye (**19**) having a visible absorption at λ_{max} (AcOEt) 634 nm.

In contrast, no indoaniline dye was produced by the reaction of 5-*tert*-butyl-substituted compound **10d** with **17**, although the former (**10d**) disappeared as monitored by visible spectroscopy at λ_{max} of **10d** (442 nm in ethyl acetate). The presence of a 1-naphthol derivative (**20a** or **20b**, cyan couplers in color photography) in the reaction system of **10d** and **17** resulted in producing the cyan dye **21** [λ_{max} (AcOEt) 654 nm]. The dye **21** was identical with a sample prepared alternatively by the oxidative coupling

Scheme VII



between **17** and **20a** by means of ammonium persulfate.

Therefore, a redox reaction between **10d** and **17** occurred initially to afford the oxidized developer $\mathbf{17}_{ox}$, which did not couple with the reduced imine counterpart **18d** but could form the cyan dye **21** when the coupler (**20a** or **20b**) was present in the reaction mixture (Scheme VII).

In the case of the 5-methyl-substituted compound **10b**, two possibilities may be present to account for the formation of **19**: (1) a direct attack of **17** on the 4-carbon atom of **10b** and (2) an initial redox reaction between **10b** and **17** and the subsequent coupling reaction (Scheme VII). The methyl-substituted imine **10b** is presumed to be more reducible than the *tert*-butyl-substituted one (**10d**) from the viewpoint of the redox potentials by the analogy of the relationship between methyl- and *tert*-butyl-*o*-benzoquinone.[16] Since the rate of the disappearance of **10b** was observed to be approximately equal to that of **10d**,[17] similar initial mechanisms account for both the reactions of **10b** and **10d**, the latter of which disappeared by the redox reaction as described above. And hence, mechanism 2 for **10b** is reasonable. These facts indicate again the steric hindrance of the *tert*-butyl group against the attacks on the 4-carbon atom of **10**.

Experimental Section

^1H NMR spectra were determined on a Varian EM-390 90-MHz NMR spectrometer at room temperature with chloroform-*d* as a solvent unless otherwise stated. Electron-impact (EI) and field-desorption (RD) mass spectra were determined on a JEOL-01SG-2 mass spectrometer. Infrared spectra (IR) were measured with a JASCO IRA-2 diffraction grating infrared spectrophotometer. Ultraviolet (UV) and visible spectra (VS) were obtained by using a Hitachi 323 spectrophotometer. TLC was carried out on Merck GF_{254} Type 60 silica gel plates. Column chromatography was performed with Merck Kieselgel 60 (70–230 mesh). HPLC data were determined by means of a Hitachi 635-A apparatus, monitoring the UV absorption at 273 nm. All melting points were uncorrected.

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(17) Fujita, S., unpublished results.

2-Amino-4-methoxy-5-methylphenol Hydrochloride (8a). Methylation of 2,6-dimethyl-5-hydroxybenzoxazole (**6a**)[18] with methyl iodide and sodium methoxide gave 2,6-dimethyl-5-methoxybenzoxazole (**7a**) in 90% yield. A mixture of **7a** (53.2 g, 0.30 mol), ethanol (250 mL), and 35% hydrochloric acid (60 mL) was stirred at the reflux temperature for 1 h. After the mixture cooled, the precipitated solid (12.2 g) was filtered, washed with water, and dried. The second crop (34.8 g) was obtained by the addition of saturated aqueous sodium chloride to the mother liquor. The total yield of **8a** was 47.0 g (80%); mp 216–223 °C dec. This product was used in the next step without further purification.

4-Methoxy-2-[[2-(2-methoxyethoxy)-5-nitrophenyl]-sulfonamido]-5-methylphenol (9a). To a solution of **8a** (34.1 g, 0.18 mol) in *N,N*-dimethylacetamide (270 mL) was added 2-(2-methoxyethoxy)-5-nitrobenzenesulfonyl chloride[9] (53.2 g, 0.18 mol) and pyridine (71.2 g) below 20 °C. The reaction mixture was stirred at room temperature for 2 h, diluted with 810 mL of 2-propanol, and then treated with 5 g of activated carbon. After filtration, the filtrate was poured into 1.5 L of water. The precipitate was filtered by suction and washed with a mixture of 2-propanol and water (6:1). The crystals of **9a** (42.2 g, 57%) had a melting point of 94–95 °C. Anal. Calcd for $C_{17}H_{20}N_2O_8S·H_2O$: C, 47.44; H, 5.15; N, 6.51. Found: C, 47.42; H, 5.21; N, 6.61.

4-Methoxy-*N*-[[2-(2-methoxyethoxy)-5-nitrophenyl]-sulfonyl]-5-methyl-*o*-benzoquinone Imine (10a). To a solution of **9a** (6.2 g, 0.015 mol) in acetone (75 mL) was added manganese dioxide (15.0 g), and the mixture was stirred for 3 h at room temperature. After filtration of the reaction mixture, the filtrate was evaporated. Addition of 2-propanol to the residue caused crystallization. The crystals were collected by filtration: 3.60 g (59%); mp 138–142 °C; ^{1}H NMR δ 8.87 (1 H, d, J = 3 Hz), 8.41 (1 H, dd, J = 3, 9 Hz), and 7.20 (1 H, d, J = 9 Hz) (aryl protons), 3.28 (3 H, s, CH_3O), 4.33 (2 H, m, OCH_2), 3.70 (2 H, m, CH_2OMe), 6.89 (1 H, s, =CHC=N), 6.26 (1 H, m coupled with 5-Me, =CHC=O), 2.11 (3 H, br s, 5-CH_3), 4.00 (3 H, s, 4-OCH_3).

4-(Hexadecyloxy)-*N*-[[2-(2-methoxyethoxy)-5-nitrophenyl]sulfonyl]-5-methyl-*o*-benzoquinone Imine (10b). To a solution of 4-(hexadecyloxy)-2-[[[2-(2-methoxyethoxy)-5-nitrophenyl]sulfonyl]amino]-5-methylphenol (**9b**;[19] 11.8 g, 0.02 mol) in acetone (100 mL) was added manganese dioxide (20 g), and the suspension was stirred at room temperature for 2.6 h. After addition of acetone (90 mL), the precipitates were dissolved by warming. Manganese dioxide was removed by filtration through Celite 545, and the filtrate was allowed to cool. The crystals precipitated were collected by filtration: 7.0 g (56%); mp 90–91 °C. Anal. Calcd for $C_{32}H_{48}N_2O_8S$: C, 61.91; H, 7.79; N, 4.51. Found: C, 62.12; H, 7.96; N, 4.51. VS (acetone) λ_{max} 454 nm (ϵ 4400); ^{1}H NMR δ 8.87 (1 H, d, J = 3 Hz), 8.38 (1 H, dd, J = 3, 9 Hz), and 7.14 (1 H, d, J = 9 Hz) (aryl protons), 3.29 (3 H, s, CH_3O), 4.34 (2 H, m, OCH_2), 3.70 (2 H, m, CH_2OMe), 6.81 (1 H, s, =CHC=N), 6.25 (1 H, d, J = 2 Hz, coupled with 5-Me, =CHC=O), 2.08 (3 H, m, 5-CH_3), 0.87 (3 H, m, CH_3-$(CH_2)_{15}$), 4.11 (2 H, t, $(CH_2)_{14}CH_2O$), 1.7–1.0 (28 H, m, $(CH_2)_{14}$).

2-Amino-5-*tert*-butyl-4-methoxyphenol Hydrochloride (8c). Methylation of 6-*tert*-butyl-5-hydroxy-2-methylbenzoxazole (**6b**)[8] with methyl iodide/sodium methoxide gave 6-*tert*-butyl-5-methoxy-2-methylbenzoxazole (**7c**) in 88% yield. A mixture of **7c** (4.0 g, 0.018 mol), ethanol (20 mL), and 35% hydrochloric acid (5 mL) was stirred at reflux temperature for 1 h. The mixture was cooled and poured into a saturated aqueous solution (200 mL) of sodium chloride. The solid precipitated (4.0 g, 96%) was collected and used in the next step without further purification; mp 165–169 °C dec.

5-*tert*-Butyl-4-methoxy-2-[2-(2-methoxyethoxy)-5-nitrobenzenesulfonamido]phenol (9c). To a solution of **8c** (3.90 g, 0.017 mol) in *N,N*-dimethylacetamide (25 mL) were added 2-(2-methoxyethoxy)-5-nitrobenzenesulfonyl chloride (4.97 g, 0.017 mol) and then pyridine (6.64 g) below 20 °C. The reaction mixture was worked up as described in the preparation of **9a**. The crystals obtained (**9c**) had a melting point of 96–97 °C (phase transition at ca. 88 °C). Anal. Calcd for $C_{20}H_{26}N_2O_8S·C_3H_8O$ (2-propanol): C, 53.68; H, 6.66; N, 5.44. Found: C, 53.34; H, 6.55; N, 5.86.

5-*tert*-Butyl-4-methoxy-*N*-[[2-(2-methoxyethoxy)-5-nitrophenyl]sulfonyl]-*o*-benzoquinone Imine (10c). A solution of **9c** (5.45 g, 0.012 mol) in acetone (65 mL) was treated with manganese dioxide (12.0 g) to give the monosulfonimide **10c**: 57% yield; mp 173–175 °C; ^{1}H NMR δ 8.87 (1 H, d, J = 3 Hz), 8.38 (1 H, dd, J = 3, 9 Hz), and 7.15 (1 H, d, J = 9 Hz) (aryl protons), 3.29 (3 H, s, CH_3O), 4.32 (2 H, m, OCH_2), 3.70 (2 H, m, CH_2OMe), 6.88 (1 H, s, =CHC=N), 6.27 (1 H, s, =CHC=O), 1.31 (9 H, s, $C(CH_3)_3$), 4.01 (3 H, s, 4-OCH_3). Anal. Calcd for $C_{20}H_{24}N_2O_8S$: C, 53.09; H, 5.35; N, 6.19. Found: C, 52.56; H, 5.34; N, 6.31.

5-*tert*-Butyl-4-(hexadecyloxy)-*N*-[[2-(2-methoxyethoxy)-5-nitrophenyl]sulfonyl]-*o*-benzoquinone Imine (10d). The reaction of **6b**[8] with 1-bromohexadecane and potassium carbonate in *N,N*-dimethylformamide gave 6-*tert*-butyl-5-(hexadecyloxy)-2-methylbenzoxazole (**7d**), which was hydrolyzed into 2-amino-5-*tert*-butyl-4-(hexadecyloxy)phenol hydrochloride (**8d**).[20] The condensation of **8d** with 2-(2-methoxyethoxy)-5-nitrobenzenesulfonyl chloride[9] afforded 5-*tert*-butyl-4-(hexadecyloxy)-2-[2-(2-methoxyethoxy)-5-nitrobenzenesulfonamido]phenol (**9d**).

A mixture of **9d** (13.3 g, 0.02 mol), acetone (100 mL), and manganese dioxide (20 g) was stirred at room temperature for 1.5 h. After the manganese dioxide was filtered off, the filtrate was condensed to give crystals of crude **10d** (10.5 g), which were recrystallized from acetonitrile (315 mL): yield 8.20 g (62%); mp 68–70 °C; VS (acetone) λ_{max} 456 nm (ϵ 4600); ^{1}H NMR δ 8.92 (1 H, d, J = 3 Hz), 8.42 (1 H, dd, J = 3, 9 Hz), and 7.18 (1 H, d, J = 9 Hz) (aryl protons), 3.31 (3 H, s, CH_3O), 4.34 (2 H, m, OCH_2), 3.69 (2 H, m, CH_2OMe), 6.88 (1 H, s, =CHC=N), 6.30 (1 H, s, =CHC=O), 1.33 (s overlapped, $C(CH_3)_3$), 4.18 (2 H, t, OCH_2-$(CH_2)_{14}$), 2.0–1.1 (m, overlapped, $(CH_2)_{14}$), 0.85 (3 H, m, CH_3CH_2). Anal. Calcd for $C_{35}H_{54}N_2O_8S$: C, 63.42; H, 8.21; N, 4.23. Found: C, 63.35; H, 8.30; N, 4.30.

2-(2-Methoxyethoxy)-5-nitrobenzenesulfonamide (14). To a solution of 2-(2-methoxyethoxy)-5-nitrobenzenesulfonyl chloride[9] (455 g, 1.54 mol) in acetone (2.28 L) was added 28% ammonia (455 mL) below 50 °C. The mixture was stirred for 1 h and poured into diluted hydrochloric acid (35% HCl, 300 mL, and water, 5 L). The crystals of **14** (409 g, 96%) were collected by filtration: mp 125–130 °C; EIMS, m/e 276 (M); ^{1}H NMR (Me_2SO) δ 8.6–8.4 (2 H, m, 4-H and 6-H), 8.53 (1 H, d, J = 9 Hz, 3-H), 7.22 (2 H, br s, SO_2NH_2), 4.6–4.4 (2 H, m, OCH_2), 3.9–3.7 (2 H, m, CH_2OMe), 3.35 (3 H, s, OCH_3). Anal. Calcd for $C_9H_{12}N_2O_6S$: C, 39.13; H, 4.38; N, 10.14. Found: C, 39.01; H, 4.30; N, 9.99.

Alkaline Hydrolysis of 10a with Aqueous NaOH/MeOH. Isolation of the *p*-Benzoquinone Acetal 12a. To a solution of **10a** (0.50 g) in methanol (50 mL) was added 1 N sodium hydroxide (2.5 mL). The mixture was stirred for 40 min at room temperature and poured into a mixture of acetic acid (1 mL) and water (150 mL). The crystals precipitated were collected by suction filtration. The yield of **12a** was 0.10 g: mp 101–104 °C; FDMS, m/e 442 (M), 411 (M – OMe); UV (acetone) λ_{max} 297 nm (ϵ 12 500); ^{1}H NMR δ 8.75 (1 H, d, J = 3 Hz), 8.40 (1 H, dd, J = 3, 9 Hz), and 7.17 (1 H, d, J = 9 Hz) (aryl protons), 3.49 (3 H, s, CH_3O), 4.43 (2 H, m, OCH_2), 3.90 (2 H, m, CH_2OMe), 7.99 (1 H, br s, $NHSO_2$), 6.70 (1 H, s, CH=C—C=O), 6.10 (1 H, m coupled with 5-Me, =CHC=O), 1.90 (3 H, d, J = 2 Hz, 5-CH_3), 3.10 (6 H, s, 2 OCH_3). Anal. Calcd for $C_{18}H_{22}N_2O_9S$: C, 48.87; H, 5.01; N, 6.33. Found: C, 48.59; H, 4.94; N, 6.44.

Alkaline Hydrolysis of 10b with Aqueous NaOH/MeOH. Isolation of the *p*-Benzoquinone Monoacetal 12b. To a suspension of **10b** (2.0 g) in methanol (200 mL) was added 1 N sodium hydroxide (10 mL). The mixture was stirred for 5 min at room temperature, poured into a mixture of acetic acid (12 mL) and water (600 mL), and extracted with ethyl acetate. After the mixture was dried over anhydrous sodium sulfate and the solvent removed below 40 °C, the resulting residue was triturated with 2-propanol. The crystals precipitated were collected by filtration and washed with *n*-hexane. Recrystallization of methanol (containing a small amount of water) gave **12b**: 0.1 g; mp 42–45 °C;

(18) Aoki, K. Japanese Kokai 1977-153923, 1977.
(19) (a) Fujita, S.; Ono, S.; Hayashi, H. British Patent Application 2000505A, 1979. (b) Fujita, S.; Hayashi, H.; Ono, S.; Yoshida, Y.; Harada, T. U.S. Patent 4 268 625, 1981.
(20) Koyama, K.; Waki, K. Japanese Kokai 1981-12642, 1981.

FDMS, m/e 653 (M + 1), 652 (M), 622 (M + 1 - OMe). UV (MeOH) λ_{max} 297 nm (ϵ 12 100); ^{1}H NMR δ 8.74 (1 H, d, J = 3 Hz), 8.37 (1 H, dd, J = 3, 9 Hz), and 7.15 (1 H, d, J = 9 Hz) (aryl protons), 3.43 (3 H, s, CH_3O), 4.40 (2 H, m, OCH_2), 3.87 (2 H, m, CH_2OMe), 7.95 (1 H, br s, $NHSO_2$), 6.68 (1 H, s, CH=C—C=O), 6.06 (1 H, m coupled with 5-Me, =CHC=O), 1.87 (3 H, d, J = 2 Hz, 5-CH_3), 3.06 (3 H, s, 4-OCH_3), 3.3–3.1 (2 H, m, $OCH_2(CH_2)_{14}$), 1.6–1.1 (28 H, m, $(CH_2)_{14}$), 0.86 (3 H, m, CH_3CH_2). Anal. Calcd for $C_{33}H_{52}N_2O_9S$: C, 60.71; H, 8.03; N, 4.29. Found: C, 60.79; H, 7.95; N, 4.04.

Kinetic Measurement of Alkaline Hydrolysis of 10b. A solution of **10b** (100 mg) and diphenyl ether (an internal standard, 150 mg) in methanol (10 mL) was admixed with 1 N sodium hydroxide (0.5 mL) at 25 °C. Then, a 12-μL portion of the reaction mixture was taken out every hour and spotted on a TLC plate. After development, each separated component was scratched off and extracted with 5 mL of methanol. The UV spectrum of each extract was measured, and the amount of each compound was calculated on the basis of its relative absorbance to that of the internal standard. The results are shown in Figure 2.

Alkaline Hydrolysis of 10c with Aqueous NaOH/MeOH. Isolation of the *p*-Benzoquinone Monoacetal 12c. A solution of **10c** (100 mg) in methanol (9 mL) was admixed with 1 N sodium hydroxide (2 mL). After the reaction mixture was stirred for 30 min at room temperature, it was examined by TLC and found to contain **12c**, **11c**, and **14**. Cooling of the mixture to 0 °C gave crystals of **12c**, which were filtered and washed with water: mp 210–212 °C; FDMS, m/e 484 (M); ^{1}H NMR (CD_3OD) δ 8.74 (1 H, d, J = 3 Hz), 8.33 (1 H, dd, J = 3, 9 Hz), and 7.29 (1 H, d, J = 9 Hz) (aryl protons), 3.41 (3 H, s, OCH_3), 4.39 (2 H, m, OCH_2), 3.83 (2 H, m, CH_2OMe), 6.25 (1 H, s, CH=C—C=O), 5.84 (1 H, s, =CHC=O), 1.29 (9 H, s, $C(CH_3)$), 2.97 (ca, 3 H (varied in accordance with the conditions), OCH_3). Anal. Calcd for $C_{21}H_{28}N_2O_9S + H_2O$: C, 50.19; H, 6.02; N, 5.57. Found: C, 49.35; H, 5.34; N, 5.55.

Alkaline Hydrolysis of 10d with Aqueous NaOH/MeOH. Isolation of the *p*-Benzoquinone Acetal 12d. The compound **10d** (100 mg) was dissolved in 9 mL of methanol with heating, cooled to 20 °C, and then admixed with 1 N sodium hydroxide (2 mL). The mixture was examined by means of TLC and shown to contain **12d**, **11d,c**, and **14**. After the mixture was stirred for 10 min, crystals of **12d** began to precipitate. They were collected by filtration and washed with water: mp 148–150 °C; FDMS, m/e 694 (M); ^{1}H NMR (CD_3OD) δ 8.73 (1 H, d, J = 3 Hz), 8.32 (1 H, dd, J = 3, 9 Hz), and 7.30 (1 H, d, J = 9 Hz) (aryl protons), 3.41 (overlapped, s, OCH_3), 4.44 (2 H, m, OCH_2), 3.87 (2 H, m, CH_2OMe), 6.22 (1 H, s, CH=C—C=O), 5.90 (1 H, s, =CHC=O), 3.6–3.4 (overlapped, m, $CH_2(CH_2)_{14}$), 1.3–1.2 (overlapped, m, $(CH_2)_{14}$ and $C(CH_3)_3$), 0.90 (3 H, m, CH_3CH_2); the signals of 4-methoxy group and $NHSO_2$ were not observed probably because of exchanges between those groups and CD_3OD. Anal. Calcd for $C_{36}H_{58}N_2O_9S \cdot H_2O$: C, 60.65: H, 8.48; N, 3.92. Found: C, 60.51; H, 8.19; N, 3.90.

The reaction mixture of a separate experiment was chromatographed with silica gel to give the quinone **11d**: mp 58–60 °C; EIMS, m/e 406 (M + 2), 404 (M); VS (MeCN) λ_{max} 467 nm (ϵ 6600); ^{1}H NMR δ 5.74 (1 H, s, alkyl-OC=CHC=O), 6.26 (1 H, s, t-BuC=CHC=O), 1.33 (9 H, s, $C(CH_3)_3$), 4.01 (2 H, t, $OCH_2(CH_2)_{14}$), 2.0–1.1 (overlapped, m, $(CH_2)_{14}$), 0.87 (3 H, m, CH_3CH_2). Anal. Calcd for $C_{26}H_{44}O_3$: C, 77.18; H, 10.96. Found: C, 77.12; H, 11.24.

A prolonged reaction favored the formation of the quinone **11c** due to the exchange of the hexadecyloxy group by the methoxy. To a solution of **10d** (2.0 g) in methanol (200 mL) was added 1 N sodium hydroxide (10 mL), and the mixture was stirred for 2 h. The mixture was chromatographed with a Merck silica gel TLC plate [20 × 20 cm, benzene–ethyl acetate (2:1) as an eluent] to give the quinone **11c**: mp 92–94 °C; ^{1}H NMR δ 5.74 (1 H, s, alkyl-OC=CHC=O), 6.27 (1 H, s, t-BuC=CHC=O), 1.32 (9 H, s, $C(CH_3)_3$), 3.91 (3 H, s, OCH_3). Anal. Calcd for $C_{11}H_{14}O_3$: C, 68.02; H, 7.27. Found: C, 68.95; H, 7.29.

Formation Rates of 14 from 10b and from 10d. The compound **10b** (200 mg, 3.22×10^{-4} mol) and 1,4-di-*tert*-hexyl-2,5-dimethoxybenzene (60 mg, an internal standard) were dissolved in methanol (24 mL). The solution was kept at 30 °C and was mixed with 1 N sodium hydroxide (2 mL). At various times, a 2-mL portion of the reaction mixture was taken out, poured into 5 mL of aqueous acetic acid (AcOH, 5 mL, and water, 1000 mL), and extracted with ethyl acetate (4 mL) after addition of sodium chloride (500 mg). Each extract (12 μL) was separated by mean of TLC (benzene–AcOEt–MeOH, 150:74:3). The components corresponding to **14** and the internal standard were scratched off and extracted with 4 mL of acetonitrile. The UV spectra of the extracts were determined, and then the amount of **14** was calculated from the absorption of **14** relative to that of the internal standard.

The formation rate of **14** from **10d** was determined in a similar way. The results are shown in Figure 3.

Acidic Hydrolysis of 10b. Isolation of 2-[2-(2-Methoxyethoxy)-5-nitrobenzenesulfonamido]-5-methyl-1,4-benzoquinone (16a). To a solution of **10b** (0.50 g) in methanol (50 mL) was added 35% hydrochloric acid (2.0 mL). The mixture was stirred for 30 min at room temperature and poured into 100 mL of water. The precipitate (0.4 g) was filtered and recrystallized from 2-propanol (30 mL). The yield of **16a** was 0.2 g: mp 149–151 °C; ^{1}H NMR δ 8.81 (1 H, d, J = 3 Hz), 8.42 (1 H, dd, J = 3, 9 Hz), and 7.18 (1 H, d, J = 9 Hz) (aryl protons), 3.49 (3 H, s, OCH_3), 4.37 (2 H, m, OCH_2), 3.83 (2 H, m, CH_2OMe), 6.53 (2 H, m, 3-H and 6-H), 8.03 (1 H, br s, $NHSO_2$), 1.98 (3 H, d, J = 2 Hz, 5-CH_3). Anal. Calcd for $C_{16}H_{16}N_2O_8S$: C, 48.48; H, 4.07; N, 7.07. Found: C, 48.46; H, 4.06; N, 6.93.

Acidic Hydrolysis of 10d. Isolation of 5-*tert*-Butyl-2-[2-(2-Methoxyethoxy)-5-nitrobenzenesulfonamido]-1,4-benzoquinone (16b). The compound **16b** was obtained in 71% yield from **10d**: mp 135–137 °C; UV (MeOH) λ_{max} 271 nm (ϵ 12 300); ^{1}H NMR δ 8.80 (1 H, d, J = 3 Hz), 8.43 (1 H, dd, J = 3, 9 Hz), and 7.20 (1 H, d, J = 9 Hz) (aryl protons), 3.49 (3 H, s, OCH_3), 4.39 (2 H, m, OCH_2), 3.87 (2 H, m, CH_2OMe), 6.53 (1 H, s, 3-H), 6.44 (1 H, s, 6-H), 7.98 (1 H, br s, $NHSO_2$), 1.23 (9 H, s, $C(CH_3)_3$). Anal. Calcd for $C_{19}H_{22}N_2O_8S$: C, 52.17; H, 4.84; N, 6.40. Found: C, 52.06; H, 4.96; N, 6.50.

Heterogeneous Hydrolysis of 10b with Aqueous NaOH/AcOEt. Isolation of the Adduct 15a. To a solution of **10b** (5.0 g) in ethyl acetate (250 mL) was added 1 N sodium hydroxide (500 mL). The mixture was stirred for 40 min at room temperature. TLC of the mixture showed the formation of **11b**, **15a**, **16a**, and **14**. The organic layer was separated and dried over anhydrous sodium sulfate. After removal of the solvent, the residue was chromatographed with a silica gel column [benzene–ethyl acetate (8:1) as an eluent].

For compound **15a**: mp 162–163 °C; EIMS, m/e 656 (M + 2); FDMS, m/e 656 (M + 2), 655 (M + 1); UV (MeCN) λ_{max} 234 nm (ϵ 28 700), 302 (32 500); ^{1}H NMR δ 8.95 (1 H, d, J = 3 Hz), 8.78 (1 H, d, J = 3 Hz), 8.3–8.6 (2 H, m), and 7.3–7.1 (2 H, m) [the aryl protons of the two 2-(2-methoxyethoxy)-5-nitrophenyl groups], 4.5–4.2 (4 H, m, 2 OCH_2), 3.9–3.6 (4 H, m, 2 CH_2OMe), 3.47 (3 H, s, OCH_3), 3.23 (3 H, s, OCH_3), 7.80 (1 H, s, =CHC=N), 6.50 (1 H, d, J = 2 Hz, =CHC=O), 2.03 (3 H, d, J = 2 Hz, 5-CH_3). Anal. Calcd for $C_{25}H_{26}N_4O_{13}S_2$: C, 45.87; H, 4.00; N, 8.56. Found: C, 45.99; H, 3.89; N, 8.34.

For compound **11b**: mp 57–59 °C; EIMS, m/e 364 (M + 2); VS (MeCN) λ_{max} 460 nm (ϵ 6300); ^{1}H NMR δ 6.25 (1 H, m, MeC=CHC=O), 5.70 (1 H, s, alkyl-OC=CHC=O), 3.98 (2 H, t, CH_2) 1.5–1.1 (28 H, m, $(CH_2)_{14}$), 1.0–1.7 (3 H, m, CH_3CH_2), 2.12 (3 H, d, J = 3 Hz, 5-CH_3). Anal. Calcd for $C_{23}H_{38}O_3$: C, 76.20; H, 10.56. Found: C, 75.85; H, 10.72.

The other components (**16a** and **14**) were identical with the samples described above.

Heterogeneous Hydrolysis of 10d with Aqueous NaOH/AcOEt. Isolation of the Adduct 15b. To a solution of **10d** (2.0 g) in ethyl acetate (200 mL) was added 1 N sodium hydroxide (500 mL). The mixture was stirred until the starting **10d** disappeared. The organic layer (which contained **11d**, **15b**, **16b**, and **14** as indicated by TLC) was separated, washed with water, and dried over anhydrous sodium sulfate. After removal of half of the ethyl acetate, the crystals of **14** precipitated. The crystals were filtered, and the filtrate was condensed. The residue was chromatographed with a silica gel column ($CHCl_3$–AcOEt (3:1) and then AcOEt as eluents).

For compound **15b**: mp 165–168 °C; FDMS, m/e 696 (M); UV (MeCN) λ_{max} 298 nm (ϵ 37 100); ^{1}H NMR δ 8.99 (1 H, d, J = 3 Hz), 8.84 (1 H, d, J = 3 Hz), 8.6–8.3 (2 H, m), and 7.18 (2 H, d,

J = 9 Hz) [the aryl protons of two 2-(2-methoxyethoxy)-5-nitrophenyl groups], 4.5–4.2 (4 H, m, 2 OCH_2), 4.0–3.6 (4 H, m, 2 CH_2OMe), 3.50 (3 H, s, OCH_3), 3.22 (3 H, s, OCH_3), 7.81 (1 H, s, =CHC=N), 6.54 (1 H, s, =CHC=O), 1.18 (9 H, s, $C(CH_3)_3$). Anal. Calcd for $C_{28}H_{32}N_4O_{13}S_2$: C, 48.27; H, 4.63; N, 8.04. Found: C, 47.77; H, 4.56; N, 7.83.

The compounds **11d** and **16b** were identical with the samples described above.

Heterogeneous Hydrolysis of 10b and 10d with Aqueous NaOH/AcOEt. Determination of the Yields of the Products. To a solution of 49.98 mg of **10b** (or 53.36 mg of **10d**) in ethyl acetate (5 mL) was added 2 N (or 4 N) sodium hydroxide (10 mL) at room temperature. The mixture was stirred for 1 h at room temperature, diluted with ethyl acetate (5 mL), and then neutralized with 15 mL of aqueous acetic acid (AcOH, 1 mL, and water, 200 mL). After addition of 1,4-di-*tert*-hexyl-2,5-dimethoxybenzene (49.21 mg, as an internal standard), ethyl acetate (15 mL), and sodium chloride (2.5 g), the organic layer was separated and subjected to HPLC determination [using a μ-Bondapak C-18 as a column and MeCN–H_2O (93:7) as an eluent]. Retention times (in minutes) of the components were as follows: **15a** (1.93), **16a** (2.91), **14** (4.07), the standard (7.79) and **11b** (11.41); **15b** (2.32), **16b** (3.15), **14** (4.09), the standard (7.80), and **11d** (15.25). The results are given in Table I.

Oxidation–Hydrolysis of 9b and 9d with Potassium Hexacyanoferrate(III) under Alkaline Conditions. A solution of potassium hexacyanoferrate(III) (0.220 g, 6.44×10^{-4} mol) in 2 N sodium hydroxide (20 mL) was added to a solution of **9b** (0.100 g) and 1,4-di-*tert*-butyl-2,5-dimethoxybenzene (0.0764 g, an internal standard) in ethyl acetate (10 mL). The mixture was stirred for 1 h at room temperature, diluted with ethyl acetate (40 mL), and quenched with 30 mL of aqueous acetic acid (AcOH, 1 mL, and water, 200 mL). After addition of sodium chloride (5.0 g), the organic layer was separated and subjected to HPLC analysis.

The reaction of **9d** was effected under the same conditions. The results are collected in Table I.

Reaction of 10b and 10d with *N*-Ethyl-*N*-[2-(methanesulfonamido)ethyl]-2-methylbenzene-1,4-diamine (17). A solution of **17** (0.60 g, 2.21 mmol) in ethyl acetate (100 mL) was added to a solution of **10b** (1.00 g, 1.61 mmol) in ethyl acetate (200 mL) at room temperature. The mixture was stirred for 1.5 h during which its color changed from yellow to blue. The organic layer was separated, washed with diluted hydrochloric acid and then water, and dried over anhydrous sodium sulfate. After removal of the solvent, the residual solid was recrystallized from methanol. The crystals of **19** (0.5 g) had a melting point of 132–134 C: FDMS, m/e 649 (M); VS (AcOEt) λ_{max} 634 nm (ϵ 21 400). Anal. Calcd for $C_{28}H_{35}N_5O_9S_2 \cdot H_2O$: C, 50.35; H, 5.58; N, 10.48. Found: C, 50.46; H, 5.38; N, 10.55.

No indoaniline dye was formed by the reaction of **10d** with **17**.

Reaction between 20a and 17 in the Presence of 10d. A solution of **17** (1.02 g, 3.75 mmol) in ethyl acetate (1 L) was added to a solution of **10d** (0.50 g, 0.75 mmol) and **20a** (0.41 g, 0.75 mmol) in ethyl acetate (1 L). The mixture was stirred at room temperature for 1 h. The yield of the cyan dye **21** from **20a** and **17** was 69% as monitored by visible spectroscopy. The solvent was removed by a rotary evaporator, and the residue was separated with a silica gel column (chloroform–ethyl acetate (1:1) as an eluent). The fractions of the cyan dye **21** were collected, and the solid obtained was recrystallized from methanol. This was identified with the sample described below.

Reaction between **20b** and **17** in the presence of **10d** afforded the same cyan dye in 24% yield.

Synthesis of the Cyan Dye 21. Oxidative Coupling between 20 and 17 with Ammonium Persulfate. To a solution of **20a** (2.0 g, 3.7 mmol) in ethyl acetate (50 mL) and ethanol (25 mL) were added an aqueous solution (40 mL) of sodium carbonate (5.0 g), the developer **17** (1.92 g, 4.4 mmol), and then an aqueous solution (20 mL) of ammonium persulfate (1.25 g, 5.50 mmol). The mixture was stirred for 2 h at room temperature. The organic layer was separated, washed with water, and then dried over anhydrous sodium sulfate. After the removal of the solvent, the residue was purified by column chromatography. The fractions of the cyan dye **21** were collected and condensed. The solid obtained was recrystallized from methanol: 0.50 g (20%); mp 98–101 °C; EIMS, m/e 678 (M), 570 (M – $CH_2NHSO_2CH_3$), 438 (M – $C_{16}H_{33}NH$); VS (AcOEt) λ_{max} 654 nm (ϵ 26 000). Anal. Calcd for $C_{39}H_{58}N_4O_4S$: C, 68.99; H, 8.61; N, 8.26. Found: C, 69.16; H, 8.78; N, 8.34.

Acknowledgment. The expert technical assistance of Mr. Kazuharu Hattori is gratefully acknowledged.

Registry No. **6a**, 66481-29-6; **6b**, 77406-46-3; **7a**, 84011-43-8; **7c**, 84011-44-9; **7d**, 78819-49-5; **8a**, 84011-45-0; **8c**, 84011-46-1; **8d**, 78819-50-8; **9a**, 78826-17-2; **9b**, 69920-07-6; **9c**, 84011-47-2; **9d**, 84011-48-3; **10a**, 78826-15-0; **10b**, 78826-16-1; **10c**, 84011-49-4; **10d**, 84011-50-7; **11b**, 84011-51-8; **11c**, 36122-03-9; **11d**, 84011-52-9; **12a**, 78826-18-3; **12b**, 78826-19-4; **12c**, 84011-53-0; **12d**, 84011-54-1; **14**, 78826-20-7; **15a**, 84011-55-2; **15b**, 84011-56-3; **16a**, 78826-21-8; **16b**, 84011-57-4; **17**, 92-09-1; **19**, 84011-58-5; **20a**, 76379-54-9; **20b**, 74918-83-5; **21**, 84011-59-6; 2-(2-methoxyethoxy)-5-nitrobenzenesulfonyl chloride, 69920-06-5; 1-bromohexadecane, 112-82-3.

Gas-Phase Reactions of Anions with 2-, 3-, and 4-Fluoroanisole

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Received May 7, 1982

The gas-phase reactions between some anions (NH_2^-, OH^-, and RO^-) and 2-, 3-, and 4-fluoroanisole have been studied by Fourier transform ion cyclotron resonance (FT-ICR). The main reactions are proton transfer, S_N2 substitution, and nucleophilic aromatic substitution leading to a F^- ion–molecule complex. The competition between proton transfer and nucleophilic displacement reactions has been probed by hydrogen–deuterium exchange reactions of the conjugate bases of 2-, 3-, and 4-fluoroanisole. In the 2- and 4-fluoroanisole cases exchange of the aryl hydrogen atoms *and* exchange of the hydrogen atoms of the methyl group are observed. A possible mechanism accounting for the exchange occurring at the methyl group is discussed.

There is growing interest in studying reactions between anions and molecules in the absence of solvents.[1,2] Detailed investigations of the mechanisms of gas-phase ion–molecule reactions have revealed that loose ion–molecule complexes held together by ion–dipole/ion–induced dipole interactions are formed before real chemical bonding oc-

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