Aromatic Nucleophilic Substitution. XIII.[1] Confirmation of the Anionic σ Complexes in the Reactions of 2,4-Dinitro- and 2,4,5-Trinitro-1-(1-piperidyl)naphthalenes with Piperidine in Dimethyl Sulfoxide

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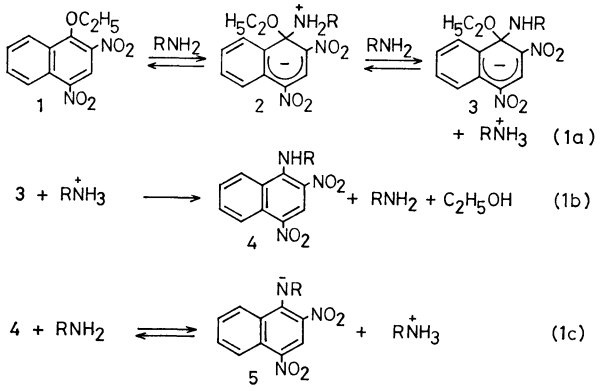
In the reactions of 2,4-dinitro- and 2,4,5-trinitro-1-(1-piperidyl)naphthalenes with piperidine in dimethyl sulfoxide, the 1,1-disubstituted anionic σ complex was confirmed to exist with visible absorption and NMR spectra. Especially in the latter case the 1,3-disubstituted anionic σ complex was formed, the cause of formation of which was ascribed to the deactivating effect of 1-piperidyl group on C_1-position of a napthtalene ring and the steric effect of 1-piperidyl group on the nucleophilic attack of piperidine on C_1-position. These factors make the 1,1-disubstituted anionic σ complex unstable.

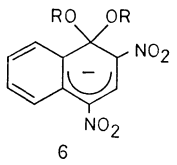
Many Jackson-Meisenheimer complexes have been prepared by nucleophilic attack on aromatic polynitro compounds.[2] In 1970 Orvik and Bunnett[3] carried out the detailed kinetics of the reactions of 1-ethoxy-2,4-dinitronaphthalene (**1**) with primary amines in dimethyl sulfoxide (DMSO), and confirmed the presence of relatively stable Meisenheimer complex (**3**, hereafter referred to as anionic σ complex) during the course of reaction (Eq. 1).



Before and since then much attention of many chemists has been concentrated on the properties and reactions of anionic σ complexes. As for anionic σ complexes found before 1970, Strauss' excellent review already appeared.[4] The later development in the chemistry of anionic σ complexes have been recently summarized by Sekiguchi.[5]

However, almost all the familar aromatic nucleophilic reactions studied so far have been limited to those of activated alkoxyarenes with primary and secondary amines or metal alkoxides[6] or to those of activated dialkylaminoarenes with metal alkoxides.[7–10] Therefore, anionic σ complexes obtained are such as **3** and **6** (hereafter referred to as 1,1-disubstituted anionic σ complex).

Although it was confirmed spectrophotometrically that in the reaction (Eq. 1) the final species is **5**,[3] what would become the final species, when a secondary amine is used in place of a primary one? In such a case, an



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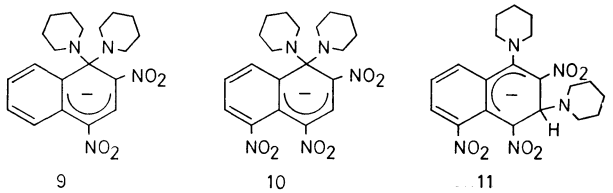
amine could not abstract a proton from **4** (Eq. 1c). Furthermore, how would 1-secondary amino group affect the rate of nucleophilic attack of corresponding amine compared with 1-alkoxyl group?

Prior to carrying out the kinetics of the reactions of 2,4-dinitro- (**7**) and 2,4,5-trinitro-1-(1-piperidyl)naphthalenes (**8**) with piperidine in DMSO, respectively, we have examined their reaction courses using NMR and visible absorption spectra.

This paper reports the presence of stable 1,1-disubstituted anionic σ complexes (**9** and **10**) in both reactions, and the presence of 1,3-disubstituted anionic σ complex (**11**) in the reaction of **8** with piperidine in addition to **10**.



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Results and Discussion

Visible Absorption Spectra Relevant to the Reactions of 2,4-Dinitro- (7) and 2,4,5-Trinitro-1-(1-piperidyl)naphthalenes (8) with Piperidine in DMSO. Figure 1 shows the time-dependent spectral change of the reaction of **7** (6.63×10^{-5} M; hereafter M means mol dm^{-3}) with piperidine (1.01 M) in DMSO at room temperature. In our previous work,[11] the electronic structure of 1,1-disubstituted 2,4-dinitronaphthalene anionic σ complexes such as **3** and **6** was determined and the electronic transitions in them were assigned. From this MO calculation and the NMR spectral evidence as will be shown later, the spectrum (d)

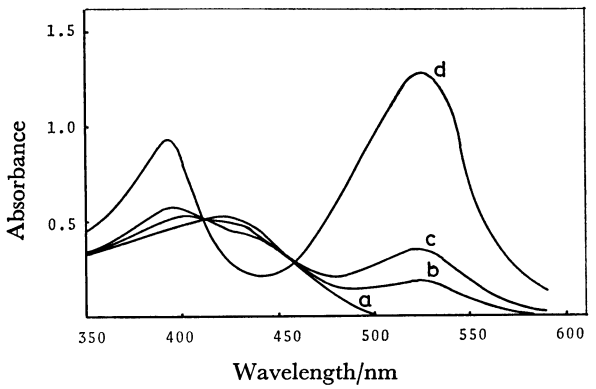
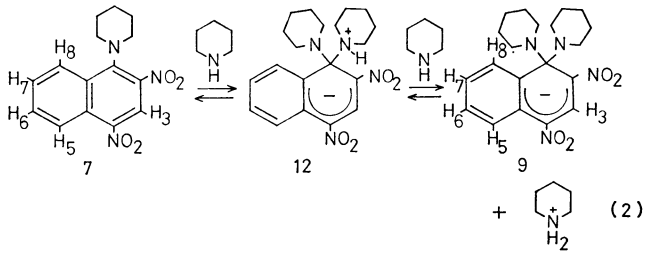


Fig. 1. Absorption spectra of 2,4-dinitro-1-(1-piperidyl)-naphthalene (**7**) with piperidine in DMSO.
a **7**; b, c, and d 10, 24, and 480 h after addition of piperidine.

obtained in 480 h after mixing of **7**, piperidine and piperidinium chloride can be clearly attributed to **9**. As a result, the reaction is considered to proceed as follows: piperidine slowly attacks C_1-position of **7** (rate-determining), followed by the fast abstraction of ammonium hydrogen by piperidine.[3]



For comparison, we tried to carry out the reaction of 1-ethoxy-2,4-dinitronaphthalene [**1**, 2.87×10^{-5} M, λ_{max} 358 nm (ε 8.9×10^{-3})] with piperidine (1.01 M) in the presence of piperidinium chloride (8.08×10^{-2} M), in which immediately after mixing, the similar spectrum was obtained [λ_{max} 524 (ε 2.50×10^{4}), 365 (ε 1.55×10^{4}), and 357 nm (sh)]. Accordingly it is found that 1-piperidyl group deactivates C_1-position of a naphthalene ring considerably, compared with 1-ethoxyl one.

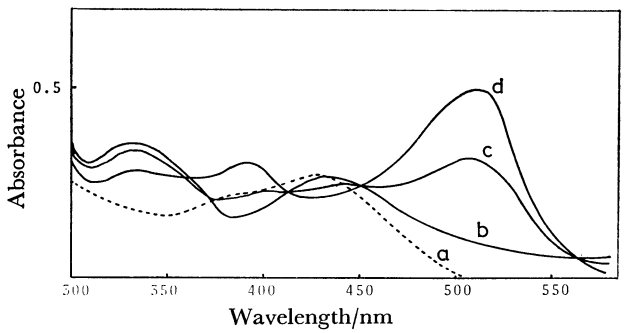
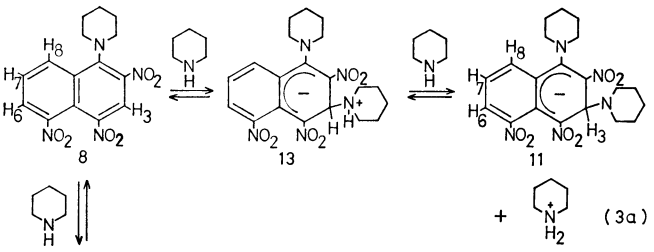
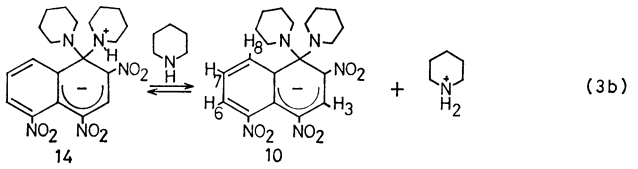


Fig. 2. Absorption spectra of 2,4,5-trinitro-1-(1-piperidyl)naphthalene (**8**) with piperidine in DMSO.
a **8**; b, c, and d immediately, 46, and 260 h after addition of piperidine.

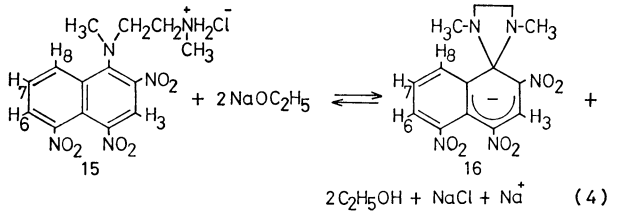
Figure 2 shows the time-dependent spectral change of the reaction of **8** (3.11×10^{-5} M) with piperidine (0.37 M) in the presence of piperidinium chloride (0.01 M) in DMSO at room temperature. Immediately after piperidine and piperidinium chloride has been added to the DMSO solution of **8**, it turned out red at once and the spectrum with double maxima [λ_{max} 434 (ε 1.00×10^{4}) and 330 nm (ε 1.29×10^{4})] was obtained. As will be shown later by NMR spectral evidence, the spectrum (b) can be attributed to **11** (Eq. 3a). There is no isosbestic point among curves a, b, c and d. That is to say, after excess piperidine is added to the DMSO solution of **8**, the equilibrium (**8**⇄**11**) is rapidly established. Just after then, **11** slowly changes into **10** *via* **8** (**11**⇄**8**⇄**14**⇄**10**). Therefore, the isosbestic points are seen among curves b, c, and d.





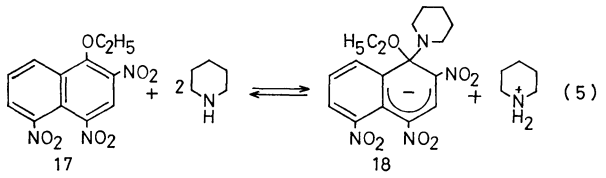
This is the first case in which a 1,3-disubstituted naphthalene anionic σ complex is found on the nucleophilic attack of an amine.

The spectrum (d) obtained in 260 h after mixing is attributed to **10** by considering the NMR spectral evidence in the next paragraph. In order to get the detailed information, we tried to carry out the following reaction in DMSO[12,13] (Eq. 4). In the case of the reaction of **15** with $NaOC_2H_5$ such an anionic σ complex

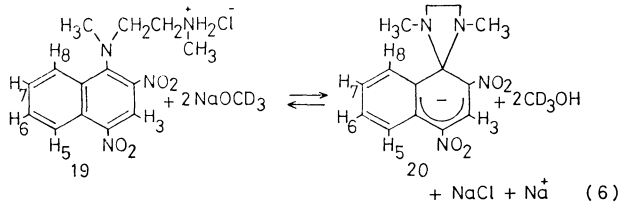


as **11** could not be formed but such one as **10** should be always formed. In 20 min after 20 equivalents of ethanolic $NaOC_2H_5$ had been added to the DMSO solution of **15** (2.57×10^{-5} M) at room temperature, the solution turned out red at once, indicating the absorption with double maxima [λ_{max} 511 (ε 2.34×10^{4}) and 352 nm (ε 9.6×10^{3})]. This result strongly supports that the spectrum (d) in Fig. 2 is due to **10** and the spectrum (b) due to **11**.

Furthermore, in the reaction of 1-ethoxy-2,4,5-trinitronaphthalene (**17**, 3.12×10^{-5} M) with piperidine



(0.377 M) and piperidinium chloride (0.020 M) in DMSO at room temperature the solution instantly turned out red after mixing, indicating the absorption with double maxima [λ_{max} 506 (ε 2.35×10^4) and 354 nm (ε 1.00×10^4)], which is attributed to **18** by the NMR spectral evidence in the next paragraph. As with **1**, 1-ethoxyl group activates C_1-position of a naphthalene ring of **17** considerably, compared with 1-piperidyl group (Eq. 3). Together with the less steric hindrance exerted by 1-ethoxyl group compared with 1-piperidyl one, this effect makes the formation of 1,1-disubstituted anionic σ complex much easier than that of 1,3-disubstituted one.



NMR Spectra Relevant to the Reaction of **7** *and* **8** *with Piperidine in DMSO.* For comparison, the time-dependent NMR spectra of the reactions of **19** and **15** with $NaOCD_3$ in DMSO-d_6 are shown in Figs. 3A—B and 3C—D, respectively. In these cases, on addition of methanolic $NaOCD_3$ (2 equivalents) to the DMSO-d_6 solution of **19** or **15** the solution turned out red at once, indicating the formation of σ complex. In the reaction course (Eq. 6) each singlet of the two CH_3 groups of **19** [not shown in Fig. 3A, δ 3.17 (N–CH_3) and 3.42 ($\overset{+}{N}$–CH_3, overlapped with the signal of $-CH_2-CH_2-$ group)] coalesced to one sharp singlet [δ 1.98 (6H)], indicating the change in hybrid orbital of C_1 ($sp^2\rightarrow sp^3$). The broad singlet of ammonium hydrogen (δ 9.30) of **19** disappeared in the spectrum of **20** (Fig. 3B). In the transformation of **19** to **20**, the H_3 singlet and H_8 doublet [δ *ca.* 8.81, $J_{8,7}$=8 Hz, the signal is finely splitted by the long-range coupling between the H_8 and H_6 protons] shifted downfield (δ 8.74→9.23 and 8.81→8.83), and the H_5 doublet (δ 8.56, $J_{5,6}$=8 Hz, $J_{5,7}$=2 Hz) and $H_{6,7}$ multiplet shifted upfield (δ 8.56→7.68 and 7.96→7.17) (Fig. 3B), respectively. With **15**, too, the similar change was found [δ 3.23 (N–CH_3) and 3.45 ($\overset{+}{N}$–CH_3, overlapped with the signal of $-CH_2-CH_2-$ group)→2.02 (6H, sharp singlet for N–CH_3 in **16**)]. The broad singlet of ammonium hydrogen of **15** [δ 9.30, overlapped with the H_6 doublet ($J_{6,7}$=8 Hz)] disappeared in the spectrum of **16** (Figs. 3C and D)]. In the transformation of **15** to **16**, the H_3 singlet shifted downfield (δ 8.83→9.03), and the H_6 ($J_{6,7}$=8 Hz) and H_8 ($J_{7,8}$=8 Hz) doublets and H_7 triplet ($J_{6,7}=J_{7,8}$=8 Hz) shifted upfield (δ 9.30→7.92, 8.65→7.68, and 8.01→7.21), respectively.

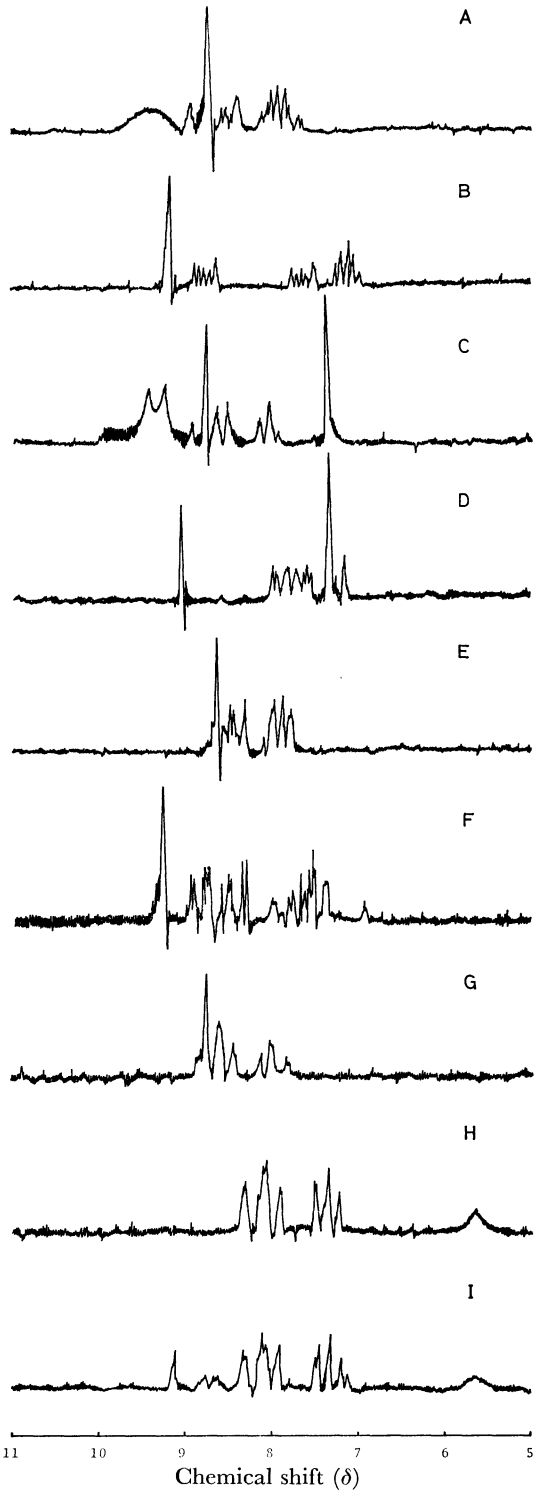


Fig. 3. NMR spectra of the reactions of *N*-methyl-2-[*N*-methyl-*N*-(2,4-dinitro-1-naphthyl)amino]ethyl-(**19**) and *N*-methyl-2-[*N*-methyl-*N*-methyl-*N*-(2,4,5-trinitro-1-naphthyl)amino]ethylammonium chlorides (**15**), and of the reactions of 2,4-dinitro- (**7**) and 2,4,5-trinitro-1-(1-piperidyl)naphthalenes (**8**) with piperidine in DMSO-d_6. A **19**; B immediately after addition of $NaOCD_3$ to the DMSO solution of **19**; C **15**; D immediately after addition of $NaOCD_3$ to the DMSO solution of **15**; E **7**; F 64 d after addition of piperdine to the DMSO solution of **7**; G **8**; H and I 8 and 14 d after addition of piperidine.

The difference between the chemical shifts of the H_8 doublets in **15** and **16** is much larger, compared with that in **19** and **20**. In **15**, 4- and 5-nitro groups deviate from coplanarity with a naphthalene ring by steric hindrance. However, when one negative charge is donated by an amino group (**15**⇄**16**), it is delocalized over three nitro groups, especially over 4-nitro one.[4] As a result, the coplanarity of 4-nitro group with a naphthalene ring increases. Accordingly 5-nitro group in **16** deviates from coplanarity to a larger extent and then comes to exert a less electron-attracting effect to H_8, which may bring about the larger upfield shift. The sharp singlet (δ 7.39) in Figs. 3C and D is due to the protons of benzene, which remained in the preparation of **15** (see Experimental).

The change in chemical shifts in both transformation is characteristic of the formation of 1,1-disubstituted anionic σ complexes.[4,5,14]

With **7**, the H_3 singlet and $H_{6,7}$ multiplet appeared at δ 8.60 and 7.90, respectively, and the $H_{5,8}$ multiplet at δ 8.47 (Fig. 3E). Sixty four days after 20 equivalents of piperidine had been added to the DMSO-d_6 solution of **7**, the H_3 singlet and H_8 doublet shifted downfield, respectively [δ 8.60→9.26 and 8.47→8.82 (d-d, $J_{7,8}$= 8 Hz, $J_{6,8}$=2 Hz)], the H_5 doublet (d-d, $J_{5,6}$=8 Hz, $J_{5,7}$=2 Hz) appeared at δ 8.49, and the $H_{6,7}$ multiplet shifted upfield (δ 7.90→7.56) (Fig. 3F). Even after a long time (64 d) the $H_{6,7}$ signals of **7** still remained (δ *ca.* 7.96), indicating the very slow nucleophilic attack of piperidine (Fig. 3F).

On the other hand, with **8** the conspicuously different signal pattern was obtained. Figures 3G, H, and I show the time-dependent NMR spectra of the reaction of **8** (6.6×10^{-5} M) with piperidine (18 equivalents) in DMSO-d_6 at room temperature. Five days after piperidine had been added to the DMSO solution of **8**, the H_3 singlet (δ 8.77), H_6 (δ 8.71) and H_8 (δ 8.58) doublets (d-d, $J_{6,7}=J_{7,8}$=8 Hz, $J_{6,8}$=2 Hz), and H_7 triplet (δ 8.05, $J_{7,8}=J_{6,7}$=8 Hz) shifted upfield (δ 5.70 singlet for H_3, δ 8.00, multiplet for $H_{6,8}$, and δ 7.43, triplet for H_7 (Figs. 3G—H)).

The extraordinary upfield shift of the H_3 singlet indicates the formation of **11**.[4,5,8,9,16-19] The intensity of the H_3 singlet corresponds to one proton. As was already mentioned, **11** slowly rearranges to **10** just after the equilibrium (**8**⇄**11**) is established. Therefore, the sharpness of the H_3 signal of **11** may depends upon the life time of **11** and the NMR resolving power. Formation of 1,3-disubstituted anionic σ complexes such as **11** is usually kinetically controlled,[15] and such complexes, therefore, are so unstable as to rearrange to 1,1-disubstituted ones, which are equilibrium-controlled.[5,8] However, even after 8 days had passed after mixing, a considerable amount of the 1,3-disubstituted anionic σ complex (**11**) still remained (Fig. 3H). Figure 3I shows that 14 d after mixing a small part of **11** rearranged to **10**, the H_3 singlet of which appeared at δ 9.13. Here, the summation of the intensities of the H_3 signals at δ 5.79 and 9.13 nearly corresponds to one proton. Fifty days after mixing, the same pattern as that in Fig. 3D was obtained. It is, therefore, considered that 1-piperidyl group considerably deactivates C_1-position of a naphthalene ring and furthermore **10** becomes more unstable owing to steric crowding of two piperidyl groups, compared with **18**. As a result, such factors would make the rearrangement of 1,3- to 1,1-disubstituted anionic σ complex slower.

In conclusion, the 1,1-disubstituted anionic σ complex is confirmed to exist in the reaction course of **7** or **8** with piperidine in DMSO and, in the latter case, the 1,3-disubstituted one confirmed additionally to be formed.

Experimental

NMR spectra were recorded on a Varian A-60D spectrometer. Visible absorption spectra were measured on a Hitachi Model 200-10 spectrophotometer. Capillary Mps were uncorrected. Elemental analyses were conducted at the Microanalytical Center of Gunma University.

Materials. *2,4-Dinitro- (**7**) and 2,4,5-Trinitro-1-(1-piperidyl)naphthalenes (**8**)*: To a stirred 50 ml DMSO solution of 2.52 g (0.01 mol) of 1-chloro-2,4-dinitronaphthalene (CDNN, Eastman Kodak) was dropwise added 2 equivalents of piperidine (*ca.* 2 ml) at room temperature. Furthermore, the mixture was poured into *ca.* 500 ml of ice water to form the yellow precipitate. It was filtered, dried, and recrystallized from ethanol to give 2.4 g of **7** (80%); MP 136—136.5 °C, λ_{max} 422 nm (ε 7.88×10^3, DMSO). Found: C, 60.05; H, 5.35; N, 14.13%. Calcd for $C_{15}H_{15}N_3O_4$: C, 59.80; H, 5.02; N, 13.95%.

Compound **8** was prepared by the similar method to the above-described one; yield 75%, mp 194—195 °C, λ_{max} 430 nm (ε 8.4×10^3, DMSO). Found: C, 52.21; H, 4.25; N, 16.33%. Calcd for $C_{15}H_{14}N_4O_6$: C, 52.02; H, 4.08; N, 16.18%.

*1-Ethoxyl-2,4-dinitronaphthalene (**1**)*: Compound **1** was prepared by the action of C_2H_5ONa on an ethanolic solution of CDNN;[20] yield 76%, mp 91—92 °C (92 °C[20]).

*N-Methyl-2-[N-methyl-N-(2,4-dinitro-1-naphthyl)amino]-ethylammonium Chloride (**19**)*: To a stirred 400 ml ethanol solution of 2.5 g (0.0147 mol) of CDNN was dropwise added 1.3 g (0.0099 mol) of commercial *N,N'*-dimethylethylenediamine (DMED) at room temperature. The mixture was further stirred for 3 h at room temperature to form the precipitate. The filtrate was acidified with HCl and the alcohol was evaporated to *ca.* 30 ml. Then, the solution was allowed to stand 1 d. Of two kinds of crystals formed (orange and yellow) the orange ones were seperated with tweezers. If the yellow crystals were precipitated at frist, they were filtered off and the filtrate was concentrated and allowed to stand. The orange cubic crystals were obtained and recrystallized from HCl-acidified ethanol, yielding an analytical sample (1.3 g, 39%); mp 199.5—201 °C. Found: C, 49.51; H, 5.25; N, 16.60%. Calcd for $C_{14}H_{17}ClN_4O_4$: C, 49.34; H, 5.03; N, 16.44%.

*N-Methyl-2-[N-methyl-N-(2,4,5-trinitro-1-naphthyl)amino]-ethylammonium Chloride (**15**)*: 1-Chloro-2,4,5-trinitronaphthalene (CTNN) was prepared by Rindl's method;[21] yield 60%, mp 143.5—144.5 °C (143—144 °C[20]). The compound (**15**) was prepared from CTNN and *N,N'*-dimethylethylenediamine according to the method for **19** except for the following procedure: at the later stage the concentrated filtrate was allowed to stand overnight. The orange crystals were formed and filtered, and the residue was dissolved in the solution of benzene (30 ml), ethanol (10 ml) and a small amount of aqueous HCl. Then, the mixture was refluxed for 1.5 h. After the evaporation of the solvent the oily product (**15**) was

obtained, the crystallization of which was unsuccessful. Then, the product was dried over P_2O_5 in an evacuated desiccator for 7 d. The NMR spectrum shows that **15** has a certain amount of benzene. Found: C, 45.06; H, 4.64; N, 17.75%. Calcd for $C_{14}H_{16}ClN_5O_6 \cdot 1/6C_6H_6$: C, 44.61; H, 4.72; N, 17.34%.

Piperidinium Chloride. To a stirred 20 ml solution of piperidine (0.201 mol) was added dropwise 17 ml (0.205 mol) of concd HCl at room temperature and then the mixture was cooled in an ice-water bath. After 10 min's stirring the precipitate formed was filtered and washed with cooled ethanol. Recrystallization from ethanol gave 5.43 g (22%) of an analytical sample: Mp 246—247 °C. Found: C, 49.59; H, 10.10; N, 11.77%. Calcd for $C_5H_{12}ClN$: C, 49.38; H, 9.95; N, 11.52%.

NMR Measurement. A certain amount of a sample (*ca.* 35 mg) was dissolved in a small amount of DMSO-d_6 (*ca.* 0.25 ml) in a NMR tube. After excess amine (*ca.* 200 μl) had been added into the solution through a microsyringe and shaken vigorously, the mixture was measured.

Absorption Spectra Measurement. With **7**, just after *ca.* 28 μl of piperidine had been added to *ca.* 3 ml of the DMSO solution of **7** (nearly equal to 6.63×10^{-5} M) throughout a microsyringe and the mixture stirred rapidly, the spectra were taken. With **8**, the DMSO solution of **8** (6.22×10^{-5} M) and the other solution of piperidine (0.74 M) and piperidinium chloride (0.02 M) were prepared. Just after 1.5 ml of the latter solution had been added to 1.5 ml of the former one and the mixture stirred rapidly, the spectra were taken. With **1**, the spectra were measured by the similar procedure to that with **8**.

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