  Bull. Chem. Soc. Jpn., 56, 3457—3463 (1983)

The Reaction of Nitrile Oxides with Alkyl- and Alkyl-halo-substituted *p*-Benzoquinones

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(Received December 14, 1982)

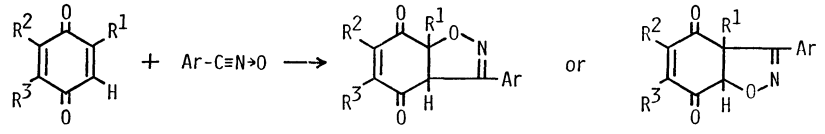
Various aromatic nitrile *N*-oxides, sterically stabilized and unstabilized ones, were allowed to react with several alkyl- and alkyl-halo-substituted *p*-benzoquinones with a view to studying the influence of quinone substituents on the mode of the addition reaction. Mono-, di-, and tri-substituted quinones with such substituents gave isoxazoline derivatives formed through addition of nitrile oxides to the C=C bond of the quinones. 2-Chloro-5- and -6-methyl-*p*-benzoquinones gave two kinds of C=C adducts, one formed through the addition to the C=C of methyl-substituted side and the other to that of chlorine-substituted side, and the latter adducts were not isolable due to the prompt dehydrochlorination forming the fully-conjugated isoxazoloquinones and subsequent C=O addition of another nitrile *N*-oxide forming spirodioxazole derivatives.

Nitrile *N*-oxide, a typical 1,3-dipole, reacts with various unsaturated compounds to give heterocycles.[1] The reactions of nitrile *N*-oxides with substituted *p*-benzoquinones, which have two kinds of potential reactive sites, *i.e.* C=C and C=O bonds, have been studied and reported in the previous papers.[2,3] All the tetrasubstituted quinones gave dioxazole derivatives through addition at the carbonyl site(s), while the disubstituted quinones gave dioxazole or isoxazoline derivatives depending on the substituents and substitution pattern. With a view to studying the influence of substituents on the mode of the addition of nitrile *N*-oxides to quinones, reactions of several alkyl- and alkyl-halo-substituted quinones with nitrile *N*-oxides have been investigated and the result is reported in this paper.

Results and Discussion

Several aromatic nitrile *N*-oxides (**1**) were allowed to react with various kinds of alkyl- and alkyl-halo-substituted *p*-benzoquinones (**2**). Three sterically stabilized nitrile *N*-oxides, *viz.*, 2,4,6-trimethylbenzonitrile *N*-oxide (MNO), 2,3,5,6-tetramethylbenzonitrile *N*-oxide (DNO), and 2,6-dichlorobenzonitrile *N*-oxide (CNO) were chosen for the reaction with quinones. The reactions were conducted in benzene using equimolar reactants at room temperature. The progress of the reaction was followed by thin layer chromatography (TLC) on silica gel plates. In most cases, isoxazoline derivatives were obtained as the main products in rather good yields. The result is summarized in Tables 1—3. The structure of the products were determined by IR, ^{1}H NMR, and mass spectra and elemental analyses. The isoxazoline derivatives formed have the structure as shown in Scheme 1. Trisubstituted olefinic double bond was the exclusive or at least the main reaction site to undergo the C=C addition forming the C–O bond between the oxygen atom of the nitrile oxide and the carbon atom bearing a substituent of the quinone moiety even in the reaction of methyl-*p*-benzoquinone, where the adduct **3a** (see Table 1) was the main product. This indicates that steric factors are less important for the site-selectivity of the addition reaction than electronic factors, though that is the governing factor in the reaction with 2-*t*-butyl-6-methyl-*p*-benzoquinone where the addition occurs selectively at the C=C bond of the methyl-substituted side. In the reaction of CNO with 2-*t*-butyl-5-methyl-*p*-benzoquinone, however, addition occurred at both sides to give a 2:1-mixture of the adduct on the less hindered side (**3d**) and that on the other side (**3m**). In the reaction of CNO with 2-isopropyl-5-methyl-*p*-benzoquinone, the formation ratio of the two isomers was determined to be 3:2 from the ^{1}H NMR spectrum of the crude reaction product, though the separation was not conducted.

The IR spectra of the most adducts showed either a broad or a split carbonyl absorption around 1670—1690 cm^{-1}. The IR spectra of some of the adducts from chlorine-substituted quinones, however, showed two distinct carbonyl absorptions around 1680 and 1700 cm^{-1}. The ^{1}H NMR spectrum of the product **3e** from 2,6-dimethyl-*p*-benzoquinone (26DMQ) and CNO shows three singlets at δ 7.32, 2.16, and 1.73, each integrating to three protons. The signals at δ 1.73 and 2.16 are assigned to the angular and olefinic methyl groups on the quinone moiety respectively, and the singlet at δ 7.32 is due to the three aromatic protons. The olefinic proton and the angular methine proton



2 **1** **3 - 5**

Scheme 1.

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Table 1. Characterization data of the isoxazoline derivatives (**3a—p**) from 2,6-dichlorobenzonitrile *N*-oxide (CNO)

Compd No.	R^1	R^2	R^3	React. time d	Yield %	Mp θ_m/°C	IR $\nu_{C=O}$/cm^{-1}	Found (Calcd) (%) C	H	N
3a	Me	H	H	7	51[a]	175—177	1680	54.41 (54.22	2.87 2.92	4.90 4.52)
3b	Me	H	Me	5	77	150—152	1670	55.79 (55.58	3.41 3.42	4.63 4.32)
3c	Me	H	Cl	7	35[b]	155—160	1680	48.57 (48.80	2.19 2.34	4.25 4.06)
3d	Me	H	*t*-Bu	10	—[c]	148—151	1670	59.01 (59.03	4.82 4.68	3.65 3.82)
3e	Me	Me	H	5	86	156—158	1680	55.77 (55.58	3.53 3.42	4.13 4.32)
3f	Me	Me	Me	5	89	152—154	1670	56.80 (56.82	3.79 3.87	4.08 4.14)
3g	Me	Me	Cl	3	89	168—171	1680	50.02 (50.24	2.80 2.81	3.96 3.91)
3h	Me	Cl	H	5	46[b]	158—160	1670, 1710	49.11 (48.80	2.09 2.34	3.93 4.06)
3i	Me	Cl	Me	5	81	136—138	1670, 1700	50.32 (50.24	2.70 2.81	3.44 3.91)
3j	Me	*t*-Bu	H	5	90	151—154	1660, 1695	58.99 (59.03	4.56 4.68	3.81 3.82)
3k	Me	benzo		5	82	154—155	1680	60.15 (60.02	3.04 3.08	4.00 3.89)
3l	*i*-Pr	*i*-Pr	H	5	86	161—164	1670, 1680	60.12 (60.01	5.22 5.04	3.64 3.68)
3m	*t*-Bu	H	Me	10	—[c]	162—165	1670	59.06 (59.03	4.82 4.68	3.85 3.82)
3n	*t*-Bu	H	*t*-Bu	7	81	151—154	1670	61.89 (61.77	5.36 5.68	3.14 3.43)
3p	*t*-Bu	*t*-Bu	H	3	90	165—168	1680	61.54 (61.77	5.68 5.68	3.60 3.43)

a) A dimer of the nitrile *N*-oxide (11%, mp 200—202 °C) and an appreciable amount of unidentified product were also obtained. b) A few other products were observed but isolation of them was not successful. Addition of CNO to the C=C bond of the chlorine-substituted side and subsequent reactions are conceivable (see the text). c) The products **3d** and **3m** were obtained in the same reaction in a 2:1-ratio in a total yield of 90% (see Experimental section).

Table 2. Characterization data of the isoxazoline derivatives (**4a—f**) from 2,4,6-trimethylbenzonitrile *N*-oxide (MNO)

Compd No.	R^1	R^2	R^3	React. time d	Yield %	Mp θ_m/°C	IR $\nu_{C=O}$/cm^{-1}	Found (Calcd) (%) C	H	N
4a	Me	Me	Me	7	74	119—122	1660	73.38 (73.29	6.91 6.80	4.52 4.50)
4b	Me	Me	Cl	7	79	141—145	1680	65.46 (65.16	5.37 5.47	4.39 4.22)
4c	Me	*t*-Bu	H	7	82	179—181	1670	74.27 (74.31	7.60 7.42	4.11 4.13)
4d	*i*-Pr	*i*-Pr	H	5	85	113—115	1660, 1680	74.78 (74.76	7.64 7.70	3.96 3.96)
4e	*t*-Bu	H	*t*-Bu	30	63[a]	135—140	1670	75.45 (75.56	8.53 8.19	3.90 3.67)
4f	*t*-Bu	*t*-Bu	H	7	78	144—148	1670, 1690	75.86 (75.56	8.03 8.19	3.73 3.67)

a) A 93% yield on the basis of the quinone reacted.

Table 3. Characterization data of the isoxazoline derivatives (**5a—i**) from 2,3,5,6-tetramethylbenzonitrile *N*-oxide (DNO)

Compd No.	R^1	R^2	R^3	React. time d	Yield %	Mp θ_m/°C	IR $\nu_{C=O}$/cm^{-1}	Found (Calcd) (%) C	H	N
5a	Me	H	Me	7	87	169—172	1670	73.62 (73.29	6.80 6.80	4.81 4.50)
5b	Me	Me	H	3	90	171—173	1660, 1680	73.50 (73.29	6.78 6.80	4.59 4.50)
5c	Me	Me	Me	7	80	162—166	1670	73.56 (73.82	7.39 7.12	4.08 4.30
5d	Me	Me	Cl	7	83	176—179	1680	66.31 (65.99	5.95 5.83	4.17 4.05)
5e	Me	Cl	H	5	30[a)]	183—184	1680, 1720	64.90 (65.16	5.58 5.47	4.36 4.22)
5f	Me	*t*-Bu	H	7	87	172—173	1660, 1695	74.83 (74.76	7.89 7.70	4.13 3.96)
5g	*i*-Pr	*i*-Pr	H	5	87	165—168	1660	74.97 (75.17	8.09 7.95	3.93 3.81)
5h	*t*-Bu	H	*t*-Bu	30	40[b)]	154—160	1670	75.70 (75.91	8.74 8.41	3.45 3.54)
5i	*t*-Bu	*t*-Bu	H	7	86	176—180	1660, 1680	75.86 (75.91	8.53 8.41	3.64 3.54)

a) See the text and Experimental section. b) An 87% yield on the basis of the quinone reacted.

resonate as each singlet at δ 6.70 and 4.44, respectively. The chemical shift of the angular methine signal shows undoutedly that the orientation of the addition reaction is such as indicated in Scheme 1.[4)] Similar ^{1}H NMR spectra are observed for all the CNO adducts and the spectral data are summarized in Table 4.

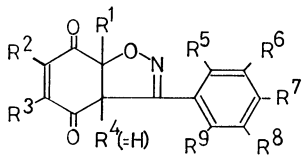
The reactions of DNO and MNO with quinones were slower in reaction rate than those of CNO; *e.g.* in the reaction of either DNO or MNO with 2,5-di-*t*-butyl-*p*-benzoquinone (25DBQ), the starting materials were recovered almost quantitatively even after a week and only a partial reaction was observed after a month. The addition products from DNO and MNO are also found to be isoxazoline derivatives. In the ^{1}H NMR spectra of the adducts, the signals due to the methyl protons of the quinone moiety overlapped with those originated from aromatic moiety in some cases, but all the adducts are characterized by the characteristic singlet due to the angular methine proton at δ 4.1—4.8, which confirm the isoxazoline structure of the same orientation in the addition reactions. The ^{1}H NMR spectral data are also summarized in Table 4.

In the mass spectra of the C=C adducts obtained from the reactions of the nitrile oxides with quinones, the molecular ion peak was generally very weak and the major peaks were due to the fragment ions. In most cases, the most intense signal is due to the fragment E (in some cases the fragment F). The molecular ion underwent initially the fragmentation with the loss of the angular alkyl substituent or the scission forming the fragment E. The fragments A, D, E, and F were always observed in the mass spectra of the 1:1-C=C adducts, and the structure of the fragment species were confirmed to be such by high resolution mass spectrometry. Some other fragmentation processes were observed. The major fragmentation modes were such as shown in Scheme 2. The adducts from CNO showed an intense peak of M^+-Cl, in some cases as the base peak, but the major fragmentation pattern was substantially similar.

The unstabilized nitrile *N*-oxides, generated just before the reaction in the same pot, reacted with 25DBQ at far faster rates than those of MNO or DNO to give two products in each reaction, the major one of which was identified to be the same type of C=C adduct as in the previous cases and the other was found to be a 1:2-adduct formed through the addition to both of the C=C double bonds. The results of the reaction and the characterization data of the products are summarized in Table 5.

The reactions of nitrile *N*-oxides with 2-chloro-6-(26CMQ) and -5-methyl-*p*-benzoquinones (25CMQ) were somewhat complex owing to the formation of two types of C=C adducts, one is the adduct formed by addition of the nitrile oxides on the C=C of methyl-substituted side and the other is that formed by addition on the opposite side. The former was isolable as formed but the latter was not due to the elimination of hydrogen chloride forming a fully-conjugated isoxazoloquinone and subsequent addition of another nitrile oxide onto the C=O of the isoxazoloquinone to form a spiro-dioxazole derivative. The isoxazoloquinone and the spiro-dioxazole derivatives were both isolated in the reaction of DNO with 26CMQ and characterized. The reactions of the combinations of the other nitrile oxides with 26CMQ or 25CMQ showed similar reaction patterns to that of DNO with 26CMQ but isolation of isoxazoloquinones or spiro-dioxazole derivatives except the isoxazoline derivatives was not successful. The reaction of DNO with 26CMQ gave an isoxazoline derivative **5e** in a 30% yield. The structure of **5e** is confirmed by the fact that the ^{1}H NMR spectrum showed two singlets at δ 4.30 and 1.73 having the intensities corresponding to one and three

Table 4. ^{1}H NMR spectral data of the isoxazoline derivatives (**3**—**5**)

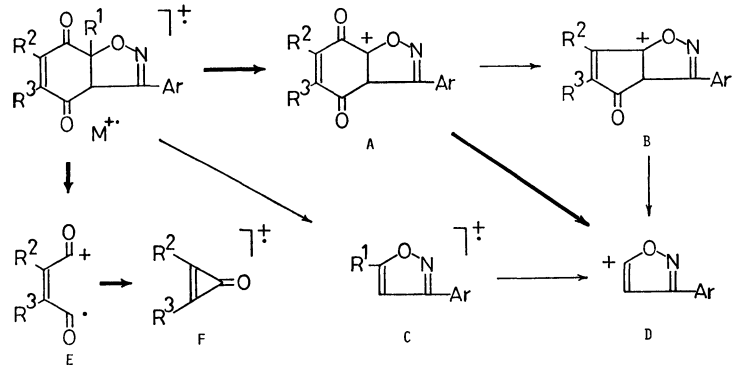


Compd No.	Quinone moiety				Aromatic moiety				
	R^1	R^2	R^3	R^4(=H)	R^5	R^6	R^7	R^8	R^9
3a	Me 1.76(s)	H 7.00(d) $J_{2,3}$=10 Hz	H 6.83(d)	4.48(s)	Cl —	H	H 7.36(s)	H	Cl —
3b	Me 1.72(s)	H 6.86(s)	Me 2.02(s)	4.48(s)	—		7.36(s)		—
3c	Me 1.74(s)	H 7.14(s)	Cl —	4.54(s)	—		7.26(s)		—
3d	Me 1.74(s)	H 6.84(s)	*t*-Bu 1.20(s)	4.62(s)	—		7.32(s)		—
3e	Me 1.72(s)	Me 2.16(s)	H 6.70(s)	4.44(s)	—		7.32(s)		—
3f	Me 1.66(s)	Me 2.06(s)	Me 1.94(s)	4.42(s)	—		7.26(s)		—
3g	Me 1.76(s)	Me 2.30(s)	Cl —	4.52(s)	—		7.34(s)		—
3h	Me 1.82(s)	Cl —	H 7.09(s)	4.52(s)	—		7.36(s)		—
3i	Me 1.76(s)	Cl —	Me 2.16(s)	4.52(s)	—		7.34(s)		—
3j	Me 1.68(s)	*t*-Bu 1.30(s)	H 6.60(s)	4.32(s)	—		7.30(s)		—
3k	Me 1.86(s)	benzo- 7.6—8.1(m)		4.67(s)	—		7.32(s)		—
3l	*i*-Pr 2.72(sep) 1.09(d, 3H) 0.93(d, 3H) J=6.7 Hz	*i*-Pr 3.15(qui) 1.14(d, 6H) J=6.7 Hz	H 6.56(s)	4.57(s)	—		7.28(s)		—
3m	*t*-Bu 1.16(s)	H 6.84(s)	Me 2.00(s)	4.84(s)	—		7.30(m)		—
3n	*t*-Bu 1.12(s)	H 6.82(s)	*t*-Bu 1.18(s)	4.84(s)	—		7.26(m)		—
3p	*t*-Bu 1.12(s)	*t*-Bu 1.32(s)	H 6.56(s)	4.78(s)	—		7.28(m)		—
4a[a]	Me 1.68(s)	Me 2.10(s)	Me 1.94(s)	4.26(s)	Me 2.10	H 6.88	Me 2.26	H 6.88	Me 2.10
4b[b]	Me 1.70(s)	Me 2.28(s)	Cl —	4.36(s)	2.14(br)	6.86	2.28	6.86	2.14(br)
4c	Me 1.64(s)	*t*-Bu 1.28(s, 9H)	H 6.48(s)	4.12(s)	2.14	6.76	2.24	6.76	2.14
4d	*i*-Pr 2.68(qui) 0.89(d), 1.11(d), J=6.8 Hz	*i*-Pr 3.14(qui) 1.08(d), 1.13(d)	H 6.50(s)	4.45(s)	2.01(br)	6.80	2.24	6.80	2.01(br)
4e	*t*-Bu 1.08(s)	H 6.48(s)	*t*-Bu 1.16(s)	4.76(s)	2.14	6.76	2.24	6.76	2.14
4f	*t*-Bu 1.10(s)	*t*-Bu 1.30(s)	H 6.51(s)	4.64(s)	1.91(br)	6.79(br)	2.24	6.79(br)	2.24(br)
5a	Me 1.74(s)	H 6.82(s)	Me 2.00(s)	4.28(s)	Me 1.86	Me 2.22(br)	H 6.98	Me 2.22(br)	Me 2.22(br)
5b	Me 1.72(s)	Me 2.14(s)	H 6.66(s)	4.22(s)	1.92	2.20(br)	7.00	2.20(br)	2.20(br)
5c	Me 1.70(s)	Me 2.12(s)	Me 1.96(s)	4.24(s)	1.86	2.22(br)	6.96	2.22(br)	2.22(br)
5d	Me 1.72(s)	Me 2.28(s)	Cl —	4.30(s)	1.86	2.22(br)	6.98	2.22(br)	2.22(br)

Table 4. (Continued)

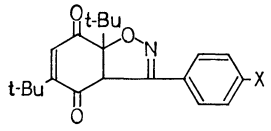
Compd No.	Quinone moiety				Aromatic moiety				
	R^1	R^2	R^3	R^4(=H)	R^5	R^6	R^7	R^8	R^9
5e	Me 1.73(s)	Cl —	H 7.00(s)	4.30(s)	1.84	2.22(br)	7.00	2.22(br)	2.22(br)
5f	Me 1.64(s)	*t*-Bu 1.28(s)	H 6.50(s)	4.10(s)	1.90	2.18(br)	6.90	2.18(br)	2.18(br)
5g	*i*-Pr 2.72(qui) 0.92(d), 1.14(d), J=7.0 Hz	*i*-Pr 3.16(qui) 1.08(d), 1.20(d)	H 6.52(s)	4.44(s)	1.86	2.16	6.86	2.24	2.24
5h	*t*-Bu 1.12(s)	H 6.84(s)	*t*-Bu 1.16(s)	4.70(s)	1.82	2.12	6.94	2.18	2.24
5i	*t*-Bu 1.13(s)	*t*-Bu 1.33(s)	H 6.54(s)	4.60(s)	1.78	2.14	6.93	2.23	2.23

Abbreviations in the NMR data: s=singlet; d=doublet; qui=quintet; sep=septet; m=multiplet; br=broad. a) The signal at δ=2.10 is overlapped with a broad peak and integrated totally for 9H. b) The signals at δ=2.28 and 2.14 integrate for 6H each.

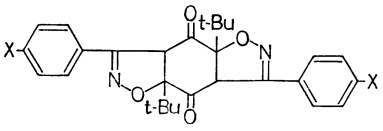


Scheme 2.

Table 5. Products in the reactions of unstabilized nitrile *N*-oxides with 2,5-di-*t*-butyl-*p*-benzoquinone (25 DBQ)

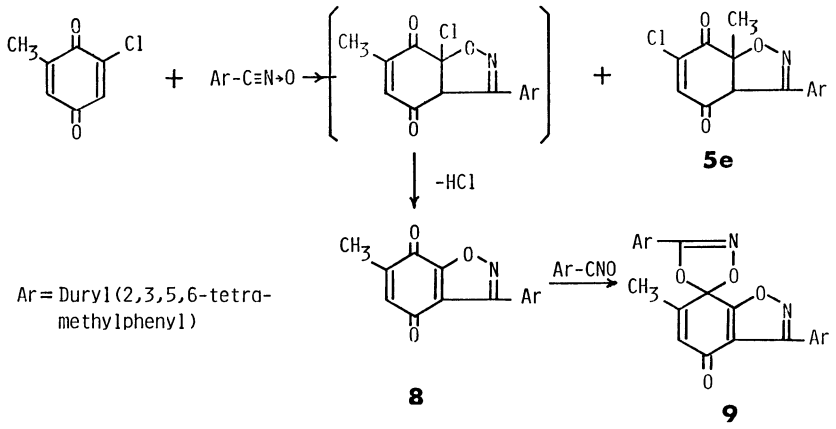


6a–b



7a–b

Compd No.	X	Yield %	Mp θ_m/°C	IR $\nu_{C=O}$/cm^{-1}	Found (Calcd) (%) C	H	N	M^+ Found (Calcd)	^{1}H NMR ($CDCl_3$) (δ) Quinone moiety	Aromatic moiety
6a	Cl	88	151—152	1680	67.77 (67.46	6.57 6.47	3.89 3.75)	373.1448 (373.1443)	1.08(s, 9H) 1.16(s, 9H) 4.78(s, 1H) 6.70(s, 1H)	7.32(d, 2H) 7.58(d, 2H) J=9.0 Hz
7a	Cl	4	189—190	1710	63.16 (63.75	5.34 5.35	5.23 5.31)	526.1428 (526.1427)	1.00(s, 18H) 4.52(s, 2H)	7.34(d, 4H) 7.58(d, 4H) J=9.0 Hz
6b	Br	70	144—146	1670 1700	60.47 (60.29	5.89 5.78	3.42 3.35)	417.0983 (417.0939)	1.06(s, 9H) 1.12(s, 9H) 4.80(s, 1H) 6.72(s, 1H)	7.52(s, 4H)
7b	Br	4	228—229	1710	55.09 (54.56	5.05 4.58	4.54 4.55)	614.0413 (614.0415)	1.00(s, 18H) 4.56(s, 2H)	7.52(s, 8H)



Scheme 3.

protons respectively, which are assigned to the angular methine and methyl protons. The signals due to the quinone olefinic methine and aromatic protons are overlapped and appeared as a singlet at δ 7.00. The methyl protons of the duryl moiety resonate as broad singlets at δ 1.84 and 2.22, the former integrating for three protons and the latter for nine protons and having an inflection at δ 2.17. This pattern is interpreted in terms of the hindered rotation of the duryl group and one of the 2,6-methyl groups being in a close proximity of the quinone moiety. The ^{1}H NMR spectral pattern is similar to those of the other isoxazoline derivatives shown in Table 3. Besides this isoxazoline derivative, isoxazoloquinone **8**, formed by the addition of DNO to the C=C bond at the other side and subsequent dehydrochlorination, and a spiro-dioxazole derivative **9**, formed by addition of another DNO to the C=O bond of **8**, were isolated in 7 and 15% yields, respectively. Their structures were also determined by NMR, IR, and mass spectra and elemental analyses. In the ^{1}H NMR spectrum of **8**, the duryl methyl protons are seen as two singlets of the same intensity at δ 2.28 and 1.94, while the methyl on quinone moiety appears at δ 2.22 as a singlet. No absorption characteristic of the angular methine proton was observed in the region of δ 4.0—5.0. The integration of the ^{1}H NMR spectrum of **9** clearly shows that the product is a 1:2-adduct of the quinone and the nitrile *N*-oxide. The olefinic proton of **9** resonates at δ 6.24, being upper field than that of **8** which appears at δ 6.64, while the olefinic methyl signal of **9** appears at δ 2.30, slightly lower field than that of **8**. Taking into consideration the shift pattern of the signals on C=O addition, this suggests that the second nitrile *N*-oxide added across the carbonyl group adjacent to the methyl substituent. If so, this also supports the orientation of the first addition of the nitrile *N*-oxide and is well consistent with the reactivity enhancement of carbonyl bond toward cycloaddition by adjacent oxygen substitution described in the previous paper.[2]

Experimental

All melting points are uncorrected. The ^{1}H NMR spectra were recorded with a JEOL MH-100 100 MHz NMR spectrometer and the mass spectra with a Hitachi RMU-7L high-resolution mass spectrometer.

Materials. Methyl-*p*-benzoquinone (MQ), 2-methyl-1,4-naphthoquinone (MNQ), and 2,5-di-*t*-butyl-*p*-benzoquinone (25DBQ) were obtained commercially and were used after recrystallization. 2,6-Dimethyl-*p*-benzoquinone (26DMQ), 2,5-dimethyl-*p*-benzoquinone (25DMQ), 2,3,5-trimethyl-*p*-benzoquinone (TMQ), 2-methyl-5-isopropyl-*p*-benzoquinone (25MPQ), 2-methyl-6-*t*-butyl-*p*-benzoquinone (26MBQ), 2-methyl-5-*t*-butyl-*p*-benzoquinone (25MBQ) 2,6-diisopropyl-*p*-benzoquinone (26DPQ) were prepared from the corresponding phenols by the procedures of McLamore[5] with some modifications.[6] 2-Chloro-6-methyl-*p*-benzoquinone (26CMQ) was prepared by chlorination of o-cresol and subsequent oxidation of the 4,6-dichloro-*o*-cresol.[7] 2-Chloro-5-methyl-*p*-benzoquinone (25CMQ) was prepared from 2-methyl-*p*-benzoquinone by its hydrochlorination and subsequent oxidation[8]. By adopting a similar procedure, 3-chloro-2,6-dimethyl-*p*-benzoquinone (26DMCQ) and 3-chloro-2,5-dimethyl-*p*-benzoquinone (25DMCQ) were prepared from 26DMQ and 25DMQ respectively. The stable nitrile oxides (MNO, DNO, and CNO) were prepared according to the Grundmann's procedure.[9]

Reactions of Quinones with Nitrile N-*Oxides. General procedure*: The reaction was carried out by dissolving the reactants in benzene in a concentration of 5 mmol/100 ml each and allowing the mixture to stand at ambient temperature for 3—7 d. The progress of the reaction was followed by TLC using silica gel plates (Merck). After an appropriate reaction period the solvent was removed by evaporation under reduced pressure and the residue was triturated with petroleum ether or methanol. The solid product thus obtained was subjected to column chromatography on silica gel (Wako gel C-100 or C-200) using benzene as an eluent. The nitrile *N*-oxide, the quinone and the product were eluted in that order. The fractions containing the products were collected and evaporated under reduced pressure to afford the product, which was purified by recrystallization from benzene or a mixture of benzene and petroleum ether or hexane. The reaction conditions, physical constants, analytical and IR data are tabulated in Tables 1—3. The ^{1}H NMR data are summarized in Table 4.

Reactions of Unstabilized Nitrile N-*Oxides with 2,5-Di-*t*-butyl-*p*-benzoquinone (25DBQ).* A typical example follows: A solution of *p*-chlorobenzhydroxamoyl chloride (950 mg, 5 mmol) in CH_2Cl_2 (30 ml) was cooled to -10 °C in an ice-salt bath. Triethylamine (0.55 g, 5 mmol) in CH_2Cl_2 (20 ml) was slowly added to the above solution with stirring and maintaining the temperature below -5 °C. After the

addition of the amine, a solution of 25DBQ (1.1 g, 5 mmol) in CH_2Cl_2 (30 ml) was added dropwise during 15 minutes maintaining the temperature below 0 °C. The reaction mixture was allowed to stand at ambient temperature for 2 d and then the solvent was removed by evaporation to dryness under reduced pressure. The residue was extracted with benzene to leave triethylammonium chloride as white solid. The extract was concentrated and subjected to column chromatography on silica gel using benzene as an eluent. The first fraction gave 100 mg (4%) of colorless crystals of 1:2-adduct, **7a**, mp 189—190 °C. The second fraction contained 100 mg (8%) of the unreacted quinone. The third fraction yielded 1.65 g (88%) of 1:1-adduct, **6a**, which was recrystallized from a mixture of benzene–petroleum ether to give stout yellow needles, mp 151—152 °C. Characterization data are given in Table 5.

*Reaction of 2-Chloro-6-methyl-*p*-benzoquinone (26CMQ) with 2,3,5,6-Tetramethylbenzonitrile* N-*Oxide (DNO)*: A solution of 26CMQ (0.78 g, 5 mmol) and DNO (0.87 g, 5 mmol) in chloroform (200 ml) was stirred at room temperature for 3 d. The solvent was removed by evaporation under reduced pressure and the residue was triturated with methanol. A yellow solid was obtained. This was collected by filtration and subjected to column chromatography on silica gel using benzene as an eluent. The first fraction gave colorless crystals of **9**, which was recrystallized from ethanol into silky white needles (300 mg, 15%), mp 163—164 °C. IR(KBr) 1680 cm^{-1}($\nu_{C=O}$). ^1H NMR ($CDCl_3$) δ=7.12 (1H, s) and 7.08 (1H, s)(duryl aromatic), 6.24 (1H, s, quinone olefinic), 2.44 (6H, s, duryl methyl), 2.26 (15H, m, duryl and quinone methyl), 1.92 and 1.96 (6H, two s, duryl methyl). M^+ was not observed and the fragmentation pattern was almost the sum of those of the isoxazoloquinone **8** and DNO, showing the peaks at *m/e* 295.1247 (calcd for **8**: 295.1207) and 175.0978 (calcd for DNO: 175.0997).

Found: C, 74.16; H, 6.30; N, 6.17%. Calcd for $C_{29}H_{30}N_2O_4$: C, 74.02; H, 6.43; N, 5.95%.

The second fraction gave yellow micro needles of isoxazoloquinone, **8** (100 mg, 7%) on recrystallization from ethanol, mp 174—176 °C. IR(KBr) 1650 and 1670 cm^{-1} ($\nu_{C=O}$). ^1H NMR($CDCl_3$) δ=7.12(1H, s, duryl aromatic), 6.64(1H, s, quinone olefinic), 2.28(6H, s, duryl 2,6-methyls), 2.22(3H, s, quinone methyl), 1.94(6H, s, duryl 3,5-methyls).

Found: C, 73.43; H, 5.16; N, 4.79%; M^+, 295.1171. Calcd for $C_{18}H_{17}NO_3$: C, 73.20; H, 5.80; N, 4.74%; M, 295.1207.

The third fraction gave yellow flakes of isoxazoline derivative, **5e** (450 mg, 30%) on usual work-up and recrystallization from benzene–petroleum ether, mp 183—184 °C. The characterization data for **5e** are given in Tables 3 and 4.

*Reaction of 2-Methyl-5-*t*-butyl-*p*-benzoquinone (25MBQ) with CNO*: A solution of 25MBQ (0.89 g, 5 mmol) and CNO (0.94 g, 5 mmol) in benzene (100 ml) was stirred for 10 d at room temperature. Evaporation of the solvent left a solid, which was washed with petroleum ether to give 1.65 g (90%) of the product. The NMR spectrum of the crude product revealed this to be a mixture of two C=C adducts (the signals at 4.84 and 4.62 due to the angular methines of the two adducts in the ratio of 1:2. The crude product was recrystallized from benzene–petroleum ether and the two kinds of crystals were separated manually under a microscope, giving yellow microcubes of **3d** and pale yellow microneedles of **3m**. The characterization data are given in Tables 1 and 4.

The authors greatly acknowledge to Japan Society for Promotion of Science (JSPS) for the Fellowship to B. S. H.

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