2,3-Dichloro-5,6-dicyano-*p*-benzoquinone (DDQ) as the useful synthetic reagent

Kiyoshi TANEMURA, Yoko NISHIDA, and Tsuneo SUZUKI

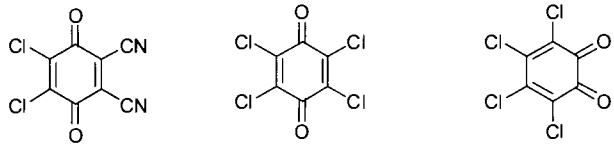
The Nippon Dental University, School of Life Dentistry at Niigata, Hamaura-cho, Niigata 951-8580, JAPAN

(Received 18 November 2010)

The reactions of 2,3-Dichloro-5,6-dicyano-*p*-benzoquinone (DDQ) such as dehydrogenation, oxidation of allylic and benzylic alcohols, deprotection of *p*-methoxybenzyl and 3,4-dimethoxybenzyl protecting groups, tetrahydropyranylation of alcohols, deprotection of acetals, silyl ethers, and dithianes are described.

Key words : DDQ, protection, deprotection, π-acceptors

2,3-Dichloro-5,6-dicyano-*p*-benzoquinone (DDQ) (1) is one of the most important reagents in synthetic organic chemistry. DDQ was first synthesized in 1906 by Thiele and Günther.[1] After the first synthesis, some utilities have been developed for the dehydrogenation of hydroaromatic compounds.[2] Among the quinones possessing electron-withdrawing groups, tetrachloro-*p*-benzoquinone (chloranil) (2) and tetrachloro-*o*-benzoquinone (*o*-chloranil) (3) are often employed for the dehydrogenation. However, DDQ is most frequently employed because of strong activities (Fig. 1). For example, DDQ reacts 550 times faster than chloranil in the dehydrogenation of tetralin.[2] For dehydrogenation by DDQ, the hydride transfer mechanism has been proposed as shown in Scheme 1.[2,3] This mechanism includes the transfer of hydride to the quinone oxygen, followed by the transfer of a proton to the phenolate ion.



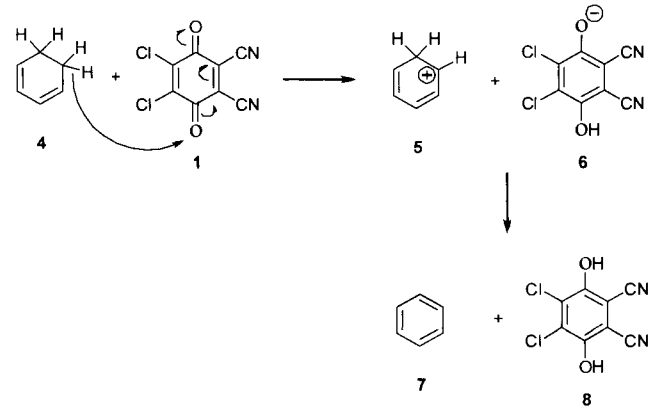
1 2 3

Figure 1.

In the following sections, some representative reactions of DDQ are mentioned.

1. Conversion of cyclic ketones to α,β-unsaturated ketones

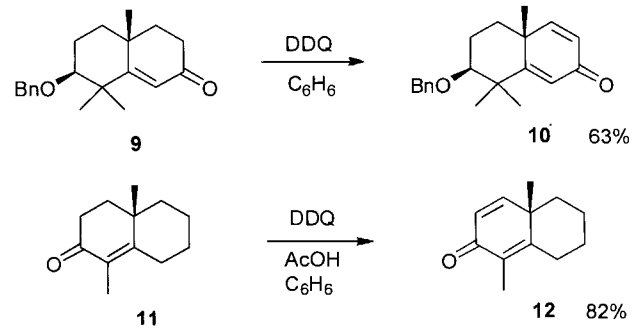
Cyclic ketones are converted into α,β-unsaturated ketones by the treatment with DDQ (Scheme 2). For instance, enones 9[4] and 11[5] are converted into dienones 10 and 12, respectively.



Scheme 1.

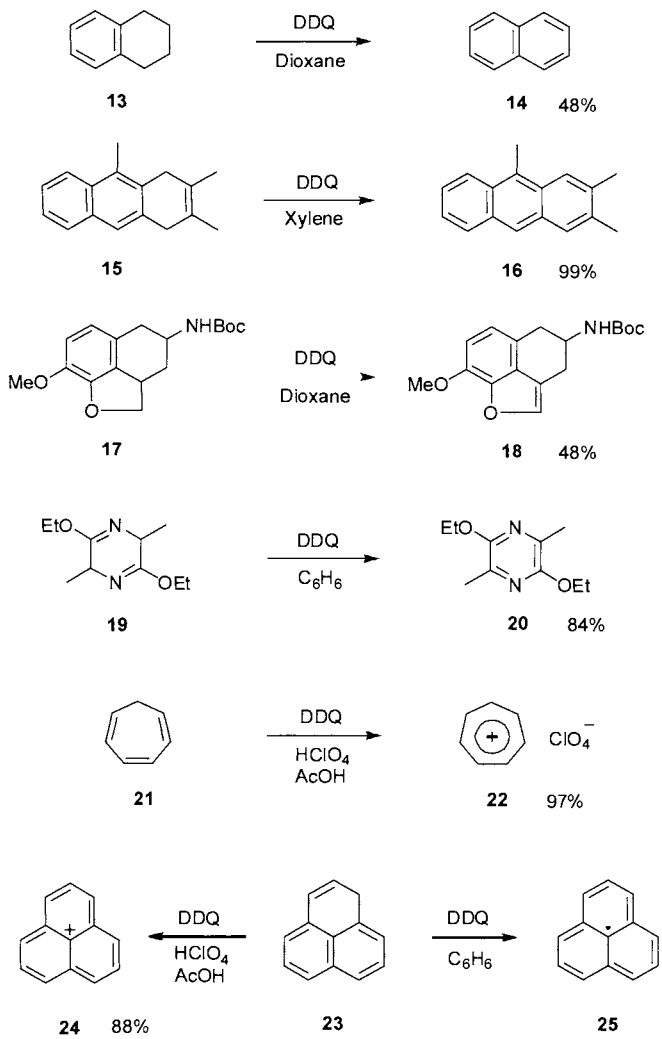
2. Dehydrogenation of cyclic hydroaromatic compounds

Cyclic hydroaromatic compounds such as 13[6] and



Scheme 2.

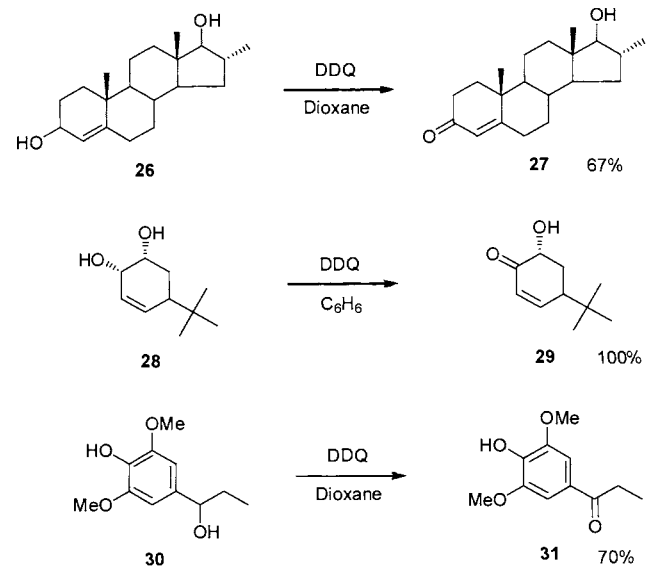
15[7] are dehydrogenated by DDQ to give aromatic compounds as shown in Scheme 3. DDQ is also useful for the synthesis of unsaturated heterocyclic compounds such as 18[8] and 20.[9] Synthesis of stable cations or radicals using DDQ is possible. Cycloheptatriene (21) is treated with DDQ and $HClO_4$ in acetic acid to give tropylium cation (22). Perinaphthalene (23) reacts with DDQ to afford the perinaphthyl radical (25). On the other hand, compound 23 reacted with DDQ and $HClO_4$ in acetic acid to form the perinaphthyl cation (24).[11]



Scheme 3.

3. Oxidation of allylic and benzylic alcohols

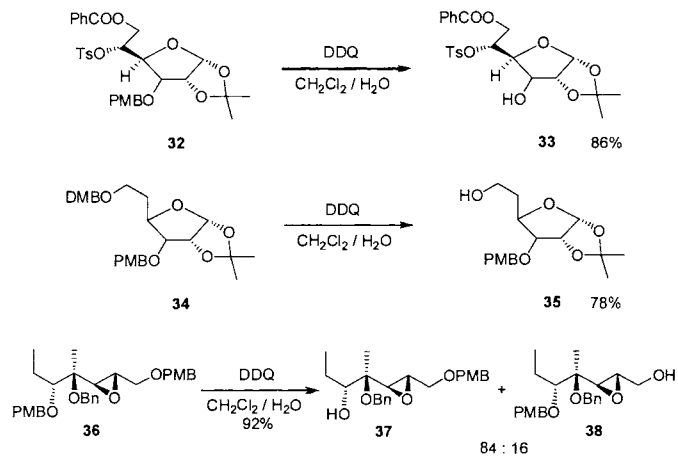
Allylic and benzylic alcohols are oxidized by DDQ to afford α,β-unsaturated carbonyl compounds (Scheme 4).[12-14]



Scheme 4.

4. Deprotection of *p*-methoxybenzyl and 3,4-dimethoxybenzyl protecting groups

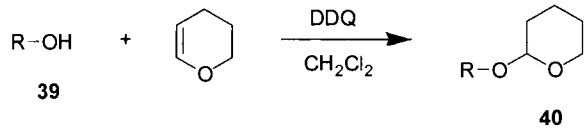
p-Methoxybenzyl (PMB) and 3,4-dimethoxybenzyl (DMB) groups are removed by the treatment with DDQ in CH_2Cl_2-H_2O under neutral conditions (Scheme 5). Compound 32 is converted into 33 by the treatment with DDQ.[15] DMB ethers are oxidized faster than PMB ethers by DDQ. DMB ether 34 is deprotected by DDQ to give compound 35 without removal of the PMB group.[16] The reactivities of secondary PMB and DMB ethers are higher than those of primary ones. For example, the reaction of 36 with DDQ in CH_2Cl_2-H_2O gave compounds 37 and 38 in the ratio 84 : 16.[16]



Scheme 5.

5. Tetrahydropyranylation of alcohols

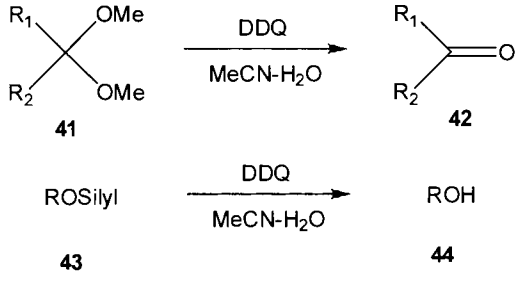
Hydroxy compounds readily add to 3,4-dihydro-*2H*-pyran in the presence of a catalytic amount of DDQ to give high yields of the corresponding tetrahydropyranyl ethers (Scheme 6).[17]



Scheme 6.

6. Deprotection of acetals and silyl ethers

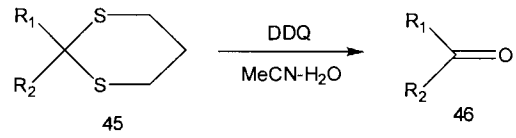
Acetals[18] and silyl ethers[19] are deprotected by a catalytic amount of DDQ in aqueous MeCN (Scheme 7). Oku *et al.* have reported the similar cleavage of acetals catalyzed by DDQ in wet ethyl acetate and explained *via* the protonic and / or the Lewis acid mechanism.[20] Masaki *et al.* reported some reactions catalyzed by TCNE.[21] These reactions were caused by π-acceptors as well as DDQ.[22] Formation of the acidic compounds by the decomposition of DDQ, chloranil, 7,7,8,8-tetracyanoquinodimethane (TCNQ), and 2,3,5,6-tetrafluoro-7,7,8,8-tetracyanoquinodimethane ($TCNQF_4$) via an single electron transfer (SET) mechanism was reported.[23]



Scheme 7.

7. Deprotection of dithianes

Dithianes[24,25] are deprotected by DDQ in aqueous MeCN (Scheme 8). On the other hand, dithiolanes and diphenyl dithioacetals are inert under the same conditions. The SET mechanism was proposed for deprotection. Sankararaman *et al.* reported the similar deprotection under photochemical and thermal conditions.[26] Interestingly, the reactions of dithioacetals derived from cinnamaldehyde with DDQ



Scheme 8.

afford benzaldehyde.[27]

References

1) Thiele, J. and Günther, F., *Ann.*, **349**, 45 (1906).
2) Braude, E. A. and Linstead, R. P., *J. Chem. Soc.*, **1954**, 3544.
3) Lewis, E. S., Perry, J. M., and Grinstein, R. H., *J. Am. Chem. Soc.*, **92**, 899 (1970).
4) Davis, B. R. and Halsall, T. G.., *J. Chem. Soc.*, **1962**, 1833.
5) Kropp, P. J., *J. Org. Chem.*, **29**, 3110 (1964).
6) Braude, E. A., Jackman, L. M., and Linstead, R. P., *J. Chem. Soc.*, **1954**, 3548.
7) Wolthuis, E., *J. Org. Chem.*, **26**, 2215 (1961).
8) Haefliger, W. and Kloppner, E., *Helv. Chim. Acta*, **65**, 1837 (1982).
9) Blake, K.W., Porter, A. E. A., and Sammes, P. G.., *J. Chem. Soc., Perkin Trans. 1*, **1972**, 2924.
10) Reid, D. H., Fraser, M., Molloy, B. B., Payne, H. A. S., and Sutherland, R. G.., *Tetrahedron Lett.*, **1961**, 530.
11) Reid, D. H. and Sutherland, R. G.., *J. Chem. Soc.*, **1963**, 3295.
12) Burn, D., Petrov, V., and Weston, G.. O., *Tetrahedron Lett.*, **1960**, 14.
13) Mckittrick, B. A. and Ganem, B., *J. Org. Chem.*, **50**, 5897 (1985).
14) Becker, H. -D., Bjork, A., and Alder, E., *J. Org. Chem.*, **45**, 1596 (1980).
15) Oikawa, Y., Yoshioka, T., and Yonemitsu, O., *Tetrahedron Lett.*, **23**, 885 (1982); **23**, 889 (1982).
16) Oikawa, Y., Tanaka, T., Horita, K., Yoshioka, T., and Yonemitsu, O., *Tetrahedron Lett.*, **25**, 5393 (1984).
17) Tanemura, K., Horaguchi, T., and Suzuki, T., *Bull. Chem. Soc. Jpn.*, **65**, 304 (1992).
18) Tanemura, K., Suzuki, T., and Horaguchi, T., *J. Chem. Soc., Chem. Commun.*, **1992**, 979.
19) Tanemura, K., Suzuki, T., and Horaguchi, T., *J. Chem. Soc., Perkin Trans. 1*, **1992**, 2997.

20) Oku, A., Kinugasa, M., and Kamada, T., *Chem. Lett.*, **1993**, 165.
21) Masaki, Y., Miura, T., and Ochiai, M., *Chem. Lett.*, **1993**, 17.
22) Tanemura, K., Suzuki, T., and Horaguchi, T., *Bull. Chem. Soc. Jpn.*, **67**, 290 (1994).
23) Tanemura, K., Nishida, Y., Suzuki, T., Satsumabayashi, K., and Horaguchi, T., *J. Chem. Res. (S)*, **1999**, 40.
24) Tanemura, K., Dohya, H., Imamura, M., Suzuki, T., and Horaguchi, T., *Chem. Lett.*, **1994**, 965.
25) Tanemura, K., Dohya, H., Imamura, M., Suzuki, T., and Horaguchi, T., *J. Chem. Soc., Perkin Trans. 1*, **1996**, 453.
26) Mathew, L. and Sankararaman, S., *J. Org. Chem.*, **58**, 7576 (1993).
27) Tanemura, K., Nishida, Y., Suzuki, T., Satsumabayashi, K., and Horaguchi, T., *J. Heterocycl. Chem.*, **34**, 457 (1997).