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ON THE SELECTIVITY OF DEPROTECTION OF BENZYL, MPM (4-METHOXYBENZYL) AND DMPM (3,4-DIMETHOXYBENZYL) PROTECTING GROUPS FOR HYDROXY FUNCTIONS

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Abstract—The 4-methoxybenzyl (MPM) protecting group for hydroxy functions is readily removed with DDQ in dichloromethane containing a small amount of water at room temperature. Under these neutral conditions, several other protecting and functional groups remained unchanged. 3,4-Dimethoxybenzyl (DMPM) groups are more reactive than MPM groups with DDQ. The benzyl (Bn) protecting group was removed by catalytic hydrogenation over Raney nickel. Selective deprotection of DMPM, MPM and Bn groups is also presented.

In multistep syntheses of complex natural products such as polyketide-derived macrolide and polyether antibiotics, selection of the most suitable protecting group for each hydroxy function is very important and sometimes holds the key to success. Although a number of protecting groups for hydroxy functions are already available, simple and versatile protecting groups with new selectivities are still in need of development because commonly used protecting groups, except benzyl groups, are inherently usually sensitive to acid.[1]

In the course of our studies on the synthesis from D-glucose of some typical macrolide and polyether antibiotics, we recently demonstrated a new deprotection method of MPM (4-methoxyphenylmethyl) protecting groups for hydroxy functions consisting of DDQ (2,3-dichloro-5,6-dicyanobenzoquinone) oxidation under neutral conditions[2] and some extensions.[3] In this paper, we describe not only the deprotection of the MPM and more readily removable DMPM (3,4-dimethoxyphenylmethyl) protecting groups[4] in some representative compounds, but also selectivity among the three benzyl-type protecting groups, MPM, DMPM and Bn (benzyl).

Deprotection of MPM groups by DDQ oxidation

Benzylic oxidation by DDQ has been well studied, especially in the electron-donating phenol and indole series.[5] The reaction proceeds via initial formation of a charge-transfer (CT) complex between an electron-donating aromatic ring and electron-accepting DDQ followed by benzylic dehydrogenation. Therefore, when an MPM ether (**1**) is treated with DDQ in the presence of water, the oxidation is expected to take place affording an alcohol (**2**) and anisaldehyde (**3**) as shown in Scheme 1. This implies that an MPM protection is removed under mild DDQ oxidation conditions.

Usual treatment of phenethyl MPM ether (**4**) with an equimolar amount of DDQ in methanol at room temperature led to the initial formation of a brownish green colored solution of the CT complex, and then the color slowly faded into pale brownish yellow. Phenethyl alcohol (**5**) and **3** were isolated from the reaction mixture in excellent yields (86 and 87%, respectively), but the time taken to complete the reaction was 24 h. Similarly, in 90% aqueous tetrahydrofuran‡ the reaction also proceeded efficiently, but very slowly. However, addition of dichloromethane to the methanol solution accelerated the reaction,[6] and the reaction rate increased on increasing the proportion of dichloromethane. The deep green color of the CT complex faded quite rapidly to colorless in dichloromethane containing a small amount of water (1/18) instead of methanol, and the reaction was completed within only 40 min. This solvent system has an additional merit, that is, weakly acidic DDQH (2,3-dichloro-5,6-dicyanohydroquinone) precipitated from the solution as the reaction proceeded because DDQH is almost insoluble in both dichloromethane and water, and the reaction medium was consequently kept almost neutral all through the reaction. This is sometimes very important in the case of substrates bearing acid-sensitive functional and protecting groups.§ A stoichiometric amount of DDQ was sufficient for this oxidation, but 10% excess of DDQ brought about a reduction in the reaction time to one-half.

In order to examine the behavior of common functional and protecting groups to the DDQ oxidation, compounds **6**, **8**, **10**, **12**, **14**, **16** and **18** were chosen. The MPM ether containing an allylic double bond (**6**) readily gave geraniol (**7**). Compound **8**, easily derived from D-glucose, with two acid-sensitive isopropylidene groups also gave the corresponding alcohol (**9**)[7] in excellent yield, but required rather prolonged DDQ treatment, which caused a slight loss of one isopropylidene group (detectable on TLC). This defect was removed by use of 1.5 equivalents of DDQ. Similarly, another isopropylidene compound (**10**)

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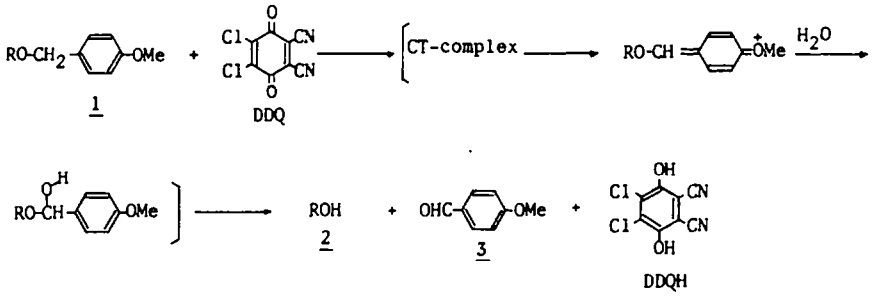
‡ This was reported to be the best solvent system for the selective oxidation of C-3 side chains in indoles.[3f]

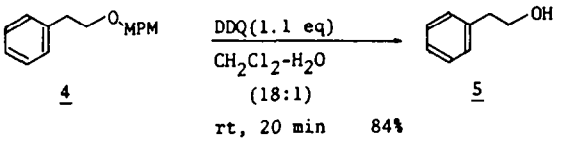
§ Addition of triethylamine or sodium bicarbonate inhibits the DDQ oxidation.

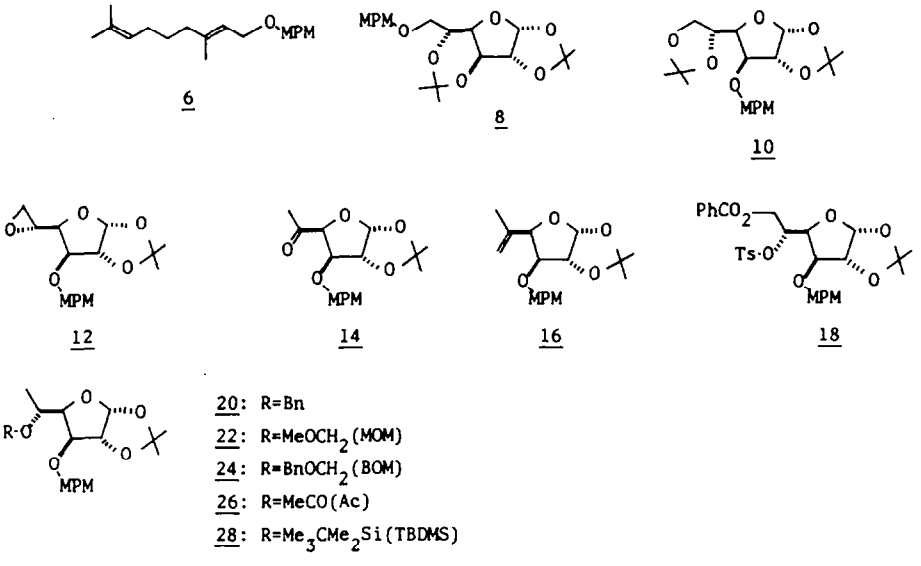


Scheme 1.

gave diacetoneglucose (**11**).[8] Other D-glucose-derived compounds containing epoxide (**12**), keto (**14**), unsaturated (**16**), benzoyl and tosyl (**18**) groups gave good results (Table 1). Common protecting groups for hydroxy functions were also unaffected under the DDQ oxidation conditions as exemplified by the deprotection of MPM ethers containing benzyl (**20**), methoxymethyl (**22**), benzyloxymethyl (**24**), acetyl (**26**), and t-butyldimethylsilyl groups (**28**) (Table 1). Compound **30** is a synthetic intermediate of the 12-membered macrolide, methynolide.[9] Under usual conditions in dichloromethane–water, loss of the isopropyl protection occurred concomitantly to give no expected product (**31**). This side reaction could be avoided by the addition of isopropanol. When **30** was oxidized with DDQ in dichloromethane–isopropanol–water (20 : 1 : 1), only **31** was isolated.

Benzyl ethers were almost unreactive to DDQ under these conditions as shown in the oxidation of **20**, and actually, 92% of **72** was recovered after treatment with 1.5 equivalents of DDQ for 2.5 h. The DDQ oxidation of synthetic intermediates **32** and **34** of salinomycin (polyether)[10] and tylosin (16-membered macrolide),[11] respectively, provided good examples of the selective deprotection of MPM groups in the presence of Bn groups. Compound **32** gave **33** in quantitative yield under usual conditions, and **34** gave **35** in 97% yield in the presence of isopropanol (Table 1).





Scheme 2.

Table 1. Oxidative cleavage of MPM and DMPM ethers with DDQ at room temperature

Ether	DDQ (equiv)	Solvent	Reaction time (h)	Alcohol	Yield (%)
4	1.0	MeOH	24	**5**	86
4	1.0	THF–H_2O(10:1)	24	**5**	85
4	1.0	CH_2Cl_2–MeOH(4:1)	6	**5**	87
4	1.0	CH_2Cl_2–MeOH(9:1)	3.5	**5**	80
4	1.0	CH_2Cl_2–H_2O(18:1)	0.6	**5**	89
4	1.1	CH_2Cl_2–H_2O(18:1)	0.3	**5**	84
6	1.1	CH_2Cl_2–H_2O(18:1)	1	**7**	82
8	1.1	CH_2Cl_2–H_2O(18:1)	4	**9**	93
8	1.5	CH_2Cl_2–H_2O(18:1)	1	**9**	92
10	1.1	CH_2Cl_2–H_2O(18:1)	5	**11**	86
10	1.5	CH_2Cl_2–H_2O(18:1)	3	**11**	86
12	1.5	CH_2Cl_2–H_2O(18:1)	2.5	**13**	84
14	1.5	CH_2Cl_2–H_2O(18:1)	7	**15**	84
16	1.5	CH_2Cl_2–H_2O(18:1)	2.5	**17**	89
18	1.5	CH_2Cl_2–H_2O(18:1)	2	**19**	86
20	1.5	CH_2Cl_2–H_2O(18:1)	1.5	**21**	85
22	1.5	CH_2Cl_2–H_2O(18:1)	1	**23**	90
24	1.5	CH_2Cl_2–H_2O(18:1)	1.5	**25**	87
26	1.5	CH_2Cl_2–H_2O(18:1)	2.5	**27**	85
28	1.5	CH_2Cl_2–H_2O(18:1)	0.75	**29**	87
30	2.0	CH_2Cl_2–i-PrOH–H_2O[a]	2[b]	**31**	78
32	1.1	CH_2Cl_2–H_2O(20:1)	1	**33**	100
34	2.0	CH_2Cl_2–i-PrOH–H_2O[a]	1[b]	**35**	94
36	1.1	CH_2Cl_2–H_2O(18:1)	0.25	**5**	86
37	1.1	CH_2Cl_2–H_2O(18:1)	2.5	**11**	86
38	1.5	CH_2Cl_2–H_2O(18:1)	0.25	**39**	85
40	1.2	CH_2Cl_2–H_2O(20:1)	1.8[b]	**41**	75
				42	6.5
43	1.2	CH_2Cl_2–H_2O(20:1)	0.6[b]	**44**	80
				45	4
46	1.2	CH_2Cl_2–H_2O(20:1)	0.08[b]	**47**	86
48	1.2	CH_2Cl_2–H_2O(20:1)	1[c]	**49**	66
				50	5.5

[a] 20:1:1.
[b] At 5°.
[c] At 10°.

Deprotection of DMPM groups by DDQ oxidation

Because veratrol has a lower oxidation potential ($E_{1/2}$ = 1.45 V)[12] and is more reactive for the CT complex formation than anisole ($E_{1/2}$ = 1.78 V),[12] the DMPM groups were expected to afford more readily removable protecting groups.† Although only a small difference in reactivity was observed between simple compounds such as **36** and **4**, a rather hindered DMPM compound (**37**) was clearly more reactive to DDQ than the corresponding MPM compound (**10**) and the reaction time was reduced to one-third. In the case of **38** bearing Bn protecting groups, deprotection of only the DMPM group took place rapidly to give **39** in 85% yield.

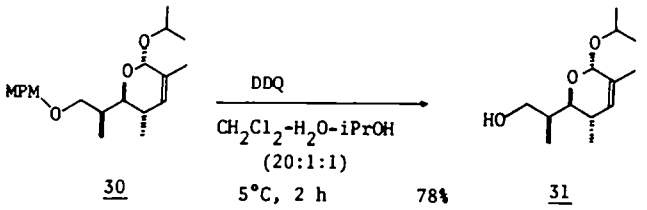
Selective deprotection of DMPM groups in the presence of MPM groups was examined in the DDQ treatment of three compounds having both MPM and DMPM protecting groups. When **40**, in which two primary alcohols are protected with MPM and DMPM groups, was treated with 1.2 equivalents of DDQ at 5°, the DMPM group was removed to give **41** with more than 92% selectivity. Compound **43** having two protected secondary alcohols also gave a similar result, and **44** was obtained with 95% selectivity. In the case of **46** having an MPM protected primary alcohol and a DMPM protected secondary alcohol only the DMPM protecting group was removed affording **47** in high yield.‡ Compound **48** containing an MP (4-methoxyphenyl) methylene acetal also gave mainly **49** deprotected only the DMPM group[3a,9] (Table 1). A successful application of this selective deprotection in the final stage of a total synthesis of tylonolide from D-glucose will be reported soon.[11]

Selective hydrogenolysis of Bn groups in the presence of MPM and DMPM groups

As shown in the oxidation of **20**, **32**, **34**, **40**, and **46** MPM and/or DMPM groups were selectively removed in the presence of Bn groups. On the contrary, the selective removal of Bn groups in the presence of MPM

† 1,4-Dimethoxybenzene, 1,2,3-trimethoxybenzene and indole derivatives are more electron donating, but 1,2-benzene derivatives are practically useful because of ease of preparation and stability to acid.

‡ In acyclic compounds, deprotection of secondary alcohols was more readily achieved than that of primary alcohols,[4] and hence the complete selectivity was observed in the deprotection of **46**.



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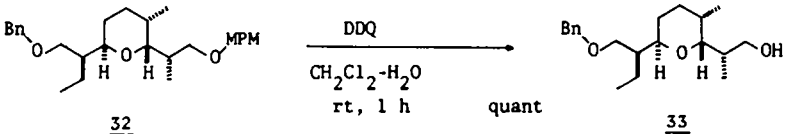

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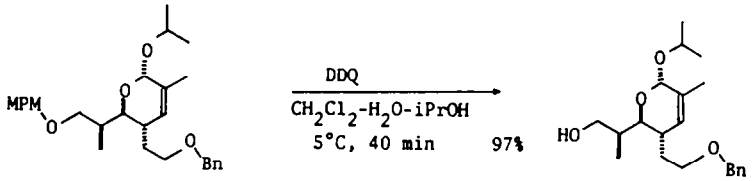

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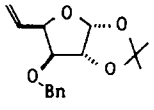

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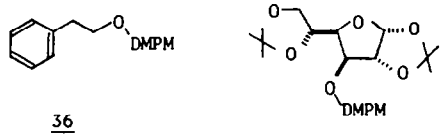
Scheme 3.



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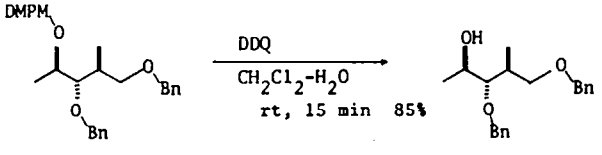

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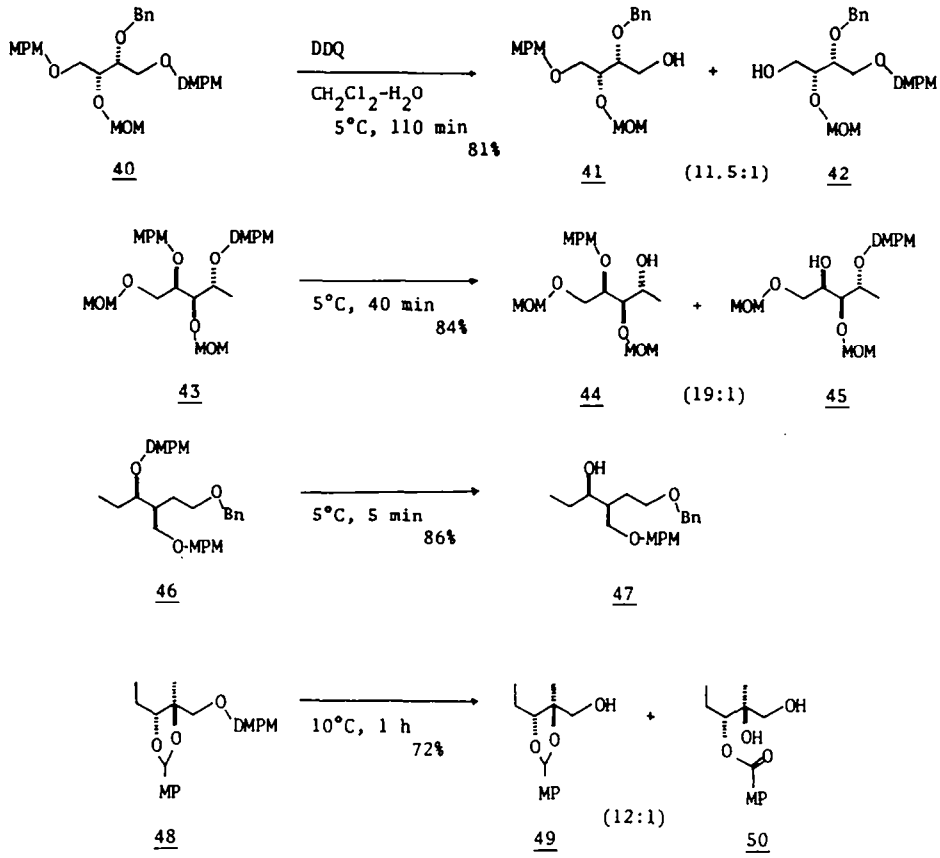
Scheme 4.



Scheme 5.

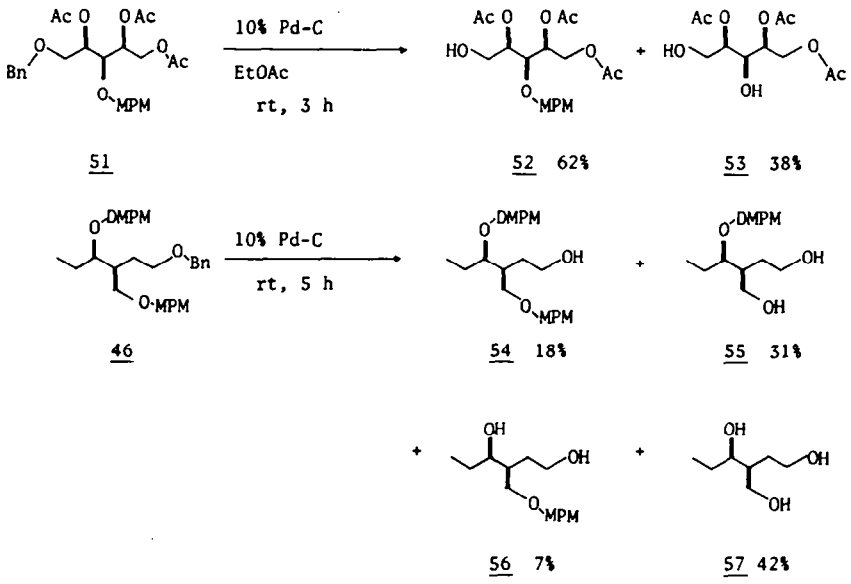
and/or DMPM groups was examined next. Reductive cleavage by catalytic hydrogenation or alkali metal in liquid ammonia, is most commonly used for the deprotection of Bn groups.† However, no selectivity was observed in the catalytic reduction with platinum on charcoal and rhodium on alumina catalysts, or in the sodium in liquid ammonia reduction.[14] The catalytic reduction with palladium on charcoal gave better results. When **51** was hydrogenated in the presence of 10% palladium on charcoal, the debenzylated alcohol (**52**) was isolated as the main product, but simultaneous removal of the MPM protection occurred to give a considerable amount of the diol (**53**). Under similar conditions, **46** containing Bn, MPM and DMPM gave four products (**54**–**57**). The product distribution shows clearly the order of reactivity to be Bn, MPM and DMPM. Although this catalytic reduction is still not useful for practical purposes because of poor selectivity, the results prompted a search for a more practical catalyst, and finally it was found that Raney nickel gave excellent results.

When **34** was hydrogenated over W-2 Raney nickel[15] in ethanol at room temperature, completely selective removal of the Bn protection took place to give **58** in excellent yield, although 24 h was required to complete the reacton. Similarly, **59** gave only **60** in 85% yield, but even after 24 h 12% of the starting material (**59**) was recovered (net yield of **60**: 96%).

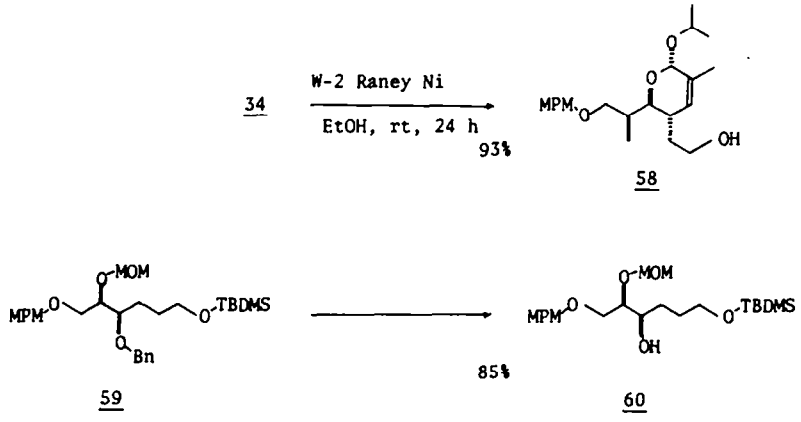
This catalytic hydrogenolysis was significantly accelerated by use of a large amount of more reactive W-4 Raney nickel catalyst.[16] When **51** was hydrogenated over W-4 Raney nickel, **52** was isolated in 90% yield as the sole product within 2 h. In the case of **46** the hydrogenolysis proceeded more rapidly to give **54** in high yield (88%), but a small amount (4%) of **55** deprotected by both Bn and MPM groups was concomitantly obtained even after 40 min. Compound **61** containing a DMP (3,4-dimethoxyphenyl) methylene acetal group gave again only the debenzylated alcohol (**62**) almost in quantitative yield. Similarly, **63** and **65** gave only **64** and **66**, respectively, in excellent yields. Rather prolonged hydrogenation of the tylonolide intermediate (**34**) over a large amount of W-4 Raney nickel caused a simultaneous reduction of the double bond to afford mainly the expected product (**67**), but a fair amount of the isomer (**68**) was also obtained.‡[11] The salinomycin intermediate

† Facile cleavage of Bn ethers by catalytic transfer hydrogenation with 20% palladium oxide on carbon and cyclohexene in refluxed ethanol was reported, but the selectivity between Bn and MPM protecting groups is unknown.[13]

‡ The ratio of **67** and **68** was 6.7:1 indicating that the stereoselectivity for the reduction of the double bond of **34** under these conditions was somewhat insufficient for practical use.



Scheme 6.



Scheme 7.

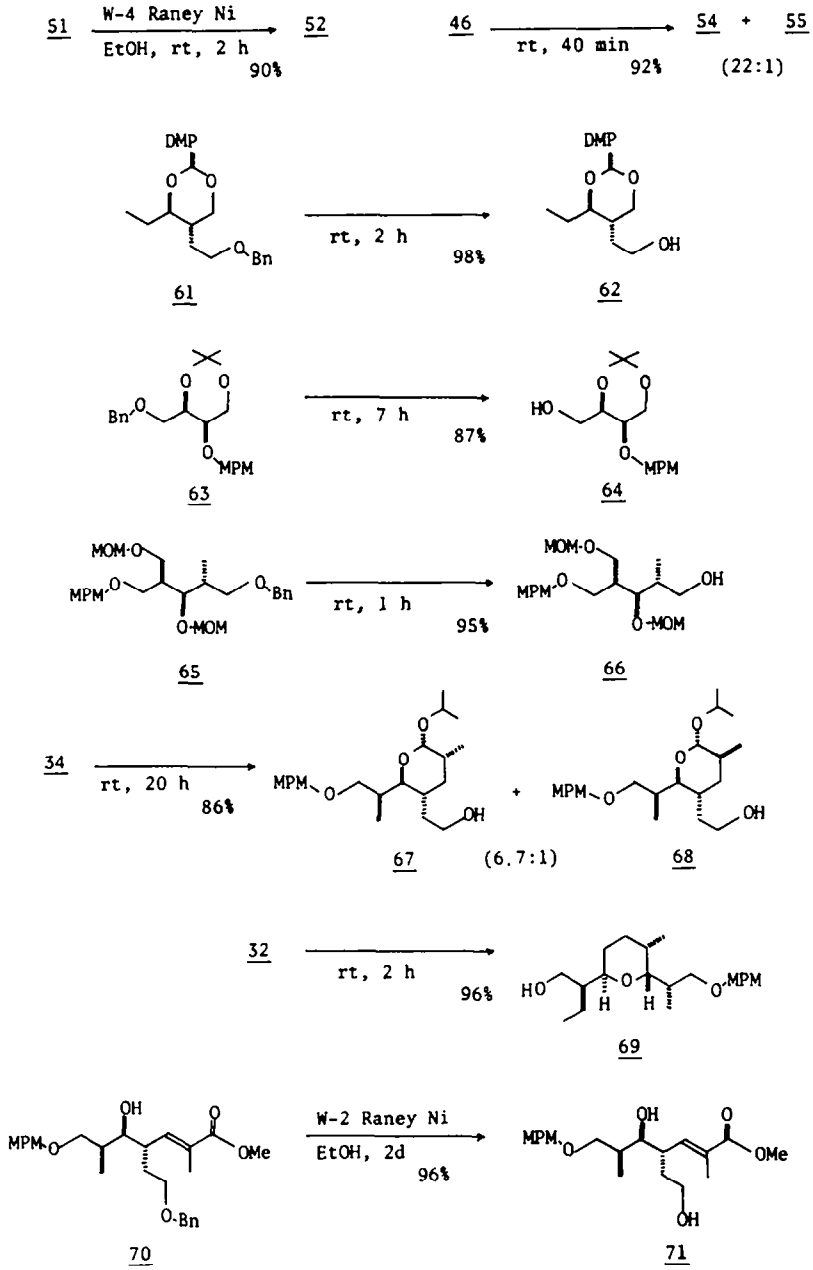
(**32**) containing no reducible double bond gave the corresponding debenzylated alcohol (**69**) in nearly quantitative yield.[10] Finally, in the case of **70** containing a double bond, only the debenzylation took place to give **71** in excellent yield, though two days were required to complete the reaction over W-2 Raney nickel (Table 2).

EXPERIMENTAL

M.ps were measured on a Yamato MP-1 micro m.p. apparatus and are uncorrected. ^{1}H-NMR spectra were recorded on a JEOL JNM FX-100, JEOL JNM FX-200 or JEOL JNM GX-270 instrument. Low- and high-resolution mass spectra were taken on a JEOL JMS D-300 or JEOL JMS-01 GS spectrometer.

Table 2. Hydrogenolysis of Bn ethers over Raney Ni catalyst in ethanol

Ether	Raney Ni	Reaction time (h)	Alcohol	Yield (%)
32	W-4	2	**69**	96
34	W-2	24	**58**	93
34	W-4	20	**67**	75
			68	11
46	W-4	0.6	**54**	88
			55	4
51	W-4	2.5	**52**	90
59	W-2	24	**60**	96
61	W-4	2	**62**	98
63	W-4	7	**64**	87
65	W-4	1	**66**	95
70	W-2	48	**71**	96



Scheme 8.

General preparation of MPM and DMPM ethers

To a stirred suspension of NaH (1.0–2.0 equiv) in DMF or DMSO under Ar was added dropwise an alcohol in THF and then (after *ca* 30 min) MPM (4-methoxybenzyl)[17] or DMPM (3,4-dimethoxybenzyl) chloride[18] (1.0–2.0 equiv) in THF. After the reaction was completed (30 min overnight),† the mixture was poured into ice–water (or sat NH_4Cl aq with ice if necessary to avoid strong alkali) and extracted with ether. The extract was washed with sat NaCl aq, dried over $MgSO_4$, and concentrated *in vacuo*. The residue was chromatographed on a short column of silica gel to give an MPM or DMPM ether in 85% quantitative yield. A typical example is shown as follows.

Benzyl 2(S) - [2(R) - [1(S) - (4 - methoxybenzyloxy - methylethyl)] - 3(S) - methyl - 6(R) - tetrahydropyranyl]butyl ether **32**. To a stirred suspension of NaH (26 mg, 1.09 mmol) in DMSO (1 ml) was added dropwise a THF soln (3 ml) of **33** (250 mg, 0.78 mmol) under Ar. After 45 min at room temp, MPM chloride (158 mg, 1.01 mmol) was added, and the stirring was continued for 3 h. The mixture was poured into sat NH_4Cl aq and then extracted with ether. The extract was washed with sat NaCl aq, dried over $MgSO_4$, and concentrated *in vacuo* to leave an oil, which was chromatographed on a short silica gel

† If excess MPM or DMPM chloride remained in the reaction mixture, a partial loss of acid-sensitive groups such as acetonide groups sometimes happened during the final silica gel chromatography, probably due to a small amount of hydrochloric acid coming from the chloride. This side reaction was avoided by the addtion of diethylamine to quench the excess chloride.

column. Elution with EtOAc–n-hexane (1 : 11) gave a colorless oil of **32** (296 mg, 86%). ^{1}H-NMR ($CDCl_3$) δ 0.87 (3H, t, J = 8 Hz), 0.89 (3H, d, J = 7 Hz), 0.96 (3H, d, J = 7 Hz), 1.23–2.17 (9H, m), 3.29–3.45 (2H, m), 3.49–3.57 (3H, m), 3.77 (3H, s), 3.78–3.83 (1H, m), 4.31 (1H, d, J = 11.5 Hz), 4.38 (1H, d, J = 11.5 Hz), 4.41 (1H, d, J = 12 Hz), 4.48 (1H, d, J = 12 Hz), 6.84 (2H, d, J = 8.5 Hz), 7.21 (2H, d, J = 8.5 Hz), 7.31 (5H, s); MS *m/z* 349 ($M^+ - 91$, 3%), 319 (2.5), 304 (1.1), 121 (100), 91 (57.5). Exact MS: found, 349.2379; calc for $C_{21}H_{33}O_4$, 349.2381.

General procedure of deprotection of MPM and DMPM groups by DDQ oxidation

To a stirred CH_2Cl_2 soln of an MPM or DMPM ether containing a small amount of water (1/18–1/20 of CH_2Cl_2) was added DDQ (1.0–1.5 equiv) at room temp or 5°. After the reaction was completed, sat $NaHCO_3$ aq was added, and the mixture was extracted with CH_2Cl_2. The extract was washed with sat $NaHCO_3$ aq and sat NaCl aq, and dried over $MgSO_4$ or Na_2SO_4. The solvent was evaporated and the residue was chromatographed on a silica gel column to give a deprotected alcohol and anisaldehyde or veratrum aldehyde (Table 1). A typical example is given below.

5,6-*Anhydro*-1,2-O-*isopropylidene*-α-D-*glucofuranose* **13**. To a stirred soln of **12** (92 mg, 0.286 mmol) in CH_2Cl_2 (2.9 ml) and water (0.17 ml) was added DDQ (97 mg, 0.427 mmol) at room temp. After 2.5 h precipitated DDQH was removed by decantation and washed with a small amount of CH_2Cl_2. The combined CH_2Cl_2 soln was then washed with sat $NaHCO_3$ aq and sat NaCl aq, and dried over Na_2SO_4. Evaporation of the solvent *in vacuo* gave an oil, which was chromatographed on a silica gel column with n-hexane–EtOAc (1 : 1) as eluent to give a colorless solid of **13** (48.3 mg, 84%): m.p. 130–131° (ligroin); ^{1}H-NMR ($CDCl_3$) δ 1.32 (3H, s), 1.48 (3H, s), 2.84–3.09 (3H, m), 3.38–3.50 (1H, m), 4.02–4.15 (1H, m), 4.26 (1H, brs), 4.52 (1H, d, J = 4 Hz), 5.99 (1H, d, J = 4 Hz); MS *m/z* 187 ($M^+ - 15$), 59 (base), 43. (Found: C, 53.45; H, 7.00. Calc for $C_9H_{14}O_4$: C, 53.46; H, 6.98%.)

Catalytic hydrogenolysis of **46** *with* 10% Pd–C. A soln of **46** (27.6 mg) in EtOAc (2 ml) was hydrogenated over 10% Pd–C (10 mg) at ordinary pressure and temp for 5 h. After removal of the catalyst, the solvent was evaporated to leave an oil, which was separated on a preparative TLC with EtOAc to give **54** (18%), **55** (31%), **56** (7%) and **57** (42%).

(3*S*,4*R*) - 4 - (3,4 - *Dimethoxybenzyloxy*) - 3 - (4 - *methoxybenzyloxymethyl*)*hexan* - 1 - *ol* **54**. ^{1}H-NMR ($CDCl_3$) δ 0.93 (3H, t, J = 7 Hz), 1.26–1.80 (4H, m), 1.98–2.25 (1H, m), 2.62 (1H, brs), 3.39 (1H, dd, J = 3, 9 Hz), 3.48 (1H, dd, J = 2, 9 Hz), 3.65 (2H, t, J = 6 Hz), 3.80 (3H, s), 3.87 (6H, s), 3.38–4.05 (1H, m), 4.43 (2H, s), 4.46 (2H, s), 6.77–6.90 (3H, m), 6.87 (2H, d, J = 9 Hz), 7.24 (2H, d, J = 9 Hz); MS *m/z* 418 (M^+, 1.7%), 297 (7.8), 167 (100), 151 (60), 137 (35), 121 (52). Exact MS: found, 418.2373; calc for $C_{24}H_{34}O_6$, 418.2357.

(3*S*,4*R*) - 4 - (3,4 - *Dimethoxybenzyloxy*) - 3 - *hydroxymethylhexan* - 1 - *ol* **55**. Colorless oil: ^{1}H-NMR ($CDCl_3$) δ 0.87 (3H, t, J = 7.5 Hz), 1.10–1.77 (7H, m), 3.30–3.47 (1H, m), 3.57–3.76 (4H, m), 3.80 (3H, s), 3.81 (3H, s), 4.33 (2H, d, J = 10.5 Hz), 4.50 (2H, J = 10.5 Hz), 6.78 (3H, brs); MS *m/z* 298 (M^+, 4.3%), 167 (56), 151 (100). Exact MS: found, 298.1757; calc for $C_{16}H_{26}O_5$, 298.1782.

(3*S*,4*R*) - 3 - (4 - *Methoxybenzyloxymethyl*)*hexane* - 1,4 - *diol* **56**. Colorless oil: ^{1}H-NMR ($CDCl_3$) δ 0.97 (3H, t, J = 7 Hz), 1.23–2.10 (7H, m), 3.40–3.95 (5H, m), 3.81 (3H, s), 4.43 (2H, s), 6.88 (2H, d, J = 9 Hz), 7.24 (2H, d, J = 9 Hz).

(3*S*,4*R*)-3-*Hydroxymethylhexane*-1,4-*diol* **57**. Colorless oil: ^{1}H-NMR ($CDCl_3$) δ 0.97 (3H, t, J = 7 Hz), 1.42–2.30 (8H, m), 3.55–4.00 (5H, m).

General procedure of hydrogenolysis of Bn groups over Raney Ni *catalyst*

An EtOH soln of a Bn ether was hydrogenated over a large amount of Raney Ni W-2 or W-4 at ordinary pressure and temp. After the reaction was complete, the catalyst was removed by filtration, and the soln was concentrated *in vacuo*. The residue was chromatographed on a silica gel column to give the corresponding debenzylated alcohol in high yield (Table 2). A typical example is given below.

3,6 - *Dihydro* - 3(*S*) - (2 - *hydroxyethyl*) - 6(*S*) - *isopropyloxy*-2(*R*) - [2 - (4 - *methoxybenzyloxy*) - 1(*S*) - *methylethyl*] - 5 - *methyl* - 2H - *pyran* **58**. An EtOH soln (10 ml) of **34** (114 mg) was hydrogenated over Rany Ni W-2 (0.4 ml) at ordinary pressure and temp for 24 h. After removal of the catalyst by filtration, the solvent was evaporated *in vacuo* to leave an oil, which was chromatographed on a silica gel column. Elution with n-hexane–EtOAc (3 : 2) gave a colorless oil of **58** (86 mg, 93%). ^{1}H-NMR ($CDCl_3$) δ 0.92 (3H, d, J = 7 Hz), 1.16 (3H, d, J = 6 Hz), 1.19 (3H, d, J = 6.5 Hz), 1.30–2.45 (5H, m), 1.69 (3H, s), 3.20–4.10 (5H, m), 3.80 (3H, s), 4.44 (2H, q, J = 11 Hz), 4.87 (1H, s), 5.57 (1H, s), 6.86 (2H, d, J = 9 Hz), 7.26 (2H, d, J = 9 Hz); MS *m/z* 320 ($M^+ - 58$, 1.8%), 275 (1), 259 (2.1), 245 (1.9), 224 (1), 208 (1), 197 (15), 147 (13), 121 (100).

Physicial data of other compounds described here are available from the Hokkaido University.

REFERENCES

[1] T. W. Greene, *Protective Groups in Organic Synthesis*, pp. 10–86. Wiley, New York (1980).

[2] Y. Oikawa, T. Yoshioka and O. Yonemitsu, *Tetrahedron Lett.* **23**, 885 (1982).

[3a] Y. Oikawa, T. Yoshioka and O. Yonemitsu, *Ibid.* **23**, 889 (1982); [b] Y. Oikawa, T. Nishi and O. Yonemitsu, *Ibid.* **24**, 4037 (1983).

[4] Y. Oikawa, T. Tanaka, K. Horita, T. Yoshioka and O. Yonemitsu, *Ibid.* **25**, 5393 (1984).

[5a] H.-D. Becker, *J. Org. Chem.* **30**, 982 (1965); [b] S. Patai (Editor), *Chemistry of the Quinoid Compounds*, p. 335. Wiley, New York (1974); [c] J. W. A. Findlay and A. B. Turner, *J. Chem. Soc. (C)* 23 (1971); [d] A. B. Turner, *Synthetic Reagents* (Edited by J. S. Pizey), p. 193. Wiley, New York (1977); [e] Y. Oikawa and O. Yonemitsu, *Heterocycles* **5**, 233 (1976); [f] *J. Org. Chem.* **42**, 1213 (1977); [g] Y. Oikawa, T. Yoshioka, K. Mohri and O. Yonemitsu, *Heterocycles* **12**, 1457 (1979); [h] H.-D. Becker and A. B. Turner, *J. Synth. Org. Chem. Japan* (in Japanese, translated by Y. Oikawa and O. Yonemitsu) **38**, 1163 (1980).

[6] A. Ohki, T. Nishiguchi and K. Fukuzumi, *Tetrahedron* **35**, 1737 (1979).

[7] C. H. Lee, *Carbohyd. Res.* **22**, 230 (1972).

[8] O. T. Schmidt, *Meth. Carbohyd. Res.* **2**, 318 (1963).

[9] Y. Oikawa, T. Tanaka and O. Yonemitsu, submitted to *J. Am. Chem. Soc.*

[10] Y. Oikawa, K. Horita, S. Nagato and O. Yonemitsu, to be published.

[11] T. Tanaka, Y. Oikawa, T. Hamada and O. Yonemitsu, submitted to *J. Am. Chem. Soc.*

[12] A. Zweig, W. G. Hodgson and W. H. Jura, *J. Am. Chem. Soc.* **86**, 4124 (1964).

[13] S. Hanessian, T. J. Liak and B. Vanasse, *Synthesis* 369 (1981).

[14] Y. Oikawa, T. Tanaka, K. Horita and O. Yonemitsu, *Tetrahedron Lett.* **25**, 5397 (1984).

[15] R. Mozingo, *Org. Synth. Coll. Vol.* **3**, 181 (1955).

[16] A. A. Pavlic and H. Adkins, *J. Am. Chem. Soc.* **68**, 1471 (1946); H. Adkins and A. A. Pavlic, *Ibid.* **69**, 3039 (1947).

[17] A. Sosa, *Ann. Chim.* **14**, 5 (1940).

[18] K. Kindler and E. Gehlhaar, *Arch. Pharm.* **274**, 377 (1936).