82.0 mmol), was dissolved in 150 mL of THF and added to a 1-L three-necked round-bottom flask containing 150 mL of THF, 17.5 mL (18.7 g 246.0 mmol) of thiolacetic acid, and 4.7 mL of TMSOTf (5.5 g, 24.6 mmol). An exothermic reaction resulted (temperature rise from 23 °C to 38 °C). The mixture was stirred for 1 h at room temperature, and then diluted with 50 mL of ethyl acetate. The reaction was quenched by careful addition of saturated sodium bicarbonate solution until effervescing stopped. The mixture was transferred to a separatory funnel, extracted with ethyl acetate, dried over magnesium sulfate, and concentrated to give 38.0 g of light brown solids. HPLC analysis showed that the product obtained was 77% pure with an α/β ratio of 70:1 85% yield corrected for purity. The crude product was crystallized from methanol to afford 23.2 g (64%) of 98% pure spironolactone 1. Mp: 155–159 °C. ^{1}H NMR ($CDCl_3$): 1.03 (s, 3 H), 1.57 (s, 3 H), 2.33 (s, 3 H), 4.0 (m, 1 H), 5.7 (d, J = 1.6 Hz, 1 H). IR ($CHCl_3$): 2940, 2860, 1760, 1675, 1415, 1350, 1175, 1110, 950 cm^{-1}. R_f (10 $CHCl_3$/acetone) 1 = 0.56; 2 = 0.49; 8 = 0.42.

Registry No. 1, 52-01-7; 5, 50407-76-6; 6, 121936-43-4; 7, 75219-50-0; 8, 976-70-5; 9, 976-71-6; 10, 33784-05-3; $HOCH_2CH_2OH$, 107-21-1; ACSH, 507-09-5; ethisterone, 434-03-7.

Heterogeneous Permanganate Oxidations: An Improved Procedure for the Direct Conversion of Olefins to α-Diketones/α-Hydroxy Ketones

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A large number of solid-supported permanganate reagents have been developed in recent years for the oxidation of organic substrates under heterogeneous conditions.[1] Potassium permanganate supported on molecular sieves[2] or silica gel[3] has been used to oxidize alcohols to carbonyl compounds and for the cleavage of carbon–carbon double bonds.[4] Zinc permanganate supported on silica gel has been applied for the conversion of acetylenes to α-diketones and cyclic olefins to ketols.[5] Permanganate supported on copper sulfate pentahydrate has been used for the oxidation of alcohols to the corresponding carbonyl compounds,[6] diols to lactones,[7] and sulfides to sulfones.[8] The proposed mechanism[9] for the conversion of alcohols to carbonyl compounds using potassium permanganate and copper sulfate pentahydrate showed that olefins retard the reaction by forming a π-complex with the permanganate ion and thus remain unaffected under the reaction conditions.

Herein, we report that a slight modification of the heterogeneous permanganate oxidations with $KMnO_4$/$CuSO_4 \cdot 5H_2O$ can be used effectively for the direct conversion of olefins to α-diketones and α-hydroxy ketones under very mild conditions. It turns out that when olefins are treated with a well-ground mixture of $KMnO_4$/$CuSO_4 \cdot 5H_2O$ in dichloromethane containing catalytic amounts of *tert*-butyl alcohol/water at room temperature, α-diketones or α-hydroxy ketones are obtained in good yields. The results obtained by this modified procedure are summarized in Table I.

There are a number of interesting features of this methodology worth pointing out. The most common method widely used for the conversion of olefins to α-diketones is that of Sharpless[10a] using a $KMnO_4$–acetic anhydride system that involves a tedious workup procedure and fails to produce significant amounts of α-diketones from small-ring olefins. *cis*-Cyclooctene, the smallest cyclic olefin to be successfully oxidized, gave only a 23% yield of diketone. On the other hand, the present methodology gave the α-hydroxy ketones **2** (30%), **4** (59%), and **6a** (50%) from the corresponding olefins. In the case of cyclooctene when the same reaction was done along with cupric acetate (solid, 1 mole equiv) for 4 h, the intermediate α-hydroxy ketone **6a** was converted to cyclooctane 1,2-dione **6b** (48%), and cyclododecene **7**[10b] under similar conditions gave **8** (58%). Oxidation of olefinic ketone **9** afforded the hydroxy ketone **10** in 79% yield. In the reaction of **11** a mixture of epoxide **12a** and hydroxy ketone **12b** (1:1) was obtained (80%), and cholesteryl acetate **15** gave the β-epoxide **16** as the only product (92%). *trans*-Stilbene (**17**) and acylic olefins **19** and **21** underwent oxidative cleavage under the reaction conditions. However, diphenylacetylene **23** yielded benzil in high yield (97%). The amount of *tert*-butyl alcohol and water added in this reaction is very crucial for the success of this reaction. In the absence of either water or *tert*-butyl alcohol the reaction does not take place. This reaction would be particularly useful for cyclic (small, medium, and large) olefins and acylic trisubstituted olefins.

In studying the kinetics of substitution of benzyl halides with cyanide ion catalyzed by 18-crown-6, Liotta[11] observed a dramatic increase in rate with the addition of minute quantities of water. Ω-phase catalysis, a nonclassical phase-transfer system, has been invoked to explain the role of water in these reactions. It is very likely that in our oxidation the water/*tert*-butyl alcohol forms a third phase, i.e., Ω phase, by surrounding the inorganic solids, and it is in or on or by means of this interface that the reaction takes place.[12] It is noteworthy that, in general, the oxidation of alkenes with potassium permanganate under aqueous conditions yields insignificant amount of epoxides.[13] However, in the present study the epoxides **12a** and **16** were found to be formed either as a major product or sole product in the reaction of substrates **11** and **15**, respectively. It is possible that the epoxide formation increases with increasing lipophilicity of the substrates, and this would be in line with Ω-phase catalysis.[12] This observation is interesting and needs to be explored further.

Compared to all the existing procedures for olefin oxidation, this method appears to be more general, the reaction conditions are milder, and the yields of the product

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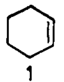
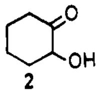
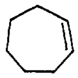
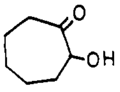
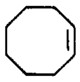
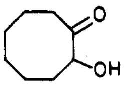
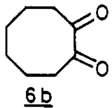
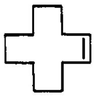
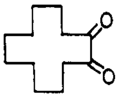
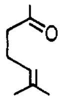
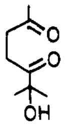
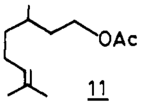
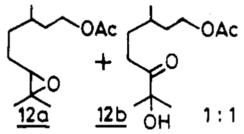
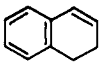
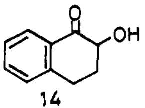
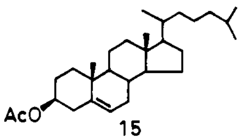
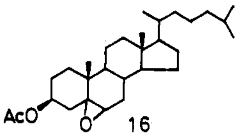
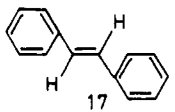
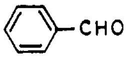
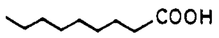
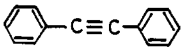
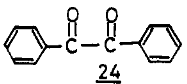
Table I. Oxidation of Olefins with $KMnO_4/CuSO_4 \cdot 5H_2O$ at 25 °C

entry	substrate struct	substrate mmol	oxidant $KMnO_4$:$CuSO_4 \cdot 5H_2O$:$Cu(OAc)_2H_2O$, g	t-BuOH:H_2O, mL	product	reaction time, h	yield, %
1	 1	4	4:2:0	1:0.2	 2	0.5	30
2	 3	4	4:2:0	1:0.2	 4	0.5	59
3	 5	4	4:2:0	1:0.2	 6a	0.5	50
4	5	2	4:2:1	1:0.3	 6b	4	48
5	 7	2	4:2:1	1:0.3	 8	6	58
6	 9	4	4:2:0	1:0.3	 10	2	79
7	 11	4	4:2:0	1:0.3	 12a + 12b 1 : 1	2	80
8	 13	2	4:2:0	1:0.2	 14	3	55
9	 15	2	4:2:0	1:0.4	 16	2	92
10	 17	4	4:2:0	1:0.4	 18	2	92
11	 19	4	4:2:0	1:0.3	 20	4	72
12	 21	4	4:2:0	1:0.3	 22	4	78
13	 23	2	4:2:0	1:0.3	 24	24	97

are usually better. α-Diketones are valued as precursors of transition-metal ligands, of acetylenes, and of heterocyclic compounds. Our modified permanganate oxidation makes this relatively rare functional group more readily accessible.

Experimental Section

Infrared spectra were determined with a Perkin-Elmer 1320 spectrometer, and NMR spectra with a Bruker WP-80 spectrometer. Melting points are uncorrected.

General Procedure for the Oxidation of Olefins.[14] **Oxidation of Cyclohexene (1).** A mixture of solid $KMnO_4$ (4.0 g) and $CuSO_4 \cdot 5H_2O$ (2.0 g) was ground to a fine powder in a pestle and mortar. To this water (200 μL) was added, and the slightly

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[14] The order of addition as indicated in the general procedure was used in all the reactions. Slightly inferior yields were obtained by changing the order of addition.

wet mixture was transfered to a reaction flask. To a stirred suspension of this mixture in dichloromethane (15 mL) was added cyclohexene (**1**) (0.329 g, 4 mmol) in dichloromethane (5 mL) followed by the addition of *tert*-butyl alcohol (1.0 mL). Within a few minutes the reaction mixture started to reflux for a while (5 min) and then cooled down. After stirring the reaction mixture for 0.5 h at room temperature (25 °C) it was filtered over a pad of Celite and washed thoroughly with dichloromethane. Removal of solvent gave adipoin (**2**,[15a] 0.137 g, 30%) as a dimer, mp 97–101 °C (lit.[15b] 97–102 °C).

Oxidation of Cycloheptene (3). A mixture of $KMnO_4$ (4.0 g), $CuSO_4{\cdot}5H_2O$ (2.0 g), and water (200 μL) in dichloromethane (15 mL) was treated with cycloheptene (**3**, 0.385 g, 4 mmol) in dichloromethane (5 mL) followed by *tert*-butyl alcohol (1 mL) at 25 °C. The course of the reaction was monitered by thin-layer chromatography. After 0.5 h, the reaction mixture was filtered over a pad of Celite and washed thoroughly with dichloromethane, and solvent was evaporated to afford α-hydroxycycloheptanone (**4**,[16] 0.302 g, 59%) as an oil.

Oxidation of Cyclooctene (5). A stirred mixture of $KMnO_4$ (4.0 g), $CuSO_4{\cdot}5H_2O$ (2.0 g), and water (200 μL) in dichloromethane (15 mL) was treated with cyclooctene (**5**, 0.441 g, 4 mmol) in dichloromethane (5 mL) and *tert*-butyl alcohol (1 mL). After 0.5 h, the reaction mixture was filtered, and solvent was removed to yield α-hydroxycyclooctanone (**6a**,[17a] 0.285 g, 50%) as the only product; bp 79–81 °C/2 mmHg (lit.[17b] bp 75 °C/1.5 mmHg).

Oxidation of Cyclooctene (5) to Diketone 6b. When a mixture of $KMnO_4$ (4.0 g), $CuSO_4{\cdot}5H_2O$ (2.0 g), and water (300 μL) in dichloromethane (15 mL) was treated with solid $Cu(OAc)_2{\cdot}H_2O$ (1.0 g), cyclooctene (**5**, 0.220 g, 2 mmol) in dichloromethane (5 mL), and *tert*-butyl alcohol (1 mL), cyclooctane-1,2-dione (**6b**,[18] 0.134 g, 48%) was obtained after distillation; bp 130 °C/3 mmHg (lit.[19] bp 130 °C/3 mmHg); IR (thin film) 1702 cm^{-1}; NMR ($CDCl_3$) δ 1.7 (s, 8 H), 2.53–2.76 (m, 4 H).

Oxidation of Cyclododecene (7).[10b] Cyclododecene (**7**, 0.332 g, 2 mmol) under similar reaction conditions afforded cyclododecane-1,2-dione (**8**, 0.227 g, 58%) after distillation, bp 82–85 °C/0.1 mmHg, as a yellow solid: mp 42–44 °C (lit.[20] mp 43 °C); IR (thin film) 1701 cm^{-1}; NMR ($CDCl_3$) δ 1.3 (s, 16 H), 2.66–2.86 (m, 4 H).

Oxidation of Compound 9. A mixture of $KMnO_4$ (4.0 g), $CuSO_4{\cdot}5H_2O$ (2.0 g), and water (300 μL) in dichloromethane (15 mL) treated with compound **9** (0.568 g, 4 mmol) in dichloromethane (5 mL) and *tert*-butyl alcohol (1 mL) yielded, after chromatography, compound **10** (0.550 g, 79%): IR (thin film) 3450, 1720, 1705 cm^{-1}; NMR ($CDCl_3$) δ 1.43 (s, 6 H), 2.2 (s, 3 H), 2.83 (s, 4 H), 3.76 (br s, 1 H); MS, *m/e* 159 (M + 1)$^+$. Anal. Calcd for $C_8H_{14}O_3$: C, 60.76; H, 8.86. Found: C, 60.88; H, 8.94.

Oxidation of Citronellol Acetate (11). To a mixture of $KMnO_4$ (4.0 g), $CuSO_4{\cdot}5H_2O$ (2.0 g), and water (300 μL) in dichloromethane (15 mL) was added citronellol acetate (**11**, 0.792, 4 mmol) in dichloromethane (5 mL) and *tert*-butyl alcohol (1 mL) and stirred for 2 h. On purification by chromatography the epoxy compound **12a** (0.342 g, 40%) and ketol acetate **12b** (0.368 g, 40%) were obtained.

12a: IR (thin film) 1735 cm^{-1}; NMR ($CDCl_3$) δ 0.93 (d, 3 H), 1.33 (d, 6 H), 1.43–1.83 (m, 7 H), 2.06 (s, 3 H), 2.66–2.83 (t, 1 H), 4.0–4.3 (t, 2 H); MS, *m/e* 194 (M$^+$). Anal. Calcd for $C_{12}H_{22}O_3$: C, 67.29; H, 10.28. Found: C, 67.38; H, 10.35.

12b: IR (thin film) 3450, 1735, 1710 cm^{-1}; NMR ($CDCl_3$) δ 0.9 (d, 3 H), 1.34 (s, 6 H), 1.43–1.83 (m, 5 H), 2.0 (s, 3 H), 2.40–2.56 (t, 2 H), 3.7 (br s, 1 H), 4.0–4.2 (t, 2 H); MS, *m/e* 231 (M + 1)$^+$. Anal. Calcd for $C_{12}H_{22}O_4$: C, 62.61; H, 9.56. Found: C, 62.82; H, 9.68.

Oxidation of 1,2-Dihydronaphthalene (13). When a mixture of $KMnO_4$ (4.0 g), $CuSO_4{\cdot}5H_2O$ (2.0 g), and water (200 μL) in dichloromethane (15 mL) was treated as above with compound **13** (0.260 g, 2 mmol) in dichloromethane (5 mL) and *tert*-butyl alcohol (1 mL), 2-hydroxy-1-tetralone (**14**, 0.178 g, 55%), mp 36–37 °C (lit.[21] mp 36–36.5 °C), was obtained after chromatography on silica gel; IR (thin film) 3460, 3060, 1680, 1600 cm^{-1}; NMR ($CDCl_3$) δ 1.76–2.73 (br m, 2 H), 3.06–3.26 (m, 2 H), 3.8 (br s, 1 H), 4.26–4.56 (dd, 1 H), 7.26–7.66 (m, 3 H), 8.0–8.23 (m, 1 H).

Oxidation of Cholesteryl Acetate (15). Cholesteryl acetate (**15**, 0.857 g, 2 mmol) was treated under similar conditions with $KMnO_4$ (4.0 g), $CuSO_4{\cdot}5H_2O$ (2.0 g), water (400 μL), and *tert*-butyl alcohol (1 mL) to give β-epoxy compound **16** (0.820 g, 92%), mp 110–112 °C (lit.[22] mp 111–112 °C).

Oxidation of *trans*-Stilbene (17). *trans*-Stilbene (**17**, 0.720 g, 4 mmol) was allowed to react with a mixture of $KMnO_4$ (4.0 g), $CuSO_4{\cdot}5H_2O$ (2.0 g), water (300 μL), and *tert*-butyl alcohol (1 mL), to give benzaldehyde (**18**, 0.780 g, 92%), found to be identical with an authentic sample.

Oxidation of 1-Decene (19). A mixture of $KMnO_4$ (4.0 g), $CuSO_4{\cdot}5H_2O$ (2.0 g), and water (300 μL) was treated under similar conditions with 1-decene (**19**, 0.560 g, 4 mmol) and *tert*-butyl alcohol (1 mL), to yield nonanoic acid (**20**, 0.455 g, 72%), found to be identical with an authentic sample.

Oxidation of 2-Octene (21). When compound **21** (0.448 g, 4 mmol) was treated as above with $KMnO_4$ (4.0 g), $CuSO_4{\cdot}5H_2O$ (2.0 g), water (300 μL), and *tert*-butyl alcohol (1.0 mL), hexanoic acid (**22**, 0.324 g, 78%) was obtained, found to be identical with an authentic sample.

Oxidation of Diphenylacetylene (23). Compound **23** (0.356 g, 2 mmol) was treated with a mixture of $KMnO_4$ (4.0 g), $CuSO_4{\cdot}5H_2O$ (2.0 g), water (300 μL), and *tert*-butyl alcohol (1 mL) under similar conditions of oxidation to afford benzil (**24**, 0.407 g, 97% mp 94–95 °C) as a yellow solid, found to be identical with an authentic sample.

Acknowledgment. We express our thanks to the Ministry of Defence, New Delhi, and C.S.I.R., New Delhi, for financial assistance.

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5-Isothiocyanatopupukeanane from a Sponge of the Genus *Axinyssa*

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Marine sponges of the order Halichondrida have provided an unprecedented array of sesquiterpene isonitriles, isothiocyanates, and formamides.[1] These metabolites are thought to inhibit feeding by omnivorous browsers, but they do not deter nudibranches that are specific predators on the sponges. In 1975, the Scheuer group[2] reported the isolation of 9-isocyanopupukeanane (**1**) from both the

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[1] For recent reviews, see: Faulkner, D. J. *Nat. Prod. Rep.* **1984**, *1*, 551; **1986**, *3*, 1; **1987**, *4*, 539. Edenborough, M. S.; Herbert, R. B. *Nat. Prod. Rep.* **1988**, *5*, 229.

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