

Figure 3. Rate of formation of benzyl cyanide from the reaction of benzyl chloride with 2.5 mol equiv of optimized KCN-F-alumina in (□) acetoneitrile, (○) toluene, and (Δ) petroleum ether (80-100) at ca. 80 °C. Recovered yields may be greater than observed here (see text).

general. The rate curves for reactions of several substituted benzyl chlorides are shown in Figure 4. Reaction rates were generally similar in reactions employing the optimized KCN-alumina and KCN-F-alumina although the products were sometimes rather more easy to recover from systems involving the latter reagent. This suggests that while the enhanced acidity of the partially fluorinated surface of F-alumina has little effect on the reactivity of the reagent, the reduction in surface hydroxyls may act to reduce product-support interactions.

Experimental Section

Infrared spectra were obtained on a Perkin-Elmer 683 ratio recording spectrophotometer interfaced to a 64K dedicated computer for spectral processing. Spectra were usually obtained from a disc made up of KBr and reagent in the ratio 20:1 by weight. Spectra were found to be independent of the type of window material. X-Ray photographs were obtained with a Debye-Scherrer Chamber 807 camera. Powdered samples were mounted on a glass filament using glue. Exposure times were typically about 6 h.

The silica and alumina supports were provided by BDH (see text). F-Alumina was prepared at the University of Leicester by treatment of the alumina with elemental fluorine at a final F_2 pressure of 400 mmHg. Solvents were routinely dried before use but all other chemicals were commercial materials used without further treatment. The supported reagents were prepared by thorough mixing of a solution of KCN in water (usually 1 M) with the required amount of the support followed by slow evaporation of the mixture on a rotary evaporator. Final drying of the resulting white solids is achieved at 100 °C and <1 mmHg for not less than 12 h. The final materials should be free flowing powders (at or near optimum loadings).

Reactions were carried out in ordinary glassware with use of a mechanical stirrer to ensure good agitation. The reactions were monitored by 1H NMR and products were known materials identified by NMR, IR, and mass spectrometry. In a typical reaction, benzyl chloride (3.2 g, 0.025 mol) was added to a mixture of the supported cyanide (75 g of the optimized KCN-alumina, for example, which is equivalent to 0.0625 mol of KCN) and the solvent (ca. 2× the weight with respect to the weight of the reagent,

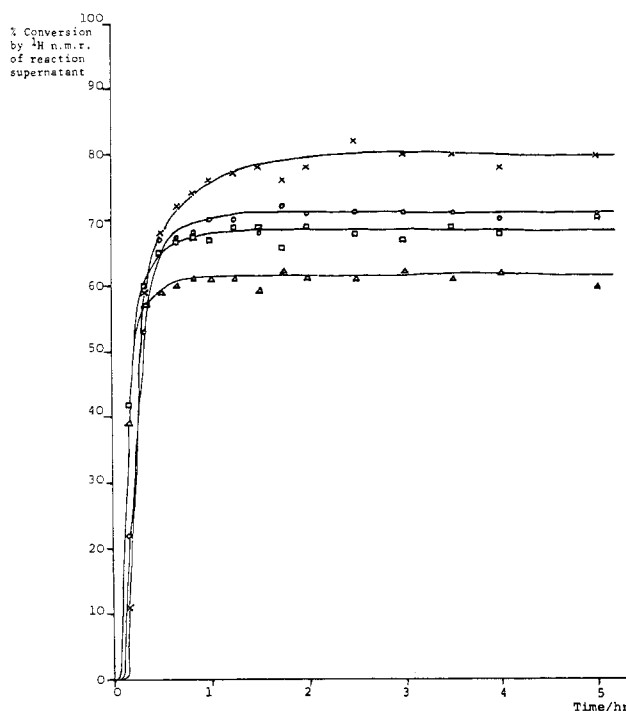


Figure 4. Rate of formation of benzyl cyanides from the reaction of the respective chlorides with 2.5 mol equiv of optimized KCN-F-alumina in refluxing toluene: (×) C_6H_5Cl , (○) o - $CH_3C_6H_4Cl$, (□) p - $CH_3C_6H_4Cl$; (Δ) p - t - BuC_6H_4Cl .

e.g., 150 g.). The resulting mixture was then brought to reflux with stirring, and the supernatant monitored by 1H NMR until no further increase in the amount of product was observed. The mixture was then filtered and the solid material washed with 150 cm^3 of diethyl ether. The combined solutions were evaporated to dryness, and the resulting product was analyzed. The purity of the products obtained in this way was better than 99% by NMR and typical recovered yields were better than 75% (higher yields could be obtained by more thorough washing of the solid residues).

Acknowledgment. We thank BDH Chemicals Ltd. for their generous support of this work. We are also grateful to M. S. Robertson for assistance with preliminary studies (carried out as part of an S.E.R.C.-supported research project on the properties and applications of supported reagents) and Dr. J. Holloway of the University of Leicester for carrying out the preparation of F-alumina.

Registry No. KCN, 151-50-8; alumina, 1344-28-1; fluorine, 7782-41-4; benzyl chloride, 100-44-7; benzyl cyanide, 140-29-4.

Selective Oxidation of Alcohols by Oxoammonium Salts ($R_2N=O^+X^-$)

Takeo Miyazawa, Takeshi Endo,* Shigeo Shiihashi, and Makoto Okawara

Research Laboratory of Resources Utilization,
Tokyo Institute of Technology, Nagatsuta, Midori-ku,
Yokohama 227, Japan

Received July 25, 1984

1-Oxo-2,2,6,6-tetramethylpiperidinium salt (I)^{1,2} is known as an oxidizing agent of alcohols to the corresponding carbonyl compounds.^{3,4} A kinetic study of this

(1) Golubev, V. A.; Zhdanov, R. I.; Rozantsev, E. G. *Izv. Akad. Nauk SSSR, Ser. Khim.* 1970, 184.

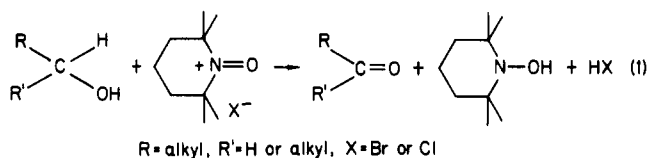
(2) Zhdanov, R. I.; Golubev, V. A.; Rozantsev, E. G. *Izv. Akad. Nauk SSSR, Ser. Khim.* 1970, 186.

Table I. Oxidation of Alcohols by Use of IV^a

alcohol	product	oxidant (equiv)	time	yield, ^b %
CH ₃ (CH ₂) ₅ OH	CH ₃ (CH ₂) ₄ CHO	IVa (1)	5 h	79
		IVa (1.5)	6 h	90
CH ₃ (CH ₂) ₃ CHCH ₃	CH ₃ (CH ₂) ₂ C(=O)CH ₃	IVb (1)	5 min	100
		IVa (1)	1.7 h	97
CH ₃ (CH ₂) ₂ CHCH ₂ CH ₃	CH ₃ (CH ₂) ₂ C(=O)CH ₂ CH ₃	IVa (1)	1.7 h	88
		IVb (1)	5 min	92
CH ₃ CH=CHCH ₂ OH	CH ₃ CH=CHCHO	IVa (1)	1 min	9
		IVb (1)	1 min	92
PhCH=CHCH ₂ OH	PhCH=CHCHO	IVa (1)	1 min	22 ^d
		IVb (1)	1 min	100
PhCH ₂ OH	PhCHO	IVa (1)	1 min	100
		IVb (1)	1 min	100
PhCHPh	PhC(=O)Ph	IVa (1)	1 h	97
PhCH(OH)C(=O)Ph	PhC(=O)C(=O)Ph	IVa (1)	17 h	13 ^c
		IVb (1)	17 h	45 ^c

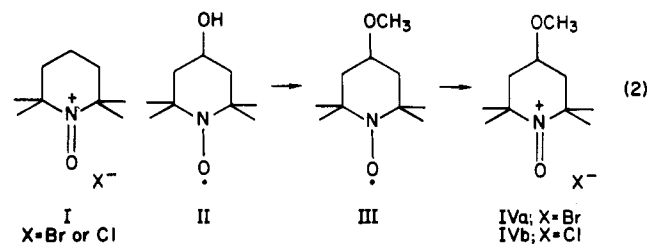
^a In CH₂Cl₂ at 25 °C. ^b GLC. ^c Isolated. ^d PhCHBrCHBrCH₂OH was obtained as a main product in 39% yield.

oxidation was reported by V. A. Golubev et al.⁵ Primary and secondary alcohols are oxidized to aldehydes and ketones with I, respectively, as shown in eq 1. Oxo-



aminium salt itself is reduced to a hydroxylamine in the oxidation of alcohols.^{3,4} The most recent report of selective oxidation of alcohols by M. F. Semmelhack⁶ involves this oxoaminium ion as a mediator for the electrolytic oxidation.

We now report the oxidative activity of oxoaminium salts and the selective oxidation of alcohols. As shown in eq 2 oxoaminium salt IV was synthesized from 4-



hydroxy-2,2,6,6-tetramethylpiperidinyl-1-oxy (II)⁷ in two steps. 4-Methoxy-2,2,6,6-tetramethylpiperidinyl-1-oxy (III), obtained by the reaction of II with methyl iodide, was oxidized by bromine or chlorine to afford 4-methoxy-1-oxo-2,2,6,6-tetramethylpiperidinium bromide (IVa) or 4-methoxy-1-oxo-2,2,6,6-tetramethylpiperidinium chloride (IVb), respectively. As shown in Table I, various alcohols were oxidized by IVa or IVb to the corresponding carbonyl compounds. In the oxidation of aliphatic alcohols by IVa, long reaction times were required but the oxidation by IVb proceeded smoothly to give the corresponding carbonyl

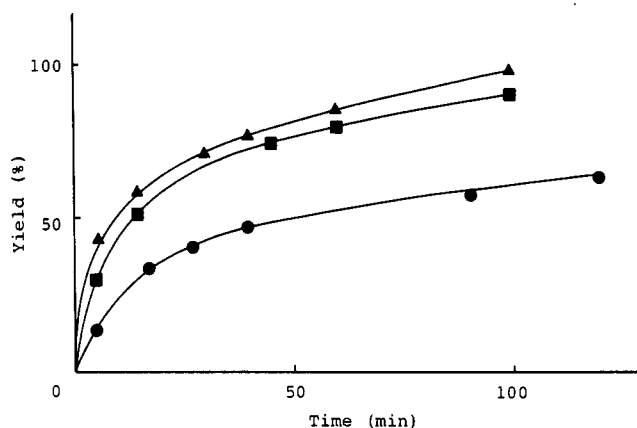


Figure 1. Oxidation of 1-hexanol, 2-hexanol, and 3-hexanol by use of IVa in CH₂Cl₂ at room temperature: (●) 2-hexanol; (▲) 1-hexanol; (■) 3-hexanol.

Table II. Relative Rate of Oxidation^a

alcohol	rel rate	alcohol	rel rate
methanol	1	benzyl alcohol	462
ethanol	21	3-hexanol	37
1-propanol	22	3-pentanol	52
1-hexanol	32	2-propanol	62

^a In CH₂Cl₂ at 30 °C. [alcohol]/[IVa] = 10, -d[IVa]/dt = k[IVa][alcohol].

compounds in quantitative yield. In addition, alcohols were not oxidized with bromine or chlorine under the same conditions.

In the oxidation of allylic alcohols with IVa, the halogenated alcohols were produced as main products, while starting alcohols still remained. The expected aldehydes were obtained in low yield. When IVb was used instead of IVa, allylic alcohols were oxidized rapidly in quantitative yield to α,β -unsaturated aldehydes. These differences in reactivity between IVa and IVb may be attributable to the nucleophilicity of the counter anion of this cationic oxidizing agent. Benzhydrol was also oxidized quantitatively to benzophenone, but benzoin had a low reactivity under these conditions.

The oxidation rates of primary and secondary alcohols with IVa were studied. 1-Hexanol, 2-hexanol, and 3-hexanol were each reacted with equimolar IVa, and the resulting aldehyde or ketone was detected by GLC (Figure

(3) Golubev, V. A.; Rozantsev, E. G.; Neiman, M. B. *Bull. Acad. Sci. USSR* 1965, 1898.

(4) Rozantsev, E. G.; Sholle, V. D. *Synthesis* 1971, 401.

(5) Golubev, V. A.; et al. *Izv. Akad. Nauk SSSR, Ser. Khim.* 1977, 2025.

(6) Semmelhack, M. F.; Chou, C. S.; Cortes, D. A. *J. Am. Chem. Soc.* 1983, 105, 4492.

(7) Kuroski, T.; Lee, K. W.; Okawara, M. *J. Polym. Sci., Polym. Chem. Ed.* 1972, 10, 3295.

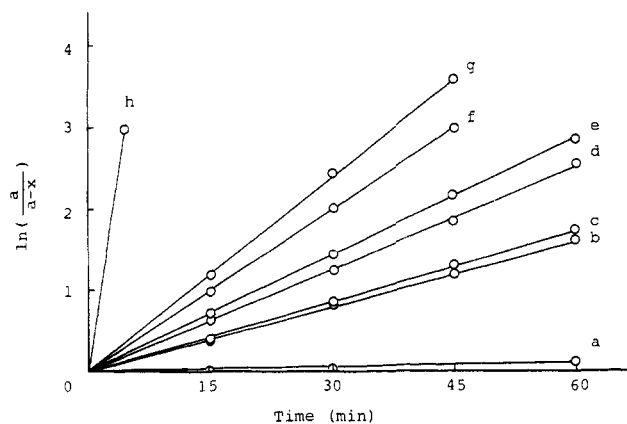


Figure 2. A plot of $\ln [a/(a-x)]$ for the reaction of IVa with alcohols ($[\text{alcohol}]/[\text{IVa}] = 10$): (a) methanol; (b) ethanol; (c) 1-propanol; (d) 1-hexanol; (e) 3-hexanol; (f) 3-pentanol; (g) 2-propanol; (h) benzyl alcohol.

1). In this oxidation, no other products were detected. As shown in Figure 1, the oxidation rates for secondary alcohols were faster than those of primary alcohols. Then, excesses of various alcohols were treated with IVa and the consumption of IVa was followed by iodometric titration. As shown in Figure 2, various alcohols were oxidized and the rates demonstrates pseudo-first-order kinetics (eq 3).

$$-d[\text{IVa}]/dt = k[\text{IVa}] \quad (3)$$

The relative rates of oxidation of alcohols, referenced to methanol, are shown in Table II. For primary alcohols, bulky alcohols are oxidized rapidly by IVa. Secondary alcohols are oxidized faster than primary alcohols by IVa.

On the other hand, primary alcohols are oxidized faster than secondary alcohols with IVb. Oxidations with IVb were so rapid that the rate of oxidation could not be measured by the same method as described above. Equimolar 1-hexanol and 3-hexanol were oxidized by IVb in one pot. Hexanal was obtained in a 1.7-times excess over 3-hexanone. When the oxidation was carried out by use of IVa in the same method, 3-hexanone was obtained in a 3.6-times excess over hexanal. This result shows that the relative rate of oxidation of primary and secondary alcohols is very dependent on the counter anion of the oxoammonium salt.

We investigated the selective oxidation of alcohols by use of an oxoammonium salt. This reaction proceeds cleanly under mild condition with a satisfactory yield of carbonyl compounds uncomplicated by the presence of side products.

Experimental Section

4-Methoxy-2,2,6,6-tetramethylpiperidyl-1-oxo (III). To a stirred solution of 17.2 g (100 mmol) of 4-hydroxy-2,2,6,6-tetramethylpiperidyl-1-oxo (II)⁷ in 150 mL of anhydrous DMF was added 3.6 g (150 mmol) of NaH. After this suspension was stirred under nitrogen, 9.34 mL (150 mmol) of methyl iodide, dissolved in 34 mL of DMF, was added dropwise to the solution at 0 °C. The reaction mixture stood at room temperature for 5 h. After filtration of NaI, 500 mL of ether was added. The resulting mixture was washed with water and separated, and the ether layer was dried with anhydrous magnesium sulfate. The ether solution was concentrated in vacuo to give a viscous red liquid. *n*-Hexane was added and the mixture was stored at -20 °C. A total of 16.5 g of red needle crystals of III were obtained: 89% yield, mp 35-36 °C; mass spectrum, m/e 186; IR (KBr) 2980, 2940, 2820, 1470, 1390, 1360, 1350, 1315, 1180, 1100 cm^{-1} . Anal. Calcd for $\text{C}_{10}\text{H}_{20}\text{NO}_2$: C, 64.48; H, 10.28; N, 7.52. Found: C, 64.11; H, 10.59; N, 7.64.

4-Methoxy-1-oxo-2,2,6,6-tetramethylpiperidinium Bromide (IVa). To a stirred solution of 3.37 g (18.1 mmol) of III in 100

mL of *n*-hexane was added dropwise 1.45 g (9.1 mmol) of bromine which was dissolved in 20 mL of CCl_4 at room temperature. The dark-red precipitate appeared from the red solution. The precipitate was filtered and washed with CCl_4 to give 4.04 g (84%) of IVa: mp 206-207 °C dec; IR (KBr) 2940, 1620, 1460, 1370, 1320, 1240, 1160, 1100 cm^{-1} . Anal. Calcd for $\text{C}_{10}\text{H}_{20}\text{NO}_2\text{Br}$: C, 45.12; H, 7.57; N, 5.26; Br, 30.02. Found: C, 45.11; H, 7.45; N, 5.29; Br, 29.59.

4-Methoxy-1-oxo-2,2,6,6-tetramethylpiperidinium Chloride (IVb). Anhydrous chlorine was bubbled into the stirred solution of 2.0 g (10.7 mmol) of III in 100 mL of CCl_4 . The orange precipitate appeared and it was filtered and washed with CCl_4 to give 2.1 g (9.5 mmol, 89%) of IVb: mp 121-123 °C dec; IR (KBr) 2951, 2897, 2827, 1616, 1466, 1446, 1388, 1377, 1219, 1161, 1106 cm^{-1} . Anal. Calcd for $\text{C}_{10}\text{H}_{20}\text{NO}_2\text{Cl}$: C, 54.17; H, 9.09; N, 6.32; Cl, 15.99. Found: C, 53.60; H, 9.22; N, 6.29; Cl, 16.88.

General Procedure for Oxidation of Alcohols by Use of IVa or IVb. To a solution of 15 mg (0.15 mmol) of 1-hexanol in 0.8 mL of anhydrous methylene chloride were added 40 mg (0.15 mmol) of IVa or 33 mg (0.15 mmol) of IVb. The reaction mixture was kept at room temperature until the oxoammonium salt (IVa or IVb) was no longer detectable. The product was determined by GLC and the yield was calculated. 2-Hexanol, 3-hexanol, crotyl alcohol, cinnamyl alcohol, benzyl alcohol, and benzhydryl were oxidized by the same method.

Oxidation of Benzoin by Use of IVa or IVb. To a solution of 49 mg (0.23 mmol) of benzoin in 1 mL of anhydrous methylene chloride were added 61 mg (0.23 mmol) of IVa or 52 mg (0.23 mmol) of IVb. After the dark-red color of oxoammonium salt disappeared, the reaction mixture was condensed in vacuo and the products were purified with silica gel column chromatography to give benzil: 6 mg (0.03 mmol, 13% by use of IVa), 22 mg (0.11 mmol, 45% by use of IVb). The physical and spectral data of the product agreed with those of an authentic sample of benzil.

Kinetic Method. The rate of consumption of the oxidizing agent (IVa) was followed by iodometric titration.¹

To a solution of 37.5 mmol of the alcohol in 50 mL of anhydrous methylene chloride was added 1.0 g (3.75 mmol) of IVa. The reaction mixture was kept at room temperature. After 15, 30, 45, and 60 min, 5 mL of the solution was sampled and poured into 25 mL of acetic acid contained 5 mL of a 20% aqueous solution of potassium iodide. The mixture was left for 15 min in the dark. After 100 mL of water was added to the solution, the produced iodine was titrated with 0.1 N sodium thiosulfate solution.

Registry No. II, 2226-96-2; III, 95407-69-5; IVa, 90246-27-8; IVb, 95407-70-8; $\text{CH}_3(\text{CH}_2)_5\text{OH}$, 111-27-3; $\text{CH}_3(\text{CH}_2)_3\text{CH}(\text{OH})\text{CH}_3$, 626-93-7; $\text{CH}_3(\text{CH}_2)_2\text{CH}(\text{OH})\text{CH}_2\text{CH}_3$, 623-37-0; $\text{CH}_3\text{CH}=\text{CHCH}_2\text{OH}$, 6117-91-5; $\text{PhCH}=\text{CHCH}_2\text{OH}$, 104-54-1; PhCH_2OH , 100-51-6; $\text{PhCH}(\text{OH})\text{Ph}$, 91-01-0; $\text{PhCH}(\text{OH})\text{C}(\text{O})\text{Ph}$, 119-53-9; $\text{CH}_3(\text{CH}_2)_4\text{CHO}$, 66-25-1; $\text{CH}_3(\text{CH}_2)_3\text{C}(\text{O})\text{CH}_3$, 591-78-6; $\text{CH}_3(\text{C}-\text{H}_2)_2\text{C}(\text{O})\text{CH}_2\text{CH}_3$, 589-38-8; $\text{CH}_3\text{CH}=\text{CHCHO}$, 4170-30-3; $\text{PhCH}=\text{CHCHO}$, 104-55-2; PhCHO , 100-52-7; $\text{PhC}(\text{O})\text{Ph}$, 119-61-9; $\text{PhC}(\text{O})\text{C}(\text{O})\text{Ph}$, 134-81-6; methanol, 67-56-1; ethanol, 64-17-5; 1-propanol, 71-23-8; 3-pentanol, 584-02-1; 2-propanol, 67-63-0.

Reaction of 2-Bromo-1,4-dimethoxybenzene with Various Nucleophiles via Aryne Reaction

Yu Xin Han, Misa V. Jovanovic, and Edward R. Biehl*

Department of Chemistry, Southern Methodist University, Dallas, Texas 75275

Received July 10, 1984

We have shown recently¹ that the reaction of 4-bromoveratrole (4-bromo-1,2-dimethoxybenzene, 1) with various primary and secondary aliphatic amines under aryne-

(1) Han, Y. X.; Biehl, E. R. *J. Org. Chem.* 1983, 48, 4397.