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of Reliable Methods  
for the Preparation  
of Organic Compounds

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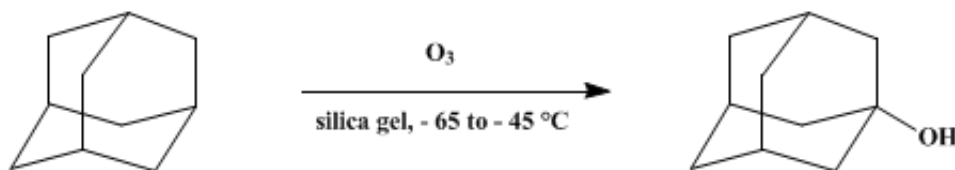
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*These paragraphs were added in September 2014. The statements above do not supersede any specific hazard caution notes and safety instructions included in the procedure.*

# TERTIARY ALCOHOLS FROM HYDROCARBONS BY OZONATION ON SILICA GEL: 1-ADAMANTANOL

[Tricyclo[3.3.1.1<sup>3,7</sup>]decan-1-ol]



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Checked by Frank E. Blaney and Robert M. Coates.

## 1. Procedure

*Caution! Ozone is extremely toxic and can react explosively with certain oxidizable substances. Ozone also reacts with some compounds to form explosive and shock-sensitive products. Ozone should only be handled by individuals trained in its proper and safe use and all operations should be carried out in a well-ventilated fume hood behind a protective safety shield.*

*Caution! Ozone is toxic and potentially explosive. This procedure should be carried out in an efficient hood and behind a suitable protective shield.*

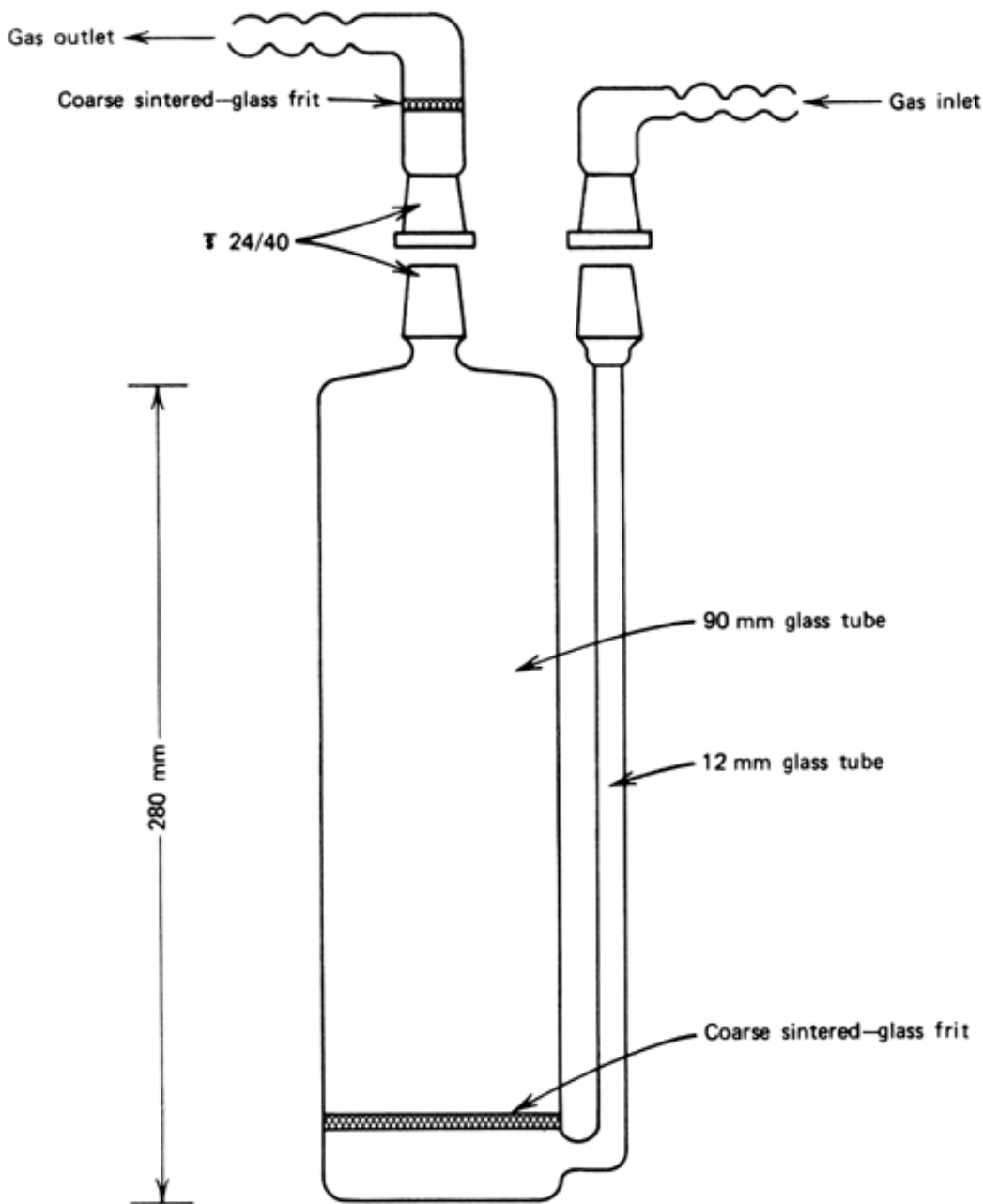
A solution of 6 g. (0.044 mole) of **adamantane** (Note 1) in 100 ml. of **pentane** and 500 g. of silica gel (Note 2) are placed in a 2-l., round-bottomed flask (Note 3). The **pentane** is removed by rotary evaporation at room temperature under reduced pressure (20 mm.), and the resulting dry silica gel is allowed to rotate for an additional 2 hours (Note 4). The adamantane–silica gel dispersion is poured through a powder funnel into the ozonation vessel (Note 5), which is then immersed in a 2-propanol–dry ice bath at  $-78^{\circ}$ . A flow of **oxygen** is passed through the vessel at a rate of 1 l. per minute for 2 hours, after which the internal temperature reaches  $-60$  to  $-65^{\circ}$  (Note 6). The ozone generator (Note 7) is turned on, and the **ozone–oxygen** mixture is passed through the vessel for *ca.* 2 hours, causing the silica gel to become dark blue (Note 8) and (Note 9). The cooling bath is removed, and the vessel is allowed to warm to room temperature in the hood over a 3-hour period. The silica gel is transferred to a chromatography column, and the organic material is eluted with 3 l. of **ethyl acetate**. Evaporation of the solvent affords 6.1–6.4 g. of crude **adamantanol** (Note 10), which is dissolved in 200 ml. of 1:1 (v/v) **dichloromethane–hexane** by heating on a steam bath. The solution is filtered, concentrated to incipient crystallization and placed in a freezer at  $-20^{\circ}$ . After a crop of fine, white needles (3.0–3.2 g.), m.p.  $280$ – $282^{\circ}$  (sealed capillary), is collected, the mother liquor is concentrated and cooled to separate two additional crops, which give 2.2–2.6 g. and have melting point ranges of  $270$ – $274^{\circ}$  to  $275$ – $280^{\circ}$  (sealed capillary) (Note 11). The total yield of **1-adamantanol** is 5.4–5.6 g. (81–84%) (Note 12).

## 2. Notes

1. **Adamantane** is available from Aldrich Chemical Company, Inc., and Fluka AG, Buchs, Switzerland.
2. Silica gel 60, with particle sizes ranging from 0.063 to 0.200 mm. (70–230 mesh), is suitable and may be purchased from Brinkmann Instruments, Inc., or E. Merck, Darmstadt, Germany. The submitters report that silica gel of this type normally contains *ca.* 5% water, which may be removed by drying at  $300^{\circ}$  for several hours, and that somewhat better yields are obtained when the silica gel is dried in this manner before use.

3. The submitters have found that the absorption of [adamantane](#) on silica gel may also be accomplished by mixing the dry solids in a closed flask for a few hours.
4. Heating should be avoided to prevent loss of some of the [adamantane](#) through sublimation.
5. The submitters have used both a tightly closed, 1-l. gas-washing bottle and the apparatus shown in [Figure 1](#) for ozonation vessels. They recommend that the glass joints not be greased. The apparatus used by the checkers consisted of a cylindrical, two-necked vessel having dimensions given in [Figure 1](#). One neck of the vessel was fitted with a Claisen distillation head and the other with a thermometer with its bulb positioned in the middle of the vessel. A bent gas-dispersion tube with an extra-coarse sintered-glass frit extending through the vertical branch of the Claisen head to within 2–3 mm. of the center of the bottom of the flask served as the gas inlet. The curved branch of the Claisen head was fitted with a drying tube and this functioned as the gas exit.

**Figure 1.**



6. The checkers found that the maintenance of a flow of [oxygen](#) during the cooling period prevented clogging of the glass frit and a building up of pressure in the gas-inlet tube in their apparatus.
7. A Welsbach T-816 Ozonator purchased from the Welsbach Corporation, Philadelphia, Pennsylvania, was used. The [oxygen](#) stream was dried by passage through dry silica gel and molecular sieves and introduced into the ozonator with the operating voltage set at 115 V., the gas pressure at 8 p.s.i.g., and the gas flow rate at 1 l. per minute. The resulting [ozone](#) flow rate was 0.00245 mole per minute, as

determined by titration of a potassium iodide trap. *Org. Synth., Coll. Vol. 5, 489 (1973)*]<sup>2</sup>.

8. In the apparatus used by the checkers, the internal temperature was between  $-45^{\circ}$  and  $-65^{\circ}$  while **ozone** was being passed through the silica gel. The use of lower bath temperatures results in the adsorption of a greater quantity of **ozone** on the silica gel; consequently, shorter reaction times and higher conversions were realized. *However, since ozone liquifies at  $-112^{\circ}$ , there is a serious danger of explosion.*

9. The **ozone** flow is stopped when the silica gel reaches a constant, dark blue color. The time required for saturating the silica gel with **ozone** depends on the type of silica gel used and on whether it has been dried (Note 2).

10. A GC analysis on the crude **adamantanol** was carried out by the checkers using a 1.8 m.  $\times$  3 mm. column packed with 5% silicone oil (SE-30) supported on Chromosorb W and the following column temperature program: hold at  $120^{\circ}$  for 6 minutes and then increase at *ca.*  $8^{\circ}$  per minute. The chromatogram of the product from one run showed a major peak at retention time of 10 minutes and three minor peaks with retention times of 11.2, 12, and 13.7 minutes and relative areas amounting to 1.5, 1.6, and 4% of the major peak, respectively. A GC analysis by the submitters with 5% **diethylene glycol succinate** supported on Chromosorb W as a stationary phase at  $110$ – $160^{\circ}$  showed peaks for **adamantan-1,3-diol** and **adamantanone**, as by-products totaling 7%, in addition to the peak for **1-adamantanol**.

11. A GC analysis by the checkers (see (Note 10)) on the material in the third crop from one run showed a major peak for **1-adamantanol** and a second minor peak having an area *ca.* 12% of that of the major peak. In another run the area of the peak from this by-product in the third crop was less than 2% relative to that of **1-adamantanol**.

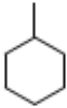
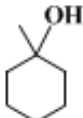
12. A yield of 5.8 g. (87%), m.p.  $280$ – $282^{\circ}$ , was obtained by the submitters. The IR,  $^1\text{H}$  NMR,  $^{13}\text{C}$  NMR, and mass spectra of the product were identical to those of an authentic sample of **1-adamantanol**. A mixed melting point with an authentic sample of **1-adamantanol** showed no depression.


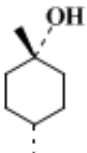

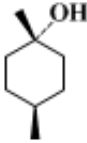
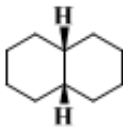
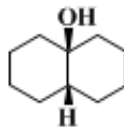
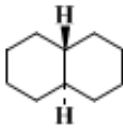
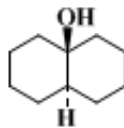
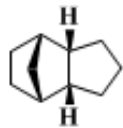
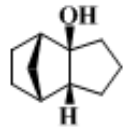
The spectral characteristics of the product are as follows: IR (KBr)  $\text{cm.}^{-1}$  3350(OH), 1455, 1352, 1302, 1118, 1088;  $^1\text{H}$  NMR ( $\text{CDCl}_3$ ),  $\delta$  (multiplicity, number of protons, assignment): 1.53 (s, 1H, OH), 1.55–1.80 (m, 12H, 6  $\text{CH}_2$ ), 2.17 (broad s, 3H, 3CH);  $^{13}\text{C}$  NMR ( $\text{CDCl}_3$ ),  $\delta$  (assignment): 30.7 (3CH), 36.1 (3CH), 36.1 (3 $\text{CH}_2$ ), 45.4 (3 $\text{CH}_2$ ), 68.2 (COH).

### 3. Discussion

This "dry ozonation" procedure is a general method for hydroxylation of tertiary carbon atoms in saturated compounds (Table I).<sup>3,4,5,6</sup> The substitution reaction occurs predominantly with retention of configuration. Thus, **cis-decalin** gives **cis-1-decalol**, whereas **cis-** and **trans-1,4-dimethylcyclohexane** afford **cis-** and **trans-1,4-dimethylcyclohexanol**, respectively. The amount of epimeric alcohol formed in these ozonation reactions is usually less than 1%. The tertiary alcohols may be further oxidized to diols by repeating the ozonation; however, the yields in these reactions are poorer. For instance, **1-adamantanol** is oxidized to **1,3-adamantanediol** in 43% yield. Secondary alcohols are converted to the corresponding ketone. This method has been employed for the hydroxylation of tertiary positions in saturated acetates and bromides.

TABLE I  
PREPARATION OF TERTIARY ALCOHOLS FROM HYDROCARBONS WITH OZONE ON SILICA GEL

Hydrocarbon	Tertiary Alcohol	Conversion (%)	Yield (%) <sup>a</sup>
		>99.5	65 <sup>b</sup>

		72	79 <sup>c</sup>
		92	76 <sup>d</sup>
		>99.5	99
		88	72 <sup>e</sup>
		>99.5	90

*a* Based on the amount of hydrocarbon consumed, as determined by GC.

*b* A mixture of the three methyl cyclohexanones was also formed to the extent of 34%.

*c* The epimeric alcohol was also present to the extent of 0.6%.

*d* The epimeric alcohol was also present to the extent of 3.5%.

*e* *trans*-1-Decalone (10%) and *trans*-2-decalone (16%) were also formed.

Dry ozonation may be carried out according to the following alternative procedure: The ozone–oxygen mixture is passed through the silica gel at  $-45^{\circ}\text{C}$  followed by removal of the excess ozone at the same temperature ( $-45^{\circ}\text{C}$ ) by passing an inert gas (nitrogen or argon) through the sample.

1-Adamantanol has been prepared by oxidation of adamantane with peroxyacetic acetic<sup>7</sup> and by hydrolysis of 1-bromoadamantane with silver nitrate<sup>8</sup> or hydrochloric acid.<sup>9</sup>

## References and Notes

1. Department of Organic Chemistry, Weizmann Institute of Science, Rehovot, Israel.
2. P. S. Bailey, *Chem. Rev.*, **58**, 986 (1958).
3. Z. Cohen, E. Keinan, Y. Mazur, and T. H. Varkony, *J. Org. Chem.*, **40**, 2141 (1975);
4. Z. Cohen, E. Keinan, Y. Mazur, and A. Ulman, *J. Org. Chem.*, **41**, 2651 (1976);
5. E. Keinan and Y. Mazur, *Synthesis*, 523 (1976);
6. E. Keinan and T. H. Varkony, "Ozonization of Single Bonds," in S. Patai, Ed., "The Chemistry of Peroxides," Wiley-Interscience, New York, in press.
7. P. von R. Schleyer and R. D. Nicholas, *J. Am. Chem. Soc.*, **83**, 182 (1961).
8. H. Stetter, M. Schwarz, and A. Hirschhorn, *Chem. Ber.*, **92**, 1629 (1959).
9. H. W. Geluk and J. L. M. A. Schlatmann, *Tetrahedron*, **24**, 5361 (1968).

**Appendix**  
**Chemical Abstracts Nomenclature (Collective Index Number);**  
**(Registry Number)**

silica gel

hydrochloric acid (7647-01-0)

ethyl acetate (141-78-6)

silver nitrate (7761-88-8)

oxygen (7782-44-7)

nitrogen (7727-37-9)

methyl (2229-07-4)

Pentane (109-66-0)

dichloromethane (75-09-2)

ozone (10028-15-6)

hexane (110-54-3)

argon (7440-37-1)

Adamantane (281-23-2)

1-Adamantanol,  
adamantanol,

Tricyclo[3.3.1.1<sup>3,7</sup>]decan-1-ol (768-95-6)

1-bromoadamantane (768-90-1)

diethylene glycol succinate

Adamantanone (700-58-3)

adamantan-1,3-diol,  
1,3-adamantanediol

cis-decalin

cis-1-decalol

e trans-1-Decalone (21370-71-8)

trans-2-decalone

cis- and trans-1,4-dimethylcyclohexane

cis- and trans-1,4-dimethylcyclohexanol