Cleavage of Oximes, Semicarbazones, and Phenylhydrazones with Supported Potassium Permanganate

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Abstract: Potassium permanganate supported on manganese(II) sulfate or activated manganese dioxide can be used effectively for the oxidative cleavage of oximes and semicarbazones under solvent-free conditions and for the cleavage of phenylhydrazones in dichloromethane. The residue that remains after extraction of the organic products, primarily manganese oxides, can be recycled, making the process, in theory, infinitely sustainable.

Key words: oximes, semicarbazones, phenylhydrazones, potassium permanganate

Imine derivatives of carbonyl compounds, such as oximes, semicarbazones, and phenylhydrazones, which are used extensively for the purification and characterization of carbonyl compounds, may be prepared as illustrated in Scheme 1.



Scheme 1

Because of their hydrolytic stability, oximes are also used as carbonyl protectors^{1,2} from which the parent carbonyl compounds must be regenerated at the completion of a synthetic procedure. Regeneration of the carbonyl compound requires the use of mild reagents and reaction conditions that will cleave the C=N bond without modification to the rest of the molecule.

Furthermore, since oximes can also be prepared from noncarbonyl compounds, the generation of carbonyl compounds from them provides an alternative method for the preparation of aldehydes and ketones.^{3–6}

Over the last two decades, the use of solid supports in synthetic chemistry has become popular and in recent years the use of supported reagents under solvent-free conditions has opened up new and surprisingly useful approaches to chemistry.⁷ Among oxidants, supported potassium permanganate has proven to be a reagent whose reactions are easily adapted to solvent-free conditions.⁸

Recently, several reports of the oxidative cleavage of oximes, semicarbazones, or phenylhydrazones with potassium permanganate supported on alumina,9 silica gel,10 zeolites,¹¹ and montmorillonite K10 have appeared.¹² However, in spite of the high potential utility of potassium permanganate adsorbed to these solid supports, the reactions are not completely optimized because the coproduct of the oxidation, manganese dioxide, cannot be easily separated from these solid supports when the reaction has been completed. The reaction residue must, therefore, be consigned to a landfill site. This prevents the recycling of the manganese dioxide, as shown in Scheme 2, and diminishes the possibility of developing a sustainable process. Therefore, the discovery of new conditions for the oxidation of organic compounds with potassium permanganate that result in the deposition of manganese dioxide in a recyclable form is a prime objective of our laboratories.¹³

$$MnO_2 \xrightarrow[KOH]{O_2} K_2MnO_4 \xrightarrow[e^-]{e^-} KMnO_4$$



In previous papers^{14,15} we have shown that a recyclable byproduct can be obtained if activated manganese dioxide is used as a solid support for potassium permanganate. In this paper, we wish to report additional progress on this procedure. The results are of potential importance from an environmental perspective because the production of recyclable byproducts is an essential requirement for a sustainable process.

Herein, we describe procedures for the cleavage of oximes and semicarbazones with supported potassium permanganate under solvent-free conditions, and the cleavage of phenylhydrazones in dichloromethane solutions. When either manganese(II) sulfate or activated manganese dioxide is used as a support to the oxidant (Scheme 3), the organic products are obtained in good yields and the inorganic products are recyclable.

The results obtained from five variations of an optimized procedure have been summarized in Table 1.

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Scheme 3

The yields from the reaction using finely powdered, but unsupported, potassium permanganate are compared with those obtained when activated manganese dioxide or manganese(II) sulfate are added to the potassium permanganate (in each case, 1.00 g of either MgSO₄·H₂O or MnO₂ was added to 1.00 g of KMnO₄). Experimentation also revealed that addition of a small amount of water to the oxidant often improved yields and shortened reaction times, as indicated by the data in Table 1.

From consideration of these results (Table 1) and those previously reported,¹⁰ it is apparent that finely powdered potassium permanganate is not a satisfactory general purpose oxidant for use under solvent-free conditions or in dichloromethane. However, addition of either activated manganese dioxide or manganese(II) sulfate markedly increases the yields, especially if some moisture is present. Although the difference is marginal for some reactions, generally, the use of activated manganese dioxide gives better yields.

It was necessary to carry out the oxidative cleavage of phenylhydrazones in dichloromethane because the reactions under solvent-free conditions were so vigorous that they often burst into flame.

It has been known for many years that manganese(II) ions act as catalysts for the oxidation of certain organic compounds with potassium permanganate in aqueous solutions.^{16,17} Therefore, it is not surprising to observe that addition of manganese(II) ions aids the oxidation of the organic compounds described here. At this time, any suggestion of the role manganese(II) plays would be highly speculative; however, it is possible that the initial interaction between potassium permanganate and manganese(II) would be an electron transfer that results in the formation of manganese(III) ions, which could act as a catalyst for these reactions.¹⁸

It is also known that manganese dioxide supported on silica gel can be used to cleave oximes.¹⁹ Hence, it is not surprising that activated manganese dioxide is a good solid support for solvent-free potassium permanganate oxidations.

Potassium permanganate supported on manganese(II) sulfate or activated manganese dioxide can be used effectively for the oxidative cleavage of oximes and semicarbazones under solvent-free conditions and for the cleavage of phenylhydrazones in dichloromethane. Addition of a small amount of water usually results in higher yields and shorter reaction times. Removal of the organic products by extraction leaves a residue that consists primarily of manganese oxides containing small amounts of potassium permanganate. Since industrial processes for recycling and reoxidizing manganese dioxide to permanganate are well established, the reactions are, in theory, infinitely sustainable.¹³ The reactions, therefore, represent progress in the search for methods that can be applied to make chemistry more environmentally friendly.

Oxidation of Oximes and Semicarbazones; General Procedure

The five oxidants were prepared and used under identical conditions. The first oxidant was prepared by grinding KMnO₄ (1.00 g), using a pestle and mortar, until a fine powder was obtained. A second oxidant was prepared in exactly the same way with the exception that MnSO₄·H₂O (1.00 g) was added to the KMnO₄ (1.00 g). For the third oxidant, activated MnO₂ (1.00 g) was added to finely ground KMnO₄ (1.00 g). The fourth and fifth oxidants were prepared in the same way as the second and third oxidants, but with the addition of a small amount of H₂O (0.3 mg).

These oxidants were placed in five separate round-bottom flasks and to each flask was added the oxime or semicarbazone (1.0 mmol). The reactants were stirred continuously at r.t. using a magnetically controlled stirring bar; TLC was used to monitor the progress of the reactions until the oxime or semicarbazone had completely reacted or until a reasonable amount of time had elapsed. Then, CH₂Cl₂ (15 mL) was added to each flask and the mixtures were filtered through a sintered glass funnel. The residues were washed with additional CH₂Cl₂ (2 × 10 mL) and the solvent collected from each reaction was combined and evaporated on a flash evaporator. The yields were determined by GC analysis or by weight after preparation of 2,4-dinitrophenylhydrazone derivatives. All products are known compounds and were characterized from their well-defined ¹H NMR spectra.

Oxidation of Phenylhydrazones; General Procedure

The oxidations were completed similarly to those described above using the first three oxidants, except that CH_2Cl_2 (15 mL) was added to the oxidant before using it in the reaction with the phenylhydrazone.

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Table 1	Oxidative Cleavage of Oximes,	Semicarbazones and Phenylhy	drazones to the Correspondin	g Aldehydes and Ketones
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	Yield (%) (Time)				
Substrate	KMnO ₄ (unsupported)	KMnO ₄ /MnSO ₄ ·H ₂ O	$KMnO_4/MnSO_4 \cdot H_2O$ (moisture added)	KMnO ₄ /MnO ₂	KMnO ₄ /MnO ₂ (moisture added)
Benzaldehyde oxime	45 (90 min)	72 (75 min)	79 (45 min)	73 (50 min)	84 (40 min)
<i>p</i> -Methylbenzaldehyde oxime	41 (90 min)	71 (70 min)	80 (44 min)	80 (35 min)	84 (30 min)
<i>p</i> -Methoxybenzaldehyde oxime	46 (90 min)	65 (65 min)	70 (40 min)	79 (35 min)	85 (30 min)
<i>p</i> -Nitrobenzaldehyde oxime	41 (110 min)	49 (100 min)	55 (75 min)	73 (55 min)	82 (45 min)
Acetophenone oxime	49 (120 min)	75 (90 min)	78 (50 min)	78 (45 min)	81 (30 min)
Ethyl phenyl ketone oxime	48 (90 min)	71 (85 min)	78 (50 min)	79 (45 min)	82 (30 min)
<i>p</i> -Methylacetophenone oxime	45 (150 min)	73 (100 min)	80 (75 min)	85 (55 min)	94 (45 min)
<i>p</i> -Chloroacetophenone oxime	43 (180 min)	70 (120 min)	82 (90 min)	75 (75 min)	80 (60 min)
<i>p</i> -Bromoacetophenone oxime	44 (180 min)	83 (110 min)	90 (90 min)	85 (90 min)	90 (75 min)
<i>p</i> -Nitroacetophenone oxime	12 (360 min)	81 (150 min)	85 (90 min)	84 (75 min)	93 (60 min)
Acetophenone semicarbazone	<5 (50 min)		77 (50 min)		73 (50 min)
<i>p</i> -Methylacetophenone semicarbazone	10 (270 min)		68 (35 min)		77 (60 min)
<i>p</i> -Chloroacetophenone semicarbazone	25 (210 min)		76 (120 min)	88 (210 min)	
Acetophenone phenylhydrazone	50 (9 h)	65 (9 h)		70 (9 h)	
<i>p</i> -Methylacetophenone phenylhydrazone	35 (8 h)	62 (8 h)		68 (8 h)	
<i>p</i> -Chloroacetophenone phenylhydrazone	35 (10 h)	76 (10 h)		72 (10 h)	
<i>p</i> -Bromoacetophenone phenylhydrazone	43 (10 h)	58 (10 h)		68 (10 h)	
Benzophenone phenylhydrazone	40 (10 h)	68 (10 h)		58 (10 h)	

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