

# Synthesis of *gem*-dihydroperoxides from ketones using silica-supported sodium hydrogen sulfate as a heterogeneous catalyst<sup>☆</sup>

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## Abstract

NaHSO<sub>4</sub>·SiO<sub>2</sub> was found to be an efficient catalyst for the synthesis of *gem*-dihydroperoxides from ketones and aqueous (50%) H<sub>2</sub>O<sub>2</sub> under mild and heterogeneous conditions at room temperature within a short period of time. The method presented here has the advantages of environmental benignancy, good to excellent yields and simple operational procedure.

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**Keywords:** NaHSO<sub>4</sub>·SiO<sub>2</sub>; Ketones; *gem*-Dihydroperoxides; Heterogeneous catalyst

## 1. Introduction

*gem*-Dihydroperoxides are useful intermediates in the synthesis of trioxanes [1], tetraoxanes [2], endoperoxides [3] and their acyclic analogues with a variety of functional groups [4]. Organic peroxides are also important radical initiators and oxidants [5,6]. Generally, *gem*-dihydroperoxides are synthesized by ozonolysis of ketone enol ether or  $\alpha$ -olefins in the presence of H<sub>2</sub>O<sub>2</sub> [7]. In other reported methods preparation of dihydroperoxides from ketones or ketals and H<sub>2</sub>O<sub>2</sub> has been achieved using tungstic acid [8], BF<sub>3</sub>·Et<sub>2</sub>O [9], HCl [10], methyltrioxorhenium (MeReO<sub>3</sub>) in trifluoro ethanol [11], I<sub>2</sub> [12] and CAN [13]. However, these methods are associated with different drawbacks such as longer reaction time, requirement of expensive starting materials, use of concentrated H<sub>2</sub>O<sub>2</sub> and excess acid, non-reusability of the catalyst and lower yields.

To the best of our knowledge, there is no report for synthesis of *gem*-dihydroperoxides using heterogeneous catalysts. We have studied this synthesis using various heterogeneous catalysts and have found that NaHSO<sub>4</sub>·SiO<sub>2</sub> is most effective for this synthesis.

## 2. Experimental

Silica-supported sodium hydrogen sulfate was prepared by reported method [14]. All ketones and aldehydes were purchased from Aldrich. ACME silica gel (60–120 mesh) was used for column chromatography and thin-layer chromatography was performed on Merck-precoated silica gel 60-F254 plates. All other solvents and chemicals were obtained from commercial sources and purified following standard methods.

### 2.1. General procedure for the synthesis of *gem*-dihydroperoxides

A mixture of ketone (1 mmol), 50% aqueous H<sub>2</sub>O<sub>2</sub> (1 ml) and NaHSO<sub>4</sub>·SiO<sub>2</sub> (100 mg) in MeCN (4 ml) was stirred at room temperature. After completion of the reaction, as indicated by TLC, the reaction mixture was filtered. The catalyst was recovered from the residue. The filtrate was diluted with water and extracted with EtOAc (3 × 5 ml). The combined organic extract was dried (Na<sub>2</sub>SO<sub>4</sub>) and concentrated in vacuo. The residue, on purification by column chromatography (silica gel, hexane-EtOAc) afforded pure *gem*-dihydroperoxide.

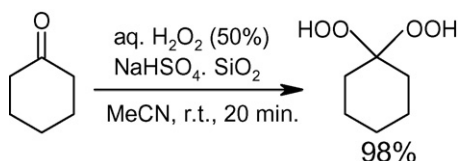
The spectral (<sup>1</sup>H NMR and MS) and analytical data of unknown *gem*-dihydroperoxides are given below.

Product 2a: <sup>1</sup>H NMR (CDCl<sub>3</sub>, 200 MHz): ( 9.42 (2H, brs), 1.82–1.67 (2H, m), 1.48–1.25 (7H, m), 0.92 (3H, t, *J* = 7.5 Hz),

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Scheme 1. Reaction of cyclohexanone with 50% aqueous  $\text{H}_2\text{O}_2$  in  $\text{CH}_3\text{CN}$  using silica-supported sodium hydrogen sulfate.

FABMS:  $m/z$  173  $[\text{M}+\text{Na}]^+$ ; Anal. Calcd. for  $\text{C}_6\text{H}_{14}\text{O}_4$ : C, 48.00; H, 9.33%. Found: C, 48.18; H, 9.42%.

Product **2g**:  $^1\text{H}$  NMR ( $\text{CDCl}_3$ , 200 MHz): ( 9.72 (2H, brs), 1.95–1.71 (4H, m), 1.68–1.41 (6H, m). FABMS:  $m/z$  171  $[\text{M}+\text{Na}]^+$ ; Anal. Calcd. for  $\text{C}_6\text{H}_{12}\text{O}_4$ : C, 48.64; H, 8.11%. Found: C, 48.58; H, 8.24%.

Product **2h**:  $^1\text{H}$  NMR ( $\text{CDCl}_3$ , 200 MHz): ( 8.85 (2H, brs), 4.23 (1H, dd  $J = 7.5, 2.4$  Hz), 2.23–1.39 (8H, m); FABMS:  $m/z$  205, 207  $[\text{M}+\text{Na}]^+$ ; Anal. Calcd. for  $\text{C}_6\text{H}_{11}\text{O}_4\text{Cl}$ : C, 39.34; H, 6.01%. Found: C, 39.48; H, 6.14%.

### 3. Results and discussion

In continuation of our work [15,16] on the application of heterogeneous catalyst for the development of useful synthetic methodologies we have synthesized *gem*-dihydroperoxides from ketones and aqueous  $\text{H}_2\text{O}_2$  (50%) using  $\text{NaHSO}_4\cdot\text{SiO}_2$  (Scheme 1) as a heterogeneous catalyst.

Initially cyclohexanone and acetophenone were separately treated with 50% aqueous  $\text{H}_2\text{O}_2$  in acetonitrile at room temperature in the presence of various heterogeneous catalysts (Tables 1 and 2). Considering the reaction times and yields of the corresponding *gem*-dihydroperoxides, in

Table 1

Reaction of cyclohexanone with 50% aqueous  $\text{H}_2\text{O}_2$  in  $\text{CH}_3\text{CN}$  using various heterogeneous catalysts<sup>a</sup>

Entry	Catalyst	Time (min)	Isolated yield (%)
1	$\text{NaHSO}_4\cdot\text{SiO}_2$	20	98
2	Sulfonic acid functionalized silica	60	68
3	Amberlyst-15	60	62
4	$\text{PMA}\cdot\text{SiO}_2$	60	60
5	Montmorillonite clay	60	25
6	$\text{KF}\cdot\text{Al}_2\text{O}_3$	60	Trace

<sup>a</sup> Cyclohexanone (1 mmol), 50% aq.  $\text{H}_2\text{O}_2$  (1 ml) and  $\text{CH}_3\text{CN}$  (4 ml) were used in the presence of a heterogeneous catalyst (100 mg) at RT.

Table 2

Reaction of acetophenone with 50% aqueous  $\text{H}_2\text{O}_2$  in  $\text{CH}_3\text{CN}$  using various heterogeneous catalysts<sup>a</sup>

Entry	Catalyst	Time (h)	Isolated yield (%)
1	$\text{NaHSO}_4\cdot\text{SiO}_2$	4	80
2	Sulfonic acid functionalized silica	4	40
3	Amberlyst-15	4	0
4	$\text{PMA}\cdot\text{SiO}_2$	4	25
5	Montmorillonite clay	4	0
6	$\text{KF}\cdot\text{Al}_2\text{O}_3$	4	0

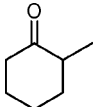
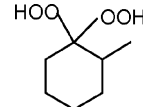
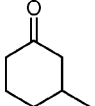
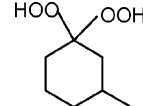
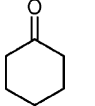
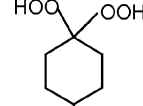
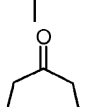
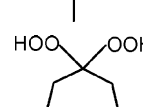
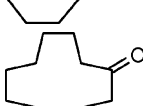
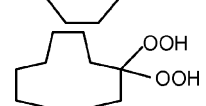
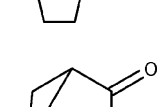
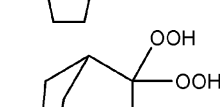

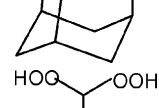
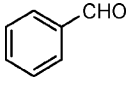
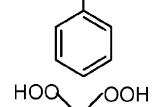
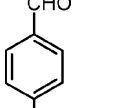
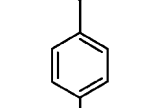
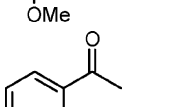
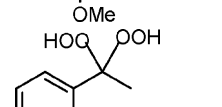
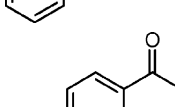
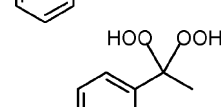
<sup>a</sup> Acetophenone (1 mmol), 50% aq.  $\text{H}_2\text{O}_2$  (1 ml) and  $\text{CH}_3\text{CN}$  (4 ml) were used in the presence of a heterogeneous catalyst (100 mg) at RT.

both the cases  $\text{NaHSO}_4\cdot\text{SiO}_2$  was found to be the most active catalyst. The other catalysts such as sulfonic acid functionalized silica, amberlyst-15 and silica supported phosphomolybdic acid ( $\text{PMA}\cdot\text{SiO}_2$ ) gave moderate yields for preparation of cyclohexane-1,1-diyl dihydroperoxide. Montmorillonite caly and  $\text{KF}\cdot\text{Al}_2\text{O}_3$  was found to be completely

Table 3  
Synthesis of dihydroperoxides using  $\text{NaHSO}_4\cdot\text{SiO}_2$ <sup>a</sup>

Entry	Ketone or Aldehyde 1	Product 2	Time (min)	Yield (%) <sup>b</sup>
a			30	96
b			30	92
c			40	90
d			30	92
e			30	94
f			40	90
g			20	98
h			60	40 <sup>c</sup>

Table 3 (Continued)

Entry	Ketone or Aldehyde 1	Product 2	Time (min)	Yield (%) <sup>b</sup>
i			45	92
j			40	96
k			30	98
l			60	92
m			60	97
n			40	95
o			120	68
p			120	72
q			240	80
r			240	84
s			16 <sup>d</sup>	60

<sup>a</sup> The structures of the products were established from their spectral (<sup>1</sup>H NMR and MS) and analytical data.

<sup>b</sup> Isolated yield.

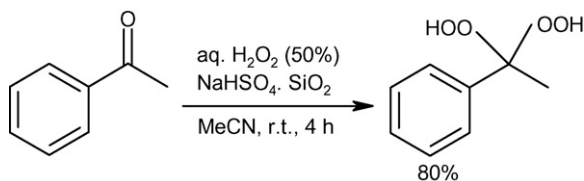
<sup>c</sup> The crude <sup>1</sup>H NMR spectrum of the reaction mixture showed the formation of the product in a yield of 75%, however, it decomposed during isolation.

<sup>d</sup> Reaction time in hour.

unsuitable for the preparation of 1-phenylethane-1,1-diyl dihydroperoxide.

A series of ketones were directly converted into the corresponding *gem*-dihydroperoxides (Table 3). Both cyclic and

acyclic aliphatic ketones furnished the products in excellent yields. Aromatic ketones having electron-donating groups afforded the corresponding dihydroperoxides in good yields while those compounds having electron-withdrawing groups



Scheme 2. Reaction of acetophenone with 50% aqueous H<sub>2</sub>O<sub>2</sub> in CH<sub>3</sub>CN using silica-supported sodium hydrogen sulfate.

furnished the corresponding products in relatively less yield (Scheme 2).

Silica-supported sodium hydrogen sulfate acts as a catalyst by enhancing the electrophilic character of carbonyl C-atom and the nucleophilic character of hydrogen peroxide. The catalyst can be prepared conveniently with readily available inexpensive reagents [14] and is heterogeneous and non-hazardous. It can easily be removed from the reaction mixture by simple filtration. In recent years, heterogeneous catalysts have gained much importance in laboratories and industries. They exhibit high catalytic activities and allow for cleaner processing compared to conventional liquid catalysts. The supported catalysts are also more active than typical solid acids. Here silica-supported sodium hydrogen sulfate has been utilized properly to explore its catalytic activity.

#### 4. Conclusion

In summary, we have developed an efficient method for the synthesis of *gem*-dihydroperoxides from ketones and aqueous (50%) H<sub>2</sub>O<sub>2</sub> using NaHSO<sub>4</sub>·SiO<sub>2</sub> as a catalyst. The major advantages of this protocol include mild reaction conditions,

easy workup procedure, short reaction times, excellent yields and application of an inexpensive heterogeneous catalyst.

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