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# NaBr/98% H<sub>2</sub>SO<sub>4</sub>: An Efficient Reagent for the Regioselective Monobromination of Least Reactive Alkanes and Cycloalkanes

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## Abstract

An efficient, simple and regioselective monobromination of least reactive acyclic and cyclic alkanes by sodium bromide/ 98% H<sub>2</sub>SO<sub>4</sub> is reported. The yields are high and the reactions go to completion within 15–35 min. at 40–65 °C.

**Keywords:** Monobromination, Acyclic and Cyclic Alkanes, Sodium bromide, 98% H<sub>2</sub>SO<sub>4</sub>

## 1. Introduction

Bromination of organic compounds and the chemistry of organic halides are of great interest to chemists due to the theoretical and practical value of halogenation reactions and the halogenation products. Efficient functionalization of alkanes leading to the production of useful organic chemicals in an industrial scale is of considerable interest for the chemical and pharmaceutical industries and it has gained acceptance and popularity among the synthetic chemist community recently. The conversion of unactivated carbon-hydrogen bonds into carbon-halogen bonds generally could be accomplished by the use of reagents like Br<sub>2</sub>/HgO [1], Br<sub>2</sub>/MnO<sub>2</sub> [2], Br<sub>2</sub>/H<sub>2</sub>O [3], NBS/DMF [4], Br<sub>2</sub>/Al<sub>2</sub>O<sub>3</sub> [5], BrCCl<sub>3</sub> [6], Polyhalomethane ·AlBr<sub>3</sub> [7], CH<sub>2</sub>Br<sub>2</sub>/(SbF<sub>5</sub>)<sub>2</sub> [8], CuBr<sub>2</sub>

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[9a-9c],  $\text{Ar}_2\text{C}=\text{NBr}$  [10], by  $\text{GoAgg}^{\text{IV}}$  Chemistry [Fe (III) Species, tert-butyl hydroperoxide in a mixture of pyridine and acetic acid] [11] and free-radical halogenation of alkanes initiated by transition metal complexes [12]. Most of these reagents are complex with potential environmental problems due to the generation of hazardous waste and handling of molecular  $\text{Br}_2$  is generally found to be difficult. However, each example has its own specific set of conditions; hence the reagents have their own advantages and limitations. Therefore, there is a need for the development of alternative methods for the bromination of least reactive acyclic and cycloalkanes using simple reagents.

We in our work suggest that, the combination of NaBr and 98%  $\text{H}_2\text{SO}_4$  could allow the bromination of deactivated alkanes and cyclic hydrocarbons. This combination indeed acts as a very effective reagent for bromination of the saturated hydrocarbons by easy to handle, economically viable NaBr and 98%  $\text{H}_2\text{SO}_4$ . This method gives the products in good yields within short reaction duration.

## 2. Experimental

Cyclopentane was prepared from cyclopentanone by Clemmensen reduction. All the solvents used and other alkanes were commercially available and distilled before use. Reactions were monitored on TLC and by GC with reference samples. Yields refer to the isolated yields of the products after purification by column chromatography (light petrol). IR,  $^1\text{H}$  NMR and GC-MS spectra were recorded on Nicolet 400D FT-IR Spectrophotometer, 300 MHz Bruker Spectrometer and SHIMADZU GC-MS QP 5050A instrument equipped with a 30 m long and 0.32 mm dia BP-5 column with the column temperature programme 80–15–250°C respectively.

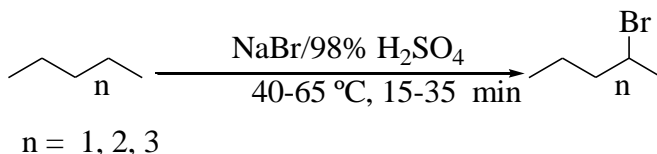
### 2.1 General procedure for the bromination of *n*-hexane

In a typical experiment, NaBr (1.03 g, 10 mmol) and 98%  $\text{H}_2\text{SO}_4$  (1.96 g, 20 mmol) were treated with *n*-hexane (1.72 g, 20 mmol) and the contents were heated with constant stirring in an oil bath at 40–65°C. After completion of the reaction (15 min, GC), the reaction was quenched with water (10 mL) and the organic layer was

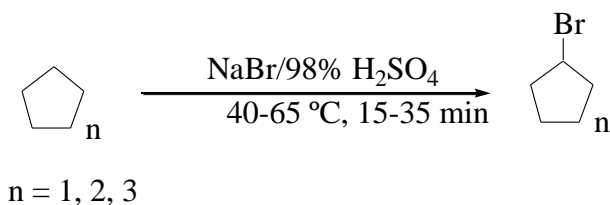
extracted with ether ( $3 \times 10$  mL), the combined ethereal extract was washed with saturated sodium bicarbonate solution, water and dried over anhydrous sodium sulphate and the solvent was evaporated. The product after drying under vacuum was identified to be 2-bromohexane by the IR,  $^1\text{H}$  NMR, and mass spectral analysis.

### 3. Results and Discussion

Previous work from our laboratory describes the nuclear monohalogenation (bromination and iodination) of electron rich arenes by tetraalkylammonium halides or alkali metal halides in the presence of conc.  $\text{H}_2\text{SO}_4$  [13–15]. In continuation of our work on bromination reactions, we are reporting a simple and convenient method of bromination of unactivated acyclic and cyclic alkanes by  $\text{NaBr} / 98\% \text{H}_2\text{SO}_4$  at  $40\text{--}65^\circ\text{C}$ . This is a new protocol, the yields are high and the reactions go to completion within  $15\text{--}35$  min as shown in Schemes I and II.



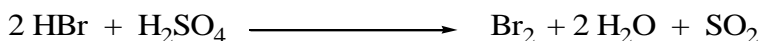
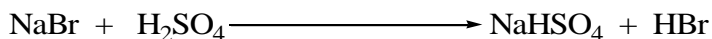
Scheme I



Scheme II

The present reaction is expected to proceed by the *in situ* generation and reaction of the bromine molecule [13–14] formed from  $\text{NaBr}$  and  $98\% \text{H}_2\text{SO}_4$  at  $40\text{--}65^\circ\text{C}$  (which can be made out from appearance and disappearance of bromine color), and is

*regioselective*, in the sense, more substituted bromide is formed from acyclic alkanes as shown in Scheme III.



Scheme III

A series of hydrocarbons were subjected to bromination by NaBr/98% H<sub>2</sub>SO<sub>4</sub> in order to find the applicability of the reagent system. The results of this study are listed in Table 1.

Entry	Substrate	Reaction Temp (°C)	Reaction time (min)	Product <sup>a</sup>	Yield (%) <sup>b</sup>
1	<i>n</i> -Pentane	45	30	2-Bromopentane	78
2	<i>n</i> -Hexane	55	30	2-Bromohexane	75
3	<i>n</i> -Heptane	50	30	2-Bromoheptane	85
4	Cyclopentane	65	20	Cyclobromopentane	72
5	Cyclohexane	65	15	Cyclobromohexane	75
6	Cycloheptane	65	20	Cyclobromoheptane	70

Table 1: Bromination of alkanes and cycloalkanes by NaBr/98% H<sub>2</sub>SO<sub>4</sub>

### 3.1 Spectral data:

#### 2-Bromopentane

IR (KBr)  $\nu_{\text{max}}$  = 2996, 2936, 2875, 2733, 1466, 1468, 1430, 1380, 1302, 1297, 1263, 1202, 1149, 1071, 1028, 980, 872, 844, 638, 818 cm<sup>-1</sup>; <sup>1</sup>H NMR (CDCl<sub>3</sub>, 300 MHz):  $\delta$ H = 0.96–0.99 (m, 3H, CH<sub>3</sub>), 1.26–1.40 (m, 2H, CH<sub>2</sub>), 1.70–1.78 (m, 2H, CH<sub>2</sub>), 1.79 (d, 3H, CH<sub>3</sub>), 3.6 (m, 1H, CH) ppm; MS (70 ev), m/Z: 151 [M<sup>+</sup>]

**2-Bromohexane**

IR (KBr)  $\nu_{\max}$  = 2961, 2931, 2874, 2862, 2835, 2734, 1467, 1378, 1345, 1303, 1290, 1238, 1194, 1045, 1007, 980, 885, 800, 750, 620, 532  $\text{cm}^{-1}$ ;  $^1\text{H}$  NMR ( $\text{CDCl}_3$ , 300 MHz):  $\delta\text{H}$  = 0.86–0.93 (m, 3H,  $\text{CH}_3$ ), 1.18–1.24 (m, 2H,  $\text{CH}_2$ ), 1.26–1.36 (m, 2H,  $\text{CH}_2$ ), 1.7 (m, 3H,  $\text{CH}_3$ ), 3.5 (m, 1H,  $\text{CH}$ ) ppm; MS (70 eV),  $m/Z$ : 165 [ $\text{M}^+$ ]

**2-Bromoheptane**

IR (KBr)  $\nu_{\max}$  = 2966, 2930, 2872, 2828, 2737, 1465, 1430, 1380, 1300, 1292, 1286, 1260, 1200, 1149, 1080, 1076, 1025, 990, 927, 875, 845, 613  $\text{cm}^{-1}$ ;  $^1\text{H}$  NMR ( $\text{CDCl}_3$ , 300 MHz):  $\delta\text{H}$  = 0.87–0.9 (m, 3H,  $\text{CH}_3$ ), 1.21–1.24 (m, 2H,  $\text{CH}_2$ ), 1.31 (m, 2H,  $\text{CH}_2$ ), 3.48 (m, 1H,  $\text{CH}$ ) ppm; MS (70 eV),  $m/Z$ : 179 [ $\text{M}^+$ ]

**Bromocyclopentane**

IR (KBr)  $\nu_{\max}$  = 3445, 2923, 2828, 2789, 2675, 1463, 1459, 1448, 1370, 1332, 1299, 1206, 1189, 1152, 1084, 1044, 980, 886, 810, 682, 462  $\text{cm}^{-1}$ ;  $^1\text{H}$  NMR ( $\text{CDCl}_3$ , 300 MHz):  $\delta\text{H}$  = 1.52 (t, 2H,  $\text{CH}_2$ ), 2.10 (m, 2H,  $J$  = 16 Hz,  $\text{CH}_2$ ), 3.45–3.5 (m, 1H,  $\text{CH}$ ) ppm; MS (70 eV),  $m/Z$ : 149 [ $\text{M}^+$ ]

**Bromocyclohexane**

IR (KBr)  $\nu_{\max}$  = 3448, 2933, 2848, 2796, 2670, 1463, 1460, 1448, 1370, 1336, 1299, 1206, 1191, 1152, 1085, 1048, 989, 886, 810, 687, 464  $\text{cm}^{-1}$ ;  $^1\text{H}$  NMR ( $\text{CDCl}_3$ , 300 MHz):  $\delta\text{H}$  = 1.3 (t, 2H,  $J$  = 9.6,  $\text{CH}_2$ ), 2.14–2.18 (d, 2H,  $J$  = 16.2 Hz,  $\text{CH}_2$ ), 4.16–4.24 (m, 1H,  $\text{CH}$ ) ppm; MS (70 eV),  $m/Z$ : 163 [ $\text{M}^+$ ]

**Bromocycloheptane**

IR (KBr)  $\nu_{\max}$  = 3440, 2932, 2858, 2793, 2671, 1453, 1448, 1371, 1330, 1297, 1206, 1191, 1150, 1083, 1040, 989, 880, 810, 685, 463  $\text{cm}^{-1}$ ;  $^1\text{H}$  NMR ( $\text{CDCl}_3$ , 300 MHz):  $\delta\text{H}$  = 1.24–1.34 (t, 2H,  $J$  = 10,  $\text{CH}_2$ ), 1.7 (m, 2H,  $J$  = 16.5,  $\text{CH}_2$ ), 3.42 (m, 1H,  $\text{CH}$ ) ppm; MS (70 eV),  $m/Z$ : 177 [ $\text{M}^+$ ]

**4. Conclusion**

In conclusion, a novel approach to the regioselective bromination of alkanes and cycloalkanes by  $\text{NaBr}/98\% \text{H}_2\text{SO}_4$  has been described. The reactions involve simple workup, use of commercial, readily available and inexpensive chemicals and high yields of the product make this procedure a useful alternative to the currently available methods.

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