Mapana J Sci, 12, 2 (2013), 1-7
ISSN 0975-3303 | doi:10.12723/mjs.25.1

NaBr/98% H_2SO_4: An Efficient Reagent for the Regioselective Monobromination of Least Reactive Alkanes and Cycloalkanes

Mohamed Afzal Pasha [*] and Nagashree Shrivatsa[†]

Abstract

An efficient, simple and regioselective monobromination of least reactive acyclic and cyclic alkanes by sodium bromide/ 98% H_2SO_4 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_2SO_4

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 un-activated carbon-hydrogen bonds into carbon-halogen bonds generally could be accomplished by the use of reagents like Br_2/HgO [1], Br_2/MnO_2 [2], Br_2/H_2O [3], NBS/DMF [4], Br_2/Al_2O_3 [5], $BrCCl_3$ [6], Polyhalomethane $\cdot AlBr_3$ [7], $CH_2Br_2/(SbF_5)_2$ [8], $CuBr_2$

---

[*] Department of Studies in Chemistry, Central College Campus, Bangalore University, Bangalore–560 001 (DCCCBU), India; m_af_pasha@ymail.com.

[†] DCCCBU; nachu.shree@gmail.com

Received: January 2013; Reviewed: February 2013

[9a-9c], $Ar_2C{=}NBr$ [10], by GoAgg^{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 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% H_2SO_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% H_2SO_4. This method gives the products in good yields within short reaction duration.

2. Experimental

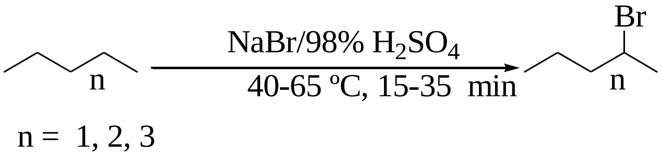
Cyclopentane was prepared from cyclopentanone by Clemmensen reduction. All the solvents used and other alkanes were commercially available and distilled before use. Reactions were monitored on TLC and by GC with reference samples. Yields refer to the isolated yields of the products after purification by column chromatography (light petrol). IR, ^1H NMR and GC-MS spectra were recorded on Nicolet 400D FT-IR Spectrophotometer, 300 MHz Brucker 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

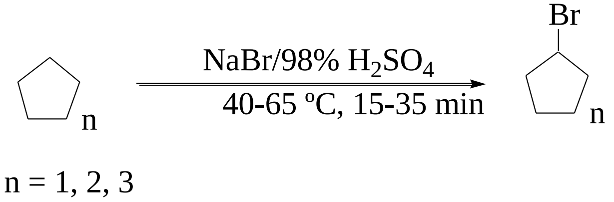
In a typical experiment, NaBr (1.03 g, 10 mmol) and 98% H_2SO_4 (1.96 g, 20 mmol) were treated with *n*-hexane (1.72 g, 20 mmol) and the contents were heated with constant stirring in an oil bath at 40–65°C. After completion of the reaction (15 min, GC), the reaction was quenched with water (10 mL) and the organic layer was extracted with ether (3 × 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}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. H_2SO_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 NaBr / 98% H_2SO_4 at 40–65 °C. This is a new protocol, the yields are high and the reactions go to completion within 15–35 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 NaBr and 98% H_2SO_4 at 40–65 °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.

$$NaBr + H_2SO_4 \longrightarrow NaHSO_4 + HBr$$

$$2\,HBr + H_2SO_4 \longrightarrow Br_2 + 2\,H_2O + SO_2$$

Scheme III

A series of hydrocarbons were subjected to bromination by NaBr/98% H_2SO_4 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[a]	Yield (%)[b]
1	*n*-Pentane	45	30	2-Bromopentane	78
2	*n*-Hexane	55	30	2-Bromohexane	75
3	*n*-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_2SO_4

3.1 Spectral data:

2-Bromopentane

IR (KBr) vmax = 2996, 2936, 2875, 2733, 1466, 1468, 1430, 1380, 1302, 1297, 1263, 1202, 1149, 1071, 1028, 980, 872, 844, 638, 818 cm^{-1}; ^1H NMR ($CDCl_3$, 300 MHz): δH = 0.96–0.99 (m, 3H, CH_3), 1.26–1.40 (m, 2H, CH_2), 1.70–1.78 (m, 2H, CH_2), 1.79 (d, 3H, CH_3), 3.6 (m, 1H, CH) ppm; MS (70 ev), m/Z: 151 [M^+]

2-Bromohexane

IR (KBr) ν_{max} = 2961, 2931, 2874, 2862, 2835, 2734, 1467, 1378, 1345, 1303, 1290, 1238, 1194, 1045, 1007, 980, 885, 800, 750, 620, 532 cm^{-1}; ^{1}H NMR ($CDCl_3$, 300 MHz): δH = 0.86–0.93 (m, 3H, $C\underline{H}_3$), 1.18–1.24 (m, 2H, $C\underline{H}_2$), 1.26–1.36 (m, 2H, $C\underline{H}_2$), 1.7 (m, 3H, $C\underline{H}_3$), 3.5 (m, 1H, $C\underline{H}$) ppm; MS (70 ev), *m/Z*: 165 [M$^+$]

2-Bromoheptane

IR (KBr) ν_{max} = 2966, 2930, 2872, 2828, 2737, 1465, 1430, 1380, 1300, 1292, 1286, 1260, 1200, 1149, 1080, 1076, 1025, 990, 927, 875, 845, 613 cm^{-1}; ^{1}H NMR ($CDCl_3$, 300 MHz): δH = 0.87–0.9 (m, 3H, $C\underline{H}_3$), 1.21–1.24 (m, 2H, $C\underline{H}_2$), 1.31 (m, 2H, $C\underline{H}_2$), 3.48 (m, 1H, $C\underline{H}$) ppm; MS (70 ev), *m/Z*: 179 [M$^+$]

Bromocyclopentane

IR (KBr) ν_{max}=3445, 2923, 2828, 2789, 2675, 1463, 1459, 1448, 1370, 1332, 1299, 1206, 1189, 1152, 1084, 1044, 980, 886, 810, 682, 462 cm^{-1}; ^{1}H NMR ($CDCl_3$, 300 MHz): δH = 1.52 (t, 2H, $C\underline{H}_2$), 2.10 (m, 2H, *J* = 16 Hz, $C\underline{H}_2$), 3.45–3.5 (m, 1H, $C\underline{H}$) ppm; MS (70 ev), *m/Z*: 149 [M$^+$]

Bromocyclohexane

IR (KBr) ν_{max}=3448, 2933, 2848, 2796, 2670, 1463, 1460, 1448, 1370, 1336, 1299, 1206, 1191, 1152, 1085, 1048, 989, 886, 810, 687, 464 cm^{-1}; ^{1}H NMR ($CDCl_3$, 300 MHz): δH = 1.3 (t, 2H, *J* =9.6, $C\underline{H}_2$), 2.14–2.18 (d, 2H, *J* =16.2 Hz, $C\underline{H}_2$), 4.16–4.24 (m, 1H, $C\underline{H}$) ppm; MS (70 ev), *m/Z*: 163 [M$^+$]

Bromocycloheptane

IR (KBr) ν_{max}=3440, 2932, 2858, 2793, 2671, 1453, 1448, 1371, 1330, 1297, 1206, 1191, 1150, 1083, 1040, 989, 880, 810, 685, 463 cm^{-1}; ^{1}H NMR ($CDCl_3$, 300 MHz): δH = 1.24–1.34 (t, 2H, *J* =10, $C\underline{H}_2$), 1.7 (m, 2H, *J* =16.5, $C\underline{H}_2$), 3.42 (m, 1H, $C\underline{H}$) ppm; MS (70 ev), *m/Z*: 177 [M$^+$]

4. Conclusion

In conclusion, a novel approach to the regioselective bromination of alkanes and cycloalkanes by NaBr/98% H_2SO_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.

Acknowledgement

The authors would like to acknowledge Prof. N. Suryaprakash, Scientist, Sophisticated Instrument Facility Department, Indian Institute of Science, Bangalore, for recording the ^{1}H NMR spectra; and the financial assistance by the VGST, Department of Science & Technology, Government of Karnataka for the CESEM Award Grant No. 24 (2010-2011).

References

[1] M. Siddiq, S. A. Khan and M. A. Munawar, "Monobromination of deactivated active rings using bromine, mercuric oxide, and strong acid", *J. Org. Chem.*, vol. 53, pp. 1799-1800, 1988. doi:10.1021/jo00243a037

[2] X. Jiang, M. Shen, Y. Tang and C. Li, "Chemoselective monobromination of alkanes promoted by unactivated MnO_2", *Tetrahedron Lett.*, vol. 46, pp. 487-489, 2005. doi:10.1016/ j.tetlet.2004.11.113

[3] H. Shaw, H. D. Perlmutter, C. Gu, S. D. Acro and T.O. Quibuyen, "Free-radical bromination of selected organic compounds in water", *J. Org. Chem.*, vol. 62, pp. 236-237, 1997.

[4] A. McKillop, D. Bromley and E. C. Taylor, "Thallium in Organic Synthesis. XXV. Electrophilic Aromatic Bromination Using Bromine and Thallium(III) Acetate 1-3", *J. Org. Chem.*, vol. 37, pp. 88-92, 1972. doi:10.1021/jo00966a024

[5] R. H. Mitchell, Y. H. Lai and R. V. Williams, "N-Bromosuccinimide-dimethylformamide: a mild, selective nuclear monobromination reagent for reactive aromatic compounds", *J. Org. Chem.*, vol. 44, pp. 4733-4735, 1979. doi:10.1021/jo00393a066

[6] E. S. Huyser, "The Photochemically Induced Reactions of Bromotrichloromethane with Alkyl Aromatics", *J. Am. Chem. Soc.*, vol. 82, pp. 391-393 , 1960.

[7] I. S. Akhrem, A. V. Orlinkov, L.V. Afanas'eva, E. I. Mysov and M. E. Vol'pin, "Ionic bromination of ethane and other alkanes (cycloalkanes) with bromine catalyzed by the polyhalomethane$\cdot$2$AlBr_3$ aprotic organic superacids under mild conditions", *Tetrahedron Lett.*, vol. 36, pp. 9365-9368, 1995. doi:10.1016/0040-4039(95)01986-R

[8] G. A. Olah, A. H. Wu and Farooq, "Synthetic methods and reactions. 137. Ionic chlorination (bromination) of alkanes and cycloalkanes with methylene chloride (bromide)/antimony pentafluoride", *J. Org. Chem.*, vol. 54, pp. 1463-1465, 1989 . doi:10.1021/jo00267a047

[9] (9a) S. J. Coats and H. H. Wasserman, "The conversion of α-bromo-β-dicarbonyls to vicinal tricarbonyls using dimethyldioxirane and base", *Tetrahedron Lett.*, vol. 36, pp. 7735-7738, 1995.

(9b) A.V.R. Rao, A. K. Singh, K. M. Reddy and K. Ravikumar, "Regioselective free radical cyclization : a general method for the synthesis of the spiro[4.4]nonane system of fredericamycin A", *J. Chem. Soc., Perkin Trans. 1*, pp. 3171-3175, 1993.

(9c) X. Shi, L. Dai, "Halogenation of Stablized Ester Enolates by Cupric Halides", *J. Org. Chem.*, vol. 58, pp. 4596-4598, 1993.

[10] D. Y. Curtin and C. G. McCarty, "Use of benzophenone N-chlorimine and N-bromimine as halogenating agents", *J. Org. Chem.*, vol. 32, pp. 223-225, 1967. doi:10.1021/jo01277a058

[11] D. H. R. Barton, S. D. Beviere and W. Chavasiri, "The functionalization of saturated hydrocarbons. Part 25. Ionic substitution reactions in GoAgg^{IV} chemistry: the formation of carbon-halogen bonds", *Tetrahedron*, vol. 50, pp. 31-46, 1994. doi:10.1016/S0040-4020(01)80736-5

[12] R. Davis, L. A. Jim, Durrant and C. R. Christopher, "Free radical halogenation of alkanes initiated by transition metal complexes", *J. Organometallic Chem.*, vol. 316, pp. 147-162, 1986.

[13] Yi. Yi. Myint and M. A. Pasha, "Monohalogenation (bromination and iodination) of electron rich arenes by tetraalkylammonium halides in presence of conc. H_2SO_4", *Indian J. Chem.* vol. 43B, pp. 357-360, 2004.

[14] Yi. Yi. Myint and M. A. Pasha, "Oxidative monobromination of electron-rich arenes by conc. H_2SO_4 / alkali metal bromides", *J. Chem.* Res. *(S)*, vol. 2004, pp. 732-734, 2004.

[15] M. A. Pasha and Yi. Yi. Myint,"Acid-Catalysed Selective Monoiodination of Electron-Rich Arenes by Alkali Metal Iodides", *Synth. Commun.*, vol. 34, pp. 2829-2833, 2004.