Develop New Approaches to the Synthesis of N, N, N-triethyl-4-[(Hexahydro-2-oxo-1H-azepin-1-yl) Carbonyl]-Bromine/Chloride

Weijian Chen and Yujie Ren

***Abstract*—New approaches have been developed here: 4-methyl-benzoic acid first reacted with thionyl chloride, then with caprolactam, and last with N-bromosuccinimide to produce the 4-bromomethyl benzoyl caprolactam. Further, N, N, N-triethyl-4-[(hexahydro-2-oxo-1H-azepin-1-yl) carbonyl]-, Bromine was prepared through the reaction with triethylamine and 4-bromomethyl benzoyl caprolactam. The total yield was 61%. 4-methyl-benzoic acid reacted N-bromosuccinimide, then with chlorohydric acid, and last with caprolactam to produce 4 - chloromethyl benzoyl caprolactam. N, N, N-triethyl-4-[(hexahydro -2-oxo-1H-azepin-1-yl) carbonyl]-,Chloride was further synthesized via the reaction with triethylamine and 4 - chloromethyl benzoyl. The total yield was 41%.**

***Index Terms*—Hydrogen peroxide bleaching, amide, activator, synthesis.**

I. Introduction

Since the 1950s, with the promotion of hydrogen peroxide bleaching technology, the hydrogen peroxide bleaching has been used widely in printing and dyeing industry. However, there are two weak points in the process of hydrogen peroxide bleaching; on one hand, hydrogen peroxide is unstable and broke down easily, especially when some alkali metal ions or transition metal ions are present in its solution. On the other hand, a good bleaching result can be obtained only with very high temperature, mostly, at boiling point, which results in energy over consumption and excessive degradation of fiber.

To solve the problems mentioned above, activator can be added to enhance the oxidation activity of hydrogen peroxide, improving the bleaching efficiency and adapting the bleaching in multiple fiber fabric.

Tetraacetylethylenediamine (TAED) [1], the amide compounds activator, is the first generation of commercial bleach activator. However, an expected effect of the bleach of the hydrophobicity pigment cannot be obtained, which reduces the scope of TAED greatly [2], [3]. The reasons are as follows:

One is the low-temperature effect of TAED is not obvious [4]; the other is the low solubility in water of TAED [5]-[7].

Nonanoyloxybenzene sulfonate (NOBS) [8], [9], the alkyl acyloxy activator, is the second generation commercial bleach activator. It has lower activation energy of oxygen releasing than that of TAED. However, in the process of blenching, NOBS is unstable, and depends greatly on the concentrations of acid-base and its own, resulting in high production costs. Thus, the application of NOBS is limited.

Following the TAED and NOBS, a new cationic quaternary ammonium salts peroxide activator has been developed. Scientists in University of Northern California College of Textiles and University of Istanbul Turkey have studied this action-activator, of which N,N,N-triethyl-4-[(hexahydro-2-oxo-1H-azepin-1-yl)-carbonyl]-,Chloride (TBCC) is an important species. TBCC is a cationic oxygen activator, which has a strong adsorption capacity. It is not only a bleach activator, but also a cationic activator; its activation capacity stronger than NOBS. The bleaching time has been shorted from 20h to 6h, so the time effect was more pronounced. During bleaching TBCC demanded the lower temperature and bleaching was also superior to other oxygen bleach, TBCC can save a lot of energy. In short, TBCC can get excellent results such as shorten time, save energy and improve products quality [10], [11]. The synthesis of N, N, N-triethyl-4-[(hexahydro-2-oxo-1H-azepin-1-yl)-carbonyl]-, Chloride (TBCC) has been reported in the references [12]-[14]. The 4-Chloromethyl benzoyl chloride was used as the raw material, which was synthesized by the reaction with diethylamide, caprolactam and chloroethane (Fig. 1). However, this method has some weak points: high cost, complex operation and low yield.

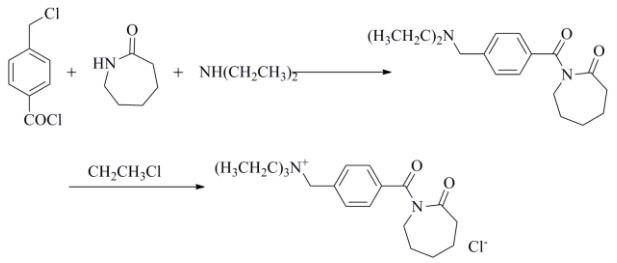


Fig. 1. Synthesis of N, N, N-triethyl-4-[(hexahydro-2-oxo-1H-azepin-1-yl)-carbonyl]-, Chloride (TBCC).

For the synthesis of N, N, N-triethyl-4-[(hexahydro-2-oxo-1H-azepin-1-yl) carbonyl]-, Bromine, the approach was original and novel. It had some advantages as follows: short reaction time, cheap raw materials, mild reaction conditions, simple operation and high yield. This activator can be produced industrially, which will promote the process of hydrogen peroxide bleaching. However, we have failed to synthesize 4-chloromethyl benzoyl caprolactam with this route (Fig. 2) and we have chosen another approach to synthesis TBCC (Fig. 4).

Manuscript received September 24, 2013; revised November 30, 2013.

Yujie Ren is with the School of Chemistry and Environmental Engineering, Shanghai Institute of Technology, Shanghai 201418, China (e-mail: clab@sit. edu.cn).

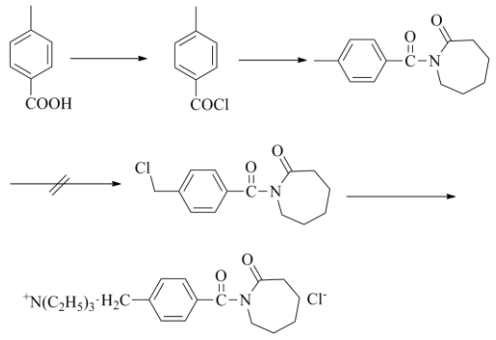
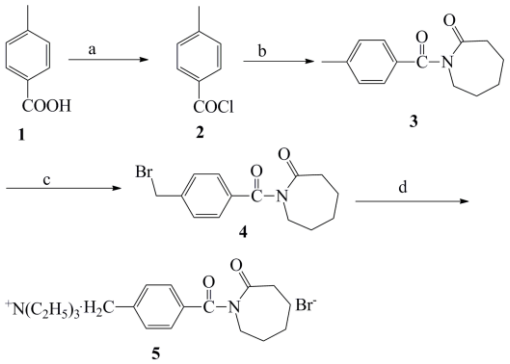


Fig. 2. Synthesis of 4-chloromethyl benzoyl caprolactam.

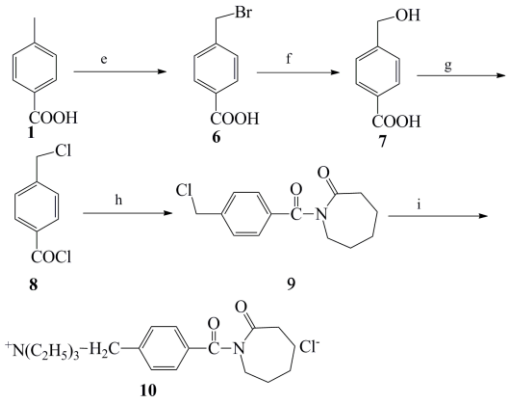
4-methyl-benzoic acid reacted with thionyl chloride, then with caprolactam, and last with N-bromosuccinimide to give the compound 4-bromomethyl benzoyl caprolactam. And then, N, N, N-triethyl-4-[(hexahydro-2-oxo-1H-azepin-1-yl) carbonyl]-, Bromine was prepared by the reaction with triethylamine and 4-bromomethyl benzoyl caprolactam (Fig. 3).



(a, b) $SOCl_2$,$CHCl_3$,DMF,Caprolactam, Et_3N; (c)NBS,CCl_4;(d)Acetone, Et_3N.

Fig. 3. Synthetic routs of N, N, N-triethyl-4-[(hexahydro-2-oxo-1H-azeazepin-1-yl) carbonyl]-, Bromine.

4-methyl-benzoic acid reacted N-bromosuccinimide, then with chlorohydric acid, and last with caprolactam to give the compound 4-chloromethyl benzoyl caprolactam. At last, N, N, N-triethyl-4-[(hexahydro-2-oxo-1H-azepin-1-yl) carbonyl]-, Chloride was prepared by the reaction with triethylamine and 4-chloromethyl benzoyl (Fig. 4).



(e) NBS,CCl_4; (f) HCl; (g) $SOCl_2$, $CHCl_3$, DMF;
(h) Caprolactam, Et_3N; (i) Methyl cyanide, Et_3N.

Fig. 4. Synthetic routs of N, N, N-triethyl-4-[(hexahydro-2-oxo-1H-azepin-1-yl) carbonyl]-, Chloride (TBCC).

II. Experimental

A. Materials and Methods

The melting points were recorded on a WPS-2A digital melting point apparatus and were uncorrected; ^{1}H NMR and spectra were recorded at 400MHz on a Bruker Avance Ⅲ 400 spectrometer with TMS as the internal standard; All the reagents were analytical reagent grade.

B. General Method for the Preparation of Compounds (3-10)

1) 4-methyl-benzoyl caprolactam (3)

4-methyl-benzoic acid **1** (6.8g, 0.050mol) and chloroform 30mL were added to a flask. Thionyl chloride 6mL (0.070mol) and dimethylformamide 3~6 drops was dropped into the flask slowly. The mixture was stirred at reflux temperature for 4h. The remaining solvent thionyl chloride was evaporated to dryness by rota vapor. Yellow liquid **2** was acquired, which was used as such in the next reaction.

Caprolactam 5.6g (0.050mol), chloroform 20mL and triethylamine 7mL was added to a flask. Yellow liquid **2** was dropped into the flask slowly with chloroform 20mL at 0-5℃.After dropping, the mixture was stirred at room temperature for 2h. The reaction mixture was concentrated. The compound **3** was washed with water and purified by recrystallization from ethyl acetate (39.50g, 82%, m. p. 128~130℃). ^{1}HNMR (400 MHz, $CDCl_3$): δ (ppm) 7.46（d, 2H), 7.18(d, 2H), 3.95(d, 2H), 2.7(t, 2H), 2.38(s, 3H), 1.88(m, 6H).

2) 4-bromomethyl benzoyl caprolactam (4)

The compound 3 (5.35g, 0.023mol), N-bromosuccimide 12g (0.023mol), peroxybenzoic acid 0.28g and CCl_4 (40 mL) were added and refluxed for 4h. The mixture was filtered after cooled. The residue was washed with water and purified by recrystallization from ethyl acetate. Then the compound 4 was given (5.85g, 82%, m.p. 120~122 ℃). ^{1}HNMR (400 MHz, $CDCl_3$): δ (ppm) 7.52 (d, 2H), 7.42(d, 2H), 4.48(s, 2H), 3.97(s, 2H), 2.70(m, 2H), 1.85(m, 6H).

3) N, N, N-triethyl-4-[(hexahydro-2-oxo-1H-azepin-1-yl) carbonyl]-, Bromine (5)

The compound 4 (5.0g, 0.016mol), triethylamine 6.7mL (0.048mol) and acetone 30mL were added to a flask. The mixture was stirred at reflux temperature for 4h. Then the mixture was concentrated, the compound 5 was given by recrystallization from ethanol (5.92g, 90%, m. p. 214~215℃). ^{1}HNMR (400 MHz, $CDCl_3$): δ (ppm) 7.70(d, 2H), 7.55(d, 2H), 4.95(s, 2H), 3.95(s, 2H), 3.48(m, 6H), 2.70(d, 2H), 1.86(m, 6H), 1.47(t, 9H).

4) 4-bromomethyl benzoic acid (6)

The compound 1 (13.6g, 0.100mol), N-bromosuccimide 17.82g (0.100mol), peroxybenzoic acid1.99g (8%) and CCl_4 (120 mL) were added and ref luxed for 4h. The mixture was filtered after cooled and washed with water. The compound 6 was given as a white solid (17.96g, 84%, m. p. 225-227℃).

5) 4-hydroxymethyl-benzoic acid (7)

The compound 6 (8.6g, 0.040mol), hydrochloric acid 10mL and water 90mL were added to a flask .The mixture was stirred at 100℃ for 4h. The mixture was filtered after

cooled and washed with water. The compound **7** was given as a white solid (5.46g, 90%, m.p.173-175℃).

6) 4-Chloromethyl benzoyl chloride 8, 4 - chloromethyl benzoyl caprolactam (9)

4 - hydroxymethyl-benzoic acid **7** (5.1g, 0.034mol) and chloroform 40mL were added to a flask. Thionyl chloride 10mL (0.134mol) and dimethylformamide 3~6 drops were dropped into the flask slowly. The mixture was stirred at reflux temperature for 4h.The solvent and the remaining thionyl chloride were evaporated to dryness by rota vapor. Yellow liquid 8 was acquired, which was used in the next reaction.

Caprolactam 3.8g (0.034mol), chloroform 20mL and triethylamine 3.39g (0.034mol) were added to a flask. Yellow liquid 8 was dropped into the flask slowly with chloroform 20mL at 0~5℃. After dropping, the mixture was stirred at room temperature for 2h. The mixture was concentrated; the residue was washed with water and purified by recrystallization from ethyl acetate; then the compound **9** was given (5.40g, 60%, m. p. 105-107℃). 1HNMR (400 MHz, $CDCl_3$): δ (ppm), 7.54(d, 2H), 7.42(d, 2H), 4.59(s, 2H), 3.98(t, 2H), 2.72(t, 2H), 1.89(m, 6H).

7) N, N, N-triethyl-4-[(hexahydro-2-oxo-1H-azepin-1-yl) carbonyl]-chloride (10)

The compound 9 (1.76g, 0.007mol), triethylamine 2.03g (0.020mol) and acetonitrile 20mL were added to a flask. The mixture was stirred at reflux temperature for 4h. The mixture was concentrated and the product was purified by recrystallization from ethanol. The compound 10 was given (2.18g, 90%, m. p. 204-206℃). ^{1}HNMR (400 MHz, $CDCl_3$): δ (ppm) 7.72(d, 2H), 7.56(d, 2H), 4.97(s, 2H), 3.99(s, 2H), 3.46(m, 6H), 2.70(d, 2H), 1.85(m, 6H), 1.47(t, 9H).

III. Results and Discussion

It is very important to keep the reagents dryness in the synthesis of 4-chloromethyl benzoyl caprolactam. Otherwise, a side reaction would be happened (Fig. 5), which increased the difficulty of separation.

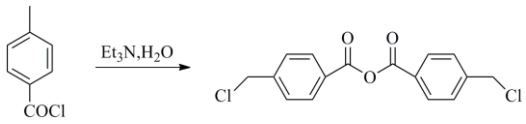
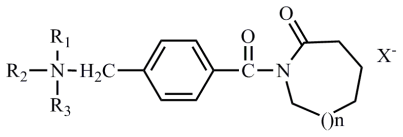


Fig. 5. Synthesis of 4-chloromethyl benzoyl caprolactam.



R_1, R_2, R_3 =Long-chain alkyl
X^-=Anion(Include halogen atoms)
n=4,5,6,7,8

Fig. 6. **S**ynthesis of amide compounds activator.

According to the experimental route, more amide compounds activator can be synthesized (Fig. 6). By the activity test, the best bleach activity in those activators will be chosen.

IV. Conclusion

N, N, N-triethyl-4-[(hexahydro-2-oxo-1H-azepin-1-yl) carbonyl]-, Bromine/Chloride were prepared successfully. The approaches were feasible, and the approaches had some advantages as follows: short reaction time, cheap raw materials, mild reaction conditions, simple operation and high yield. Those activators can be produced industrial, which will promote the process of hydrogen peroxide bleaching.

Acknowledgment

This work was financially supported by *Innovation Program of Shanghai Municipal Education Commission* (No.12ZZ188) and *the Program for Professor of Special Appointment (Eastern* Scholar*) at Shanghai Institutions of Higher Learning* （No.405ZK110060002） .It was also supported by *Shanghai* Science *and Technology Committee* (No.11430502500).

References

[1] S. J. Scarborough, A. J. Mathews, "Using TAED in bleaching fiber blends to improve fiber quality," *Text Chem. Color Am D*, vol. 32, issue 3, pp. 33-37, 2000.
[2] O. A. kofi and H. H. David, "Method for stain removal on hard surfaces with detergent compositions containing bleach," U.S. Patent 6 306 219, October 23, 2001.
[3] G. S. Miracle and R. R. Dykstra, "O-substituted N, N-diacylhydroxylamine bleach activators and compositions employing the same," U.S. Patent 6 423 676, July 23, 2002.
[4] J. P. Wang, N. M. Washington, and K. D. Moe, "Method for the use of hydrophobic bleadching systems in textile preparation," CN Patent 14 390 70, August 27, 2003.
[5] K. M. Preissner and A. D. Brown, "Bleach activators with improved solubility," U.S. Patent 6 806 246B2, October 19, 2004.
[6] P. K. Lavric, F. Kovac, P. F. Tavcer, P. Hauser, and D. Hinks, "Enhanced PAA bleaching of cotton by incorporating a cationic bleach activator," *Coloration Technology*, vol. 230-236, pp. 123, 2007.
[7] J. P. Wang, "Method for the one step preparation of textiles," U.S. Patent 6 743 761 B2, June 1, 2004.
[8] Y. Liu, "Detergent- principles, materials, processes, formulas," Beijing: Chemical Industry Press, 1998.
[9] M. D. Davies, S. J. Foggo, and P. M. Paradis, "Micellar kinetics of acyl transfer from *n*-nonanoyloxybenzenesulfonate and phenyl nonanoate bleach activators to hydrogen peroxide and pernonanoic acid: effect of charge on the surfactant and activator," *J. Chem. Soc.*, Perkin Trans, 2, pp. 1597-1602, 1998.
[10] C. Weijian, J. Jiajun, and R. Yujie, "Synthesis and Study on Amide Activator TBCC/TBCB and Imatinib," East China University of Science and Technology, 2012.
[11] R. Yujie, C. Weijian, and J. Jiajun, "Preparation method of oxygen bleaches activator (TBCC)," CN Patent 201110190805.3, July 8, 2011.
[12] G. R. Kelm and G. L. Manring, "Pharmaceutical dosage form with multiple enteric polymer coatings for colonic delivery," U.S. Patent 5 686 105, November 11, l997.
[13] S. H. Lim, J. J. Lee, H. David, and P. Hauser," Bleaching of cotton with activated peroxide systems," *Coloration Technology*, vol. 121, issue 2, pp. 89-95, 2005.
[14] G. M .A. Baillely, M. E. Burns, N. E. Guedira, F. E. Hardy, K. L. Kott, G. S. Miracle *et al.*, "Quaternary substituted bleach activators," WO Patent 19 96006915 A1, July 20, 1995.

Yujie Ren was born in 1965 in China, who was dubbed the Ph.D. Currently, he as a professor at Shanghai Institute of Technology has published more than 30 research papers at journals at home and abroad, there were 3 patents have been licensed. The research direction was synthetic organic and the chemistry of fine chemicals.