

Jitai LI, Xiaoliang LI, Xianfeng LIU, Jiejie MA

# Synthesis of O-benzyl oximes by combination of phase transfer catalysis and ultrasound irradiation

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**Abstract** The reactions of oximes with benzyl bromide catalyzed by benzyldimethyltetradecylammonium chloride are carried out at room temperature for 30–60 min in aqueous sodium hydroxide solution under ultrasound irradiation to offer O-benzyl oxime derivatives in 60–96% yields. In comparison to classical methods, the advantages of the present procedure include short reaction time, high yields and environmental friendliness.

**Keywords** oxime ether, phase transfer catalysis, ultrasound, etherification

## 1 Introduction

Oxime-ethers compounds frequently exhibit satisfactory insecticidal, fungicidal or herbicidal activity. Many of them have characteristics of low toxicity and residue. Cymoxan is a first oxime-ether type fungicide, which was manufactured in 1974. Alloxydim is a first herbicide with oxime-ether skeleton, which was developed in 1976. A great number of fungicides and herbicides containing oxime skeleton has been used in agricultures since 1990s [1]. Recent efforts have been focused on the study on molecular design, synthesis and biological activity of oxime compounds. Among the rest, the application of oxime-ethers in agrochemicals has attracted more and more attention because of their characteristics including high biological activity and broad application prospects.

In the literature, the oxime-ethers were prepared under anhydrous conditions using a strong base such as NaH or sodium alkoxides to realize the substitution reaction between alkyl halide and oxime [1]. However, low yields,

long reaction times, and side reactions to give byproducts such as nitrones were the drawbacks of the method.

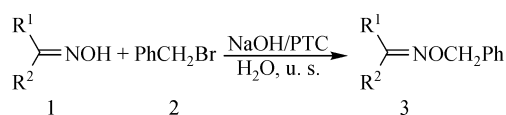
A new challenge has been the recent interest in green chemistry for organic synthesis, *i.e.* new reaction conditions need to be found to reduce the emission of volatile organic solvents and the use of hazardous toxic chemicals. Organic reactions in aqueous media have currently attracted increasing interest because of environmental issues and the understanding of biochemical processes. As a reaction solvent, water offers many practical and economic advantages including low cost, safe handling and environmental compatibility [2–4]. Recently, many organic reactions in aqueous media, such as Diels-Alder reactions [5–8], Claisen rearrangements [9–14], Aldol condensations [15,16] and Michael reactions [17,18], have been described in the literatures [19–23].

Phase-transfer catalysis is a technique by which reactions between substances located in different phases are brought about or accelerated. Although examples of the phase-transfer catalysis can be found in the early literature, the technique has only been developed since the middle of the 1960s. Phase-transfer catalyst (PTC), such as quaternary ammonium salt, is well known to accelerate many reactions under mild conditions where the reactions hardly take place in the absence of the catalyst [24].

Ultrasound irradiation has been considered as a clean and useful protocol in organic synthesis in the last three decades. Compared with traditional methods, the procedure is more convenient. A large number of organic reactions can be carried out in higher yield, with a shorter reaction time or under milder conditions by ultrasonic irradiation [25,26]. In recent years, the combined ultrasonic technique and phase-transfer catalysis for the organic reactions have been reported [27–31]. Recently, an improved synthesis of oxime-ethers by the combination of phase-transfer catalysis and ultrasonic technique was carried out in high yield within a short time [1,32]. Herein, we wish to report an efficient synthesis of the O-benzyl oximes with aqueous sodium hydroxide in the presence of benzyldimethyltetradecylammonium chloride under ultrasound irradiation (Scheme 1).

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Jitai LI (✉), Xiaoliang LI, Xianfeng LIU, Jiejie MA  
Key Laboratory of Analytical Science and Technology of Hebei Province, College of Chemistry and Environmental Science, Hebei University, Baoding 071002, China  
E-mail: lijitai@hbu.cn



Scheme 1 Synthesis of O-benzyl oximes

## 2 Experimental

### 2.1 Apparatus and analysis

Oximes were prepared according to the method reported in literature [33,34]. Melting points were uncorrected. Sonication was performed in a Shanghai Branson BUG25-06 ultrasonic cleaner with a frequency of 25 kHz and a nominal power of 250 W. The  $^1\text{H}$  NMR spectra were measured on a Bruker AVANCE 400 (400 MHz) or Bruker AC-P300 (300 MHz) spectrometer using TMS as internal standard and  $\text{CDCl}_3$  as solvent. Elemental analyses were carried out using an AGILENT 6890N 5973N Mass spectrometer.

### 2.2 Typical procedure

The oxime (**1**, 1 mmol), NaOH (1 mmol), water (3 mL), benzyl bromide (**2**, 1.5 mmol) and benzyldimethyltetradecylammonium chloride (0.040 g, 0.1 mmol) were added to a 50 mL round flask. The mixture was irradiated in the water bath of the ultrasonic cleaner at r. t. for the period indicated in Table 1 (the reaction was monitored by TLC). After the completion of the reaction, the mixture was extracted with  $\text{CH}_2\text{Cl}_2$  (3  $\times$  10 mL). The combined organic layers were dried over anhydrous sodium sulfate, filtered and evaporated to dryness in vacuo. The product was purified by chromatography on  $\text{Al}_2\text{O}_3$ . Elution with petroleum ether or a mixture of petroleum ether and dichloromethane afforded the O-benzyl oximes. The authenticity of the product was established by MS and  $^1\text{H}$  NMR data.

**O-Benzyl 2-methoxybenzaloxime (3a)**: liquid;  $^1\text{H}$  NMR ( $\text{CDCl}_3$ , 400 MHz)  $\delta$ : 3.87 (s,  $\text{OCH}_3$ , 3H), 5.28 (s,  $\text{OCH}_2\text{Ph}$ , 2H), 6.92–7.87 (m, ArH, 9H), 8.62 (s,  $\text{CH}=\text{N}$ , 1H); MS (EI, 70 eV)  $m/z$  (%): 241 ( $\text{M}^+$ , 10), 210 (9), 119 (8), 91 (100), 77 (7.5), 65 (5).

**O-Benzyl 4-methoxybenzaloxime (3b)**: white solid; m. p. 40–42  $^\circ\text{C}$ ;  $^1\text{H}$  NMR ( $\text{CDCl}_3$ , 400 MHz)  $\delta$ : 3.86 (s,  $\text{OCH}_3$ , 3H), 5.22 (s,  $\text{OCH}_2\text{Ph}$ , 2H), 6.91–7.57 (m, ArH, 9H), 8.13 (s,  $\text{CH}=\text{N}$ , 1H). MS (EI, 70 eV)  $m/z$  (%): 241 ( $\text{M}^+$ , 30), 211 (4), 91(100), 77 (11).

**O-Benzyl 4-nitrobenzaloxime (3c)**: white solid; m.p. 115–117  $^\circ\text{C}$ ;  $^1\text{H}$  NMR ( $\text{CDCl}_3$ , 400 MHz)  $\delta$ : 5.29(s,  $\text{OCH}_2\text{Ph}$ , 2H), 7.29–7.78 (m, ArH, 7H), 8.21 (s,  $\text{CH}=\text{N}$ , 1H), 8.24–8.26 (m, ArH, 2H); MS (EI, 70 eV)  $m/z$  (%): 256 ( $\text{M}^+$ , 0.9), 91(100), 77 (6.7), 65(7.2).

**O-Benzyl 2,4-dichlorobenzaloxime (3d)**: white solid;

m.p. 50–52  $^\circ\text{C}$ ;  $^1\text{H}$  NMR ( $\text{CDCl}_3$ , 400 MHz)  $\delta$ : 5.26 (s,  $\text{OCH}_2\text{Ph}$ , 2H), 7.25–7.87 (m, ArH, 8H), 8.52 (s,  $\text{CH}=\text{N}$ , 1H); MS (EI, 70 eV)  $m/z$  (%): 281 ( $\text{M}+1$ , 4), 279 ( $\text{M}^+$ , 5), 249 (5), 123 (7.5), 91(100), 77 (8), 65(8).

**O-Benzyl 2-chlorobenzaloxime (3e)**: liquid;  $^1\text{H}$  NMR ( $\text{CDCl}_3$ , 400 MHz)  $\delta$ : 5.33 (s,  $\text{OCH}_2\text{Ph}$ , 2H), 7.30–7.97 (m, ArH, 9H), 8.67 (s,  $\text{CH}=\text{N}$ , 1H); MS (EI, 70 eV)  $m/z$  (%): 245 ( $\text{M}^+$ , 2.5), 215 (7), 111(1), 91(100), 77 (3), 65 (2.5).

**O-Benzyl 3-chlorobenzaloxime (3f)**: liquid;  $^1\text{H}$  NMR ( $\text{CDCl}_3$ , 400 MHz)  $\delta$ : 5.28 (s,  $\text{OCH}_2\text{Ph}$ , 2H), 7.31–7.66 (m, ArH, 9H), 8.13 (s,  $\text{CH}=\text{N}$ , 1H); MS (EI, 70 eV)  $m/z$  (%): 245 ( $\text{M}^+$ , 5), 215 (4), 111 (2.5), 91 (100), 77 (4.5).

**O-Benzyl 4-chlorobenzaloxime (3g)**: white solid; m.p. 43–45  $^\circ\text{C}$ ;  $^1\text{H}$  NMR ( $\text{CDCl}_3$ , 400 MHz)  $\delta$ : 5.23 (s,  $\text{OCH}_2\text{Ph}$ , 2H), 7.29–7.56 (m, ArH, 9H), 8.12 (s,  $\text{CH}=\text{N}$ , 1H); MS (EI, 70 eV)  $m/z$  (%): 245 ( $\text{M}^+$ , 3), 215 (0.3), 111 (0.3), 91 (100), 77 (0.4), 65 (0.4).

**O-Benzyl benzaloxime (3h)**: liquid;  $^1\text{H}$  NMR ( $\text{CDCl}_3$ , 300 MHz)  $\delta$ : 5.23 (s,  $\text{OCH}_2\text{Ph}$ , 2H), 7.29–7.62 (m, ArH, 10H), 8.17 (s,  $\text{CH}=\text{N}$ , 1H); MS (EI, 70 eV)  $m/z$  (%): 211 ( $\text{M}^+$ , 5), 181 (6), 91 (100), 77 (10), 65 (10).

**O-Benzyl 4-chloroacetophenoxime (3i)**: white solid; m.p. 47–48  $^\circ\text{C}$ ;  $^1\text{H}$  NMR ( $\text{CDCl}_3$ , 300 MHz)  $\delta$ : 2.27 (s,  $\text{CH}_3$ , 3H), 5.26 (s,  $\text{OCH}_2\text{Ph}$ , 2H), 7.29–7.62 (m, ArH, 9H), 8.17 (s,  $\text{CH}=\text{N}$ , 1H); MS (EI, 70 eV)  $m/z$  (%): 259 ( $\text{M}^+$ , 8), 229 (3.5), 137 (2), 111(4.5), 91(100), 77(6).

**O-Benzyl 4-methoxyacetophenoxime (3j)**: white solid; m.p. 51–52  $^\circ\text{C}$ ;  $^1\text{H}$  NMR ( $\text{CDCl}_3$ , 300 MHz)  $\delta$ : 2.28 (s,  $\text{CH}_3$ , 3H), 3.84 (s,  $\text{OCH}_3$ , 3H), 5.26 (s,  $\text{OCH}_2\text{Ph}$ , 2H), 6.90–7.65 (m, ArH, 9H); MS (EI, 70 eV) ( $m/z$ ) (%): 255 ( $\text{M}^+$ , 27.5), 225 (3), 198 (2.5), 164 (2), 134 (3.5), 119 (4), 91 (100), 77 (6).

## 3 Results and discussion

The experimental results are summarized in Table 1 and Table 2.

Under ultrasound irradiation, the effect of the reaction conditions on the etherification of 2-methoxybenzaloxime with benzyl bromide were examined, the results are shown in Table 1. In the presence of MeONa, when the molar ratio of 2-methoxybenzaloxime/benzyl bromide was 1:1.1, the etherification was carried out in 76% yield (Table 1, Entry 1) in EtOH within 30 min under ultrasound. Changing the molar ratio to 1:1.5, the yield of oxime-ether increased (80%) (Table 1, Entry 3). In the presence of NaOH and phase-transfer catalyst benzyldimethyltetradecylammonium chloride, with remaining the molar ratio of 2-methoxybenzaloxime

/benzyl bromide at 1:1.5, the yield increased to 89% (Table 1, Entry 6) within 30 min. This indicates that the phase-transfer catalyst has a significant influence on the reaction. The phase-transfer catalyst can accelerate the reaction in the organic-water phase. Based on this idea, we tried to improve the reaction by Phase transfer catalyst under ultrasound irradiation and good results were obtained. For example, in the presence of benzyldimethyltetradecylammonium chloride and ultrasound irradiation, the reaction of 2-methoxybenzaloxime with benzyl bromide gave O-benzyl 2-methoxybenzaloxime in 94% yield (Table 1, Entry 7) in aqueous NaOH solution within 30 min at room temperature.

**Table 1** The effect of reaction conditions on the etherification of 2-methoxybenzaloxime with benzyl bromide under ultrasound action

Entry	Cat. <sup>a</sup>	Solvent	Oxime/PhCH <sub>2</sub> Br <sup>b</sup>	T/min	Yield/%
1	NaOMe	EtOH	1:1.1	30	76
2	NaOMe	EtOH	1:1.1	100	67
3	NaOMe	EtOH	1:1.5	30	80
4	NaOH/A	EtOH	1:1.5	30	84
5	NaOH/B	EtOH	1:1.5	30	75
6	NaOH/C	EtOH	1:1.5	30	89
7	NaOH/C	H <sub>2</sub> O	1:1.5	30	94

<sup>a</sup>A: cetyltrimethylammonium bromide, B: tetrabutylammonium bromide,

C: benzyldimethyltetradecylammonium chloride;

<sup>b</sup>Ratio of mole

Of the three phase-transfer catalysts which were tested (cetyltrimethylammonium bromide, tetrabutylammonium bromide, and benzyldimethyltetradecylammonium chloride), benzyldimethyltetradecylammonium chloride was found to be the most effective.

From the results given in Table 1, the reaction conditions were chosen: mole ratio of oxime/PhCH<sub>2</sub>Br was 1:1.5, water as the solvent, NaOH as the base, benzyldimethyltetradecylammonium chloride as the phase-transfer catalyst. Under this condition, a series of experiments for the etherification of oximes with PhCH<sub>2</sub>Br was performed under ultrasound action. The results were listed at Table 2. As shown in Table 2, the etherification of oximes with PhCH<sub>2</sub>Br catalyzed by benzyldimethyltetradecylammonium chloride was carried out in good to excellent yields in aqueous NaOH solutions for 30–60 min at r.t. under ultrasound irradiation.

A comparison experiment in the absence of ultrasound was also carried out. Thus, the etherification of 2-methoxybenzaloxime with benzyl bromide catalyzed by benzyldimethyltetradecylammonium chloride was carried out in 87% yield (**3a**) only with stirring for 30 min while under ultrasound action within the same time **3a** obtaining a 94% yield. It is apparent that ultrasound dramatically accelerates the phase-transfer catalyzed etherification to give high yield. In order to examine the effect of the phase-transfer catalyst on the reaction, we also did the experiment

**Table 2** The reaction of oximes with benzyl bromide in aqueous media catalyzed by benzyldimethyltetradecylammoniumchloride in combination with ultrasound irradiation

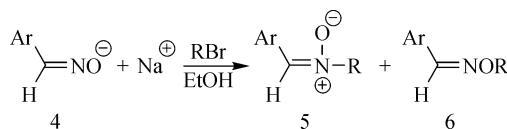
Entry	R <sup>1</sup>	R <sup>2</sup>	T/min	Product	Isolated yield/%
a	2-CH <sub>3</sub> OC <sub>6</sub> H <sub>4</sub>	H	30	<b>3a</b>	94
	2-CH <sub>3</sub> OC <sub>6</sub> H <sub>4</sub>	H	30 <sup>a</sup>	<b>3a</b>	67
b	4-CH <sub>3</sub> OC <sub>6</sub> H <sub>4</sub>	H	35	<b>3b</b>	86
c	4-O <sub>2</sub> NC <sub>6</sub> H <sub>4</sub>	H	30	<b>3c</b>	78
d	2,4-Cl <sub>2</sub> C <sub>6</sub> H <sub>3</sub>	H	30	<b>3d</b>	96
e	2-ClC <sub>6</sub> H <sub>4</sub>	H	20	<b>3e</b>	68
f	3-ClC <sub>6</sub> H <sub>4</sub>	H	50	<b>3f</b>	89
g	4-ClC <sub>6</sub> H <sub>4</sub>	H	20	<b>3g</b>	73
h	C <sub>6</sub> H <sub>5</sub>	H	30	<b>3h</b>	78
i	4-ClC <sub>6</sub> H <sub>4</sub>	CH <sub>3</sub>	60	<b>3i</b>	90
j	4-CH <sub>3</sub> OC <sub>6</sub> H <sub>4</sub>	CH <sub>3</sub>	60	<b>3j</b>	60

<sup>a</sup>Stirring without ultrasound

in the absence of the phase-transfer catalyst. It was found that practically no reaction was observed after 30 min with or without ultrasound. It is clear that the phase-transfer catalyst plays a significant role for the etherification.

A problem dealing with syntheses involving immiscible liquids (e.g. aqueous/organic mixtures) is that the reagents are often dissolved in different phases. Any reaction between these species can only occur in the interfacial region between the liquids. The chemical effects of sonication arise from acoustic cavitation, namely the formation, growth and implosive collapse of bubbles in a liquid, which produces unusual chemical and physical environments. The collapse of bubbles generates localized “hot spots” with transient high temperature and pressures. The cavitation collapse at or near the interface disrupts it and impels jets of one liquid into the other, and facilitate the contact of substrates to reagent molecules [25]. Phase-transfer catalyst can transfer activated hydroxide ion from aqueous phase to organic phase and reacts with oxime to form oxygen anion of oxime, which can make an attack on benzyl bromide rapidly [30]. The synergistic effect of phase-transfer catalyst and ultrasound may have led to improved performance within a short time, giving the product in a high yield.

In general, the reaction of oxime with activated alkyl halide can form N-alkyl (**5**) and O-alkyl products (**6**). The ratio (**5**/**6**) relates to the configuration and steric hindrance of the oximes. There are two nucleophilic centers including oxygen and nitrogen atom in the oxime anion (**4**), which can react with RBr *via* S<sub>N</sub>2 mechanisms to form products. In the *Z*-oxime, the steric factors of the aryl group plays a role in making the S<sub>N</sub>2 mechanism difficult for the oxygen atom, and so the N-alkyl product **5** is obtained preferentially. In contrast, for the *E*-oxime, O-alkyl product **6** is the major product [35]. In the present procedure, only O-alkylated products were obtained, no N-alkyl product was



**Scheme 2** Formation of N-alkyl and O-benzyl product

found. It indicates that the O-benylation of the aromatic aldoximes are regioselective (Scheme 2).

## 4 Conclusion

In conclusion, we have found an efficient and convenient procedure for the preparation of O-benzyl oximes via the reaction of oximes with benzyl bromide in the presence of aqueous sodium hydroxide solution catalyzed by benzyl-dimethyltetradecylammoniumchloride under ultrasonication. In comparison, the main advantages of the present system are mild conditions, high yields and a shorter reaction period.

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## References

- Song B A, Liu X H, Yang S, Hu D Y, Jin L H, Zhang Y T. Recent advance in synthesis and biological activity of oxime derivatives. *Chin J Org Chem*, 2005, 25 (5): 507–525 (in Chinese)
- Grieco P A. *Organic Synthesis in Water*. London: Blackie Academic and Professional, 1998
- Li C J. Organic reactions in aqueous media—with a focus on carbon-carbon bond formation. *Chem Rev*, 1993, 93 (6): 2023–2035
- Li C J. Organic reactions in aqueous media with a focus on carbon-carbon bond formations: a decade update. *Chem Rev*, 2005, 105 (8): 3095–3166
- Rideout D C, Breslow R. Hydrophobic acceleration of Diels-Alder reactions. *J Am Chem Soc*, 1980, 102 (26): 7816–7817
- Breslow R, Maitra U, Rideout D. Selective Diels-Alder reactions in aqueous solutions and suspensions. *Tetrahedron Lett*, 1983, 24 (18): 1901–1904
- Eggelte T A, De Koning H, Huisman H O. Diels-Alder reaction of furan with some dienophiles. *Tetrahedron*, 1973, 29 (16): 2491–2493
- Amantini D, Fringuelli F, Piermatti O, Pizzo F, Vaccaro L. 3-Nitrocoumarins as dienophiles in the Diels-Alder reaction in water. An approach to the synthesis of nitrotetrahydrobenzo[c]chromenones and dihydrodibenzo[b,d]furans. *J Org Chem*, 2003, 68 (24): 9263–9268
- Gajewski J J, Jurayj J, Kimbrough D R, Grande M E, Ganem B, Carpenter B K. The mechanism of rearrangement of chorismic acid and related compounds. *J Am Chem Soc*, 1987, 109 (4): 1170–1186
- Brandes E, Grieco P A, Gajewski J J. Effect of polar solvents on the rates of Claisen rearrangements: assessment of ionic character. *J Org Chem*, 1989, 54 (3): 515–516
- Grieco P A, Brandes E B, Mc Cann S, Clark J D. Water as a solvent for the Claisen rearrangement: practical implications for synthetic organic chemistry. *J Org Chem*, 1989, 54 (25): 5849–5851
- Severance D L, Jorgensen W L. Effects of hydration on the Claisen rearrangement of allyl vinyl ether from computer simulations. *J Am Chem Soc*, 1992, 114 (27): 10966–10968
- Gao J. Combined QM/MM simulation study of the Claisen rearrangement of allyl vinyl ether in aqueous solution. *J Am Chem Soc*, 1994, 116 (4): 1563–1564
- Gajewski J J, Brichford N L. Secondary deuterium kinetic isotope effects in the aqueous claisen rearrangement: evidence against an ionic transition state. *J Am Chem Soc*, 1994, 116 (6): 3165–3166
- Lubineau A. Water-promoted organic reactions: aldol reaction under neutral conditions. *J Org Chem*, 1986, 51 (11): 2142–2144
- Lubineau A, Meyer E. Water-promoted organic reactions. aldol reaction of silyl enol ethers with carbonyl compounds under atmospheric pressure and neutral conditions. *Tetrahedron*, 1988, 44 (19): 6065–6070
- Keller E, Feringa B L. Ytterbium triflate catalyzed Michael additions of  $\beta$ -ketoesters in water. *Tetrahedron Lett*, 1996, 37 (11): 1879–1882
- Manabe K, Mori Y, Kobayashi S. Effects of Lewis acid-surfactant-combined catalysts on aldol and Diels-Alder reactions in water. *Tetrahedron*, 1999, 55 (37): 11203–11208
- Meijer A, Otto S, Engberts J B F N. Effects of the hydrophobicity of the reactants on Diels-Alder reactions in water. *J Org Chem*, 1998, 63 (24): 8989–8994
- Li C J, Chan T H. *Organic Reactions in Aqueous Media*, New York: Wiley, 1997
- Fringuelli F, Pizzo F, Vaccaro L. Azidolysis of  $\alpha$ ,  $\beta$ -epoxycarboxylic acids. A water-promoted process efficiently catalyzed by indium trichloride at pH 4.0. *J Org Chem*, 2001, 66 (10): 3554–3558
- Amantini D, Fringuelli F, Pizzo F, Vaccaro L. Bromolysis and iodolysis of  $\alpha$ ,  $\beta$ -epoxycarboxylic acids in water catalyzed by indium halides. *J Org Chem*, 2001, 66 (13): 4463–4467
- Jin T S, Xiao J C, Wang S J, Li T S, Song X R. An efficient and convenient approach to the synthesis of benzopyrans by a three-component coupling of one-pot reaction. *Synlett*, 2003, 13: 2001–2004
- Fan R L, Xu C N. *Phase Transfer Catalysis in Organic Chemistry*, Shanghai: Shanghai Scientific & Technical Publishers, 1982 (in Chinese)
- Mason T J, Peters D. *Practical Sonochemistry*, second ed., London: Ellis Horwood, 2002
- Li J T, Wang S X, Chen G F, Li T S. Some applications of ultrasound in organic synthesis. *Curr Org Synth*, 2005, 2 (3): 415–436
- Polackova V, Tomova V, Elecko P, Toma S. Ultrasound-promoted

- Cannizzaro reaction under phase-transfer conditions. *Ultrason Sonochem*, 1996, 3 (1): 15–17
28. Bhathkhande B S, Samant S D. Ultrasound assisted PTC catalyzed saponification of vegetable oils using aqueous alkali. *Ultrason Sonochem*, 1998, 5 (1): 7–12
29. Davidson R S, Patel A M, Safdar A, Thornthwaite D. The application of ultrasound to the n-alkylation of amines using phase transfer catalysis. *Tetrahedron Lett*, 1983, 24 (52): 5907–5910
30. Entezari M H, Shameli A A. Phase-transfer catalysis and ultrasonic waves I. Cannizzaro reaction. *Ultrason Sonochem*, 2000, 7 (4): 169–172
31. Li J T, Li X L. An efficient and practical synthesis of methylene dioximes by combination of ultrasound and phase transfer catalyst. *Ultrason Sonochem*, 2007, 14 (6): 677–679
32. Liu A P, Liu X P, Chen C, Liu Z J, Yao J R. Synthesis and biological activity of oxime-ethers. *Journal of Central China Normal University (Nat Sci)*, 2004, 38 (1): 66–68,75 (in Chinese)
33. Li J T, Li X L, Li T S. Synthesis of oximes under ultrasound irradiation. *Ultrason Sonochem*, 2006, 13 (3): 200–202
34. Li J T, Li X L, Li T S. Synthesis of aldoximes in aqueous solution under ultrasound irradiation. *Chin J Org Chem*, 2006, 26 (11): 1594–1596 (in Chinese)
35. Chen Q H, Wang X L, Meng M. Alkylation of some aromatic aldoximes. *Chem J Chin Univ*, 1987, 8 (10): 911–913 (in Chinese)