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Efficient Synthesis of Tolunitriles by Selective Ammoxidation

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Efficient Synthesis of Tolunitriles by Selective Ammoxidation

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ABSTRACT

Tolunitriles have been efficiently synthesized by selective ammoxidation of methylbenzyl chlorides prepared with chlorination of xylenes. In comparison with ammoxidation of xylenes themselves, the reaction temperature of ammoxidation of methylbenzyl chlorides has been lowered more than 100° C and the selectivity forming mono-nitriles is almost 100%.

Key Words: Selective ammoxidation; Tolunitrile.

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As important synthetic intermediates, tolunitriles can be converted into methylbenzamides,^[1,2] methylbenzoic acids,^[3] cyanobenzoic acids,^[4] methylbenzylamines^[5] and so on, from which many pharmaceuticals, dyes, fluorescence whitener and other fine chemicals can be produced.^[6,7]

The traditional synthesis routes of tolunitriles are: dehydration of amide^[8] or aldoxime,^[9] cyanation of aryl chloride^[10] or toluic acid,^[11] diazotization of methylbenzamine^[12] and so on. These methods usually need expensive starting materials or cause serious pollution. The method prepared from ammoxidation of xylenes can overcome the shortcomings mentioned above, but the yield and selectivity forming tolunitriles is very low.^[13] Because two methyl groups in xylenes are identical, and the reaction temperature of ammoxidation of xylenes is usually about 400°C to activate methyl group in the ring, it is difficult for only one methyl to be converted to cyano group. The yields and selectivity to obtain tolunitriles are very low. Angstadt^[13] invented a kind of new catalysts for ammoxidation of *p*-xylene. According to his report, when the temperature was over 400° C, the selectivity forming tolunitrile reached 63.9%, but the conversion of p-xylene was only 42.4% and the portion of dinitrile in products was 30.9%. The products are difficult to be separated. In order to improve the yields and selectivity forming mono-nitriles, Shik et al. attempted to prepare mono-nitriles by liquid phase ammoxidation of xylenes in 1980s.^[14] Though Shik claimed that the yield and selectivity of p-tolunitrile reached 73% and 78% respectively, resent papers^[6,7] reported that the result was not so good.

Recently we have found an effective method to synthesize tolunitriles by selective ammoxidation. First xylenes are chlorinated to methylbenzyl chlorides to make two methyl groups different, then the intermediates are ammoxidized to tolunitriles.

The routes of ammoxidation of xylenes and methylbenzyl chlorides are shown as Sch. 1.



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After one methyl of the xylenes was chlorinated, the ammoxidation of methylbenzyl chloride could be carried out on VCrO/SiO₂ catalyst,^[15,16] which exerts good catalytic activity at relatively low temperature. In practice the reaction took place at the temperature near the boiling point of methylbenzyl chloride (ca. 200°C). The reaction temperature has reduced for more than 100°C in comparison with the situation in the ammoxidation of xylenes themselves, therefore the selectivity forming mono-nitriles can be increased remarkably. It is well known that in the ammoxidation of xylenes or other methylaromatics, H-extraction of methyl, forming benzyl species, is the control step of the reaction. In the case of ammoxidation of methylbenzyl chloride, the benzyl species needed can be formed by the cleavage of C-Cl bond. The bond energy of C-Cl (339 kJ mol⁻¹) in chloromethyl group is less than the bond energy of C-H (414 kJ mol^{-1}) in methyl group.^[17] The former cleaves more easily and the activation energy of reaction would be decreased. So after one H is displaced by chlorine in the chain methyl of xylenes, the ammoxidation reaction becomes milder. The relatively lower temperature of reaction guarantees the high selectivity to obtain mononitriles with high yield.

EXPERIMENTAL

Xylenes and reagents from which catalysts were prepared were analytically or chemically pure. Products were characterized by ¹H NMR and IR spectra. The ¹H NMR spectrum was measured on a FX-90Q ¹H NMR spectrometer with (CH₃)₄Si as internal standard. The IR spectrum was recorded on an AVATAR 380 infrared spectrophotometer. The melting points were determined with a X6 microscopic warming apparatus (the thermometer was not calibrated). The purity of products was tested with SP-502 gas chromatograph.

CHLORINATION OF XYLENES

Two hundred millliter *p*-xylene was added in an equipment according as the literature.^[18] The temperature was raised to make xylene reflux violently, then Cl₂ (about 40 g h⁻¹) was passed through the reaction zone under UV light. The reaction process was monitored by GC. After 2 h, the conversion of *p*-xylene reached 90.3%. The chlorination was ceased. The product was shifted into a 500 mL flask for vacuum rectifying. The product was collected (100–102°C/10 mm Hg), obtaining 192.8 g PMBC (yield 83.6% with purity 98% by GC).

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Table 1. The results of chlorination of xylenes and ammoxidation of corresponding methylbenzyl chlorides.

	Chlorination			Ammoxidation				Total
isomer	Conversion (%)	Yield (%)	Purity (%)	Conversion (%)	Yield (%)	Selectivity (%)	Purity (%)	yield (%)
0-	87.6	81.8	98.2	97.5	95.8	98.3	97.7	78.4
<i>m</i> -	86.5	78.9	97.6	97.8	96.2	98.4	97.9	75.9
<i>p</i> -	90.3	83.6	98.0	98.2	97.0	98.8	98.3	81.1

Similarly the *o*- and *m*-methylbenzyl chlorides were synthesized. The conversions, yields and purity are shown as Table 1.

Preparation of Tolunitriles by Selective Ammoxidation

The experiment was carried out in a 30 mm-inside-diameter quartz tube fixed-bed reactor^[19] loaded 10 g 10 wt.% VCrO/SiO₂ catalyst. PMBC was vaporized, then mixed with Air and NH₃. The mixed gas was preheated, and then passed through the reactor. The reaction temperature was controlled at $210 \pm 2^{\circ}$ C. PMBC was entered 0.6 mL per hour by a micropump. The molar ratio of air/PMBC and NH₃/PMBC were 25 and 5, respectively. After reaction, the product was cooled and condensed in a condensing apparatus. White solid (at r.t. 5°C) was obtained after rushing, filtering and drying under vacuum. The reaction can be carried out continuously. The condensing apparatus was altered every 8 h. The test lasted nearly 80 h. 4.12 g *p*-methylbenzonitrile per 8 h was obtained, yield: 97%. M.p.: 25–27°C. The purity was 98.3% by GC. The product was confirmed by IR and ¹H NMR compared with the Sadtler Standard Spectra.

The *o*- or *m*-tolunitrile were prepared by ammoxidation of *o*- or *m*-methylbenzyl chloride as the same method, except the products are liquid. The conversion of xylenes, the yields, selectivity and purity of tolunitriles are also shown as Table 1.

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