Chinese Journal of Catalysis 36 (2015) 204–208

available at www.sciencedirect.com

ScienceDirect

journal homepage: www.elsevier.com/locate/chnjc

Article

Simple primary amine catalyzed aerobic reductive ring-cleavage of isoxazole motif

Zhongkui Zhao *, Renzhi Li, Yu Li, Guiru Wang

State Key Laboratory of Fine Chemicals, Department of Catalysis Chemistry and Engineering, School of Chemical Engineering, Dalian University of Technology, Dalian 116024, Liaoning, China

ARTICLE INFO

Article history:
Received 25 June 2014
Accepted 18 July 2014
Published 20 February 2015

Keywords:
Organocatalysis
Simple primary amine
Aerobic reductive ring cleavage
1-Amino-2-acetyl anthraquinone
Green chemistry

ABSTRACT

A clean and highly efficient catalytic aerobic reductive ring-cleavage of 3-methylanthra[1,2-*c*]isoxazole-6,11-dione to 1-amino-2-acetylanthraquinone was performed using simple organic amines as organocatalysts and water as a green reaction medium. This method provides a new clean transformation of isoxazole-containing compounds to the corresponding *ortho*-amino ketones. The catalytic performance of various organic amines was carefully screened, and simple organic primary amines were found to be promising practical catalysts with outstanding catalytic performance. Isopropylamine as the organocatalyst gave 97.2% conversion of 3-methylanthra[1,2-*c*]isoxazole-6,11-dione, with 97.2% selectivity to 1-amino-2-acetylanthraquinone, in the presence of oxygen only, using 1 equiv. of hydrazine hydrate at room temperature for 3 h. A possible mechanism is also proposed.

1. Introduction

ortho-Amino ketones, a series of important organic intermediates, are widely used in the dye, pigment, medical, and petrochemical fields [1–3]. Recently, the preparation of *ortho*-amino ketones has attracted much attention. The synthesis of this type of amino ketone via ring cleavage of an isoxazole motif is an efficient strategy, e.g., for the synthesis of 1-amino-2-acetylanthraquinone for Vat blue 66 [4].

Stoichiometric reduction processes have generally been used in the synthesis of *ortho*-amino ketones, with ferrous sulfate [5], sodium hydrosulfite [6], $Mo(CO)_6$ [7], CuI [8], EtMgBr/Ti(O*i*-Pr) [9], or sodium [10] as reducing agents. However, large amounts of chemical reagents are required, and large amounts of wastes are produced. The heavy pollution caused by this process is inconsistent with the increasing demands of green chemistry. The search for a clean and efficient method for reductive cleavage under mild reaction conditions is therefore important. Electron-transfer reactions by AlI_3 [11], iron dichloride [12–14], $TiCl_3$ [15], SmI_2 [16,17] or iodotrimethylsilane [18,19] are feasible alternative strategies for isoxazole cleavage, but stringent anhydrous conditions are essential, and heavy pollution cannot be avoided. The development of clean methods for synthesizing *ortho*-amino ketones such as 1-amino-2-acetylanthraquinone, an important dye intermediate, is therefore desirable.

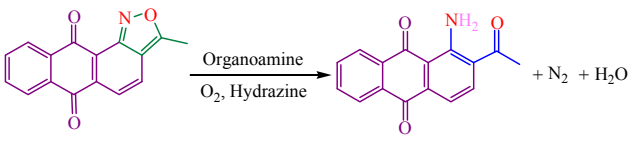
To overcome the above issues, catalytic hydrogenation, which is a clean method, has been used in the ring-cleavage of isoxazole motifs for the production of *ortho*-amino ketone derivatives. Precious metals such as palladium or platinum [20–23] and non-precious metals such as Raney nickel efficiently catalyze the production of various isoxazole motifs [24].

* Corresponding author. Fax: +86-411-84986354; E-mail: zkzhao@dlut.edu.cn
This work was supported by the Chinese Ministry of Education via the Program for New Century Excellent Talents in University (NCET-12-0079) and the Fundamental Research Funds for the Central Universities (DUT12LK51).
DOI: 10.1016/S1872-2067(14)60200-X | http://www.sciencedirect.com/science/journal/18722067 | Chin. J. Catal., Vol. 36, No. 2, February 2015

The high costs and poor availability of precious metals limit their extensive use, and careful handling and finely controlled reaction conditions are required if Raney nickel is used. We previously demonstrated that copper can efficiently catalyze this reaction for the clean synthesis of *ortho*-amino ketones, including 1-amino-2-acetylanthraquinone [25]. However, the problem of pollution by residual transition metals still needs to be resolved. The search for metal-free highly efficient catalysts for catalytic hydrogenation reactions for *ortho*-amino ketone production is therefore important.

Organocatalysis, or the use of small organic molecules to catalyze organic transformations, is a relatively new and popular research field. Although chemical transformations that use organocatalysts have been documented sporadically over the past century, it was not until the late 1990s that the field of organocatalysis was born, based on a small number of articles that inspired an explosion of research. Between 1998 and 2008, the field of organocatalysis grew rapidly, and at least 1500 papers describing the use of organocatalysts in more than 130 discrete reaction types were published [25,26]. Organocatalytic methods have also been used in hydrogenations [27–29] and ring-opening reactions [30]. In our previous research [31], dimethyl formamide (DMF)-promoted ring-opening reactions of 3-methylanthra[1,2-*c*]isoxazole-6,11-dione to 1-amino2-acetylanthraquinone were established. However, a large amount of DMF, which is poisonous, and excess hydrazine are required to obtain a good catalytic performance. The development of more efficient organocatalysts, with water as a clean solvent, is an increasingly important goal for chemists, for both economic and environmental reasons. Simple and complex organic amines are popular organocatalysts, and have been extensively used in many transformations, with excellent results [32–34]. However, the catalytic performance of organic amines in ring cleavage of isoxazole-containing compounds to produce the corresponding *ortho*-amino ketones has not been investigated.

In this study, using the ring cleavage of 3-methylanthra[1,2-*c*]isoxazole-6,11-dione to produce 1-amino-2-acetylanthraquinone as a model reaction (Scheme 1), we explored the possibility of using simple amines as organocatalysts for the ring cleavage of isoxazole motifs to produce the corresponding *ortho*-amino ketones. The aim of the present work is to construct a clean and efficient strategy for the synthesis of 1-amino-2-acetylanthraquinone via a ring-opening route, by the reduction of 3-methylanthra[1,2-*c*]isoxazole-6,11-dione in the presence of organocatalysts. An excellent catalytic performance was achieved using isopropylamine as the catalyst, and 97.2% 3-methylanthra[1,2-*c*]isoxazole-6,11-dione conversion, with 97.2% 1-amino-2-acetylanthraquinone selectivity, was achieved. It has been shown [27] that oxygen is important in guanidine-catalyzed selective hydrogenation of olefins using aqueous hydrazine as the reducing reagent; we therefore thought that oxygen in the air could be used in the amine-catalyzed reductive ring-cleavage of 3-methylanthra[1,2-*c*] isoxazole-6,11-dione. A possible mechanism for the highly efficient amine-catalyzed transformation in the presence of air is also proposed. The organic-amine-catalyzed aerobic reductive ring-cleavage of 3-methylanthra[1,2-*c*]isoxazole-6,11-dione can be extended to other isoxazole-containing compounds to produce the corresponding *ortho*-amino ketones.



Scheme 1. Synthesis of 1-amino-2-acetylanthraquinone.

2. Experimental

2.1. Materials and instruments

All reagents were purchased from Aladdin and were used without further purification. ^{1}H nuclear magnetic resonance (NMR) spectroscopy was performed using a Bruker Avance 400M instrument at room temperature, with tetramethylsilane as the internal standard; coupling constants (*J*) were measured in hertz; mass spectrometry (MS) was performed using an HP1100LC/MSD instrument.

2.2. Catalytic performance measurement

In a typical experimental procedure, 3-methylanthra[1,2-*c*]isoxazole-6,11-dione was placed in a 25 mL one-necked round-bottomed flask, and deionized water (3.0 mL, a green reaction medium) and an appropriate amount of isopropylamine were introduced. The reaction mixture was stirred at room temperature for 30 min to obtain good dispersion, and the desired amount of hydrazine hydrate was then added, with continuous stirring. The mixture was continuously stirred for the desired reaction time. The product was insoluble in water, and was easily separated by filtration. After the reaction, the mixture was filtered, and the solid product was washed with deionized water and dried at 105 °C overnight. The product was quantitatively analyzed using high-performance liquid chromatography (HPLC). The conversion was calculated, based on the HPLC results, as the ratio of the consumed amount to the total amount of 3-methylanthra[1,2-*c*]isoxazole-6,11-dione, expressed as a percentage. The product was characterized using ^{1}H NMR and MS spectroscopies. Characterization results: red powder, mp 222–226 °C; ^{1}H NMR ($CDCl_3$): δ 2.68 (3H, s, CH_3), 7.55 (1H, d), 7.72–7.83 (2H, t), 8.16 (1H, d), 8.23–8.32 (2H, d), 9.51, and 9.92 (2H, s, NH_2); MS (APCI, *m*/*z*) for 1-amino-2-acetylanthraquinone [*M* +1] = 266.

3. Results and discussion

3.1. Effect of type of organic amine

The molecular structure of the product obtained via organic-amine-catalyzed ring-cleavage of 3-methylanthra[1,2-*c*] isoxazole-6,11-dione was determined using ^{1}H NMR and MS spectroscopies. The results confirm that the molecular structure is 1-amino-2-acetylanthraquinone, i.e., the desired product was successfully obtained using organic-amine-catalyzed