



Digest paper

Recent advances in aerobic oxidation with ruthenium catalysts



Subramaniam Muthusamy^a, Nandarapu Kumarswamyreddy^a, Venkitasamy Kesavan^{a,*},
Srinivasan Chandrasekaran^{b,*}

^a Department of Biotechnology, Bhupat & Jyothi Mehta School of Biosciences, Indian Institute of Technology Madras, Chennai 600036, India

^b Department of Organic Chemistry, Indian Institute of Science, Bangalore 560012, India

ARTICLE INFO

Article history:

Received 16 August 2016

Revised 2 November 2016

Accepted 5 November 2016

Available online 8 November 2016

Keywords:

Aerobic oxidation

Ruthenium catalyzed oxidation

C–H activation/annulation

Alcohol oxidation

Amine oxidation

ABSTRACT

Oxidation reactions are significant transformations used extensively in chemical production. Use of molecular oxygen as an oxidant is certainly environmental friendly and adds to the greenness of the process. A number of metal catalysts have been developed for aerobic oxidation. This digest summarizes the recent advances in aerobic oxidation reactions using ruthenium catalysts for various transformations such as C–H activation/cyclization, alkyne/alkene oxidation, and oxidation of alcohols and amines.

© 2016 Elsevier Ltd. All rights reserved.

Contents

Introduction	5551
Oxidative cyclization of alkynes	5552
Oxidative <i>ortho</i> C–H alkenylation	5552
Synthesis of 1,2-diketones	5553
C–N coupling	5553
Oxidation of 5-hydroxymethylfurfural	5554
Aerobic oxidation of alcohols	5555
Oxidation of amines	5556
Miscellaneous reactions	5558
Conclusion	5558
Acknowledgments	5558
References	5558

Introduction

Oxidation reactions are ubiquitous tool in synthetic organic chemistry for a wide range of transformations used in the synthesis of pharmaceuticals and fine chemicals.^{1–3} Classical methods of oxidation employ stoichiometric amount of oxidants based on manganese, chromium and hypervalent halogens.^{4,5} Despite their ability to oxidize a wide array of functional groups these oxidants

have various limitations such as associated toxicity, atom inefficiency, potentially explosive nature and generation of inorganic wastes. Consequently, synthetic chemists have devoted considerable efforts to develop elegant methods of oxidation involving greener chemical processes utilizing molecular oxygen as an oxidant.⁶ A broad range of non-noble, biocompatible metals such as copper,^{7–9} cobalt,¹⁰ palladium^{11,12} and iron¹³ have been used as catalysts under aerobic conditions. The utility of these aerobic oxidation reactions, prompted synthetic chemists to explore sustainable and efficient protocols which can replace unsafe oxidation processes.

* Corresponding authors.

E-mail address: scn@orgchem.iisc.ernet.in (S. Chandrasekaran).

Ruthenium based catalysts have emerged as effective catalysts for oxidative cyclization of alkynes, oxidative ortho C–H alkenylation, C–N coupling and oxidation of alcohol under aerobic conditions. In general, ruthenium catalyzed oxidation has been carried out with wide variety of ligands.^{5,6,14,15} Ruⁿ species is oxidized by either molecular oxygen or co-catalyst to form a labile Ruⁿ⁺² oxo species which is the active oxidant, leading to oxidation of the organic substrate.

In this review, we wish to focus on various oxidative transformations reported in the last five years involving ruthenium complexes using molecular oxygen/air as an oxidant.

Oxidative cyclization of alkynes

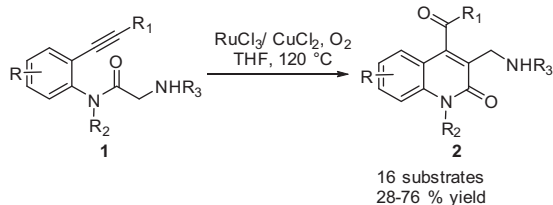
Coumarins and pyrroles are indispensable structural motifs present in bioactive natural products, potent pharmaceuticals and various functional materials.

Efficient synthesis of these structural motifs is of great interest to synthetic chemists. Rhodium catalysts played pivotal role in oxidative annulation reactions of alkynes by C–H bond cleavage. These synthetic methods had set the stage for environmentally benign syntheses of polycyclic heteroarenes. However, employment of significantly less expensive ruthenium complexes is desirable.

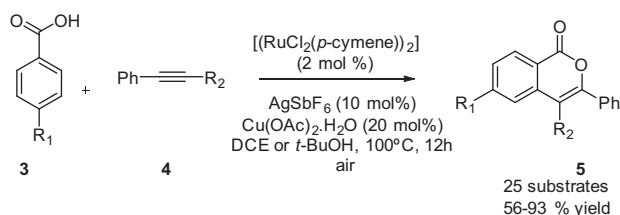
Though ruthenium has been widely used as catalyst for various cyclization reactions,¹⁶ activating sp³ C–H bond to achieve oxidative annulation reaction with alkyne was not known until early 2011. Li et al. developed the synthesis of quinolinones **2** via intramolecular carbocyclization strategy using RuCl₃/CuCl₂ as catalyst in the presence of molecular oxygen and this is the first example of sp³ C–H activation/cyclization with alkynes for a wide range of substrates (Scheme 1).¹⁷

In 2012 Jeganmohan reported Ru(II) catalyzed oxidative cyclization of aryl substituted carboxylic acids **3** with alkynes **4** to afford isocoumarins **5** regioselectively (Scheme 2).¹⁸ Earlier syntheses of these scaffolds involved the use of rhodium catalyst that gave rise to regioisomeric products and decarboxylative cyclization.^{19,20} These difficulties could be overcome with ruthenium and silver catalysts that gave single regioisomeric product. However these methods required elevated temperature, additives and oxidants.

To mitigate the drawbacks of the above methods Ackermann et al. reported oxidative alkyne annulation using ruthenium (II) complex and molecular oxygen in the absence of any co-oxidant



Scheme 1. Synthesis of quinolinones via carbocyclization.



Scheme 2. Synthesis of isocoumarins.

at 45 °C (Scheme 2).²¹ This method was applicable to a wide variety of substituted aromatic and hetero aromatic carboxylic acids (25 substrates) which afforded the corresponding isocoumarins in excellent yield (up to 95%).

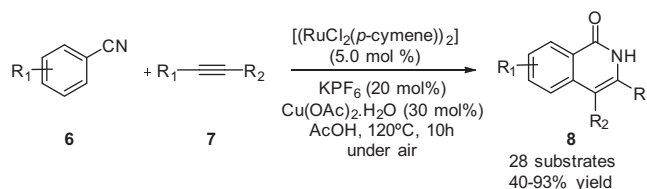
Biologically important isoquinolones **8** were obtained by treating readily available aromatic and hetero aromatic nitriles **6** with alkynes **7** in the presence of [(RuCl₂(*p*-cymene))₂], Cu(OAc)₂·H₂O and air (Scheme 3).²² This co-operative catalysis by ruthenium and copper species enabled aerobic oxidative cyclization of aromatic and hetero aromatic nitriles with alkynes to provide isoquinolones in fair to good yields.

Diversely substituted *N*-fused polycyclic heteroarenes **10** were synthesized from dihydroquinozolinones **9** and alkynes **7** using Ru(II) via oxidative dehydrogenation followed by cross coupling/cyclization (Scheme 4).²³ These nitrogen containing polycyclic heteroarenes are privileged scaffolds because of their presence in many natural products. This transformation displayed high level of functional group tolerance. The reaction led to regioisomers when unsymmetrical alkynes were used.

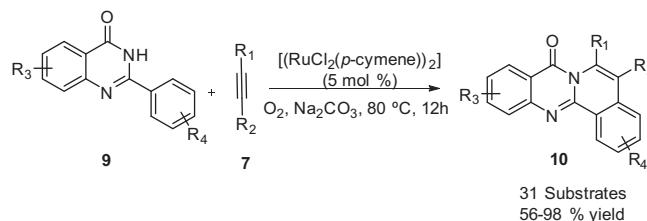
Earlier using the same catalyst Ackermann achieved the aerobic oxidative cyclization of 2-aryl indoles and pyrroles with alkynes under aerobic conditions (Scheme 5).²⁴ This unprecedented methodology enabled the conversion of disubstituted alkynes **7** to nitrogen-containing polycyclic systems **12** in fair to excellent yields. (Scheme 5).

Oxidative ortho C–H alkenylation

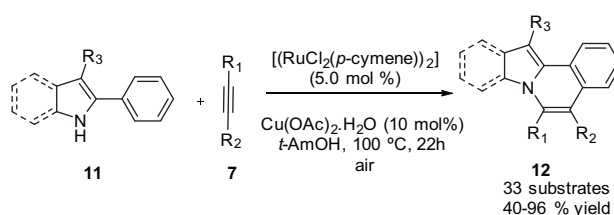
Highly atom economical synthesis of substituted olefins could be achieved via C–H bond activation followed by alkenylation at ortho position of aromatic rings. The first C–H alkenylation of electron rich aromatics and alkenes was achieved via electrophilic



Scheme 3. Synthesis of isoquinolones.



Scheme 4. Aerobic oxidative cross coupling/cyclization to *N*-fused polycyclic heteroarenes.



Scheme 5. Aerobic oxidative cyclization of 2-aryl indoles.

Download English Version:

<https://daneshyari.com/en/article/5265892>

Download Persian Version:

<https://daneshyari.com/article/5265892>

[Daneshyari.com](https://daneshyari.com)