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A mild and highly efficient Friedländer synthesis of quinolines in the presence of heterogeneous solid acid nano-catalyst

Abbas Teimouri [a,*], **Alireza Najafi Chermahini** [b]

[a] *Chemistry Department, Payame Noor University, 19395-4697, Tehran, Iran*
[b] *Department of Chemistry, Faculty of Science, Yasouj University, Yasouj, P.O. Box 75918-74831, Iran*

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Abstract A simple highly versatile and efficient synthesis of various poly-substituted quinolines in the Friedländer condensation of 2-aminoarylketones with carbonyl compounds and β-keto esters using Montmorrilonite K-10, zeolite, nano-crystalline sulfated zirconia (SZ) as a catalyst in ethanol at moderate temperature. The advantages of methods are short reaction times and milder conditions, easy work-up and purification of products by non-chromatographic methods. The catalysts can be recovered for the subsequent reactions and reused without any appreciable loss of efficiency.

1. Introduction

Quinoline is a well-known structural unit in alkaloids and their derivatives are very important compounds that show a broad range of biological and pharmaceutical activities such as antagonists (Bennacef et al., 2007), analgesic agents (Gopalsamy and Pallai, 1997), $5HT_3$ (Anzini et al., 1995), NK-3 receptors (Giardian et al., 1997), anti-malarial (Larsen et al., 1996; Chauhan and Srivastava, 2001), antitumor (Myers et al., 1997; Comins et al., 1994; Shen et al., 1993), anti-inflammatory (Roma et al., 2000), anti-bacterial (Chen et al., 2001), anti-asthmatic (Dube et al., 1998), anti-hypertensive (Ferrarini et al., 2000) and anti-platelet agents, and as tyrosine kinase inhibiting agents. (Larsen et al., 1996; Kalluraya and Sreenivasa, 1998). In addition, quinolines are valuable synthons used in a variety of nano-structures and meso-structures with enhanced electronic and photonic functions (Agarwal and Jenekhe, 1991; Zhang et al., 2000; Jenekhe et al., 2001). Moreover, quinolines are advantageously employed in the fields of natural products (Larsen et al., 1996; Chauhan and Srivastava, 2001), bioorganic (Saito et al., 2001), bioorganometallic processes (He and Lippard, 2001; Nakatani et al., 2000) and industrial organic chemistries (Jenekhe et al., 2001). Because of their importance as substructures in a broad

* Corresponding author. Address: Department of Chemistry, Payame Noor University (PNU), Isfahan, P.O. Box 81395-671, Iran. Tel.: +98 311 35218046; fax: +98 311 3521802.
E-mail addresses: a_teimoory@yahoo.com, a_teimouri@pnu.ac.ir (A. Teimouri).

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range of natural and designed products, significant effort continues to be directed into the development of new quinoline based structures (Hoemann et al., 2000) and new methods for their construction (Du and Curran, 2003; Lindsay et al., 2002; Dormer et al., 2003). Various methods such as Skraup, Doebner von Miller, Friedländer, Pfitzinger, Conrad-Limpach, and Combes methods have been developed for the preparation of quinoline derivatives (Abass, 2005; Kouznetsov et al., 2005; Jones et al., 1996; Skraup, 1880; Friedländer, 1882; Mansake and Kulka, 1953; Arisawa et al., 2001). Among them, the Friedländer annulation (Marco-Contelles et al., 2009) appears to be still one of the most simple and straightforward approaches for the synthesis of quinolines. This method involves the acid or base catalyzed or thermal condensation between a 2-aminoaryl ketone and an other carbonyl compound possessing a reactive α-methylene group followed by cyclodehydration.

Brønsted acids catalysts, such as sulfamic acid, hydrochloric acid, sulfuric acid, *p*-toluene sulfonic acid, PEG-supported sulfonic acid, propylsulfonic silica, sulfonic acid-functionalized ionic liquids, oxalic acid, dodecylphosphonic acid (DPA) and o-benzenedisulfonimide were widely used for Friedländer annulation (Yadav et al., 2005; Wang et al., 2006; Strekowski et al., 2000; Zhang et al., 2009; Akbari et al., 2010; Dabiri et al., 2007; Barbero et al., 2010). Lewis acids such as $FeCl_3$, $ZnCl_2$, $SnCl_2$, $CuSO_4{\cdot}5H_2O$, $FeSO_4{\cdot}7H_2O$, $AuCl_3$, $CeCl_3{\cdot}7H_2O$, $Zr(NO_3)_4$ or $Zr(HSO_4)_4$, $GdCl_3{\cdot}6H_2O$, $BiCl_3$, $Yb(PFO)_3$, $Bi(OTf)_3$, $Sc(OTf)_3$, $Y(OTf)_3$, I_2, NaF, TMSCl, Sulfonated cellulose starch, Silica supported perchloric acid ($HClO_4$–SiO_2), $NaHSO_4$–SiO_2, H_2SO_4–SiO_2, Amberlyst-15 and $HClO_4$–SiO_2 have also recently been utilized for this synthesis (Das et al., 2007; Narasimhulu et al., 2007; Zolfigol et al., 2007; Prabhakar Reddy et al., 2008; Jia and Wang, 2006; Wang et al., 2009; Shaabani et al., 2008).

However, most of the earlier methods are associated with different disadvantages such as harsh reaction conditions, long reaction times, harmful organic solvents, low yields, and difficulties in the work-up procedures. The recovery of the catalyst is also a problem. Although different methods are available for the synthesis of quinolines, the development of an easy and efficient method for the preparation of quinoline derivatives is still a challenging task. Thus, the development of simple, convenient, and environmentally benign methods for the synthesis of quinolines is still required. For these reasons, the use of solid and heterogeneous catalysts in organic reactions in aqueous media and solvent-free conditions has drawn the attention of chemists for the Friedländer quinoline synthesis.

In the recent years, the use of heterogeneous catalysts has received considerable interest in organic synthesis (Corma and Garcia, 2003). This extensive application of heterogeneous catalysts in synthetic organic chemistry can make the synthetic process more efficient from both the environmental and economic point of view (Santor et al., 2004) and used-catalyst can be easily recycled. Montmorrilonite clay, enable to function as an efficient solid acid catalyst in organic transformations with excellent product, regio- and stereo-selectivity (Binitha and Sugunan, 2006; Joseph et al., 2005, 2006; Shanbhag and Halligudi, 2004; Albertazzi et al., 2005; Jagtap and Ramaswamy, 2006; Lal et al., 2006; Reddy et al., 2004, 2005, 2007; Sharma et al., 2006).

Nowadays, more and more heterogeneous Bronsted acids, e.g., zeolites are preferred from an economical perspective as well as from an ecological viewpoint. Due to its high protonic acidity and unique shape-selective behavior, HZSM-5, has been shown to be a highly active and stable catalyst for reactions (Marques and Moreira, 2003; Mavrodinova et al., 2003; Corma and Orchilles, 2000; Ingelsten et al., 2005; Zhao et al., 2006; Thomas, 1994; Heravi et al., 2006; Hegedus et al., 2006). Zirconia is attracting considerable interest on account of its potential use as a catalyst support. Recent investigations reveal that promoted zirconia is an exceptionally good solid acid catalyst for various organic synthesis and transformation reactions having enormous industrial applications (Indovina et al., 2002; Pietrogiacomi et al., 2003; Li et al., 2003; Tsyntsarski et al., 2003; Demirci and Garin, 2002).

As a part of our continuing effort toward the development of useful synthetic methodologies (Dabbagh et al., 2007; Najafi Chermahini et al., 2010; 30) herein, we report the synthesis of substituted quinolines from 2-amino acetophenone or benzophenone and α-methylene carbonyl compounds in the presence of heterogeneous solid acid catalysts including Montmorrilonite K-10, zeolite, nano-crystalline sulfated zirconia (SZ) in ethanol under reflux condition.

2. Experimental

2.1. Instruments and characterization

All reagents were purchased from Merck and Aldrich and used without further purification. Products were characterized by spectroscopy data (IR, FTIR, ^{1}H NMR and ^{13}C NMR spectra), elemental analysis (CHN) and melting points. A JASCO FT/IR-680 PLUS spectrometer was used to record IR spectra using KBr pellets. NMR spectra were recorded on a Bruker 400 Ultrasheild NMR and DMSO-d6 was used as solvent. Melting points reported were determined by open capillary method using a Galen Kamp melting point apparatus and are uncorrected. Mass Spectra were recorded on a Shimadzu Gas Chromatograph Mass Spectrometer GCMS-QP5050A/Q P5000 apparatus.

2.2. Catalyst preparation

2.2.1. Synthesis of ZSM-5 and HZSM-5

For synthesis of ZSM-5, hydrated aluminum sulfate and sodium silicate solution were the sources of aluminum and silicon, respectively. The tetrapropylammonium bromide was used as the structure-directing template (Argauer and Landolt, 1972; Dwyer, 1984; Guth, 1992; Choudhary et al., 2002). ZSM-5 zeolite was synthesized according to the procedure described earlier. The solid phase obtained was filtered, washed with distilled water several times, dried at 120 °C for 12 h and then calcined at 550 °C for 6 h and followed by ion exchange with NH_4NO_3 solution (three times). The acid hydrogen form of the compound is prepared by transferring the oven-dried compound to a tube furnace. Heat the ammonium zeolite for 3 h to ensure the thermal decomposition of NH_4^+ ions. Over the course of this process, zeolite should turn from white to brown/black color (Guth, 1992; Choudhary et al., 2002).

2.2.2. Synthesis of sulfated zirconia

Amorphous hydrated zirconia synthesized by hydrolysis of $ZrCl_4$ with a concentrated (25%) solution of ammonia

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