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ORIGINAL ARTICLE

The combined role of heterogeneous catalysis and ultrasonic waves on the facile synthesis of 2,3-dihydroquinazolin-4(1*H*)-ones

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Abstract Pt–MWCNTs nanocomposites are found to be an excellent and efficient catalyst to promote one-pot and three-component coupling reaction of isatoic anhydride, aldehyde and ammonium acetate or primary aromatic amine to produce 2,3-dihydroquinazolin-4(1*H*)-one derivatives under ultrasound irradiation. This novel method has the advantages such as short reaction times, convenient manipulation, excellent yields and the use of effective catalyst.

1. Introduction

Since the first multi-component reaction was reported in 1850 by Strecker [1], this methodology has emerged as an especially attractive synthetic strategy for rapid and efficient synthesis. Since the products are formed in a single synthetic operation, the structural diversity can be achieved simply by varying the reaction components which shows high atom economy and high selectivity [2,3]. 2,3-Dihydro-4(1*H*)-quinazolinones are important bicyclic heterocycles which have emerged as versatile biologically active compounds possessing applications as diuretic [4], antitumor [5], antibacterial [6], anticonvulsant [7] and antihypertensive agents [8]. In addition, these compounds can easily be oxidized to their quinazolin-4(3*H*)-one analogues [9–11], which also are important pharmacologically active compounds [12–17]. Due to the significant interest in 2,3-dihydro-4(1*H*)-quinazolinones, several synthetic protocols have been developed for these heterocyclic compounds. The usual procedure involves one pot three-component reaction of isatoic anhydride, aldehydes and amines to synthesize 2,3-dihydro-4(1*H*)-quinazolinones. The reported catalysts for this one-pot procedure are included montmorillonite K-10 [18,19], silica sulfuric acid (SSA) [20,21], zinc(II) perfluorooctanoate [Zn(PFO)$_2$] [22], MCM-41-SO$_3$H [23], *p*-toluenesulfonic acid-paraformaldehyde copolymer (copolymer-PTSA) [24], Amberlyst-15 [25], gallium(III) triflate (Ga(OTf)$_3$) [26], $KAl(SO_4)_2 \cdot 12H_2O$ (alum) [27], molecular iodine (I$_2$) [28–30], *p*-toluenesulfonic acid (*p*-TsOH) [31], aluminium tris(dihydrogen phosphate) ($Al(H_2PO_4)_3$) [32], silica-bonded *N*-propylsulfamic acid (SBNPSA) [33], acetic acid [34], SiO_2–$FeCl_3$ [35], $SnCl_2$ [36], ceric ammonium nitrate (CAN) [37], ionic liquids [38–40], silica-bonded S-sulfonic acid [41] and Al/Al_2O_3 and Fe_3O_4 nanoparticles [42,43]. However, some reported

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methods have certain disadvantages such as tedious work-up, high reaction temperature and low yields. Therefore, development of a simple and efficient procedure is an important goal in the synthesis of 2,3-dihydroquinazolin-4(1*H*)-ones.

On the other hand, transition metal nanoparticles as exclusive materials have wide application in the homogeneous and heterogeneous catalysts. Among metal nanoparticles, Pt nanoparticles (NPs) have attracted significant attention due to their high catalytic activity [44]. It is well known that the specific electrocatalytic activity of platinum nanoparticles is strongly related to the size and dispersion of the particles, the supporting materials, preparation methods and their surface conditions. Highly distributed nanoscale Pt particles with nanometer size particles and narrow size distribution are ideal for high electrocatalytic activity owing to their large surface-to-volume ratio [45–53]. In fact, the choice of a suitable supporting material is an important aspect that may affect the performance of supported electrocatalysts due to interactions and surface reactivity [54,55]. Many researchers have demonstrated that, multi-walled carbon nanotubes (MWCNTs) are attractive supporting materials among the possible supports for Pt NPs catalyst, which can support a high dispersion of Pt nanoparticles owing to their particular morphology and large surface area [56–58]. As a result, several research papers reported that Pt NPs supported on CNTs increase the electrocatalytic activity [59,60] and also electrochemical stability [61,62]. In fact, Pt nanoparticles on the external walls contact easily with the reactant. Accordingly, various approaches have been devised to load platinum nanoparticles onto the surface of CNTs with a high specific surface area, superior catalytic activity and lower catalyst loading. These include wet chemical impregnation [63–65], electrode position [51,66–68], colloidal methods [58,69,70] and ion exchange [71,72].

Ultrasonic irradiation has been introduced as an eco-environmental technology in green chemistry to improve a large number of organic reactions [73,74]. Ultrasonic energy provides an unusual mechanism to generate high-energy chemistry owing to the extraordinary temperature and pressure generated by the cavitation bubble collapse [75]. The ‘hot-spot’ theory suggests that temperatures up to 5000 K and pressures up to 1000 bar are produced during this collapse [76–78]. The vibration movement of the ultrasonic waves causes growth of cavitation bubbles through the diffusion of solute vapor in the volume of these bubbles. After the growth process, the bubble collapse breaks the chemical bonds of the solute molecules [79]. Moreover, collapsed bubbles can carry smaller particles causing shocks among them and possibly causing surface amorphization which may result in their sintering [80].

To our knowledge, no studies have been reported on the preparation of quinazolinones using ultrasonic energy in the presence of Pt–MWCNTs nanocomposites. Herein, we have developed a novel methodology to prepare 2,3-dihydroquinazolin-4(1*H*)-ones by employing isatoic anhydride, aldehydes and ammonium acetate or primary aromatic amines using Pt–MWCNTs as an efficient catalyst under sonication conditions (Scheme 1).

2. Experimental

All materials were from commercial reagent grade and were used as received. MWCNTs were purchased from Nanotech Port Co. (Taiwan). These MWCNTs were produced via the chemical vapor deposition (CVD) method. The outer diameter of MWCNTs was between 10 and 20 nm. Melting points were obtained in open capillary tubes and were measured on an Electrothermal MK3 apparatus and were uncorrected. ^{1}H NMR and ^{13}C NMR spectra were measured with a Bruker DRX-400 spectrometer using tetramethylsilane (TMS) as an internal standard and DMSO-d_6 as the solvent at room temperature. Chemical shifts (δ) are reported in ppm downfield from TMS and coupling constant (J) values are given in Hz. FT-IR spectra were determined on a Perkin Elmer FT-IR 550 spectrophotometer using the pressed KBr. The progress of the reactions was monitored by thin-layer chromatography (TLC), which was visualized with UV light. The UV spectra were recorded on a UV–Vis Varian Perkin–Elmer UV 550-S spectrophotometer in chloroform. X-ray power diffraction (XRD) experiment was carried out in a Holland Philips Xpert X-ray powder diffraction (XRD) diffractometer (CuK, radiation, $\lambda = 0.154056$ nm), at a scanning speed of 2°/min from 10° to 100° (2θ). The prepared Pt–MWCNTs nanocomposites were also characterized by a TESCAN model VEGA II scanning electron microscope (SEM) operated at a 15 kV accelerating voltage. The Raman spectra were measured on a Bruker SENTERRA spectrometer with spectral range: 200–3500 cm^{-1} and Laser wavenumber 785 nm. Products were characterized by comparison of their physical and spectral data with those of authentic samples.

2.1. Synthesis of nanocatalyst

Pt–MWCNTs were prepared according to mentioned procedure in literature [81]. Briefly, the MWCNTs were purified in 2.5 M HNO_3 and 0.5 M H_2SO_4 at 60 °C under sonication for 6 h. Then, modified MWCNTs were washed with distilled water to neutral pH and were dried in air at 100 °C for 1 h. Then, the modified MWCNTs were added to 0.004 M $PtCl_4$ aqueous solution and the suspension was sonicated at room temperature for 30 min with the pH value of the solution adjusted to 8–10 by adding NaOH solution. An excess of $NaBH_4$ was added as reductant to reduce Pt. Then, the pH was maintained above 7. The reaction mixture was sonicated for 10 min and then was left to stand at room temperature for 24 h. Next, the product was filtered and was washed with distilled water and was dried in air at room temperature (Fig. 1).

2.2. General procedure for the synthesis of 2,3-dihydroquinazolin-4(1H)-ones under ultrasound irradiation

Pt–MWCNTs (0.04 g) were added to a mixture of isatoic anhydride (1.00 mmol, 0.13 g), aniline (1.20 mmol) or ammonium acetate (1.10 mmol) and aromatic aldehyde (1.00 mmol) in ethanol (5.00 mL). Then, the reaction mixture was irradiated in a ultrasound bath at temperature of 60 °C for appropriate time. After completion of the reaction as indicated by TLC (petroleum ether–EtOAc, 7:3), the reaction mixture was cooled to room temperature, was diluted with hot ethanol and the solid catalyst was separated by filtration. H_2O (5.00 mL) was added and the precipitated product was filtered and was recrystallized from ethanol.