Supplementary material

Volcanic ash as reusable catalyst in the green synthesis of 3*H*-1,5-benzodiazepines

1 Catalyst characterization

1.1 X-ray diffraction

The XRD patterns were collected with a Philips PW-1732 equipment. The X-ray source was Cu Kα radiation (λ = 1.5406 Å) with 40 kV and 20 mA. Nickel filter and scanning angle between 5 and 60° of 2θ at a scanning rate of 2° (2θ) per minute were used.

1.2 Scanning electron microscopy (SEM-EDS)

The catalysts were characterized with using a Philips 505 scanning electron microscope and equipped with energy-dispersive X-ray spectroscopy microanalysis by EDAX 9100, (SEM–EDS) using an accelerating voltage of 25 eV. The samples were fixed as powder on a graphitized band and metalized with Au.

1.3 Textural properties

The textural properties of the solids were determined from the N_2 adsorption–desorption isotherms at liquid nitrogen temperature using Micromeritics ASAP 2020 equipment. The samples were previously vacuum degassed at 100°C for 12 h. The specific surface area (S_{BET}) was determined by the BET method.

1.4 Fourier transform infrared spectroscopy

FT-IR spectra of the support and catalysts were obtained in the 400-4000 cm^{-1} wavenumber range using pellets of KBr in a Thermo Bruker IFS 66 FT-IR spectrometer.

1.5 Raman spectroscopy

Raman spectra were performed with a Renishaw spectrometer equipped with an air-cooled CCD detector and edge filters. A 488.0 nm emission line from an Ar^+ ion laser was focused on the sample by a Leica DLML microscope. The power of the incident beam was about 5 mW. The spectral resolution was 2 cm^{-1}, and the spectra were calibrated using the 520.5 cm^{-1} line of a silicon wafer.

1.6 Potentiometric titration

A suspension of the solid (25 mg) in acetonitrile was titrated using 0.025 N *n*-butylamine in acetonitrile, at a flow rate of 0.05 mL/min with a 794 Basic Titrino Metrohm equipment using a double junction electrode. The acidic properties of the samples measured by this technique enable the evaluation of the total number of acid sites and their acid strength. In order to interpret the results, it is suggested that the initial electrode potential (E) indicates the maximum acid strength of the surface sites, and the values (meq/g solid), where the plateau is reached, indicate the total number of acid sites. The acid strength of surface sites can be assigned according to the following ranges: very strong site, E >100 mV; strong site, 0 < E < 100 mV; weak site, -100 < E < 0 mV, and very weak site, E <-100 mV [1].

2 Catalytic test

2.1 Materials and methods

All the chemicals were purchased from Aldrich and used without further purification. Melting points were determined in open capillary tubes and were uncorrected. Thin layer chromatography (TLC) was performed on UV-active aluminum-backed plates of silica gel (TLC Silica gel 60 F254). The ^{1}H-NMR and ^{13}C-NMR spectra were measured on a Bruker 400 MHz spectrometer in DMSO-d6 with chemical shift given in ppm relative to TMS as internal standard.

2.2 General method for the synthesis of benzodiazepines

A mixture of 1,3-diphenyl-1,3-propanedione (1 mmol) and the corresponding *o*-phenyldiamine (2 mmol) was added to

the solid catalyst (1% mmol relative to dione), which was then heated at 130°C with magnetic stirring to. After that, the mixture was extracted twice with toluene (2 x 2 mL), treated with anhydrous sodium sulphate and then the solvent was removed in vacuum. The crude reaction product was purified by silica gel column chromatography using hexane-ethyl acetate as eluent. This gives pure benzodiazepines, which were characterized by comparison (thin layer chromatography and physical constants) with standard samples prepared by conventional methods and by ^{1}H-NMR and ^{13}C-NMR analysis.

2.3 Catalyst reuse

In order to study catalyst reuse, the used catalyst was washed with toluene (3 mL) after its filtration from the reaction media and dried in vacuum at 80°C up to constant weight.

2.4 ^{1}H and ^{13}C-NMR spectra of synthetized 3*H*-1,5-benzodiazepines

Compound 3a: m.p.: 137-138°C (lit. m.p.: 138-140°C) [2]. ^{1}H NMR (400 MHz, DMSO-d6): δ 3.70 (br s, 2H); 7.38 (dd, 2H, J = 3 Hz, 6 Hz); 7.41-7.47 (6H, m); 7.64 (dd, 2H, J = 3 Hz, 6 Hz); 7.97-8.01 (4H, m). ^{13}C NMR (100 MHz, DMSO-d6): δ 35.1, 125.5, 128.2, 128.7, 128.7, 130.6, 137.3, 140.7, 154.2.

Compound 3b: m.p.: 98-99°C (lit. m.p.: 98-100°C) [3]. 1H NMR (400 MHz, DMSO-d6): δ 2.60 (s, 3H); 3.70 (br s, 2H); 7.24-7.30 (m, 2H); 7.41-7.51 (m, 7H); 7.98-8.05 (m, 4H). ^{13}C NMR (100 MHz, DMSO-d6): δ 18.7, 35.0, 125.1, 126.5, 128.1, 128.2, 128.6, 128.7, 129.3, 130.4, 130.5, 136.3, 137.4, 137.5, 139.1, 140.4, 151.8, 153.9.

Compound 3c: m.p.: 161-162°C. (lit. m.p.: 160-162°C) [3]. 1H NMR (400 MHz, DMSO-d6): δ 3.70 (br s, 2H); 7.31 (dd, 1H, J = 2.3 Hz, 8.4 Hz); 7.42- 7.49 (m, 6H); 7.56 (dd, 1H, J = 0.45 Hz, 8.4Hz); 7.63 (dd, 1H, J = 0.45 Hz, J = 2.3 Hz); 7.97-8.00 (m, 4H). ^{13}C NMR (100 MHz, DMSO-d6): 35.2, 125.8, 128.1, 128.2, 128.8, 130.1, 130.5, 129.5, 130.9, 131.0, 136.9, 137.1, 139.3, 141.4, 154.4, 154.9.

Compound 3d: m.p.: 169-171°C (lit. m.p.: 170-172°C) [3]. ^{1}H NMR (400 MHz, DMSO-d6): δ 3.75 (br s, 2H); 7.42-7.50 (m, 8H); 7.79 (dd, 1H, J = 2.0 Hz, J = 0.6 Hz); 8.00-7.98 (m, 4H). ^{13}C NMR (100 MHz, DMSO-d6): 35.2, 118.3, 128.8, 128.2, 128.5, 128.8, 128.8, 130.3, 130.9, 131.0, 131.1, 136.9, 137.0, 139.7, 141.7, 154.5, 154.0.

Compound 3g: m.p.: 180-181°C (lit. m.p.: 183-184°C) [4]. ^{1}H NMR (400 MHz, DMSO-d6): δ 3.80 (br s, 2H); 6.87-6.92 (m, 1H); 7.02 (dd, 1H, J = 8.0 Hz, J = 1.14 Hz), 7.35-7.45 (m, 3H); 7.48-7.52 (m, 3H); 7.58 (dd, 1H, J = 7.2 Hz, J = 2.0 Hz); 7.66 (dd, 1H, J = 7.2 Hz, J = 2.0 Hz); 7.82 (dd, 1H, J = 8.0 Hz, J = 2.0 Hz); 8.04-8.07 (m, 2H); 14.52 (S, 1H). ^{13}C NMR (100 MHz, DMSO-d6): δ 33.4, 118.0, 118.4, 118.6, 125.9, 126.4, 128.0, 128.4, 128.4, 128.8, 129.1, 131.0, 133.6, 136.8, 137.3, 141.7, 155.3, 158.5, 162.6.

Compound 3h: m.p.: 187-188°C (lit. m.p.: 187-188°C) [4]. ^{1}H NMR (400 MHz, DMSO-d6): δ 2.30 (s, 3H); 3.74 (br s,2H); 6.92 (dd, 1H, J = 8.0 Hz); 7.18 (dd, 1H, J = 8 Hz, J = 2.0 Hz), 7.36-7.44 (m, 2H); 7.49-7.52 (m, 3H); 7.56-7.59 (m, 2H); 7.64-7.67 (m, 1H); 8.04-8.09 (m, 2H) ; 14.22 (s, 1H). ^{13}C NMR (100 MHz, DMSO-d6): δ 20.7, 33.5, 117.6, 118.2, 125.9, 126.2, 127.5, 128.0, 128.4, 128.5, 128.8, 129.0, 131.0, 134.5, 136.8, 137.4, 141.6, 155.2, 158.3, 160.3.

Compound 3i: m.p.: 183-184°C (lit. m.p.: 186-187°C) [4]. ^{1}H NMR (400 MHz, DMSO-d6): δ 3.80 (br s, 2H); 6.96 (d, 1H, J = 8.0 Hz); 7.29 (dd, 1H, J = 2.0 Hz, J = 9.0 Hz); 7.37-7.46 (m, 2H); 7.51-7.58 (m, 4H); 7.66 (dd, 1H, J = 2 Hz, J = 8.0 Hz); 7.76 (d, 1H, J = 2.5 Hz); 8.04-8.08 (m, 2H m); 14.45 (s, 1H). ^{13}C NMR (100 MHz, DMSO-d6): δ 33.4, 118.7, 119.9, 123.2, 126.0, 126.7, 127.8, 127.9, 128.4, 129.0, 129.1, 131.3, 133.3, 136.4, 136.9, 141.7, 154.7, 157.0, 161.0.

Compound 3k: m.p. higher to 193°C. (lit. m.p.: 191-193°C) [3]. ^{1}H NMR (400 MHz, DMSO-d6): δ 3.75 (br s, 2H); 6.56 (dd, 1H, J = 3.0, J = 8.0 Hz); 7.00 (d, 1H, J = 2.0 Hz); 7.06 (d, 1H, J = 8.0 Hz); 7.43-7.70 (m, 8H); 7.93-8.00 (m, 3H); 14.45 (s, 1H). ^{13}C NMR (100 MHz, DMSO-d6): δ 38.7, 116.5, 118.3, 119.1, 125.0, 125.0, 126.3, 126.5, 126.6, 127.0, 127.4, 127.8, 128.8, 128.9, 129.3, 130.5, 130.9, 134.0, 135.9, 136.8, 139.0, 141.3, 156.9, 157.2, 163.1.

The compounds are indicated in Table 9.

References

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