Epoxidation of vinyl cyanides by lithium hypochlorite in the presence of Fe₃O₄@Ag-CTAB as a new eco-friendly catalyst in aqueous medium

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Abstract
To cater to the requirement of environmental protection, cetyltrimethylammonium bromide (CTAB)-coated Fe₃O₄@Ag Nanoparticles as a new hybrid magnetic catalyst was prepared for the one-pot multicomponent epoxidation of a wide range of alkenes by lithium hypochlorite (LiOCl) in aqueous medium. FT-IR, TEM, XRD, EDS and VSM techniques were employed to characterize the structure of the magnetic catalyst. The results obtained revealed that the CTAB modification effectively decreased the particle size and enhanced the dispersion of the particles in solution. Application of this catalyst was studied efficiently in one-pot multicomponent synthesis of epoxide derivatives. The structure of the synthesized epoxides was confirmed by FT-IR, ¹H-NMR, ¹³C-NMR and elemental analysis. The main advantages of our work are reusability of the catalyst, easy work-up, Short reaction times and use of water as a green solvent.

Graphical abstract

Keywords Epoxide · Magnetic nanocatalyst · CTAB coating

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**Introduction**

Organic synthesis in aqueous medium is an important challenge in green chemistry [1]. But, the main disadvantage of using water as a green solvent is the low solubility of most organic compounds. In order to overcome this problem, surfactants can be used [2]. Surfactants, including nonionic, cationic, anionic, nano, and zwitterionic forms improve the solubility of materials by forming micelles, easing the dispersion of organic molecules in water and reducing aqueous interfacial tension [3]. In recent years, various surfactants such as cetyltrimethylammonium bromide (CTAB), sodium dodecyl sulfate (SDS), cocamidopropyl betaine (CAPB) and didodecyldimethylammonium bromide (DDAB) have been applied in many organic reactions [4–8]. On the other hand, magnetically nanocatalysts have attracted more attention than other nanoparticles in synthesis of organic compounds because of easy separation, their high catalytic activity and improved selectivity [9, 10]. For example, lately polymer-supported Fe₃O₄ [11] and Cu₂O/Fe₃O₄@guarana nanocatalysts [12] for the synthesis of imidazole derivatives, Fe₃O₄@Cu-β-CD for the synthesis of dihydropyran[2,3-c]pyrazole derivatives [13], TiO₂-coated Fe₃O₄ nanoparticles for the synthesis of pyrroles [14] and Fe₃O₄@Ag-β-CD for the synthesis of dihydropyrimidinones [15] have been applied. In this paper, we have decorated a class of usable hybrid nanocomposites in aqueous medium which shown combining the positive properties of CTAB and magnetic nanoparticles and we used it for epoxidation of vinyl cyanide derivatives by lithium hypochlorite.

Epoxides are an important class of organic compounds which are good raw material and important intermediates for making valuable products in organic synthesis [16–18]. Furthermore, epoxide derivatives have been found to be a good precursor for the synthesis of bioactive compounds in many reactions [19–22]. Based on foregoing, several efforts have been focused on epoxidation of alkenes and various methods have been reported in recent decades. For example, synthesis of epoxides from alkenes with NaOCl and urea H₂O₂ in the presence of chiral macrocyclicsalen Mn (III) complexes [23], by LiOCl in the presence of Mn(III) porphyrins [24], by tert-butyl hydroperoxide in the presence of oxidovanadium (IV) tetradentate schiff base complex [25], by H₂O₂ in the presence of titanium-silicalite catalyst [26] and vanadium complex [27], have been reported. Epoxidation of 2-benzylidene malononitrile in the presence of cumyl hydroperoxide (CHP) was also reported in 2015 [28]. However, these methods involve some disadvantages such as long reaction times and use of organic solvents. Table 1 represents the comparative methods for the epoxidation of some alkene derivatives.
Experimental

Materials

The FeCl₂·4H₂O, FeCl₃·6H₂O, benzaldehyd derivatives, malononitrile, ethyl cyanocrylate, lithium hypochlorite, solvents and the other reagents were purchased from Merck, Aldrich or Fluka, and were used as received without further purification.

Instruments

The FTIR spectra were run on a Bruker Equinox (model 55, Germany), and the NMR spectra measured by a Bruker AC 400 Avance DPX spectrophotometer, Germany at 500 MHz for ¹H and at 125 MHz for ¹³C NMR in CDCl₃ solution. Transmission electron microscopy (TEM) was performed using a Zeiss EM10C with accelerating voltage of 100 kV. EDS analysis was carried out using ZEISS (model SIGMA VP-500, Germany) with Oxford Instrument detector (England). XRD patterns were recorded on a PAN alytical (model X’Pert PRO) X-ray diffractometer. A vibrating-sample magnetometer (VSM) (model LBKFB, Meghnatis Daghigh Kavir Co, Iran) was used for hysteresis loop determinations. The melting points were determined by a Buchi melting point B-540 B. V.CHI apparatus.

Methods

Synthesis of Fe₃O₄@Ag-CTAB MNPs

In the first step, the prepared Fe₃O₄ nanoparticles [29] (0.2 g) were dispersed in deionized water (5 mL) and then AgNO₃ solution (5 mL of 0.01 M) was added under ultrasound treatment. Thereafter, NaBH₄ solution (30 mL of 0.02 M) was added dropwise. The reaction mixture was stirred vigorously on a magnetic plate for 20 min. The obtained product was separated with external magnet and then washed.
with distilled water and finally dried at 80 °C. In the second step, CTAB solution was added to the dispersion of the prepared Fe₃O₄@Ag nanoparticles in a 1:20 ratio (1 mL of CTAB 0.02 M for 40 mL of Fe₃O₄@Ag nanoparticles dispersion). After addition of CTAB, the dispersion was sonicated until the CTAB dissolved in the solution. The final solution was then centrifuged at 6000 rpm for 40 min (Scheme 1).

**Typical procedure for the preparation of 3-Phenyloxirane-2,2-dicarbonitrile**

Benzaldehyde (1 mmol), malononitrile (1 mmol), lithium hypochlorite (1 mmol), Fe₃O₄@Ag-CTAB (0.05 g) and 10 mL H₂O were introduced into a test tube equipped with a mechanical stirrer. The mixture constantly stirred at room temperature for 2 h. After completion of the reaction, the catalyst was separated using an external magnet. The solvent of the remained mixture was evaporated and a pure product was obtained by recrystallization from ethanol with yield of 90%. Under optimized conditions, 3-aryloxirane-2-carbonitriles (2a–o) were synthesized. The results are summarized in Table 2.

Reaction of benzaldehyde, malononitrile and oxidant was selected as a model reaction. The model reaction behaviour was studied by adjusting various parameters such as presence of catalyst, type of catalyst, amount of the catalyst and type of oxidant. The results are summarized in Table 3. The model reaction was attempted in the presence of LiOCl without any catalyst and only a 20% yield was obtained (Table 3, entry 1). To find the true role of metal catalyst in this catalysis, several catalysts such as Fe₃O₄, CTAB, Fe₃O₄@Ag and Fe₃O₄@Ag-CTAB were employed. However, it was noticed that the highest yield was achieved in the presence of Fe₃O₄@Ag-CTAB as catalyst (Table 3, entries 2–5). The model reaction was then attempted in the presence of 0.02, 0.03, 0.04, 0.05 and 0.06 g of Fe₃O₄@Ag-CTAB. The results show that the use of 0.05 g of Fe₃O₄@Ag-CTAB is sufficient to push the reaction forward. Greater amounts of the catalyst had no significant influence on the reaction time and yield (Table 3, entries 5–9). Other oxidation reagents such as
Table 2  Epoxidation of vinyl cyanide derivatives by LiOCl in the presence of Fe₃O₄@Ag-CTAB as a new hybrid magnetic catalyst

![Epoxidation reaction diagram]

| Entry | R₁   | R₂   | Product | Time (min) | Yield (%) | Mp (°C) |
|-------|------|------|---------|------------|-----------|---------|
| 1     | Ph   | CN   | 2a      | 120        | 90        | 51      |
| 2     | 4-F C₆H₄ | CN   | 2b      | 90         | 89        | 87–89   |
| 3     | 4-Cl C₆H₄ | CN   | 2c      | 100        | 89        | 128     |
| 4     | 4-Br C₆H₄ | CN   | 2d      | 100        | 80        | 129–130 |
| 5     | 4-CH₃ C₆H₄ | CN   | 2e      | 160        | 70        | 75      |
| 6     | 4-OCH₃ C₆H₄ | CN   | 2f      | 160        | 85        | 79      |
| 7     | 4-NO₂ C₆H₄ | CN   | 2g      | 240        | 98        | 177     |
| 8     | 2-NO₂ C₆H₄ | CN   | 2h      | 240        | 99        | 128–129 |
| 9     | Ph   | CO₂Et | 2i      | 60         | 95        | Oil     |
| 10    | 4-F C₆H₄ | CO₂Et | 2j      | 90         | 95        | Oil     |
| 11    | 4-Cl C₆H₄ | CO₂Et | 2k      | 90         | 90        | 70–72   |
| 12    | 4-Br C₆H₄ | CO₂Et | 2l      | 100        | 85        | 94      |
| 13    | 4-CH₃ C₆H₄ | CO₂Et | 2m      | 110        | 80        | 63      |
| 14    | 4-NO₂ C₆H₄ | CO₂Et | 2n      | 160        | 99        | 128–130 |
| 15    | 2-NO₂ C₆H₄ | CO₂Et | 2o      | 160        | 99        | 61      |

Table 3  Synthesis of 3-Phenyloxirane-2,2-dicarbonitrile under different conditions

![Synthesis reaction diagram]

| Entry | Oxidant | Catalyst | Time (h) | Yield (%) |
|-------|---------|----------|----------|-----------|
| 1     | LiOCl   | –        | 5        | 20        |
| 2     | LiOCl   | Fe₃O₄   | 5        | 20        |
| 3     | LiOCl   | CTAB     | 2        | 50        |
| 4     | LiOCl   | Fe₃O₄@Ag | 4        | 45        |
| 5     | LiOCl   | Fe₃O₄@Ag-CTAB (0.02 g) | 2 | 75 |
| 6     | LiOCl   | Fe₃O₄@Ag-CTAB (0.03 g) | 2 | 75 |
| 7     | LiOCl   | Fe₃O₄@Ag-CTAB (0.04 g) | 2 | 80 |
| 8     | LiOCl   | Fe₃O₄@Ag-CTAB (0.05 g) | 2 | 90 |
| 9     | LiOCl   | Fe₃O₄@Ag-CTAB (0.06 g) | 2 | 90 |
| 10    | NaOCl   | Fe₃O₄@Ag-CTAB | 2 | 65 |
| 11    | NaIO₃   | Fe₃O₄@Ag-CTAB | 12 | – |
| 12    | NaIO₄   | Fe₃O₄@Ag-CTAB | 12 | – |
NaOCl, NaIO₃ and NaIO₄ were also used. No reaction occurred with these oxidants under optimized conditions and only a 65% yield was obtained by NaOCl (Table 3, entries 10–12). Finally, we found that this reaction optimally proceeded with LiOCl in the presence of Fe₃O₄@Ag-CTAB as catalyst and completed within 2 h to afford the corresponding product in 90% yields.

**Results and discussion**

**FT-IR study**

Figure 1 shows the FT-IR spectra of Fe₃O₄ (Fig. 1a), CTAB (Fig. 1b) and Fe₃O₄@Ag-CTAB (Fig. 1c). In FT-IR spectra of Fe₃O₄ nanoparticles, Peak at 599.24 cm⁻¹ is attributed to the Fe–O band vibration. The broad band around 3000–3500 cm⁻¹ displays the surface hydroxy stretching vibrations (Fig. 1a).

![FT-IR spectrum of Fe₃O₄ (a), CTAB (b) and Fe₃O₄@Ag-CTAB (c)](image)

Fig. 1 FT-IR spectrum of Fe₃O₄ (a), CTAB (b) and Fe₃O₄@Ag-CTAB (c)
In FT-IR spectra of CTAB, the peak at 1486.97 cm\(^{-1}\) is attributed to CN bond and the peaks at 2849.71 and 2918.15 cm\(^{-1}\) are attributed to two different CH bands vibration of CTAB (Fig. 1b). In FT-IR spectra of Fe\(_3\)O\(_4\)@Ag-CTAB, observed band at 586.03 cm\(^{-1}\) corresponds to stretching vibration of Fe–O bond. The peaks at 2850.49 and 2919.02 cm\(^{-1}\) are attributed to CH bands vibration of CTAB (Fig. 1c). Any specific signals are not observed for Ag in the FT-IR spectra because silver is a metal element.

**Particle size analysis**

Analyzing the size of prepared nanoparticles carried out according to TEM technique, in which the dimensions of them were achieved about 30–90 nm (Fig. 2). Also, the results obtained confirmed that the modification of Fe\(_3\)O\(_4\)@Ag nanoparticles using CTAB as a coating material effectively prevented the aggregation of magnetite nanocomposites and led to a better dispersion of the particles in solution.

**XRD analysis**

Figure 3 shows the XRD patterns for the Fe\(_3\)O\(_4\)@Ag-CTAB nanoparticles. The position and relative intensity of all the peaks obtained matched well with the standard Fe\(_3\)O\(_4\) (JCPDS card No. 00-001-1111) and Ag (JCPDS card No. 00-001-1167). There were seven characteristic peaks in the XRD patterns of Fe\(_3\)O\(_4\)@Ag-CTAB. The signals at \(2\theta = 30.32\), 37.9 and 57.16 are shown as nano-Fe\(_3\)O\(_4\) structure and other peaks at \(2\theta = 38.15\), 44.35, 64.51 and 77.43 prove the existence of Ag.

![TEM image of Fe\(_3\)O\(_4\)@Ag-CTAB MNPs](image)
EDS analysis

Figure 4 shows the results of energy-dispersive X-ray spectroscopy EDS analysis, which confirms the presence of C, N, Fe and Ag species. In EDS spectrum, the intensity of Ag peak is higher than that of Fe, which indicates that Fe particles
are coated with the Ag particles. Figure 4 also shows the EDX elements mapping images of Fe₃O₄@Ag-CTAB, including the contents of C, N, Ag and Fe elements. As shown in Fig. 4, the contents of C (in yellow), N (in blue), Ag (in brown) and Fe (in red) elements for Fe₃O₄@Ag-CTAB were 48.23, 40.71, 6.64 and 4.43% respectively. These results confirm the existence of C and N elements in Fe₃O₄@Ag-CTAB.

**VSM analysis**

Figure 5 shows the magnetic hysteresis curves of Fe₃O₄ and Fe₃O₄@Ag-CTAB. These results indicate that the magnetic saturation value of Fe₃O₄ decreased considerably by coating it with Ag and CTAB. The magnetic saturation value of the Fe₃O₄ nanoparticles and Fe₃O₄@Ag-CTAB are 60 and 12 emu g⁻¹ respectively.

**Mechanism**

The positively charged ammonium moiety of CTAB adsorbs on the surface of Fe₃O₄@Ag NPs by a strong electrostatic interaction, while the hydrophobic chains point outwards into a solution phase, leading to the formation of hydrophobic hemimicelle. So, organic reactants can be preconcentrated on the surface of Fe₃O₄@Ag NPs. First, Fe₃O₄@Ag-CTAB promotes the Knoevenagel condensation of the benzaldehyde with malononitrile. It should be noted that some Knoevenagel reaction could occur in water without the addition of any base [30, 31]. We, therefore, proposed a mechanism involving the ionization of malononitrile

![VSM curves for Fe₃O₄ (in red) and Fe₃O₄@Ag-CTAB MNPs (in blue) (Color figure online)](image-url)
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(pKa 11.2) in water. Then the resulting vinyl cyanide reacts with LiOCl, as an oxygen source, to give the epoxide (Scheme 2).

3-Phenyloxirane-2,2-dicarbonitrile (2a)

White crystals; mp 51 °C. FT-IR (KBr): 3066, 3033 (CH stretching), 2260 (CN stretching), 1605, 1497 (C=C stretching) 1191 (C–O stretching) cm⁻¹. ¹H NMR (400 MHz, CDCl₃): δ = 7.45–7.57 (m, 5 H, HAr), 4.74 (s, 1 H, CH). ¹³C NMR (100 MHz, CDCl₃): δ = 131.4, 129.1, 127.6, 126.8, 111.7, 110.3, 65.8, 41.8. Anal. Calcd (%) for C₁₀H₆N₂O: C, 70.58; H, 3.55; N, 16.46. Found: C, 70.29; H, 3.47; N, 16.24.
3-(4-Fluorophenyl)oxirane-2,2-dicarbonitrile (2b)

White crystals; mp 87–89 °C. FT-IR (KBr): 3078, 3036 (CH stretching), 2262 (CN stretching), 1606, 1514 (C=C stretching), 1228 (C–O stretching), 841 cm⁻¹. ¹H NMR (400 MHz, CDCl₃): δ = 7.44–7.49 (m, 2 H, Hₐ⁻), 7.19–7.25 (m, 2 H, Hₐ⁻), 4.74 (s, 1 H, CH). ¹³C NMR (100 MHz, CDCl₃): δ = 165.7, 163.2 (d, J = 251.0 Hz), 129.0, 128.9 (d, J = 8.9 Hz), 123.3, 123.3 (d, J = 3.1 Hz), 116.7, 116.4 (d, J = 22.4 Hz), 111.4, 110.0, 65.2, 41.7. Anal. Calcd (%) for C₁₀H₅FN₂O: C, 63.83; H, 2.68; N, 14.89. Found: C, 63.62; H, 2.38; N, 14.82.

3-(4-Chlorophenyl)oxirane-2,2-dicarbonitrile (2c)

White crystals; mp 128 °C. FT-IR (KBr): 3095, 3037 (CH stretching), 2260 (CN stretching), 1599, 1494 (C=C stretching), 1191 (C–O stretching), 828 cm⁻¹. ¹H NMR (400 MHz, CDCl₃): δ = 7.50 (d, J = 8.4 Hz, 2 H, Hₐ⁻), 7.39 (d, J = 8.4 Hz, 2 H, Hₐ⁻), 4.73 (s, 1 H, CH). ¹³C NMR (100 MHz, CDCl₃): δ = 149.7, 134.0, 128.0, 124.4, 110.8, 109.4, 64.3, 41.5. Anal. Calcd (%) for C₁₀H₅ClN₂O: C, 58.7; H, 2.46; N, 13.69. Found: C, 58.49; H, 2.18; N, 13.60.

3-(4-Bromophenyl)oxirane-2,2-dicarbonitrile (2d)

White powder; mp 129–130 °C. FT-IR (KBr): 3092, 3036 (CH stretching), 2258 (CN stretching), 1651, 1488 (C=C stretching), 1190 (C–O stretching), 821 cm⁻¹. Anal. Calcd (%) for C₁₀H₅BrN₂O: C, 48.22; H, 2.02; N, 11.25. Found: C, 48.02; H, 1.77; N, 11.16.

3-(P-tolyl)oxirane-2,2-dicarbonitrile (5e)

White powder; mp 75 °C. FT-IR (KBr): 3041, 3017, 2956, (C–H stretching), 2256 (CN stretching), 1613, 1513 (C=C stretching), 1181 (C–O stretching), 817 cm⁻¹. ¹H NMR (400 MHz, CDCl₃): δ = 7.29–7.36 (m, 4 H, Hₐ⁻), 4.70 (s, 1 H, CH), 2.44 (s, 3 H, Me). ¹³C NMR (100 MHz, CDCl₃): δ = 141.8, 129.8, 126.7, 124.4, 111.7, 110.3, 66.0, 41.7, 21.5. Anal. Calcd (%) for C₁₁H₈N₂O: C, 71.73; H, 4.38; N, 15.21. Found: C, 71.51; H, 4.09; N, 15.13.

3-(4-Methoxyphenyl)oxirane-2,2-dicarbonitrile (2f)

White powder; mp 79 °C. FT-IR (KBr): 3017, 2974 (CH stretching), 2259 (CN stretching), 1612, 1519 (C=C stretching), 1256 (C–O stretching), 831 cm⁻¹. ¹H NMR (400 MHz, CDCl₃): δ = 7.37 (d, J = 8.8 Hz, 2 H, Hₐ⁻), 7.03 (d, J = 8.8 Hz, 2 H, Hₐ⁻), 4.69 (s, 1 H, CH), 3.88 (s, 3 H, OMe). ¹³C NMR (100 MHz, CDCl₃):
δ = 162.0, 128.4, 119.0, 114.6, 111.7, 110.4, 66.0, 55.4, 41.8. Anal. Calcd (%) for C_{11}H_{8}N_{2}O_{2}: C, 66.00; H, 4.03; N, 13.99. Found: C, 65.78; H, 3.74; N, 13.91.

3-(4-Nitrophenyl)oxirane-2,2-dicarbonitrile (2g)

Yello powder; mp 177 °C. FT-IR (KBr): 3116, 3038 (CH stretching), 2260 (CN stretching), 1609, 1520 (C–C stretching), 1191 (C–O stretching), 859 cm\(^{-1}\). \(^1\)H NMR (400 MHz, CDCl\(_3\)): δ = 8.42 (d, \(J = 8.8\) Hz, 2 H, H\(_{Ar}\)), 7.70 (d, \(J = 8.8\) Hz, 2 H, H\(_{Ar}\)), 4.87 (s, 1 H, CH). \(^{13}\)C NMR (100 MHz, CDCl\(_3\)): δ = 137.8, 129.6, 128.1, 125.9, 111.3, 109.9, 65.1, 41.6. Anal. Calcd (%) for C\(_{10}\)H\(_5\)N\(_3\)O\(_3\): C, 55.82; H, 2.34; N, 19.53. Found: C, 55.60; H, 2.05; N, 19.45.

3-(2-Nitrophenyl)oxirane-2,2-dicarbonitrile (2h)

Yello powder; mp 128–129 °C. FT-IR (KBr): 3090, 3031 (CH stretching), 2255 (CN stretching), 1614, 1522 (C–C stretching), 1199 (C–O stretching), 823 cm\(^{-1}\). Anal. Calcd (%) for C\(_{10}\)H\(_5\)N\(_3\)O\(_3\): C, 55.82; H, 2.34; N, 19.45.

Ethyl 2-cyano-3-phenyloxirane-2-carboxylate (2i)

Oil; FT-IR (KBr): 3068, 3038, 298 (C–H stretching), 2253 (CN stretching), 1761 (C=O), 1500, 1457 (C–C stretching), 1309, 1274, 1153 (C–O stretching), 854 cm\(^{-1}\). \(^1\)H NMR (500 MHz, CDCl\(_3\)): δ = 7.46 (s, 5 H), 4.56 (s, 1 H, CH), 4.36 (q, \(J = 9.0\) Hz, 2 H), 1.36 (t, \(J = 9.0\) Hz, 3 H). \(^{13}\)C NMR (125 MHz, CDCl\(_3\)): δ = 162.7, 130.4, 129.9, 128.8, 126.8, 113.1, 64.4, 64.1, 53.4, 13.9. Anal. Calcd (%) for C\(_{12}\)H\(_{11}\)NO\(_3\): C, 66.35; H, 5.10; N, 6.45. Found: C, 66.13; H, 4.81; N, 6.37.

Ethyl 2-cyano-3-(4-fluorophenyl)oxirane-2-carboxylate (2j)

Oil; FT-IR (KBr): 3118, 3035 (CH stretching), 2260 (CN stretching), 1759 (C=O), 1605, 1516 (C–C stretching), 1224 (C–O stretching), 840 cm\(^{-1}\). \(^1\)H NMR (500 MHz, CDCl\(_3\)): δ = 7.41 (q, \(J = 5.5\) Hz, 2 H, H\(_{Ar}\)), 7.12 (t, \(J = 8.5\) Hz, 2 H, H\(_{Ar}\)), 4.51 (s, 1 H, CH), 4.37 (q, \(J = 7.0\) Hz, 2 H), 1.36 (t, \(J = 7.0\) Hz, 3 H). \(^{13}\)C NMR (125 MHz, CDCl\(_3\)): δ = 164.8, 162.8 (d, \(J = 248.0\) Hz), 162.4, 128.8, 128.7 (d, \(J = 8.7\) Hz), 125.7, 116.1, 115.9 (d, \(J = 22.5\) Hz) 112.8, 64.1, 63.8, 53.3, 13.9. Anal. Calcd (%) for C\(_{12}\)H\(_{10}\)FNO\(_3\): C, 61.28; H, 4.29; N, 5.95. Found: C, 61.06; H, 4.00; N, 5.87.

Ethyl 3-(4-chlorophenyl)-2-cyanooxirane-2-carboxylate (2k)

White powder; mp 70–72 °C. FT-IR (KBr): 3007, 2993, (C–H stretching), 2262 (CN stretching), 1757 (C=O), 1600, 1493 (C–C stretching), 1293, 1166 (C–O stretching), 818 cm\(^{-1}\). \(^1\)H NMR (500 MHz, CDCl\(_3\)): δ = 7.43 (d, \(J = 8.5\) Hz, 2 H, H\(_{Ar}\)), 7.37 (d, \(J = 8.5\) Hz, 2 H, H\(_{Ar}\)), 4.50 (s, 1 H, CH), 4.39 (q, \(J = 7.0\) Hz, 2 H), 1.39 (t, \(J = 7.0\) Hz, 3 H). \(^{13}\)C NMR (125 MHz, CDCl\(_3\)): δ = 207.8, 203.8, 162.3, 136.5.
Epoxidation of vinyl cyanides by lithium hypochlorite in the presence of Fe₃O₄@Ag-CTAB as a new environmentally friendly and reusable catalyst in aqueous medium with good to high yields (70–99%). It seems that CTAB provides a hydrophobic medium to accumulate organic reactants and the Fe₃O₄@Ag, as a Lewis acid, catalyzes the reactions.
The remarkable advantages of this method are avoidance of organic solvents, short reaction times, high yields, and easily recoverable heterogeneous magnetic catalyst.

**Supplementary Information** The online version contains supplementary material available at https://doi.org/10.1007/s11164-022-04806-6.

**Acknowledgements** The authors thank the National Iranian South Oil Company (NISOC) and the Research Council of Yazd University for partial support of this work.

**Author’s contribution** All authors contributed to the study conception, literature, analysis, and writing. Mahdi Shirali put forward the research ideas and finally approved the whole content. Fatemeh Mirhashemi did the experiments and characterizations, analyzed the results and organized the writing framework.

**Funding** Not applicable.

**Availability of data and materials** Not applicable.

**Declarations**

**Conflict of interest** Not applicable.

**Ethical approval** Not applicable.

**Consent to participate** Not applicable.

**Consent for publication** Not applicable.

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