

Microwave-assisted synthesis of the Fe₂O₃/g-C₃N₄ nanocomposites with enhanced photocatalytic activity for degradation of methylene blue

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Abstract

The preparation and photocatalytic performance of the Fe₂O₃/g-C₃N₄ nanocomposites with different weight percentage of iron was investigated in this study. Samples were successfully synthesized using melamine and ferric nitrate as the precursors via the green and facile microwave-assisted method. The physico-chemical and structural properties of the Fe₂O₃-doped g-C₃N₄ were characterized by X-ray diffraction (XRD), Fourier-transform infrared spectroscopy (FT-IR), the Brunauer–Emmett–Teller (BET) method, transmission electron microscopy (TEM), scanning electron microscopy (SEM), energy-dispersive X-ray spectroscopy (EDS), and ultraviolet–visible spectroscopy (UV–Vis). The photocatalytic activity of the Fe₂O₃/g-C₃N₄ catalysts was evaluated by the degradation of methylene blue (MB) at room temperature under visible light irradiation. As expected, the as-synthesized samples exhibited considerable improvement in the photodegradation of MB. The Fe₂O₃/g-C₃N₄ (1.0 wt%) nanocomposite had superior photocatalytic activity, with almost 70% degradation efficiency within 90 min of irradiation. The enhanced performance was ascribed to the separation and migration of the photo-induced electron–hole pairs and taking part of the charge carriers in the chemical redox reactions at the surface of the photocatalyst. In this work, the effect of Fe weight percentage on the degradation potential was also studied, and the photocatalytic mechanism was proposed with the main reactive species •OH.

KEYWORDS

Fe₂O₃/g-C₃N₄ nanocomposites, iron oxide doping, methylene blue, microwave-assisted synthesis, UV–Vis spectroscopy

1 | INTRODUCTION

Living organisms easily adsorb the majority of industrial water-soluble azo dyes. They may be toxic and carcinogenic and inflict irreversible damage on the environment in case of releasing wastewater without

refining treatments.^[1–3] Due to their complex structures, they are resistant to chemical and biological degradation methods.^[4] The photocatalytic process associated with dye surface adsorption is known as the best purification technique.^[5] It is an ecofriendly and low-cost procedure for the complete removal of hazardous dyes from

contaminated wastewater.^[6] Scientists are always searching for new and abundant photocatalysts or adsorbents to degrade organic pollutants under visible light energy.^[7] Graphitic carbon nitride ($g\text{-C}_3\text{N}_4$) is the best-known visible light-driven photocatalyst.^[8] It is applied in the decomposition of organic pollutants,^[9] hydrogen production,^[10] CO_2 photoreduction,^[11] and water splitting.^[12] It is easily prepared from cheap and nitrogen-rich precursors such as urea, melamine, cyanamide, and dicyandiamides.^[13] Pale yellow $g\text{-C}_3\text{N}_4$, in the form of nanoparticles, nanotubes, or nanosheets, is a nonmetallic polymer semiconductor^[14] that enjoys excellent properties such as high thermal and chemical stability,^[15] nontoxicity,^[16] biocompatibility,^[17] and the narrow bandgap of 2.7 eV.^[18] However, due to the rapid recombination of photoinduced electron-hole pairs and low specific surface area, $g\text{-C}_3\text{N}_4$ suffers from slow reaction kinetics in photocatalysis.^[19] So, various strategies such as metal or nonmetal doping, are followed to overcome the above disadvantages and increase the photocatalytic efficiency of pure $g\text{-C}_3\text{N}_4$.^[20] It is worth noting that, due to the design and structure of $g\text{-C}_3\text{N}_4$, much hybridization occurs between the dopant and $g\text{-C}_3\text{N}_4$ to create heterojunctions with proper energy levels in their bandgap and improve electronic and optical properties.^[21] Among different heterogeneous elements, Fe is the most common type, less toxic and harmless, and naturally abundant metal.^[22] The unique structure of the pure $g\text{-C}_3\text{N}_4$ is filled with six lone-pair electrons of nitrogen and appropriate for Fe inclusion.^[23] Iron oxide doping, due to the strong interaction between Fe_2O_3 and $g\text{-C}_3\text{N}_4$, is a suitable method to increase the photocatalytic activity of the $g\text{-C}_3\text{N}_4$ through the enlargement of the specific surface area and maximization of the lifetime of charge carriers, consistent with the previous studies.^[24–26]

The main objective of the present work was to prepare a series of Fe_2O_3 -doped $g\text{-C}_3\text{N}_4$ photoactive catalysts via the simple, short-time, low-temperature, and energy-saving microwave-assisted synthesis method. In the literature, there seems to be no direct report addressing the synthesis of the $\text{Fe}_2\text{O}_3/g\text{-C}_3\text{N}_4$ nanocomposites using the microwave absorption properties of the $g\text{-C}_3\text{N}_4$. Expectedly, doping with iron oxide promoted photocatalytic efficiency of $g\text{-C}_3\text{N}_4$ for methylene blue (MB) degradation.^[27,28] The influence of Fe weight percentage on the photodegradation potential was also studied. After demonstrating all photocatalytic activities, the possible mechanism for the best-performing sample, the $\text{Fe}_2\text{O}_3/g\text{-C}_3\text{N}_4$ (1.0%) nanocomposite, was proposed with the main reactive species hydroxyl radicals. Finally, the reusability of the $\text{Fe}_2\text{O}_3/g\text{-C}_3\text{N}_4$ (1.0%) photocatalyst was tested for four successive runs.

2 | EXPERIMENTAL METHODS

2.1 | Materials

All the chemicals used in this work, including melamine, ferric nitrate nonahydrate, sodium dodecyl sulfate, sodium hydroxide, ethanol, and MB hydrate, were used as received without further purification. Deionized (DI) water was used in all of the experiments.

2.2 | Instruments

The X-ray diffraction (XRD) patterns for studying the crystalline structure of the samples were obtained on PHILIPS X'PERT PRO X-ray diffractometer using $\text{Cu-K}\alpha$ radiation ($\lambda = 1.5406 \text{ \AA}$, $2\theta = 10^\circ\text{--}80^\circ$). The Fourier-transform infrared (FT-IR) spectra for chemical analysis were recorded on a Shimadzu IRPRESTIGE-21 IR spectrophotometer using the KBr method in the range of $400\text{--}4,000 \text{ cm}^{-1}$. The N_2 adsorption-desorption isotherms were measured using the BELSORP MINI II apparatus at 196°C . Before the measurements, the samples were degassed at 120°C for 15 hr by BEL PREP VAC II. The data of specific surface areas were assessed with the Brunauer-Emmett-Teller (BET) method. The transmission electron microscopy (TEM) structural morphologies were characterized by PHILIPS CM 120 instrument. The scanning electron microscopy (SEM) surface morphologies and energy-dispersive X-ray spectroscopy (EDS) elemental mapping micrographs were collected by MIRA III VEGA-TESCAN-XMU apparatus. Before the analysis, samples were mounted on aluminum stubs by double-sided adhesive tapes and coated with a thin layer of gold. The ultraviolet-visible spectroscopy (UV-Vis) spectra were achieved on the GBC CINTRA 20 instrument in the wavelength range of $200\text{--}800 \text{ nm}$.

2.3 | Preparation of photocatalysts

Melamine (5 g) as the precursor of $g\text{-C}_3\text{N}_4$ was calcined in a covered alumina crucible inside a muffle furnace at 550°C for 4 hr; then, it was cooled down to room temperature. The obtained yellow $g\text{-C}_3\text{N}_4$ was ground into powder. Afterward, iron(III) nitrate nonahydrate (0.22 g) as the precursor of iron oxide and sodium hydroxide (0.44 g) as the precipitating agent were dissolved in DI water (100 ml). The solution was heated at 60°C for 45 min. It led to the formation of the reddish-brown iron hydroxide $\text{Fe}(\text{OH})_3$ precipitate. Iron hydroxide was immediately converted into stable iron oxide in the presence of ambient air. Then, it was ground into a powder to form Fe_2O_3 nanoparticles.

For the preparation of the $\text{Fe}_2\text{O}_3/\text{g-C}_3\text{N}_4$ nanocomposites, $\text{g-C}_3\text{N}_4$ powder (2 g) and surfactant sodium dodecyl sulfate (30 g) were dispersed in ethanol (10 ml) and DI water (20 ml) and heated at 60°C for 30 min using a magnetic stirrer. After adding Fe_2O_3 nanoparticles to the obtained suspension, it was stirred at 60°C for 60 min under nitrogen atmosphere and then treated with ultrasound for 45 min. The next step was the dropwise addition of sodium hydroxide solution (10 ml 2 M) to the suspension over 10 min. The reaction solution was then exposed to microwave radiation (600 W) for 4 min and cooled down to room temperature. The $\text{Fe}_2\text{O}_3/\text{g-C}_3\text{N}_4$ precipitate was separated from the solution, rinsed with ethanol and DI water several times, and dried at 60°C for 24 hr. Finally, the as-prepared photocatalysts were ground into a light powder and labeled $\text{Fe}_2\text{O}_3/\text{g-C}_3\text{N}_4$ (X%), where X refers to the weight percentage of Fe (0.5, 1.0, 1.5, 2.0, 2.5, and 5.0 wt%). The whole mechanism of the experimental synthesis is illustrated in Scheme 1.

2.4 | Photocatalysis experiments

The photocatalytic activity of the as-fabricated $\text{Fe}_2\text{O}_3/\text{g-C}_3\text{N}_4$ nanocomposites was evaluated by the degradation of MB under visible light irradiation using a 50 W LED lamp. Typically, in each experiment, 0.1 g of the nanocomposite was dispersed into MB aqueous solution (100 ml, 3×10^{-5} M) inside a Pyrex glass reactor and cooled by a circulating water pump to maintain the room temperature during the reaction. Before illumination, the suspension was stirred in the dark for 30 min to reach the adsorption-desorption equilibrium between the catalyst and MB dye. After taking the first sample (2 ml), the reaction solution was placed under visible light irradiation. Before progressing to analysis, samples were taken every 10 min for 90 min and centrifuged at a speed of

4,000 rpm for 4 min to separate the catalyst particles from the solution. The residual concentration of the MB solution was measured at 664 nm (λ_{max} of MB) using a UV-Vis spectrophotometer. The photodegradation rate (η) of MB was calculated as follows:

$$\eta = (C_0 - C_t) / C_0 \times 100\%, \quad (1)$$

where C_0 is the initial concentration of MB, and C_t is the concentration of MB at the time (t).^[29]

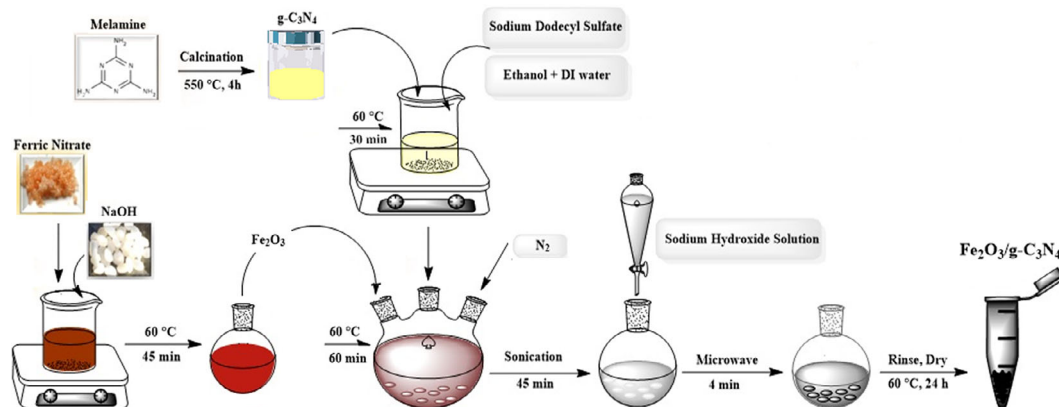
2.5 | Radical trapping experiments

A series of scavengers were added to the system to determine the major reactive species in the degradation of MB. The $\cdot\text{OH}$ and $\cdot\text{O}_2^-$ radicals plus the holes were scavenged by isopropanol (2-PrOH), benzoquinone (BQ), and potassium iodide (KI), respectively.

3 | RESULTS AND DISCUSSION

3.1 | Structural and compositional characterization

The XRD patterns of the $\text{g-C}_3\text{N}_4$ and $\text{Fe}_2\text{O}_3/\text{g-C}_3\text{N}_4$ (1.0%) nanocomposites are shown in Figure 1. Two visible diffraction peaks at 13.1° and 27.4° typically correspond to the 100 and 002 crystal planes of $\text{g-C}_3\text{N}_4$, respectively, consistent with the standard value (JCPDS 87-1526). The diffraction of the 100 plane matches the ring structure of the tri-s-triazine, the important intermediate during melamine condensation to graphitic carbon nitride. The bond reaction barrier between carbon and nitrogen is reduced to improve the crystallinity of the graphitic nanostructure layers. The diffraction of the 002 plane



SCHEME 1 The schematic diagram for the preparation of the $\text{Fe}_2\text{O}_3/\text{g-C}_3\text{N}_4$ nanocomposites

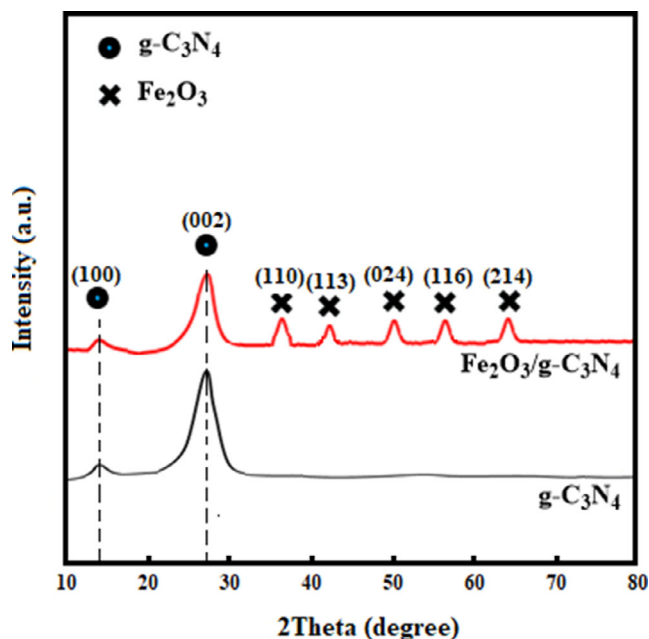


FIGURE 1 The XRD patterns of the g-C₃N₄ and Fe₂O₃/g-C₃N₄ (1.0%) nanocomposites

corresponds to the conjugated aromatic compounds, appearing for the graphitic structure. The XRD pattern of the Fe₂O₃/g-C₃N₄ (1.0%) nanocomposite shows similar peak positions to that of the g-C₃N₄ without any shift and also exhibits the characteristic peaks of the Fe₂O₃ content. It confirms that Fe (III) ions chemically coordinate with the g-C₃N₄ host, resulting in the reduction of the diffraction intensity and crystallinity of the nanocomposite.^[30]

The FT-IR spectra of the g-C₃N₄ and Fe₂O₃/g-C₃N₄ (1.0%) nanocomposites are shown in Figure 2. No apparent difference between two spectra reveals the same chemical functional groups. The broad absorption band at 3,446 cm⁻¹ originates from the O-H stretching vibration of the adsorbed water molecules on the surface of the nanocomposites.^[31,32] The absorption peak at about 2,900 cm⁻¹ corresponds to the C-H stretching vibration.^[33] The characteristic peak of g-C₃N₄, the C-N heterocycles stretching vibration, is observed at around 1,600 cm⁻¹. It seems to be weaker in the Fe₂O₃-doped g-C₃N₄, suggesting that Fe(III) ions coordinate with the C-N aromatic rings.^[34] The peak at 1,050 cm⁻¹ is ascribed to the C-O stretching vibration.^[35] The weak peak at around 670 cm⁻¹ in the spectrum of the Fe₂O₃/g-C₃N₄ (1.0%) nanocomposite is assigned to the Fe-O stretching vibration mode.^[36] The results confirm that iron oxide nanoparticles successfully interact with the pure g-C₃N₄ to form binary Fe₂O₃/g-C₃N₄ nanocomposites.

The N₂ adsorption-desorption isotherm analysis of the g-C₃N₄ and Fe₂O₃/g-C₃N₄ (1.0%) nanocomposites is

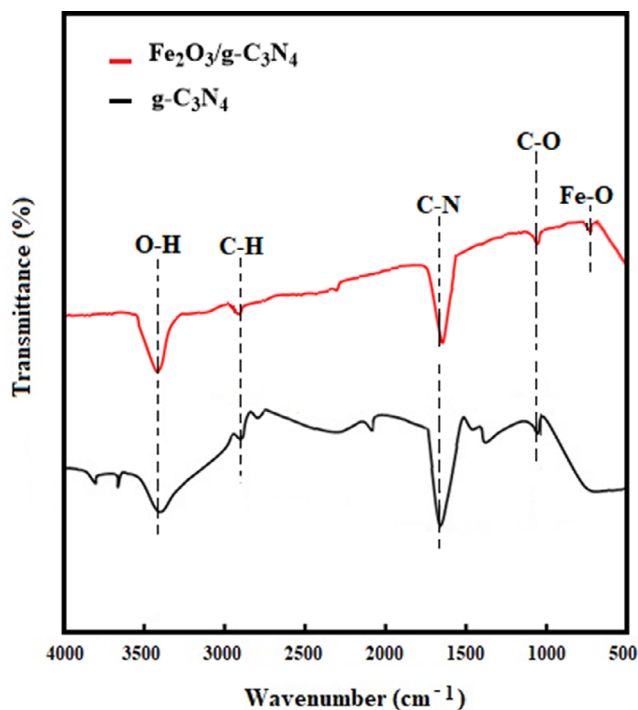


FIGURE 2 The FT-IR spectra of the g-C₃N₄ and Fe₂O₃/g-C₃N₄ (1.0%) nanocomposites

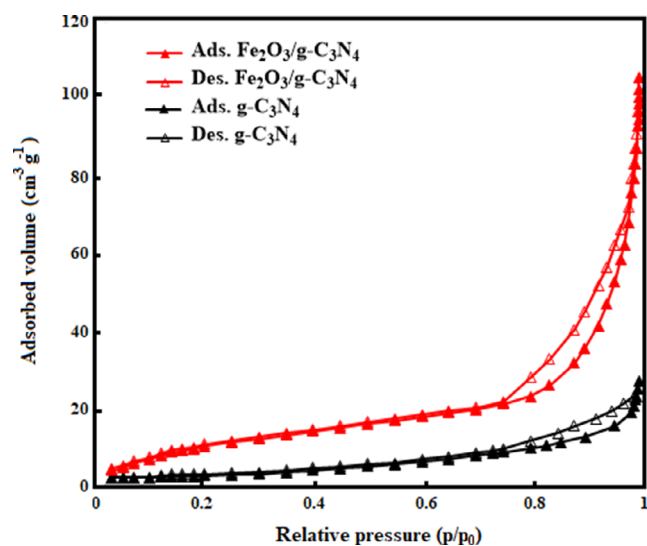


FIGURE 3 The nitrogen adsorption-desorption data for the g-C₃N₄ and Fe₂O₃/g-C₃N₄ (1.0%) nanocomposites

shown in Figure 3. The specific surface areas (SSAs) determined by the BET method are 14.8 and 45.4 m²/g for the g-C₃N₄ and Fe₂O₃/g-C₃N₄ (1.0%) nanocomposites, respectively. The increase in the SSA of the Fe₂O₃/g-C₃N₄ (1.0%) sample might be favorable for promoting the electron mobility and photocatalytic activity by providing more active sites for the chemical redox reactions.^[37]

The surface morphology and microstructure of the g-C₃N₄ and Fe₂O₃/g-C₃N₄ (1.0%) nanocomposites are shown in Figure 4. SEM images (Figure 4a–c) show the compact multilayers of the conjugated aromatic system with the rough surface, which helps to adsorb dye molecules and remove contaminants from the aqueous

solution. As can be seen in TEM images (Figure 4d–f), the g-C₃N₄ edges are thin and transparent to the electron beam. The observations confirm the successful interaction of the Fe₂O₃ particles with the g-C₃N₄ host.

The elemental mapping of the Fe₂O₃/g-C₃N₄ (1.0%) nanocomposite identified by the EDS spectrum is shown

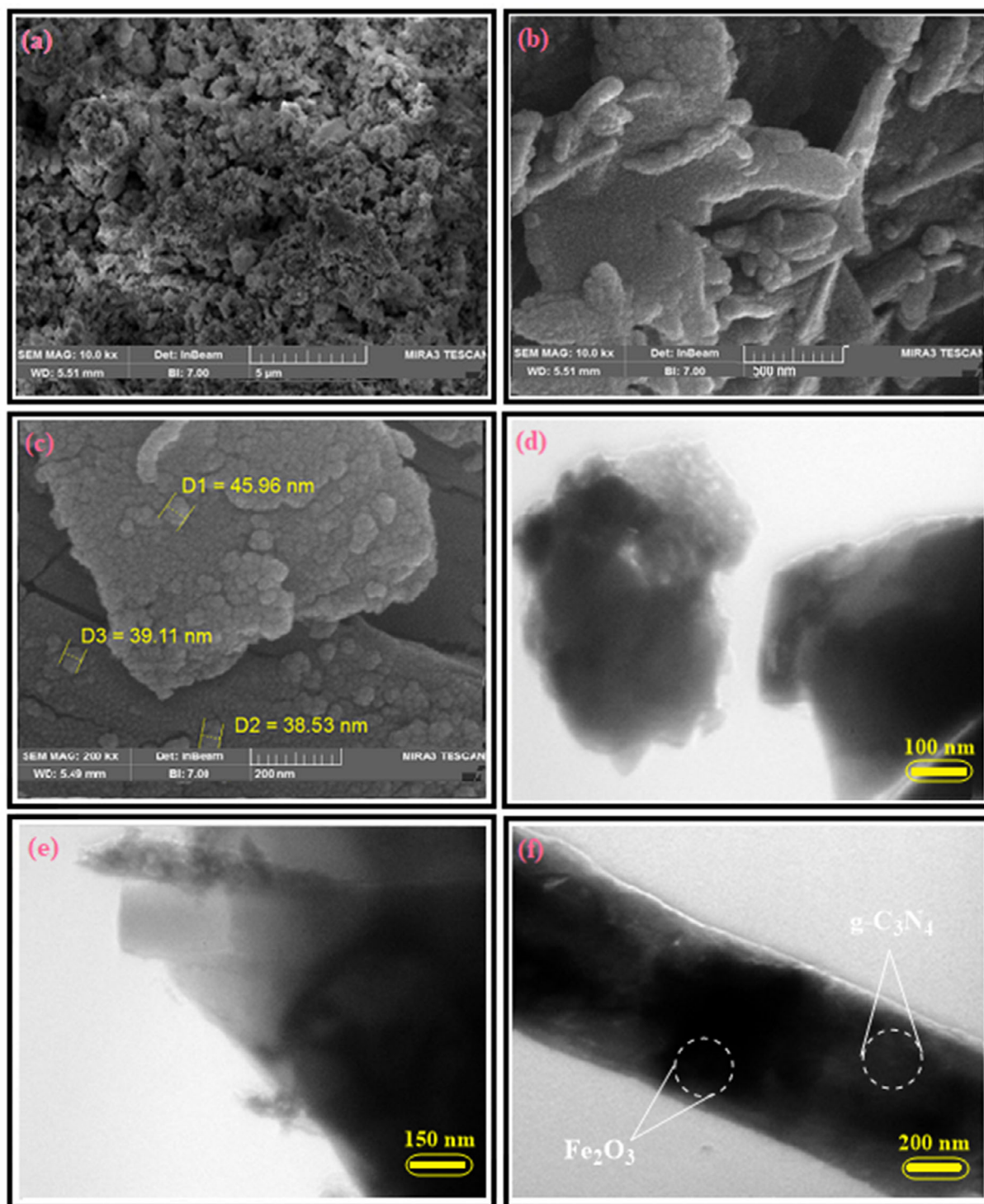


FIGURE 4 The SEM images of the (a) g-C₃N₄, (b) and (c) Fe₂O₃/g-C₃N₄ (1.0%) nanocomposites. The TEM images of the Fe₂O₃/g-C₃N₄ (1.0%) nanocomposite (d–f)

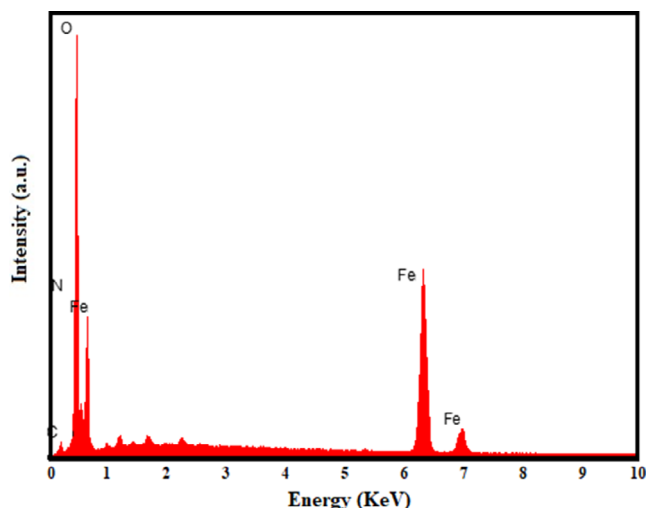


FIGURE 5 The EDS analysis of the $\text{Fe}_2\text{O}_3/\text{g-C}_3\text{N}_4$ (1.0%) nanocomposite

in Figure 5. The peaks are ascribed to C, N, O, and Fe elements and detected at their proper energy level. The results are in good harmony with other investigations and confirm the deposition of iron oxide on the $\text{g-C}_3\text{N}_4$.

Plots of absorbance versus wavelength at different irradiation times, as shown in Figure 6, evaluate the photocatalytic activity of the $\text{g-C}_3\text{N}_4$ and $\text{Fe}_2\text{O}_3/\text{g-C}_3\text{N}_4$ (1.0%) nanocomposites for the degradation of MB under the visible light irradiation. It is clear that the intensity of the absorption peaks at 664 nm gradually decreases without any change in the position. The highest activity is known for the $\text{Fe}_2\text{O}_3/\text{g-C}_3\text{N}_4$ (1.0%) nanocomposite; MB degradation efficiency accomplishes 70% within 90 min of photocatalytic reaction. Bleaching of the solution as the irradiation time proceeds might be attributed to the breaking of the chromophores, carriers of colors.^[38]

3.2 | Photocatalytic activity

Figure 7a shows plots of MB absorbance versus irradiation time over the pure $\text{g-C}_3\text{N}_4$ and $\text{Fe}_2\text{O}_3/\text{g-C}_3\text{N}_4$ nanocomposites with different weight percentage of iron. The behaviors of the nanocomposites before the illumination are also shown to reveal the effect of surface adsorption on the photocatalytic activity. After 30 min of stirring with the light off and 90 min with the light on, the degradation efficiency of the $\text{g-C}_3\text{N}_4$ reached 18.2%. The low photocatalytic activity was ascribed to the usual rapid recombination of the photoinduced electron-hole pairs in the pristine $\text{g-C}_3\text{N}_4$. By introducing Fe_2O_3 content to the $\text{g-C}_3\text{N}_4$, the photocatalytic performance of the nanocomposites was improved; however, it considerably depended on Fe weight percentage. Fe(III) ions

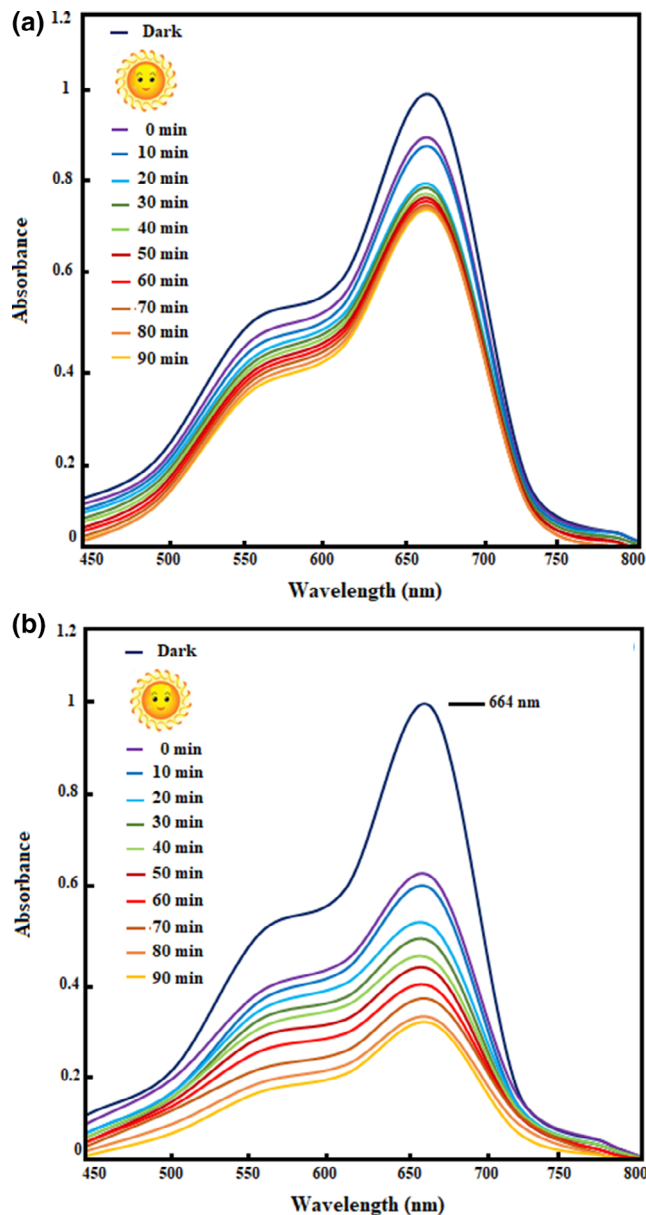


FIGURE 6 The UV-Vis spectra for degradation of MB under the visible light irradiation over the (a) $\text{g-C}_3\text{N}_4$ and (b) $\text{Fe}_2\text{O}_3/\text{g-C}_3\text{N}_4$ (1.0%) nanocomposites

suppressed the electron-hole pair recombination rate and facilitated the migration of charge carriers for participating in the photocatalytic reactions.^[39] The photodegradation efficiencies of the $\text{Fe}_2\text{O}_3/\text{g-C}_3\text{N}_4$ (0.5%), $\text{Fe}_2\text{O}_3/\text{g-C}_3\text{N}_4$ (1.0%), $\text{Fe}_2\text{O}_3/\text{g-C}_3\text{N}_4$ (1.5%), $\text{Fe}_2\text{O}_3/\text{g-C}_3\text{N}_4$ (2.0%), $\text{Fe}_2\text{O}_3/\text{g-C}_3\text{N}_4$ (2.5%), and $\text{Fe}_2\text{O}_3/\text{g-C}_3\text{N}_4$ (5.0%) nanocomposites were measured as 37.6, 69.8, 56.8, 51.2, 48.1, and 31.7%, respectively. The optimum photocatalytic activity was found for the $\text{Fe}_2\text{O}_3/\text{g-C}_3\text{N}_4$ (1.0%) nanocomposite, which was about 3.9-fold higher than that of the pure $\text{g-C}_3\text{N}_4$. It was mainly ascribed to the metal oxide doping effect resulting from the sufficient Fe weight percentage. It followed

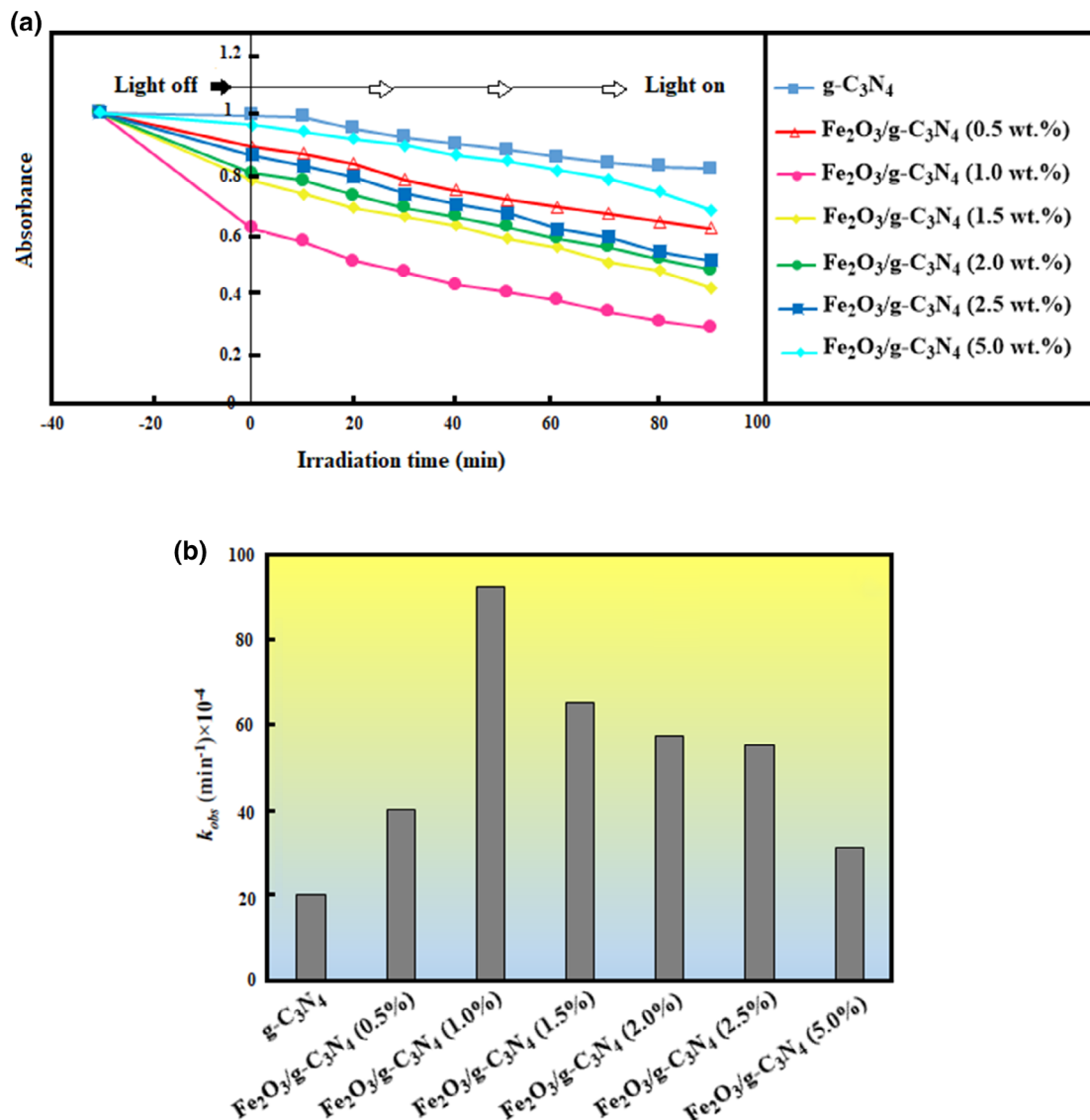


FIGURE 7 (a) The photocatalytic degradation of MB over the g-C₃N₄ and Fe₂O₃/g-C₃N₄ nanocomposites with different weight percentages of Fe. (b) The kinetic constant of MB degradation reaction over the different nanocomposites

that the iron-rich active sites on the surface of the nanocomposites were not chemically beneficial to adsorb and degrade dye molecules.^[40] As seen, lower photocatalytic activity was attributed to the sample with the highest Fe weight percentage (5.0%). The findings indicate that excessive Fe content has a negative effect on the photocatalytic performance. It may break the layered structure of g-C₃N₄, form an agglomeration of oxidation compounds, and suppress great electron mobility.^[41] It is also possible that Fe clusters do not allow the surface of the nanocomposite to absorb more visible light, resulting in a decrease of the photocatalytic activity.^[42]

The Langmuir–Hinshelwood pseudo-first-order equation expressed the photocatalytic degradation of MB over the nanocomposites at low concentrations:

$$\ln [\text{MB}] = \ln [\text{MB}]_0 - k_{\text{obs}}t, \quad (2)$$

where [MB] and [MB]₀ represent concentrations of MB at a reaction time of t and zero, respectively. The pseudo-first-order kinetic constant, $k_{\text{obs}}t$ (min⁻¹), is estimated from the slope of the linear relationship of $\ln (C_0/C_t)$ versus t .^[43] The results of $k_{\text{obs}}t$ calculation, as shown in Figure 7b, confirm that the weight percentage of Fe greatly influences the degradation kinetic constant. The k value for degradation of MB over the g-C₃N₄, Fe₂O₃/g-C₃N₄ (0.5%), Fe₂O₃/g-C₃N₄ (1.0%), Fe₂O₃/g-C₃N₄ (1.5%), Fe₂O₃/g-C₃N₄ (2.0%), Fe₂O₃/g-C₃N₄ (2.5%), and Fe₂O₃/g-C₃N₄ (5.0%) samples are 20×10^{-4} , 40×10^{-4} , 92×10^{-4} , 65×10^{-4} , 57×10^{-4} , 55×10^{-4} , and 31×10^{-4} min⁻¹, respectively. The k value results are in good harmony with the photocatalytic activities. The Fe₂O₃/g-C₃N₄

(1.0%) nanocomposite exhibits the significantly enhanced kinetic constant for photodegradation of MB, which is 4.6 times greater than that of the pure g-C₃N₄. Overall, it may be said that the adequate weight percentage of Fe improves the spatial separation and transfer of electron-hole pairs, leading to the enhancement of photocatalytic performance. On the contrary, the agglomeration of the excessive Fe content reduces the photocatalytic activity.

3.3 | Photocatalytic mechanism

The possible mechanism for MB degradation over the Fe₂O₃/g-C₃N₄ (1.0%) nanocomposite under visible light irradiation is depicted in Figure 8a. The electrons in the lower energy level, valence band (VB), absorb the photons and jump up to the higher energy level, conduction band (CB), and leave holes behind them.^[44] Then, the free electrons and holes create a negative mass on CB and a positive mass on VB, respectively, and take part in

the chemical redox reactions with the adsorbed oxygen and water molecules.^[45] Concerning the Butler and Ginnley model, electron transfer mode depends on CB and VB energies of the semiconductors at the point of zero charges, calculated by the following equations:

$$E_{CB} = X - E^e - 0.5E_g \quad (3)$$

$$E_{VB} = X - E^e + 0.5E_g, \quad (4)$$

where X is the absolute electronegativity of the semiconductor, E^e is the energy of free electrons on the hydrogen scale (4.5 eV), and E_g is the bandgap energy of the semiconductor.^[46]

The CB and VB energies of Fe₂O₃ and g-C₃N₄ were calculated as 0.3, 2.48 eV and −1.12, 1.58 eV, respectively. So, they make a matched band heterojunction.^[47] Under visible light irradiation, electrons from the VB transit to the CB of the counterparts of the Fe₂O₃/g-C₃N₄ nanocomposite owing to their low E_g values. Due to the more negative potential of the CB of g-C₃N₄ compared with that of Fe₂O₃, the photogenerated electrons easily transfer from the CB of g-C₃N₄ to the CB of Fe₂O₃ to effectively promote the separation of electron-hole pairs, prolong the lifetime of charge carriers, and enhance the photocatalytic efficiency. The close contact between Fe₂O₃ and g-C₃N₄ reduces the interfacial free energy and fastens the electron transfer process.^[48] A number of the electrons react with the adsorbed O₂ molecules to produce •O₂[−]; some of them can reduce O₂ to H₂O₂ and form •OH radicals by capturing electrons.^[49] From a thermodynamic point of view, the electrons and holes immigrate in the opposition direction. The VB potential of Fe₂O₃ is more positive than that of g-C₃N₄. Hence, the photogenerated holes transfer from the VB of g-C₃N₄ to the VB of Fe₂O₃. As the potentials of •OH/H₂O (2.72 eV) are higher than the VB potentials of the semiconductors, the photogenerated holes cannot react with the adsorbed H₂O.^[50] As a consequence, the superoxide radical anion •O₂[−], hydroxyl radical •OH, and the holes are known as the reactive species that decompose MB molecules to CO₂, H₂O, and final degradation products (mineral acid) without any secondary pollutants.^[39,42]

A series of scavengers were added to the system to reveal the role of reactive species in the degradation of MB. Figure 8b shows the plot of the degradation kinetic constant (k) in the presence of 2-PrOH as •OH scavenger, BQ as •O₂[−] scavenger, and KI as the hole scavenger.^[51] As can be seen, the k value without using any scavenger decreased from 92×10^{-4} to 11×10^{-4} , 20×10^{-4} , and $41 \times 10^{-4} \text{ min}^{-1}$ in the presence of 2-PrOH, BQ, and KI, respectively. Degradation efficiency exhibited a considerable decrease when 2-PrOH was added. The results indicate that

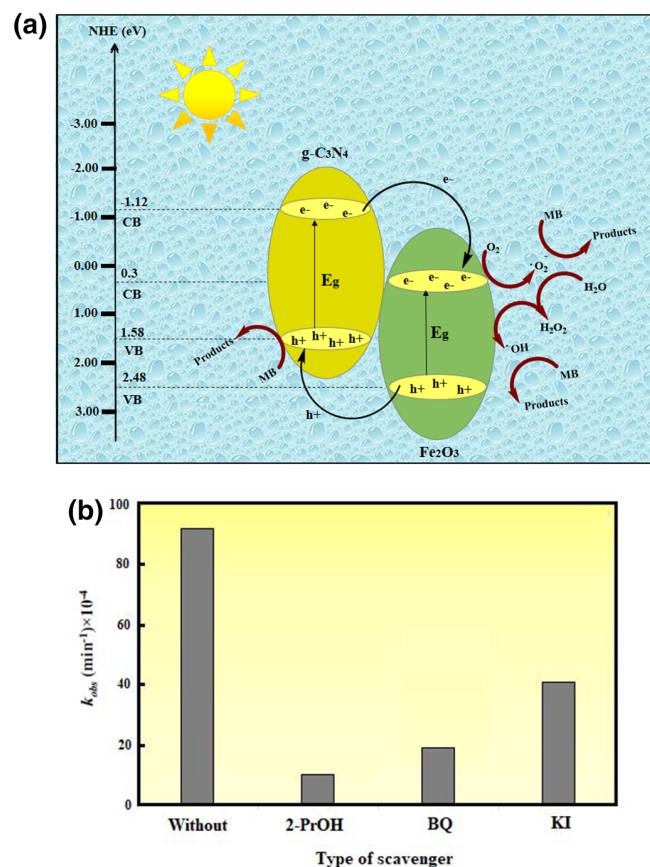


FIGURE 8 (a) The schematic illustration for the possible mechanism of MB degradation over the Fe₂O₃/g-C₃N₄ (1.0%) nanocomposite. (b) The kinetic constant of MB degradation reaction over the Fe₂O₃/g-C₃N₄ (1.0%) nanocomposite in the presence of different scavengers

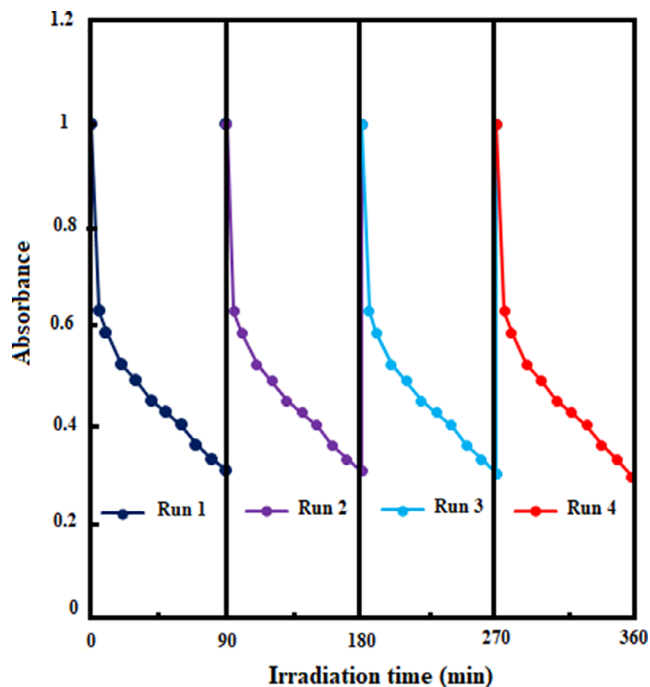


FIGURE 9 Reusability of the $\text{Fe}_2\text{O}_3/\text{g-C}_3\text{N}_4$ (1.0%) nanocomposite for four successive runs

$\bullet\text{OH}$ is the dominant reactive species in the degradation of MB over the $\text{Fe}_2\text{O}_3/\text{g-C}_3\text{N}_4$ (1.0%) nanocomposite.

3.4 | Photocatalytic stability

Four successive photocatalytic experiments were carried out to study the stability and reusability of the nanocomposite of $\text{Fe}_2\text{O}_3/\text{g-C}_3\text{N}_4$ (1.0%). After each analysis, the photoactive particles were separated from the solution, washed with ethanol/DI water, and calcined at 550°C for 2 hr. Then, the recovered catalysts were introduced to the new MB solution for the next cycle of the photocatalytic test under the same conditions. As shown in Figure 9, after four repeated runs, a slight decrease in the photocatalytic activity occurred. MB dye molecules were successfully degraded at the rate of 69.8, 69.4, 68.9, and 68.6% in the first, second, third, and fourth runs, respectively. This means that the $\text{Fe}_2\text{O}_3/\text{g-C}_3\text{N}_4$ (1.0%) nanocomposite has a useful life and reusability.

4 | CONCLUSIONS

Briefly, a series of the Fe_2O_3 -doped $\text{g-C}_3\text{N}_4$ photoactive catalysts with different weight percentages of Fe was successfully synthesized using the green and straightforward microwave-assisted method. The as-fabricated nanocomposites were characterized by XRD, FT-IR, BET, SEM,

TEM, EDS, and UV-Vis analytical techniques. The photocatalytic activity of the samples was evaluated by the degradation of MB dye under visible light irradiation. The experimental results showed that the weight percentage of Fe had a noticeable influence on the degradation potential. The enhanced photocatalytic activity of the nanocomposite with 1.0 wt% Fe was attributed to the effective separation of photogenerated electron-hole pairs, long lifetime, and high ability of charge carriers for taking part in the chemical redox reactions. The photocatalytic efficiency of the $\text{Fe}_2\text{O}_3/\text{g-C}_3\text{N}_4$ (1.0%) nanocomposite was approximately 3.9-fold higher than that of the pure $\text{g-C}_3\text{N}_4$. The $\bullet\text{OH}$ radicals were recognized as the main reactive species by the radical trapping experiments. Finally, the reusability of the nanocomposite was confirmed after four consecutive runs. The results in this work may provide a common commercial perspective for the practical applications of the visible light-driven $\text{Fe}_2\text{O}_3/\text{g-C}_3\text{N}_4$ (1.0%) photocatalyst.

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