

Communication

Sulfonated Silica Coated CoFe₂O₄ Magnetic Nanoparticles for the Synthesis of 3,4-Dihydropyrimidin-2(1H)-One and Octahydroquinazoline Derivatives

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Abstract: Sulfonated-silica-coated cobalt ferrite (CoFe₂O₄) magnetic nanoparticles (MNPs-SiCoFe-SO₃H) are efficient heterogeneous catalysts for the synthesis of 3,4-dihydropyrimidin-2(1H)-one and octahydroquinazoline derivatives in the absence of solvent. The effects of solvent, temperature, and catalyst amount on the reaction are investigated. The easy separation, reusability of the catalyst, simplicity of the procedure, mild reaction conditions, and good yields (68–95%) within short reaction times (15–70 min) are the advantages of this method. The catalyst can be reused up to eight times with not much loss of activity. Scanning electron microscopy images, X-ray diffraction spectra, and elemental analysis of the recycled catalyst show that the catalyst is stable after the reaction.

Keywords: cobalt ferrite; 3,4-dihydropyrimidin-2(1H)-one derivative; octahydroquinazoline derivatives; magnetic nanoparticles; sulfonic acid



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1. Introduction

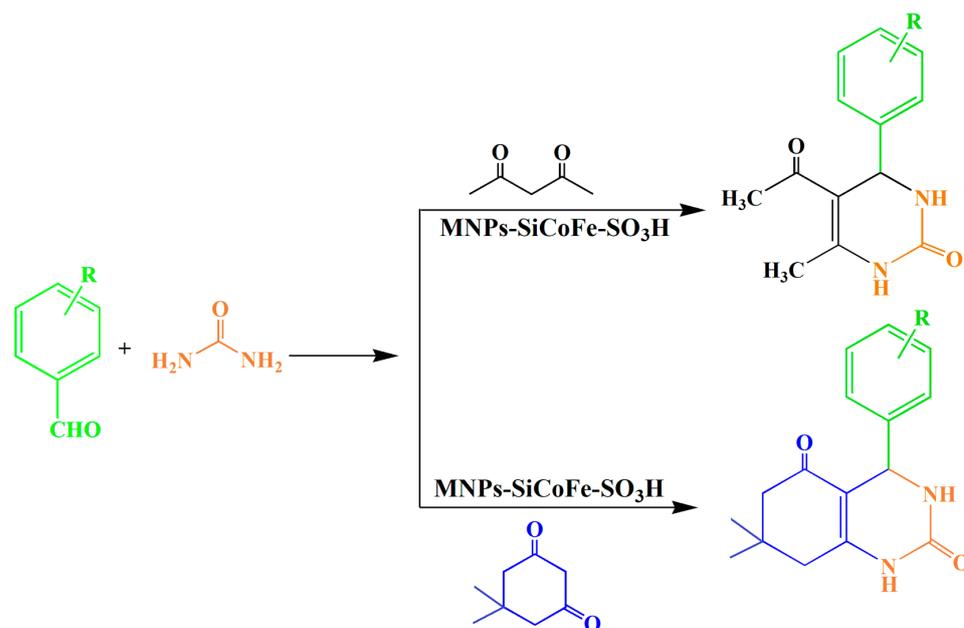
In recent decades, nanoparticles have been reported in several versatile applications, due to their high surface area. They are employed in many fields, such as biology, optics, magnetic applications, and catalysis [1–4]. Nanomagnetic catalysts are easily separated from the reaction medium and can be recycled several times, maintaining the catalytic efficiency [5–7]. Therefore, nanoparticles are significant alternatives to homogeneous catalysts, as they are able to provide high product yields with elevated reaction rates [2,8].

Recently, magnetic nanoparticles are used in the laboratory and industry as supports for sulfonic acid and reported as effective catalysts for the synthesis of benzimidazoles [9], triazolo[4,3-a]pyrimidines [10,11], thiazolidin-4-one derivatives [12], xanthene derivatives [13], 1,4-dihydropyridines [14], octahydroquinazolinone, and 3,4-dihydropyrimidinone derivatives [15]. The Biginelli reaction is a common, yet very essential, type of reaction, which provides a simple method to prepare N-heterocyclic compounds, such as octahydroquinazolinone- and 3,4-dihydropyrimidinone-based materials [16]. Such molecules are well known for their several biological and pharmacological applications, including anticonvulsant [17], antibacterial [18,19], antidiabetic [20], and anticancer [21] activities.

Several materials, such as Yb(OTf)₃ [22], MnO₂-MWCNT (MWCNT—multi-walled carbon nanotubes) [23], and Nafion-Ga [24] are reported for the preparation quinazolinone and 3,4-dihydropyrimidinone compounds, yet with low efficiencies. The use of expensive reagents is associated with a long period of destruction and deactivation of the catalyst and difficulty in recycling. Sulfonic-acid-supported, magnetic-nanoparticles-based catalysts can help to overcome these limitations due to their high catalytic activities, easy recyclability, low cost, long durability, and environmentally safe and green preparation.

The growing demand for environmentally friendly and cost-effective chemical processes led to a search for mild methods that use reusable catalysts and operate under

solvent-free conditions. In response to this need, we developed an alternative for synthesizing 3,4-dihydropyrimidin-2(1H)-one and octahydroquinazoline derivatives [25–27]. In continuation of our previous works [28,29], this paper explores a straightforward synthesis of 3,4-dihydropyrimidin-2(1H)-one and octahydroquinazoline derivatives with various substituents by a one-pot reaction under solvent-free conditions. Silica (Si)-coated cobalt ferrite (CoFe_2O_4) magnetic nanoparticles functionalized with sulfonic acid (MNPs-SiCoFe-SO₃H) are used as environmentally friendly, efficient, and reusable nanocatalysts with good yields (Scheme 1).



Scheme 1. MNPs-SiCoFe-SO₃H catalyzed synthesis of 3,4-dihydropyrimidin-2(1H)-one and octahydroquinazoline derivatives, under solvent-free conditions.

2. Results and Discussion

2.1. Characterization of Sulfonated Silica-Coated CoFe_2O_4 Magnetic Nanoparticles

The preparation of the catalysts used in this study can be found in the Experimental Section. The MNPs-SiCoFe-SO₃H catalyst was analyzed using various methods. The Fourier transform infrared spectroscopy (FT-IR) spectrum of MNPs-SiCoFe-SO₃H is shown in Figure 1. The Fe–O bonds were identified by the strong absorption bands at 589 cm^{-1} and 462 cm^{-1} . These peaks corresponded to the stretching vibrations of Fe–O bonds in the catalyst's structure. Furthermore, the FT-IR spectrum exhibited a broad peak within the range of 1000–1250 cm^{-1} , which could be attributed to the Si–O stretching vibrations present in the silica shell that surrounded the magnetic nanoparticles (MNPs) [30]. The presence of the alkyl groups in MNPs-SiCoFe-SO₃H was confirmed by the aliphatic weak C–H stretching vibrations appearing at 2943 cm^{-1} . However, detecting evidence of the SO₃H groups was challenging due to the low loadings of acidic components and the overlapping of peaks associated with Si–O–Si, Fe–O–Si, and symmetric SO₂ stretching [31].

The X-ray diffraction (XRD) patterns of MNPs-SiCoFe-SO₃H in the pure cobalt ferrite phase (JCPDS PDF #221086) showed the retention of the cubic reverse spinel structure of cobalt ferrite during coating and functionalization. An evident diffusion peak was observed around 20–28°, which could be attributed to the presence of amorphous silica in the shell of cobalt ferrite (Figure 2) [28].

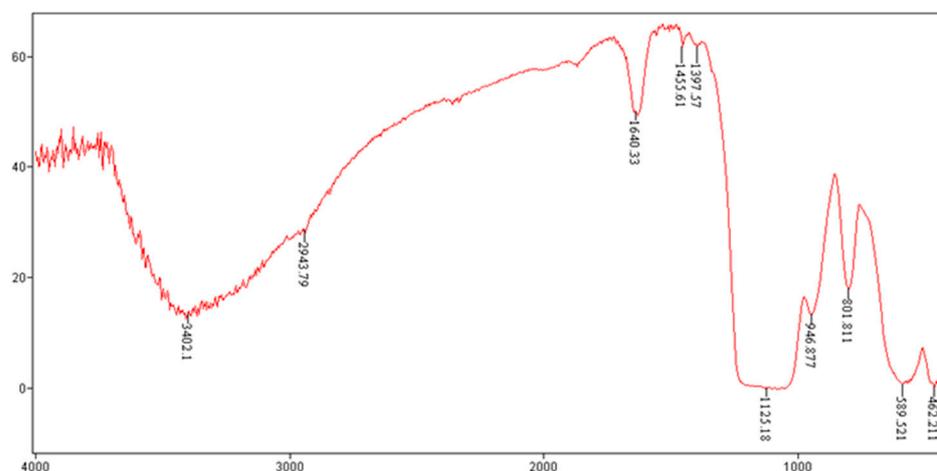


Figure 1. FT-IR spectrum of sulfonated silica-coated CoFe_2O_4 magnetic nanoparticles.

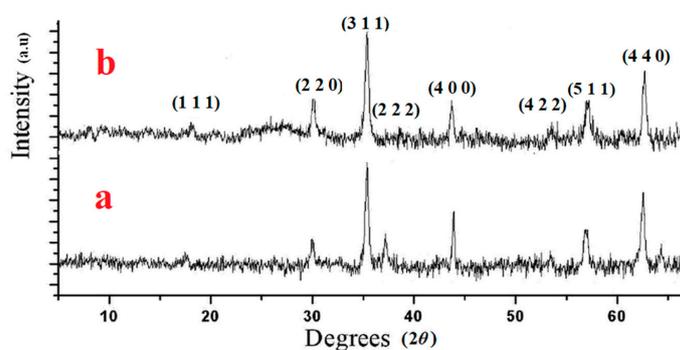


Figure 2. XRD pattern of (a) CoFe_2O_4 , (b) sulfonated-silica-coated CoFe_2O_4 magnetic nanoparticles.

A transmission electron microscopy (TEM) image of MNPs-SiCoFe-SO₃H is presented in Figure 3, revealing the quasi-spherical shape of the particles. The average size of these nanoparticles is approximately 30 nm, and the magnetic core is visible as a dark spot inside the bright spherical SiO₂ thin shell.

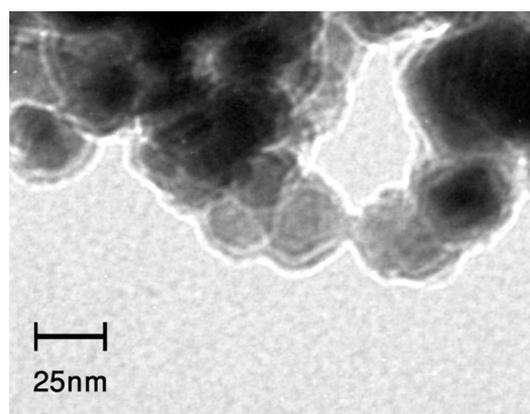


Figure 3. TEM image of the sulfonated-silica-coated CoFe_2O_4 magnetic nanoparticles.

Furthermore, sulfonic acid loadings of the catalyst (mmol of sulfonic acid per gram of MNPs-SiCoFe-SO₃H) could be determined using the back titration method. Initially, samples were allowed to react with 50 mL of distilled water containing 5 mL of 0.1 N NaOH overnight. Then, the remaining NaOH in the solution was titrated with a 0.1 M HCl solutions. The results of the back titration method showed that the value of loading of sulfonic acid was 0.56 mmol/g [32].

The magnetic properties are investigated by vibration sample magnetometry (VSM) at 27 °C, with a peak field of 10 kOe. The saturation magnetization (Ms), remanence magnetization (Mr), and coercivity (Hc) values of MNPs-CoFe, MNPs-SiCoFe, and MNPs-SiCoFe-SO₃H are shown in Table 1. The functionalization of cobalt ferrite nanoparticles led to a decrease in the mass saturation magnetization, which could be attributed to the presence of the nonmagnetic silica shell and functionalized groups. Despite the reduction in saturated magnetism from 59.49 emu/g to 31.16 emu/g, the synthesized nanocomposite exhibited the advantage of easy separation by an external magnet.

Table 1. Magnetic properties of the obtained nanoparticles: saturation magnetization (Ms), remanence magnetization (Mr), and coercivity (Hc).

Sample	Hc (Oe)	Mr (emu/g)	Ms (emu/g)
MNPs-CoFe	796.1	24.63	59.49
MNPs-SiCoFe	861.05	16.40	38.93
MNPs-SiCoFe-SO ₃ H	900	9.60	31.16

2.2. 3,4-Dihydropyrimidin-2(1H)-One Synthesis

In this work, the reaction of acetylacetone, benzaldehyde, and urea was used as a model reaction in different conditions. The results showed that the reaction proceeded slowly with low yields below 80 °C, and it did not improve above 80 °C. Additionally, the results of the model reaction, conducted with various amounts of MNPs-SiCoFe-SO₃H and urea, are presented. It was found that the amount of catalyst leading to the best results was 0.05 g and 5 mmol urea, which provided a high yield within 25 min (Table 2). In addition, we also reported the effect of the solvent on the model reaction and showed the results obtained with several solvents, such as 1,2 dichloroethane (C₂H₄Cl₂), acetonitrile (CH₃CN), and ethanol (EtOH), using MNPs-SiCoFe-SO₃H as catalysts, but the solvent-free conditions displayed the best result (Table 3). Moreover, we also tested the influence of the SO₃H group on the reaction by investigating silica magnetic nanoparticles (Si-MNPs) in the same reaction (Table 2, entry 5), showing that the catalysts displayed a weak activity in the 3,4-dihydropyrimidin-2(1H)-one synthesis.

Table 2. Optimization of synthesis conditions of 3,4-dihydropyrimidin-2(1H)-one ^a.

Entry	Urea (mmol)	Amount of Catalyst (g)	Temperature (°C)	Time (min)	Yield (%) ^b
1	3	0.03	50	30	18
2	3	0.03	80	30	24
3	5	0.03	80	15	27
4	5	0.03	80	25	56
5	5	0.03	80	45	54
6	6	0.03	100	25	55
7	3	0.05	50	25	42
8	5	0.05	50	25	49
9	5	0.05	80	25	94
10	3	0.05	100	25	65
11	5	0.05	100	25	78
12	6	0.05	80	25	90
13	10	0.05	80	25	86
14	5	0.07	80	25	88
15	5	0.07	80	45	86
16	6	0.07	80	25	82
17	6	0.07	100	25	78

Highlighted values indicate the optimal conditions. ^a Reaction conditions: acetylacetone (3 mmol), benzaldehyde (3 mmol). ^b Isolated yield.

Table 3. Effect of different solvents on the synthesis of 3,4-dihydropyrimidin-2(1H)-one ^a.

Entry	Catalyst	Solvent	Temperature (°C)	Time (min)	Yield ^b (%)
1	HSO ₃ -SiCoFe-MNPs	acetonitrile	85	25	80
2	HSO ₃ -SiCoFe-MNPs	1,2-dichloroethane	80	25	85
3	HSO ₃ -SiCoFe-MNPs	ethanol	80	25	76
4	HSO ₃ -SiCoFe-MNPs	water	100	25	35
5	HSO ₃ -SiCoFe-MNPs	-	80	25	94
6	Si-MNPs	-	80	120	25

^a Conditions: acetylacetone (3 mmol), benzaldehyde (3 mmol), urea (5 mmol), catalyst (0.05 g). ^b Isolated yield.

Additionally, different aldehydes with electron-donation or electron-withdrawing substituents are reported, under the above-mentioned optimal reaction conditions, with urea ethyl and acetoacetate, using MNPs-SiCoFe-SO₃H as catalysts. As shown in Table 4, the condensation is completed within 20–70 min and products are obtained in high yields (68–94%).

Table 4. Synthesis of several 3,4-dihydropyrimidin-2(1H)-one derivatives using MNPs-SiCoFe-SO₃H ^a.

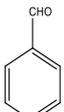
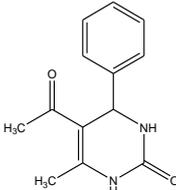
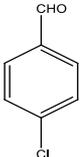
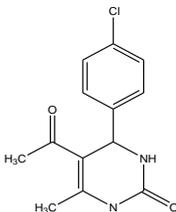
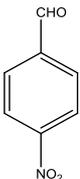
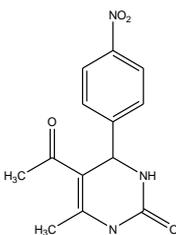
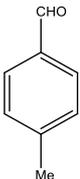
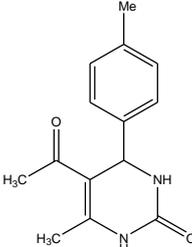
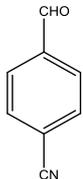
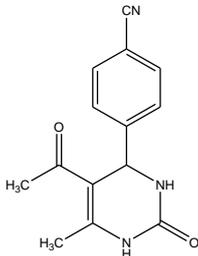
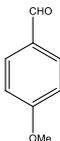
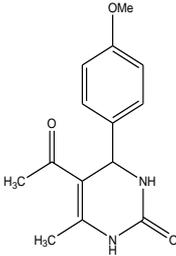
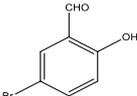
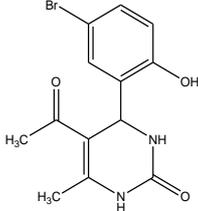
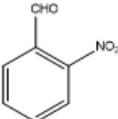
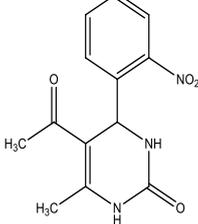
Entry	Aldehyde	Product	Time (min)	Yield ^b (%)
1			25	94
2			25	80
3			50	78
4			30	88

Table 4. Cont.

Entry	Aldehyde	Product	Time (min)	Yield ^b (%)
5			50	73
6			30	89
7			20	93
8			70	68

^a Reaction conditions: benzaldehyde (3 mmol), acetylacetone (3 mmol), urea (5 mmol), catalyst (0.05 g), 80 °C.

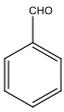
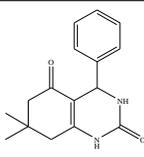
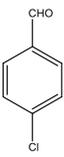
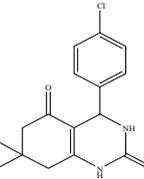
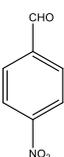
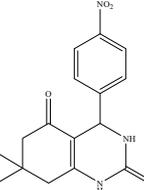
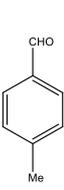
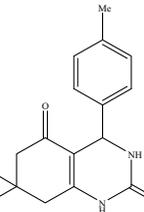
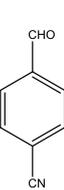
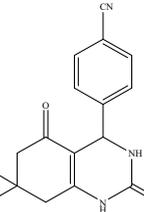
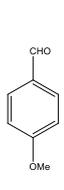
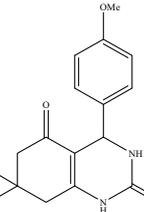
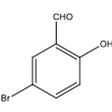
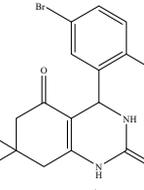
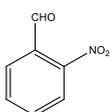
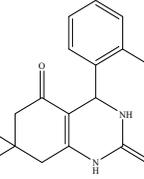
^b Isolated yield.

2.3. Octahydroquinazoline Synthesis

The efficiency of MNPs-SiCoFe-SO₃H in the condensation reactions of dimedone, benzaldehyde, and urea was also investigated. Using this reaction as a model, the temperature and amount of catalyst and solvent were optimized, similarly to what was mentioned for 3,4-dihydropyrimidin-2(1H)-one. The most effective combination was 80 °C 0.05 g MNPs-SiCoFe-SO₃H in solvent-free conditions after 15 min.

Using the optimized conditions for the model reaction, the efficiency of the MNPs-SiCoFe-SO₃H for several aromatic aldehydes with electron-withdrawing and donating groups was tested in order to obtain a series of octahydroquinazolinone derivatives (Table 5). The results showed that the substitution in the aromatic ring did not have a significant effect on the yield of the reaction (entries 3 and 8, Table 5). This method was compatible with aromatic aldehydes with different functional groups, such as -Br, -Cl, and -NO₂.

Table 5. MNPs-SiCoFe-SO₃H synthesis of diversified octahydroquinazoline derivatives ^a.

Entry	Aldehyde	Product	Time (min)	Yield (%) ^b
1			15	95
2			15	92
3			25	90
4			30	92
5			35	90
6			15	92
7			20	88
8			35	88

^a Reaction conditions: aromatic aldehydes (1 mmol), dimedone (2 mmol), urea (3 mmol), catalyst (0.05 g), 80 °C.^b Isolated yield.

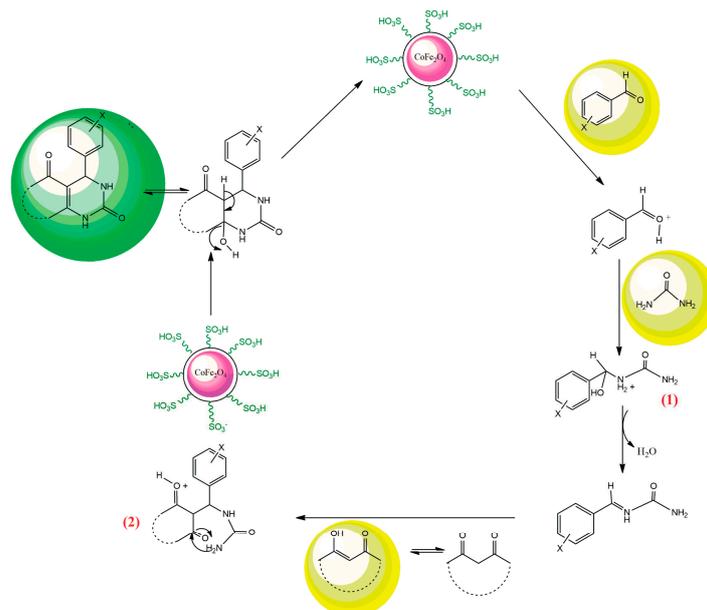
Table 6 compares the efficiency of MNPs-SiCoFe-SO₃H catalysts for the synthesis of the model compounds 3,4-dihydropyrimidin-2(1H)-one and octahydroquinazolinone, with some materials reported in earlier literature. From the collected data, it is clear that our catalytic conditions, in terms of the absence of solvent, cost-effective process, time, and high yield, are efficient in the fast synthesis of the products.

Table 6. Comparative performance of MNPs-SiCoFe-SO₃H with other reported catalysts from literature in the preparation of octahydroquinazolinone (1) and 3,4-dihydropyrimidin-2(1H)-one (2).

Entry	Catalyst	Product	Condition	Time (min)	Yield ^a	Reference
1	Fe ₃ O ₄ @SiO ₂ @OSO ₃ (0.01 g)	1	Ethanol/H ₂ O/Reflux	80	92	[33]
2	SiO ₂ -NH ₂ SO ₄ (0.1 g)	1	H ₂ O/60–80 °C	90	95	[34]
3	γ-Al ₂ O ₃ /BF ₃ /Fe ₃ O ₄ (0.04 g)	2	Solvent-free/80 °C	30	95	[35]
4	imidazole@Fe ₃ O ₄ (0.15 g)	2	Solvent-free/80 °C	30	91	[36]
5	[Btto] [p-TSA] (0.15 mmol)	2	Solvent-free/90 °C	30	96	[37]
8	Fe ₃ O ₄ @mesoporous SBA-15 (0.05 g)	2	EtOH/90 °C	360	85	[38]
9	cellulose sulfuric acid (0.05 g)	2	H ₂ O/100 °C	300	80	[39]
10	[PVPP-SO ₃ H] ⁺ Cl ⁻ (0.06 g)	1	Solvent-free/70 °C	45	86	[40]
11	[PVPP-SO ₃ H] ⁺ Cl ⁻ (0.06 g)	2	Solvent-free/70 °C	45	94	[40]
12	CuO@mTiO ₂ @CoFe ₂ O ₄ (0.025 g)	2	Solvent-free/80 °C	60	92	[41]
13	n-TiO ₂ -NH ₂ (0.024 g)	2	Solvent-free/100 °C	285	90	[42]
14	MNPs-SiCoFe-SO ₃ H (0.05 g)	1	Solvent-free/80 °C	15	95	This work
15	MNPs-SiCoFe-SO ₃ H (0.05 g)	2	Solvent-free/80 °C	25	94	This work

^a Isolated yield.

A plausible pathway for the synthesis of 3,4-dihydropyrimidin-2(1H)-one and octahydroquinazolinone using MNPs-SiCoFe-SO₃H is shown in Scheme 2. The acid catalyst used in these reactions protonated the carbonyl group and produced an electrophilic center [32], which caused the nucleophilic addition of urea and the formation of an intermediate (1), which, subsequently, lost a water molecule. In addition, β-dicarbonyl compounds could easily convert into the enol form using MNPs-SiCoFe-SO₃H, which could easily react with the product of the previous reaction (2). Finally, cyclization and dehydration reactions occurred, and products were formed.



Scheme 2. Possible pathway of MNPs-SiCoFe-SO₃H catalyzed synthesis of dihydropyrimidinone and octahydroquinazolinone derivatives.

2.4. Catalyst Recycling

The catalyst recyclability and reusability of MNPs-SiCoFe-SO₃H were investigated using the reaction between dimedone, benzaldehyde, and urea under optimized conditions. The catalyst was removed by magnetic decantation, washed with methanol and CHCl₃, and dried. The recovered catalyst was further used for up to eight consecutive cycles. The obtained yields are shown in Table 7. There was negligible change in the catalytic efficiency. The slight decrease in activity could be attributed to the inevitable loss of material during the collection process.

Table 7. Catalyst recycling experiments for octahydroquinazolinone synthesis ^a.

Cycle	0	1	2	3	4	5	6	7	8
Yield ^b	95	92	92	90	88	85	85	84	82

^a Reaction conditions: aromatic aldehydes (1 mmol), dimedone (2 mmol), urea (3 mmol), catalyst (0.05 g), 80 °C.

^b Isolated yield.

The XRD spectra (Figure 4) show the same peaks in both the fresh and recycled MNPs-SiCoFe-SO₃H, indicating retention of the crystalline spinel cobalt ferrite core structure (JCPDS PDF #221086), during the recycling process. Additionally, a comparison SEM of the fresh and separated catalysts (Figure 5) shows that reused MNPs-SiCoFe-SO₃H still keeps the nearly spherical morphological aspects, except for a slightly larger particle size than the fresh catalyst (about 30 nm), which may be due to the loss of some small particles during the recycling process. In addition, the elemental analysis shows that the amount of sulfur in the nanocomposite does not significantly change after recycling, confirming that the acidic component of the catalyst is firmly attached to it (Table 8).

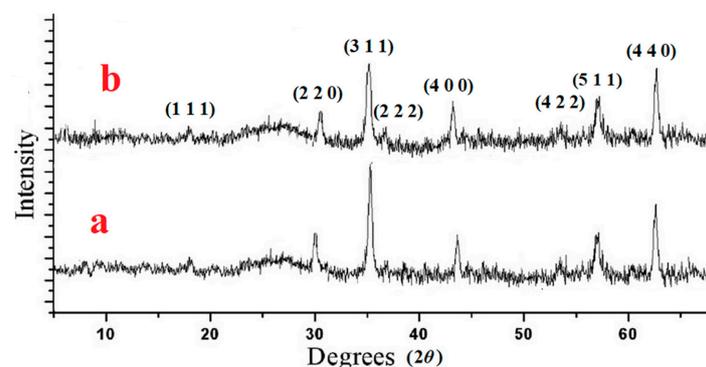


Figure 4. XRD diffractograms of (a) fresh MNPs-SiCoFe-SO₃H and (b) recycled MNPs-SiCoFe-SO₃H. The crystalline spinel cobalt ferrite core structure (JCPDS PDF #221086) is identified.

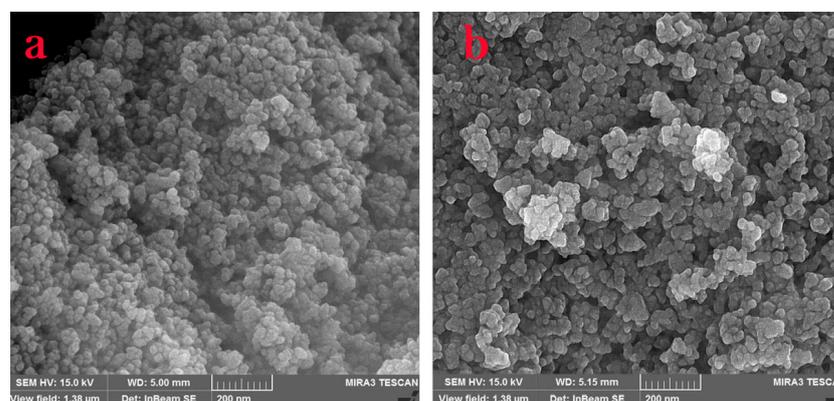


Figure 5. SEM images of (a) fresh MNPs-SiCoFe-SO₃H and (b) recycled MNPs-SiCoFe-SO₃H.

Table 8. Elemental analysis of fresh and recycled catalysts.

Compound	% C	% H	% S
Fresh MNPs-SiCoFe-SO ₃ H	3.65	0.66	3.25
MNPs-SiCoFe-SO ₃ H (1st recycle)	3.61	0.65	3.21
MNPs-SiCoFe-SO ₃ H (8th recycle)	3.50	0.63	3.11

3. Experimental Section

3.1. Materials Characterization

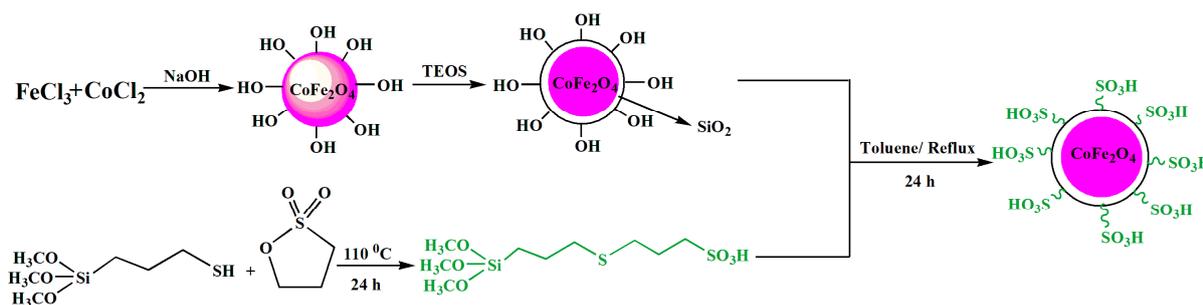
All the chemicals were supplied by Merck and used without further purification. X-ray diffraction (XRD) experiments were performed in a Philips X-ray diffractometer (PW1840 model) with Cu K α radiation ($\lambda = 1.54056 \text{ \AA}$). Fourier transform infrared spectra (FT-IR) was recorded in a BOMEM MB-Series 1998 FT-IR spectrometer. Field emission scanning electron microscopy (FESEM) used a Hitachi Japan S4160 scanning electron microscope. The size and morphologies of sulfonated-silica-coated CoFe₂O₄ magnetic nanoparticles were recorded using a Leo 912 AB transmission electron microscope operated at a 100 keV. The vibration sample magnetometry (VSM) properties of the fabricated MNPs-SiCoFe-SO₃H composite and other samples were monitored by a Meghnatis Daghigh Kavir Company device. Reactions were followed by thin-layer chromatography (TLC). Nuclear magnetic resonance (NMR) spectra were obtained on a Bruker Advanced DPX 400 MHz spectrometer.

3.2. Synthesis of Sulfonated Silica-Coated CoFe₂O₄ Magnetic Nanoparticles

Cobalt ferrite (CoFe₂O₄) magnetic nanoparticles (CoFe-MNPs) were synthesized by the method described by Maaz et al. [43]. Briefly, a solution of iron (III) chloride (0.4 M, 25 mL) was mixed with a solution of cobalt (II) chloride (0.2 M, 25 mL), and sodium hydroxide solution (3 M) was added dropwise until the pH of the mixture reached approximately 11–12. To this mixture, oleic acid (0.6 mL) was added, and the solution was heated for 1 h at 80 °C. The resulting dark brown precipitate was separated using a centrifuge and washed multiple times with hot water and ethanol. Subsequently, it was dried overnight in an oven at 100 °C. The obtained sediment was then finely ground in a mortar and further subjected to heat treatment at 600 °C for 10 h.

Silica-coated CoFe₂O₄ nanoparticles (SiCoFe-MNPs) were obtained by the Stöber method [44–46]. To achieve this, cobalt ferrite (0.04 g) was added to a mixture of distilled water (20 mL) and ethanol (80 mL). The mixture was subjected to ultrasonic waves for 1 h to ensure proper dispersion. Then, ammonia (2.4 mL, 25%) was added, followed by the dropwise addition of 2 mL of tetraethylorthosilicate (TEOS) with stirring. The solution was left at room temperature for 24 h. The resulting black sediment was separated using an external magnet and washed thoroughly with water and ethanol. Finally, the sediment was dried in an oven at 100 °C for 2 h.

Sulfonic-acid-functionalized, silica-coated MNPs (HSO₃-SiCoFe-MNPs) were synthesized through a one-pot procedure (Scheme 3) [28]. Initially, a mixture of 3-mercaptopropyl trimethoxysilane (2.95 mL, 16 mmol) and 1,3-propanesultone (1.62 mL, 16 mmol) was heated for 24 h at 110 °C. The resulting product was dissolved in 25 mL of toluene, followed by the addition of Si-MNPs (0.55 g). The mixture was refluxed under a nitrogen atmosphere for 24 h. Finally, the silica-coated cobalt ferrite magnetic nanoparticles functionalized with sulfonic acid (MNPs-SiCoFe-SO₃H) were separated using an external magnet and washed thoroughly with toluene and ether.



Scheme 3. Synthesis of sulfonated-silica-coated CoFe_2O_4 magnetic nanoparticles.

3.3. General Procedure for Catalytic 3,4-Dihydropyrimidin-2(1H)-One Synthesis

A mixture of acetylacetone (3 mmol), aromatic aldehyde (3 mmol), urea (5 mmol), and MNPs-SiCoFe-SO₃H (50 mg) was stirred at 80 °C, without any solvent, for 25–70 min. After the reaction was completed (see Table 4), the non-soluble material was dissolved in ethanol and decanted using a permanent magnet. The separated products were concentrated and recrystallized from hot ethanol and identified by Fourier transform infrared spectroscopy (FT-IR), proton nuclear magnetic resonance (¹H NMR), and melting point (mp) results (in comparison with the literature values).

Spectral Data for Selected Compounds

5-acetyl-4-(4-chlorophenyl)-6-methyl-3,4-dihydropyrimidin 2(1H)-one (Table 4, entry 2)
 M.P.: 223–224 °C; FT-IR (KBr, cm⁻¹): 3293, 3098, 1700, 1619, 1235. ¹H NMR (DMSO, 400 MHz): δ = 9.21 (s, 1H), 7.84 (s, 1H), 7.37–7.40 (d, 2H), 7.25–7.27 (d, 2H) 5.2 (s, 1H), 2.29 (s, 3H), 2.145 (s, 3H). The NMR spectra is shown in Figure S1 of Supporting Information.

5-acetyl-6-methyl-4-(4-nitrophenyl)-3,4-dihydropyrimidin 2(1H)-one (Table 4, entry 3)
 M.P.: 208–210 °C; FT-IR (KBr, cm⁻¹): 3243, 3119, 1708, 1674, 1232. ¹H NMR (DMSO, 400 MHz): δ = 9.33 (s, 1H), 7.98 (s, 1H), 8.20–8.22 (d, 2H), 7.50–7.52 (d, 2H) 5.38 (s, 1H), 2.321 (s, 3H), 2.19 (s, 3H). The NMR spectra is shown in Figure S2 of Supporting Information.

5-acetyl-4-(4-methoxyphenyl)-6-methyl-3,4-dihydropyrimidin 2(1H)-one (Table 4, entry 6)

M.P.: 172 °C, FT-IR (KBR, cm⁻¹): 3309, 1700, 1617, 14669, 13647, 1239, 1180, 835; ¹H NMR (DMSO, 400 MHz): δ = 9.91 (s, 1H), 7.84 (s, 1H), 7.21 (d, 2H), 6.86 (d, 2H), 5.40 (s, 1H), 3.79 (s, 3H), 2.35 (s, 3H), 2.12 (s, 3H). The NMR spectra is shown in Figure S3 of Supporting Information.

3.4. General Procedure for Catalytic Octahydroquinazoline Synthesis

A mixture of aromatic aldehyde (1 mmol), urea (3 mmol), dimedon (2 mmol), and MNPs-SiCoFe-SO₃H (50 mg) was stirred at a reflux of 80 °C. After the reaction was completed (see Table 5), the non-soluble product was dissolved in ethanol and decanted using an external magnet. The separated product was concentrated and purified from hot ethanol and identified by FT-IR, ¹H NMR, and melting point (M.P.) comparison with literature.

Spectral Data for Selected Compounds

4-(benzaldehyde)-7,7-dimethyl-1,2,3,4,5,6,7,8-octahydroquinazoline-2,5-dione (Table 5, entry 1)

M.P.: 291–292 °C; FT-IR (KBR, cm⁻¹): 3328, 3259, 2964, 1712, 1679, 1614, 1449, 1374, 1238, 770, 693, 568, 489, 433. ¹H NMR: (DMSO, 400 MHz): δ = 0.95 (s, 3H); 1.11 (s, 3H); 2.21 (q, 2H); 2.39 (q, 2H); 5.26 (d, 1H); 7.33–7.22 (m, 5H); 7.47 (s, 1H, NH); 9.39 (s, 1H). The NMR spectra is shown in Figure S4 of Supporting Information.

4-(4-methoxyphenyl)-7,7-dimethyl-1,2,3,4,5,6,7,8-octahydroquinazoline-2,5-dione (Table 5, entry 6)

M.P.: 274–275 °C; FT-IR (KBR, cm⁻¹): 3276 and 3025, 1638, 1251, 821, 778, 578, 523. ¹H NMR: (DMSO, 400 MHz): δ = 9.24 (s, 1H), 7.08 (s, 1H), 7.07 (d, 2H), 6.73 (d, 2H), 4.77 (s,

1H), 3.68 (s, 3H), 2.45 (d, 1H), 2.33 (d, 1H), 2.17 (d, 1H), 1.20 (d, 1H), 1.03 (s, 3H), 0.90 (s, 3H). The NMR spectra is shown in Figure S5 of Supporting Information.

4-(4-chlorobenzaldehyde)-7,7-dimethyl-1,2,3,4,5,6,7,8-octahydroquinazoline-2,5-dione (Table 5, entry 2)

M.P.: >300 °C; FT-IR (KBR, cm^{-1}): 3249, 2962, 16979, 1615, 1489, 1379, 1243, 810, 767, 569, 512. ^1H NMR: (DMSO, 400 MHz): δ = 0.95 (s, 3H); 1.09 (s, 3H); 2.20 (q, 2H); 2.38 (q, 2H); 5.31 (d, 1H, CH); 7.20–7.31 (m, 4H); 7.55 (s, 1H); 9.37 (s, 1H). The NMR spectra is shown in Figure S6 of Supporting Information.

4. Conclusions

In this paper, we report a nano solid acid material as an environmentally safe catalyst for the synthesis of 3,4-dihydropyrimidin-2(1H)-one and octahydroquinazoline derivatives, in the absence of solvent, at 80 °C.

This method, using MNPs-SiCoFe-SO₃H, can promote reactions with a high range of substitutions in the reagents and offer benefits, such as short reaction times (15–70 min), good product yields (68–95%), solvent-free conditions, and a simple procedure. In addition, the catalyst shows high stability under reaction conditions and can be separated from the reaction mixture with a permanent magnet and can be reused up to eight times with not much loss in yield.

Supplementary Materials: The following supporting information can be downloaded at: <https://www.mdpi.com/article/10.3390/catal13060989/s1>, Figure S1: ^1H -NMR: 5-acetyl-4-(4-chlorophenyl)-6-methyl-3,4-dihydropyrimidin 2(1H)-one. Figure S2: ^1H NMR: 5-acetyl-6-methyl-4-(4-nitrophenyl)-3,4-dihydropyrimidin 2(1H)-one. Figure S3: vHNMR: 5-acetyl-4-(4-methoxyphenyl)-6-methyl-3,4-dihydropyrimidin-2(1H)-one. Figure S4: ^1H NMR: 4-(benzaldehyde)-7,7-dimethyl-1,2,3,4,5,6,7,8-octahydroquinazoline-2,5-dione. Figure S5: ^1H NMR: 4-(4-methoxyphenyl)-7,7-dimethyl-1,2,3,4,5,6,7,8-octahydroquinazoline-2,5-dione. Figure S6: ^1H NMR: 4-(4-chlorobenzaldehyde)-7,7-dimethyl-1,2,3,4,5,6,7,8-octahydroquinazoline-2,5-dione.

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