Adsorption of reactive red 2BF onto Ni$_{0.3}$Co$_{0.2}$Zn$_{0.5}$Fe$_2$O$_4$ nanoparticles fabricated via the ethanol solution of nitrate combustion process

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Abstract

An ethanol solution of nitrate combustion process for the fabrication of magnetic Ni$_{0.3}$Co$_{0.2}$Zn$_{0.5}$Fe$_2$O$_4$ nanoparticles was introduced. And the Ni$_{0.3}$Co$_{0.2}$Zn$_{0.5}$Fe$_2$O$_4$ nanoparticles fabricated at 500 $^\circ$C for 2 h were characterized by means of the transmission electron microscopy (TEM), the vibrating sample magnetometer (VSM), the scanning electron microscopy (SEM), and the x-ray diffraction (XRD). The magnetic Ni$_{0.3}$Co$_{0.2}$Zn$_{0.5}$Fe$_2$O$_4$ nanoparticles were useful to remove reactive red 2BF (RR-2BF) from wastewater, and the adsorption mechanism of RR-2BF onto magnetic Ni$_{0.3}$Co$_{0.2}$Zn$_{0.5}$Fe$_2$O$_4$ nanoparticles was explored. The experimental results revealed that Temkin isotherm model and the pseudo-second kinetics model matched well with adsorption process, which indicated that there was monolayer and multilayer adsorption in the adsorption behavior of RR-2BF onto magnetic Ni$_{0.3}$Co$_{0.2}$Zn$_{0.5}$Fe$_2$O$_4$ nanoparticles. While, the effects of the adsorbent dosage and pH value of solution on the adsorption process were investigated, and it was found that with the increase of them, the adsorbances of RR-2BF onto Ni$_{0.3}$Co$_{0.2}$Zn$_{0.5}$Fe$_2$O$_4$ nanoparticles decreased. The maximum adsorption capacity of Ni$_{0.3}$Co$_{0.2}$Zn$_{0.5}$Fe$_2$O$_4$ was about 138 mg g$^{-1}$, and the adsorbance amounted to 75% of the initial one after 8 recycles.

1. Introduction

With the development of technology and science, more and more dyes are applied in textile, chemical, food and other industries. Therewith, there was increasing discharge of dyes into environment [1]. The excessive emissions of dyes have had serious impacts on surroundings, which can reduce the transparency and destroy the self-purification of water. They also contain biotoxicity, leading to a series of problems on biology and the health of human [2]. Therefore, the treatment of wastewater should involve not only reducing or avoiding environmental pollution and protecting people’s health, but also recycling the treated water and saving water resources. So, the removal of dyes from wastewater becomes an important project.

A great many approaches were commonly applied to treat the industrial wastewater containing dyes, such as the chemical process, the biological conversion process, the physical process, and so on [3–6]. However, the chemical process might produce the secondary pollution; the biological conversion process was usually unable to be carried out owing to its limits of being anti-acid, anti-alkali and the lack of sunlight, which was shielded by the dyes; in the last few years, the physical process, especially the adsorption process, received unanimous praises due to the thoroughness of the removal with no secondary pollutions [7, 8]. Compared with other methods, the adsorption method is more simple, efficient and safer, and the equipment is relatively facile. Most of the adsorption process does not require the participation of organic reagent, and the adsorbent can be reused, therefore, this method is an excellent strategy for removing dyes from water [9].

The key for the adsorption process is the adsorbent. In recent years, for the larger adsorption capacities, the nanomaterials have attracted more and more attentions. However, the separations for the ordinary
nanomaterials became more and more difficult because of their smaller size, so the researchers used the magnetic nanomaterials for adsorption processes to play their roles of magnetic separation under the external magnetic field [10, 11]. The commonly used magnetic nano adsorbents are iron based, but ferrite nanoparticles alone tend to be less magnetic than ferrite doped with other metal elements. Because the greater the magnetism is, the less the loss of nanoparticles in the recycling process will be. Moreover, some researches have showed that appropriate doping of nickel, cobalt and zinc could reduce the material’s coercive force, improve the saturation magnetization of the material, and make the material become soft magnetic material [2, 12, 13]. Therefore, as one of significant magnetic nanomaterials [14], the magnetic Ni$_{0.3}$Co$_{0.2}$Zn$_{0.5}$Fe$_2$O$_4$ nanoparticles were employed in dye removal.

The preparation methods for magnetic Ni$_{0.3}$Co$_{0.2}$Zn$_{0.5}$Fe$_2$O$_4$ nanoparticles include the extrusion through nano-porous membranes, the hydration process, the hydrothermal method, the solvothermal approach and etc [15–18]. Nevertheless, these approaches usually had rigorous requirements on the preparation devices and a long preparation period. The rapid combustion method has many advantages, such as environmental protection, low cost, facile process, and short preparation cycle [19–21].

In this work, we fabricated magnetic Ni$_{0.3}$Co$_{0.2}$Zn$_{0.5}$Fe$_2$O$_4$ nanoparticles via the ethanol solution of nitrate combustion process, and the kinetics, the isotherm, as well as the effects of influence factors for RR-2BF adsorption process with absolute ethanol as fuel and solvent were shown in figure 1. The hydration process, the hydrothermal method, the solvothermal approach and etc [15–18] could be assigned to the crystal plane of 202°, 311°, 35.60°, and 30.22° could be assigned to the crystal plane of (440), (511), (422), (400), and (311), respectively. It is universally acknowledged that the sharp and intense peaks suggested that the products

### 2. Experimental

#### 2.1. Preparation and characteristics of Ni$_{0.3}$Co$_{0.2}$Zn$_{0.5}$Fe$_2$O$_4$ nanoparticles

Magnetic Ni$_{0.3}$Co$_{0.2}$Zn$_{0.5}$Fe$_2$O$_4$ nanoparticles were fabricated via the ethanol solution of nitrate combustion process with absolute ethanol as fuel and solvent [13]. Typically, 6.89 g Fe(NO$_3$)$_3$·9H$_2$O, 1.26 g Zn(NO$_3$)$_2$·6H$_2$O, 0.75 g Ni(NO$_3$)$_2$·6H$_2$O, and 0.49 g Co(NO$_3$)$_2$·6H$_2$O were placed into 30 ml absolute ethanol. The ethanol solution of the nitrates was stirred until the homogenous solution was formed. Then, the crucible with mixed solution was ignited. As the crucible naturally cooled, the crucible in which gel had been formed was put into the program-controlled furnace following 2 h calcination at 500°C for 2 h with 30 ml absolute ethanol were shown in figure 1. The glass bottles were pulled out at designed intervals, and the magnetic property was measured using a VSM, the SEM image was obtained to analyze morphology of Ni$_{0.3}$Co$_{0.2}$Zn$_{0.5}$Fe$_2$O$_4$ nanoparticles, and their microstructure was investigated by the transmission electron microscopy.

#### 2.2. Adsorption of RR-2BF onto Ni$_{0.3}$Co$_{0.2}$Zn$_{0.5}$Fe$_2$O$_4$ nanoparticles

20 ml RR-2BF aqueous solution in range of 100–400 mg·L$^{-1}$ and 0.05 g Ni$_{0.3}$Co$_{0.2}$Zn$_{0.5}$Fe$_2$O$_4$ nanoparticles fabricated at 500°C for 2 h with 30 ml absolute ethanol in glass bottles were shaken with the speed of 100 rpm at ambient temperature. After that, the glass bottles were pulled out at designed intervals, and the magnetic field was applied to separate the Ni$_{0.3}$Co$_{0.2}$Zn$_{0.5}$Fe$_2$O$_4$ nanoparticles. The residual RR-2BF concentrations in solutions were measured using a UV–vis spectrophotometer. If the adsorption of Ni$_{0.3}$Co$_{0.2}$Zn$_{0.5}$Fe$_2$O$_4$ nanoparticles for RR-2BF would achieved equilibrium, and then the adsorption equilibrium adsorption capacities were obtained.

The adsorbance values of RR-2BF adsorbed onto Ni$_{0.3}$Co$_{0.2}$Zn$_{0.5}$Fe$_2$O$_4$ nanoparticles were determined by the following equation (1) [22].

$$q = \frac{V(C_0 - C)}{m}$$ (1)

wherein $q$ represented the adsorbance in mg g$^{-1}$, $V$ represented the volume of RR-2BF solution in L, $C$ and $C_0$ (mg·L$^{-1}$) were the RR-2BF concentrations at the predetermined and initial time, and $m$ referred to the weight of Ni$_{0.3}$Co$_{0.2}$Zn$_{0.5}$Fe$_2$O$_4$ nanoparticles in g.

### 3. Result and discussions

#### 3.1. Characterization of Ni$_{0.3}$Co$_{0.2}$Zn$_{0.5}$Fe$_2$O$_4$ nanoparticles

The characteristics for magnetic Ni$_{0.3}$Co$_{0.2}$Zn$_{0.5}$Fe$_2$O$_4$ nanoparticles fabricated at 500°C for 2 h with 30 ml absolute ethanol were shown in figure 1. The SEM morphology and TEM image for Ni$_{0.3}$Co$_{0.2}$Zn$_{0.5}$Fe$_2$O$_4$ nanoparticles were revealed in figures 1(a) and (b), and the particle size of Ni$_{0.3}$Co$_{0.2}$Zn$_{0.5}$Fe$_2$O$_4$ nanoparticles was about 30 nm. From the XRD pattern of as-fabricated nanoparticles, the observed peaks at 62.85°, 57.24°, 53.70°, 43.26°, 35.60°, and 30.22° could be assigned to the crystal plane of (440), (511), (422), (400), (311), and (220), respectively.
were well-crystallized. At the same time, it seemed that the dopings with Co$^{2+}$ and Zn$^{2+}$ ions had no obvious effects on the cubic spinel crystal construction of NiFe$_2$O$_4$ (JCPDS No. 03-0875). For Co$^{2+}$ and Zn$^{2+}$ doped samples, no corresponding peaks for cobalt and zinc compounds appeared, which indicated that Co$^{2+}$ and Zn$^{2+}$ ions were effectively inlayed into crystal lattices of NiFe$_2$O$_4$ and formed a stable Ni$_{0.3}$Co$_{0.2}$Zn$_{0.5}$Fe$_2$O$_4$ crystal phase. Figure 1(d) showed the hysteresis loop of Ni$_{0.3}$Co$_{0.2}$Zn$_{0.5}$Fe$_2$O$_4$ nanoparticles. Obviously, the magnetic Ni$_{0.3}$Co$_{0.2}$Zn$_{0.5}$Fe$_2$O$_4$ nanoparticles with specific magnetization ($M_s$) of 203.2 emu $\cdot$ g$^{-1}$ showed the typical soft magnetization behavior.

3.2. Effect of adsorbent dosage on the adsorption

Before exploring the adsorption mechanism, we first selected to focus on the appropriate dosage of adsorbent. The adsorption capacity of the adsorbent with different dosages in 20 ml RR-2BF solution (200 mg l$^{-1}$) was examined, as displayed in figure 2. Obviously, when the amount of adsorbent was greater than 0.05 g, the adsorbance showed a downward trend. This was for the reason that the magnetic properties of the nanoparticles were very strong. When the volume of dye solution remained constant, the more magnetic nanoparticles, the worse their dispersion and the more likely they were to aggregate with each other. Moreover, the surface of the agglomerated nanoparticles could not fully contact with the dye molecules, so the adsorption capacity decreased. As a result, in the adsorption process, 0.05 g adsorbent was selected for the test.

3.3. Effect of the pH value on the adsorption

The solution pH value was a key condition that could affect the adsorption process. In order to explore the adsorption mechanism, 0.05 g magnetic Ni$_{0.3}$Co$_{0.2}$Zn$_{0.5}$Fe$_2$O$_4$ nanoparticles were weighed to adsorb 20 ml dyes of 200 mg/l with pH of 2, 4, 6, 8 and 10. The results were shown in figure 3. As the increase of pH, the decreased adsorption capacity could be observed. The reason may be that RR-2BF was an anionic dye, and the material was positively charged. When the nanoparticles were dispersed in the reactive red dye, there was electrostatic attraction between the material and the RR-2BF molecules, which resulted in the adsorption of outer surface of the nanoparticles for the RR-2BF molecules. As the pH value was changed from acidity to alkalinity, the amount of OH$^-$ in the solution increased gradually, and nanoparticles had adsorption effect on both OH$^-$ and RR-2BF molecules. However, the competitive adsorption of the two made the competitive ability of RR-2BF molecules
weakened gradually with the increase of pH. As the active sites on the nanoparticles were occupied by OH\(^{-}\), the adsorbance of RR-2BF molecules onto the nanoparticles decreased gradually when the solution pH value increased.

3.4. Adsorption kinetics

It is significant to investigate adsorption rate of adsorbate onto the adsorbent for the application of the nanoparticles in wastewater treatment. The kinetics models of the pseudo-first-order, pseudo-second-order and intraparticle diffusion were often employed to measure the process of Ni\(_{0.3}\)Co\(_{0.2}\)Zn\(_{0.5}\)Fe\(_2\)O\(_4\) nanoparticles adsorbing RR-2BF.

These three kinetics models were listed as equations (2)–(4), respectively \([23, 24]\).

\[
q_t = q_e(1 - e^{-kt})
\]  

\[
q_t = \frac{q_e^2 k_2 t}{1 + q_e k_2 t}
\]

\[
Figure 2. Effects of adsorbent dosages on adsorbances of RR-2BF onto Ni\(_{0.3}\)Co\(_{0.2}\)Zn\(_{0.5}\)Fe\(_2\)O\(_4\) nanoparticles at room temperature.

\[
Figure 3. Effect of pH on adsorbance at room temperature.
\]
Wherein $q_e$ and $q_t$ (mg · g$^{-1}$) referred to quantities of RR-2BF adsorbed onto the magnetic Ni$_{0.3}$Co$_{0.2}$Zn$_{0.5}$Fe$_2$O$_4$ nanoparticles at equilibrium and an arbitrary time, correspondingly; $k_1$ (min$^{-1}$), $k_2$ (g · mg$^{-1}$ · min$^{-1}$) and $k_i$ (mg · g$^{-1}$ · min$^{-1}$) referred to the adsorption rate constants for three models, accordingly; $x_i$ referred to the boundary layer thickness.

Figure 4 displayed the adsorbances ($q_t$) at the arbitrary times when the initial concentrations of RR-2BF were 100–400 mg · l$^{-1}$. Notably, the adsorbances of RR-2BF on Ni$_{0.3}$Co$_{0.2}$Zn$_{0.5}$Fe$_2$O$_4$ nanoparticles rapidly ascended in the initial adsorption phase, and continuously ascended with the stretch of time until a state of equilibrium was achieved. This process was mainly affected by the amount of dye molecules, for Ni$_{0.3}$Co$_{0.2}$Zn$_{0.5}$Fe$_2$O$_4$ nanoparticles surface might be exposed to outer active surface sites of the nanomaterial occupied by the dye. When the nanoparticles initially contacted RR-2BF molecule, the active sites were sufficient, so the equilibrium capacity for RR-2BF adsorption increased rapidly. When the contact time was gradually extended, the dye concentration was relatively reduced, and the adsorption site on the surface of the material was also occupied, so the adsorption capacity increased slowly. Therefore, the effect of time on the adsorption process of Ni$_{0.3}$Co$_{0.2}$Zn$_{0.5}$Fe$_2$O$_4$ nanoparticles was mainly reflected in the early stage. When the adsorption site on the material under the current dye concentration was in a condition of equilibrium, the saturation state at equilibrium occurred, and the adsorption state would hardly change with time.

The fittings of three kinetics models for RR-2BF onto Ni$_{0.3}$Co$_{0.2}$Zn$_{0.5}$Fe$_2$O$_4$ nanoparticles with dye concentrations ranging from 100 to 400 mg · l$^{-1}$ were shown in figure 5. The experimental data were calculated, and the corresponding kinetic parameters were listed in table 1. The calculation results suggested that the pseudo-second-order model had the largest variance ($R^2$) values; while, the models of intraparticle diffusion and pseudo-first-order had lower $R^2$ values, which illustrated poorer fitted results. So, the pseudo-second-order kinetics model could accurately demonstrate the adsorption behavior of Ni$_{0.3}$Co$_{0.2}$Zn$_{0.5}$Fe$_2$O$_4$ nanoparticles for RR-2BF. On the other hand, the adsorption kinetics in the whole process of adsorption was mainly controlled by chemical action rather than by the material transfer step. And the line relations of $t/q_t$ with $t$ were shown in figure 6 with the large variances closed to 1.

3.5. Adsorption isotherms

The interrelation of the nanoparticles and RR-2BF molecules was significant, and the significance of adsorption isotherm was self-evident. So, the adsorption equilibrium data of RR-2BF onto Ni$_{0.3}$Co$_{0.2}$Zn$_{0.5}$Fe$_2$O$_4$ nanoparticles were fitted by the two-parameter models. The isotherms parameters could be determined by Langmuir, Freundlich and Temkin in this research.

Langmuir model presumed that the adsorbate was uniformly single-deck coverage on the adsorbent surface, however, the surface heterogeneity of adsorbent was often overlooked, and the adsorption only took place at the uncovered sites of adsorbent, with the uncovered site being defined as the active site. Langmuir model assumed that the active sites on the adsorbent surface had an average energy; therefore, the adsorption energy for

\[
q_t = x_i + k_i t^{1/2}
\]
Langmuir isotherm was considered constant, and its expression was shown in equation (5). The surface heterogeneity effect of adsorbent was raised by empirical equation of Freundlich model, which assumed that the binding strength was inversely proportional to the binding site after the binding site was first occupied. Therefore, Freundlich model, which could be expressed in formula (6), ulteriorly considered multilayer adsorption was accompanied by the interactions of adsorbed molecules and active sites with heterogeneous energetic distribution. Temkin model considered the interactions of the adsorbent and the adsorbate; it assumed that the distribution of the adsorption binding energy was uniform, the heat from adsorption decreased linearly with the coverage of adsorbent, and the binding energy finally reached maximum. And Temkin adsorption isotherms was expressed by the equation (7) [25, 26].

Table 1. Fitting parameters for three kinetics models.

| Kinetic model                  | Parameter | Initial RR-2BF concentration (mg l⁻¹) |
|-------------------------------|-----------|--------------------------------------|
|                               |           | 100        | 200        | 300        | 400        |
| Pseudo-first-order model      | R²        | 0.8725     | 0.8967     | 0.9466     | 0.9341     |
|                               | k₁        | 0.1901     | 0.1365     | 0.0837     | 0.0938     |
|                               | qₑ        | 26.7811    | 65.7899    | 99.7803    | 115.7413   |
| Pseudo-second-order model     | R²        | 0.9966     | 0.9966     | 0.9920     | 0.9980     |
|                               | k₂        | 0.0120     | 0.0031     | 0.0011     | 0.0011     |
|                               | qₑ        | 28.5886    | 71.3753    | 111.8946   | 128.8024   |
| Intraparticle diffusion model  | R²        | 0.6373     | 0.6905     | 0.7365     | 0.7485     |
|                               | kᵢ        | 0.7276     | 2.4283     | 5.2612     | 5.6935     |
|                               | Cᵢ        | 20.7797    | 44.9900    | 51.7676    | 64.4512    |

Figure 5. Adsorption kinetics fits in initial RR-2BF concentration of (a) 100 mg · 1⁻¹, (b) 200 mg · 1⁻¹, (c) 300 mg · 1⁻¹, and (d) 400 mg · 1⁻¹ at room temperature.
Wherein $q_e$ ($\text{mg} \cdot \text{g}^{-1}$) referred to the weights of RR-2BF adsorbed onto Ni$_{0.3}$Co$_{0.2}$Zn$_{0.5}$Fe$_2$O$_4$ nanoparticles; the concentration of RR-2BF at equilibrium was expressed in terms of $C_e$ ($\text{mg} \cdot \text{l}^{-1}$); $K_d$ ($\text{l} \cdot \text{mg}^{-1}$), $B$ ($=R_T/b_T$), $A_T$ ($\text{L} \cdot \text{g}^{-1}$), and $K_T$ ($\text{mg}^{1-(1/n)} \cdot \text{l}^{1/n} \cdot \text{g}^{-1}$) referred to the constants for three models; $1/n$ ($0 \rightarrow 1$) referred to the dimensionless factor, which reflected the surface heterogeneity or adsorption intensity.

When the adsorption rate of RR-2BF onto Ni$_{0.3}$Co$_{0.2}$Zn$_{0.5}$Fe$_2$O$_4$ nanoparticles was equal to desorption, the adsorption equilibrium data were obtained to fit three isotherms models, and the results were revealed in figure 7. With the increase of the initial concentration, the adsorption capacity of Ni$_{0.3}$Co$_{0.2}$Zn$_{0.5}$Fe$_2$O$_4$ nanoparticles for RR-2BF showed a trend of first increasing and then decreasing. This phenomenon was also related to the limited adsorption sites on the surface of nanoparticles. Table 2 summarized the calculated parameters for three isotherms models. Temkin model yielded the largest variance ($R^2 = 0.9953$) compared the variance values for three models with each other. However, the variances for Langmuir and Freundlich models ($R^2 = 0.9831, 0.9698$) showed lower values in comparison with Temkin isotherm. Thus, they were not fit to demonstrate the equilibrium process of RR-2BF adsorbed onto Ni$_{0.3}$Co$_{0.2}$Zn$_{0.5}$Fe$_2$O$_4$ nanoparticles. Based on the assumption from theoretical model of Temkin, the adsorption of RR-2BF onto Ni$_{0.3}$Co$_{0.2}$Zn$_{0.5}$Fe$_2$O$_4$ nanoparticles was of hybrid absorbing mechanism caused by multilayer adsorption and monolayer adsorption.

### 3.6. Regeneration of Ni$_{0.3}$Co$_{0.2}$Zn$_{0.5}$Fe$_2$O$_4$ nanoparticles

Figure 8 revealed the regeneration of Ni$_{0.3}$Co$_{0.2}$Zn$_{0.5}$Fe$_2$O$_4$ nanoparticles for adsorption of RR-2BF in aqueous solution. Due to the collapse of nanoparticle pores caused by cyclic calcination, the active sites were subsequently reduced. Therefore, the figure elucidated that the amounts of RR-2BF adsorbed on adsorbent decreased with the increase of the number of cycles. The magnetic Ni$_{0.3}$Co$_{0.2}$Zn$_{0.5}$Fe$_2$O$_4$ nanoparticles having adsorbed RR-2BF for 8 times had a capacity of 53.7 $\text{mg} \cdot \text{g}^{-1}$, which exceeded 75% of the initial equilibrium capacity, indicating that the magnetic Ni$_{0.3}$Co$_{0.2}$Zn$_{0.5}$Fe$_2$O$_4$ nanoparticles had superior regeneration ability and could be widely applied in dye adsorption in the future.

### 3.7. Adsorbance comparison of Ni$_{0.3}$Co$_{0.2}$Zn$_{0.5}$Fe$_2$O$_4$ nanoparticles with other adsorbents

The adsorption capacity of different adsorbents to dyes was investigated, and the results were displayed in table 3. The equilibrium capacity of magnetic Ni$_{0.3}$Co$_{0.2}$Zn$_{0.5}$Fe$_2$O$_4$ nanoparticles was at a medium level, and they could be reused for many times with higher adsorption amount. The magnetic Ni$_{0.3}$Co$_{0.2}$Zn$_{0.5}$Fe$_2$O$_4$ nanoparticles were of hybrid absorbing mechanism caused by multilayer adsorption and monolayer adsorption.
nanoparticles, as an excellent adsorbent, could rapidly achieve a state of equilibrium in a short time, and the adsorbent could be recycled in a way of calcination and pH adjustment to reduce secondary pollution. Therefore, magnetic Ni$_{0.3}$Co$_{0.2}$Zn$_{0.5}$Fe$_2$O$_4$ nanoparticles was a promising dye adsorbent.

![Figure 7. Modeling of RR-2BF adsorption isotherms at room temperature.](image)

![Figure 8. Reusability of Ni$_{0.3}$Co$_{0.2}$Zn$_{0.5}$Fe$_2$O$_4$ nanoparticles for removal of RR-2BF.](image)

| Isotherms model | $R^2$ | Parameter | Parameter’s value |
|-----------------|-------|-----------|-------------------|
| Langmuir       | 0.9831| $K_L$     | 0.6684            |
|                 |       | $q_{max}$ | 138.3588          |
| Freundlich     | 0.9698| 1/n       | 0.2902            |
|                 |       | $K_F$     | 57.0761           |
| Temkin         | 0.9953| $A_T$     | 9.1822            |
|                 |       | $B$       | 25.6083           |

Table 2. Parameters for RR-2BF adsorption isotherm onto magnetic Ni$_{0.3}$Co$_{0.2}$Zn$_{0.5}$Fe$_2$O$_4$ nanoparticles at room temperature.
4. Conclusion

(1) Magnetic Ni_{0.3}Co_{0.2}Zn_{0.5}Fe_{2}O_{4} nanoparticles were fabricated via the ethanol solution of nitrate combustion process with absolute ethanol as solvent and fuel. The characterization results suggested the particle size of Ni_{0.3}Co_{0.2}Zn_{0.5}Fe_{2}O_{4} nanoparticles fabricated at 500 °C for 2 h was approximately 30 nm and the saturation magnetization reached 203.2 emu • g⁻¹.

(2) Ni_{0.3}Co_{0.2}Zn_{0.5}Fe_{2}O_{4} nanoparticles had an efficient adsorption of RR-2BF, and the adsorption could achieve equilibrium in only 30 min. Analysis of calculated parameters validated that the adsorption process could be better fitted by the Pseudo-second-order kinetic model.

(3) The experimental data for the adsorption isotherm experiment could be depicted by the Temkin isotherm model. The results implied that Ni_{0.3}Co_{0.2}Zn_{0.5}Fe_{2}O_{4} nanoparticles for dislodging RR-2BF was of a hybrid absorbing mechanism accompanied by both multilayer and monolayer.

Data availability statement

All data that support the findings of this study are included within the article (and any supplementary files).

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