Application of Magnetic Nano-composites in Water Treatment: Core-Shell Fe_3O_4 Material for Efficient Adsorption of Cr(VI)

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XVIII World Water Congress
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Page Title: Purpose and significance

In the face of heavy metal pollution, we still need more effective and economical ways to deal with it. As an emerging material, functionalized magnetic nanocomposites are attempted to be used as a new type of adsorbent in the field of heavy metal removal. For example, magnetic nanoparticles modified with MoS_2 ($MoS_2@Fe_3O_4$NPs) were synthesized and used as an effective adsorbent for the removal of Cr(VI)/Cr(III) from aqueous solution by Kumar et al. [1]. $MoS_2@Fe_3O_4$NPs exhibited uniform size and shape, excellent water dispersion, and superior magnetism for enhanced adsorption. Using an in situ growth mechanism, Kumar et al. [2] prepared g-C_3N_4-Fe_3O_4 nanocomposites that could be magnetically recovered and showed good recyclability.

Inspired by other scholars, we aimed to prepare a novel nano-sorbent material (MS) with a magnetic ferric tetroxide (Fe_3O_4) core and an outer coating of amorphous silica (SiO_2) to enrich the specific surface area, forming a core-shell structure that takes into account both magnetic properties and excellent pore structure.

[1] A.S. Krishna Kumar, S.J. Jiang, J.K. Warchol, Synthesis and Characterization of Two-Dimensional Transition Metal Dichalcogenide Magnetic MoS(2)@Fe(3)O(4) Nanoparticles for Adsorption of Cr(VI)/Cr(III), ACS Omega 2(9) (2017) 6187-6200.

[2] S. Kumar, S. T, B. Kumar, A. Baruah, V. Shanker, Synthesis of Magnetically Separable and Recyclable g-C3N4–Fe3O4 Hybrid Nanocomposites with Enhanced Photocatalytic Performance under Visible-Light Irradiation, The Journal of Physical Chemistry C 117(49) (2013) 26135-26143.

Page Title: Synthesis of adsorbents

We refer to the literature of Souza DM scholars [3], on the basis of which we used the modified Sol-Gel method (sol-gel method) to prepare silica-coated Fe_3O_4 nanoparticles.

[3] D.M. Souza, A.L. Andrade, J.D. Fabris, P. Valério, A.M. Góes, M.F. Leite, R.Z. Domingues, Synthesis and in vitro evaluation of toxicity of silica-coated magnetite nanoparticles, Journal of Non-Crystalline Solids 354(42-44) (2008) 4894-4897.

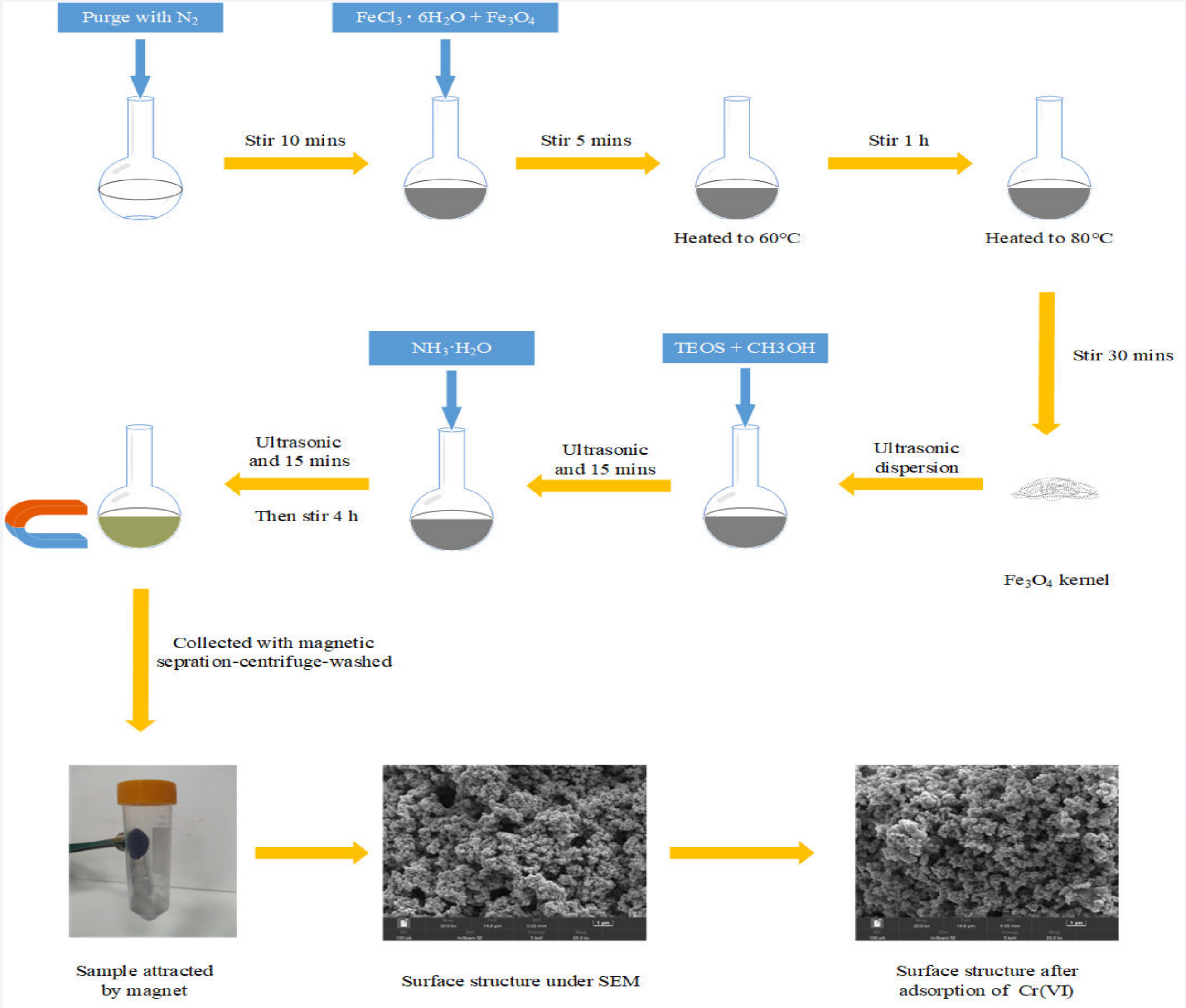


Figure 1. Flow chart of MS preparation.

Page Title: Structural characterization

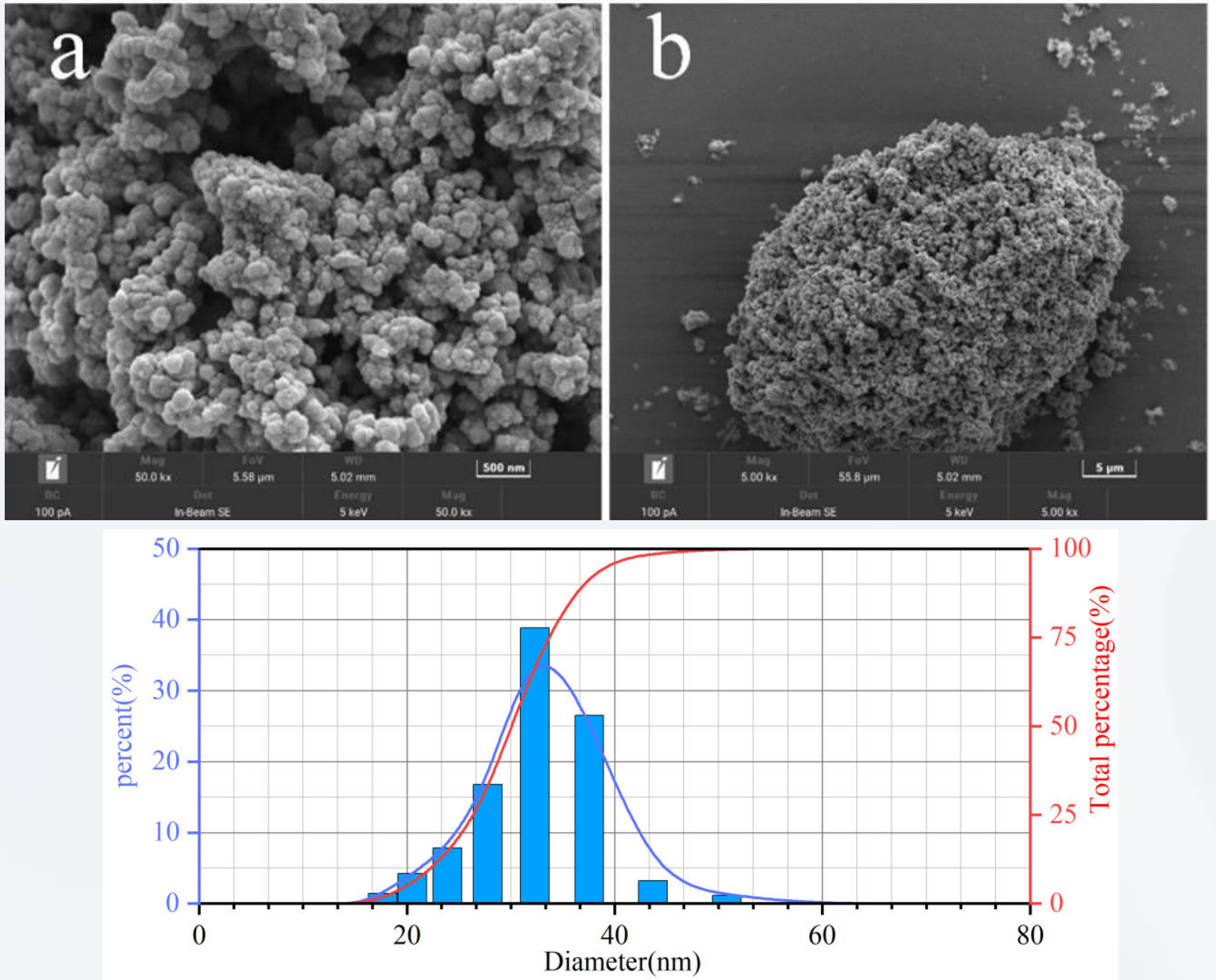


Figure 2. SEM and Particle size distribution of MS.

Page Title: Structural characterization

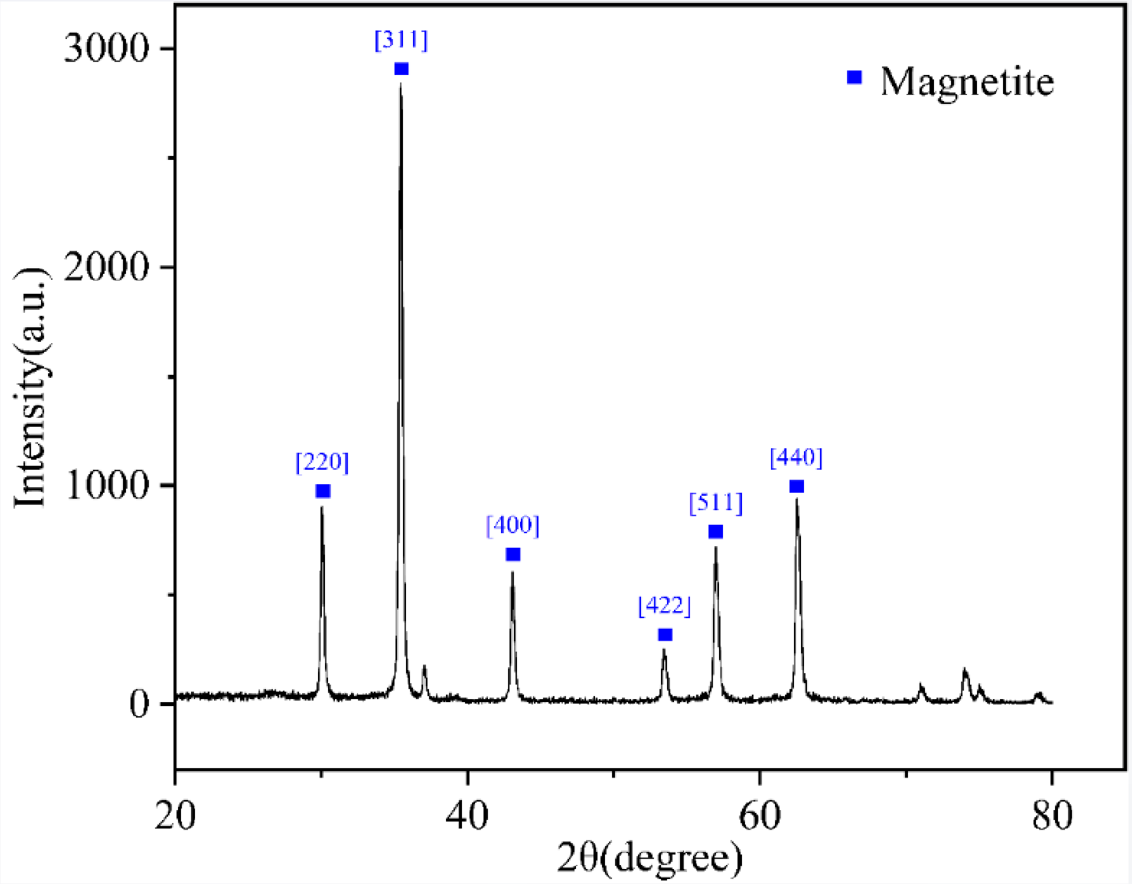
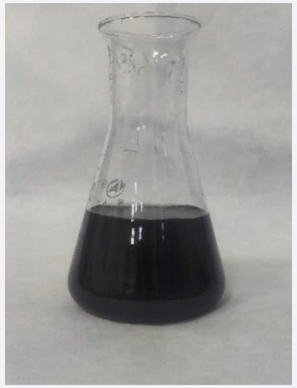


Figure 3. XRD pattern of the MS.

Page Title: Magnetic strength



Excellent dispersion

Strong magnetic

Sample	M_S （$emu \cdot g^{-1}$）	M_R （$emu \cdot g^{-1}$）	H_C （Oe）	M_R/ M_S
Fe_3O_4/SiO_2	73.26	10.33	110.91	0.14

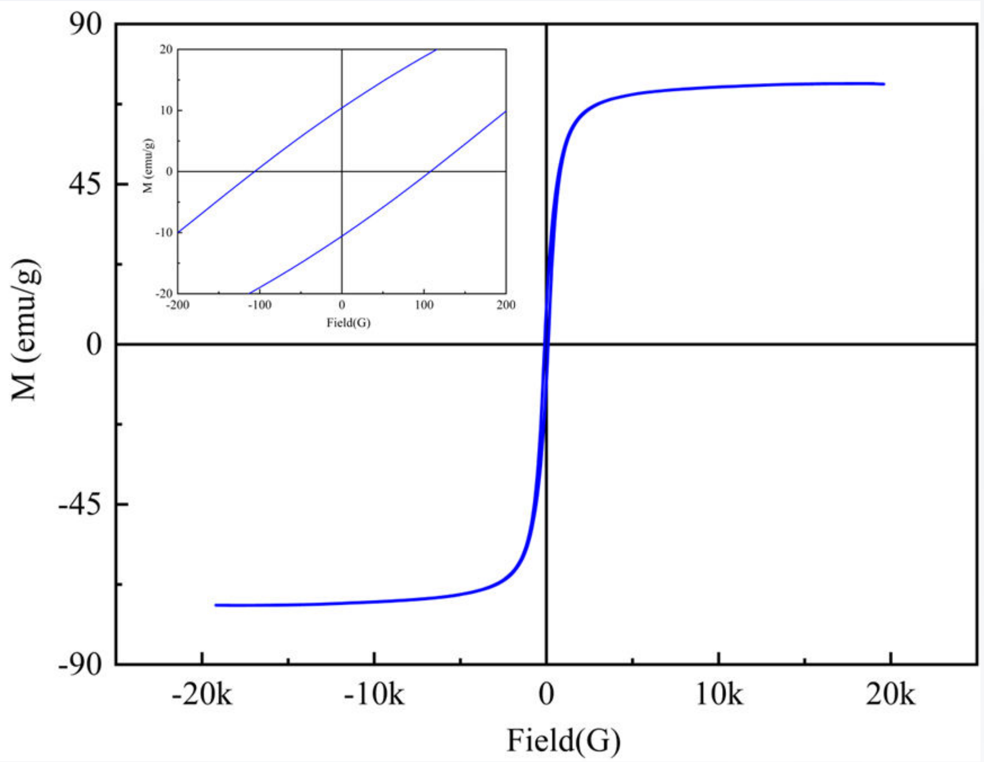


Figure 4. Hysteresis line and magnetization curve of MS.

Page Title: Adsorption performance

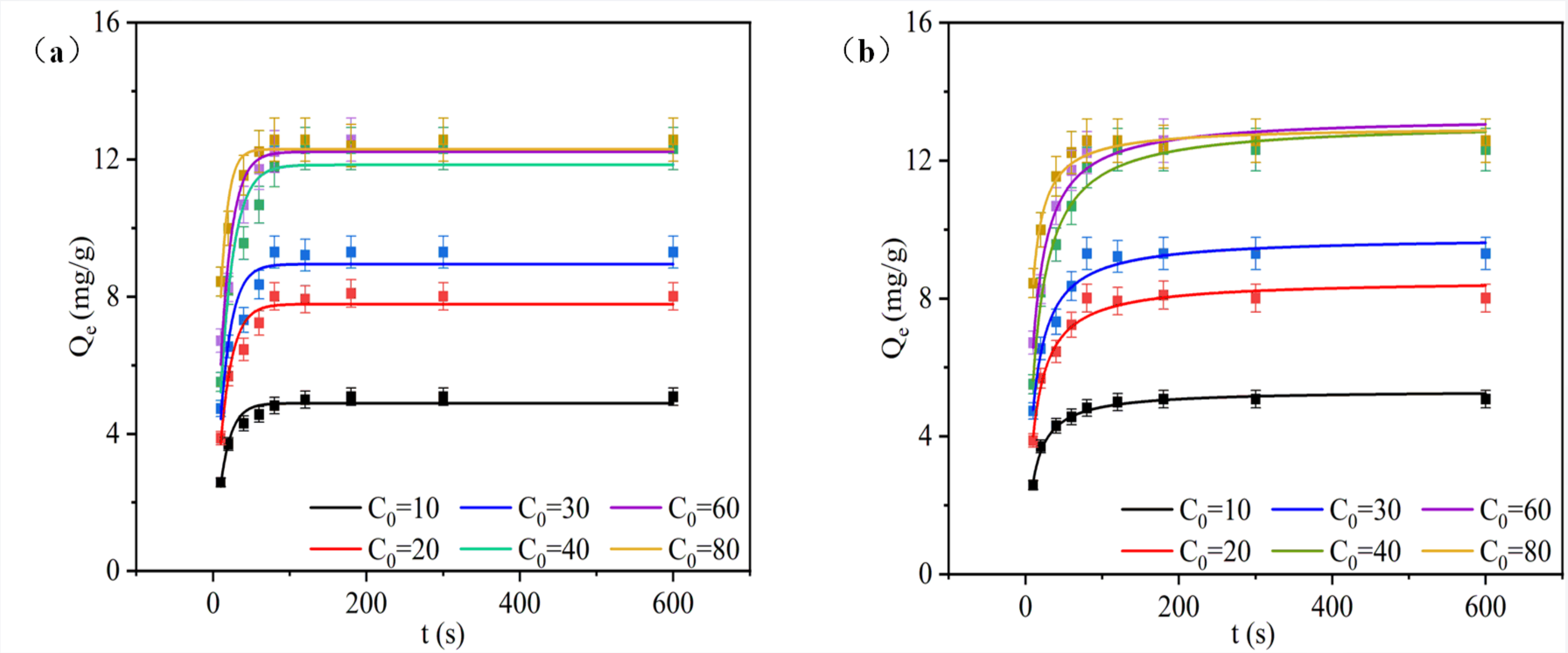
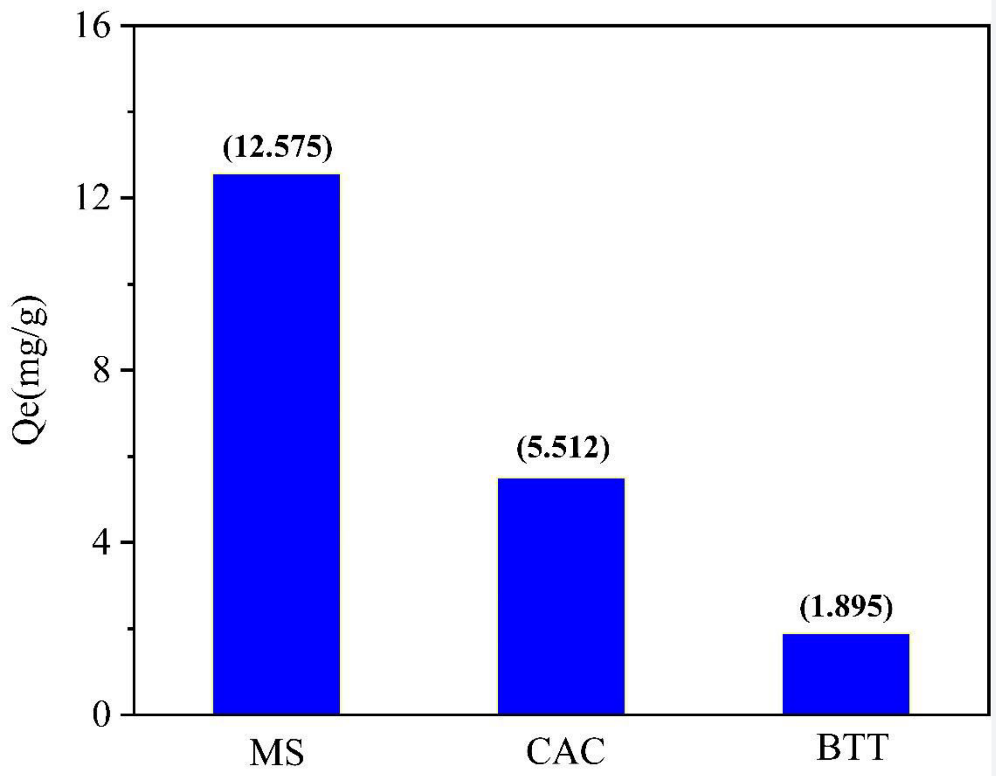


Figure 5. Fitting of the pseudo-first-order adsorption kinetic curve of MS (a); fitting of the pseudo-second-order adsorption kinetic curve of MS (b); (the reaction temperature was 25 °C, the amount of adsorbent was 25 mg, the pH of the solution was 2, and the reaction time was 600 s).

Page Title: Adsorption performance



adsorbent	specific surface area（m^2/g）	mean pore size（nm）	average pore volume（cc/g）
MS	16.468	16.254	0.067
CAC	162.175	4.133	0.168
BTT	65.176	9.024	0.147

Page Title: Adsorption performance

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adsorbents	optimum pH	Temperature (°C)	Model used to calculate adsorption capacities	maximum adsorption capacity Q_m (mg/g)	reference
MS	2	25	Langmuir	13.6	
Composite alginate–goethite beads	4	20	Langmuir	20.5	[4]
Raw rice bran	5	25	Freundlich	0.07	[5]
Maghemite nanoparticles	10	22.5	Freundlich	1.5	[6]
Sugarcane bagasse	4	25	Langmuir	4.76	[7]
Almond shell (AS)	4	10	Langmuir	2.4	[8]
Heat-treated algae (Chlamydomonas reinhardtii)	2	25	Langmuir	30.2	[9]
Bauxite	2	35	Langmuir	0.5	[10]
Hydrous titanium(IV) oxide	2	25	Langmuir	5	[11]
Bagasse fly ash	5	40	Langmuir	2.3	[12]

Table 1. Comparison of MS and other low cost adsorbents for Cr(VI) removal

[4] B. Nasernejad, T.E. Zadeh, B.B. Pour, M.E. Bygi, A. Zamani, Camparison for biosorption modeling of heavy metals (Cr (III), Cu (II), Zn (II)) adsorption from wastewater by carrot residues, Process Biochemistry 40(3-4) (2005) 1319-1322.

[5] E.A. Oliveira, S.F. Montanher, A.D. Andrade, J.A. Nóbrega, M.C. Rollemberg, Equilibrium studies for the sorption of chromium and nickel from aqueous solutions using raw rice bran, Process Biochemistry 40(11) (2005) 3485-3490.

[6] J. Hu, G. Chen, I.M. Lo, Removal and recovery of Cr(VI) from wastewater by maghemite nanoparticles, Water Res 39(18) (2005) 4528-36.

[7] U.K. Garg, M.P. Kaur, V.K. Garg, D. Sud, Removal of hexavalent chromium from aqueous solution by agricultural waste biomass, J Hazard Mater 140(1-2) (2007) 60-8.

[8] G.S. Agarwal, H.K. Bhuptawat, S. Chaudhari, Biosorption of aqueous chromium(VI) by Tamarindus indica seeds, Bioresour Technol 97(7) (2006) 949-56.

[9] M.Y. Arıca, İ. Tüzün, E. Yalçın, Ö. İnce, G. Bayramoğlu, Utilisation of native, heat and acid-treated microalgae Chlamydomonas reinhardtii preparations for biosorption of Cr(VI) ions, Process Biochemistry 40(7) (2005) 2351-2358.

[10] M. Erdem, H.S. Altundoğan, F. Tümen, Removal of hexavalent chromium by using heat-activated bauxite, Minerals Engineering 17(9-10) (2004) 1045-1052.

[11] H. Tel, Y. Altas, M.S. Taner, Adsorption characteristics and separation of Cr(III) and Cr(VI) on hydrous titanium(IV) oxide, J Hazard Mater 112(3) (2004) 225-31.

[12] V.K. Gupta, I. Ali, Removal of lead and chromium from wastewater using bagasse fly ash--a sugar industry waste, J Colloid Interface Sci 271(2) (2004) 321-8.

Page Title: Adsorption mechanism

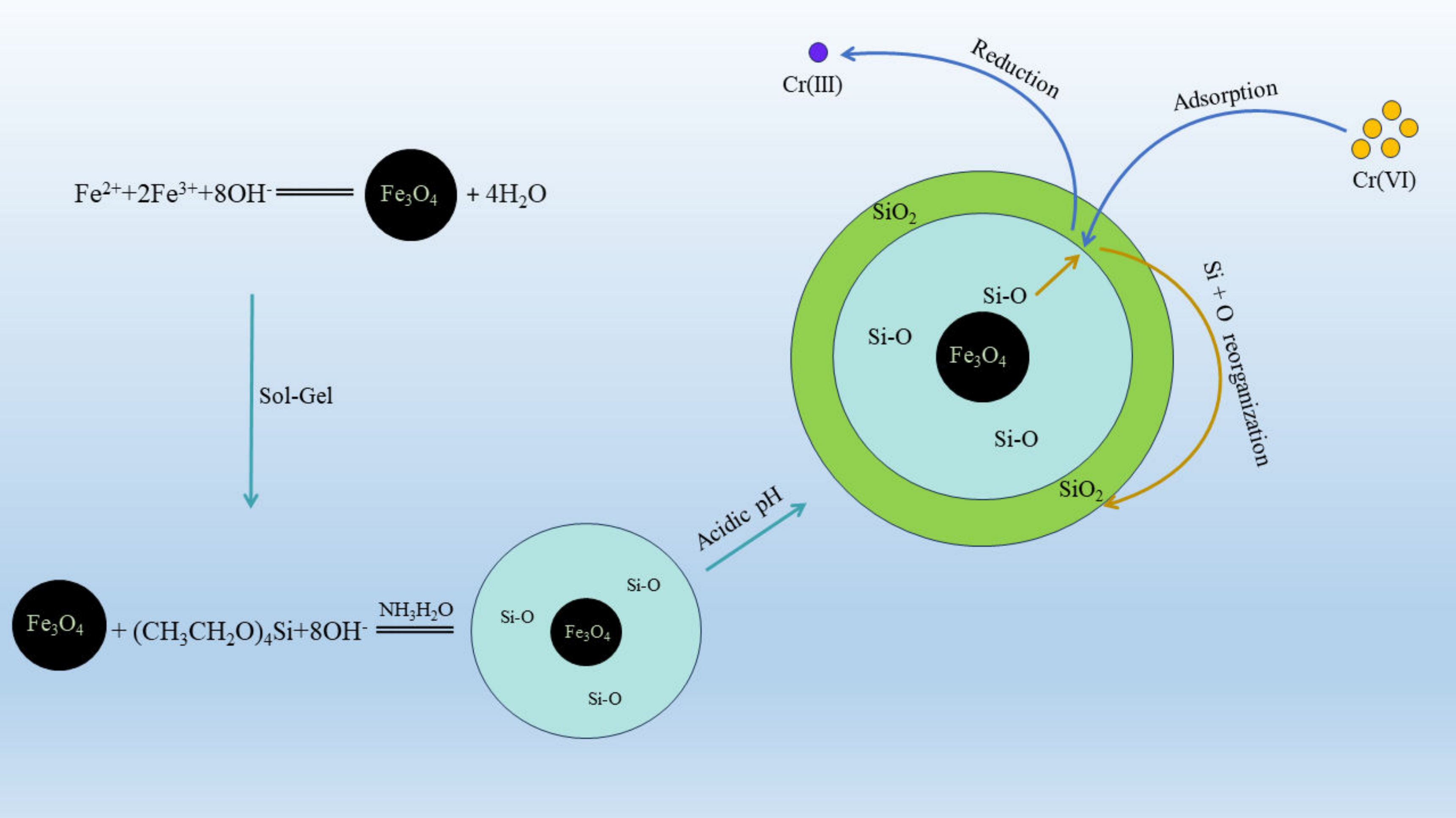

Figure 6. Synthesis route of MS and mechanism of Cr(VI) adsorption

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Thanks

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