Supplementary Materials for:

One-step fabrication of functionalized magnetic adsorbents with large surface area and their adsorption for dye and heavy metal ions

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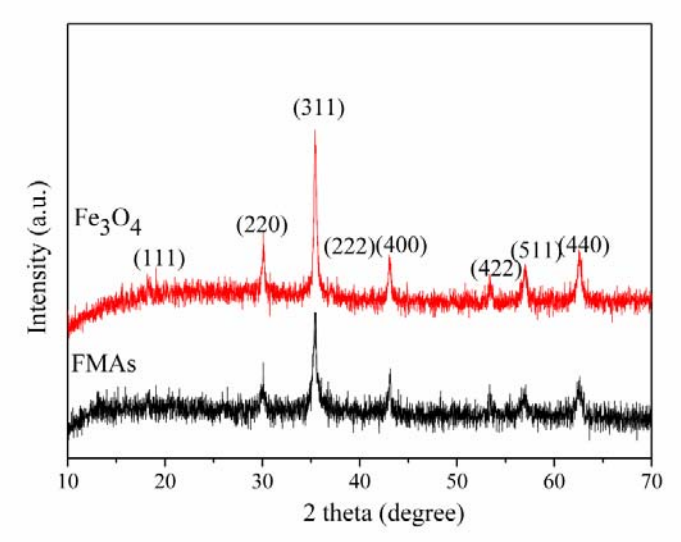

S1. XRD patterns of FMAs and Fe_3O_4 spheres.

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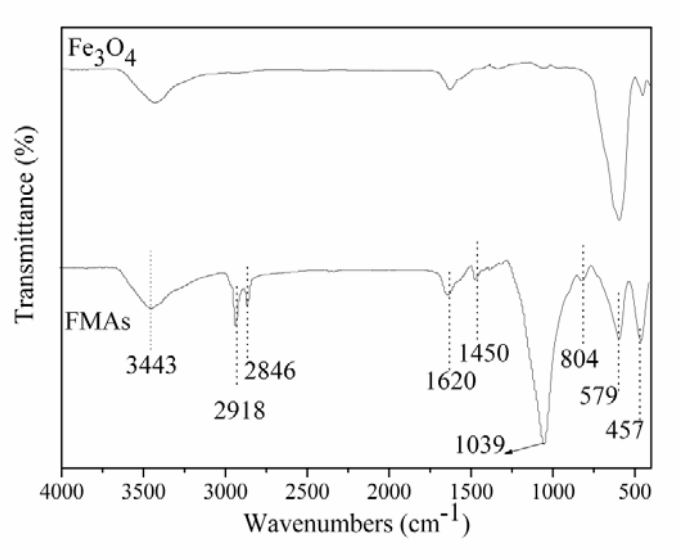
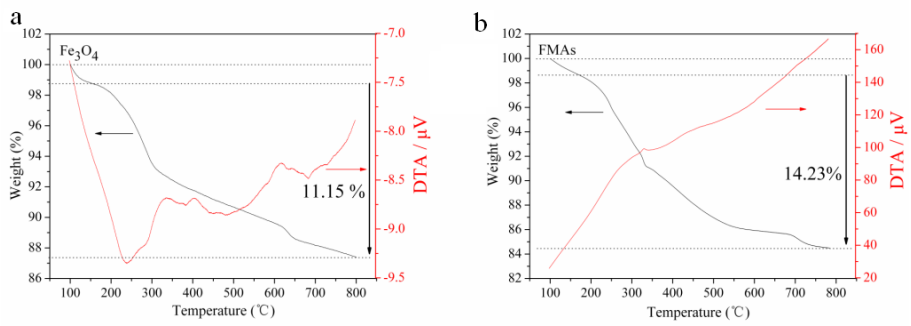
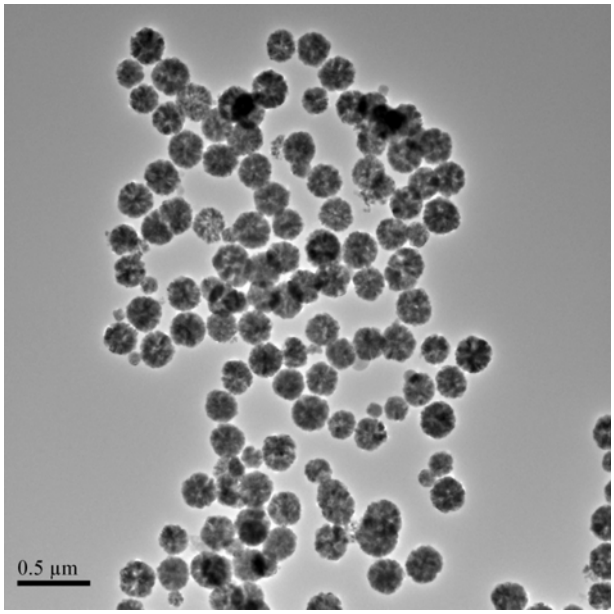


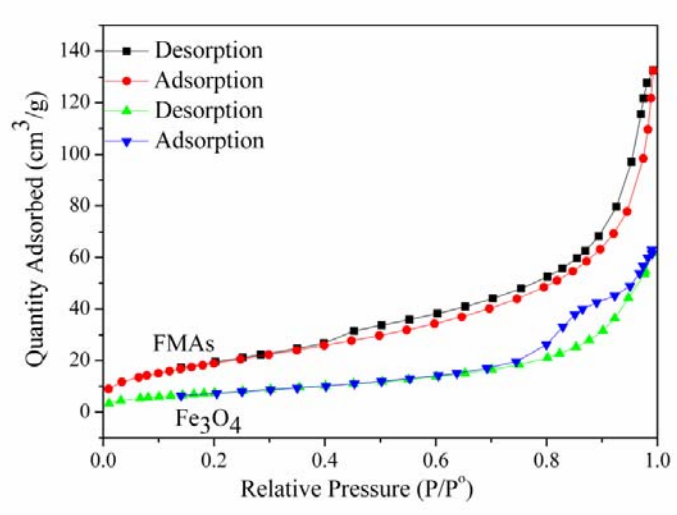
S2. FTIR spectrum of FMAs and Fe_3O_4 spheres.



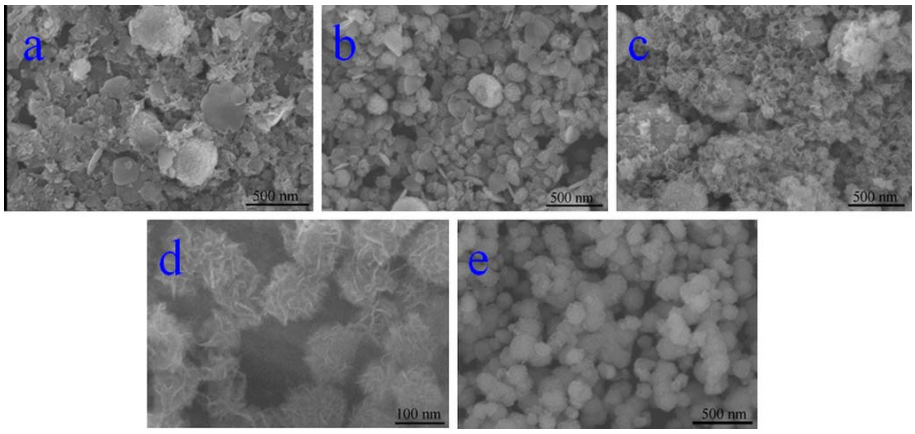
S3. TG-DTA curves of (a) Fe_3O_4 and (b) FMAs.



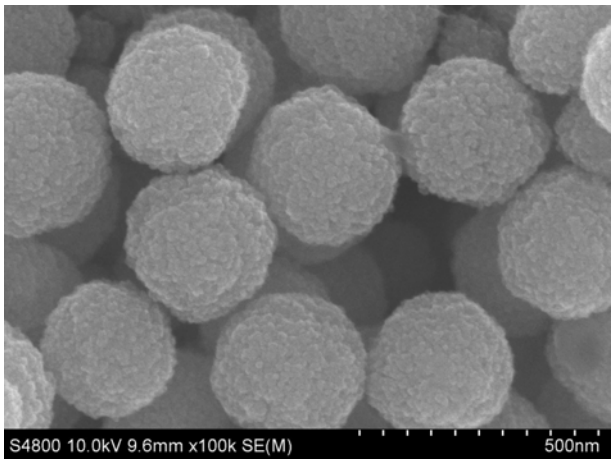
S4. TEM images of Fe_3O_4 spheres.



S5. The nitrogen adsorption-desorption isotherm of FMAs and Fe_3O_4 spheres.



S6. SEM images of the FMAs collected at different intervals: (a) 6 h, (b) 7 h, (c) 8 h, (d) 10 h and 16 h.

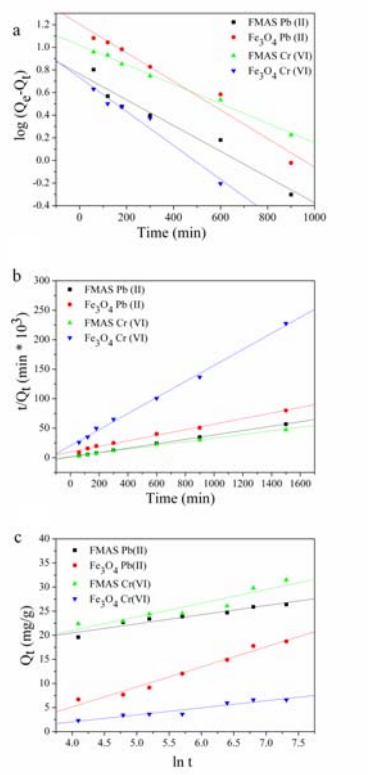


S7. The SEM images of the products without addition of addition of TEOS and C18-TMS.

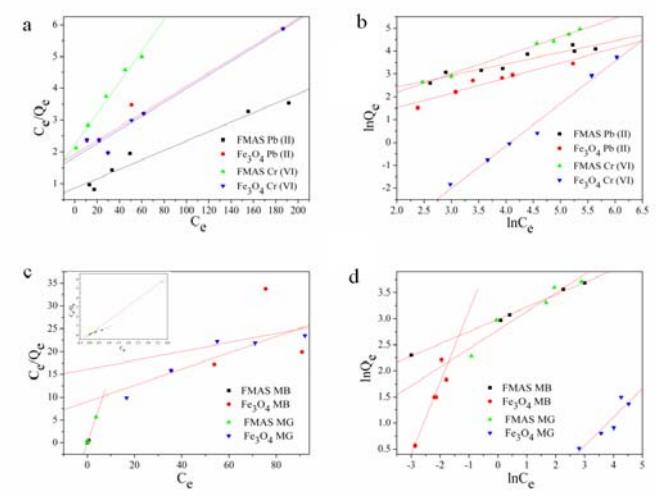
The dynamics of the adsorption process in terms of the order and the rate constant can be evaluated using the kinetic adsorption data. The kinetic parameters as important information are used in designing and modeling of the adsorption operation to predict the adsorption rate. The kinetics of removal of Pb(II) and Cr(VI) is clearly explained in the literature using pseudo first-order, second-order and Elovich kinetic models to examine the rate controlling mechanism of the adsorption process such as chemical reaction, diffusion control and mass transfer. The Kinetic parameters for the adsorption of Pb(II) and Cr(VI) were presented in Table 1. As can be seen from Table 1, the calculated Qe values show a good agreement with the experimental values and the obtained values for coefficient of determination (R^2) are more than 0.993, which indicates that the second-order kinetic model describes well the removal of Pb(II) and

Cr(VI) by magnetic particals as adsorbents. These results indicated that the rate-limiting step in the adsorption of Pb(II) and Cr(VI) was chemisorption. In addition, it was found that the FMAs showed much better adsorption ability for Pb(II) and MG than that of the solid Fe_3O_4. These results may be due to the fact that the FMAs had a large number of carboxyl groups, which can interact with Pb(II) and Cr(VI) through complexation, ion exchange, and/or electrostatic attraction.

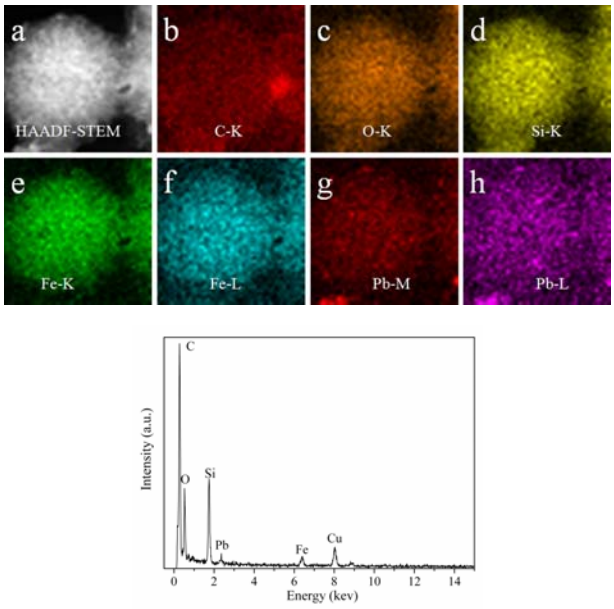
A better understanding is achieved by adsorption isotherm that reveals the distribution of adsorbed molecules between the liquid phase and solid phase. The adsorption isotherms of MB, MG, Cr(VI) and Pb(II) on the FMAs and Fe_3O_4 spheres were studied using Langmuir and Freundlich, are shown in Fig. 2.



S8. Lagergren (a), second-order (b) and Elovich kinetic model (c) plot for the adsorption of heavy metal ions.



S9. Isotherm model for the dye and heavy metal ions adsorption (a, c: Langmuir isotherm model, b, d: Freundlich isotherm model).



S10. Elemental mappings of the FMAs and the EDX spectrum acquired from the FMAs after adsorption of the Pb^{2+}.

Table 1 Calculated kinetic parameters for pseudo first-order, second-order and Elovich kinetic models for the adsorption of heavy metal ions using magnetic adsorbents.

adsorbents	Qe(mg g^{-1}) (experimental)	First-order kinetic			Second-order kinetic			Elovich kinetic		
		$k_{ad}\times10^3$	Qe	R^2	$K_2\times10^3$	Qe	R^2	α	β	R^2
FMAs Pb(II)	26.4	2.53	5.80	0.953	1.26	26.7	0.999	16.7	0.53	0.924
Fe_3O_4 Pb(II)	18.7	2.99	16.0	0.967	0.231	21.1	0.993	0.261	0.24	0.973
FMAs Cr(VI)	31.5	2.07	10.4	0.984	0.45	32.2	0.994	8.54	0.35	0.887

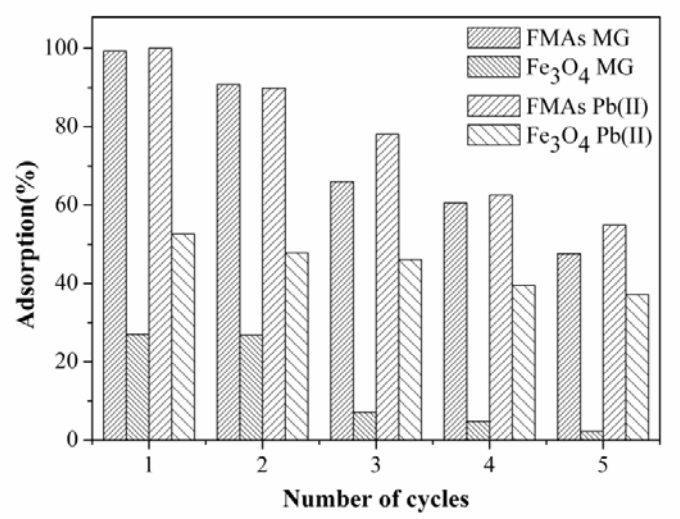
Fe_3O_4 Cr(VI)	6.6	3.45	5.41	0.970	0.90	7.35	0.997	0.107	0.69	0.923

Table 2 Langmuir and Freundlich isotherm parameters for dye and heavy metal ions adsorption on FMAs and Fe_3O_4 spheres.

	FMAs				Fe_3O_4			
	MB	MG	Pb(II)	Cr(VI)	MB	MG	Pb(II)	Cr(VI)
Langmuir								
Q_{max} (mg/g)	40.82	44.44	87.72	31.10	-	6.7	30.76	-
b (L/mg)	1.29	0.56	0.011	0.022	-	0.0159	0.030	-
R^2	0.9956	0.9857	0.9506	0.8027	-	0.6409	0.8291	-
Freundlich								
k	1.05	16.43	5.50	9.10	92.41	0.335	5.61	0.0005
n	4.28	2.81	2.34	5.58	0.296	1.82	3.50	0.532
R^2	0.9434	0.9144	0.9706	0.9879	0.8636	0.8303	0.8448	0.8497

Desorption and reusability

The stability and regeneration ability of the adsorbent is crucial for its potential industrial applications. In order to reduce the overall cost of the adsorbent, the adsorption efficiency and regeneration potential of FMAs was investigated. The solution of 1M NaOH or 1M EDTA was added into the adsorbed MG or Pb^{2+} adsorbents. Afterwards, the suspensions were shaken at 130 rpm for 8 h in order to complete release the pollutants. The solid and liquid phases were separated again by a magnetic field. The adsorption-desorption cycles of the FMAs and Fe_3O_4 adsorbent for the removal of MG and Pb^{2+} were repeated five times by using the same adsorbent. Results of batch adsorption experiment studies are depicted in Fig. S11. Adsorption/desorption performance of the FMAs decreases slightly as the number of cycle increases. More than 40% metal ion or dye removal is possible using five cycles. Hence, the regeneration ability of dye or heavy metal is not very effective currently, so it will need much further study for regeneration of the FMAs.



S11.Effect of regeneration on the adsorption capacity of MG or Pb^{2+} onto the FMAs or the solid Fe_3O_4 using batch experiments with an initial concentration of 25 mg/L at 30 °C.