Supplementary information

Synthesis, characterization and application of Cyclam-modified magnetic SBA-15 as a novel sorbent and its optimization by central composite design for adsorption and determination of trace amount of lead ions

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Supplementary information caption

Table S1. Matrix for the central composite design (CCD)

Table S2. The interfering effect of other ions on the extraction recovery of lead. Conditions: sample volume, 100.0 mL; lead concentration, 30 µg/L; amount of sorbent, 4.0 mg; volume of desorbing solution, 3.0 mL

Fig. S1. Cyclam structure

Fig. S2. X-ray diffraction patterns (a); FT-IR (b); SEM images(c) of Fe_3O_4 magnetic nanoparticles.

Fig. S3. FT-IR spectrum of the synthesized materials (a,b,c, d)

Fig. S4. Sorption/desorption N_2 analysis of SBA-15.

Fig. S5. Effect of volume of the sample solution on the extraction recovery of lead ions (Conditions: amount of sorbent, 0.004g; lead concentration, 30 µg/L; volume of the eluent,3 mL; desorption time,40min, pH, 4.8).

Fig. S6. The equilibrium isotherms (a) Langmuir (b) Freundlich (c) Temkin, for adsorption of Pb(II) ions onto Fe_3O_4@ Cyclam-SBA-15 at optimum conditions in some ion concentrations ranging.

Fig. S7. The adsorption kinetic curves related to (a) pseudo-first order (b) pseudo-second order and (c) Elovich models for adsorption of Pb(II) ions over Fe_3O_4@ Cyclam-SBA-15 at optimum conditions at various contact time.

Fig. S8. Regeneration study after five consecutive adsorption/desorption cycles with HCl (0.01M), EDTA (0.01M) and HNO_3 (0.01M) eluent

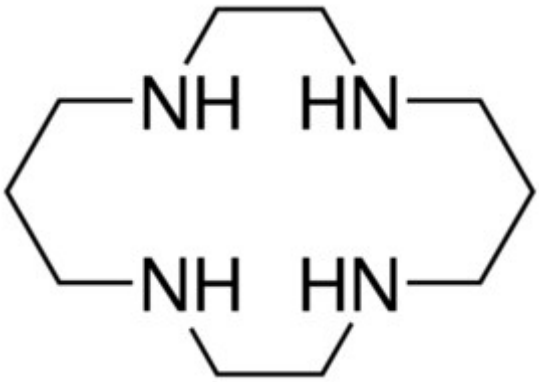
Table S1. Matrix for the central composite design (CCD)

Run	Block	A	B	C	D	Q^1 (mg/g)
1	1	6	15	4	30	85.75
2	1	4	20	5	40	206.87
3	1	8	10	3	20	54.07
4	1	8	20	3	40	109.96
5	1	4	10	3	40	132.30
6	1	4	20	3	20	168.50
7	1	6	15	4	30	75.07
8	1	8	20	5	20	117.00
9	1	4	10	5	20	79.60
10	1	8	10	5	40	57.50
11	2	8	10	5	20	54.05
12	2	4	20	5	20	197.00
13	2	4	10	3	20	87.50
14	2	4	20	3	40	190.50
15	2	6	15	4	30	82.04
16	2	6	15	4	30	81.42
17	2	8	20	5	40	118.56
18	2	8	10	3	40	69.50
19	2	8	20	3	20	86.60
20	2	4	10	5	40	94.60
21	3	6	15	6	30	69.50
22	3	6	5	4	30	41.67
23	3	6	15	2	30	67.50
24	3	6	15	4	50	121.94
25	3	2	15	4	30	209.42
26	3	6	25	4	30	179.59
27	3	6	15	4	10	87.22
28	3	6	15	4	30	83.36
29	3	10	15	4	30	75.44
30	3	6	15	4	30	79.98

1- Adsorption capacity

Table S2. The interfering effect of other ions on the extraction recovery of lead. Conditions: sample volume, 100.0 mL; lead concentration, 30 µg/L; amount of sorbent, 4.0 mg; volume of desorbing solution, 3.0 mL

Ions	**Ion concentration (µg/L)**	**Recovery (%)**	**Interference percentage %**
Na^{+}	3000	99.404	0.596
	6000	97.29	2.71
Fe^{2+}	3000	97.49	2.51
	6000	96.00	4.00
Hg^{2+}	3000	36.76	3.24
	6000	98.02	1.98
NO_3^{-}	3000	95.81	4.19
	6000	95.02	3.98
Cl^{-}	3000	99.404	0.596
	6000	97.29	2.71
CO_3^{2-}	3000	99.11	0.89
	6000	95.49	4.51
SO_4^{2-}	3000	98.79	1.21
	6000	95.46	4.54



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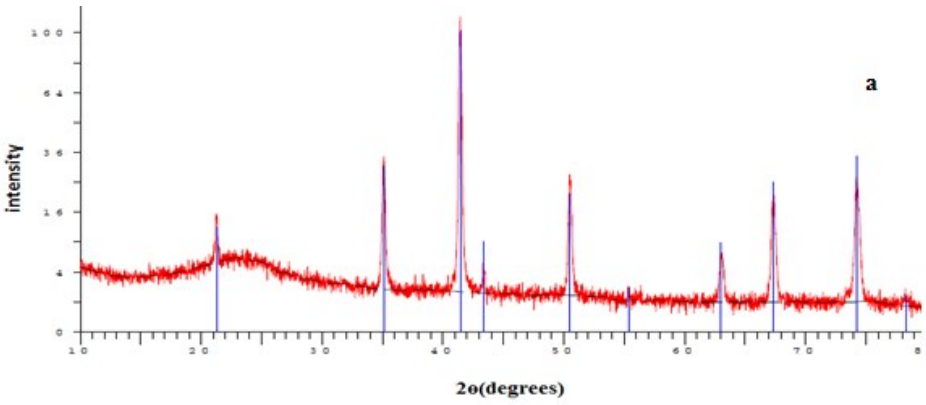

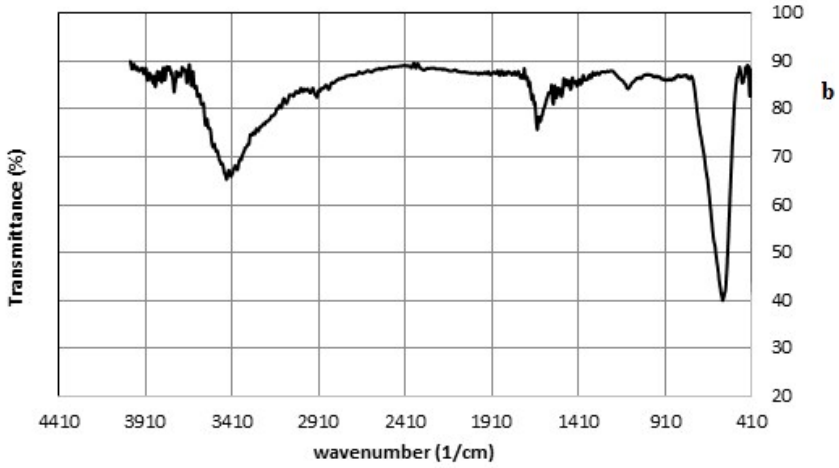

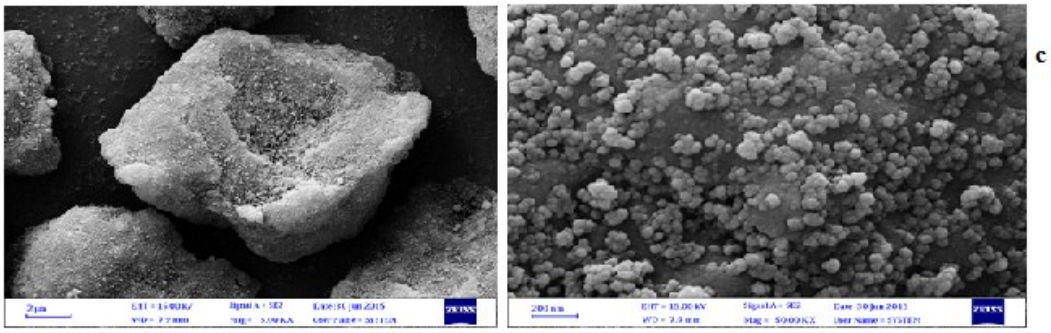

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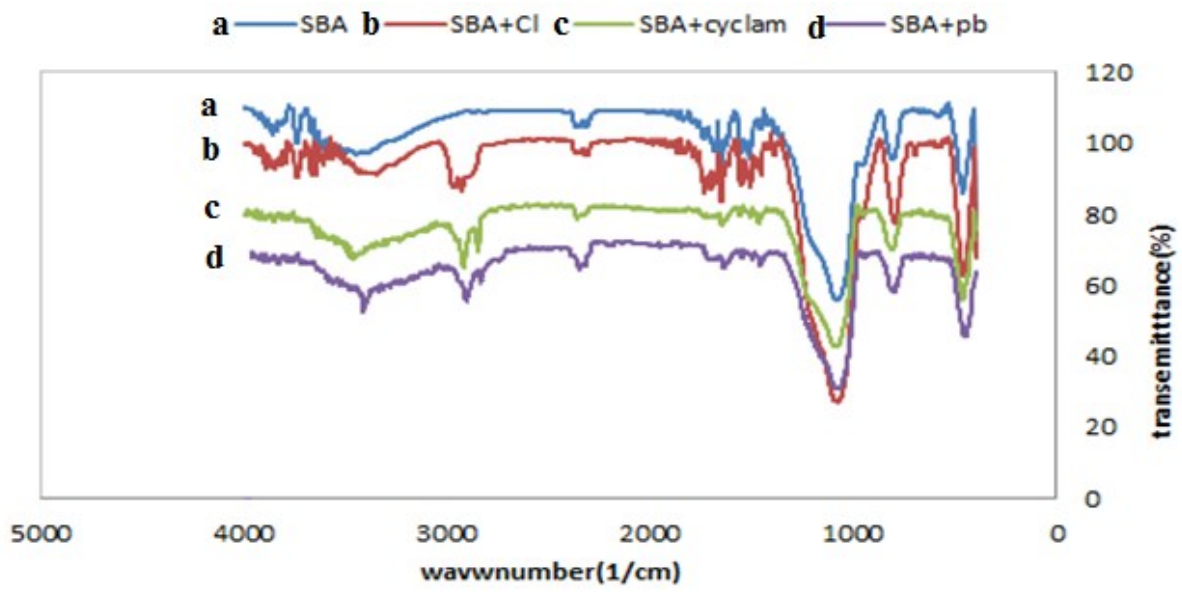

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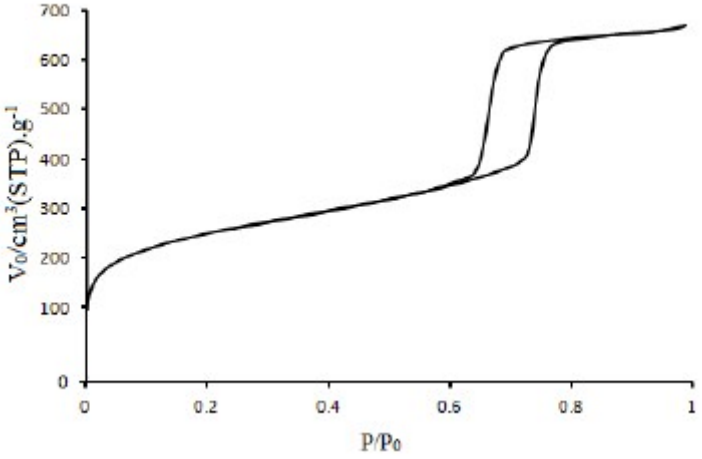

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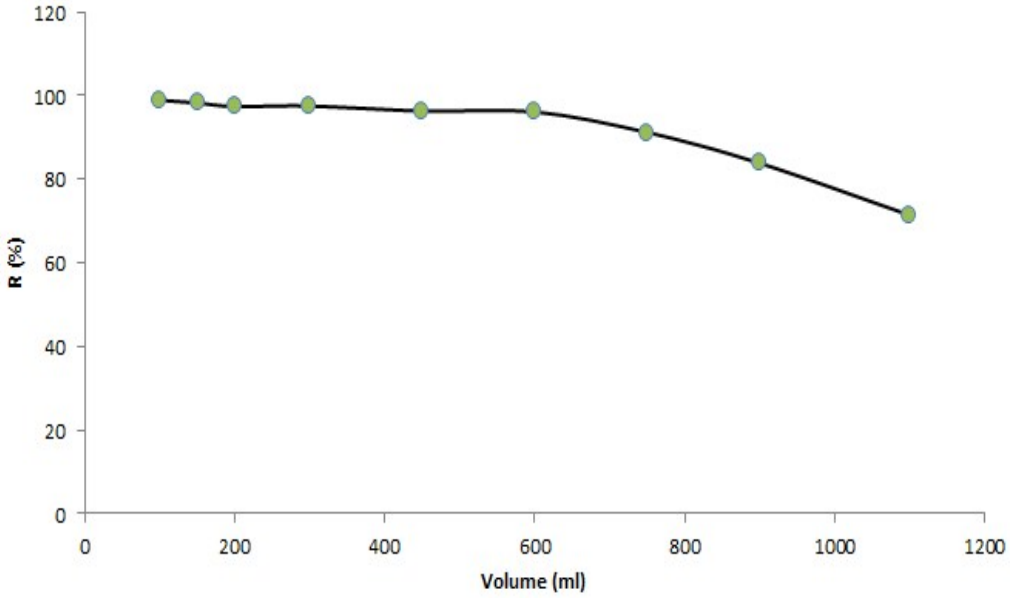

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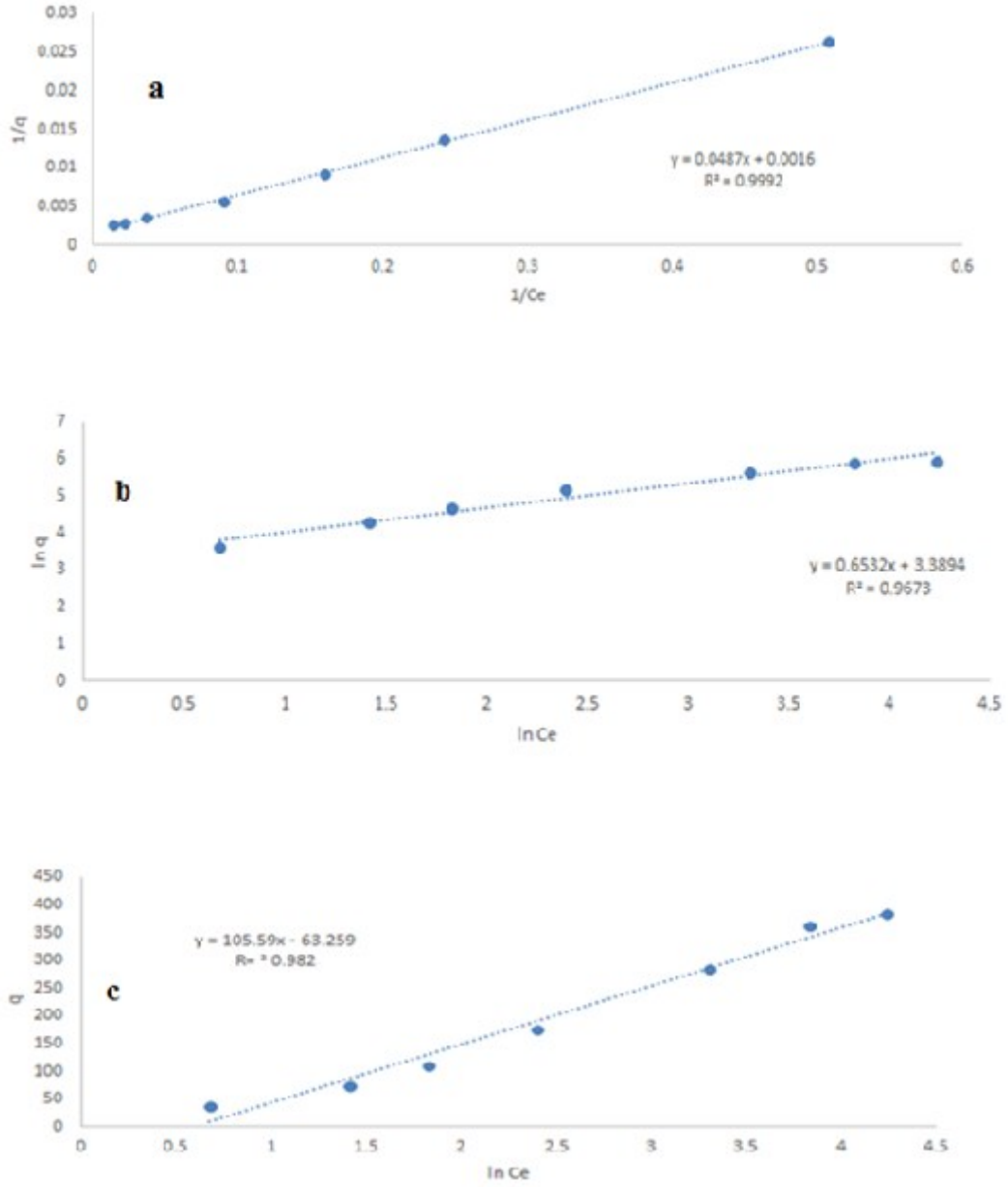

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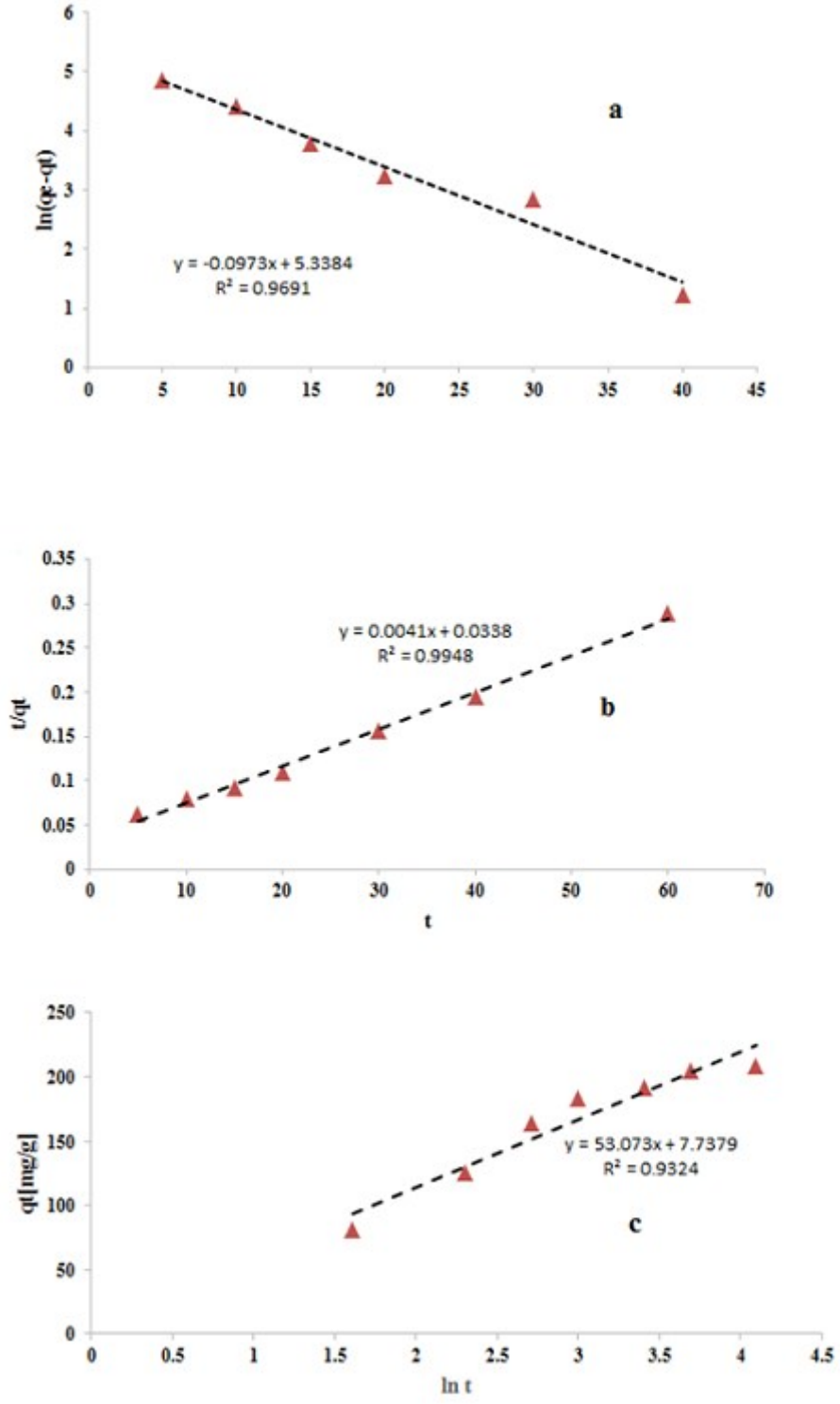

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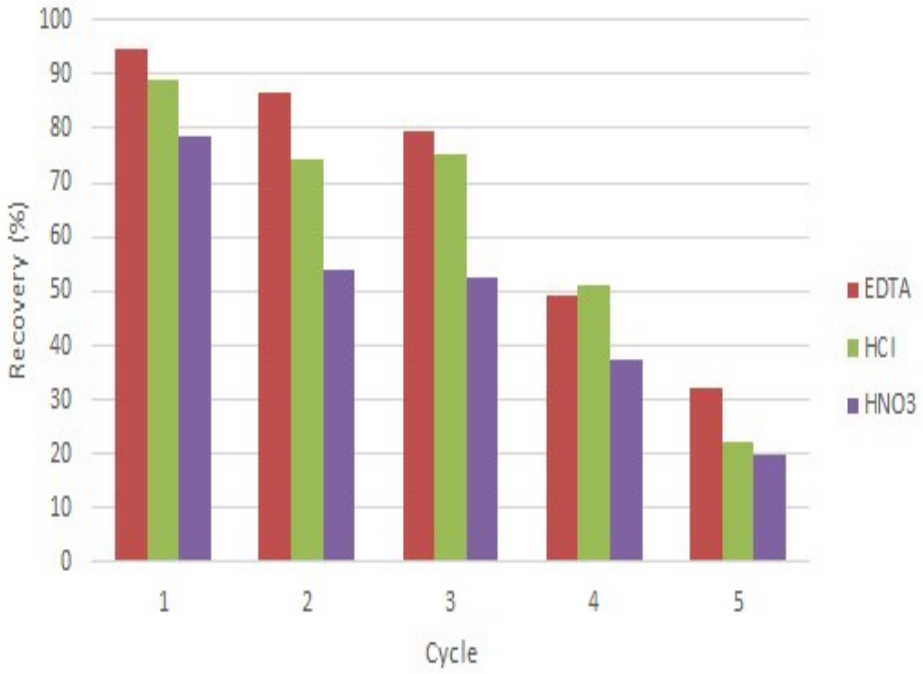

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