Electronic Supplementary Information

Synthesis of multi-ion imprinted polymers based on dithizone chelation for simultaneous removal of Hg^{2+}, Cd^{2+}, Ni^{2+} and Cu^{2+} from aqueous solutions

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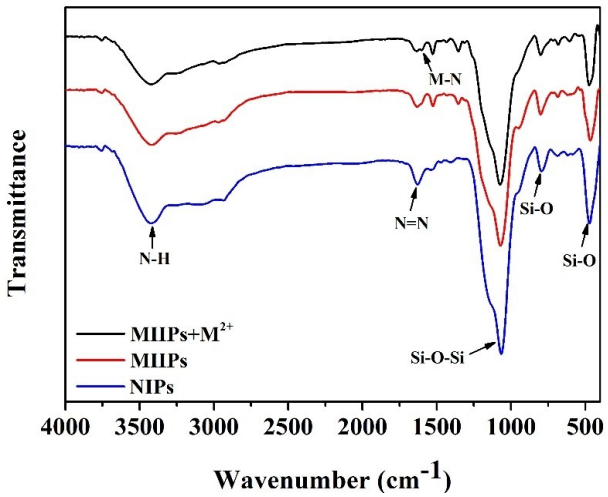

Fig. S1. FT-IR spectra of ions contained MIIPs, MIIPs and NIPs. M^{2+} is Hg^{2+}, Cd^{2+}, Ni^{2+} and Cu^{2+} here.

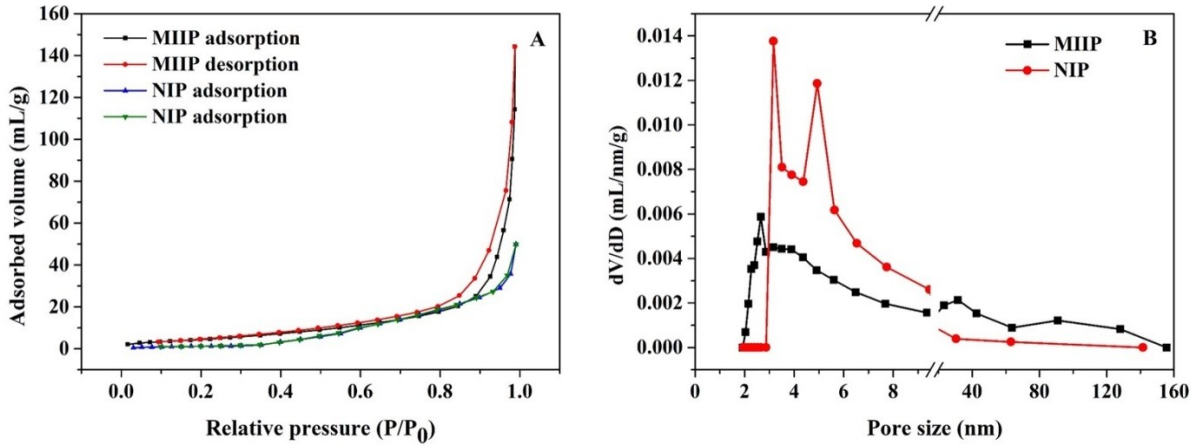

Fig. S2. (A) N_2 adsorption-desorption isotherms and (B) pore size distribution of MIIPs and NIPs.

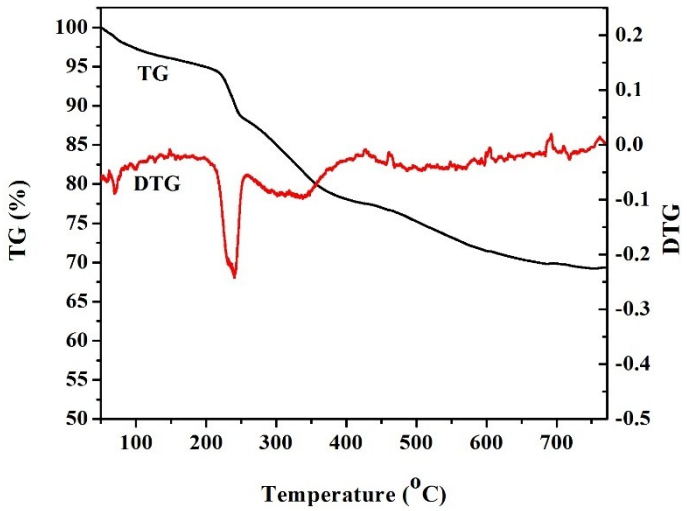

Fig. S3. TG/DTG curves of MIIPs.

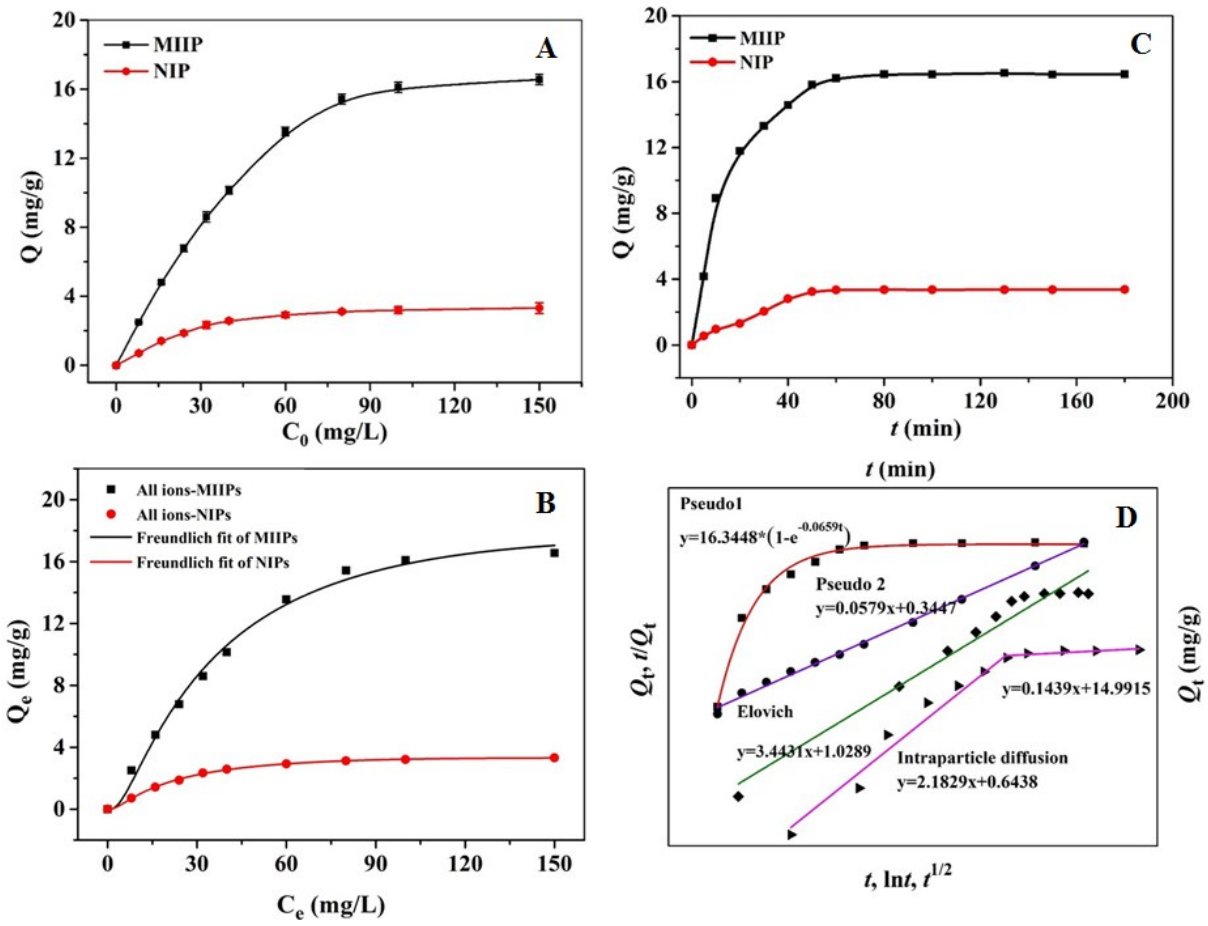

Fig. S4. (A) Static adsorption isotherm curves of MIIPs and NIPs for 4 ions in aqueous solutions. Experimental conditions: V, 10 mL; polymer, 20 mg; adsorption time, 12 h; room temperature. (B) Langmuir isotherm models for ions onto the MIIPs. (C) Adsorption kinetics curves of MIIPs and NIPs for ions in aqueous solution. Experimental conditions: the sum concentration of Hg^{2+}, Cd^{2+}, Ni^{2+} and Cu^{2+}, 100 mg/L; V, 10 mL; polymer, 20 mg; room temperature. (D) Pseudo-first-order, pseudo-second-order, Elovich and intraparticle diffusion kinetic models for ions towards MIIPs.

Table S1. Specific surface area and other related data of MIIPs and NIPs.

parameters	specific surface area (m^2/g)		cumulative pore area (m^2/g)	cumulative pore volume (mL/g)	average pore diameter (nm)
	BET method	Langmuir method			
MIIPs	15.59	27.44	43.82	0.2404	21.94
NIPs	4.62	7.37	38.26	0.0955	9.98

Table S2. Isotherm model parameters for MIIPs and NIPs.

	Langmuir model			Freundlich model		
Sorbent	Q_{max} (mg g^{-1})	K_l (L mg^{-1})	R	K_f ($mg^{1-(1/n)}$ $L^{1/n}$ g^{-1})	$1/n$	R
MIIP	18.178	0.006	0.990	0.006	4.066	0.988
NIP	3.516	0.011	0.998	0.007	3.301	0.998

Table S3. Parameters obtained of ions adsorption towards MIIPs from four kinetic models.

Kinematic model	Model parameter		
Pseudo-first-order	k_1[a] (min^{-1})	Q_e[b] (μmol/g)	r
$\ln(Q_e-Q_t) = \ln Q_e - k_1 t$	0.066	16.345	0.990
Pseudo-second-order	k_2[c] (g/(μmol·min))	Q_e (μmol/g)	r
$\frac{t}{Q_t} = \frac{1}{k_{ad}Q_e^2} + \frac{t}{Q_e}$	0.01	17.271	0.996
Elovich	α[d] (μmol/g)	β[d] (min·g/μmol)	r
$Q_t = \frac{1}{\beta}ln(\alpha\beta) + \frac{1}{\beta}ln(t)$	4.627	0.290	0.954
Intraparticle diffusion	k_p[e] (μmol/(g $min^{0.5}$))	C[f] (μmol/g)	r
$Q_t = k_p t^{1/2} + C$	2.183	0.644	0.658
	0.144	14.992	0.959

[a] k_1 is the rate constant of adsorption in pseudo-first-order model.

[b] Q_e is the final adsorption amount at equilibrium, Q_t is the instantaneous adsorption amount in the adsorbent at time t.

[c] k_2 is the rate constant of adsorption in pseudo-second-order model.

[d] α and β represent the initial adsorption rate and desorption constant in Elovich model.

[e] k_p indicates the intraparticle diffusion rate constant and relates to the particle size R with the equation $k_p = \frac{6Q_e}{R}\sqrt{\frac{D}{\pi}}$.

[f] C provides information about the thickness of the boundary layer.

Table S4. Comparative studies on MIIPs.

Template	Polymerization method	Monomer	Application	Ref.
Ce(IV)-Gd(III)	Thermal polymerization	But-2-enedioic acid bis-[(2-amino-ethyl)-amide	Screen-printed carbon electrodes	16
Cu(II)-Cd(II)	Precipitation polymerization	DEM[a]	Electrochemistry	17
Cd(II)-Pb(II)	Precipitation polymerization	DEM	Solid-phase extraction	18
As(V)-Cr(III)	Emulsion polymerization	DDDPA[b] & 4-VP[c]	—	19
Hg(II)-Cd(II)-Ni(II)-Cu(II)	Sol–gel process	Dithizone & APTES	Solid-phase extraction	This work

[a] DEM: 2-(diethylamino) ethylmetacrilate.

[b] DDDPA: 1,12-dodecanediol-O,O'-diphenyl-phosphonic acid.

[c] 4-VP: 4-vinylpyridine.