

Supplementary information

Super rapid removing copper, cadmium and lead ions from water by NTA-silica gel

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S1. The BET of non-NTA-modified silica gel

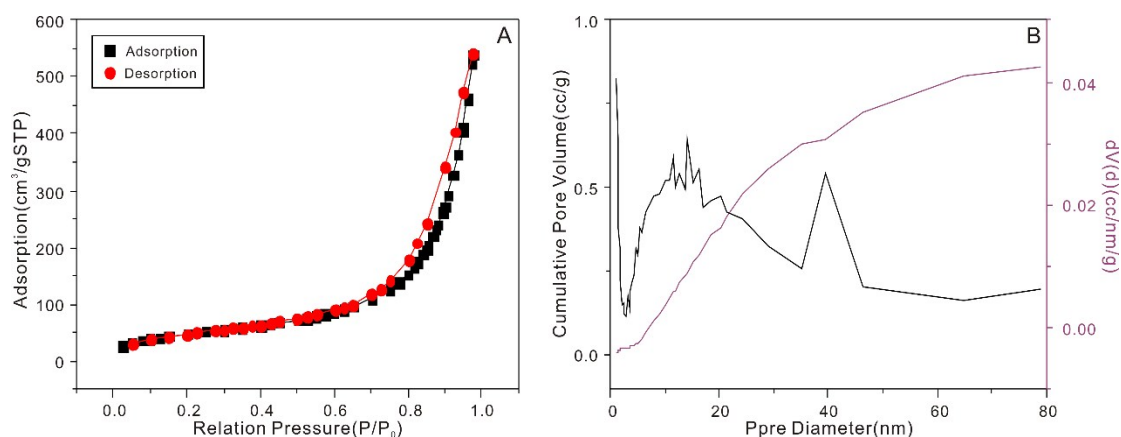


Fig. S1. (A) Nitrogen adsorption–desorption isotherm, and (B) the pore-size distribution curve of the non-NTA-modified silica gel.

S2. The pseudo-first-order kinetic plots for the adsorption of Cu²⁺, Cd²⁺ and Pb²⁺

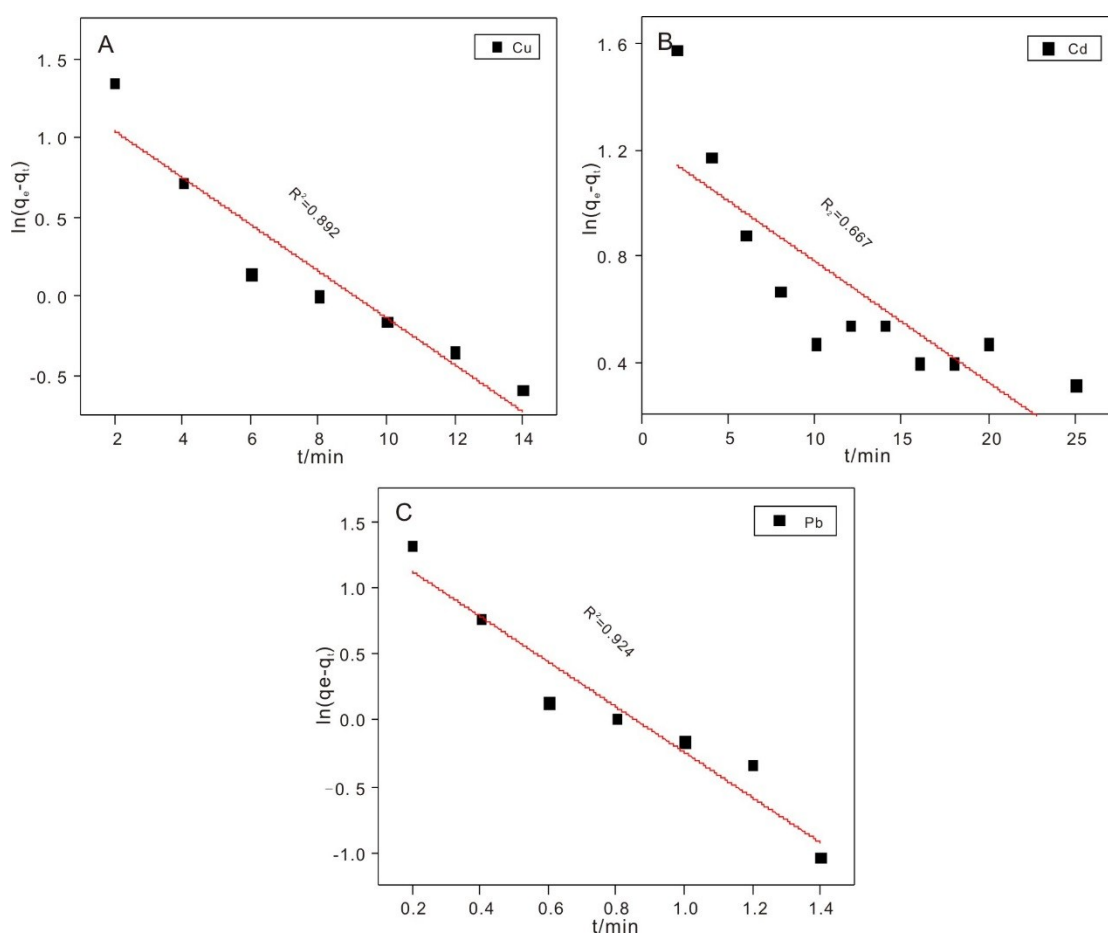


Fig. S2. The pseudo-first-order kinetic plots for the adsorption of (A) Cu²⁺, (B) Cd²⁺

and (C) Pb^{2+} on the surface of the NTA-modified silica gel. (Adsorbent dose: 1.0 g/L, 25 °C, pH: 5.0)

S3. Adsorption isotherm models for Cu^{2+} , Cd^{2+} and Pb^{2+} on NTA-modified silica

gel

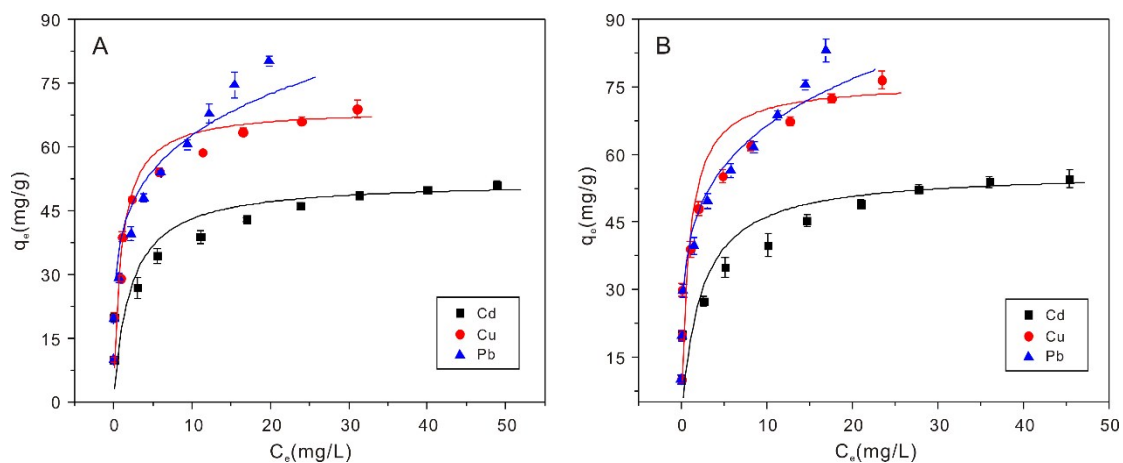


Fig. S3. Cu^{2+} , Cd^{2+} and Pb^{2+} ions adsorption isotherms onto NTA-modified silica gel at (A) 313 K and (B) 323 K (Adsorbent dose: 1.0 g/L, pH: 5.0).

S4. Langmuir and Freundlich isotherm models for fitting of Cu^{2+} , Cd^{2+} and Pb^{2+} on NTA-silica gel

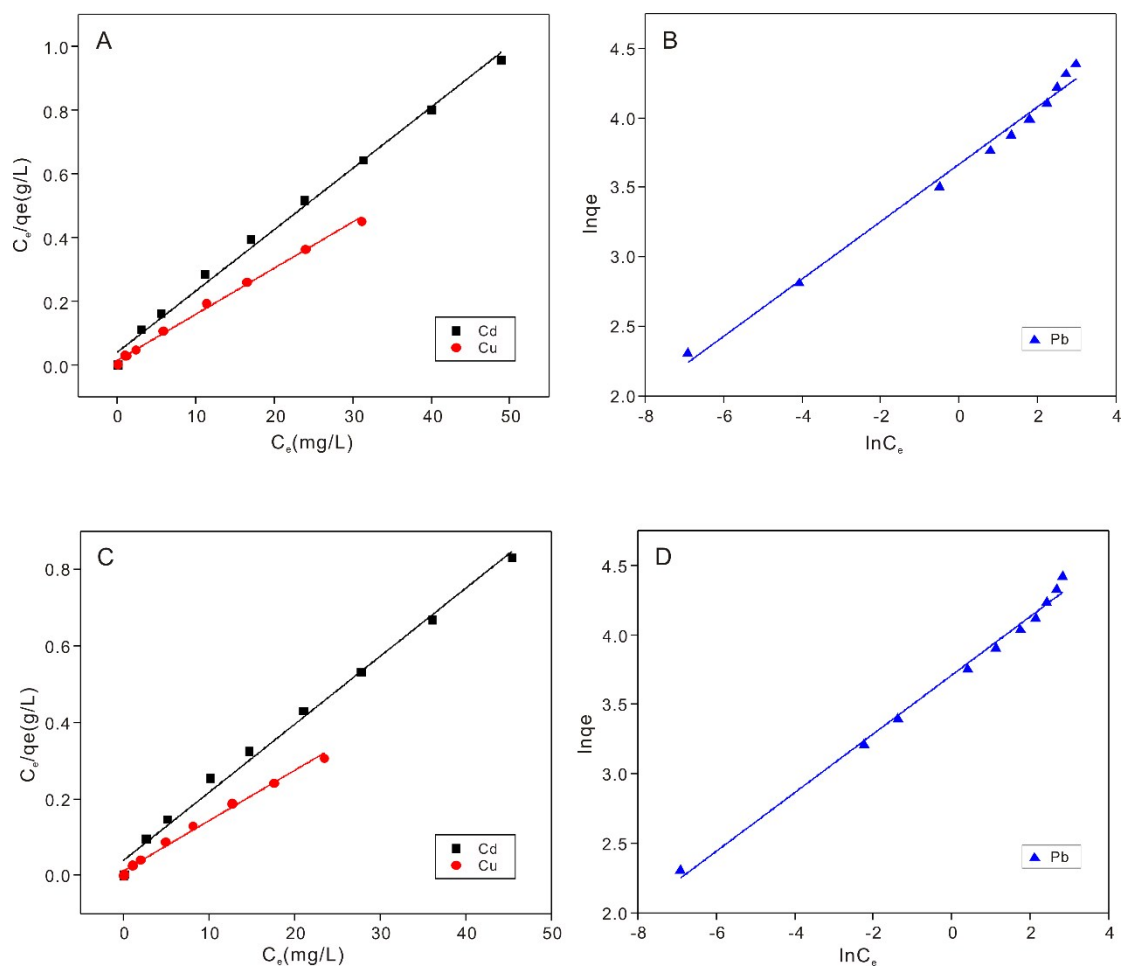


Fig. S4. Langmuir adsorption models for fitting of Cu^{2+} and Cd^{2+} at (A) 313 K and (C) 323 K and Freundlich adsorption models for fitting of Pb^{2+} at (B) 313 K and (D) 323 K on NTA-silica gel.

S5. Ill-suited adsorption isotherm models for Cu^{2+} , Cd^{2+} and Pb^{2+} on NTA-modified silica gel

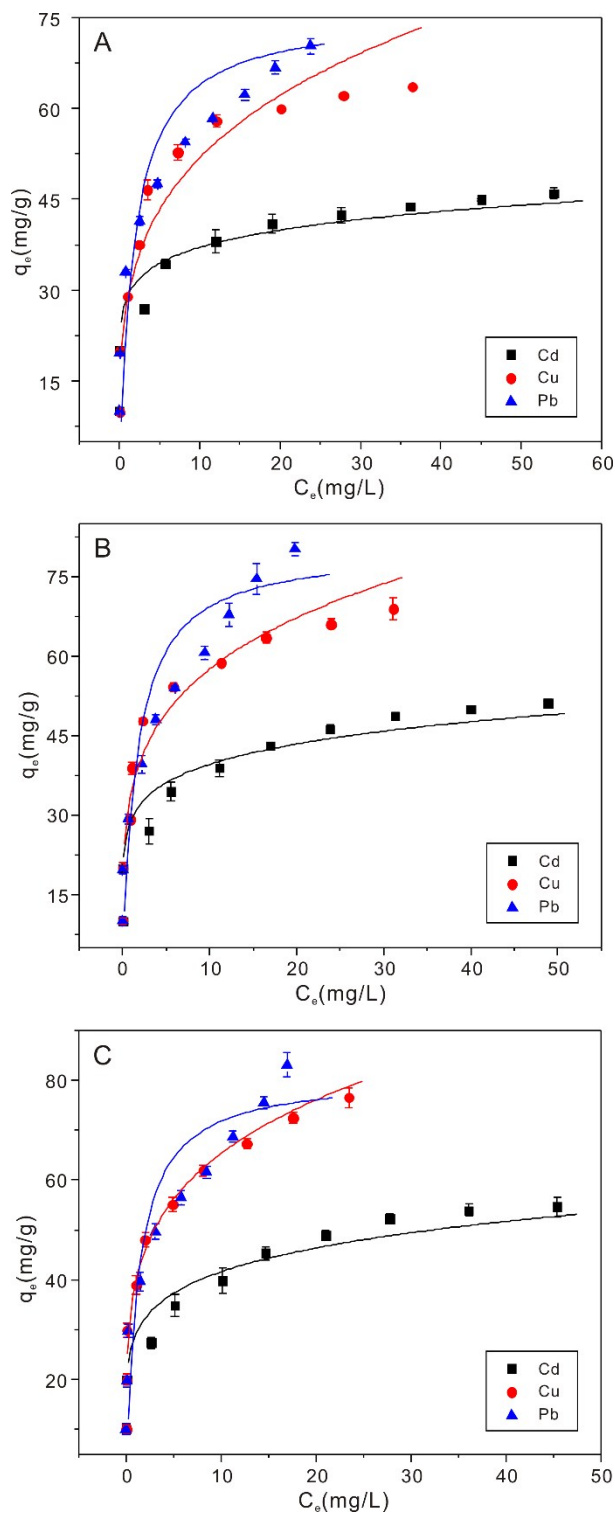


Fig. S5. Cu^{2+} , Cd^{2+} and Pb^{2+} ions adsorption isotherms onto NTA-modified silica gel at (A) 298 K, (B) 313 K and (C) 323 K (Adsorbent dose: 1.0 g/L, pH: 5.0).

S6. Langmuir and Freundlich isotherm models for fitting of Cu^{2+} , Cd^{2+} and Pb^{2+}

on NTA-silica gel

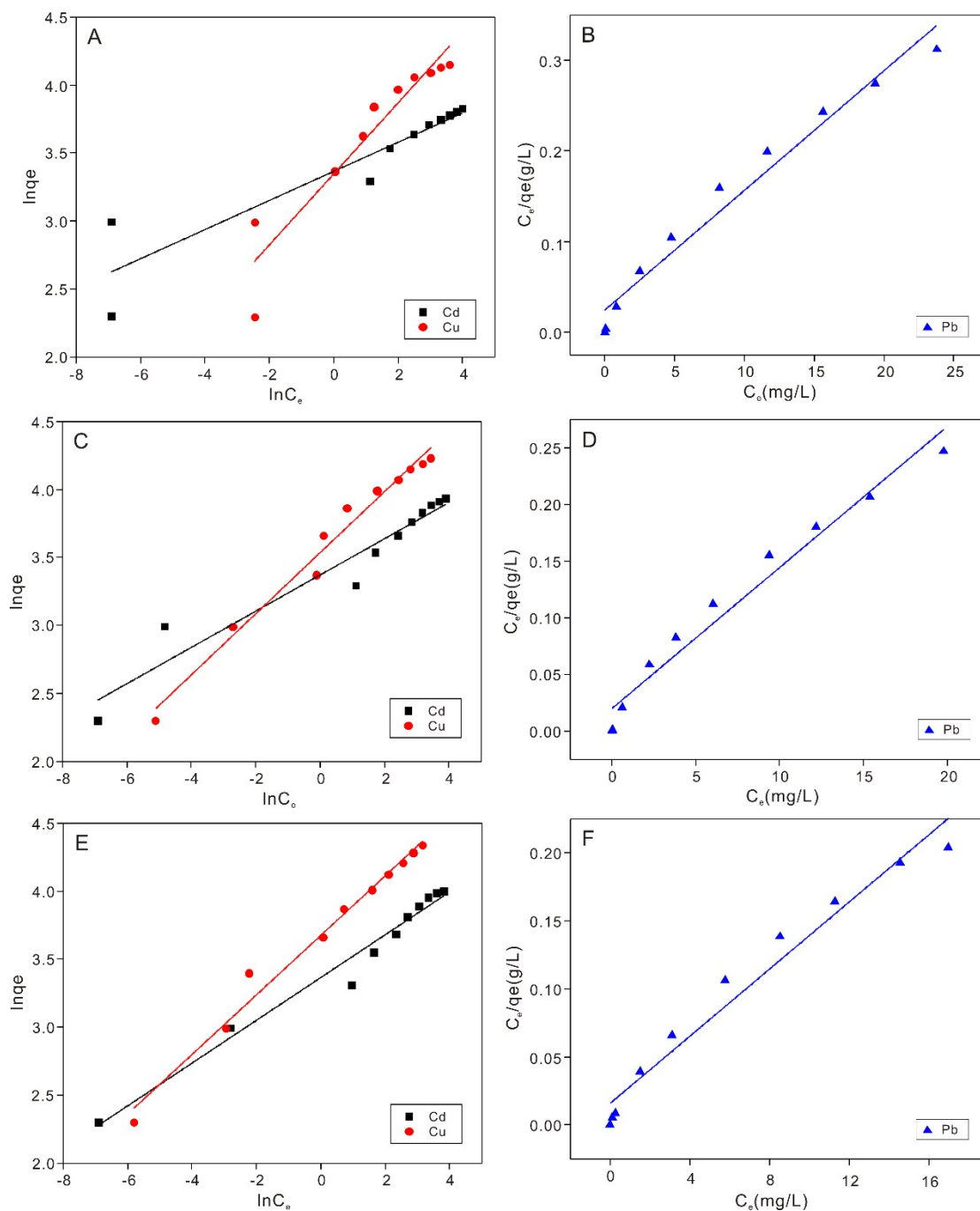


Fig. S6. Langmuir adsorption models for fitting of Cu^{2+} and Cd^{2+} at (A) 298 K, (C) 313 K and (E) 323 K and Freundlich adsorption models for fitting of Pb^{2+} at (B) 298 K, (D) 313 K and (F) 323 K on the NTA-silica gel.

S7. Calculation of thermodynamic data

The $\ln K_d$ as function of C_e at $T = 298\text{ K}$, 308 K and 318 K was given in Fig. S7. The adsorption equilibrium constants (K^0) at different temperature were obtained by linear while C_e was equal to zero. At $T = 298\text{ K}$, 313 K , 323 K , $\ln K^0 = 3.66, 4.40, 5.00$, and $\Delta G^0 = -9.06, -11.43, -13.44\text{ kJ/mol}$, respectively for Cu^{2+} ; $\ln K^0 = 5.24, 4.83, 4.41$ and $\Delta G^0 = -12.99, -12.57, -11.85\text{ kJ/mol}$, respectively for Cd^{2+} ; $\ln K^0 = 4.87, 5.26, 5.14$ and $\Delta G^0 = -12.08, -13.70, -13.80\text{ kJ/mol}$, respectively for Pb^{2+} . The values of ΔH^0 and ΔS^0 can be calculated from the plot of $\ln K^0$ vs $1/T$ (Fig. S7). The value of ΔH^0 and ΔS^0 was calculated to be $42.67, -26.10, 24.05\text{ kJ/mol}$ and $173.38, -43.77, 121.22\text{ J/mol K}$ for Cu^{2+} , Cd^{2+} , and Pb^{2+} , respectively.

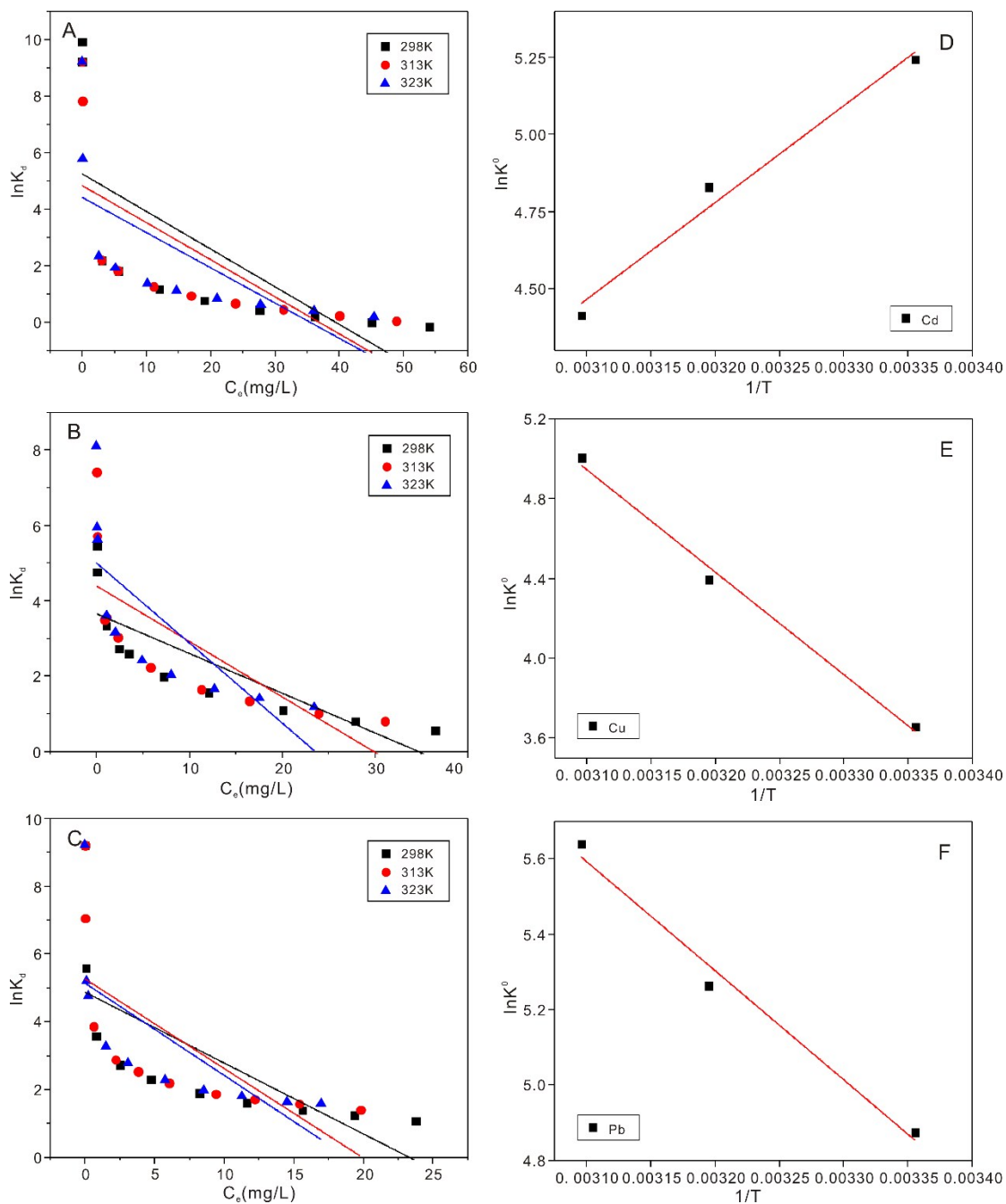


Fig. S7. (A), (B), (C) Linear plots of $\ln K_d$ vs C_e and (D), (E), (F) linear plot of $\ln K^0$ vs $1/T$ for the adsorption of Cu^{2+} , Cd^{2+} and Pb^{2+} on NTA-silica gel at 298, 308 and 318 K.

S8. Comparison about adsorption of non-and NTA-modified silica gel

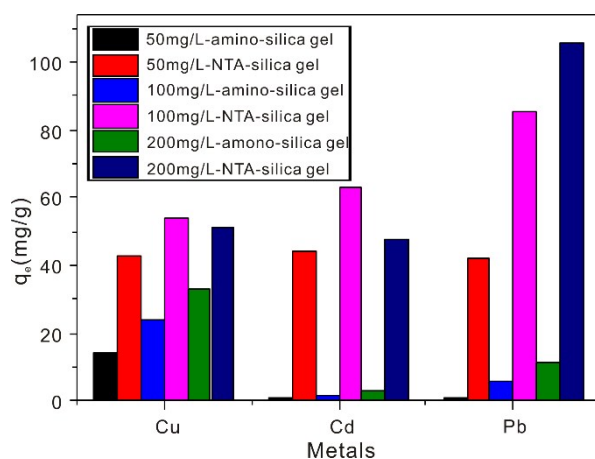


Fig. S8. Compare about adsorption of non- and NTA-modified silica gel with different concentrations (50, 100, 200 mg/L, adsorbent dose: 1.0 g/L, pH: 5.0)

S9. XPS spectra of NTA-silica gel before and after adsorption of the heavy metals

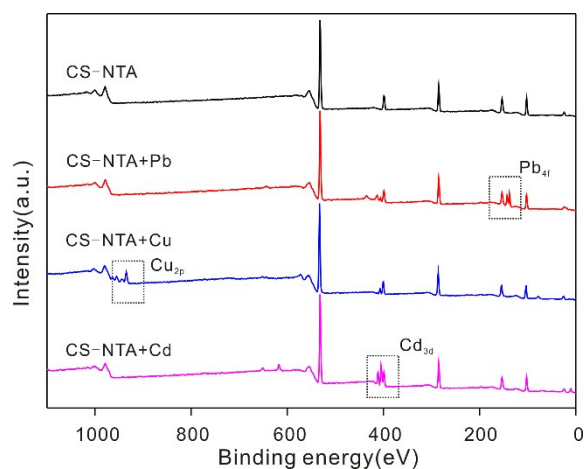


Fig. S9. XPS spectra of NTA-silica gel before and after adsorption of Cu^{2+} , Cd^{2+} and Pb^{2+} .

S10. FTIR spectra of NTA-silica gel before and after adsorbing heavy metals.

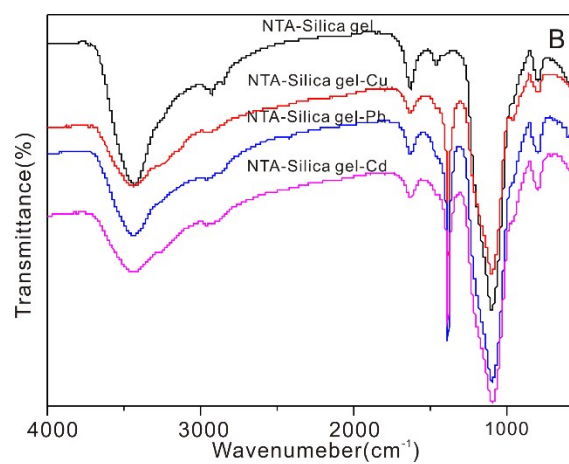


Fig. S10. FTIR spectra of NTA-silica gel before and after adsorbing Cu^{2+} , Cd^{2+} and Pb^{2+} .