Electronic Supplementary Information

Fabrication of magnetic bimetallic Fe_3O_4@Au–Pd hybrid nanoparticles with recyclable and efficient catalytic properties

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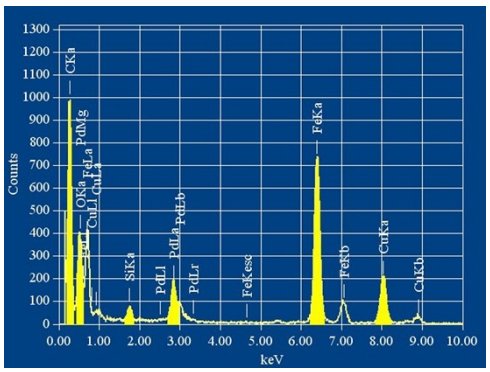

Fig. S1 EDS spectrum analysis of Fe_3O_4@Pd NPs.

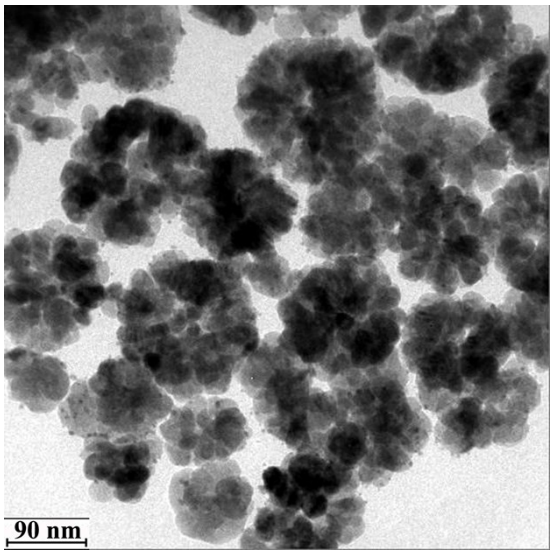

Fig. S2 TEM images of Fe_3O_4@Au nanoseeds.

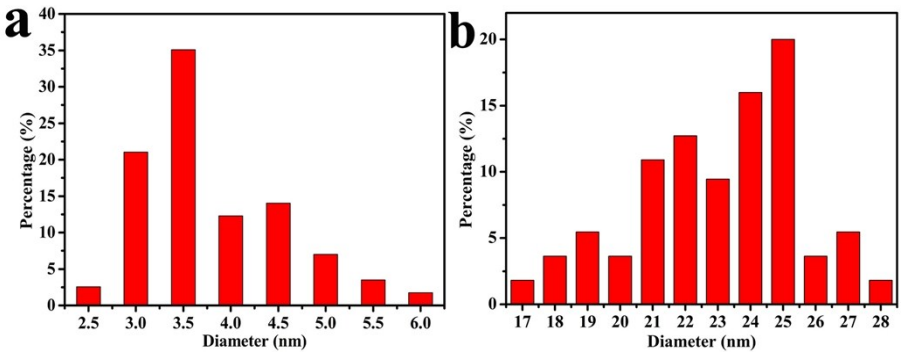

Fig. S3 The size distribution of Au NPs of (a) Fe_3O_4@Au nanoseeds and (b) Au-Pd NPs of Fe_3O_4@Au-Pd NPs.

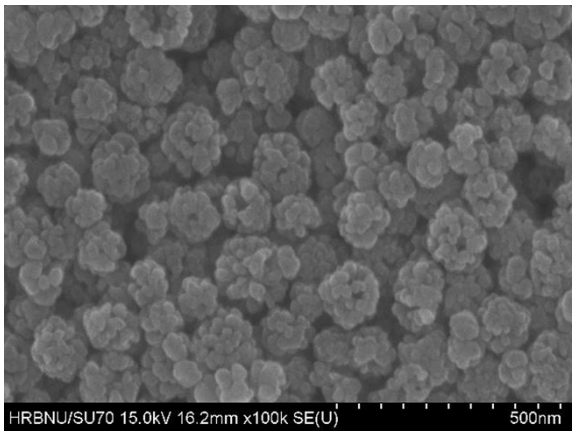

Fig. S4 SEM images of Fe_3O_4 hollow spheres.

Specific surface areas of the samples were determined using N_2 adsorption–desorption isotherms at 77 k (Micromeri–tics TriStar II 3020) with the Brunauer–Emmett–Teller (BET) method. Fig. S5 shows the nitrogen adsorption desorption isotherms.

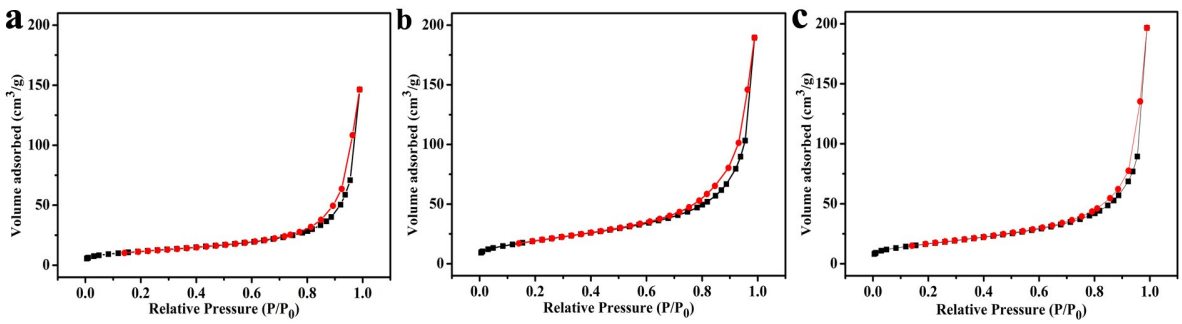

Fig. S5 N_2 adsorption/desorption isotherm of (a) Fe_3O_4 hollow spheres, (b) Fe_3O_4@Pd NPs, (c) Fe_3O_4@Au-Pd NPs.

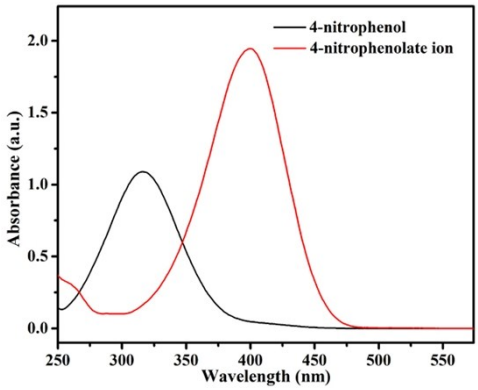

Fig. S6 The UV-vis characteristic peaks of freshly prepared 4-nitrophenol and 4-nitrophenolate ion aqueous solution at 317 and 400 nm, respectively.

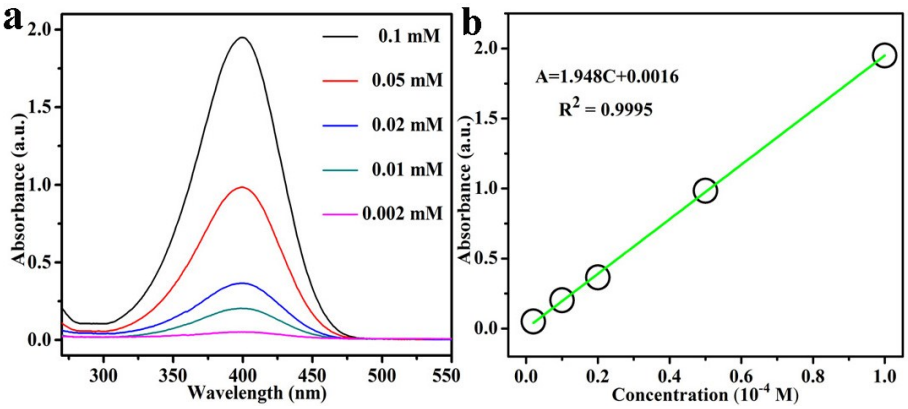

Fig. S7 (a) Absorption spectra of aqueous mixture solutions of 4-NP and $NaBH_4$ at different concentrations of 4-NP. (b) Plot of the peak absorbance against the concentration of 4-NP.

Table S1 Rates of reaction and turnover frequencies (TOF)[a] for the reduction of 4-NP by catalyst.
[a] The TOF is defined as the moles of reduced 4-NP molecules per mole of the surface noble metal atoms per second.

Catalyst	Type	Rate constant (s^{-1})	TOF[a] (s^{-1})	References
Fe_3O_4@Au-Pd NPs	Supported	28.90×10^{-3}	8.78×10^{-2}	This work
Fe_3O_4@Pd NPs	Supported	14.50×10^{-3}	3.28×10^{-2}	This work
Au-Pd carbon spheres	Nanocomposites	14.60×10^{-3}	3.37×10^{-3}	1
Fe_xO_y/Pd@mSiO_2	yolk–shell	1.60×10^{-3}	2.19×10^{-3}	2
Pd/Fe_3O_4/polypyrrol	hollow capsules	2.03×10^{-3}	1.47×10^{-2}	3
Pd@Au CSNTPs	core-shell	2.31×10^{-3}	2.46×10^{-2}	4
PdAu/Fe_3O_4	nanocomposites	5.47×10^{-3}	4.91×10^{-2}	5
Fe_3O_4@SiO_2@CeO_2 @Au-Pd	nanocomposites	4.0×10^{-3}	5.69×10^{-2}	6

References:

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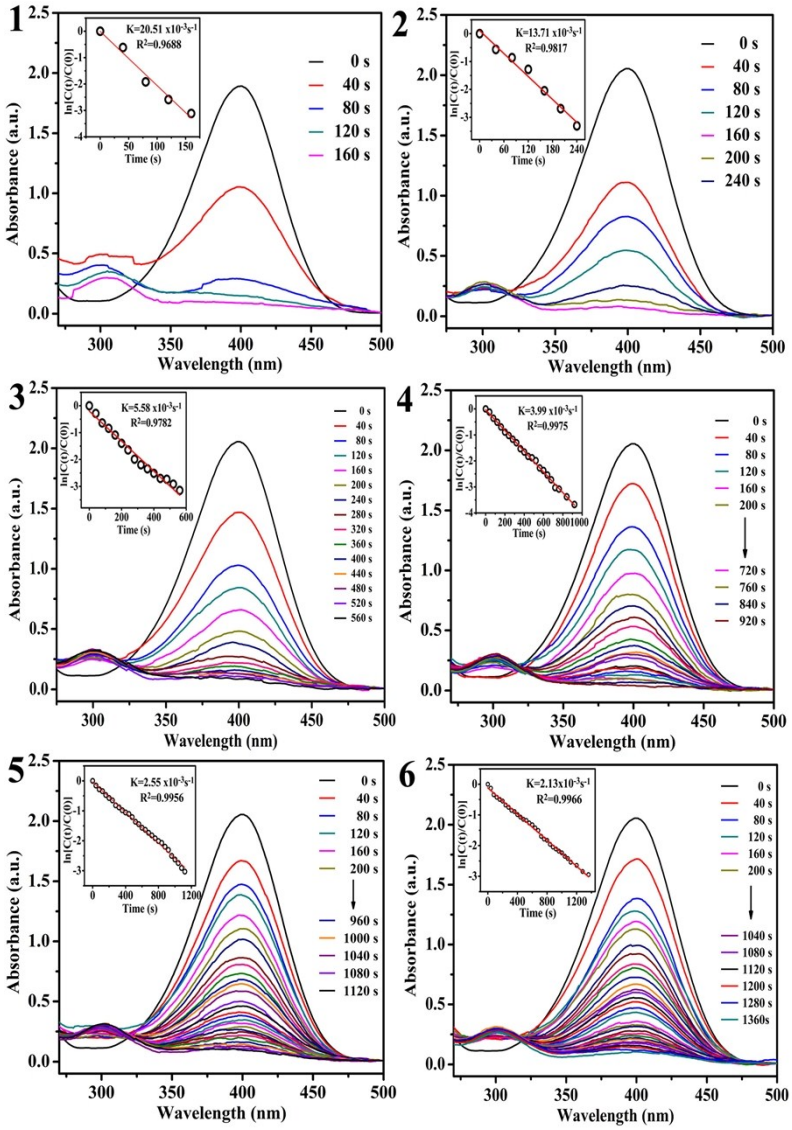

Fig. S8 The UV−vis spectra and kinetic rate of reduction of 4-NP by $NaBH_4$ under the catalysis of Fe_3O_4@Pd NPs for 1-6 times.

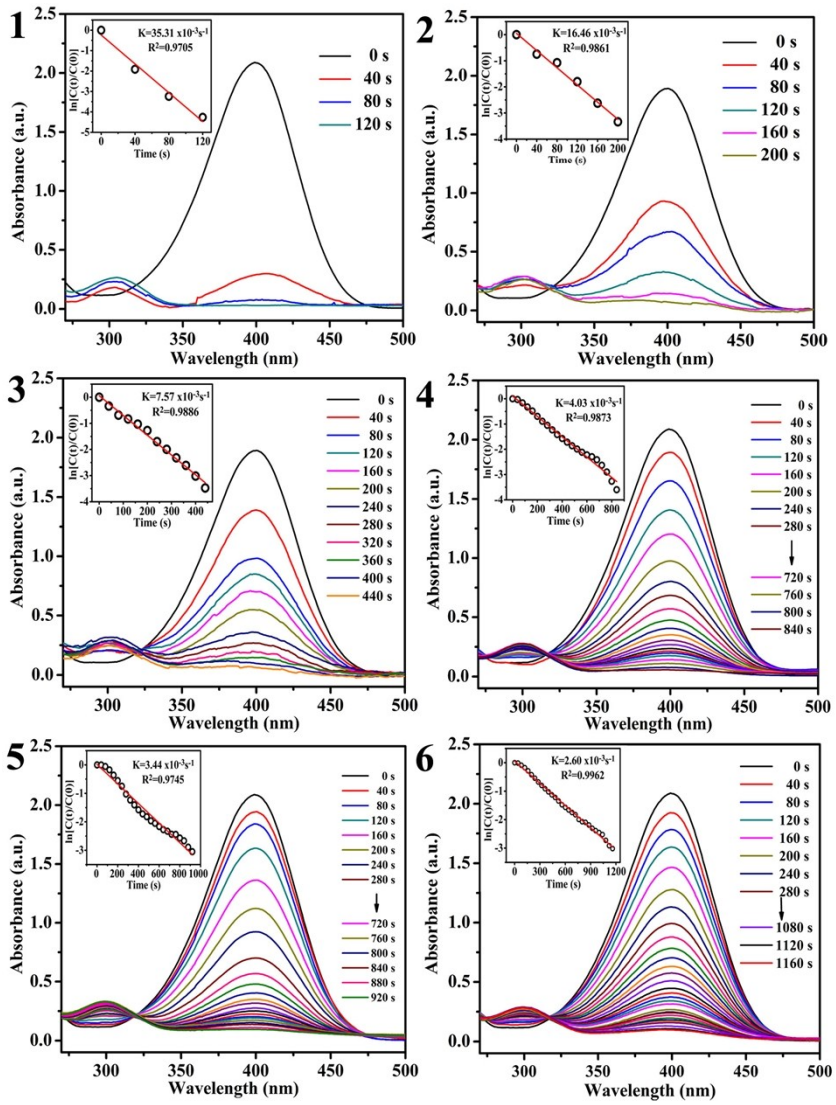

Fig. S9 The UV−vis spectra and kinetic rate of reduction of 4-NP by $NaBH_4$ under the catalysis of Fe_3O_4@Au-Pd NPs for 1-6 times.

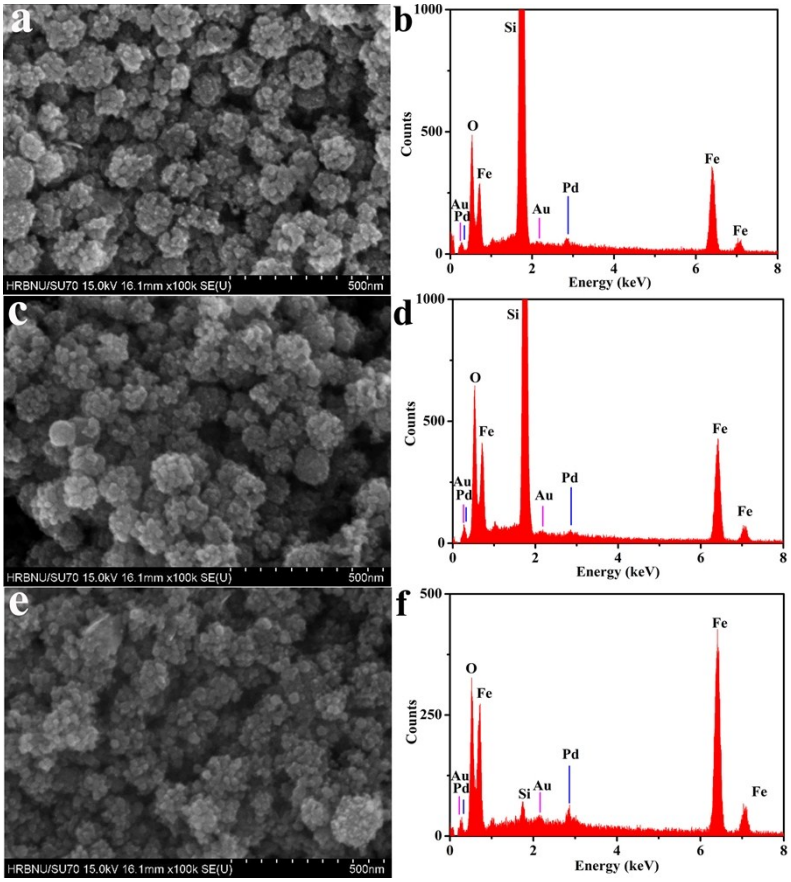

Fig. S10 The SEM (a, c, e) and EDX (b, d, f) of the Fe_3O_4@Au-Pd NPs as catalyst after reused 1st, 3rd, 6th times, respectively.

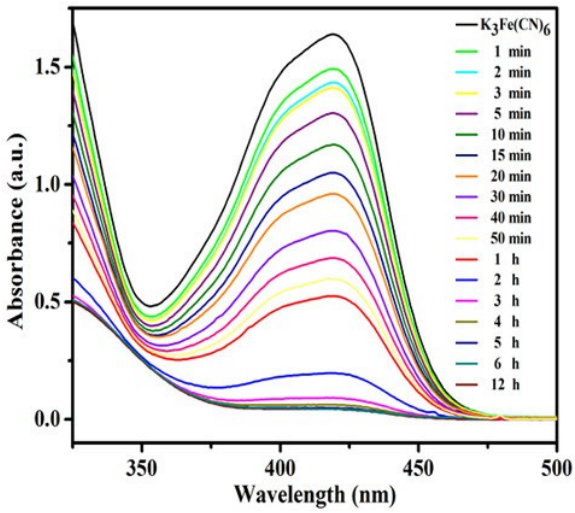

Fig. S11 UV-vis spectra of the reduction of $K_3Fe(CN)_6$ solution upon the addition of $NaBH_4$ recorded at different times from 1 min to12 h at 25℃, $[[Fe(CN)_6]^{3-}]=3\times10^{-3}$ M, $[BH^{4-}]=0.04$ M in the absence of catalyst.

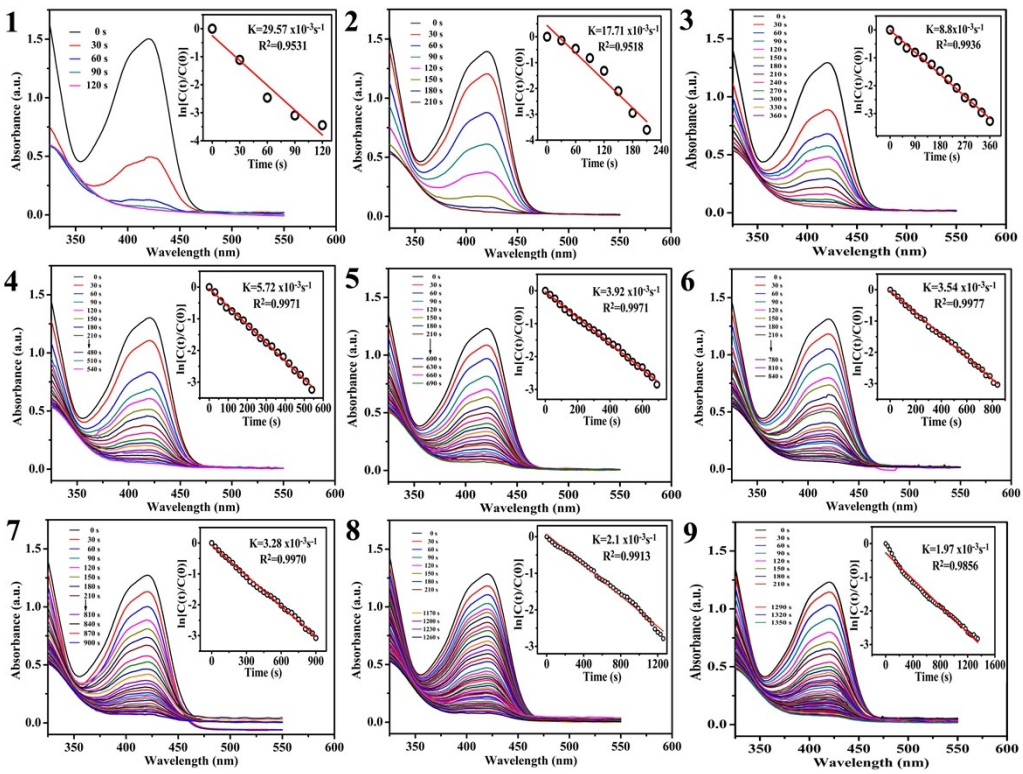

Fig. S12 The UV−vis spectra and kinetic rate of reduction of $K_3Fe(CN)_6$ by $NaBH_4$ under the catalysis of Fe_3O_4@Pd NPs for 1-9 times.

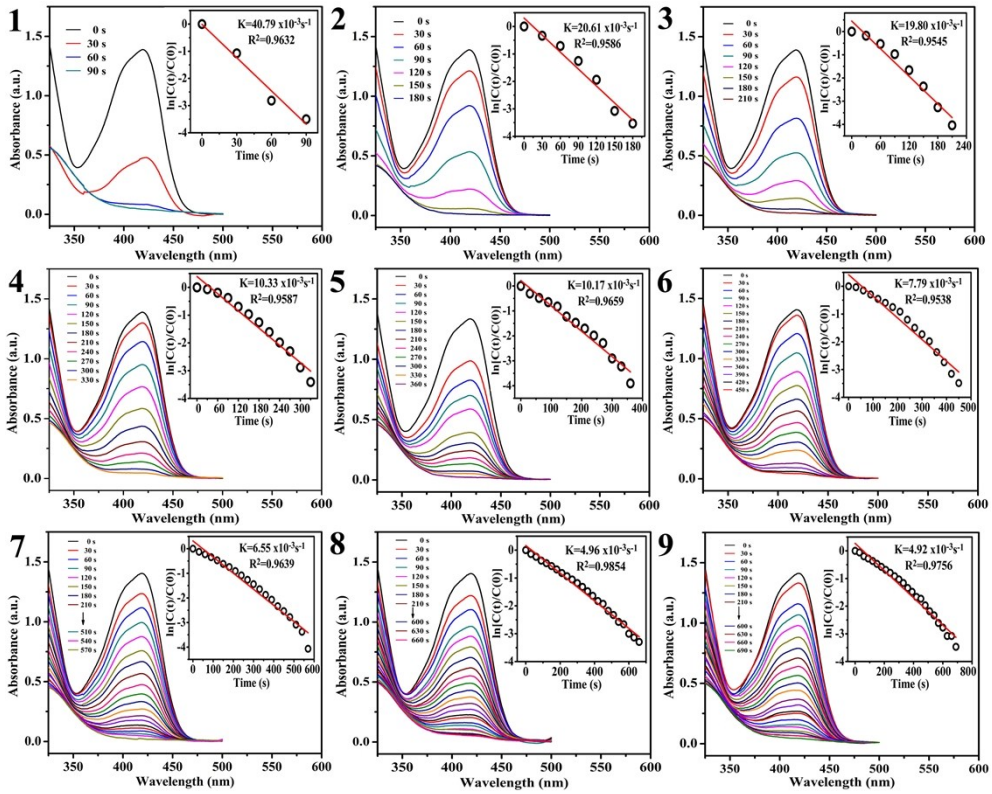

Fig. S13 The UV−vis spectra and kinetic rate of reduction of $K_3Fe(CN)_6$ by $NaBH_4$ under the catalysis of Fe_3O_4@Au-Pd NPs for 1-9 times.

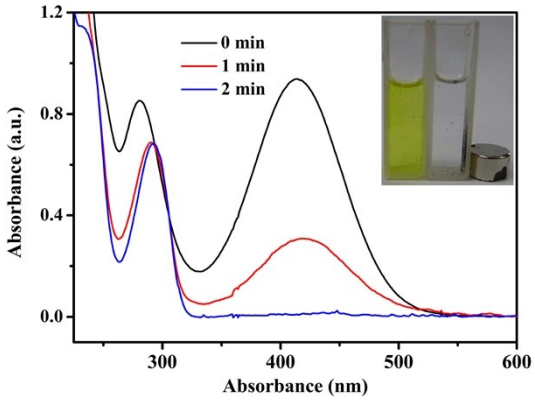

Fig. S14 UV-vis spectra of the reduction of 2-NP by $NaBH_4$ in the presence of Fe_3O_4@Au-Pd NPs, (2 mL H_2O, 90 μL 10 mM 2-NP, 600 μL 0.5 M $NaBH_4$).

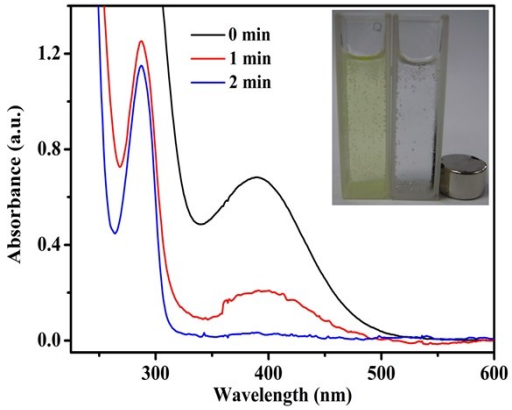

Fig. S15 UV-vis spectra of the reduction of 3-NP by $NaBH_4$ in the presence ofFe_3O_4@Au-Pd NPs, (2 mL H_2O, 150 μL 10 mM 3-NP, 1 mL 0.5 M $NaBH_4$).

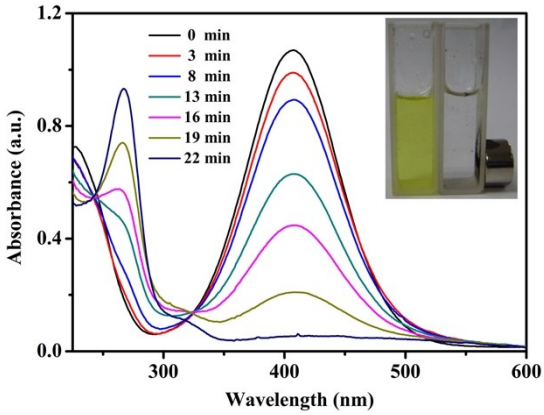

Fig. S16 UV-vis spectra of the reduction of 4-NTP by $NaBH_4$ in the presence of Fe_3O_4@Au-Pd NPs, (2 mL H_2O, 25 μL 10 mM 4-NTP, 200 μL 0.5 M $NaBH_4$).