Electronic Supplementary Material (ESI) for Analytical Methods.

Supporting information

Visual detection of different metal ions based on the tug of war between triangular Au nanoparticles and metal ions against mercaptans

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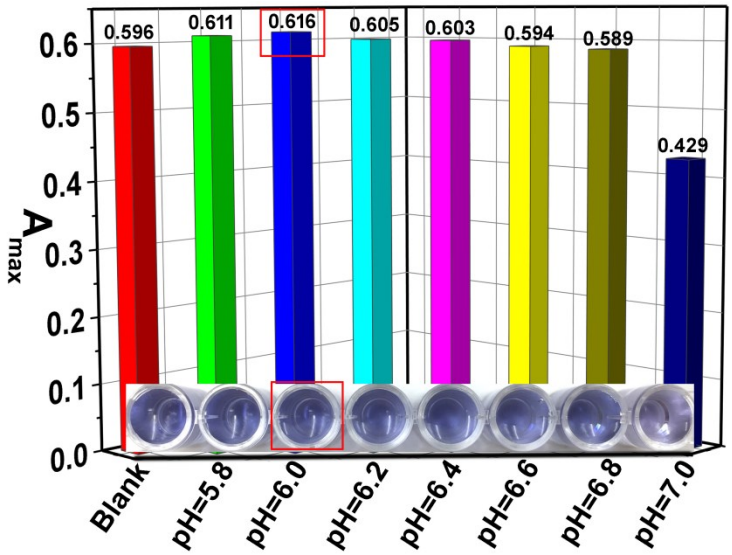

Fig.S1 The effect of pH concentration on the absorbance of AuNPLs. pH concentration was chosen 6.0.

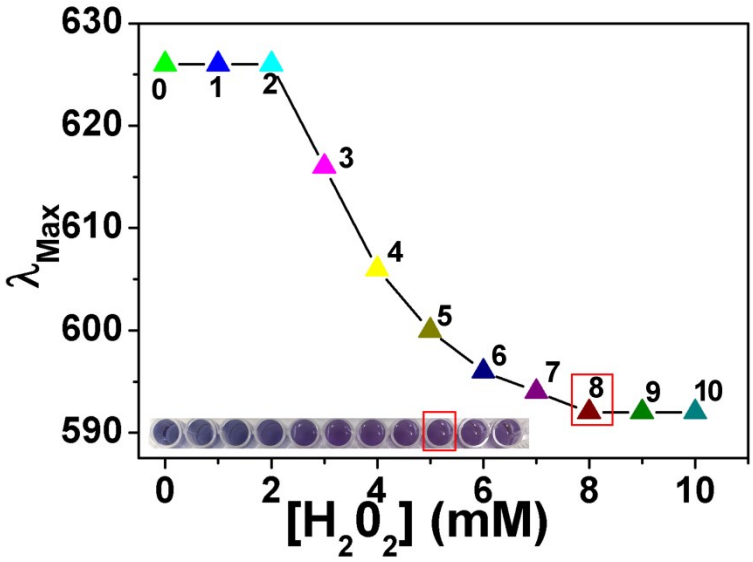

Fig.S2 The effect of H_2O_2 concentration on the absorbance of AuNPLs. H_2O_2 concentration was chosen 8 mM.

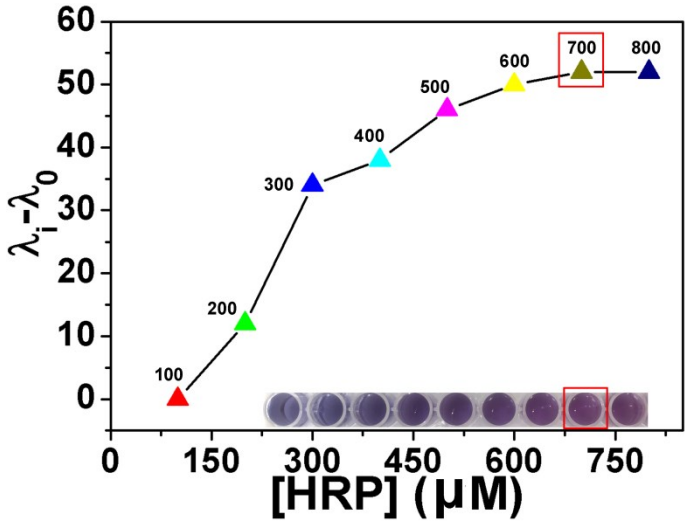

Fig.S3 The effect of HRP concentration on the absorbance of AuNPLs. HRP concentration was chosen 700 μM.

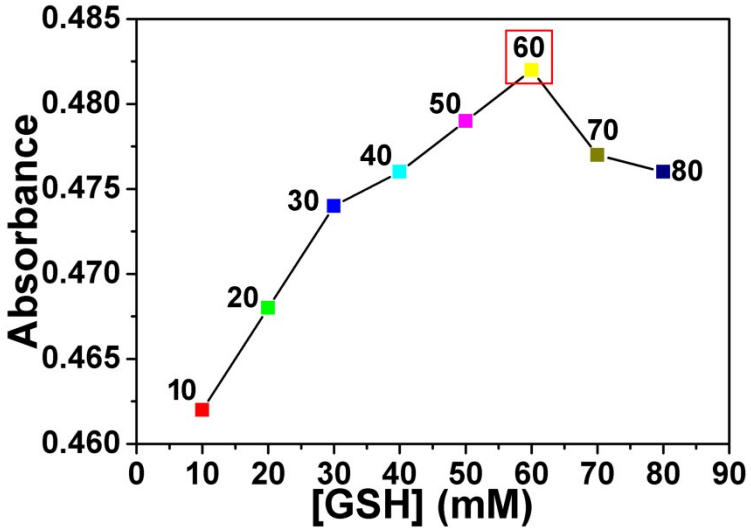

Fig.S4 The effect of GSH concentration on the absorbance of AuNPLs. GSH concentration was chosen 60 μM.

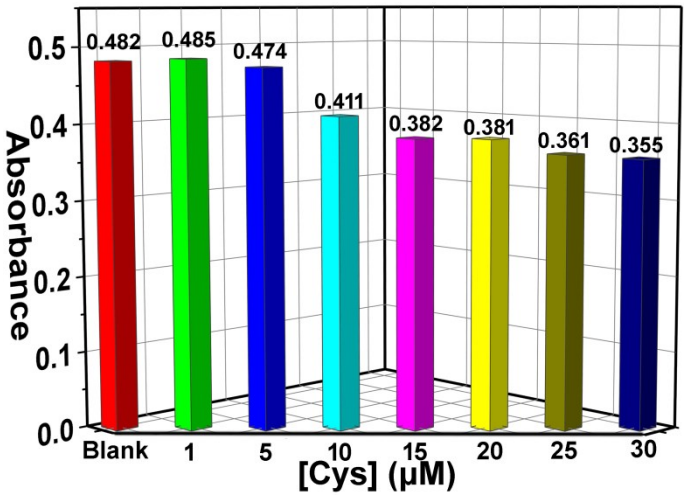

Fig.S5 The effect of Cys concentration on the absorbance of AuNPLs. Cys concentration was chosen 1μM.

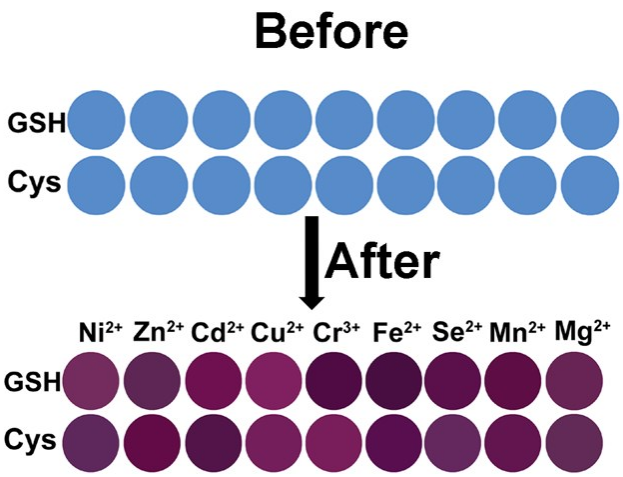

Fig.S6 The color map of the sensor array in the absence and presence of metal ions at 10 nM.

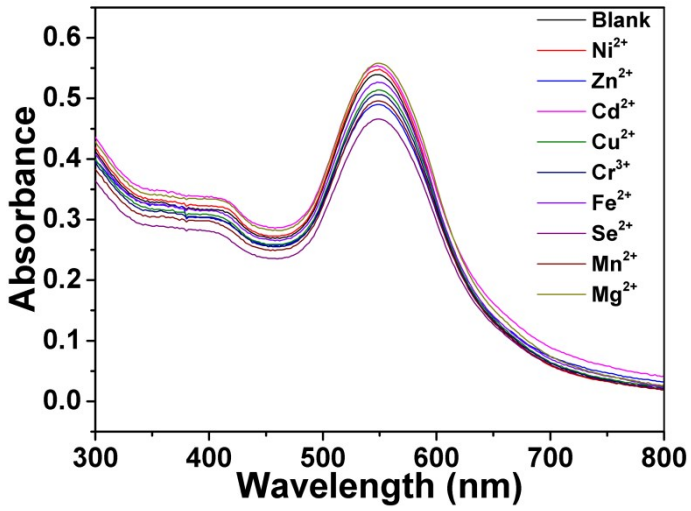

Fig.S7 UV-vis spectra of the sensing element (GSH) after reaction with the 9 metal ions at 10 nM.

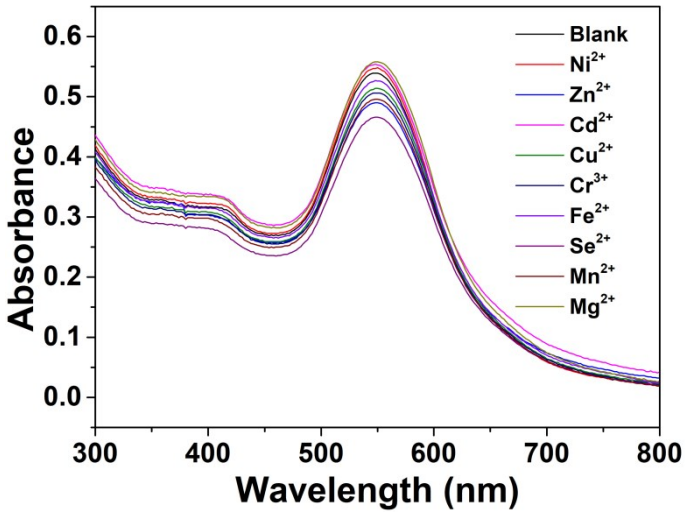

Fig.S8 UV-vis spectra of the sensing element (Cys) after reaction with the 9 metal ions at 10 nM.

Table S1 The training matrix of the colorimetric response patterns against 9 metal ions by using this sensor assay at the concentration of 10 nM.

Metal ions	A_i-A_0 GSH	A_i-A_0 Cys
Ni^{2+}	-0.055	-0.037
Ni^{2+}	-0.057	-0.036
Ni^{2+}	-0.054	-0.038
Zn^{2+}	0.024	0.004
Zn^{2+}	0.024	0.005
Zn^{2+}	0.026	0.005
Cd^{2+}	-0.013	-0.101
Cd^{2+}	-0.013	-0.101
Cd^{2+}	-0.013	-0.1
Cu^{2+}	0.014	-0.069
Cu^{2+}	0.014	-0.069
Cu^{2+}	0.014	-0.07
Cr^{3+}	-0.026	-0.03
Cr^{3+}	-0.025	-0.03
Cr^{3+}	-0.026	-0.03
Fe^{2+}	-0.091	-0.058
Fe^{2+}	-0.09	-0.056
Fe^{2+}	-0.091	-0.058
Se^{2+}	-0.034	-0.012
Se^{2+}	-0.033	-0.012
Se^{2+}	-0.033	-0.013
Mn^{2+}	-0.038	-0.081
Mn^{2+}	-0.039	-0.08
Mn^{2+}	-0.039	-0.08
Mg^{2+}	-0.045	0.012
Mg^{2+}	-0.044	0.014
Mg^{2+}	-0.043	0.011

Table S2 The training matrix of the colorimetric response patterns against 9 metal ions by using this sensor assay at the concentration of 50 nM.

Metal ions	A_i-A_0 GSH	A_i-A_0 Cys
Ni^{2+}	-0.027	-0.073
Ni^{2+}	-0.027	-0.07
Ni^{2+}	-0.028	-0.073
Zn^{2+}	-0.046	-0.033
Zn^{2+}	-0.046	-0.033
Zn^{2+}	-0.047	-0.034
Cd^{2+}	0.009	-0.042
Cd^{2+}	0.011	-0.04
Cd^{2+}	0.01	-0.041
Cu^{2+}	0.014	-0.011
Cu^{2+}	0.017	-0.009
Cu^{2+}	0.017	-0.009
Cr^{3+}	0.022	-0.061
Cr^{3+}	0.024	-0.059
Cr^{3+}	0.022	-0.061
Fe^{2+}	-0.088	-0.051
Fe^{2+}	-0.088	-0.049
Fe^{2+}	-0.088	-0.05
Se^{2+}	-0.031	-0.098
Se^{2+}	-0.031	-0.098
Se^{2+}	-0.031	-0.1
Mn^{2+}	-0.057	-0.09
Mn^{2+}	-0.054	-0.09
Mn^{2+}	-0.057	-0.089
Mg^{2+}	0.033	-0.023
Mg^{2+}	0.035	-0.022
Mg^{2+}	0.034	-0.024

Table S3 The training matrix of the colorimetric response patterns against 9 metal ions by using this sensor assay at the concentration of 100 nM.

Metal ions	A_i-A_0 GSH	A_i-A_0 Cys
Ni^{2+}	0.004	0.028
Ni^{2+}	0.006	0.031
Ni^{2+}	0.004	0.028
Zn^{2+}	-0.009	0.058
Zn^{2+}	-0.009	0.059
Zn^{2+}	-0.009	0.058
Cd^{2+}	0.069	-0.021
Cd^{2+}	0.07	-0.021
Cd^{2+}	0.068	-0.022
Cu^{2+}	0.042	0.044
Cu^{2+}	0.042	0.045
Cu^{2+}	0.042	0.043
Cr^{3+}	-0.043	0.078
Cr^{3+}	-0.043	0.079
Cr^{3+}	-0.043	0.078
Fe^{2+}	0.022	0.063
Fe^{2+}	0.022	0.066
Fe^{2+}	0.022	0.065
Se^{2+}	0.011	-0.038
Se^{2+}	0.013	-0.037
Se^{2+}	0.011	-0.039
Mn^{2+}	-0.024	0.007
Mn^{2+}	-0.024	0.008
Mn^{2+}	-0.024	0.007
Mg^{2+}	0.03	0.069
Mg^{2+}	0.032	0.072
Mg^{2+}	0.031	0.069

Table S4 The training matrix of the colorimetric response patterns against 9 metal ions by using this sensor assay at the concentration of 300 nM.

Metal ions	A_i-A_0 GSH	A_i-A_0 Cys
Ni^{2+}	0.006	0.009
Ni^{2+}	0.002	0.01
Ni^{2+}	0.002	0.009
Zn^{2+}	0.069	-0.049
Zn^{2+}	0.066	-0.045
Zn^{2+}	0.066	-0.047
Cd^{2+}	0.02	0.015
Cd^{2+}	0.02	0.016
Cd^{2+}	0.02	0.015
Cu^{2+}	0.014	-0.025
Cu^{2+}	0.012	-0.023
Cu^{2+}	0.012	-0.026
Cr^{3+}	0.025	-0.033
Cr^{3+}	0.022	-0.031
Cr^{3+}	0.021	-0.034
Fe^{2+}	0.051	-0.012
Fe^{2+}	0.048	-0.012
Fe^{2+}	0.049	-0.011
Se^{2+}	0.061	-0.018
Se^{2+}	0.059	-0.017
Se^{2+}	0.06	-0.017
Mn^{2+}	0.033	-0.043
Mn^{2+}	0.031	-0.042
Mn^{2+}	0.028	-0.043
Mg^{2+}	0.046	0.019
Mg^{2+}	0.046	0.021
Mg^{2+}	0.043	0.021

Table S5 The training matrix of the colorimetric response patterns against 9 metal ions by using this sensor assay at the concentration of 500 nM.

Metal ions	A_i-A_0 GSH	A_i-A_0 Cys
Ni^{2+}	-0.009	-0.032
Ni^{2+}	-0.007	-0.032
Ni^{2+}	-0.011	-0.03
Zn^{2+}	0.011	0.04
Zn^{2+}	0.011	0.041
Zn^{2+}	0.01	0.041
Cd^{2+}	0.052	-0.019
Cd^{2+}	0.052	-0.02
Cd^{2+}	0.051	-0.018
Cu^{2+}	0.008	-0.012
Cu^{2+}	0.008	-0.011
Cu^{2+}	0.005	-0.01
Cr^{3+}	0.015	0.008
Cr^{3+}	0.017	0.011
Cr^{3+}	0.016	0.013
Fe^{2+}	0.02	-0.005
Fe^{2+}	0.02	-0.005
Fe^{2+}	0.019	-0.005
Se^{2+}	0.06	-0.009
Se^{2+}	0.06	-0.009
Se^{2+}	0.06	-0.007
Mn^{2+}	0.075	-0.003
Mn^{2+}	0.076	-0.003
Mn^{2+}	0.074	-0.003
Mg^{2+}	0.029	0.003
Mg^{2+}	0.033	0.005
Mg^{2+}	0.03	0.006

Table S6 The linear relationship of different concentration of Cu^{2+}

Concentration (nM)	$A_i - A_0$ GSH	$A_i - A_0$ Cys
50	0.067	0.065
50	0.065	0.065
50	0.065	0.066
100	0.074	0.096
100	0.075	0.097
100	0.077	0.095
300	0.107	0.112
300	0.105	0.114
300	0.107	0.114
500	0.122	0.138
500	0.121	0.14
500	0.123	0.139

Table S7 The linear relationship of different concentration of Cd^{2+}

Concentration (nM)	$A_i - A_0$ GSH	$A_i - A_0$ Cys
50	0.098	0.083
50	0.101	0.086
50	0.1	0.082
100	0.128	0.113
100	0.129	0.115
100	0.13	0.113
300	0.157	0.141
300	0.161	0.141
300	0.161	0.14
500	0.189	0.172
500	0.19	0.172
500	0.189	0.17

Table S8 The linear relationship of different concentration of Ni^{2+}

Concentration (nM)	$A_i - A_0$ GSH	$A_i - A_0$ Cys
50	-0.055	-0.037
50	-0.057	-0.036
50	-0.054	-0.038
100	-0.009	-0.032
100	-0.007	-0.032
100	-0.011	-0.03
300	0.006	0.009
300	0.002	0.01
300	0.002	0.009
500	0.004	0.028
500	0.006	0.031
500	0.004	0.028

Table S9 The linear relationship of different concentration of Zn^{2+}

Concentration (nM)	$A_i - A_0$ GSH	$A_i - A_0$ Cys
50	0.042	0.05
50	0.043	0.05
50	0.041	0.049
100	0.084	0.108
100	0.085	0.111
100	0.084	0.108
300	0.121	0.148
300	0.124	0.151
300	0.12	0.147
500	0.156	0.2
500	0.16	0.202
500	0.156	0.199

Table S10 The training matrix of the colorimetric response patterns against the mixture of 2, 3, 4, and 5 kinds of metal ions at 100 nM by using this sensor assay.

Metal ions	A_i-A_0 GSH	A_i-A_0 Cys
Ni^{2+}: Zn^{2+}=5:5	0.025	0.01
Ni^{2+}: Zn^{2+}=5:5	0.025	0.011
Ni^{2+}: Zn^{2+}=5:5	0.024	0.009
Cu^{2+} :Fe^{2+}=4:6	0.033	-0.015
Cu^{2+} :Fe^{2+}=4:6	0.032	-0.015
Cu^{2+} :Fe^{2+}=4:6	0.034	-0.015
Se^{2+} :Mg^{2+}=3:7	-0.079	-0.074
Se^{2+} :Mg^{2+}=3:7	-0.079	-0.074
Se^{2+} :Mg^{2+}=3:7	-0.078	-0.074
Cd^{2+} :Cr^{3+} :Mn^{2+}=3:3:4	-0.017	-0.028
Cd^{2+} :Cr^{3+} :Mn^{2+}=3:3:4	-0.016	-0.028
Cd^{2+} :Cr^{3+} :Mn^{2+}=3:3:4	-0.016	-0.029
Ni^{2+}:Fe^{2+}:Mg^{2+}=2:3:5	-0.062	-0.089
Ni^{2+}:Fe^{2+}:Mg^{2+}=2:3:5	-0.062	-0.087
Ni^{2+}:Fe^{2+}:Mg^{2+}=2:3:5	-0.063	-0.088
Cu^{2+} : Se^{2+}: Zn^{2+}=4:2:4	-0.047	0.03
Cu^{2+} : Se^{2+}: Zn^{2+}=4:2:4	-0.046	0.032
Cu^{2+} : Se^{2+}: Zn^{2+}=4:2:4	-0.046	0.031
Zn^{2+} : Cd^{2+}:Cr^{3+}: Cu^{2+}=2:2:3:3	-0.03	0.099
Zn^{2+} : Cd^{2+}:Cr^{3+}: Cu^{2+}=2:2:3:3	-0.03	0.099
Zn^{2+} : Cd^{2+}:Cr^{3+}: Cu^{2+}=2:2:3:3	-0.029	0.098
Ni^{2+}: Fe^{2+}: Se^{2+}: Mg^{2+}=3:3:2:2	0.044	0.083
Ni^{2+}: Fe^{2+}: Se^{2+}: Mg^{2+}=3:3:2:2	0.045	0.083
Ni^{2+}: Fe^{2+}: Se^{2+}: Mg^{2+}=3:3:2:2	0.045	0.083
Cu^{2+} : Fe^{2+}: Cr^{3+}: Zn^{2+} : Mn^{2+}=2:2:2:2:2	-0.009	-0.047
Cu^{2+} : Fe^{2+}: Cr^{3+}: Zn^{2+} : Mn^{2+}=2:2:2:2:2	-0.009	-0.047
Cu^{2+} : Fe^{2+}: Cr^{3+}: Zn^{2+} : Mn^{2+}=2:2:2:2:2	-0.008	-0.047

Table S11 The training matrix of the colorimetric response patterns against the 9 metal ions at 50 nM in river water by using this sensor assay.

Metal ions	A_i-A_0 GSH	A_i-A_0 Cys
Ni^{2+}	0.006	-0.011
Ni^{2+}	0.006	-0.009
Ni^{2+}	0.008	-0.011
Zn^{2+}	-0.015	-0.046
Zn^{2+}	-0.018	-0.046
Zn^{2+}	-0.017	-0.046
Cd^{2+}	-0.006	0.008
Cd^{2+}	-0.008	0.01
Cd^{2+}	-0.007	0.009
Cu^{2+}	-0.012	-0.027
Cu^{2+}	-0.011	-0.027
Cu^{2+}	-0.01	-0.027
Cr^{3+}	-0.026	-0.054
Cr^{3+}	-0.028	-0.054
Cr^{3+}	-0.026	-0.055
Fe^{2+}	0.01	-0.073
Fe^{2+}	0.008	-0.073
Fe^{2+}	0.01	-0.074
Se^{2+}	-0.02	-0.058
Se^{2+}	-0.023	-0.058
Se^{2+}	-0.022	-0.058
Mn^{2+}	-0.034	-0.084
Mn^{2+}	-0.036	-0.081
Mn^{2+}	-0.034	-0.083
Mg^{2+}	-0.041	-0.063
Mg^{2+}	-0.043	-0.063
Mg^{2+}	-0.041	-0.064

Table S12 The training matrix of the colorimetric response patterns against the 9 metal ions at 50 nM in tap water by using this sensor assay.

Metal ions	A_i-A_0 GSH	A_i-A_0 Cys
Ni^{2+}	-0.009	-0.073
Ni^{2+}	-0.009	-0.07
Ni^{2+}	-0.007	-0.073
Zn^{2+}	0.02	-0.033
Zn^{2+}	0.021	-0.033
Zn^{2+}	0.02	-0.034
Cd^{2+}	-0.021	-0.042
Cd^{2+}	-0.023	-0.04
Cd^{2+}	-0.022	-0.041
Cu^{2+}	0.006	-0.011
Cu^{2+}	0.004	-0.009
Cu^{2+}	0.005	-0.009
Cr^{3+}	-0.035	-0.061
Cr^{3+}	-0.037	-0.059
Cr^{3+}	-0.035	-0.061
Fe^{2+}	-0.016	-0.051
Fe^{2+}	-0.016	-0.049
Fe^{2+}	-0.016	-0.05
Se^{2+}	0.017	-0.098
Se^{2+}	0.017	-0.098
Se^{2+}	0.018	-0.1
Mn^{2+}	0.01	-0.09
Mn^{2+}	0.011	-0.09
Mn^{2+}	0.012	-0.089
Mg^{2+}	-0.027	-0.023
Mg^{2+}	-0.027	-0.022
Mg^{2+}	-0.026	-0.024