Electronic Supplementary Material (ESI) for Polymer Chemistry.

Supporting Information

Fluorescent Electronic Tongue Based on Soluble Conjugated Polymeric Nanoparticles for the Discrimination of Heavy Metal Ions in Aqueous Solution

*Chuying Feng, Peng Zhao, Lili Wang, Tao Yang, Yusen Wu, Yun Ding, Aiguo Hu**

Shanghai Key Laboratory of Advanced Polymeric Materials, School of Materials Science and Engineering, East China University of Science and Technology, Shanghai 200237, China.

Chemicals and Materials

p-Diethynylbenzene (Energy, 97%), 1,3,5-Triethynylbenzene (TCI, 98%), 1,3,5-Triiodobenzene (Aladdin, 98%), Tris(4-iodophenyl)amine (Energy, 98%), 2,2',7,7'-Tetrabromo-9,9'-spirobifluorene (Energy, 97%), 4,7-Dibromo-2,1,3-benzothiadiazole (Energy, 98%), 5,7-Dibromo-2,3-dihydro-thieno[3,4-b][1,4]dioxine (Energy, 98%), Tetrakis(4-bromophenyl)ethene (Shanghai D&B,≥97%), diisopropylethylamine (DIPEA, Enegry, 99.5%), N,N,N',N'',N''-Pentamethyldiethylenetriamine (PMDETA, Energy, 98%), and N_3-PEG1000 (Hua Teng Pharma, 95+%) were all used without further purification. N,N-Dimethylformamide (DMF) and tetrahydrofuran (THF) were distilled with CaH_2 before use. Other chemicals were obtained from Energy Chemical (>98%, Shanghai, China).

Characterizations

UV-Vis-NIR Absorption Spectroscopy. Optical absorption spectra of dilute DMF solutions of SCPNs were recorded employing Evolution 201 UV spectrophotometer (Thermo Fisher, USA) at 25°C.

Fluorescence Spectroscopy. Fluorescence spectra of SCPN and PEGylated SCPN solutions were recorded using Fluorolog-3-P UV-Vis-NIR fluorescence spectrophotometer (Jobin Yvon, France). Both the entrance and exit slits were set at a width of 7 nm.

Nuclear Magnetic Resonance Spectroscopy. ^{1}H NMR (400 MHz) and ^{13}C NMR (100 MHz) were obtained on a Bruker AVANCE FT NMR spectrometer in chloroform-d ($CDCl_3$) and tetrahydrofuran-d (d_8-THF) on an Ultra Shield 400 spectrometer (BRUKER BIOSPIN AG, Magnet System 400 MHz/54 mm).

Dynamic Light Scattering (DLS). The hydrodynamic diameters of the SCPNs and PEGylated SCPNs were analyzed using a ZetasizerNano ZS (Malvern, UK) at 25 °C with a 633 nm laser in DMF and water.

Infrared Spectroscopy (IR). Fourier transform infrared analysis (FTIR) of SCPNs and PEGylated SCPNs were recorded from KBr pallets on a Nicolet Magna 5700 FTIR spectrometer.

High-Resolution Transmission Electron Microscopy (HR-TEM). Images were obtained on a JEM-2100 microscope (JEOL, Japan) at an acceleration voltage of 200 kV. The Pd@SS-CNMs nanoreactor samples were prepared by drop-casting anhydrous ethanol dispersion on a carbon-coated 200 mesh copper grids.

Inductively Coupled Plasma Atomic Emission Spectroscopy. The palladium content of nanoreactors was measured using a Thermo Elemental IRIS 1000 instrument.

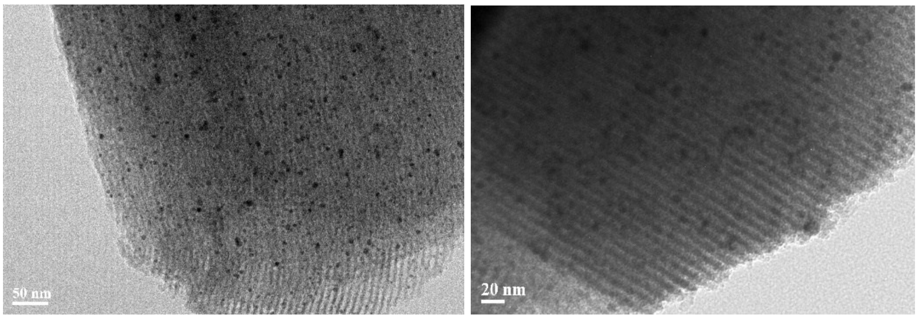


Figure S1. HR-TEM images of Pd@SS-CNMs nanoreactors.

Table S1. The structure information of the SCPNs.

SCPN$_{(x)}$	**1**	**2**	**3**	**4**	**5**	**6**
A$_{(x)}$+B$_{(y)}$	A$_{(1)}$+B$_{(2)}$	A$_{(2)}$+B$_{(2)}$	A$_{(3)}$+B$_{(2)}$	A$_{(4)}$+B$_{(1)}$	A$_{(5)}$+B$_{(1)}$	A$_{(6)}$+B$_{(2)}$

Note: The SCPNs are prepared from the Sonogashira polycondensation between monomer A$_{(x)}$ and B$_{(y)}$ in confined nanoreactors. For the PEGylated SCPN sensors, the SCPNs are grafted with N_3-PEG$_{1000}$ via click reaction.

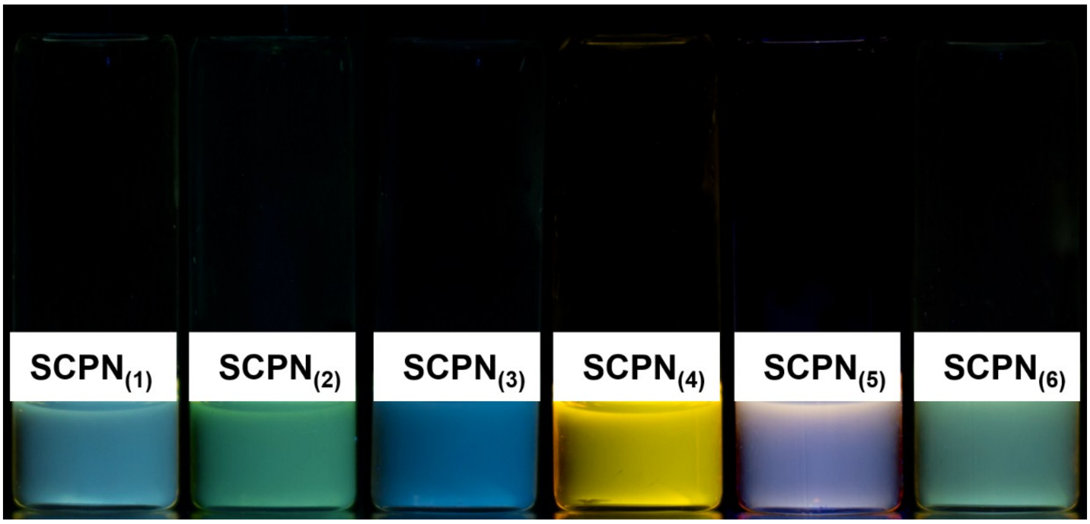


Figure S2. Fluorescent images of SCPNs in DMF solutions under the irradiation of UV light (365 nm, 1 mg/mL).

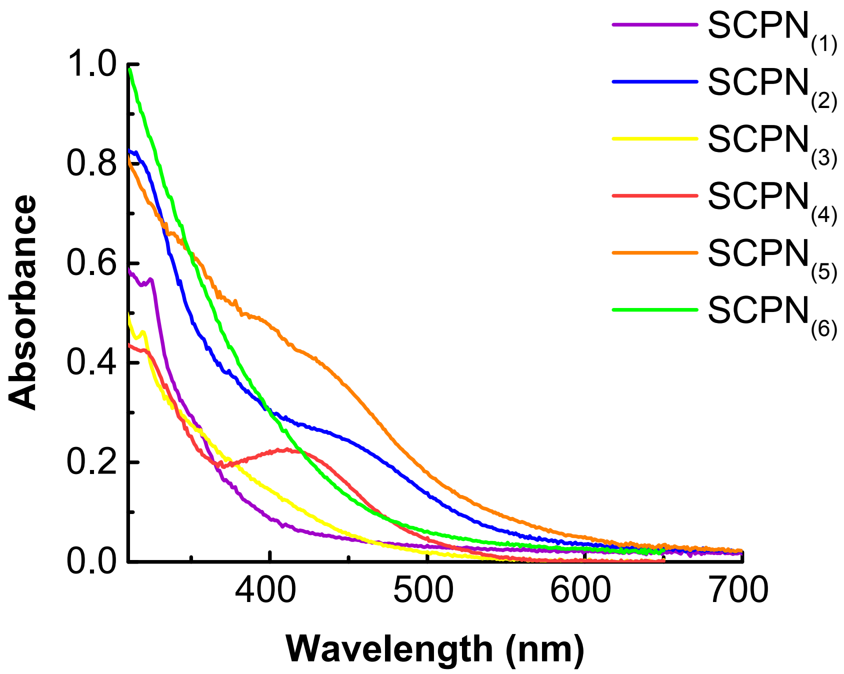


Figure S3. The UV-Vis absorption spectra of SCPNs in DMF solutions.

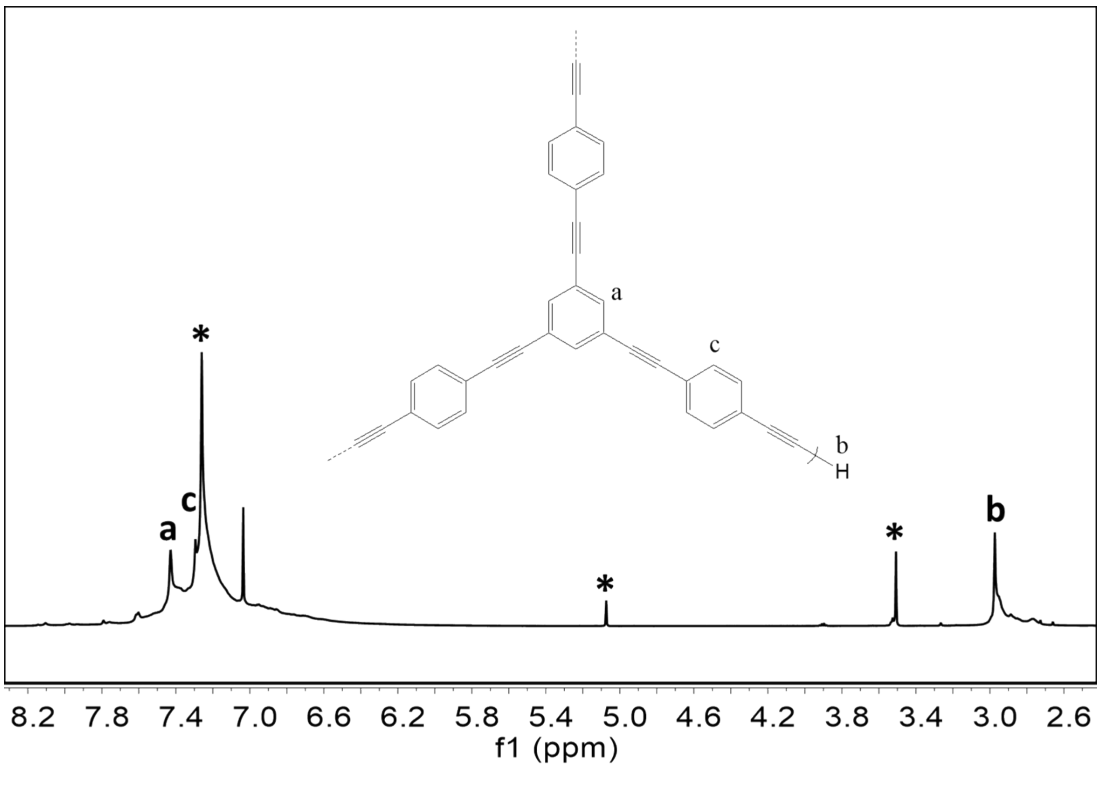


Figure S4. [1]H NMR spectrum of $SCPN_{(1)}$ in chloroform-d. The asterisk (*) indicates the solvent residue(chloroform, dichloromethane and methanol).

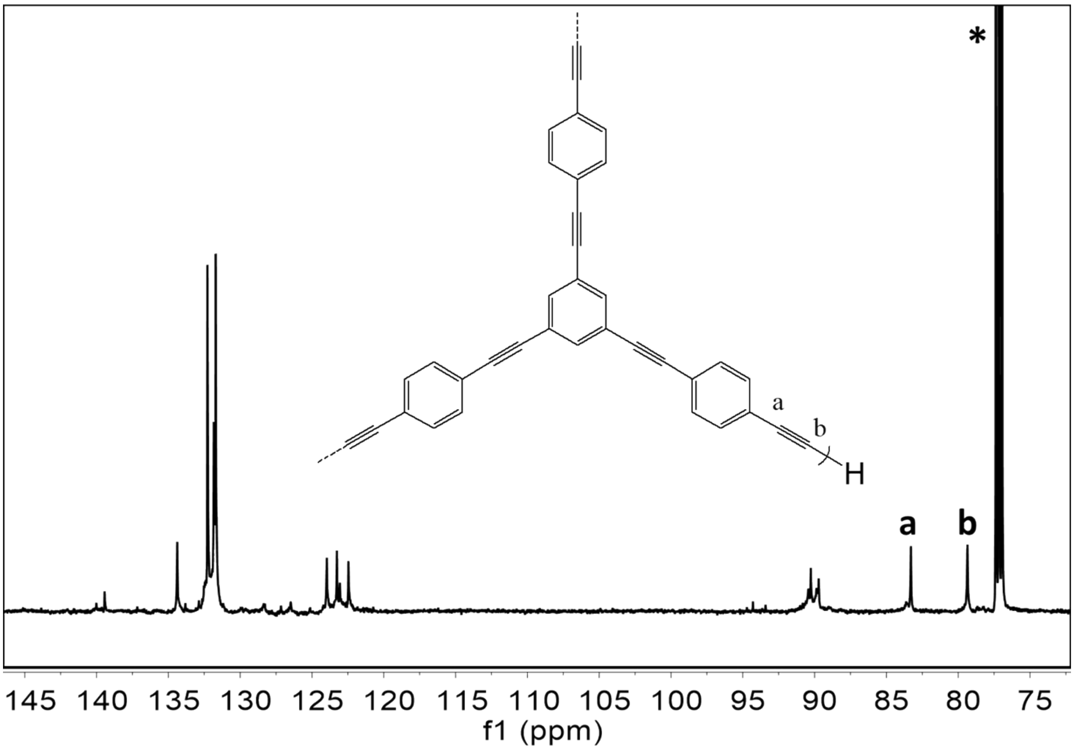


Figure S5. ^{13}C NMR spectrum of $SCPN_{(1)}$ in chloroform-d. The asterisk (*) indicates the solvent residue(chloroform).

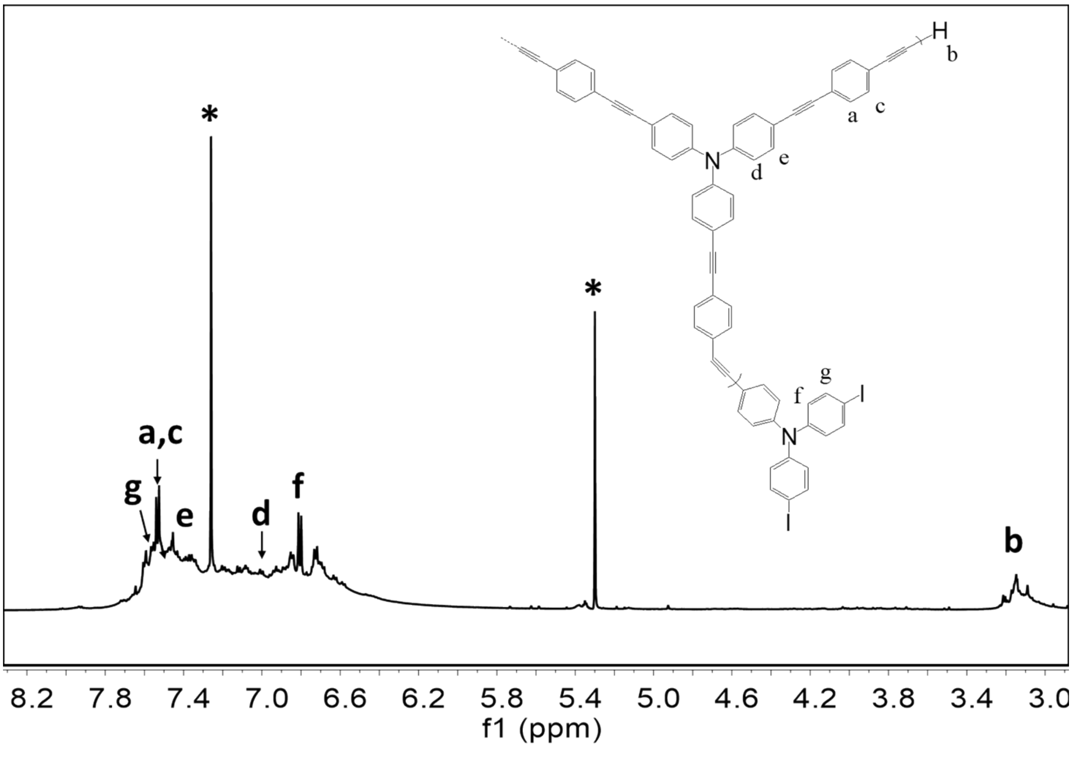


Figure S6. ^{1}H NMR spectrum of $SCPN_{(2)}$ in chloroform-d. The asterisk (*) indicates the solvent residue(chloroform and dichloromethane).

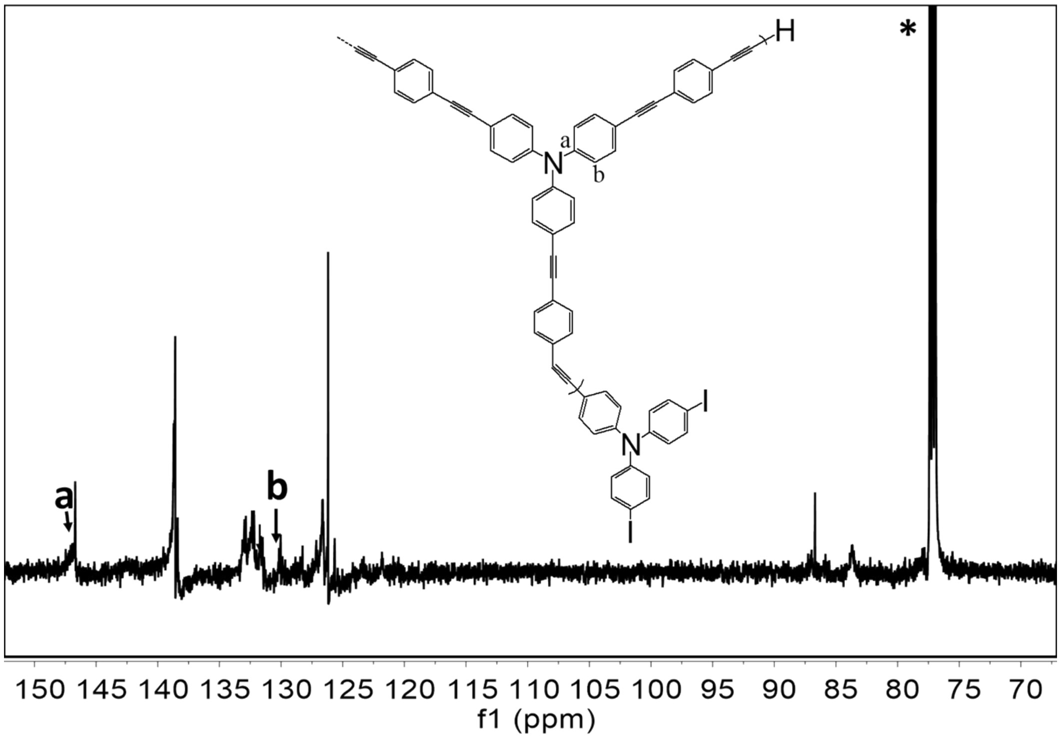


Figure S7. ^{13}C NMR spectrum of SCPN$_{(2)}$ in chloroform-d. The asterisk (*) indicates the solvent residue(chloroform).

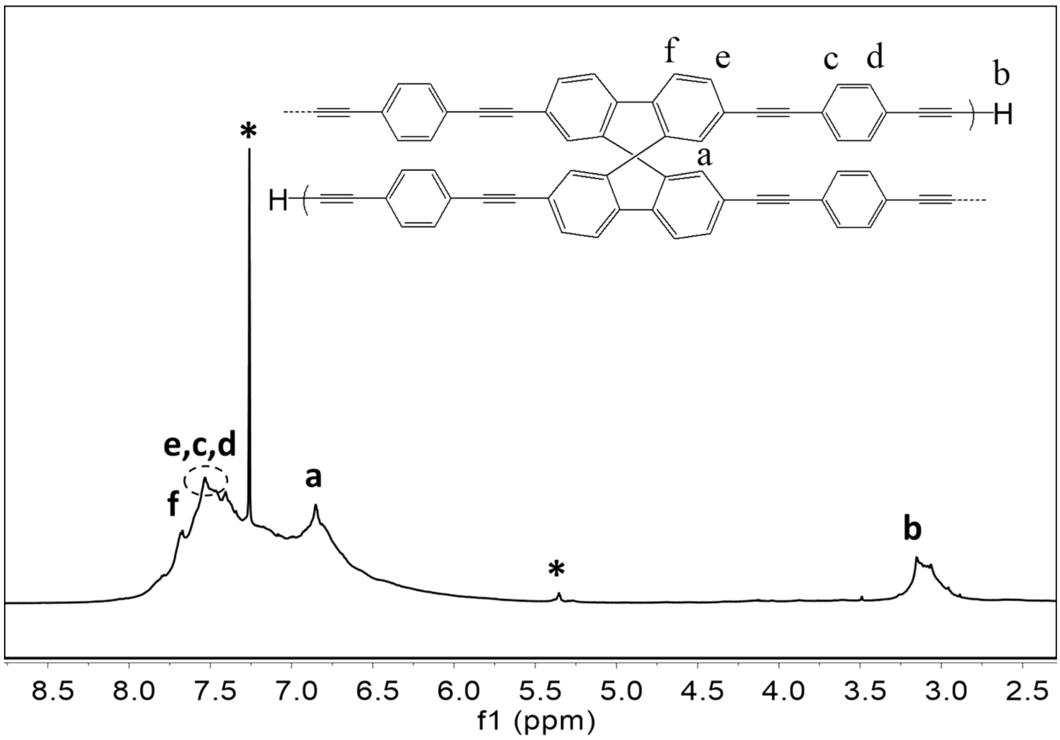


Figure S8. ^{1}H NMR spectrum of SCPN$_{(3)}$ in chloroform-d. The asterisk (*) indicates the solvent residue(chloroform and dichloromethane).

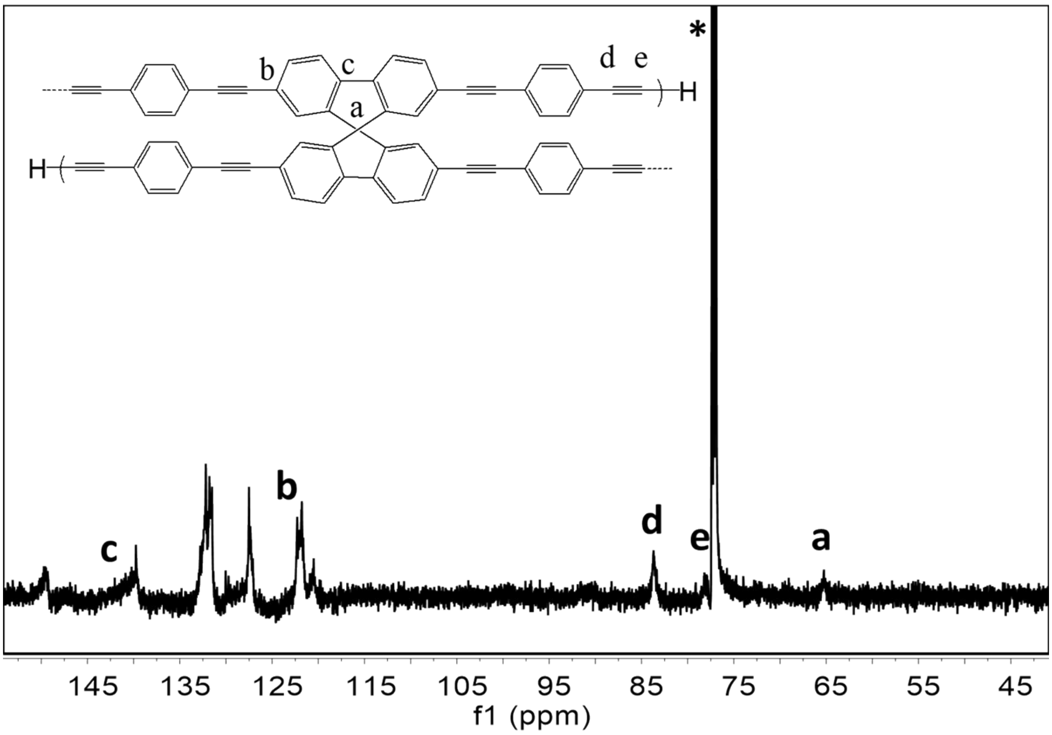


Figure S9. ^{13}C NMR spectrum of $SCPN_{(3)}$ in chloroform-d. The asterisk (*) indicates the solvent residue(chloroform).

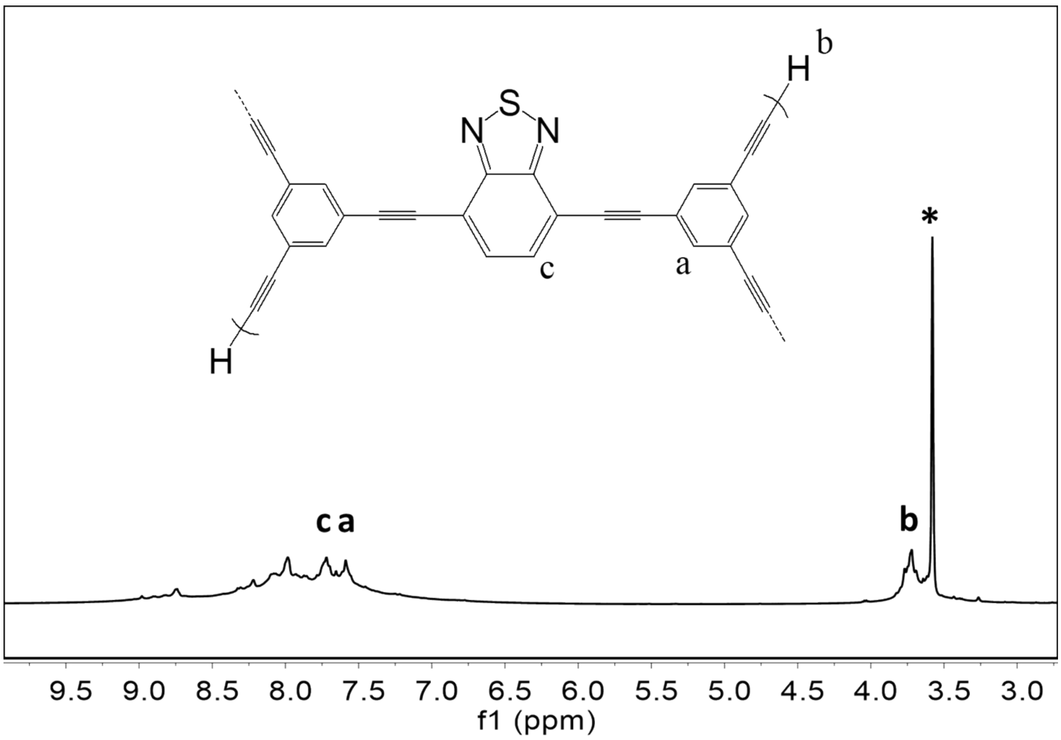


Figure S10. ^{1}H NMR spectrum of $SCPN_{(4)}$ in tetrahydrofuran-d_8. The asterisk (*) indicates the solvent residue(tetrahydrofuran).

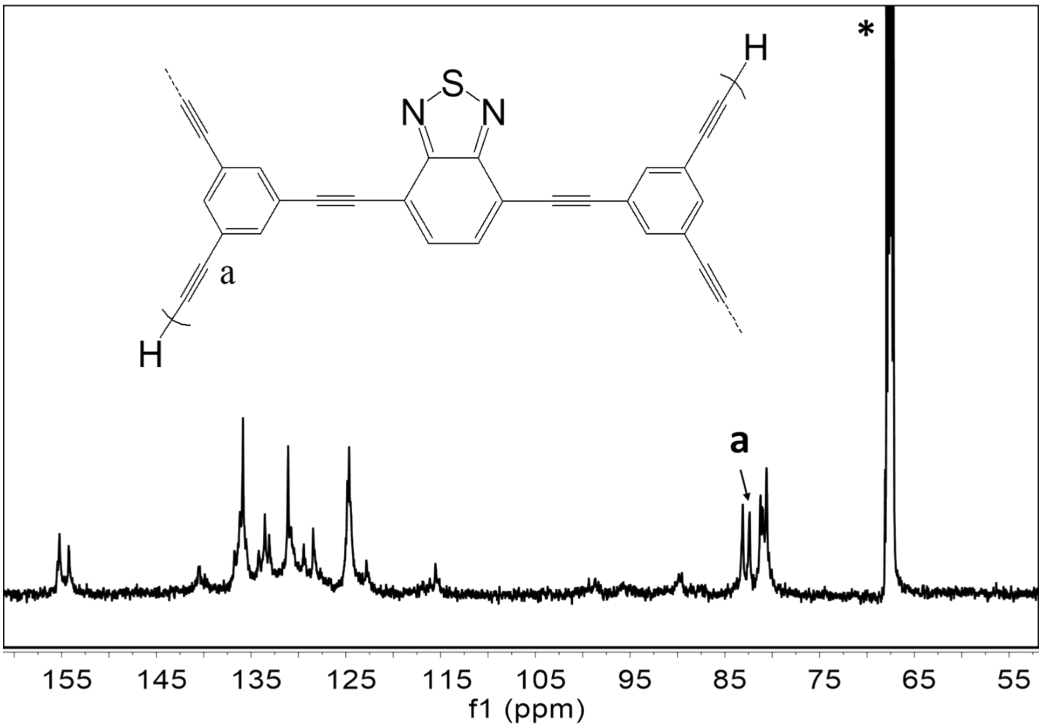


Figure S11. ^{13}C NMR spectrum of $SCPN_{(4)}$ in tetrahydrofuran-d_8. The asterisk (*) indicates the solvent residue(tetrahydrofuran).

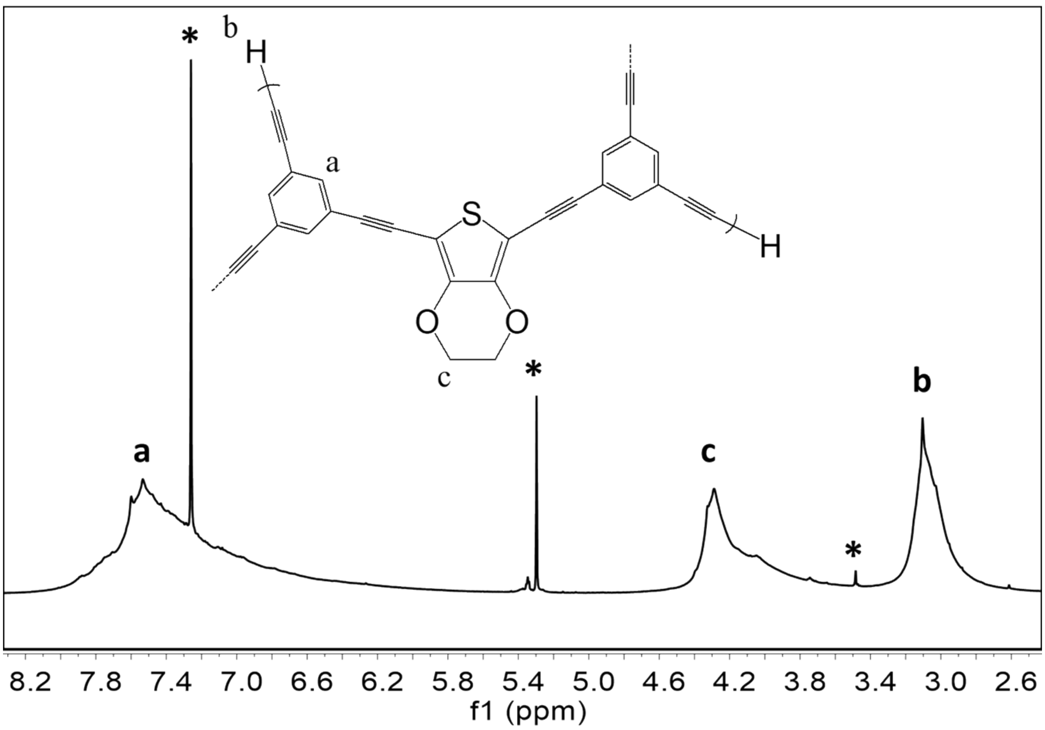


Figure S12. ^{1}H NMR spectrum of $SCPN_{(5)}$ in chloroform-d. The asterisk (*) indicates the solvent residue(chloroform).

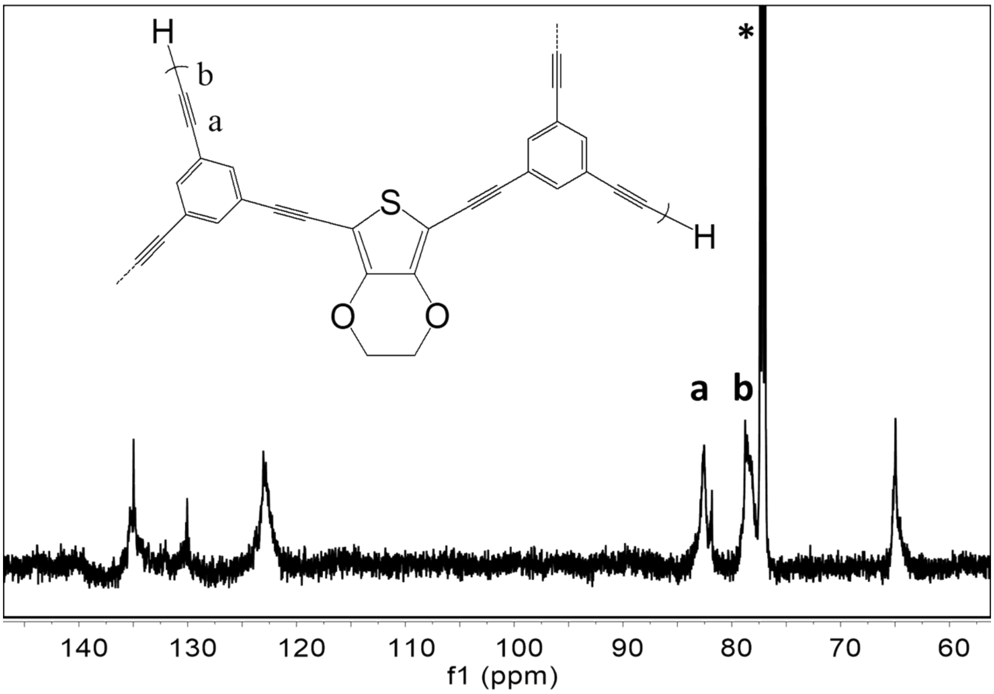


Figure S13. ^{13}C NMR spectrum of $SCPN_{(5)}$ in chloroform-d. The asterisk (*) indicates the solvent residue(chloroform).

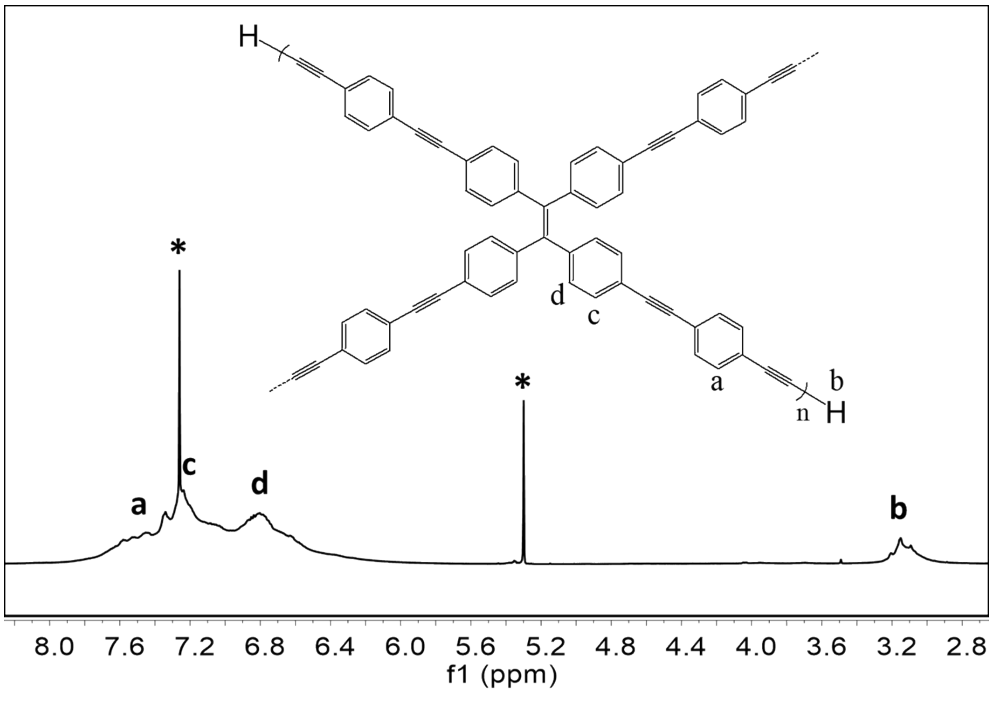


Figure S14. ^{1}H NMR spectrum of $SCPN_{(6)}$ in chloroform-d. The asterisk (*) indicates the solvent residue(chloroform).

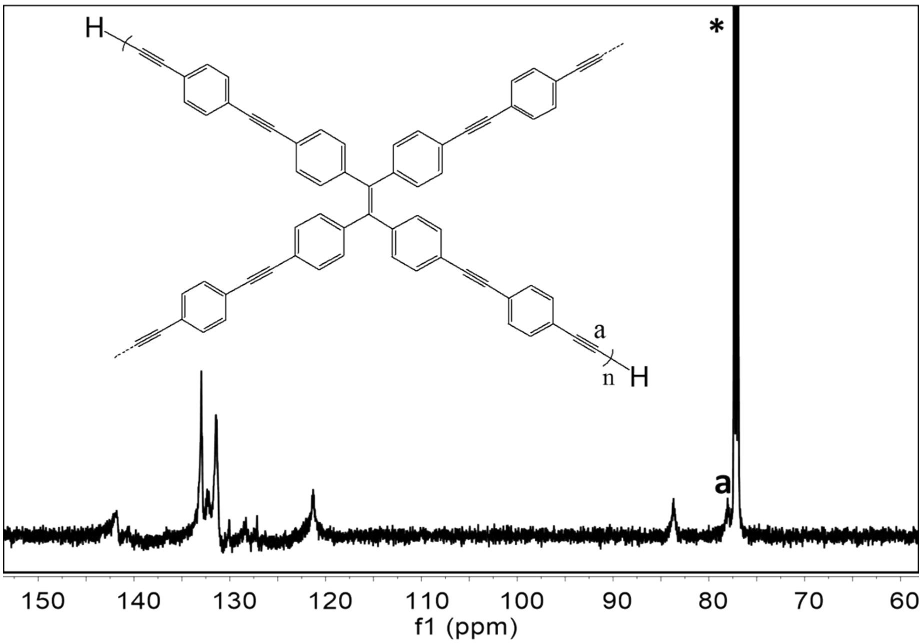


Figure S15. ^{13}C NMR spectrum of $SCPN_{(6)}$ in chloroform-d. The asterisk (*) indicates the solvent residue(chloroform).

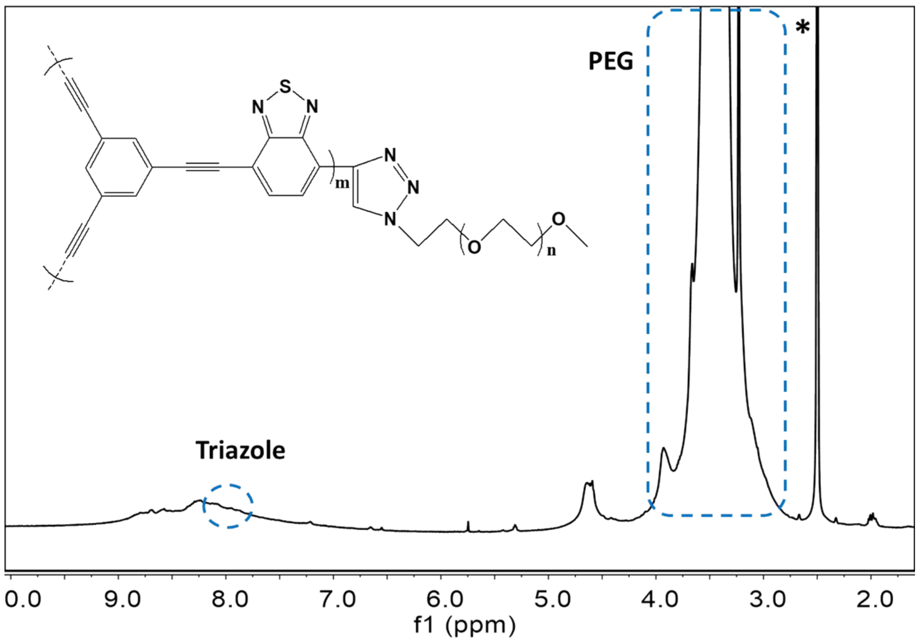


Figure S16. ^{1}H NMR spectrum of PEGylated $SCPN_{(4)}$ in dimethyl sulfoxide-d_6. The asterisk (*) indicates the solvent residue(dimethyl sulfoxide).

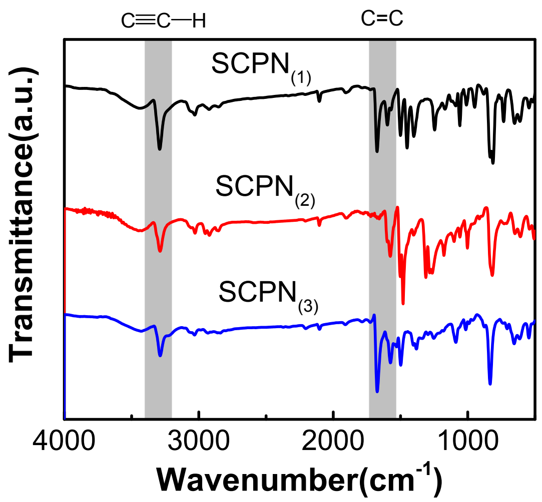


Figure S17. The FTIR spectrum of $SCPN_{(1)}$, $SCPN_{(2)}$ and $SCPN_{(3)}$.

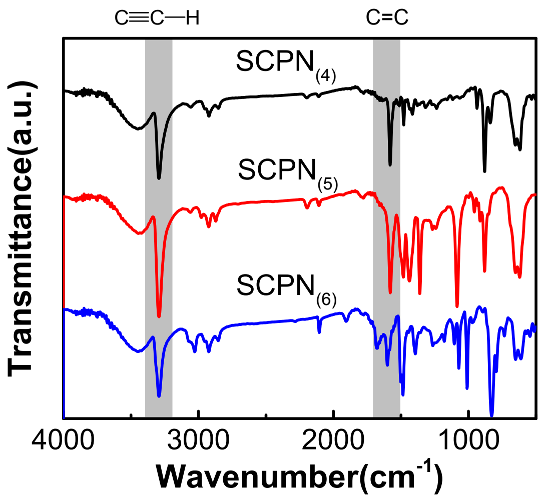


Figure S18. The FTIR spectrum of $SCPN_{(4)}$, $SCPN_{(5)}$ and $SCPN_{(6)}$.

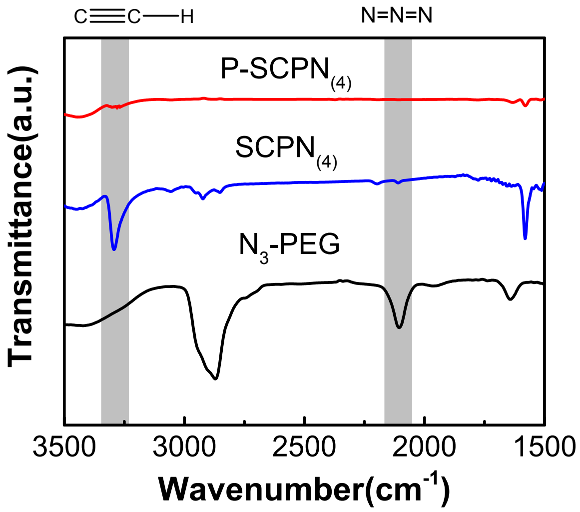
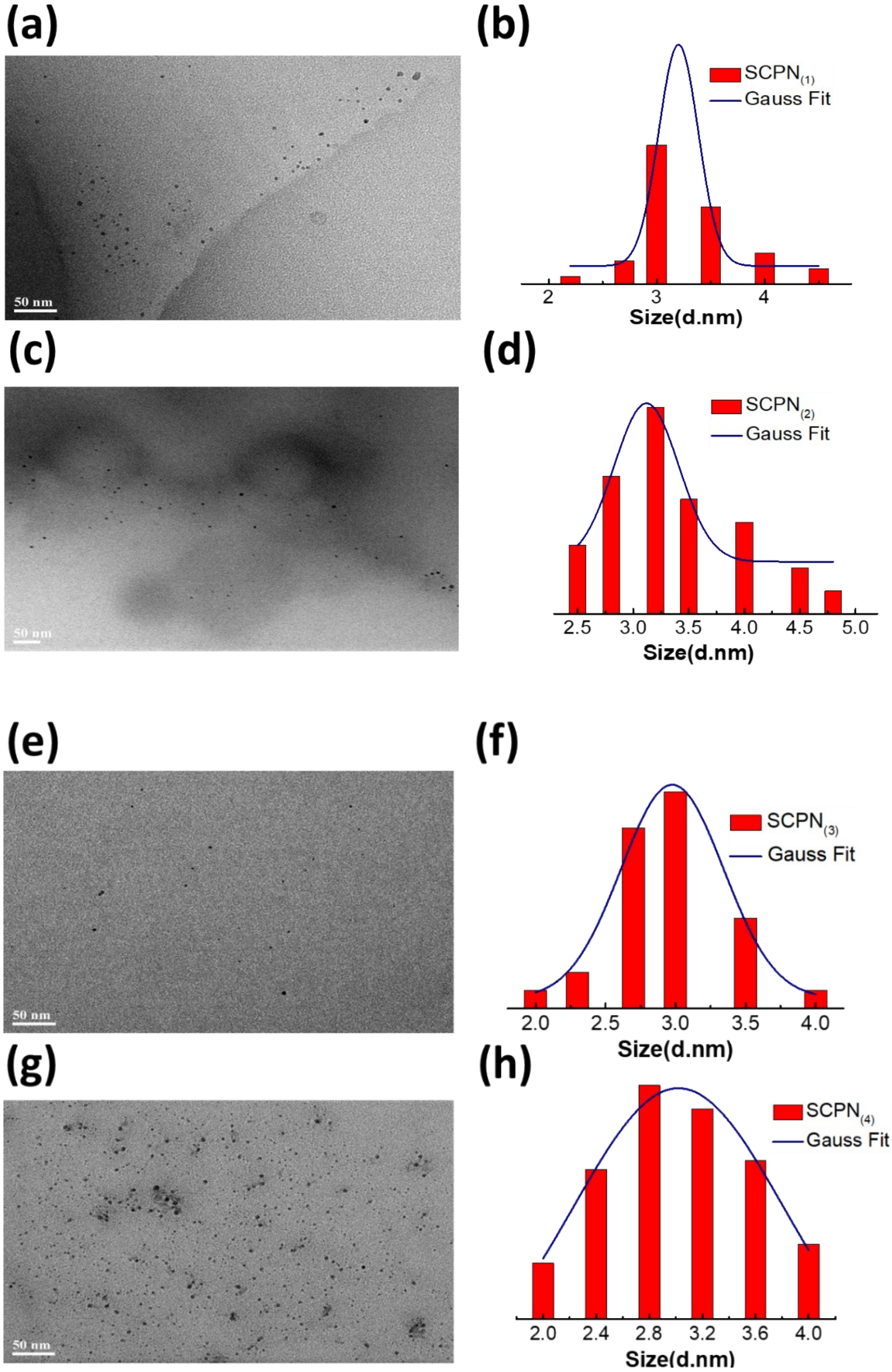


Figure S19. Comparison of the FTIR spectrum of N_3-PEG, PEGylated $SCPN_{(4)}$ and $SCPN_{(4)}$.



(a)
50 nm
(b)
SCPN(1)
Gauss Fit
2
3
4
Size(d.nm)
(c)
50 nm
(d)
SCPN(2)
Gauss Fit
2.5
3.0
3.5
4.0
4.5
5.0
Size(d.nm)
(e)
50 nm
(f)
SCPN(3)
Gauss Fit
2.0
2.5
3.0
3.5
4.0
Size(d.nm)
(g)
50 nm
(h)
SCPN(4)
Gauss Fit
2.0
2.4
2.8
3.2
3.6
4.0
Size(d.nm)

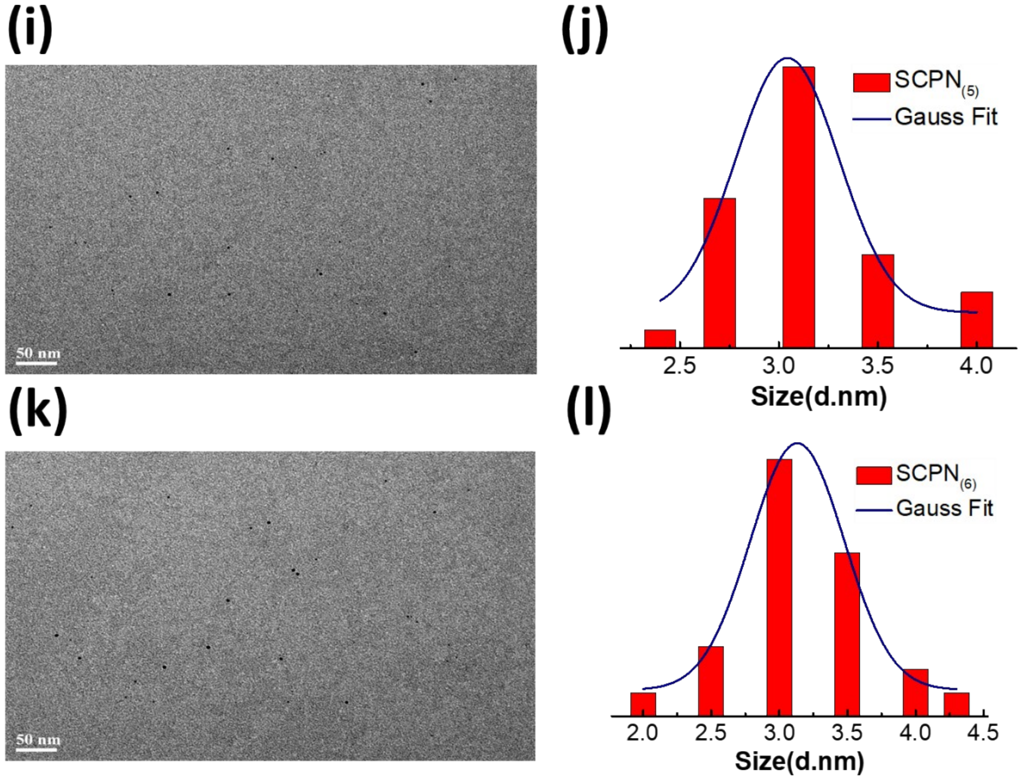


Figure S20. HR-TEM images of SCPNs nanoparticles (left) and statistical size histograms of SCPNs counted from several HR-TEM images (right). (a) and (b) $SCPN_{(1)}$; (c) and (d) $SCPN_{(2)}$; (e) and (f) $SCPN_{(3)}$; (g) and (h) $SCPN_{(4)}$; (i) and (j) $SCPN_{(5)}$; (k) and (l) $SCPN_{(6)}$.

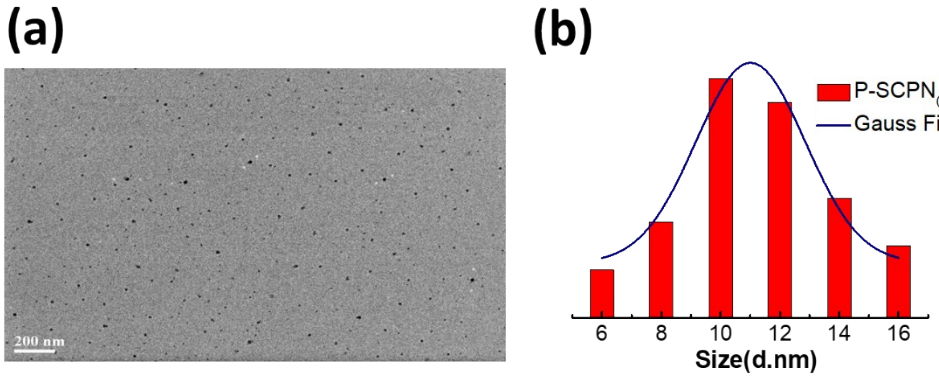


Figure S21. HR-TEM images of P-$SCPN_{(4)}$ nanoparticles (left) and statistical size histograms of $SCPN_{(4)}$ counted from several HR-TEM images (right).

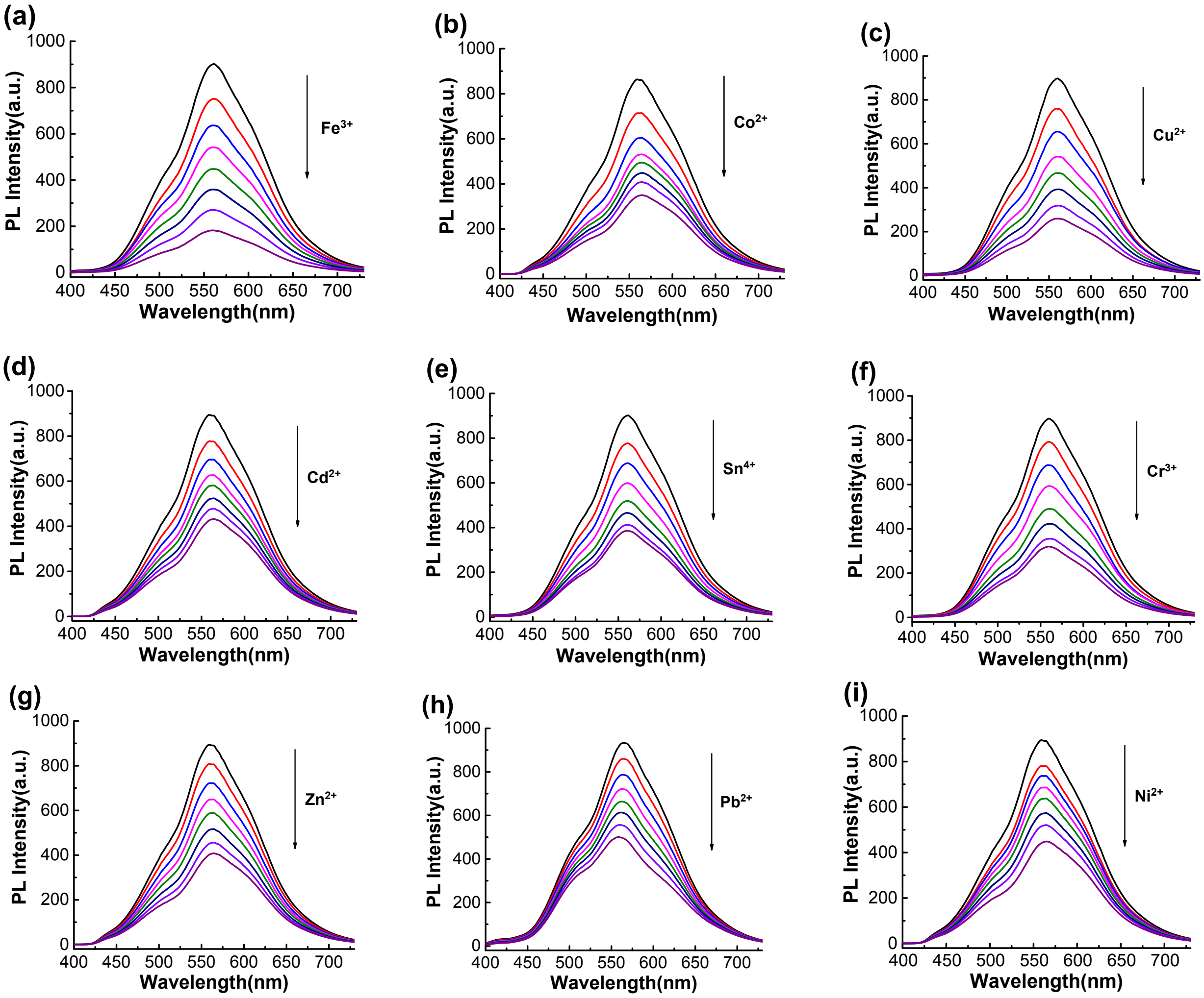


Figure S22. Fluorescence quenching titration experiments for $SCPN_{(4)}$ (as the representative SCPN) with 9 metal ions. The initial concentration of metal ions added are listed below: (a) 40 mM; (b), (c), (d), (e) and (f) 50 mM; (g), (h) and (i) 70 mM.

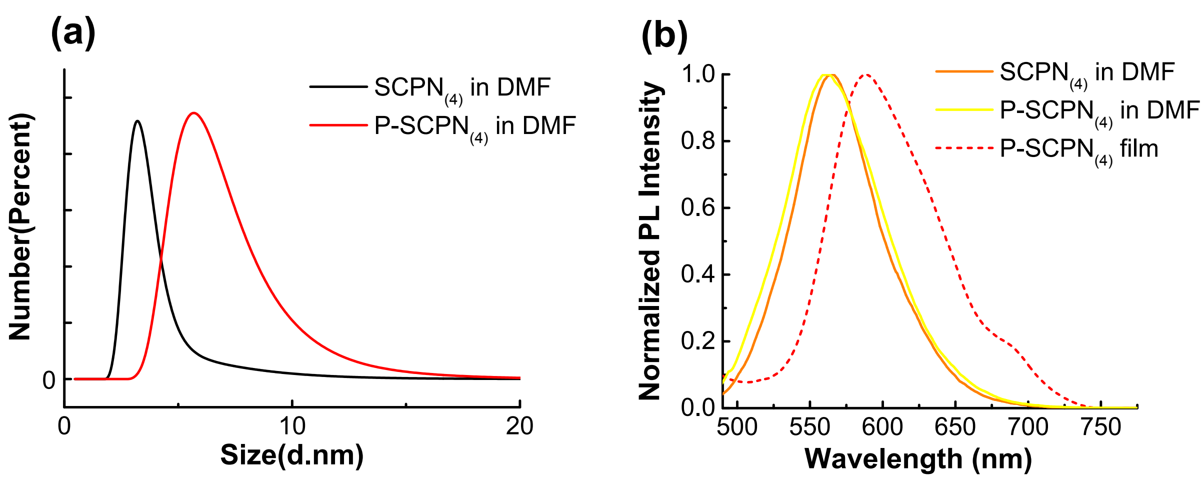
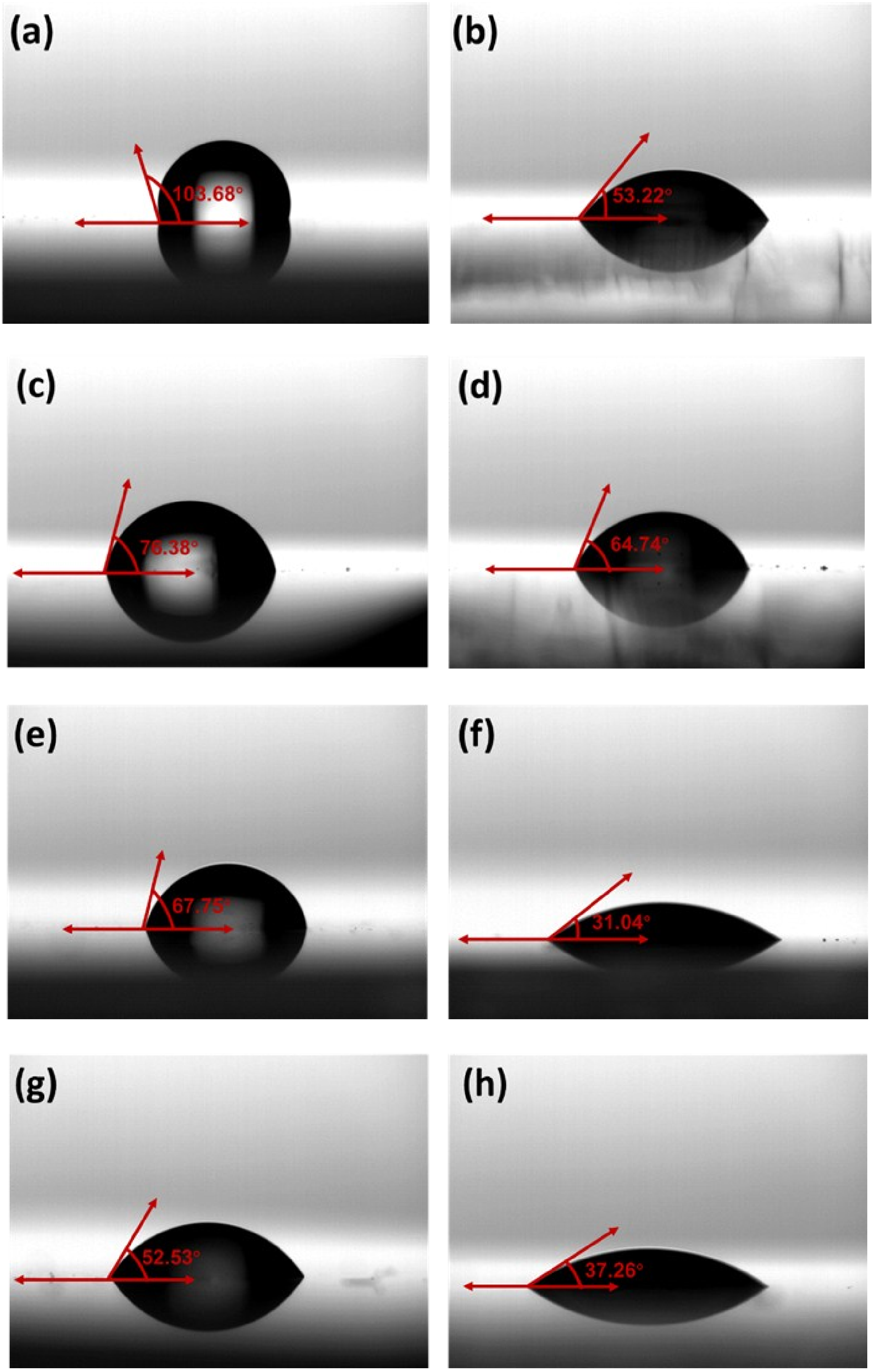


Figure S23. (a) DLS curves of $SCPN_{(4)}$ and PEGylated $SCPN_{(4)}$ ($P\text{-}SCPN_{(4)}$) in DMF solutions; (b) comparison of fluorescence emissions of $SCPN_{(4)}$ and $P\text{-}SCPN_{(4)}$ in DMF solutions (solid lines) and $P\text{-}SCPN_{(4)}$ in thin film state (dotted line).



(a)
103.68°
(b)
53.22°
(c)
76.38°
(d)
64.74°
(e)
67.75°
(f)
31.04°
(g)
52.53°
(h)
37.26°

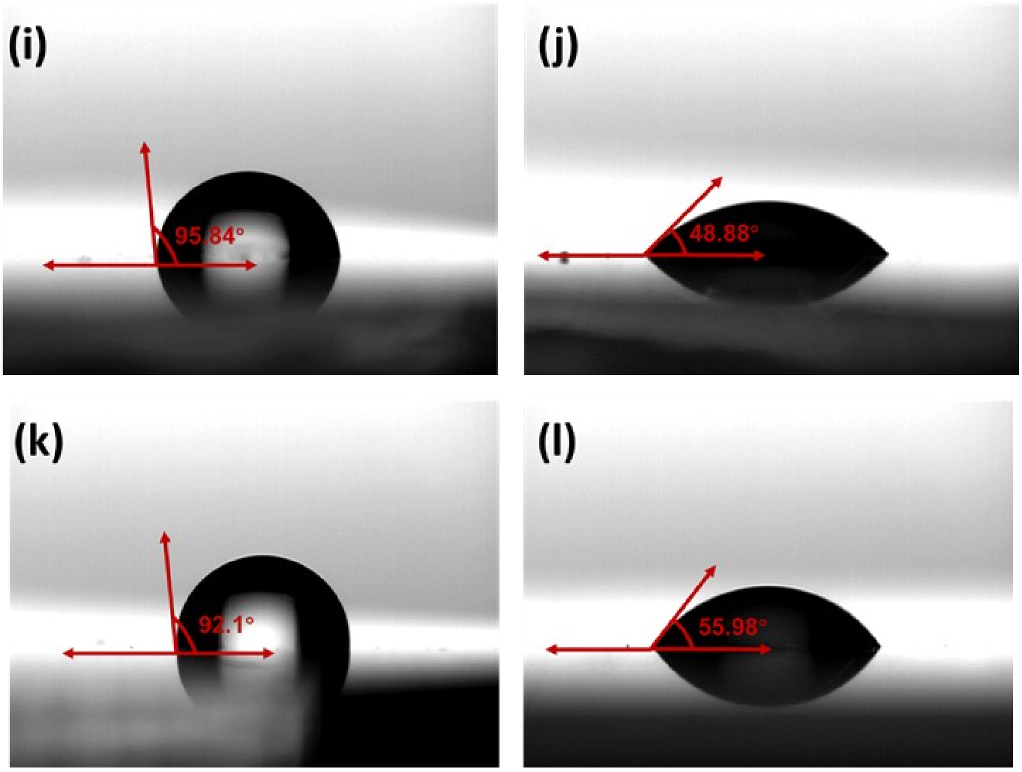


Figure S24. Profiles of a water drop on the films of the SCPNs (left) and PEGylated SCPNs (right). (a) $SCPN_{(1)}$; (b) PEGylated $SCPN_{(1)}$; (c) $SCPN_{(2)}$; (d) PEGylated $SCPN_{(2)}$; (e) $SCPN_{(3)}$; (f) PEGylated $SCPN_{(3)}$; (g) $SCPN_{(4)}$; (h) PEGylated $SCPN_{(4)}$; (i) $SCPN_{(5)}$; (j) PEGylated $SCPN_{(5)}$; (k) $SCPN_{(6)}$; (l) PEGylated $SCPN_{(6)}$.

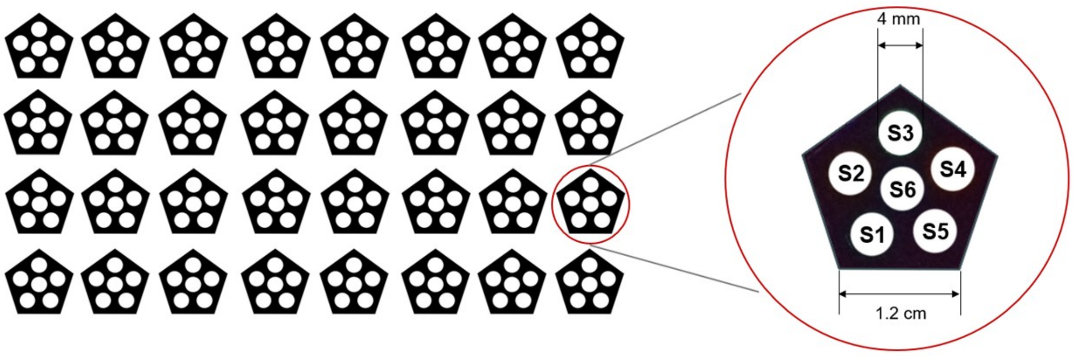


Figure S25. Ordinary array substrates cut into pentagons with all regions printed in black by a laser printer except 6 blank circles.

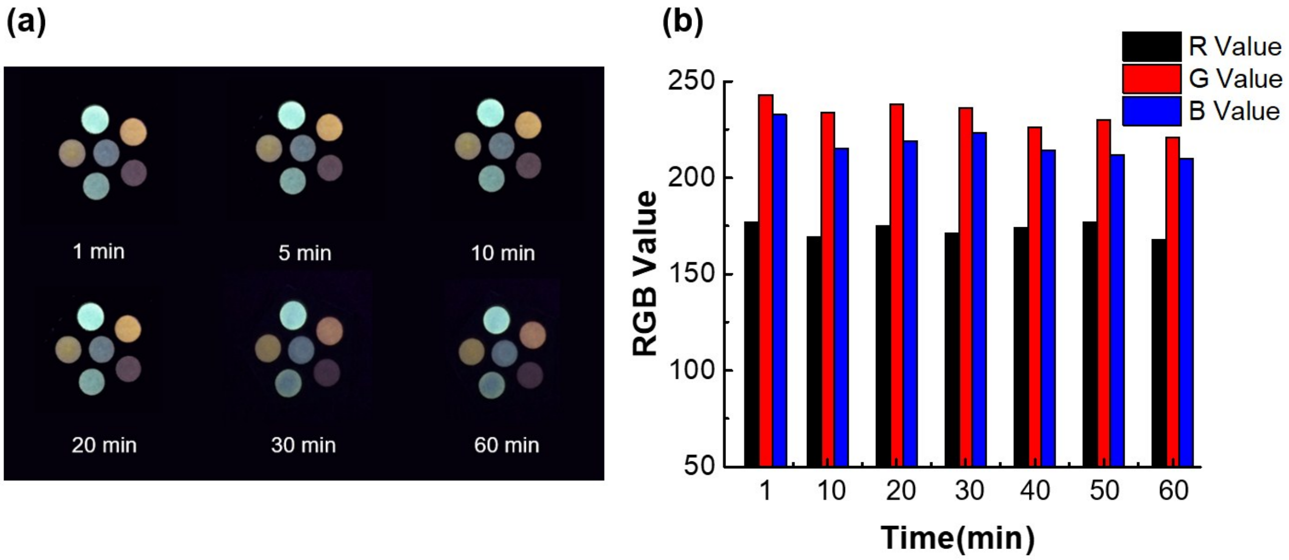


Figure S26. The stability of fluorescence sensing array in aqueous solution. (a) the fluorescence patterns of the sensing array with different exposure time; (b) the RGB value of P-SCPN$_{(3)}$ versus exposure time.

Table S2. Shortest response time for each metal ion (1 mM concentration).

Metal Ions	Cd^{2+}	Zn^{2+}	Co^{2+}	Sn^{4+}	Pb^{2+}	Fe^{3+}	Cu^{2+}	Cr^{3+}	Ni^{2+}	Ag^{+}
Shortest Response Time (min)	4	5	5	4	4	2	3	3	4	5

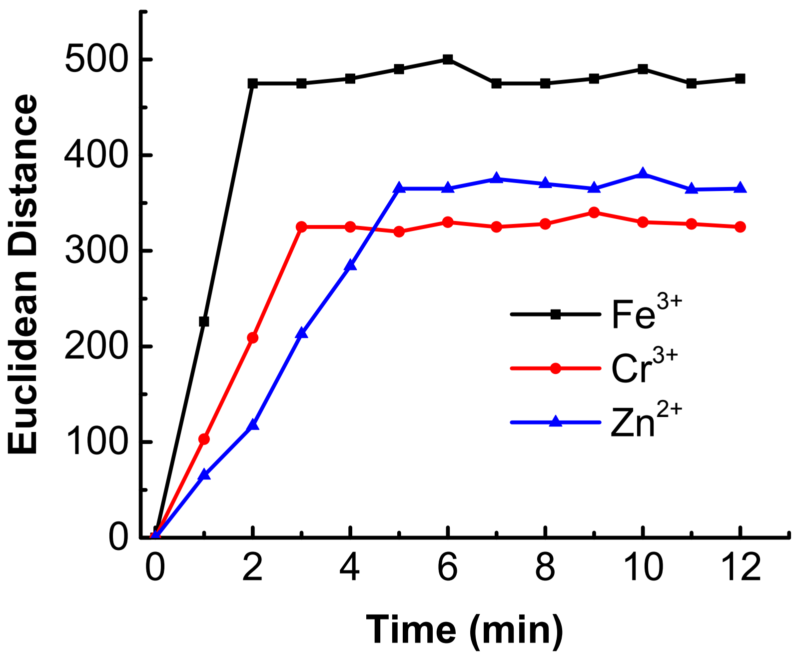


Figure S27. Euclidean distance between the representative analytes (Fe^{3+}, $Cr^{3+}$and Zn^{2+}) and the control group plotted versus exposure time at room temperature (1 mM concentration).

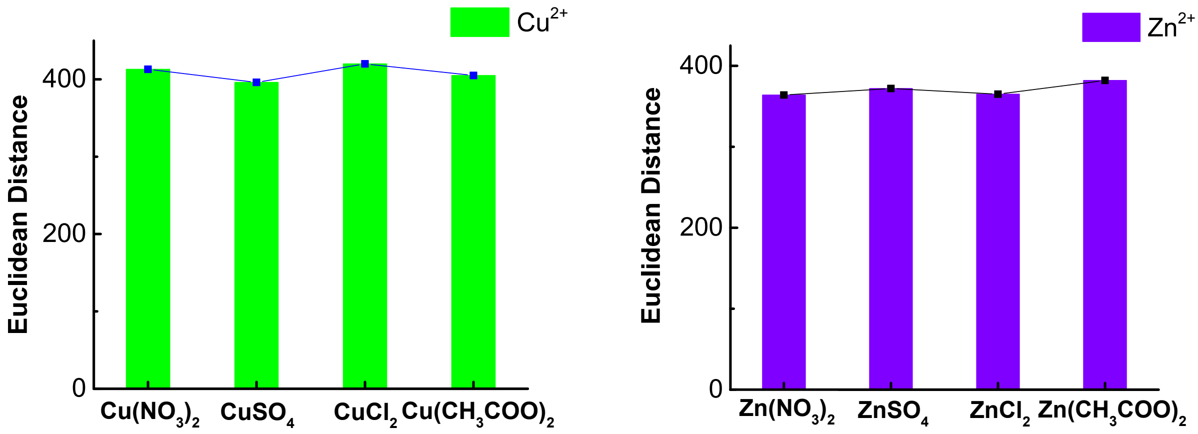


Figure S28. Euclidean distance between the representative metal salt solutions (Cu^{2+} and Zn^{2+} as cations respectively) with various anions (NO_3^-, SO_4^{2-}, Cl^- and CH_3COO^-) and the control group (1 mM concentration).

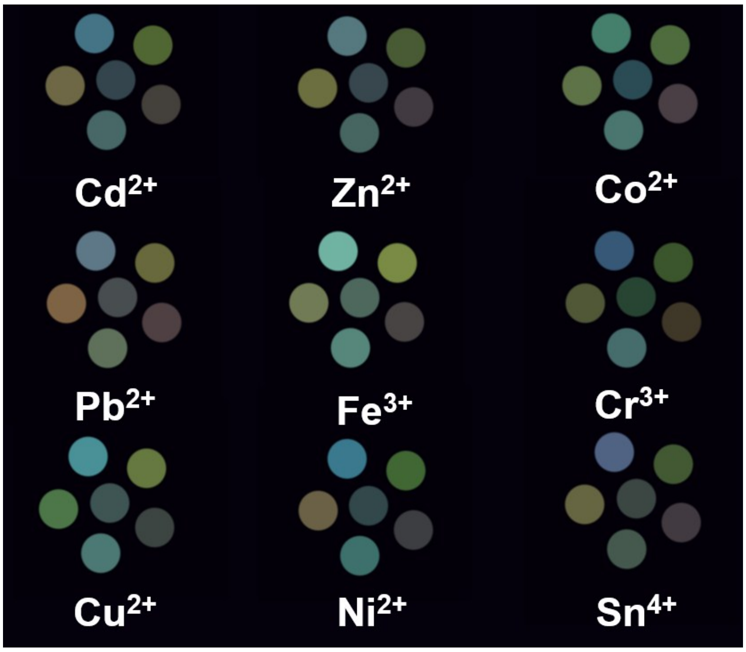


Figure S29. Color-difference patterns of the electronic tongue when exposed to nine metal ions.

Table S3. The identification of unknown metal ions at 1mM using the fluorescent electronic tongue.

Samples	**R1**	**G1**	**B1**	**R2**	**G2**	**B2**	**R3**	**G3**	**B3**	**R4**	**G4**	**B4**	**R5**	**G5**	**B5**	**R6**	**G6**	**B6**	**Identification**	**Verification**
1	-73	-100	-103	-113	-105	-69	-68	-116	-133	-81	-105	-52	-65	-68	-58	-53	-68	-77	Cd^{2+}	Cd^{2+}
2	-71	-104	-101	-113	-106	-69	-71	-116	-135	-81	-101	-50	-66	-68	-62	-52	-70	-79	Cd^{2+}	Cd^{2+}
3	-74	-105	-106	-110	-102	-69	-68	-117	-135	-81	-101	-52	-71	-62	-62	-54	-69	-77	Cd^{2+}	Cd^{2+}
4	-72	-104	-101	-107	-102	-68	-70	-115	-132	-83	-105	-48	-65	-63	-60	-54	-67	-76	Cd^{2+}	Cd^{2+}
5	-68	-105	-103	-107	-103	-73	-69	-115	-134	-82	-106	-49	-70	-63	-60	-50	-68	-75	Cd^{2+}	Cd^{2+}
6	-69	-104	-105	-111	-105	-72	-70	-119	-136	-82	-102	-53	-68	-64	-61	-51	-70	-76	Cd^{2+}	Cd^{2+}
7	-70	-102	-97	-110	-107	-65	-85	-120	-125	-71	-89	-53	-68	-57	-65	-57	-72	-76	Zn^{2+}	Zn^{2+}
8	-72	-99	-100	-112	-112	-62	-88	-121	-129	-72	-89	-51	-65	-56	-62	-54	-71	-77	Zn^{2+}	Zn^{2+}
9	-71	-103	-94	-106	-109	-65	-84	-124	-124	-71	-92	-53	-66	-59	-62	-54	-73	-76	Zn^{2+}	Zn^{2+}
10	-73	-104	-99	-106	-113	-66	-87	-123	-130	-73	-93	-50	-64	-59	-63	-54	-67	-78	Zn^{2+}	Zn^{2+}
11	-70	-104	-94	-108	-111	-65	-83	-119	-124	-75	-93	-52	-65	-58	-66	-53	-73	-78	Zn^{2+}	Zn^{2+}
12	-75	-100	-96	-108	-112	-62	-85	-118	-126	-74	-89	-51	-67	-60	-65	-55	-67	-74	Zn^{2+}	Zn^{2+}
13	-76	-117	-108	-94	-118	-70	-68	-129	-107	-79	-109	-66	-77	-65	-66	-44	-77	-84	Co^{2+}	Co^{2+}
14	-77	-119	-113	-93	-114	-72	-67	-129	-107	-77	-111	-60	-74	-63	-70	-44	-76	-86	Co^{2+}	Co^{2+}
15	-74	-118	-108	-96	-118	-74	-68	-125	-107	-78	-106	-66	-76	-60	-67	-44	-77	-84	Co^{2+}	Co^{2+}
16	-73	-116	-111	-96	-116	-69	-71	-127	-111	-80	-108	-64	-72	-63	-69	-45	-78	-86	Co^{2+}	Co^{2+}
17	-77	-114	-111	-98	-113	-72	-67	-129	-111	-82	-105	-63	-72	-60	-69	-44	-75	-84	Co^{2+}	Co^{2+}
18	-73	-118	-112	-95	-113	-72	-69	-128	-108	-80	-111	-60	-73	-65	-70	-49	-75	-85	Co^{2+}	Co^{2+}
19	-68	-88	-77	-102	-105	-67	-79	-102	-132	-66	-88	-52	-66	-57	-66	-63	-69	-69	Sn^{4+}	Sn^{4+}
20	-67	-91	-80	-102	-105	-67	-80	-97	-128	-64	-94	-55	-64	-59	-66	-61	-72	-69	Sn^{4+}	Sn^{4+}
21	-70	-87	-78	-102	-99	-69	-80	-99	-132	-68	-93	-51	-66	-61	-68	-63	-71	-68	Sn^{4+}	Sn^{4+}
22	-69	-93	-78	-105	-100	-64	-81	-97	-132	-67	-88	-54	-68	-60	-63	-63	-69	-68	Sn^{4+}	Sn^{4+}

Samples	R1	G1	B1	R2	G2	B2	R3	G3	B3	R4	G4	B4	R5	G5	B5	R6	G6	B6	Identification	Verification
23	-71	-90	-81	-101	-101	-68	-81	-97	-132	-67	-89	-51	-66	-59	-65	-57	-71	-67	Sn^{4+}	Sn^{4+}
24	-72	-91	-80	-104	-102	-66	-83	-103	-127	-69	-90	-55	-68	-60	-66	-59	-72	-69	Sn^{4+}	Sn^{4+}
25	-97	-118	-93	-128	-97	-67	-93	-117	-134	-104	-107	-61	-81	-62	-64	-72	-79	-78	Pb^{2+}	Pb^{2+}
26	-93	-113	-90	-125	-101	-67	-93	-122	-137	-106	-106	-61	-78	-62	-70	-74	-78	-79	Pb^{2+}	Pb^{2+}
27	-94	-117	-89	-125	-102	-68	-95	-121	-138	-102	-104	-61	-77	-66	-68	-71	-77	-78	Pb^{2+}	Pb^{2+}
28	-96	-112	-93	-127	-98	-73	-96	-118	-134	-102	-107	-62	-77	-68	-65	-72	-78	-80	Pb^{2+}	Pb^{2+}
29	-94	-114	-91	-125	-100	-68	-96	-119	-137	-106	-106	-61	-79	-63	-69	-70	-74	-82	Pb^{2+}	Pb^{2+}
30	-94	-112	-87	-123	-102	-70	-92	-122	-137	-101	-106	-59	-82	-63	-68	-72	-74	-83	Pb^{2+}	Pb^{2+}
31	-88	-134	-120	-116	-122	-85	-113	-180	-165	-122	-137	-71	-72	-69	-72	-78	-106	-96	Fe^{3+}	Fe^{3+}
32	-87	-134	-126	-114	-122	-87	-114	-182	-165	-123	-139	-72	-74	-68	-67	-76	-105	-91	Fe^{3+}	Fe^{3+}
33	-85	-137	-123	-115	-126	-83	-109	-178	-164	-121	-142	-69	-73	-70	-71	-76	-104	-93	Fe^{3+}	Fe^{3+}
34	-87	-132	-120	-111	-124	-85	-114	-179	-161	-123	-143	-68	-74	-66	-66	-75	-102	-93	Fe^{3+}	Fe^{3+}
35	-88	-138	-126	-117	-125	-88	-113	-180	-161	-117	-137	-67	-72	-67	-66	-80	-103	-95	Fe^{3+}	Fe^{3+}
36	-89	-132	-121	-112	-122	-87	-112	-178	-160	-122	-137	-69	-74	-68	-68	-80	-102	-94	Fe^{3+}	Fe^{3+}
37	-76	-119	-118	-81	-120	-71	-75	-146	-149	-99	-121	-64	-60	-69	-63	-62	-87	-84	Cu^{2+}	Cu^{2+}
38	-77	-121	-112	-77	-117	-72	-75	-146	-152	-101	-121	-61	-62	-68	-62	-65	-83	-82	Cu^{2+}	Cu^{2+}
39	-77	-120	-115	-76	-117	-75	-73	-143	-151	-104	-122	-65	-62	-67	-67	-64	-87	-82	Cu^{2+}	Cu^{2+}
40	-79	-121	-116	-77	-118	-75	-75	-146	-150	-98	-120	-62	-60	-71	-67	-63	-85	-84	Cu^{2+}	Cu^{2+}
41	-76	-122	-117	-79	-121	-72	-72	-143	-152	-100	-120	-65	-62	-73	-67	-61	-84	-80	Cu^{2+}	Cu^{2+}
42	-73	-120	-112	-75	-120	-70	-73	-144	-151	-102	-123	-65	-60	-67	-68	-64	-83	-85	Cu^{2+}	Cu^{2+}
43	-69	-108	-106	-83	-87	-56	-52	-88	-122	-60	-85	-46	-56	-65	-54	-39	-69	-52	Cr^{3+}	Cr^{3+}
44	-70	-109	-111	-83	-86	-57	-53	-88	-117	-58	-88	-43	-57	-61	-56	-39	-71	-54	Cr^{3+}	Cr^{3+}
45	-70	-111	-105	-77	-90	-56	-58	-87	-120	-58	-84	-46	-53	-60	-56	-44	-66	-53	Cr^{3+}	Cr^{3+}
46	-72	-106	-108	-80	-88	-58	-56	-90	-117	-59	-87	-47	-55	-61	-57	-39	-68	-49	Cr^{3+}	Cr^{3+}

Samples	R1	G1	B1	R2	G2	B2	R3	G3	B3	R4	G4	B4	R5	G5	B5	R6	G6	B6	Identification	Verification
47	-70	-112	-108	-82	-91	-53	-57	-93	-119	-57	-86	-43	-52	-65	-55	-38	-69	-48	Cr^{3+}	Cr^{3+}
48	-71	-108	-110	-82	-86	-57	-55	-88	-120	-63	-87	-41	-52	-64	-53	-42	-70	-52	Cr^{3+}	Cr^{3+}
49	-63	-113	-110	-107	-100	-70	-58	-120	-144	-64	-104	-52	-60	-64	-65	-51	-71	-78	Ni^{2+}	Ni^{2+}
50	-64	-114	-110	-107	-98	-71	-57	-121	-140	-65	-104	-54	-65	-64	-65	-49	-75	-73	Ni^{2+}	Ni^{2+}
51	-61	-110	-106	-107	-97	-67	-59	-120	-143	-65	-103	-52	-61	-64	-65	-49	-70	-74	Ni^{2+}	Ni^{2+}
52	-63	-113	-106	-109	-99	-69	-59	-122	-141	-67	-104	-52	-59	-59	-67	-47	-73	-75	Ni^{2+}	Ni^{2+}
53	-61	-114	-106	-105	-98	-70	-62	-123	-141	-66	-102	-53	-59	-61	-67	-52	-70	-73	Ni^{2+}	Ni^{2+}
54	-64	-116	-110	-107	-94	-70	-60	-120	-144	-63	-99	-56	-64	-60	-64	-51	-74	-77	Ni^{2+}	Ni^{2+}

Table S4. 18-dimensional vector of 6 sorts of P-SCPNs when soaked in aqueous solutions of metal ions (differences in RGB values).

Metal Ions	R1	G1	B1	R2	G2	B2	R3	G3	B3	R4	G4	B4	R5	G5	B5	R6	G6	B6
Cd^{2+}	-73	-100	-103	-113	-105	-69	-68	-116	-133	-81	-105	-52	-65	-68	-58	-53	-68	-77
Cd^{2+}	-71	-104	-101	-113	-106	-69	-71	-116	-135	-81	-101	-50	-66	-68	-62	-52	-70	-79
Cd^{2+}	-74	-105	-106	-110	-102	-69	-68	-117	-135	-81	-101	-52	-71	-62	-62	-54	-69	-77
Cd^{2+}	-72	-104	-101	-107	-102	-68	-70	-115	-132	-83	-105	-48	-65	-63	-60	-54	-67	-76
Cd^{2+}	-68	-105	-103	-107	-103	-73	-69	-115	-134	-82	-106	-49	-70	-63	-60	-50	-68	-75
Cd^{2+}	-69	-104	-105	-111	-105	-72	-70	-119	-136	-82	-102	-53	-68	-64	-61	-51	-70	-76
Ave.	-71	-104	-103	-110	-104	-70	-69	-116	-134	-82	-103	-51	-68	-65	-61	-52	-69	-77
Zn^{2+}	-70	-102	-97	-110	-107	-65	-85	-120	-125	-71	-89	-53	-68	-57	-65	-57	-72	-76
Zn^{2+}	-72	-99	-100	-112	-112	-62	-88	-121	-129	-72	-89	-51	-65	-56	-62	-54	-71	-77
Zn^{2+}	-71	-103	-94	-106	-109	-65	-84	-124	-124	-71	-92	-53	-66	-59	-62	-54	-73	-76
Zn^{2+}	-73	-104	-99	-106	-113	-66	-87	-123	-130	-73	-93	-50	-64	-59	-63	-54	-67	-78
Zn^{2+}	-70	-104	-94	-108	-111	-65	-83	-119	-124	-75	-93	-52	-65	-58	-66	-53	-73	-78
Zn^{2+}	-75	-100	-96	-108	-112	-62	-85	-118	-126	-74	-89	-51	-67	-60	-65	-55	-67	-74
Ave.	-72	-102	-97	-108	-111	-64	-85	-121	-126	-73	-91	-52	-66	-58	-64	-55	-71	-77
Co^{2+}	-76	-117	-108	-94	-118	-70	-68	-129	-107	-79	-109	-66	-77	-65	-66	-44	-77	-84
Co^{2+}	-77	-119	-113	-93	-114	-72	-67	-129	-107	-77	-111	-60	-74	-63	-70	-44	-76	-86
Co^{2+}	-74	-118	-108	-96	-118	-74	-68	-125	-107	-78	-106	-66	-76	-60	-67	-44	-77	-84
Co^{2+}	-73	-116	-111	-96	-116	-69	-71	-127	-111	-80	-108	-64	-72	-63	-69	-45	-78	-86
Co^{2+}	-77	-114	-111	-98	-113	-72	-67	-129	-111	-82	-105	-63	-72	-60	-69	-44	-75	-84
Co^{2+}	-73	-118	-112	-95	-113	-72	-69	-128	-108	-80	-111	-60	-73	-65	-70	-49	-75	-85
Ave.	-75	-117	-111	-95	-115	-72	-68	-128	-109	-79	-108	-63	-74	-63	-69	-45	-76	-85
Sn^{4+}	-68	-88	-77	-102	-105	-67	-79	-102	-132	-66	-88	-52	-66	-57	-66	-63	-69	-69

Metal Ions	R1	G1	B1	R2	G2	B2	R3	G3	B3	R4	G4	B4	R5	G5	B5	R6	G6	B6
Sn^{4+}	-67	-91	-80	-102	-105	-67	-80	-97	-128	-64	-94	-55	-64	-59	-66	-61	-72	-69
Sn^{4+}	-70	-87	-78	-102	-99	-69	-80	-99	-132	-68	-93	-51	-66	-61	-68	-63	-71	-68
Sn^{4+}	-69	-93	-78	-105	-100	-64	-81	-97	-132	-67	-88	-54	-68	-60	-63	-63	-69	-68
Sn^{4+}	-71	-90	-81	-101	-101	-68	-81	-97	-132	-67	-89	-51	-66	-59	-65	-57	-71	-67
Sn^{4+}	-72	-91	-80	-104	-102	-66	-83	-103	-127	-69	-90	-55	-68	-60	-66	-59	-72	-69
Ave.	-70	-90	-79	-103	-102	-67	-81	-99	-131	-67	-90	-53	-66	-59	-66	-61	-71	-68
Pb^{2+}	-97	-118	-93	-128	-97	-67	-93	-117	-134	-104	-107	-61	-81	-62	-64	-72	-79	-78
Pb^{2+}	-93	-113	-90	-125	-101	-67	-93	-122	-137	-106	-106	-61	-78	-62	-70	-74	-78	-79
Pb^{2+}	-94	-117	-89	-125	-102	-68	-95	-121	-138	-102	-104	-61	-77	-66	-68	-71	-77	-78
Pb^{2+}	-96	-112	-93	-127	-98	-73	-96	-118	-134	-102	-107	-62	-77	-68	-65	-72	-78	-80
Pb^{2+}	-94	-114	-91	-125	-100	-68	-96	-119	-137	-106	-106	-61	-79	-63	-69	-70	-74	-82
Pb^{2+}	-94	-112	-87	-123	-102	-70	-92	-122	-137	-101	-106	-59	-82	-63	-68	-72	-74	-83
Ave.	-95	-114	-91	-126	-100	-69	-94	-120	-136	-104	-106	-61	-79	-64	-67	-72	-77	-80
Fe^{3+}	-88	-134	-120	-116	-122	-85	-113	-180	-165	-122	-137	-71	-72	-69	-72	-78	-106	-96
Fe^{3+}	-87	-134	-126	-114	-122	-87	-114	-182	-165	-123	-139	-72	-74	-68	-67	-76	-105	-91
Fe^{3+}	-85	-137	-123	-115	-126	-83	-109	-178	-164	-121	-142	-69	-73	-70	-71	-76	-104	-93
Fe^{3+}	-87	-132	-120	-111	-124	-85	-114	-179	-161	-123	-143	-68	-74	-66	-66	-75	-102	-93
Fe^{3+}	-88	-138	-126	-117	-125	-88	-113	-180	-161	-117	-137	-67	-72	-67	-66	-80	-103	-95
Fe^{3+}	-89	-132	-121	-112	-122	-87	-112	-178	-160	-122	-137	-69	-74	-68	-68	-80	-102	-94
Ave.	-87	-135	-123	-114	-124	-86	-113	-180	-163	-121	-139	-69	-73	-68	-68	-78	-104	-94
Cu^{2+}	-76	-119	-118	-81	-120	-71	-75	-146	-149	-99	-121	-64	-60	-69	-63	-62	-87	-84
Cu^{2+}	-77	-121	-112	-77	-117	-72	-75	-146	-152	-101	-121	-61	-62	-68	-62	-65	-83	-82
Cu^{2+}	-77	-120	-115	-76	-117	-75	-73	-143	-151	-104	-122	-65	-62	-67	-67	-64	-87	-82
Cu^{2+}	-79	-121	-116	-77	-118	-75	-75	-146	-150	-98	-120	-62	-60	-71	-67	-63	-85	-84

Metal Ions	R1	G1	B1	R2	G2	B2	R3	G3	B3	R4	G4	B4	R5	G5	B5	R6	G6	B6
Cu^{2+}	-76	-122	-117	-79	-121	-72	-72	-143	-152	-100	-120	-65	-62	-73	-67	-61	-84	-80
Cu^{2+}	-73	-120	-112	-75	-120	-70	-73	-144	-151	-102	-123	-65	-60	-67	-68	-64	-83	-85
Ave.	-76	-121	-115	-78	-119	-73	-74	-145	-151	-101	-121	-64	-61	-69	-66	-63	-85	-83
Cr^{3+}	-69	-108	-106	-83	-87	-56	-52	-88	-122	-60	-85	-46	-56	-65	-54	-39	-69	-52
Cr^{3+}	-70	-109	-111	-83	-86	-57	-53	-88	-117	-58	-88	-43	-57	-61	-56	-39	-71	-54
Cr^{3+}	-70	-111	-105	-77	-90	-56	-58	-87	-120	-58	-84	-46	-53	-60	-56	-44	-66	-53
Cr^{3+}	-72	-106	-108	-80	-88	-58	-56	-90	-117	-59	-87	-47	-55	-61	-57	-39	-68	-49
Cr^{3+}	-70	-112	-108	-82	-91	-53	-57	-93	-119	-57	-86	-43	-52	-65	-55	-38	-69	-48
Cr^{3+}	-71	-108	-110	-82	-86	-57	-55	-88	-120	-63	-87	-41	-52	-64	-53	-42	-70	-52
Ave.	-70	-109	-108	-81	-88	-56	-55	-89	-119	-59	-86	-44	-54	-63	-55	-40	-69	-51
Ni^{2+}	-63	-113	-110	-107	-100	-70	-58	-120	-144	-64	-104	-52	-60	-64	-65	-51	-71	-78
Ni^{2+}	-64	-114	-110	-107	-98	-71	-57	-121	-140	-65	-104	-54	-65	-64	-65	-49	-75	-73
Ni^{2+}	-61	-110	-106	-107	-97	-67	-59	-120	-143	-65	-103	-52	-61	-64	-65	-49	-70	-74
Ni^{2+}	-63	-113	-106	-109	-99	-69	-59	-122	-141	-67	-104	-52	-59	-59	-67	-47	-73	-75
Ni^{2+}	-61	-114	-106	-105	-98	-70	-62	-123	-141	-66	-102	-53	-59	-61	-67	-52	-70	-73
Ni^{2+}	-64	-116	-110	-107	-94	-70	-60	-120	-144	-63	-99	-56	-64	-60	-64	-51	-74	-77
Ave.	-63	-113	-108	-107	-98	-70	-59	-121	-142	-65	-103	-53	-61	-62	-66	-50	-72	-75