Electronic Supplementary Material (ESI) for Journal of Materials Chemistry C.

Surface Active Magnetic Iron Oxide Nanoparticles for Extracting Metal Nanoparticles across Aqueous – Organic Interface

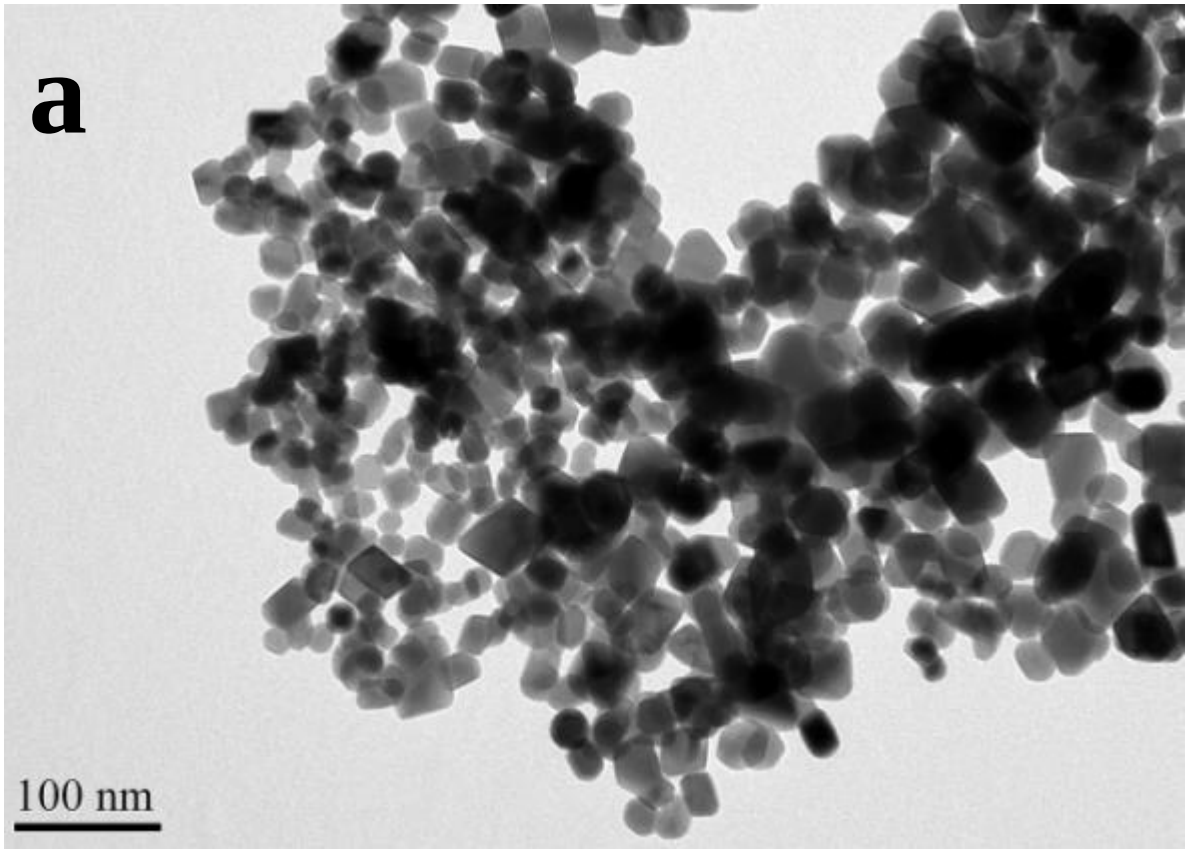
Meenakshi Verma, Kultar Singh, Mandeep Singh Bakshi

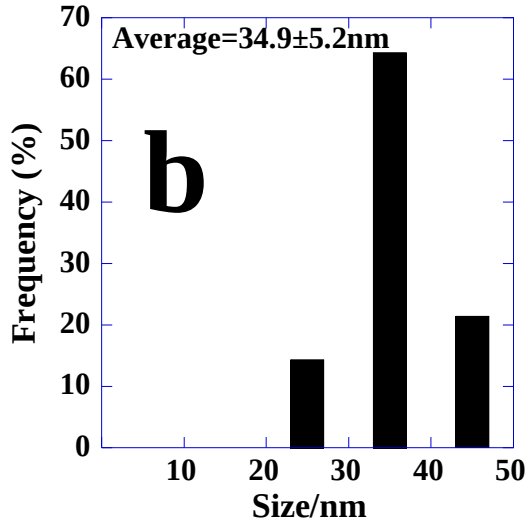
Table S1

Table S1. Complete compositions of all ingredients along with the concentrations of Gemini surfactants which lead to the synthesis of surface active iron oxide NPs.

Sample Code	$FeCl_3$ (mM)	Fe_2SO_4 (mM)	Water (ml)	Gemini Surfactant		Ammonium (50 v/v)	Final Color	Magnetic Yes/No
12-2-12								
A10	4	4	8	48.8 mM		4 mL	Black	Yes
A11	4	4	8	65.1 mM		4 mL	Black	Yes
14-2-14								
A15	4	4	8	29.8 mM		4 mL	Black	Yes
A16	4	4	8	44.7 mM		4 mL	Black	Yes
16-2-16								
A19	4	4	8	17.2 mM		4 mL	Black	Yes
A20	4	4	8	27.4 mM		4 mL	Black	Yes
A21	4	4	8	41.3 mM		4 mL	Black	Yes
C10S2								
A26	4	4	8	33.1 mM		4 mL	Black	Yes
A27	4	4	8	49.6 mM		4 mL	Black	Yes
C12S2								
A29	4	4	8	30.3 mM		4 mL	Black	Yes
A30	4	4	8	45.4 mM		4 mL	Black	Yes
C14S4								
A31	4	4	8	16.8 mM		4 mL	Black	Yes
A32	4	4	8	26.9 mM		4 mL	Black	Yes
A33	4	4	8	40.3 mM		4 mL	Black	Yes

Fig S1





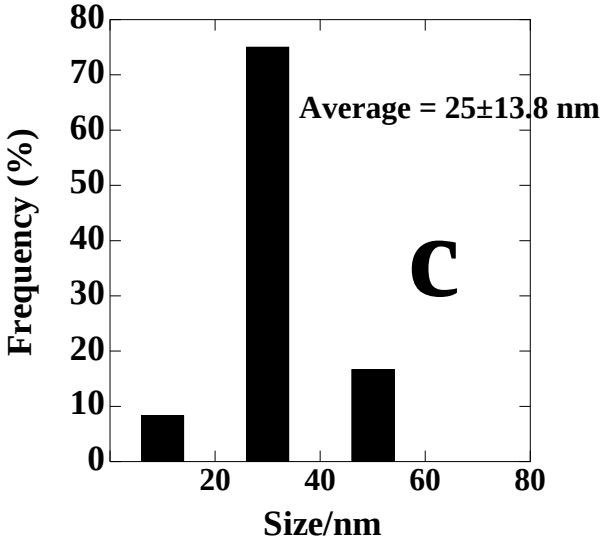


Fig S1. (a) TEM image of Fe_3O_4 NPs in the absence of surfactant along with size distribution histogram (b). (c) A collective size distribution histogram of Fig 2c.

Fig S2

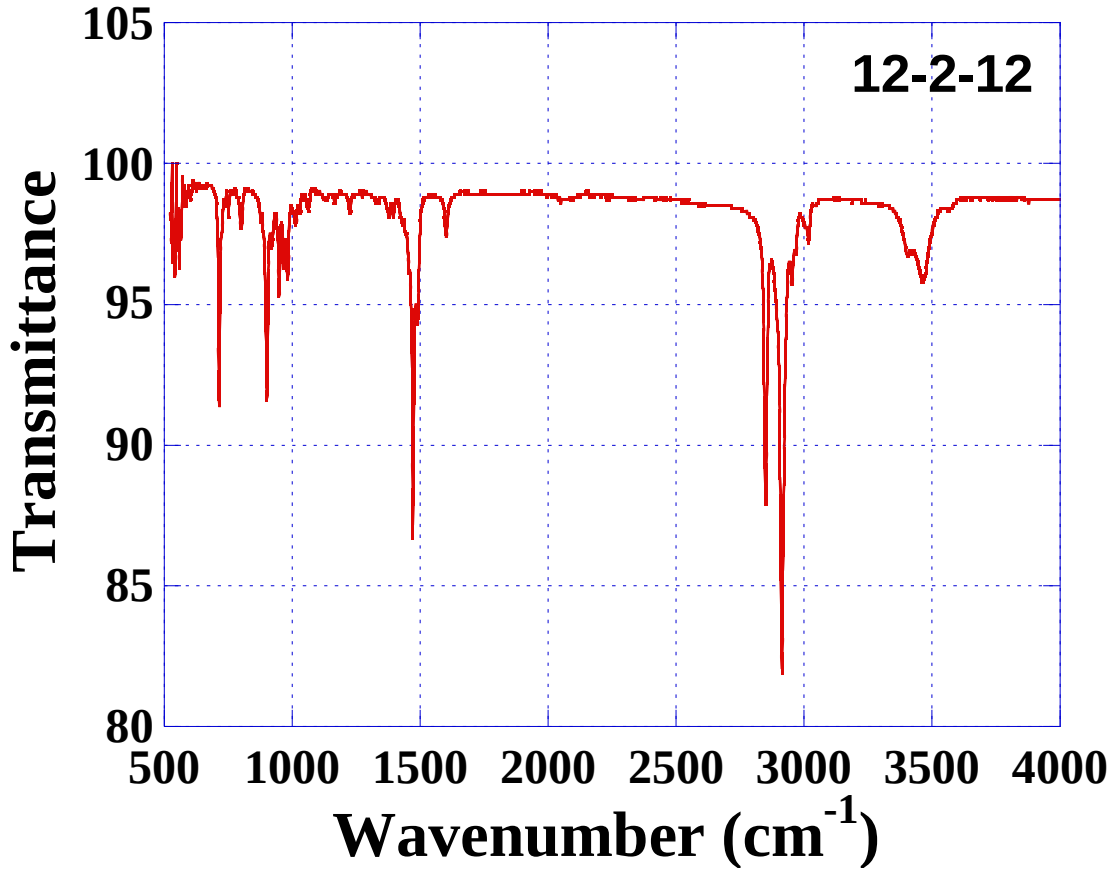


Fig S2. FT-IR spectrum of pure 12-2-12.

Fig S3

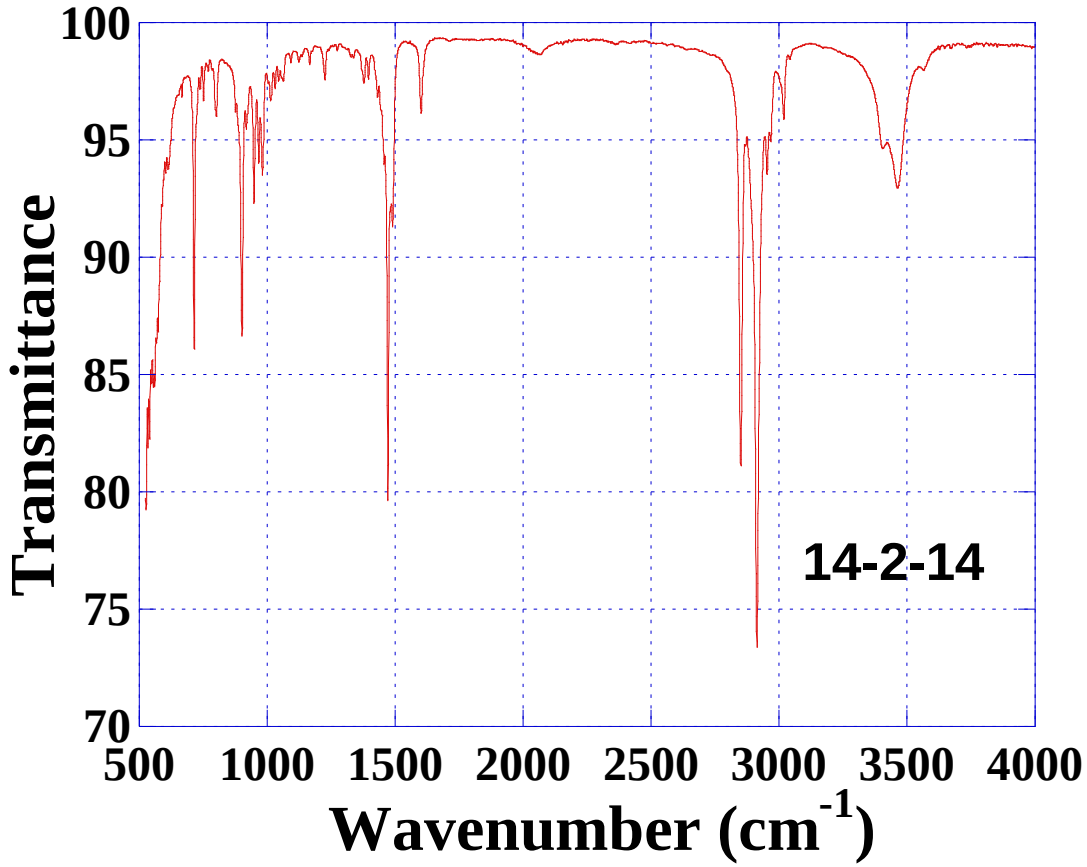


Fig S3. FT-IR spectrum of pure 14-2-14.

Fig S4

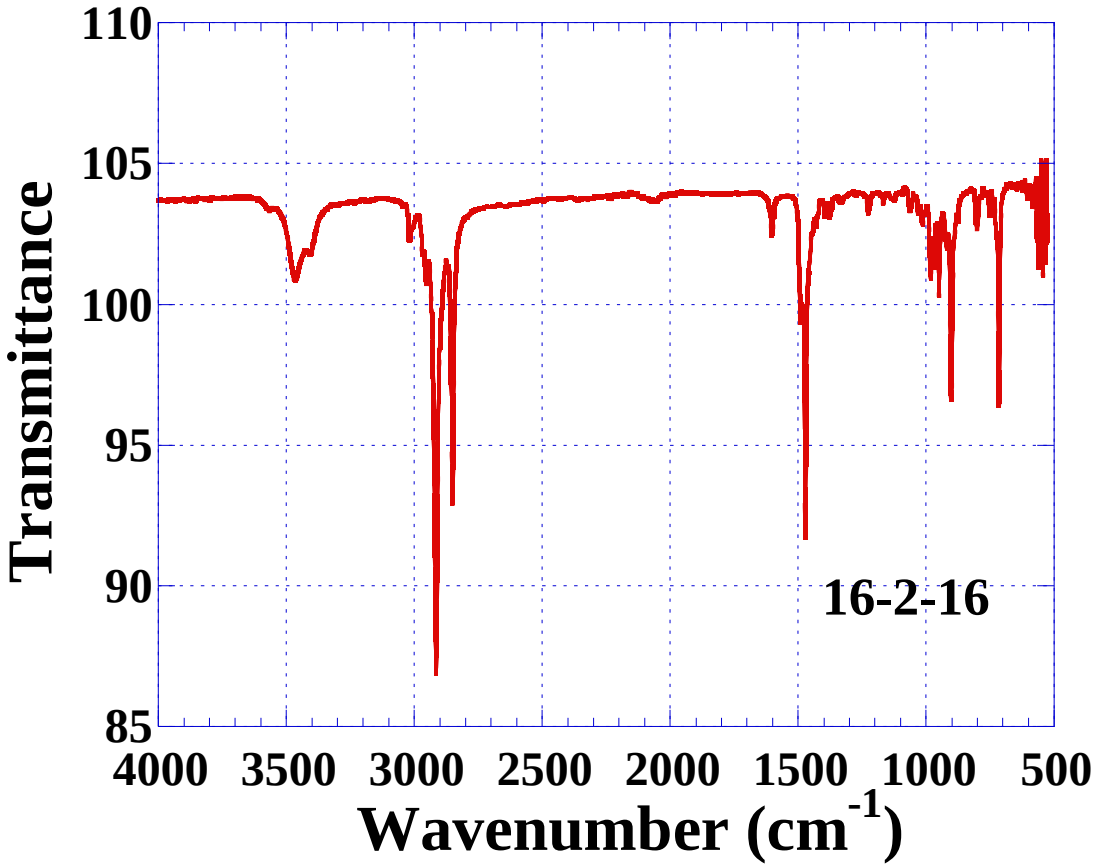


Fig S4. FT-IR spectrum of pure 16-2-16.

Fig S5

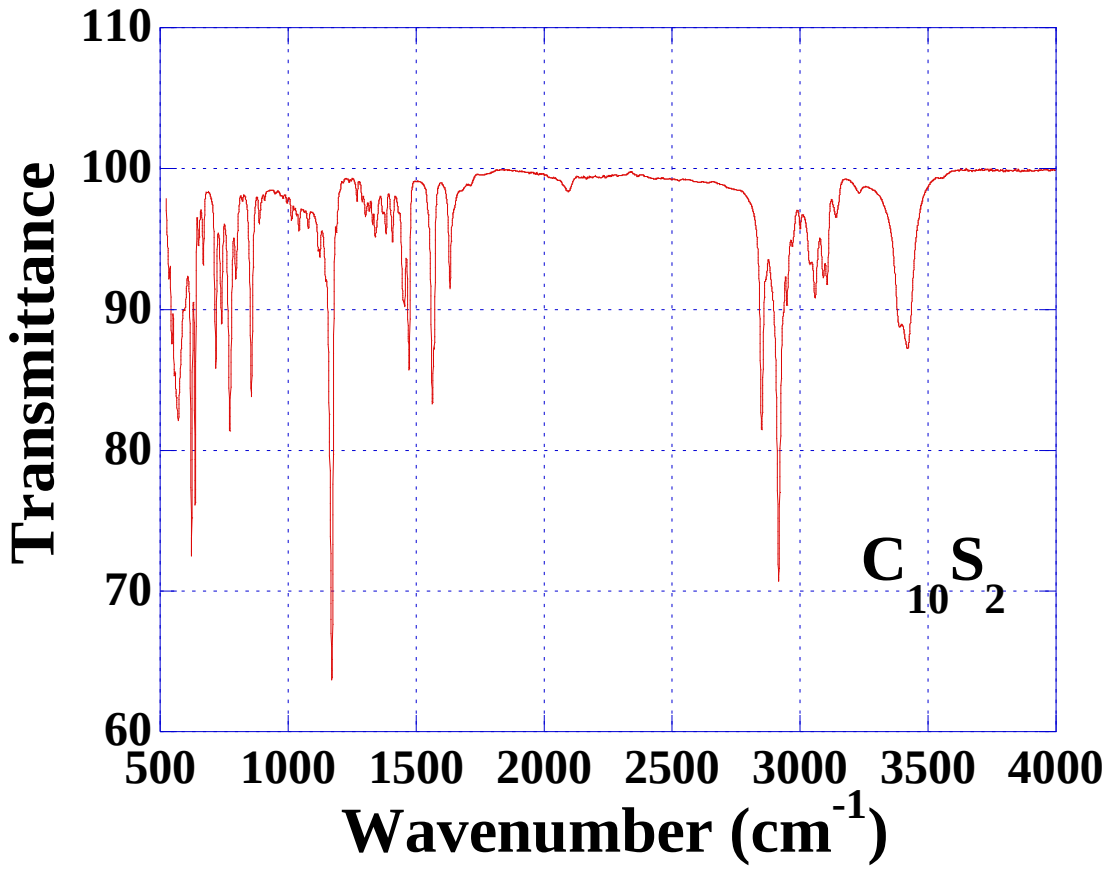


Fig S5. FT-IR spectrum of pure C10S2.

Fig S6

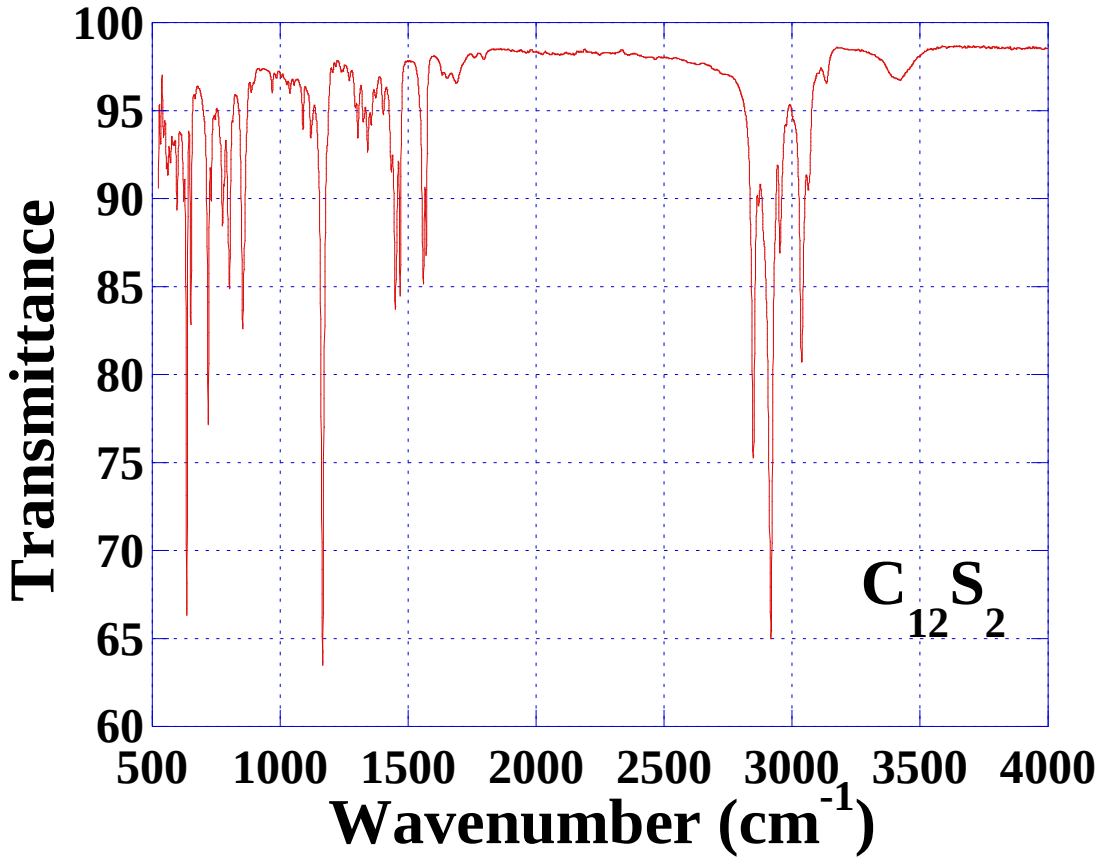


Fig S6. FT-IR spectrum of pure C12S2.

Fig S7

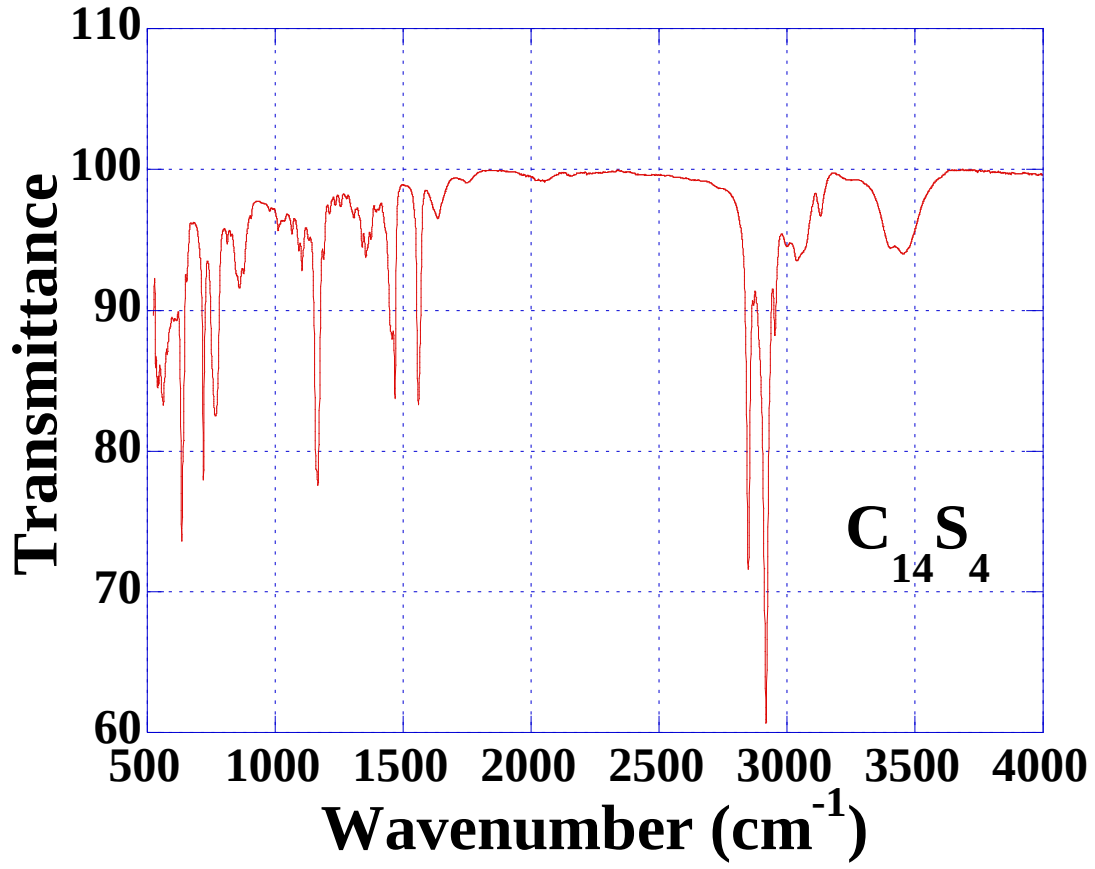


Fig S7. FT-IR spectrum of pure C14S4.

Table S2

Table S2. FT-IR peaks of Gemini surfactants in presence and absence of magnetic NPs.

Sample Name	Finger Print region (cm^{-1})	CH_2(rock) (cm^{-1})	CH_2(def) (cm^{-1})	$CH_{(str)}$ (cm^{-1})	C-$N_{(str)}$ (cm^{-1})	(CN^+) (cm^{-1})
Pure 16-2-16	-	715.00	1472.55	2850.03, 2921.72	-	3466.58
Fe/[16-2-16] 11.0 mM	-	720.97	1464.61	2852.04, 2921.42	1041.94	-
Fe/[16-2-16] 15.5 mM	-	720.75	1465.00	2852.15, 2921.64	1041.92	-
Fe/[16-2-16] 41.3 mM	-	720.47	1464.03	2851.97, 2921.36	1040.98	

Table S3

Table S3. FT-IR peaks of imidazolium surfactants in presence and absence of magnetic NPs.

Sample Name	Finger print region (cm^{-1})	CH_2(rock) (cm^{-1})	C-C (cm^{-1})	CH_2(def) (cm^{-1})	C=C (cm^{-1})	C=N (cm^{-1})	Π (Im) (cm^{-1})	Ar-H (cm^{-1})	CH_{st} (cm^{-1})	(CN^+) (cm^{-1})
Pure $C_{14}S_4$	-	719.87	1157.29	1468.81	1563.21	1615.41	2055.23	3049.32, 3133.34	2848.94, 2918.13	3464.06
Fe/[C14S4] = 26.9 mM	Broad	720.11	1166.23	1464.81	1509.00	1639.71	2122.28	-	2852.02, 2921.54	3304.35 (Broad)
Fe/[C14S4] = 40.3 mM	Broad	722.17	1165.21	1465.23	1509.36	1640.75	2122.28	-	2852.53, 2922.06	3359.14 (Broad)

Fig S8

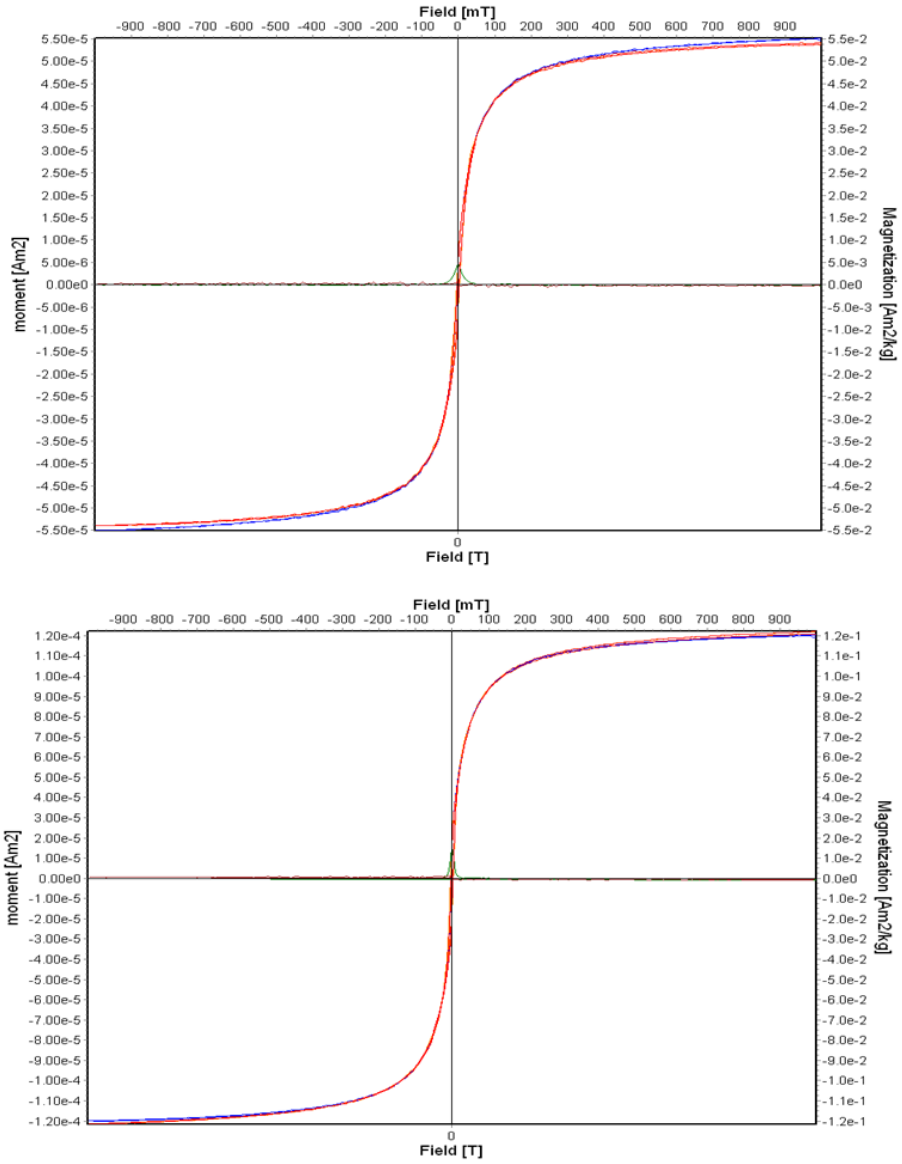


Fig S8. Hysteresis curve of iron oxide NPs prepared in the presence of 12-2-12 (above) and 14-2-14 (below).

Table S4

Table S4. Complete compositions of all ingredients along with the concentrations of monomeric double chain surfactants which lead to the synthesis of magnetic NPs responsive to external permanent magnet.

Sample Code	$FeCl_3$ (mM)	Fe_2SO_4 (mM)	Water (ml)	Gemini Surfactant		Ammonium (50 v/v)	Final Color	Magnetic Yes/No
12-0-12								
A40	4	4	8	5.65 mM		4 mL	Orange Brown	No
A41	4	4	8	2.82 mM		4 mL	Orange Brown	No
A42	4	4	8	1.41 mM		4 mL	Orange Brown	Yes
14-0-14								
A43	4	4	8	4.82 mM		4 mL	Orange Brown	No
A44	4	4	8	2.41 mM		4 mL	Orange Brown	No
A45	4	4	8	1.20 mM		4 mL	Orange Brown	Yes

Fig S9

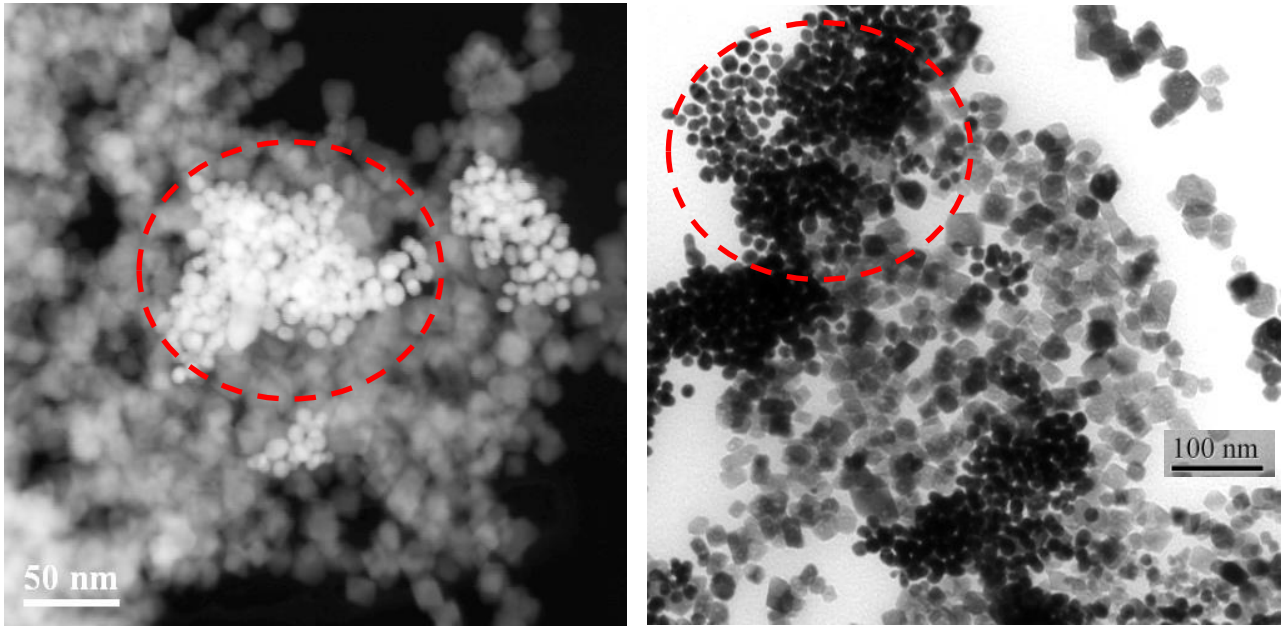


Fig S9. High resolution images showing a clear diffraction contrast between the Au and Fe_3O_4 NPs where high contrast circled NPs are the groups of Au NPs in comparison to low contrast Fe_3O_4 NPs .

Fig S10

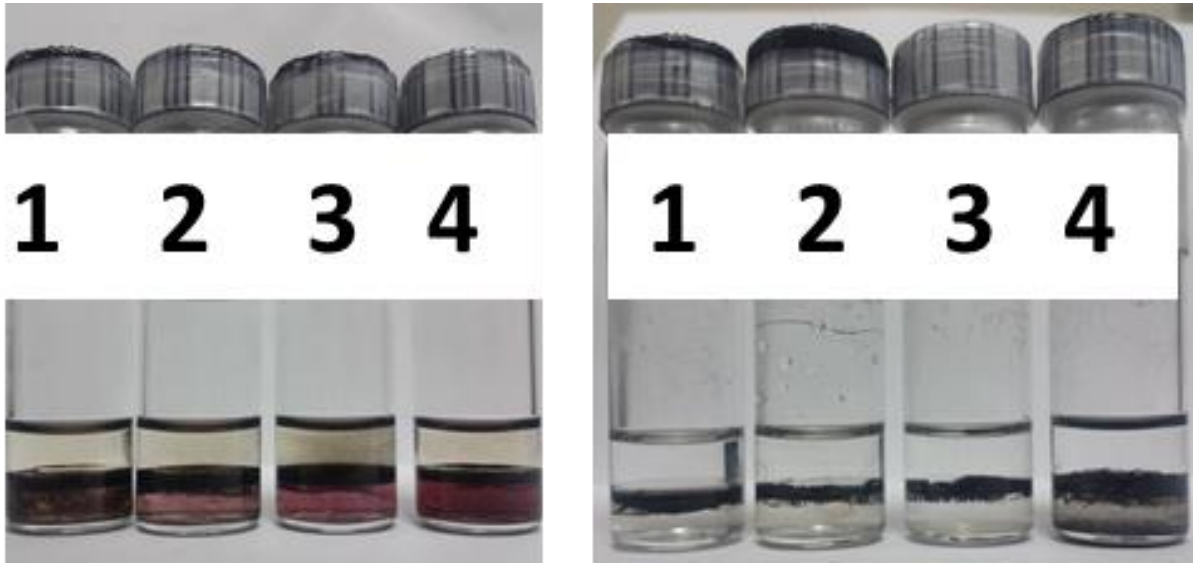


Fig S10. Photos of the samples (1 – 4) with increasing amount (0.05, 0.1, 0.2, and 0.4 mM, respectively) of CTAB stabilized Au NPs in aqueous bulk (pink color, lower layer) at a fixed 0.6 mM of $C_{14}S_4$ coated iron oxide NPs (dark band) present at the aqueous – organic immiscible interface before (left) and after (right) the extraction process.

Table S5

Table S5. Quantitative estimation of the amount of Au or Ag NPs extracted from the aqueous bulk by the surface active Fe_3O_4 NPs .

Gemini surfactant Coated Fe_3O_4 NPs			Mole ratio*	Mole ratio**	Complete Extraction
Alkylammonium	Chain length	Spacer	[Fe_3O_4/Au]	[Fe_3O_4/Au]	
	C16	2	6	8	Yes
	C14	2	12	14	Yes
	C12	2	20	23	Yes
Imidazolium					
	C14	2	1.5	2	Yes
	C12	2	3	6	Yes
	C10	2	6	10	Yes
Alkylammonium	Chain length	Spacer	[Fe_3O_4/Ag]	[Fe_3O_4/Ag]	
	C16	2	3	6	Yes
	C14	2	6	12	Yes
	C12	2	12	23	Yes
Imidazolium					
	C14	2	1	1.5	Yes
	C12	2	2	3	Yes
	C10	2	4	6	Yes

*SDS stabilized Au/Ag NPs, **CTAB stabilized Au/Ag NPs