Supplementary Information

A. Resin characteristics

The manufacturer's information for each of the resins tested is given in Table S1.

Table S1: Physical and chemical characteristics of the resins tested throughout this study, as obtained from suppliers' information data sheets (PS = polystyrene, PA = polyacrylic, DVB = divinylbenzene). All are spherical beads.

Name	TP214	MTS9100	MTS9570	MTS9301	MTS9501	C107E
Manufacturer	Lanxess	Purolite	Purolite	Purolite	Purolite	Purolite
Functionality	Thiourea	Amidoxime	Phosphonic + sulfonic acid	Iminodiacetic acid	Amino phosphonic acid	Carboxylic acid
Commercial equivalent	Puromet MTS9140	Duolite ES346	n/a	Chelex 100, Lewatit TP208	Amberlite IRC747	Dowex MAC-3
Matrix	PS-DVB	PA-DVB	PA-DVB	PS-DVB	PS-DVB	PA-DVB
Size (μm)	550	330 -1200	550 -750	425 -1000	425 -800	300 -1600
Capacity	1.0 eq.L^{-1}	40 g.L^{-1} Cu^{2+}	18 g.L^{-1} Fe^{3+}	50 g.L^{-1} Cu^{2+}	24 g.L^{-1} Ca^{2+}	3.6 eq.L^{-1}
Ionic form	Freebase	Freebase	H+	Na^{+}	Na^{+}	H+
Cost			> £30·L^{-1}	≈ £10·L^{-1}	≈ £10·L^{-}	

B. Separation factors

Table S2: TP214 separation factors of copper, iron, lead and zinc from acetate media at 20 °C after 24hr of contact time

	Cu			Fe			Pb			Zn		
pH	Fe	Pb	Zn	Cu	Pb	Zn	Cu	Fe	Zn	Cu	Fe	Pb
3.74	36.4	17.2	119	0.027	0.473	3.25	2.11	0.0580	6.88	0.307	0.00844	0.145
3.97	0.20	20.6	101	4.81	99.2	488	0.0101	0.0485	4.92	0.00205	0.00986	0.203
4.25	0.14	27.3	109	7.11	195	755	0.00514	0.0366	3.99	0.00129	0.00918	0.251
4.51	0.15	36.4	106	6.79	247	721	0.00404	0.0275	2.92	0.00139	0.00942	0.343
4.74	4.99	41.1	94.0	0.200	8.24	18.8	0.121	0.0243	2.29	0.0531	0.0106	0.437
4.91	7.99	50.3	105	0.125	6.30	13.1	0.159	0.0199	2.09	0.0761	0.00952	0.479
5.04	24.4	48.3	95.2	0.0409	1.98	3.89	0.506	0.0207	1.97	0.257	0.0105	0.508
5.22	45.9	57.1	96.1	0.0218	1.24	2.09	0.804	0.0175	1.68	0.478	0.0104	0.594
5.51	42.2	54.9	102	0.0237	1.30	2.42	0.769	0.0182	1.86	0.413	0.00978	0.537
5.73	171	50.2	103	0.00584	0.293	0.601	3.41	0.0199	2.05	1.66	0.00972	0.488

Table S3: MTS9100 separation factors of copper, iron, lead and zinc from acetate media at 20 °C after 24hr of contact time

	Cu			Fe			Pb			Zn		
pH	Fe	Pb	Zn	Cu	Pb	Zn	Cu	Fe	Zn	Cu	Fe	Pb
3.74	4.19	8.59	53.1	0.239	2.05	12.7	0.116	0.488	6.18	0.0188	0.0789	0.162
3.97	3.51	8.35	58.1	0.285	2.38	16.6	0.120	0.420	6.96	0.0172	0.0604	0.144
4.25	3.00	7.98	62.0	0.333	2.66	20.7	0.125	0.376	7.77	0.0.161	0.0484	0.129
4.51	2.90	8.24	59.6	0.345	2.84	20.6	0.121	0.352	7.23	0.0168	0.0486	0.138
4.74	1.95	8.16	48.4	0.513	4.19	24.9	0.122	0.239	5.93	0.0206	0.0402	0.169
4.91	1.18	7.56	42.0	0.845	6.39	35.5	0.132	0.157	5.55	0.0238	0.0282	0.180
5.04	1.02	7.28	38.9	0.983	7.16	38.2	0.137	0.140	5.34	0.0257	0.0262	0.187
5.22	0.773	8.01	40.8	1.29	10.4	52.7	0.125	0.0965	5.09	0.0245	0.0190	0.197
5.51	3.92	7.34	33.0	0.255	1.87	8.42	0.136	0.534	4.49	0.0303	0.119	0.222
5.73	6.59	7.25	28.1	0.152	1.10	4.26	0.138	0.910	3.88	0.356	0.235	0.258

Table S4: MTS9570 separation factors of copper, iron, lead and zinc from acetate media at 20 °C after 24hr of contact time

	Cu			Fe			Pb			Zn		
pH	Fe	Pb	Zn	Cu	Pb	Zn	Cu	Fe	Zn	Cu	Fe	Pb
2.84	0.0172	0.105	1.31	58.0	6.09	76.2	9.52	0.164	12.5	0.761	0.0131	0.0799
3.71	0.0186	0.152	0.562	53.7	8.19	30.2	6.56	0.122	3.69	1.78	0.0331	0.271
4.02	0.0163	0.151	0.368	61.5	9.27	22.7	6.63	0.108	2.44	2.72	0.0441	0.409
4.34	0.01614	0.124	0.232	62.0	7.67	14.4	8.07	0.130	1.87	4.31	0.0696	0.534
4.50	0.0143	0.106	0.190	70.1	7.46	13.3	9.40	0.134	1.78	5.26	0.0751	0.560
4.70	0.0118	0.101	0.151	85.1	8.56	12.8	9.94	0.117	1.50	6.63	0.0780	0.667
4.75	0.0144	0.0921	0.146	69.4	6.39	10.1	10.9	0.157	1.59	6.84	0.0986	0.630
4.99	0.0129	0.0850	0.118	77.9	6.61	9.14	11.8	0.151	1.38	8.50	0.109	0.723
5.22	0.0164	0.0778	0.0978	60.8	4.74	5.95	12.8	0.211	1.26	10.2	0.168	0.796
5.42	0.0178	0.0714	0.0922	56.3	4.02	5.19	14.0	0.249	1.29	10.8	0.193	0.774

Table S5: MTS9301 separation factors of copper, iron, lead and zinc from acetate media at 20 °C after 24hr of contact time

	Cu			Fe			Pb			Zn		
pH	Fe	Pb	Zn	Cu	Pb	Zn	Cu	Fe	Zn	Cu	Fe	Pb
3.26	49.1	30.5	40.9	0.0204	0.623	0.834	0.0327	1.61	1.34	0.0244	1.20	0.746
3.62	15.7	27.3	18.7	0.0636	1.74	1.19	0.0366	0.575	0.685	0.0535	0.841	1.46
3.99	6.38	21.3	9.25	0.157	3.33	1.45	0.0470	0.300	0.435	0.108	0.689	2.30
4.30	4.82	19.3	7.40	0.208	4.01	1.54	0.0517	0.249	0.383	0.135	0.650	2.61
4.55	17.7	71.3	23.0	0.0565	4.03	1.30	0.0140	0.248	0.322	0.0436	0.771	3.11
4.70	2.87	10.1	2.95	0.349	3.51	1.03	0.0994	0.285	0.293	0.339	0.973	3.41
4.85	2.78	7.69	2.20	0.360	2.77	0.791	0.130	0.361	0.286	0.455	1.26	3.50
4.95	9.10	9.18	2.34	0.110	1.01	0.257	0.109	0.991	0.254	0.428	3.90	3.93
5.12	13.2	6.80	1.50	0.0760	0.516	0.114	0.147	1.94	0.221	0.667	8.79	4.53
5.32	4.69	7.78	3.34	0.213	1.66	0.713	0.129	0.602	0.429	0.299	1.40	2.33

Table S6: MTS9501 separation factors of copper, iron, lead and zinc from acetate media at 20 °C after 24hr of contact time

	Cu			Fe			Pb			Zn		
pH	Fe	Pb	Zn	Cu	Pb	Zn	Cu	Fe	Zn	Cu	Fe	Pb
3.67	0.0651	18.6	9.19	15.4	285	141	0.0538	0.00350	0.494	0.109	0.00709	2.02
4.03	0.0750	16.3	5.88	13.3	216.9	78.4	0.0615	0.00461	0.361	0.170	0.0128	2.77
4.32	0.124	13.4	4.50	8.06	108	36.3	0.0744	0.00923	0.335	0.222	0.0276	2.99
4.54	0.0969	13.3	3.89	10.3	137	40.2	0.0754	0.00730	0.293	0.257	0.0249	3.41
4.75	0.0374	12.1	3.57	26.8	323	95.6	0.0828	0.00309	0.296	0.280	0.0105	3.38
4.92	0.0359	11.8	3.26	27.9	329	90.9	0.0848	0.00304	0.276	0.307	0.0110	3.62
5.02	0.0296	12.5	3.31	33.8	423	112	0.0798	0.00236	0.264	0.302	0.00895	3.79
5.19	0.0163	10.9	2.97	61.5	673	183	0.0914	0.00149	0.271	0.337	0.00548	3.68
5.37	0.116	8.161	3.28	8.59	70.1	28.2	0.123	0.0143	0.402	0.305	0.0355	2.49
5.71	4.32	5.83	2.60	0.232	1.35	0.602	0.171	0.740	0.446	0.385	1.66	2.24

Table S7: C107E separation factors of copper, iron, lead and zinc from acetate media at 20 °C after 24hr of contact time

	Cu			Fe			Pb			Zn		
pH	Fe	Pb	Zn	Cu	Pb	Zn	Cu	Fe	Zn	Cu	Fe	Pb
3.74	0.00767	0.508	8.25	130	66.3	1080	1.97	0.0151	16.2	0.121	0.000929	0.0616
3.97	0.00776	0.632	8.11	129	81.5	1050	1.58	0.0123	12.8	0.123	0.000956	0.0779
4.25	0.0141	0.752	7.95	71.0	53.4	565	1.33	0.0187	10.6	0.126	0.00177	0.0946
4.51	0.748	0.815	7.72	1.34	1.09	10.3	1.23	0.0918	9.47	0.130	0.0969	0.106
4.74	2.07	1.13	8.29	0.482	0.544	4.00	0.887	1.84	7.35	0.121	0.250	0.136
4.91	8.06	1.27	7.19	0.124	0.158	0.892	0.787	6.34	5.65	0.139	1.12	0.177
5.04	18.1	1.60	8.46	0.0552	0.0886	0.467	0.623	11.3	5.27	0.118	2.14	0.190
5.22	24.9	1.95	8.06	0.0401	0.0782	0.324	0.513	12.8	4.14	0.124	3.09	0.242
5.51	70.0	3.34	8.48	0.0143	0.0477	0.121	0.299	21.0	2.54	0.118	8.25	0.394
5.73	138	5.11	10.5	0.00726	0.0371	0.0759	0.196	27.0	2.05	0.0956	13.2	0.489

Table S8: TP214 separation factors of copper, iron, lead and zinc from lactate media at 20 °C after 24hr of contact time

	Cu			Fe			Pb			Zn		
pH	Fe	Pb	Zn	Cu	Pb	Zn	Cu	Fe	Zn	Cu	Fe	Pb
2.98	6690	174	2740	0.000149	0.026	0.409	0.00576	38.5	15.8	0.000365	2.44	0.063
3.14	8830	235	2840	0.000113	0.0264	0.322	0.00428	37.8	12.2	0.000352	3.11	0.0822
3.37	4790	247	3530	0.000209	0.0515	0.737	0.00405	19.4	14.3	0.000283	1.36	0.0698
3.55	8180	319	3490	0.000122	0.0390	0.426	0.00313	25.6	10.9	0.000287	2.35	0.0915
3.83	454	375	3270	0.000220	0.083	0.721	0.00267	12.1	8.73	0.000306	1.39	0.11563
4.00	6260	528	3960	0.000160	0.0843	0.633	0.00189	11.9	7.50	0.000252	1.58	0.133
4.24	3850	680	4750	0.000260	0.177	1.24	0.00147	5.66	6.99	0.000210	0.809	0.143
4.51	6350	896	5350	0.000157	0.141	0.842	0.00112	7.09	5.97	0.000187	1.19	0.167
4.740	5920	909	7320	0.000169	0.154	1.24	0.00110	6.51	8.06	0.000137	0.808	0.124
4.85	7710	1220	9370	0.000130	0.158	1.22	0.000823	6.35	7.71	0.000107	0.823	0.13066

Table S9: MTS9100 separation factors of copper, iron, lead and zinc from lactate media at 20 °C after 24hr of contact time

	Cu			Fe			Pb			Zn		
pH	Fe	Pb	Zn	Cu	Pb	Zn	Cu	Fe	Zn	Cu	Fe	Pb
2.60	0.338	1.23	0.408	2.96	3.65	1.21	0.812	0.274	0.331	2.45	0.828	3.02
2.81	0.417	1.07	0.356	2.40	2.56	0.853	0.936	0.391	0.333	2.811	1.17	3.00
2.96	0.574	1.05	0.543	1.74	1.83	0.946	0.952	0.547	0.517	1.84	1.0574	1.93
3.12	0.713	0.920	0.451	1.40	1.29	0.633	1.09	0.776	0.491	2.22	1.58	2.04
3.43	0.660	0.834	0.551	1.52	1.26	0.836	1.20	0.791	0.661	1.82	1.20	1.51
3.67	0.875	0.510	0.520	1.14	0.583	0.594	1.96	1.72	1.02	1.92	1.68	0.981
3.85	1.28	0.660	0.987	0.780	0.515	0.770	1.51	1.94	1.50	1.01	1.30	0.670
4.10	1.20	0.489	0.878	0.835	0.408	0.733	2.05	2.45	1.80	1.14	1.36	0.556
4.28	2.19	0.406	1.68	0.456	0.185	0.764	2.46	5.40	4.13	0.596	1.31	0.242
4.39	1.85	0.472	2.28	0.540	0.255	1.23	2.12	3.92	4.83	0.438	0.811	0.207

Table S10: MTS9570 separation factors of copper, iron, lead and zinc from lactate media at 20 °C after 24hr of contact time

	Cu			Fe			Pb			Zn		
pH	Fe	Pb	Zn	Cu	Pb	Zn	Cu	Fe	Zn	Cu	Fe	Pb
2.53	0.000966	0.0578	0.291	1030	59.8	301	17.3	0.0167	5.03	3.44	0.00332	0.199
2.7	0.000743	0.0314	0.242	1350	42.2	325	31.9	0.0237	7.71	4.14	0.00307	0.13
3.06	0.00103	0.0227	0.182	969	22	176	44	0.0454	7.99	5.51	0.00568	0.125
3.35	0.00049	0.00626	0.0664	2040	12.8	136	160	0.0783	10.6	15.1	0.00738	0.0942
3.66	-0.00087	-0.00752	-0.0951	-1150	8.64	109	-133	0.116	12.7	-10.5	0.00915	0.07981
3.81	0.000668	0.00476	0.0595	1500	7.12	89	210	0.14	12.5	16.8	0.0112	0.0799
4.01	0.00196	0.00395	0.145	511	2.02	74.3	253	0.496	36.8	6.87	0.0135	0.0271
4.19	0.00177	0.00713	0.109	565	4.03	61.8	140	0.248	15.3	9.14	0.0162	0.0652
4.35	-0.00146	-0.00483	-0.0754	-684	3.3	51.6	-207	0.303	15.6	-13.3	0.0194	0.064
4.51	0.00197	0.00557	0.0888	506	2.82	45	180	0.355	16	11.3	0.0222	0.0626

Table S11: MTS9301 separation factors of copper, iron, lead and zinc from lactate media at 20 °C after 24hr of contact time

	Cu			Fe			Pb			Zn		
pH	Fe	Pb	Zn	Cu	Pb	Zn	Cu	Fe	Zn	Cu	Fe	Pb
2.75	7.32	18	54.1	0.137	2.46	7.39	0.0554	0.406	3	0.0185	0.135	0.333
3.01	7.1	12.1	43.9	0.141	1.7	6.18	0.0828	0.588	3.64	0.0228	0.162	0.275
3.31	10	8.34	37.1	0.0997	0.832	3.7	0.12	1.2	4.45	0.0269	0.27	0.225
3.51	11.7	7.53	30.9	0.0852	0.642	2.63	0.133	1.56	4.1	0.0324	0.38	0.244
3.73	14.2	6.49	27.7	0.0704	0.457	1.95	0.154	2.19	4.27	0.0361	0.513	0.234
3.93	18.1	7.77	23	0.0551	0.428	1.27	0.129	2.34	2.96	0.0436	0.79	0.338
4.14	21.3	8.51	20.6	0.047	0.4	0.967	0.118	2.5	2.42	0.0486	1.03	0.414
4.29	21.3	11.7	16.3	0.0469	0.55	0.764	0.0852	1.82	1.39	0.0614	1.31	0.721
4.43	18.6	10.1	11.5	0.0537	0.545	0.62	0.0986	1.84	1.14	0.0866	1.61	0.879
4.52	21.2	10.9	11.2	0.0471	0.515	0.528	0.0914	1.94	1.02	0.0892	1.89	0.976

Table S12: MTS9501 separation factors of copper, iron, lead and zinc from lactate media at 20 °C after 24hr of contact time

	Cu			Fe			Pb			Zn		
pH	Fe	Pb	Zn	Cu	Pb	Zn	Cu	Fe	Zn	Cu	Fe	Pb
2.96	0.00103	0.279	0.623	970	270	604	3.59	0.0037	2.23	1.61	0.00166	0.448
3.2	0.00159	0.266	0.657	629	168	413	3.75	0.00597	2.47	1.52	0.00242	0.405
3.48	0.00171	0.262	0.678	584	153	396	3.81	0.00652	2.58	1.48	0.00253	0.387
3.72	0.002	0.251	0.764	499	125	381	3.98	0.00797	3.04	1.31	0.00262	0.329
3.97	0.00191	0.279	0.9	524	146	472	3.59	0.00685	3.23	1.11	0.00212	0.31
4.19	0.00212	0.287	0.94	471	135	443	3.48	0.00739	3.27	1.06	0.00226	0.306
4.37	0.0037	0.302	1.04	270	81.5	280	3.31	0.0123	3.44	0.965	0.00357	0.291
4.58	0.00509	0.331	1.11	197	65.1	218	3.02	0.0154	3.36	0.9	0.00458	0.298
4.77	0.00913	0.376	1.21	110	41.2	133	2.66	0.0243	3.22	0.826	0.00755	0.311
4.88	0.00879	0.422	1.32	114	48	150	2.37	0.0208	3.12	0.76	0.00668	0.321

Table S13: C107E separation factors of copper, iron, lead and zinc from lactate media at 20 °C after 24hr of contact time

	Cu			Fe			Pb			Zn		
pH	Fe	Pb	Zn	Cu	Pb	Zn	Cu	Fe	Zn	Cu	Fe	Pb
2.77	0.148	0.379	1.13	6.77	2.57	7.67	2.64	0.39	2.99	0.883	0.13	0.335
3.04	0.247	0.203	1.5	4.04	0.82	6.08	4.93	1.22	7.41	0.665	0.165	0.135
3.22	0.264	0.0927	0.525	3.79	0.351	1.99	10.8	2.85	5.66	1.91	0.503	0.177
3.53	0.551	0.0563	0.578	1.81	0.102	1.05	17.7	9.79	10.3	1.73	0.954	0.0975
3.75	-2.76	0.0288	0.578	-0.363	-0.0105	-0.21	34.7	-95.6	20.1	1.73	-4.77	0.0499
3.9	-0.302	-0.00591	-0.122	-3.31	0.0195	0.403	-169	51.2	20.6	-8.21	2.48	0.0485
4.12	1.81	0.0326	0.725	0.553	0.018	0.401	30.7	55.5	22.3	1.38	2.5	0.0449
4.26	19	0.0401	2.06	0.0527	0.00211	0.108	24.9	473	51.3	0.486	9.23	0.0195
4.46	12.4	0.0335	1.43	0.0804	0.00269	0.115	29.9	371	42.8	0.698	8.67	0.0234
4.61	2.28	0.0404	1.74	0.439	0.0178	0.765	24.7	56.3	43.1	0.574	1.31	0.0231

Table S14: TP214 separation factors of copper, iron, lead and zinc from citrate media at 20 °C after 24hr of contact time

	Cu			Fe			Pb			Zn		
pH	Fe	Pb	Zn	Cu	Pb	Zn	Cu	Fe	Zn	Cu	Fe	Pb
2.27	163	58.5	817	0.00612	0.358	5	0.0171	2.79	14	0.00122	0.2	0.0716
2.73	202	84.6	1050	0.00494	0.418	5.21	0.0118	2.39	12.5	0.000948	0.192	0.0802
3.39	584	183	1420	0.00171	0.313	2.43	0.00547	3.2	7.77	0.000705	0.412	0.129
3.89	786	377	2490	0.00127	0.48	3.17	0.00265	2.08	6.61	0.000401	0.315	0.151
4.51	477	321	854	0.0021	0.672	1.79	0.00312	1.49	2.66	0.00117	0.559	0.376
5.08	80.5	87.7	218	0.0124	1.09	2.7	0.0114	0.919	2.48	0.00459	0.37	0.403
5.69	39.2	52.6	57.8	0.0255	1.34	1.47	0.019	0.746	1.1	0.0173	0.679	0.91
6.23	34.8	50	50.6	0.0288	1.44	1.46	0.02	0.695	1.01	0.0198	0.687	0.988
6.93	23.9	33	31.1	0.0418	1.38	1.3	0.0303	0.725	0.942	0.0322	0.77	1.06
7.29	23.2	25.5	29	0.0432	1.1	1.25	0.0393	0.91	1.14	0.0345	0.799	0.878

Table S15: MTS9100 separation factors of copper, iron, lead and zinc from citrate media at 20 °C after 24hr of contact time

	Cu			Fe			Pb			Zn		
pH	Fe	Pb	Zn	Cu	Pb	Zn	Cu	Fe	Zn	Cu	Fe	Pb
2.11	0.18	2.28	2.29	5.55	12.7	12.7	0.0789	0.438	1	0.0786	0.436	0.995
2.77	1.35	2.26	2.9	0.742	1.67	2.15	0.597	0.443	1.29	0.464	0.345	0.777
3.34	6.01	1.57	1.81	0.166	0.261	0.301	3.84	0.638	1.15	3.32	0.553	0.867
3.96	22.9	0.814	1.12	0.0437	0.0356	0.0491	28.1	1.23	1.38	20.4	0.89	0.725
4.51	2.14	0.466	0.692	0.467	0.218	0.324	4.6	2.15	1.49	3.09	1.44	0.673
5.07	1.28	0.468	0.595	0.781	0.366	0.465	2.73	2.14	1.27	2.15	1.68	0.787
5.66	1.34	0.713	0.739	0.745	0.531	0.55	1.88	1.4	1.04	1.82	1.35	0.965
6.15	1	0.693	1.63	0.999	0.693	1.63	1.44	1.44	2.35	0.614	0.613	0.425
6.33	1.52	0.761	1.9	0.657	0.5	1.25	2	1.31	2.5	0.8	0.526	0.4
6.43	1.75	0.742	2.97	0.573	0.425	1.7	2.35	1.35	4	0.588	0.337	0.25

Table S16: MTS9570 separation factors of copper, iron, lead and zinc from citrate media at 20 °C after 24hr of contact time

	Cu			Fe			Pb			Zn		
pH	Fe	Pb	Zn	Cu	Pb	Zn	Cu	Fe	Zn	Cu	Fe	Pb
1.87	0.00123	0.173	0.384	815	141	313	5.78	0.00709	2.22	2.6	0.00319	0.45
2.59	0.00365	0.0595	0.206	274	16.3	56.3	16.8	0.0614	3.46	4.86	0.0177	0.289
3.23	0.00433	0.0259	0.121	231	6	27.9	38.5	0.167	4.65	8.29	0.0358	0.215
3.84	0.0118	0.0228	0.117	84.4	1.92	9.89	43.9	0.52	5.14	8.54	0.101	0.195
4.41	0.00238	0.0023	0.00997	420	0.964	4.18	435	1.04	4.34	100	0.239	0.23
4.98	0.0265	0.0143	0.0422	37.8	0.538	1.6	70.2	1.86	2.96	23.7	0.627	0.337
5.55	0.187	0.0627	0.138	5.36	0.336	0.741	15.9	2.98	2.21	7.22	1.35	0.453
5.98	0.151	0.0373	0.158	6.61	0.247	1.05	26.8	4.06	4.25	6.31	0.954	0.235
6.27	0.0398	0.00745	0.0315	25.1	0.187	0.792	134	5.35	4.23	31.7	1.26	0.236
6.38	0.404	0.0627	0.249	2.48	0.155	0.617	16	6.45	3.98	4.01	1.62	0.253

Table S17: MTS9301 separation factors of copper, iron, lead and zinc from citrate media at 20 °C after 24hr of contact time

	Cu			Fe			Pb			Zn		
pH	Fe	Pb	Zn	Cu	Pb	Zn	Cu	Fe	Zn	Cu	Fe	Pb
1.44	14.4	76.5	91	0.0694	5.31	6.32	0.0131	0.188	1.19	0.011	0.158	0.841
2.13	80.5	94.1	45.2	0.0124	1.17	0.561	0.0106	0.856	0.48	0.0221	1.78	2.08
2.76	270	21.9	22.5	0.00371	0.081	0.0835	0.0457	12.3	1.03	0.0444	12	0.971
3.38	451	25.7	15.7	0.00222	0.0569	0.0347	0.039	17.6	0.61	0.0639	28.8	1.64
3.94	542	37.4	12.1	0.00185	0.069	0.0224	0.0268	14.5	0.325	0.0823	44.6	3.08
4.51	627	48.1	10.1	0.0016	0.0768	0.0161	0.0208	13	0.209	0.0991	62.1	4.77
5.05	708	56.2	9.6	0.00141	0.0794	0.0136	0.0178	12.6	0.171	0.104	73.7	5.85
5.53	672	42.7	6.65	0.00149	0.0636	0.00989	0.0234	15.7	0.156	0.15	101	6.42
5.73	540	35.2	5.07	0.00185	0.0652	0.0094	0.0284	15.3	0.144	0.197	106	6.94
5.82	654	37.9	5.24	0.00153	0.0579	0.00801	0.0264	17.3	0.138	0.191	125	7.23

Table S18: MTS9501 separation factors of copper, iron, lead and zinc from citrate media at 20 °C after 24hr of contact time

	Cu			Fe			Pb			Zn		
pH	Fe	Pb	Zn	Cu	Pb	Zn	Cu	Fe	Zn	Cu	Fe	Pb
2.15	0.00292	0.501	0.433	343	172	148	2	0.00583	0.864	2.31	0.00674	1.16
2.76	0.0159	0.369	0.34	63	23.3	21.4	2.71	0.043	0.919	2.95	0.0468	1.09
3.38	0.000294	0.348	0.341	3410	1190	1160	2.87	0.000843	0.979	2.93	0.000861	1.02
3.97	0.00455	0.418	0.433	220	91.9	95.2	2.39	0.0109	1.04	2.31	0.0105	0.965
4.55	0.0124	0.687	0.814	80.7	55.4	65.6	1.46	0.0181	1.19	1.23	0.0152	0.844
5.12	0.0188	0.883	0.994	53.3	47.1	53	1.13	0.0212	1.13	1.01	0.0189	0.889
5.71	0.0267	1.1	1.27	37.5	41.2	47.7	0.909	0.0242	1.16	0.787	0.021	0.865
6.3	0.0521	1.09	1.52	19.2	20.9	29.2	0.917	0.0478	1.4	0.656	0.0342	0.715
6.54	0.0883	1.02	1.44	11.3	11.6	16.3	0.98	0.0866	1.41	0.696	0.0615	0.711
6.7	0.131	0.995	1.41	7.63	7.59	10.8	1	0.132	1.42	0.709	0.0929	0.705

Table S19: C107E separation factors of copper, iron, lead and zinc from citrate media at 20 °C after 24hr of contact time

	Cu			Fe			Pb			Zn		
pH	Fe	Pb	Zn	Cu	Pb	Zn	Cu	Fe	Zn	Cu	Fe	Pb
2.21	0.25	0.494	2.55	4.01	1.98	10.2	0.505	2.03	5.17	0.0977	0.392	0.193
2.8	0.234	0.218	0.784	4.28	0.934	3.35	1.07	4.58	3.59	0.298	1.28	0.278
3.34	0.184	0.142	0.591	5.45	0.772	3.22	1.3	7.06	4.17	0.311	1.69	0.24
3.95	0.168	0.124	0.831	5.96	0.737	4.95	1.36	8.08	6.72	0.202	1.2	0.149
4.44	0.502	0.0176	0.319	1.99	0.0351	0.636	28.5	56.8	18.1	1.57	3.13	0.0552
5.02	-0.517	0.0853	0.611	-1.93	-0.165	-1.18	-6.07	11.7	7.17	-0.846	1.64	0.139
5.45	0.0663	-0.0179	-0.145	15.1	-0.27	-2.19	-3.7	-55.8	8.11	-0.456	-6.88	0.123
5.87	0.594	-0.0328	-1.8	1.68	-0.0552	-3.03	-18.1	-30.5	54.9	-0.33	-0.556	0.0182
5.99	-1.6	-0.0778	1.46	-0.626	0.0487	-0.916	20.5	-12.9	-18.8	-1.09	0.683	-0.0531
6.05	-1	0.0122	-0.471	-1	-0.0122	0.471	-82	81.9	-38.6	2.12	-2.12	-0.0259

C. Solution-phase speciation

The speciation of metals and complexes within solution will be very pH dependent due pH dependence of conjugate base concentration of the weak acids. With a higher concentration of conjugate base leading to the potential for more complexation and even dimerization of complexes, in order to explain extraction trends observed, the speciation of metals in solution was modelled. All speciation data used for the modelling is included within Tables S20 - 37. As suggested by the difference in in proton concentration, each metal transitions between free metal to metal-anion complex as the pH approaches the pK_a of the acids, due to the higher available concentration of conjugate base. Generally speaking, the more bound moieties in the complex (mono-, bis-, tris-), the higher the stability constant. The referencing of species in tables is [1] Brown and Ekberg (2016), [2] Martell, *et al.* (2009), [3] Gorman and Clydesdale (1984) and [4] Field, *et al.* (1974).

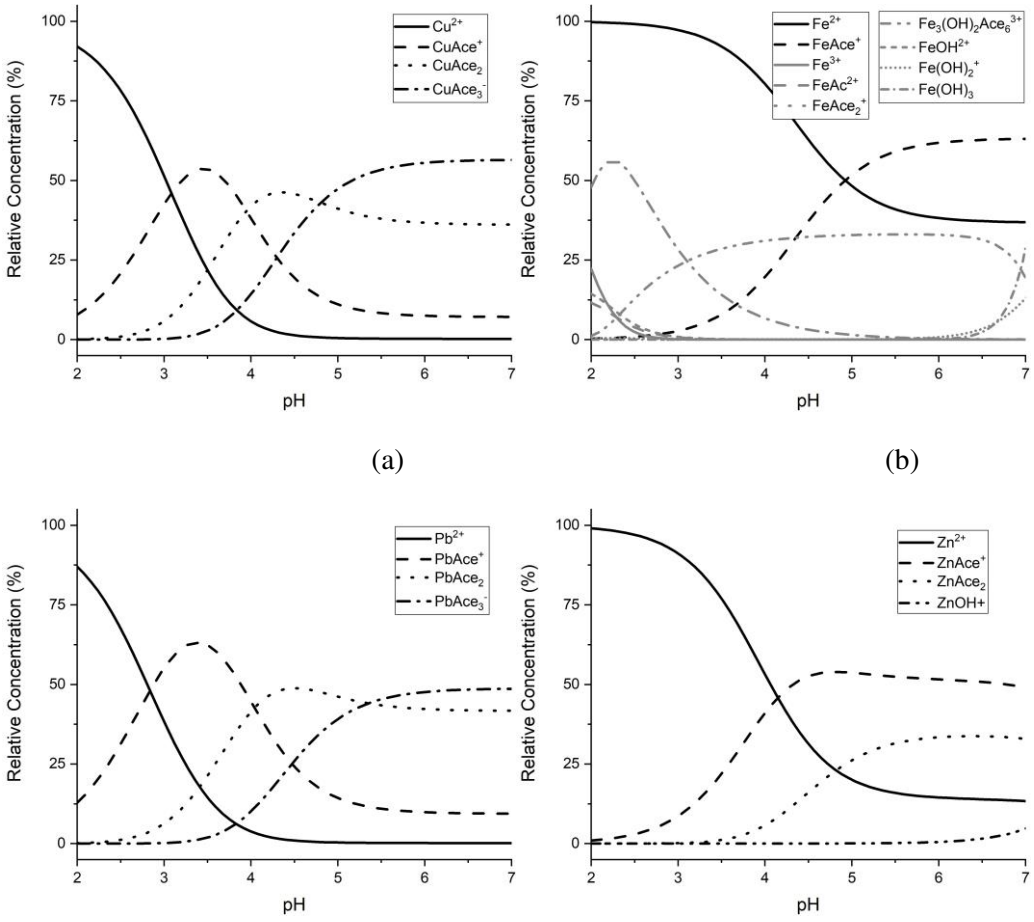
Table S20: Stability constants for the solid phase hydrolysis products of each metals.

Metal	Species	$\log K_{sp}$	Ionic Strength	Reference
Copper(II)	CuO	7.90	0	[1]
	CuO	8.68	0	[1]
Iron(II)	Fe3O4	12.02	0	[1]
Iron(III)	FeOOH	0.3	0	[1]
	Fe2O3	-0.1	0	[1]
Lead	PbO	12.6	0	[1]
Zinc	ZnO	11	0	[1]
	$Zn(OH)_2$	12	0	[1]

172 Table S22: Stability constants for the solution phase hydrolysis products of each metal.

Metal	Species	logβ	Ionic Strength	Reference
Copper(II)	$CuOH^+$	-7.53	0	[1]
	$Cu(OH)_2$	-16.22	0	[1]
	$Cu(OH)^-_3$	-26.59	0	[1]
	Cu2OH3+	-6.4	0	[1]
	$Cu_2(OH)_2^{2+}$	-10.43	0	[1]
	$Cu_3(OH)_4^{2+}$	-21.10	0	[1]
Iron(II)	$FeOH^+$	-9.32	0	[1]
	$Fe(OH)_2$	-20.6	0	[1]
	$Fe(OH)_3^-$	-32.6	0	[1]
Iron(III)	$FeOH^{2+}$	-2.19	0	[1]
	$Fe(OH)_2^+$	-5.7	0	[1]
	$Fe(OH)_3$	-12.4	0	[1]
	$Fe(OH)_4^-$	-22	0	[1]
	$Fe_2(OH)_2^{4+}$	-2.91	0	[1]
	$Fe_3(OH)_4^{5+}$	-6.3	0	[1]
Lead	$PbOH^+$	-7.46	0	[1]
	$Pb(OH)_2$	-16.9	0	[1]
	$Pb(OH)^-_3$	-28	0	[1]
	$Pb_3(OH)_4^{2+}$	-23.7	0	[1]
	$Pb_4(OH)_4^{4+}$	-20.3	0	[1]
	$Pb_6(OH)_8^{4+}$	-43.2	0	[1]
Zinc	$ZnOH^+$	-9	0	[1]
	$Zn(OH)_2$	-17.8	0	[1]
	$Zn(OH)_3^-$	-28.4	0	[1]
	$Zn(OH)_4^{2-}$	-40.5	0	[1]
	Zn_2OH^{3+}	-8.7	0	[1]

173



(a) (b)

(c) (d)

Figure S1: Solution speciation of Cu^{2+} (a), Fe^{2+} and Fe^{3+} (b), Pb^{2+} (c) and Zn^{2+} (d) in acetic acid, calculated by the HySS software (Gans, *et al.*, 2009) with stability constants attained from the NIST database (Martell, *et al.*, 2009).

Table S23: Stability constants for copper acetate species in solution. [L] = complexing acid, [M] = metal, [H] = proton, [OH] = hydroxide.

Ion	Species	logβ	Ionic Strength	Reference
$Acetate^-$	[HL]	4.56	0.1	[2]
Cu2+	[ML]	1.79	0.1	[2]
	$[ML_2]$	2.80	0.1	[2]
	$[ML_3]$	3.30	0.1	[2]

Table S24: Stability constants for iron(II) acetate species in solution. [L] = complexing acid, [M] = metal, [H] = proton, [OH] = hydroxide.

Ion	Species	logβ	Ionic Strength	Reference
$Acetate^-$	[HL]	4.78	3	[2]
Fe2+	[ML]	0.54	3	[2]

Table S25: Stability constants for iron(III) acetate species in solution. [L] = complexing acid, [M] = metal, [H] = proton, [OH] = hydroxide.

Ion	Species	logβ	Ionic Strength	Reference
$Acetate^-$	[HL]	4.58	1	[2]
Fe3+	[ML]	2.8	1	[2]
	$[ML_2]$	6.5	1	[2]
	$[M_3(OH)_2L_6]$	20	1	[2]

Table S26: Stability constants for lead acetate species in solution. [L] = complexing acid, [M] = metal, [H] = proton, [OH] = hydroxide.

Ion	Species	logβ	Ionic Strength	Reference
$Acetate^-$	[HL]	4.58	1	[2]
Pb2+	[ML]	2.05	1	[2]
	$[ML_2]$	3.00	1	[2]
	$[ML_3]$	3.37	1	[2]

Table S27: Stability constants for zinc acetate species in solution. [L] = complexing acid, [M] = metal, [H] = proton, [OH] = hydroxide.

Ion	Species	logβ	Ionic Strength	Reference
$Acetate^-$	[HL]	4.58	1	[2]
Zn2+	[ML]	0.87	1	[2]
	$[ML_2]$	1	1	[2]

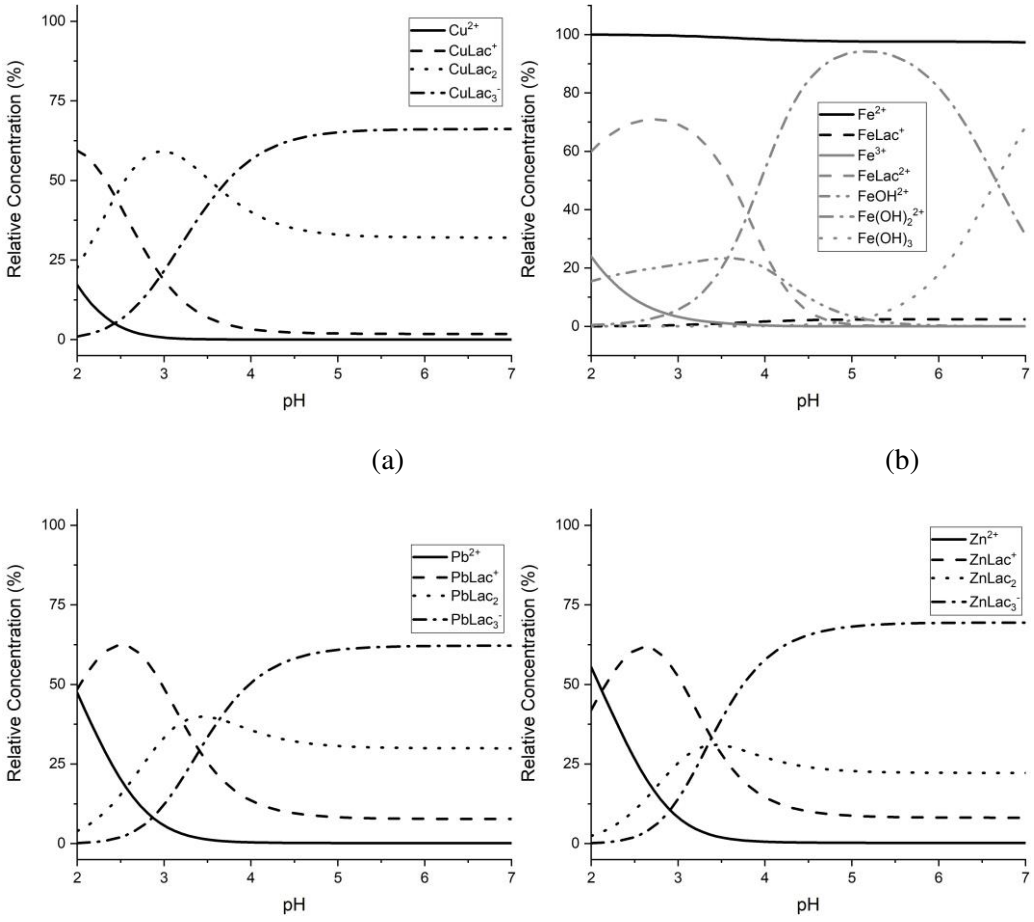


Figure S2: Solution speciation of Cu^{2+} (a), Fe^{2+} and Fe^{3+} (b), Pb^{2+} (c) and Zn^{2+} (d) in lactic acid, calculated by the HySS software (Gans, *et al.*, 2009) with stability constants attained from the NIST database (Martell, *et al.*, 2009), apart from Fe^{2+} and Fe^{3+}, that were gathered from Gorman and Clydesdale (1984).

Table S28: Stability constants for copper lactate species in solution. [L] = complexing acid, [M] = metal, [H] = proton, [OH] = hydroxide.

Ion	Species	logβ	Ionic Strength	Reference
$Lactate^{-}$	[HL]	3.59	1	[2]
Cu2+	[ML]	2.47	1	[2]
	$[ML_2]$	4.08	1	[2]
	$[ML_3]$	4.70	1	[2]

Table S29: Stability constants for iron(II) lactate species in solution. [L] = complexing acid, [M] = metal, [H] = proton, [OH] = hydroxide.

Ion	Species	logβ	Ionic Strength	Reference
$Lactate^{-}$	[HL]	3.67	0.1	[2]
Fe2+	[ML]	-1.30	0.1	[4]

Table S30: Stability constants for iron(III) lactate species in solution. [L] = complexing acid, [M] = metal, [H] = proton, [OH] = hydroxide.

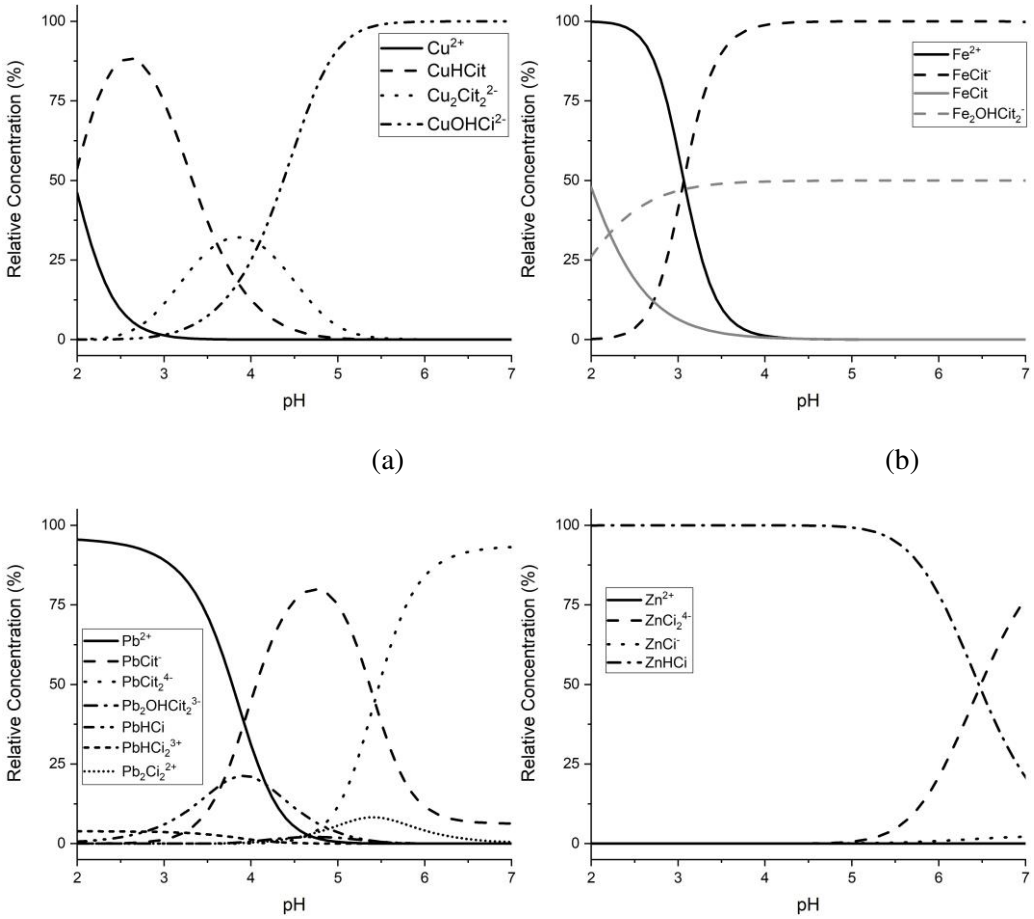
Ion	Species	logβ	Ionic Strength	Reference
$Lactate^-$	[HL]	3.67	0.1	[2]
Fe3+	[ML]	2.38	0.1	[3]

Table S31: Stability constants for lead lactate species in solution. [L] = complexing acid, [M] = metal, [H] = proton, [OH] = hydroxide.

Ion	Species	logβ	Ionic Strength	Reference
$Lactate^-$	[HL]	3.59	1	[2]
Pb2+	[ML]	1.99	1	[2]
	$[ML_2]$	2.88	1	[2]

Table S32: Stability constants for zinc lactate species in solution. [L] = complexing acid, [M] = metal, [H] = proton, [OH] = hydroxide.

Ion	Species	logβ	Ionic Strength	Reference
$Lactate^-$	[HL]	3.59	1	[2]
Zn2+	[ML]	1.86	1	[2]
	$[ML_2]$	2.6	1	[2]
	$[ML_3]$	3.4	1	[2]



(a) (b)

(c) (d)

Figure S3: Solution speciation of Cu^{2+} (a), Fe^{2+} and Fe^{3+} (b), Pb^{2+} (c) and Zn^{2+} (d) in citric acid, calculated by the HySS software (Gans, *et al.*, 2009) with stability constants attained from the NIST database (Martell, *et al.*, 2009), apart from Cu^{2+}, Fe^{2+} and Fe^{3+}, that were gathered from Field, *et al.* (1974).

Table S33: Stability constants for copper citrate species in solution. [L] = complexing acid, [M] = metal, [H] = proton, [OH] = hydroxide.

Ion	Species	logβ	Ionic strength	Reference
$Citrate^{-}$	[HL]	5.64	0.1	[2]
	$[HL_2]$	9.99	0.1	[2]
	$[HL_3]$	12.89	0.1	[2]
Cu2+	[MHL]	9.31	0.1	[4]
	$[M_2L_2]$	14.72	0.1	[4]
	[MOHL]	1.61	0.1	[4]

Table S34: Stability constants for iron(II) citrate species in solution. [L] = complexing acid, [M] = metal, [H] = proton, [OH] = hydroxide.

Ion	Species	logβ	Ionic Strength	Reference
$Citrate^{-}$	[HL]	5.64	0.1	[2]
	$[HL_2]$	9.99	0.1	[2]
	$[HL_3]$	12.89	0.1	[2]
Fe2+	[MHL]	8.62	0.1	[4]
	[ML]	4.80	0.1	[4]
	$[MHL_2]$	11.81	0.1	[4]

Table S35: Stability constants for iron(III) citrate species in solution. [L] = complexing acid, [M] = metal, [H] = proton, [OH] = hydroxide.

Ion	Species	logβ	Ionic strength	Reference
$Citrate^{-}$	[HL]	5.64	0.1	[2]
	$[HL_2]$	9.99	0.1	[2]
	$[HL_3]$	12.89	0.1	[2]
Fe3+	[MHL]	12.38	0.1	[4]
	[ML]	11.21	0.1	[4]
	[MOHL]	8.60	0.1	[4]

Table S36: Stability constants for lead citrate species in solution. [L] = complexing acid, [M] = metal, [H] = proton, [OH] = hydroxide.

Ion	Species	logβ	Ionic Strength	Reference
$Citrate^{-}$	[HL]	5.13	1	[2]
	$[HL_2]$	9.19	1	[2]
	$[HL_3]$	11.98	1	[2]
Pb2+	[ML]	4.44	1	[2]
	$[ML_2]$	5.92	1	[2]
	[MHL]	8.11	1	[2]
	$[MH_2L]$	10.89	1	[2]
	$[MHL_2]$	10.61	1	[2]
	$[M_2L_2]$	10.70	1	[2]
	$[M_2OHL_2]$	2.76	1	[2]
	$[M_2(OH)_2L_2]$	-3.79	1	[2]

247 Table S37: Stability constants for zinc citrate species in solution. [L] = complexing acid, [M] = metal,
248 [H] = proton, [OH] = hydroxide.

249

Ion	Species	logβ	Ionic Strength	Reference
$Citrate^{-}$	[HL]	5.64	0.1	[2]
	$[HL_2]$	9.99	0.1	[2]
	$[HL_3]$	12.89	0.1	[2]
Zn2+	[ML]	4.93	0.1	[2]
	$[ML_2]$	6.8	0.1	[2]
	[MHL]	12.91	0.1	[2]
	$[MH_2L]$	11.19	0.1	[2]
	$[M_2(OHL)_2]$	-2.85	0.1	[2]

250

251