

Supplementary Material

Evaluation of uptake mechanisms of phosphate by Fe(III) (oxyhydr)oxides in Early Proterozoic oceanic conditions

Christoffer Hemmingsson,^{A,C} Iain K. Pitcairn^A and Ernest Chi Fru^B

^ADepartment of Geological Sciences, Stockholm University, SE-10691, Stockholm, Sweden.

^BSchool of Earth and Ocean Sciences, Cardiff University, Cardiff, CF10 3AT, United Kingdom.

^CCorresponding author. Email: christoffer.hemmingsson@geo.su.se

Table 1. Concentrations of As, Fe and P in ppb in the mineral precipitates after adsorption experiments measured by ICP-OES

Starting concentrations in the experimental solutions were 100 μM P and 100 μM As. The relative concentrations of As and P in the supernatant is calculated by subtracting the concentrations in the precipitate from the starting concentrations. Concentrations of Fe and Si were set at 7.16 mM and 0, 0.67 & 2.2 mM, respectively.

Sample	pH	Precipitate			Precipitate		Supernatant	
		As ppb	Fe ppb	P ppb	As μM	P μM	As μM	P μM
0 Si. P + AsIII	5	189	25100	239	25	78	75	22
0 Si. P + AsIII	6	220	22377	182	30	59	70	41
0 Si. P + AsIII	7	272	29404	114	37	37	63	63
0 Si. P + AsIII	8	409	25420	62	55	20	45	80
0 Si. P + AsIII	9	349	27046	18	47	6	53	94
0 Si. P + AsIII	10	404	27759	8	54	3	46	97
0 Si. P + AsV	5	127	25349	149	17	49	83	51
0 Si. P + AsV	6	141	27323	190	19	62	81	38
0 Si. P + AsV	7	112	27655	80	15	26	85	74
0 Si. P + AsV	8	81	22434	57	11	18	89	82
0 Si. P + AsV	9	54	27872	76	7	25	93	75
0 Si. P + AsV	10	50	29989	32	7	11	93	89
0 Si. P + AsIII + AsV	5	217	29047	244	29	79	71	21
0 Si. P + AsIII + AsV	6	198	30324	117	27	38	73	62
0 Si. P + AsIII + AsV	7	214	27949	100	29	32	71	68
0 Si. P + AsIII + AsV	8	253	28911	51	34	17	66	83
0 Si. P + AsIII + AsV	9	269	28371	26	36	9	64	91
0 Si. P + AsIII + AsV	10	323	29862	32	43	11	57	89
0.67 Si. P + AsIII	5	213	29259	164	29	53	71	47
0.67 Si. P + AsIII	6	219	24324	156	29	51	71	49
0.67 Si. P + AsIII	7	245	20577	83	33	27	67	73
0.67 Si. P + AsIII	8	332	25747	50	45	16	55	84
0.67 Si. P + AsIII	9	334	30369	17	45	5	55	95
0.67 Si. P + AsIII	10	226	22263	0	30	0	70	100

Sample	pH	Precipitate			Precipitate		Supernatant	
		As ppb	Fe ppb	P ppb	As uM	P uM	As uM	P uM
0.67 Si. P + AsV	5	155	28821	143	21	47	79	53
0.67 Si. P + AsV	6	118	23880	124	16	40	84	60
0.67 Si. P + AsV	7	87	24453	59	12	19	88	81
0.67 Si. P + AsV	8	65	23933	44	9	14	91	86
0.67 Si. P + AsV	9	40	28555	19	5	6	95	94
0.67 Si. P + AsV	10	20	28938	0	3	0	97	100
0.67 Si. P + AsIII + AsV	5	228	29824	176	31	57	69	43
0.67 Si. P + AsIII + AsV	6	194	24615	104	26	34	74	66
0.67 Si. P + AsIII + AsV	7	167	25556	55	22	18	78	82
0.67 Si. P + AsIII + AsV	8	219	24500	47	29	15	71	85
0.67 Si. P + AsIII + AsV	9	227	25170	22	31	7	69	93
0.67 Si. P + AsIII + AsV	10	128	27724	0	17	0	83	100
2.2 Si. P + AsIII	5	163	27711	89	22	29	78	71
2.2 Si. P + AsIII	6	156	25241	69	21	23	79	77
2.2 Si. P + AsIII	7	243	25824	44	33	14	67	86
2.2 Si. P + AsIII	8	258	26364	0	35	0	65	100
2.2 Si. P + AsIII	9	190	28323	0	26	0	74	100
2.2 Si. P + AsIII	10	133	24700	0	18	0	82	100
2.2 Si. P + AsV	5	96	25904	72	13	23	87	77
2.2 Si. P + AsV	6	82	22910	72	11	23	89	77
2.2 Si. P + AsV	7	56	21180	30	7	10	93	90
2.2 Si. P + AsV	8	43	26185	46	6	15	94	85
2.2 Si. P + AsV	9	7	28948	0	1	0	99	100
2.2 Si. P + AsV	10	6	26474	0	1	0	99	100
2.2 Si. P + AsIII + AsV	5	141	25923	62	19	20	81	80
2.2 Si. P + AsIII + AsV	6	157	22333	85	21	28	79	72
2.2 Si. P + AsIII + AsV	7	166	23494	85	22	28	78	72
2.2 Si. P + AsIII + AsV	8	181	27073	13	24	4	76	96
2.2 Si. P + AsIII + AsV	9	144	27836	0	19	0	81	100
2.2 Si. P + AsIII + AsV	10	85	24333	0	11	0	89	100

Table 2. Concentrations of As, Fe and P in ppb in the mineral precipitates after coprecipitation experiments from Chi Fru et al. (2016)

Starting concentrations in the experimental solutions were 100 μM P and 100 μM As. P and As in the precipitate are also presented in $\mu\text{mol liter}^{-1}$ calculated from ICP data. The relative concentrations of As and P in the supernatant is calculated by subtracting the concentrations in the precipitate from the starting concentrations

Sample	pH	Precipitate			Precipitate		Supernatant	
		As ppb	Fe ppb	P ppb	As μM	P μM	As μM	P μM
1.0 Fe. 0 Si. P + AsIII	5	39	440	86	4	25	96	75
1.0 Fe. 0 Si. P + AsIII	6	38	427	81	4	36	96	64
1.0 Fe. 0 Si. P + AsIII	7	739	5103	331	90	100	10	0
1.0 Fe. 0 Si. P + AsIII	8	727	5096	305	91	95	9	5
1.0 Fe. 0 Si. P + AsIII	9	735	5287	282	90	84	10	16
1.0 Fe. 0 Si. P + AsIII	10	647	5066	153	80	48	20	52
1.0 Fe. 0 Si. P + AsV	5	37	522	97	16	23	95	77
1.0 Fe. 0 Si. P + AsV	6	74	755	145	37	42	90	58
1.0 Fe. 0 Si. P + AsV	7	211	5578	368	100	100	72	0
1.0 Fe. 0 Si. P + AsV	8	197	5403	353	95	100	73	0
1.0 Fe. 0 Si. P + AsV	9	183	5656	283	85	79	75	21
1.0 Fe. 0 Si. P + AsV	10	136	5397	57	62	22	82	78
1.0 Fe. 0 Si. P + AsIII + AsV	5	0	0	0	100	100	0	0
1.0 Fe. 0 Si. P + AsIII + AsV	6	0	0	0	100	100	0	0
1.0 Fe. 0 Si. P + AsIII + AsV	7	0	3	0	100	100	0	0
1.0 Fe. 0 Si. P + AsIII + AsV	8	0	5	0	100	100	0	0
1.0 Fe. 0 Si. P + AsIII + AsV	9	40	562	91	95	70	5	30
1.0 Fe. 0 Si. P + AsIII + AsV	10	79	892	178	89	38	11	62
1.0 Fe. 0.67 Si. P + AsIII	5	55	879	82	7	26	93	74
1.0 Fe. 0.67 Si. P + AsIII	6	134	2037	238	16	77	84	23
1.0 Fe. 0.67 Si. P + AsIII	7	622	5227	294	79	100	21	0
1.0 Fe. 0.67 Si. P + AsIII	8	608	5074	269	77	90	23	10

Sample	pH	Precipitate			Precipitate		Supernatant	
		As ppb	Fe ppb	P ppb	As uM	P uM	As uM	P uM
1.0 Fe. 0.67 Si. P + AsIII	9	569	5245	238	72	76	28	24
1.0 Fe. 0.67 Si. P + AsIII	10	583	5686	209	64	60	36	40
1.0 Fe. 0.67 Si. P + AsV	5	15	272	26	2	7	98	93
1.0 Fe. 0.67 Si. P + AsV	6	111	1852	207	15	62	85	38
1.0 Fe. 0.67 Si. P + AsV	7	195	5178	325	26	98	74	2
1.0 Fe. 0.67 Si. P + AsV	8	197	5306	313	27	97	73	3
1.0 Fe. 0.67 Si. P + AsV	9	175	5531	267	23	82	77	18
1.0 Fe. 0.67 Si. P + AsV	10	149	5295	228	20	69	80	31
1.0 Fe. 0.67 Si. P + AsIII + AsV	5	410	4478	301	55	100	45	0
1.0 Fe. 0.67 Si. P + AsIII + AsV	6	423	4685	293	57	100	43	0
1.0 Fe. 0.67 Si. P + AsIII + AsV	7	406	4548	258	55	89	45	11
1.0 Fe. 0.67 Si. P + AsIII + AsV	8	322	4183	142	43	54	57	46
1.0 Fe. 0.67 Si. P + AsIII + AsV	9	30	653	44	4	15	96	85
1.0 Fe. 0.67 Si. P + AsIII + AsV	10	80	1354	139	11	56	89	44
1.0 Fe. 2.2 Si. P + AsIII	5	57	2179	132	7	49	93	51
1.0 Fe. 2.2 Si. P + AsIII	6	110	3159	192	14	70	86	30
1.0 Fe. 2.2 Si. P + AsIII	7	331	4733	264	43	88	57	12
1.0 Fe. 2.2 Si. P + AsIII	8	326	4886	243	41	79	59	21
1.0 Fe. 2.2 Si. P + AsIII	9	315	5006	216	38	64	62	36
1.0 Fe. 2.2 Si. P + AsIII	10	253	5086	171	30	50	70	50
1.0 Fe. 2.2 Si. P + AsV	5	395	8728	293	53	60	47	40
1.0 Fe. 2.2 Si. P + AsV	6	16	7	0	2	0	98	100
1.0 Fe. 2.2 Si. P + AsV	7	164	4833	284	22	95	78	5
1.0 Fe. 2.2 Si. P + AsV	8	161	5203	264	22	78	78	22
1.0 Fe. 2.2 Si. P + AsV	9	148	5196	239	20	69	80	31
1.0 Fe. 2.2 Si. P + AsV	10	114	5047	198	15	57	85	43
1.0 Fe. 2.2 Si. P + AsIII + AsV	5	403	4530	298	54	100	46	0
1.0 Fe. 2.2 Si. P + AsIII + AsV	6	400	4703	300	54	100	46	0
1.0 Fe. 2.2 Si. P + AsIII + AsV	7	365	4794	265	49	88	51	12
1.0 Fe. 2.2 Si. P + AsIII + AsV	8	331	4646	226	44	76	56	24

Sample	pH	Precipitate			Precipitate		Supernatant	
		As ppb	Fe ppb	P ppb	As uM	P uM	As uM	P uM
1.0 Fe. 2.2 Si. P + AsIII + AsV	9	59	2008	121	8	43	92	57
1.0 Fe. 2.2 Si. P + AsIII + AsV	10	107	3014	204	14	69	86	31
2.0 Fe. 0 Si. P + AsIII	5	55	1043	206	7	68	93	32
2.0 Fe. 0 Si. P + AsIII	6	291	2429	316	36	100	64	0
2.0 Fe. 0 Si. P + AsIII	7	753	9900	307	97	100	3	0
2.0 Fe. 0 Si. P + AsIII	8	769	10198	302	97	98	3	2
2.0 Fe. 0 Si. P + AsIII	9	717	9862	258	95	83	5	17
2.0 Fe. 0 Si. P + AsIII	10	771	10969	220	90	62	10	38
2.0 Fe. 0 Si. P + AsV	5	97	1086	206	13	63	87	37
2.0 Fe. 0 Si. P + AsV	6	199	7644	321	27	100	73	0
2.0 Fe. 0 Si. P + AsV	7	206	10492	327	28	97	72	3
2.0 Fe. 0 Si. P + AsV	8	194	10095	316	26	100	74	0
2.0 Fe. 0 Si. P + AsV	9	171	9814	261	23	81	77	19
2.0 Fe. 0 Si. P + AsV	10	146	9370	187	20	56	80	44
2.0 Fe. 0 Si. P + AsIII + AsV	5	262	4575	288	35	92	65	8
2.0 Fe. 0 Si. P + AsIII + AsV	6	260	4702	274	35	83	65	17
2.0 Fe. 0 Si. P + AsIII + AsV	7	215	4576	223	29	69	71	31
2.0 Fe. 0 Si. P + AsIII + AsV	8	180	4772	187	24	55	76	45
2.0 Fe. 0 Si. P + AsIII + AsV	9	85	1176	226	11	75	89	25
2.0 Fe. 0 Si. P + AsIII + AsV	10	283	2805	313	38	100	62	0
2.0 Fe. 0.67 Si. P + AsIII	5	59	1310	163	7	49	93	51
2.0 Fe. 0.67 Si. P + AsIII	6	605	5592	340	72	98	28	2
2.0 Fe. 0.67 Si. P + AsIII	7	805	10591	333	97	100	3	0
2.0 Fe. 0.67 Si. P + AsIII	8	770	9920	353	96	98	4	2
2.0 Fe. 0.67 Si. P + AsIII	9	757	10761	290	92	85	8	15
2.0 Fe. 0.67 Si. P + AsIII	10	275	4325	91	69	45	31	55
2.0 Fe. 0.67 Si. P + AsV	5	48	979	89	7	17	93	83
2.0 Fe. 0.67 Si. P + AsV	6	189	6445	307	25	100	75	0
2.0 Fe. 0.67 Si. P + AsV	7	198	9898	319	27	100	73	0
2.0 Fe. 0.67 Si. P + AsV	8	177	9614	280	24	95	76	5

Sample	pH	Precipitate			Precipitate		Supernatant	
		As ppb	Fe ppb	P ppb	As uM	P uM	As uM	P uM
2.0 Fe. 0.67 Si. P + AsV	9	124	7009	198	17	81	83	19
2.0 Fe. 0.67 Si. P + AsV	10	147	9679	204	20	65	80	35
2.0 Fe. 0.67 Si. P + AsIII + AsV	5	451	9466	315	61	100	39	0
2.0 Fe. 0.67 Si. P + AsIII + AsV	6	458	9380	317	61	100	39	0
2.0 Fe. 0.67 Si. P + AsIII + AsV	7	428	9159	273	58	89	42	11
2.0 Fe. 0.67 Si. P + AsIII + AsV	8	362	8270	182	49	62	51	38
2.0 Fe. 0.67 Si. P + AsIII + AsV	9	53	1168	115	7	41	93	59
2.0 Fe. 0.67 Si. P + AsIII + AsV	10	188	2452	272	25	100	75	0
2.0 Fe. 2.2 Si. P + AsIII	5	396	9223	295	35	73	65	27
2.0 Fe. 2.2 Si. P + AsIII	6	580	7508	310	73	100	27	0
2.0 Fe. 2.2 Si. P + AsIII	7	772	10579	314	93	95	7	5
2.0 Fe. 2.2 Si. P + AsIII	8	710	9944	302	88	96	12	4
2.0 Fe. 2.2 Si. P + AsIII	9	662	9794	255	81	83	19	17
2.0 Fe. 2.2 Si. P + AsIII	10	592	9916	239	72	68	28	32
2.0 Fe. 2.2 Si. P + AsV	5	25	6	0	3	0	97	100
2.0 Fe. 2.2 Si. P + AsV	6	201	7451	321	27	100	73	0
2.0 Fe. 2.2 Si. P + AsV	7	200	9874	293	27	100	73	0
2.0 Fe. 2.2 Si. P + AsV	8	172	9414	263	23	96	77	4
2.0 Fe. 2.2 Si. P + AsV	9	172	10364	261	23	81	77	19
2.0 Fe. 2.2 Si. P + AsV	10	148	10443	226	20	70	80	30
2.0 Fe. 2.2 Si. P + AsIII + AsV	5	438	9285	312	59	100	41	0
2.0 Fe. 2.2 Si. P + AsIII + AsV	6	419	8827	296	56	100	44	0
2.0 Fe. 2.2 Si. P + AsIII + AsV	7	410	9033	266	55	91	45	9
2.0 Fe. 2.2 Si. P + AsIII + AsV	8	366	9131	208	49	69	51	31
2.0 Fe. 2.2 Si. P + AsIII + AsV	9	82	2596	170	11	58	89	42
2.0 Fe. 2.2 Si. P + AsIII + AsV	10	329	6348	303	44	100	56	0