CEE 680 24 November 2009

SECOND EXAM

Closed book, two pages of notes allowed.

Answer all questions. Please state any additional assumptions you made, and show all work.

1. Carbonate System.

(60% for 1A-D) Two different drinking water supplies are used to provide a total plant flow of 15 MGD. Water #1 is a groundwater that has elevated levels of sulfide. Water #2 is an alkaline surface water. The two are characterized as follows:

Water	**Flow (MGD)**	**Alkalinity (mg/L as $CaCO_3$)**	**pH**
#1	10	5	6.50
#2	5	300	8.85

A. Water #1 is pre-treated with chlorine to oxidize the sulfide to sulfate prior to blending with water #2. If water #1 has a sulfide concentration of 3 mg/L, how much NaOCl must be added to oxidize the sulfide without any extra chlorine left (i.e., no residual chlorine; hint: 4M of chlorine react with 1 M of sulfide)?

B. What is its pH and alkalinity of water #1 immediately after the chlorine and sulfide react?

C. What will the pH of the blended water be immediately after mixing?

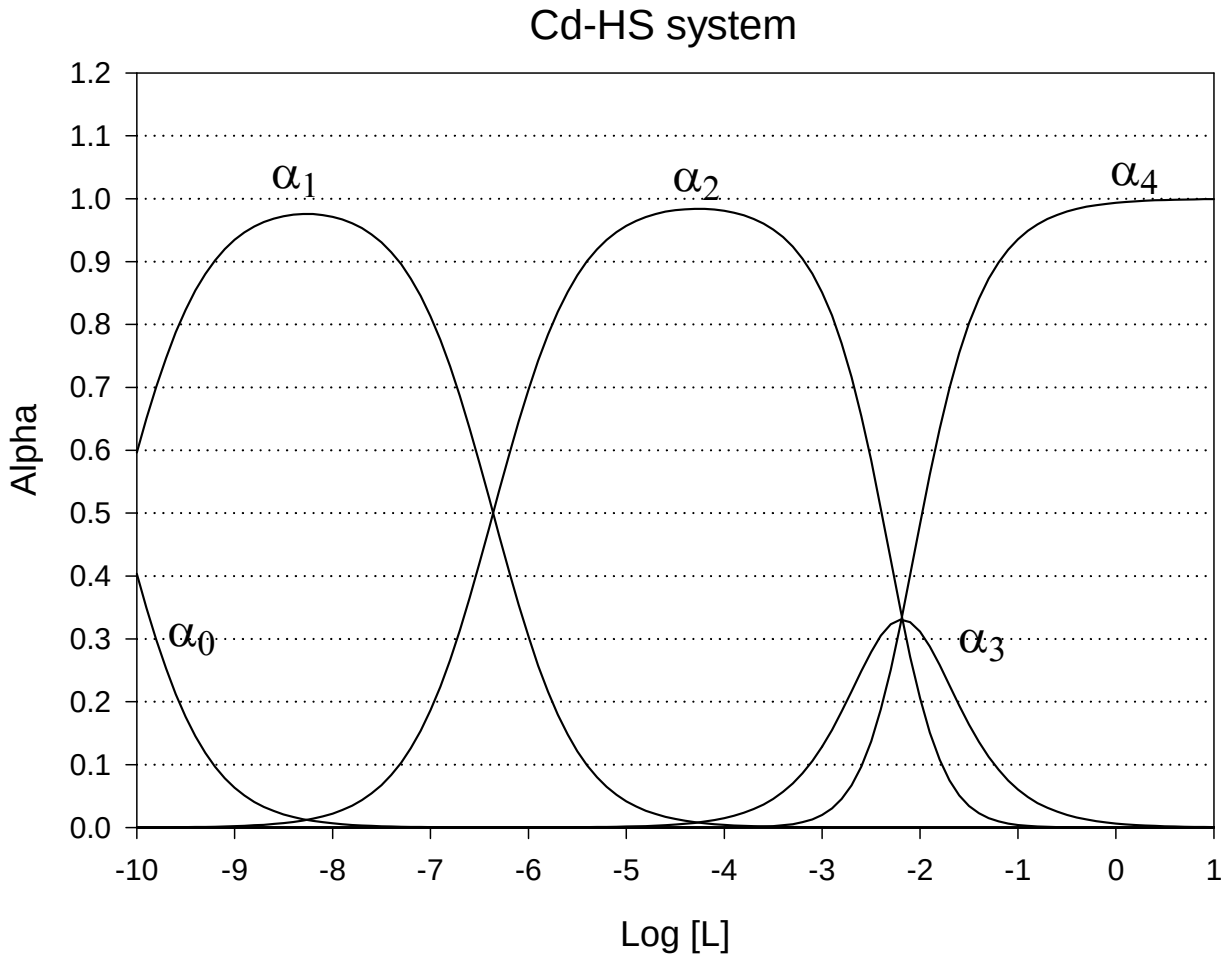
D. What will the pH of the blended water be after it has reached equilibrium with the bulk atmosphere?

2. Complexation

(40% total for both parts) Bisulfide forms strong complexes with many metals. The following two part problem concerns complexes with Cadmium and Copper.

A. (20%) Attached is an accurate graph of alpha values (vs log[HS-]) for the Cadmium-Bisulfide system (equilibria data shown below). Using this graph determine the complete species composition when the total Cadmium concentration is 0.50 mM and the total sulfide concentration is 1.0 mM. Ignore the possible formation of any other complexes other than

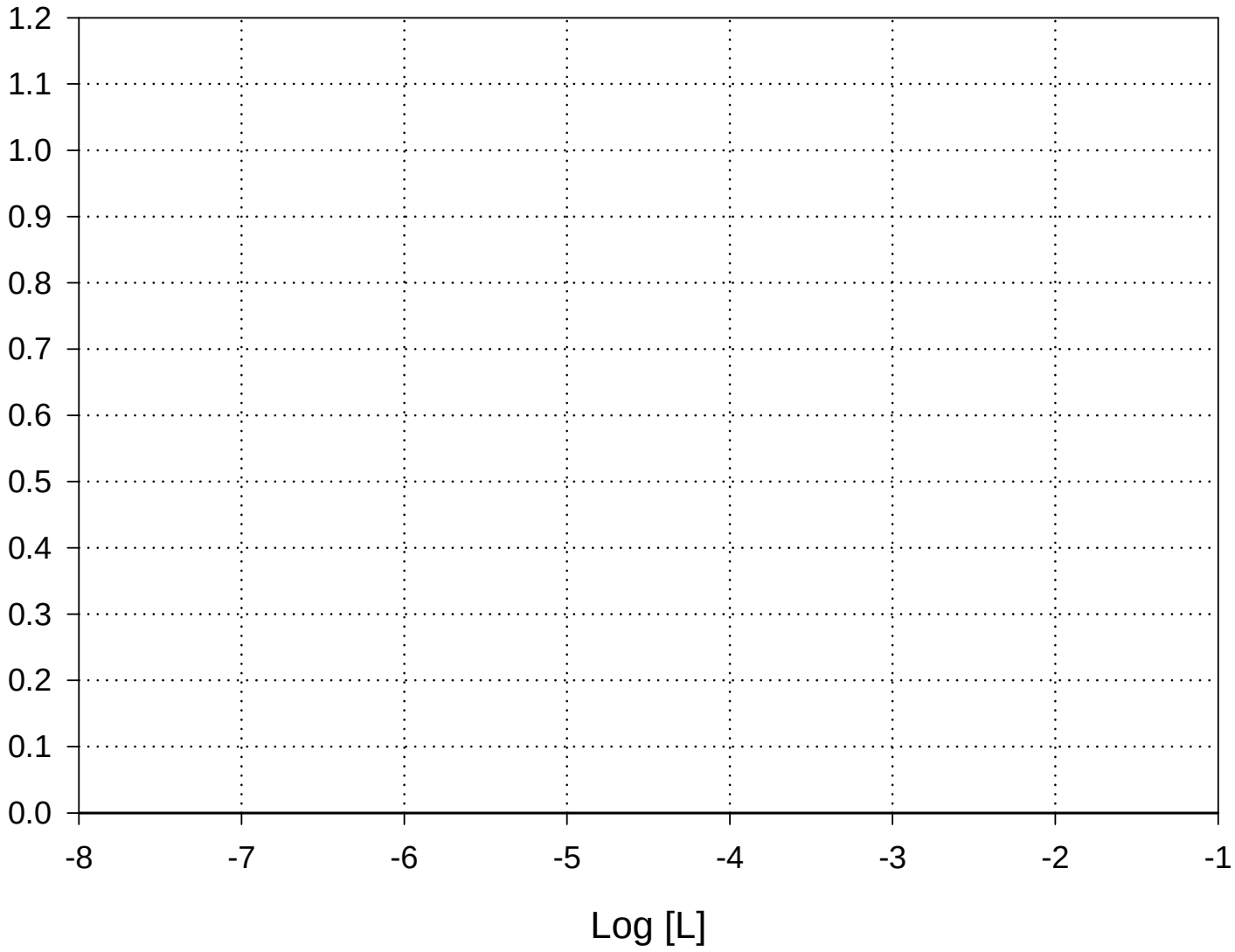
those from Cd and HS; also ignore any possible precipitation reactions. Assume the water is at neutral pH 9.

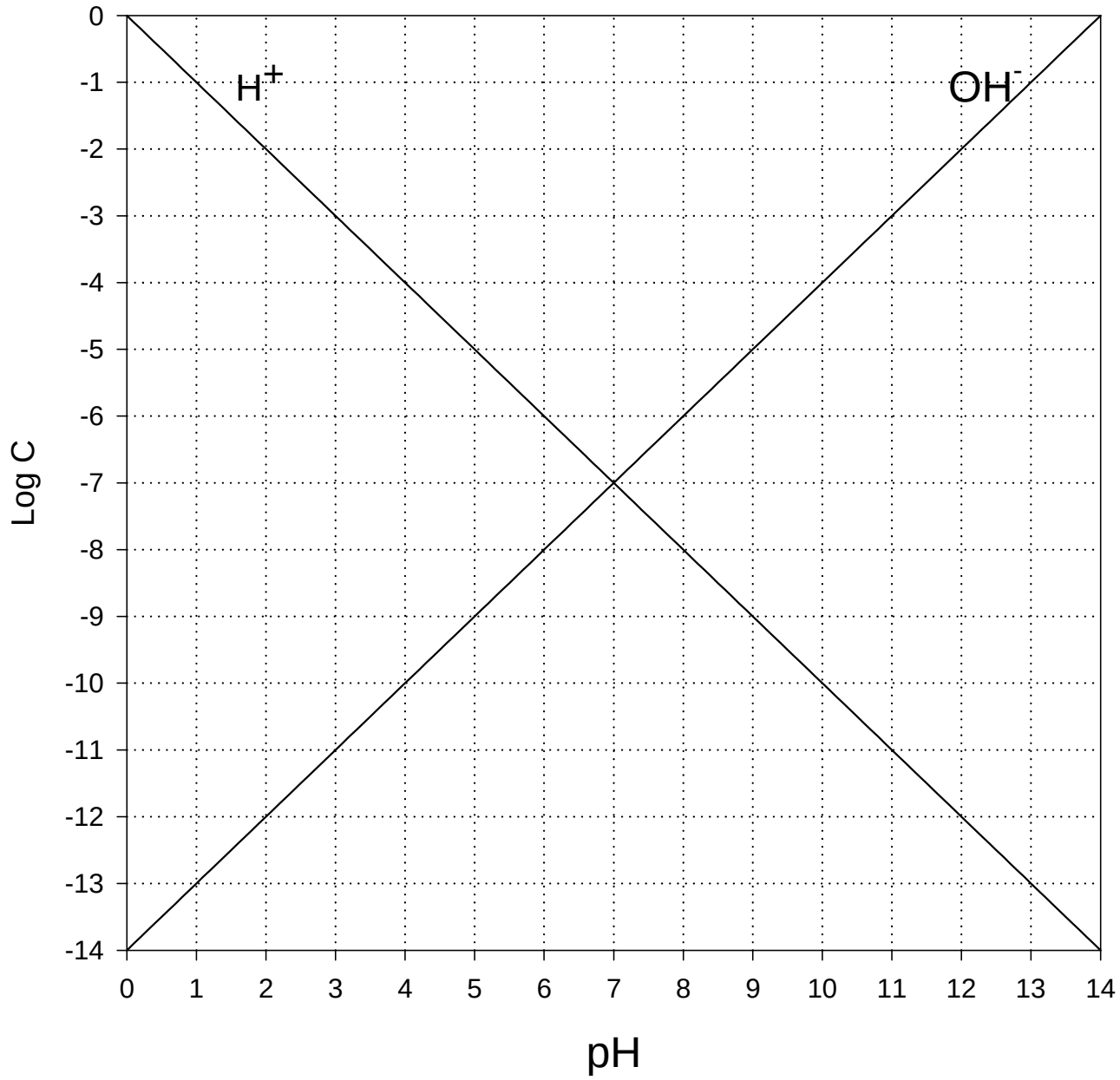


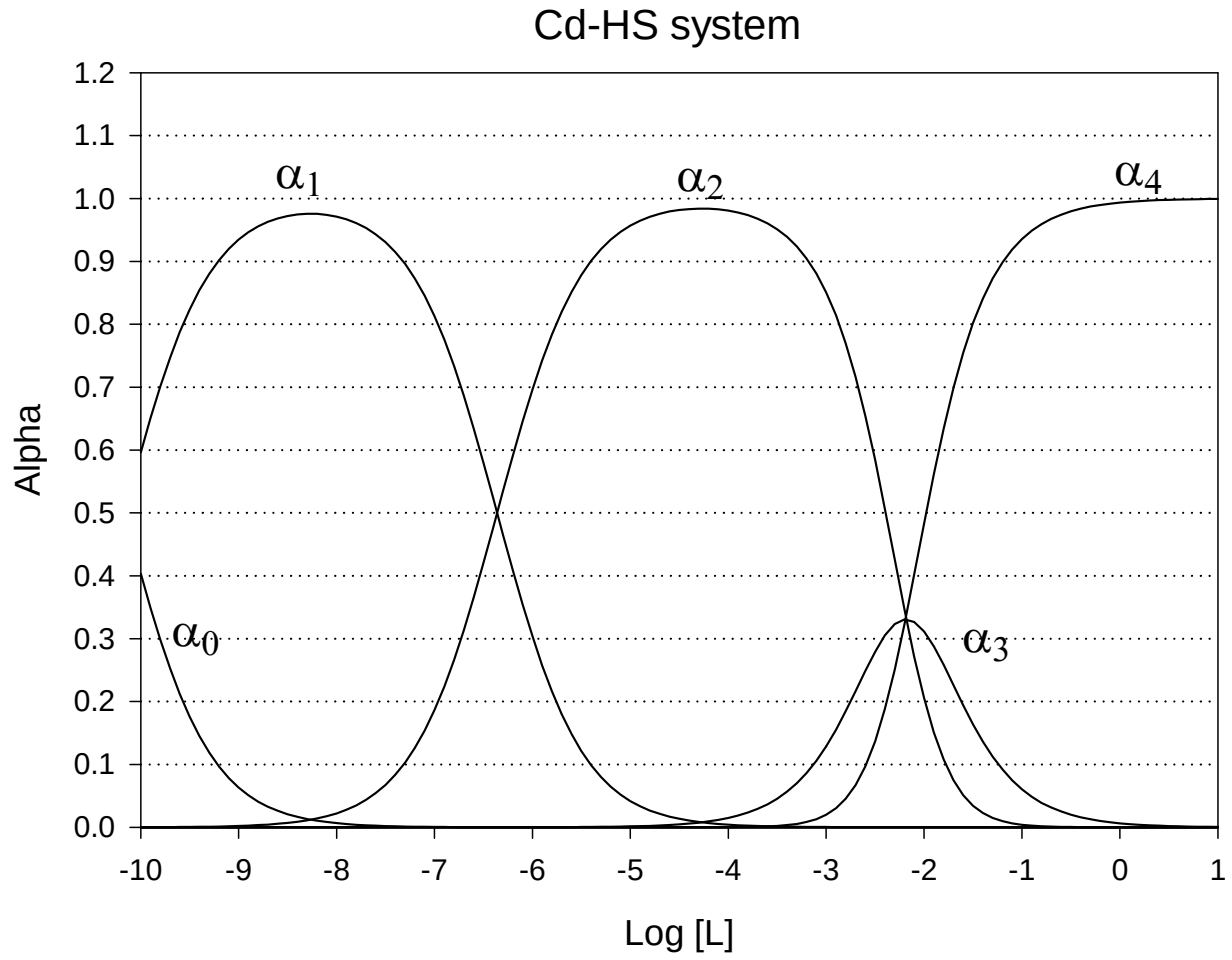
B. (20%) Your textbook notes that copper forms an especially strong $Cu(HS)_3^-$ complex with a log$ß_3$ equal to 25.9. No other Cu-HS complexes are listed. Based on this information, if you add 0.25 mM total copper to the solution in part A, what will the solution composition be?

Selected Acidity Constants (Aqueous Solution, 25°C, I = 0)

NAME	FORMULA	pK_a
Perchloric acid	$HClO_4 = H^+ + ClO_4^-$	-7 STRONG
Hydrochloric acid	$HCl = H^+ + Cl^-$	-3
Sulfuric acid	$H_2SO_4 = H^+ + HSO_4^-$	-3 (&2) ACIDS
Nitric acid	$HNO_3 = H^+ + NO_3^-$	-0
Hydronium ion	$H_3O^+ = H^+ + H_2O$	0
Trichloroacetic acid	$CCl_3COOH = H^+ + CCl_3COO^-$	0.70
Iodic acid	$HIO_3 = H^+ + IO_3^-$	0.8
Bisulfate ion	$HSO_4^- = H^+ + SO_4^{-2}$	2
Phosphoric acid	$H_3PO_4 = H^+ + H_2PO_4^-$	2.15 (&7.2,12.3)
Citric acid	$C_3H_5O(COOH)_3 = H^+ + C_3H_5O(COOH)_2COO^-$	3.14 (&4.77,6.4)
Hydrofluoric acid	$HF = H^+ + F^-$	3.2
Nitrous acid	$HNO_2 = H^+ + NO_2^-$	4.5
Acetic acid	$CH_3COOH = H^+ + CH_3COO^-$	4.75
Propionic acid	$C_2H_5COOH = H^+ + C_2H_5COO^-$	4.87
Carbonic acid	$H_2CO_3 = H^+ + HCO_3^-$	6.35 (&10.33)
Hydrogen sulfide	$H_2S = H^+ + HS^-$	7.02 (&13.9)
Dihydrogen phosphate	$H_2PO_4^- = H^+ + HPO_4^{-2}$	7.2
Hypochlorous acid	$HOCl = H^+ + OCl^-$	7.5
Boric acid	$B(OH)_3 + H_2O = H^+ + B(OH)_4^-$	9.2 (&12.7,13.8)
Ammonium ion	$NH_4^+ = H^+ + NH_3$	9.24
Hydrocyanic acid	$HCN = H^+ + CN^-$	9.3
Phenol	$C_6H_5OH = H^+ + C_6H_5O^-$	9.9
m-Hydroxybenzoic acid	$C_6H_4(OH)COO^- = H^+ + C_6H_4(O)COO^{-2}$	9.92
Bicarbonate ion	$HCO_3^- = H^+ + CO_3^{-2}$	10.33
Monohydrogen phosphate	$HPO_4^{-2} = H^+ + PO_4^{-3}$	12.3
Bisulfide ion	$HS^- = H^+ + S^{-2}$	13.9
Water	$H_2O = H^+ + OH^-$	14.00
Methane	$CH_4 = H^+ + CH_3^-$	34


1.2
1.1
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
-8
-7
-6
-5
-4
-3
-2
-1
Log [L]


0
-1
-2
-3
-4
-5
-6
-7
-8
-9
-10
-11
-12
-13
-14
Log C
H+
OH-
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
pH


Cd-HS system
Alpha
Log [L]
α0
α1
α2
α3
α4
1.2
1.1
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
-10
-9
-8
-7
-6
-5
-4
-3
-2
-1
0
1