National Exams December 2018

12-Mtl-B2, Hydrometallurgy and Electrometallurgy

3 hours duration

NOTES:

1. If doubt exists as to the interpretation of any question, the candidate is urged to submit with the answer paper, a clear statement of any assumptions made.
2. An approved Sharp or Casio calculator is permitted. This is a closed book exam.
3. Answer the first two problems and chose any 3 out of the remaining 4 problems (i.e., problems 3-6).
4. All sub-questions within a problem are of equal value.

Marking scheme

Each problem is worth 20 marks

Given:
$R=8.314\ J\ mol^{-1}\ K^{-1}$
$F=96{,}485\ C\ g\text{-}eq^{-1}$
For all aqueous species, take activities = concentrations

Problem 1

Sketch and discuss a generic process flow diagram for a hydrometallurgical process that is or should always be applicable to recover pure metals from minerals

Start with freshly excavated ore that contains the valuable metal as well as impurities, and end with a finished product (metal or pure compound). Show liquid, solid, recycle and bleed streams, as well as effluents and residues produced. Try to be as detailed as possible.

Problem 2

Define the differences of the following terms briefly by giving an example from a hydrometallurgical process operation:

a) Hydrolysis and Hydration
b) Speciation Diagram and Distribution Diagram
c) Cementation and Precipitation
d) Anode and Cathode
e) Galvanic cell and electrolytic cell
f) Solubility and Dissolution
g) Saturation, supersaturation, and undersaturation
h) Filtrate and raffinate
i) Ion exchange and solvent extraction
j) Electrowinning and electrorefining

Problem 3

The Figures below present Eh-pH diagrams for the systems Au-, Ag-, Cu-, and Fe-CN-H_2O respectively. In the light of these diagrams consider the following process systems:

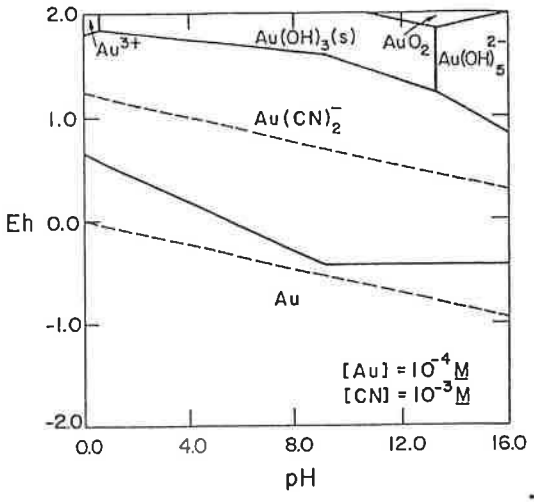
a) A piece of copper metal is immersed in a gold-cyanide ($Au(CN)_2^-$) solution at pH ~ 9.3 in the presence of air.

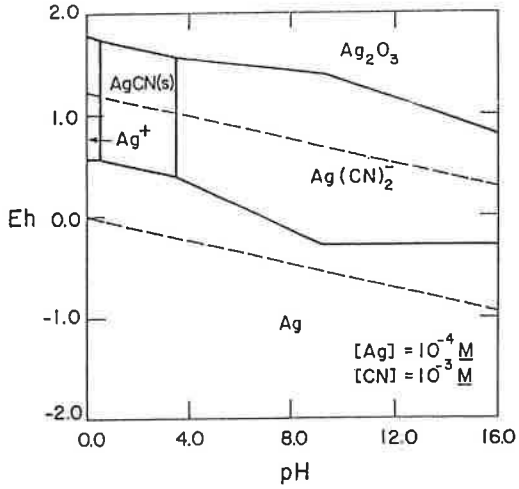
b) A piece of silver metal is immersed in a gold-cyanide solution at pH ~8 in the presence of air.

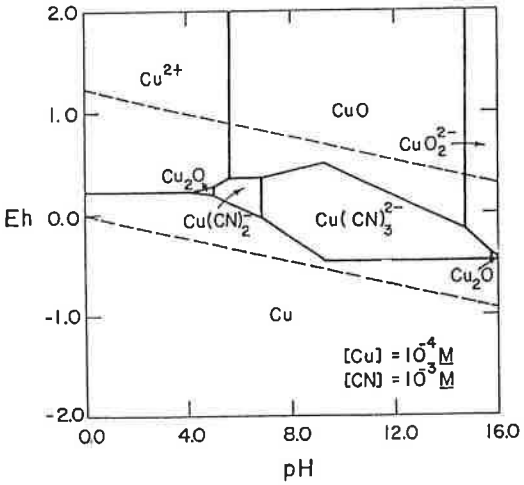
c) A piece of metallic (elemental) gold is immersed in a ferricyanide ($Fe(CN)_6^{3-}$) solution at pH ~ 9.3 in the absence of air.

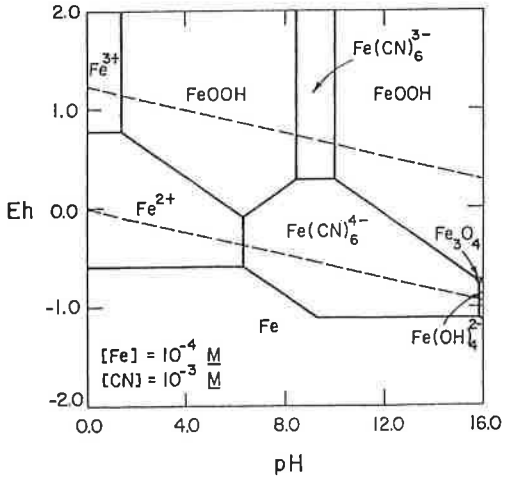
d) A piece of metallic (elemental) iron is immersed in a gold-cyanide solution at pH ~ 9.3 in the absence of air.

For each system, (i) describe in a sentence what you expect to happen, by referring to appropriate features in the Eh-pH diagrams provided; (ii) provide the relevant balanced chemical equations in the box below the Eh-pH diagrams; (iii) which metals can be produced by electrolysis and within which pH ranges; (iv) which metals can be produced by hydrogen reduction and within which pH ranges.









Problem 4

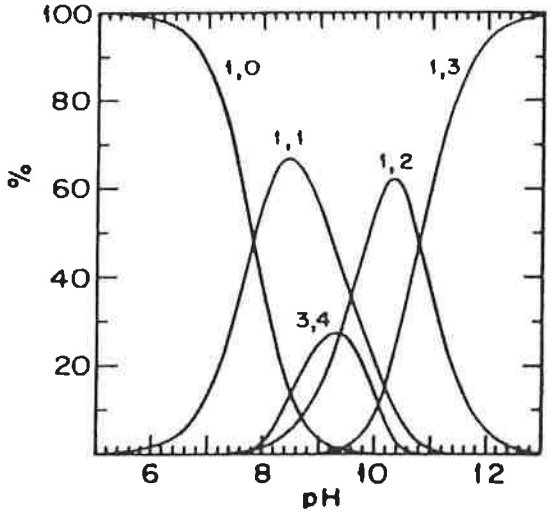
The Figure below presents speciation data (in mol % units) for a divalent metal in aqueous solution, where the symbol (x,y) refer to the species $M_x(OH)_y^{(2x-y)+}$.

a) Use this figure to determine the equilibrium constants for the following reactions:

$M^{2+} + OH^- = M(OH)^+$

$M(OH)^+ + OH^- = M(OH)_2(aq)$

$M(OH)^+ + 2OH^- = M(OH)_3^-$



b) Sketch the solubility curve of the metal hydroxide if its solubility product is 1.2×10^{-5}. Draw the solubility diagram and put appropriate units and values.

Problem 5

a) Given: 2×10^{-4} mol each of Mn^{2+} and Cu^{2+} are in 1 L of a 0.003 M HCl solution; then this solution is saturated with H_2S. Determine whether or not each of these ions, Mn^{2+} and Cu^{2+}, will precipitate as metal sulfide. Take the solubility of H_2S to be equal to 0.1 mol/L and assume to be independent of the presence of other components in the solution. K_{sp} of MnS is 3×10^{-14} and the K_{sp} of CuS is 8×10^{-37}. For H_2S, K_{a1} is 1×10^{-7} and K_{a2} is 1.2×10^{-13}.

b) How much Cu^{2+} remains in solution?

c) If the solution in part (a) is reduced to 10^{-7} M by lowering the [H+], will MnS precipitate?

Problem 6

(a) Provide the definition of the following terms and give an industrial example in each case: electrorefining, electrowinning, electroplating, overpotential, slimes, current efficiency, current density.

(b) Calculate the specific energy consumption expressed in units of kWh/kg of Zn^{2+} deposited on the cathode, during zinc electrowinning. You are given that the cell voltage is 3 V, the atomic mass of Zn is 65.4, and the current efficiency is 95%.