FACULTY OF ENGINEERING AND ENVIRONMENT

DEPARTMENT OF METALLURGICAL ENGINEERING

INTRODUCTION TO HYDROMETALLURGY

EMR 3201

Final Examination Paper

JULY 2019

This examination paper consists of 5 pages

Time Allowed: 3 hours

Total Marks: 100

Examiner's Name: Dr P. NCUBE

INSTRUCTIONS

1. Answer **ANY FOUR QUESTIONS**
2. Each question carries 25 marks
3. Use of calculators is permissible

Additional Requirements

Graph paper (on request)

MARK ALLOCATION

Question 1 to 6	**25 Marks**
Part Questions	**As shown in each part question**
Total Attainable	**100 Marks**

QUESTION 1

1.1 Inorganic acids such hydrochloric acid are commonly used as lixiviants in the leaching process. The concentration of the acid lixiviant solution and residential time are parameters that need to be optimized by carrying out leaching experiments with different concentrations at different residential time

Show how you would prepare a 1.5 M HCl solution in 1000 ml, given that the HCl concentration you are using is 32 %. Density is 1.16 g/cm^{-3} and molecular weight is 36.46 g/mol. **[5 marks]**

1.2 The table below shows the leaching data for Co^{2+} in different concentrations of hydrochloric acid as a function of the residential time. The leaching data is given as percentage Co^{2+} recovery. The feed to the leaching vessel was 70 ppm Co.

Table 3: Leaching data for Co^{2+} in different concentrations of hydrochloric acid as a function of the residential time

Time (minutes)	**0.5 M HCl Co^{2+} recovery**	**1.0 M HCl Co^{2+} recovery**	**1.5 M HCl Co^{2+} recovery**
30	10	15	20
60	25	35	45
90	50	60	70
120	65	78	83
150	75	80	88
180	80	86	95
210	83	90	99
240	86	95	105

1.2.1 Draw the curve expressing:

(i) the concentration of Co^{2+} in the leachate as a function of time and **[5 marks]**

(ii) as a function of the concentration of the lixiviant. **[5 marks]**

(Hint: show tabulated and related values). **[5 marks]**

(iii) Identify on the plot of Co^{2+} concentration versus time and give the optimum time to stop the leaching process. **[2 marks]**

(iv) Explain the effect of the concentration of the lixiviant on the recovery of cobalt. **[3 marks]**

QUESTION 2

2.1 A mine has recently introduced a bacterial leaching process. The mine needs to engage with stakeholders to explain some of the activities at their metallurgical bio-plant and ensure them of its safe and viable operation. You are appointed as a young metallurgist at the said mine. You are required to write short explanatory notes on the following:

2.1.1 Heap leaching **[3 marks]**

2.1.2 In-situ leaching **[3 marks]**

2.1.3 Discuss the advantages and disadvantages of bioleaching **[4 marks]**

2.1.4 Discuss direct and indirect bacterial leaching. What are microbial media? State the name and composition of bacterial media used for bioleaching of sulfidic ores. **[5 marks]**

2.1.5 Give a detailed account on the bioleaching of zinc sulfide ores. Give a detailed process with reactions and mechamisms, mentioning the bacterial strains used for each step in the process. **[10 marks]**

QUESTION 3

3.1 Calculate the mass of Zn deposited onto an inert lead cathode in an electrolytic extraction of zinc where the electrolytic cell is receiving a current of 20 Amps, for a duration of 6 hours. The atomic weight of Zn is 65.409. **[5 marks]**

3.2 Calculate the percentage of copper precipitated from a solution containing originally 0.5 copper/dm^3, pH is 6.05 and K_{sp} for the reaction;

$Cu(OH)_2(s) = Cu^{2+}(aq) + 2OH^-(aq)$ is 2.20×10^{-20} **[5 marks]**

3.3 A pregnant solution from the leaching of an oxidized Cu-Co ore contains 3% Co and 35% Cu and 30% Fe with the balance made out of the commonly found siliceous gangue compoments. Suggest and design hydrometallurgical recovery routes for Co and Cu where appropriate solvent extraction reagents are used. [Hint: a flowsheet may be useful]. **[5 marks]**

3.4 Ion-exchange is a reversible process in which ions attached to or incorporated in the molecular structure of a solid structure exchange with the surrounding solution.

3.4.1 Two main steps take place during the ion-exchange process: loading and elution. Draw and explain a typical ion-exchange loading curve showing breakthrough and saturation points. **[5 marks]**

3.4.2 Dowex 50 is a typical ion-exchange resin commonly used for the recovery of K^+, Na^+, Ba^{2+}, Sr^{2+}, Zn^{2+}, Cd^{2+} and La^{3+}. Based on the size and charge of the metal ions, explain the selectivity on their uptake from the same solution. **[5 marks]**

QUESTION 4

4.1 With the aid of relevant chemical equations, describe the role of cyanide and mercury in gold extraction. **[12 marks]**

4.2 Use the (micro)structure of an activated carbon flake to explain the mechanisms involved in the uptake of gold from its cyanide solution. A drawing of the (micro)structure would assist in the explanation. **[8 marks]**

4.3 Activated carbon is used in the extraction of gold. Progressively carbon become poisoned and loses its activity. The continuing activity of the carbon is very dependent upon its regeneration process. Explain the thermal regeneration of carbon for gold extraction. **[5 marks]**

QUESTION 5

5.1 During the metal extraction through electrowining, hydrogen may evolve from the electrodes. This would impede onto the effectiveness of the metal extraction process. Explain how to minimize or prevent the above hydrogen evolvement from happening.

[5 marks]

5.2 Metal activity in the electrolyte decrease as time evolves during the electrowining process. Using the Nernst equation in the electrowining of nickel explain the need to replenish the electrolytic bath with the feed of the same initial concentration for a fixed operating external voltage. **[5 marks]**

5.3 With the aid of standard reduction potentials explain why for the electrolytic extraction of Zn from its hydrometallurgical solution one has first to remove Fe present.

[4 marks]

5.4 An hydrometallurgical solution contains Cu, Ni and Co in quantities enough to be recovered in an economical electrolytic route. Suggest a specific way for the extraction of each of the individual metals. Justify your opinion. **[8 marks]**

5.5 During the electrowinning of base metals the Nernst equation is used to set and fix the potential of the electrolytic cell for an optimized metal recovery. As the process proceeds, bleeding of the electrolyte is required.

Explain the electrolyte bleeding process. **[3 marks]**

QUESTION 6

6.2 Copper ores naturally with significant amounts of iron, either as sulfides incorporated in the ore mineralogy like chalcopyrite or as attached out layer oxides. The inevitable consequence of this presence of iron minerals is that iron finds its way into the leachate. There is a strong need to remove iron by precipitation, to clarify the resulting leachate, to remove the existing impurities like cobalt and possibly nickel. The resulting purified solution is sent to the electrowining plant where copper is extracted prior to its refining through electrolysis.

6.2.1 Discuss with the aid of relevant equations, the iron precipitation process. **[5 marks]**

6.2.2 You are given a strip solution from a solvent extraction (SX) plant feeding into an eletrowining (EW) tank containing 50 g/L copper. The EW discharge is 40 g/L at a flow rate of 1 m3/min. There are 36 electrowining cells consisting of 30 cathodes, each cathode is 1 m x 1 m and operates at 3.5 V and 250 A/m^2 (Cu = 63.5 g/mol; F = 96500 C/mol]

(i) Calculate the mass of copper plated in one hour. **[5 marks]**

(ii) Using Faraday's law of electrolysis, calculate the total charge through the system for a duration of one hour. **[5 marks]**

(iii) Calculate the currency efficiency. **[5 marks]**

6.2.3 Explain the electrodynamics of the cell as the electrowining proceeds. **[5 marks]**

***************************END OF QUESTION PAPER**************************