Program	**National Diploma**
	EXTRACTION METALLURGY
SUBJECT	**HYDROMETALLURGY 3**
CODE	**MHD 311**
DATE	: SUMMER EXAMINATION 2015 24 NOVEMBER 2015
DURATION	: (SESSION 2) 12:30 - 15:30
WEIGHT	**40:60**
TOTAL MARKS	**100**

ASSESSORS	**PROF. A. F. MULABA-BAFUBIANDI**
MODERATOR	**Dr W. BOLHA**

INSTRUCTIONS: ONLY ONE POCKET CALCULATOR PER CANDIDATE MAY BE USED

PLEASE ANSWER ALL QUESTIONS

REQUIREMENTS: NONE

QUESTION 1 [30]

1.1. Base metal bearing sulfide minerals are often leached in sulfuric acid after the concentrate has been roasted and the calcine appropriately milled. Pachucas are used as leaching vessels. Suggest the shape of the vessel and discuss the lining materials onto the walls of the Pachucas to allow the leaching of the above mentioned base metal bearing minerals (Hint: a non-dimensioned drawing may be helpful). **(1+3)**

1.2. Leaching tanks are often used in a counter-current leaching arrangement or in a co-current leaching arrangement. In any of the above arrangements plot and explain the distribution function curves of the effect of the number of leach vessels in series on residence time. **(2.5 + 5)**

Table 1: Leaching data for Co^{2+} in different concentrations of sulfuric acid in function of the residential time.

Time (minutes)	0.5 M H_2SO_4 Co^{2+} % recovery	1 M H_2SO_4 Co^{2+}% recovery	1.5 M H_2SO_4 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

1.3. Leaching data for cobalt in sulfuric acid, table 1 here above, are expressed as percentage Co^{2+} recovery. The feed to the leaching vessel graded at 700 ppm cobalt.

1.3.a..Draw the curve expressing the concentration of Co^{2+} in the leachate in function of time and in function of the concentration of the lixiviant. (Hint: show tabulated and related values) **(5+5+5)**

1.3.b.Identify on the plot of Co^{2+} concentration versus time and give the optimum time to stop the leaching process. **(1.5)**

1.3.c. Explain the effect of the concentration of the lixiviant on the recovery of cobalt. **(2)**

QUESTION 2 [20]

Base metals are often extracted using electrolysis route. The atmospheric leaching or bioleaching are common processes. Zn, Co, Ni and Cu are often co-leached from the same feed. Using the standard electrode reduction potentials listed here below

2.1.Explain the expected natural dissolution sequence between Ni, Cu and Zn in a sulphuric acid aqueous solution. **(5)**

2.2. Explain why zinc scrap would be appropriate to be used in the cementation of gold. **(5)**

Standard electrode reduction potentials

Metal	E^0
Ca	-2.87
Mn	-1.18
Zn	-0.76
Co	-0.28
Ni	-0.25
H	0.00
Cu	+0.34
Au	+1.42

2.3. Copper is extracted and refined using electrolysis process. Explain with typical reactions at electrodes the copper electro refining process and elaborate on the role of the "anodic bag". (5)

2.4. Any hydrometallurgical process would produce wastes and present possible environmental challenges.

2.4.a. Explain the need to properly size the volume and concentrations of reagents to use and solutions to generate during the hydrometallurgical laboratory practicals. **(2.5)**

2.4.b. Elaborate on the necessity of a proper laboratory induction process. **(2.5)**

QUESTION 3 [30]

3.1. Gold bearing minerals from the Witwatersrand area are often leached in a cyanide solution prior to solid–liquid separation in a thickener. Consider a scenario where 25 tons per day solution grading 100 g gold per ton together with 25 tons per day of solids are pumped into the thickener and a 100 tons per day (barren) water ie containing 0 g Au per ton is used as wash water feeding the above thickener. An amount of 125 tons per day of solution (i.e.100 tons per day as pregnant overflowing solution and 25 tons per day solution in the residue) together with 25 tons per day solids in the residue leave the thickener.

3.1.a. Represent graphically ie draw the above mentioned thickener showing its feeds and products. **(2)**

3.1.b. calculate the amount of dissolved value (g/day) in the incoming solution. **(2)**

3.1.c. Using the mass balance approach calculate the average concentration of gold in the thickener. **(2)**

3.1.d. Calculate the mass of the dissolved values leaving the system in the residue (ie underflow) **(2)**

3.1.e. Calculate the mass of the dissolved values leaving the system in the overflowing pregnant liquor. **(2)**

3.1.f. Explain the role of the wash water and calculate the recovery ie washing efficiency. **(2)**

3.2. A metal like Cu, Zn, Ni, Au may be extracted from its aqueous by electrowinning.

3.2.a. Explain the electrolytic extraction (ie electrowinning) of Cu from its sulphuric aqueous solution. Use the electrode reactions in the explanation. **(4)**

3.2.b. Electrolytic extraction of Cu from its aqueous solution requires the use of electricity. In the unfortunate event of a load shading or complete absence of electricity for a while, and without any alternative electricity sources, cementation process is used. Explain the copper cementation when iron scrap is used. Describe the reaction mechanisms involved and calculate the equilibrium ionic ratio of $[Fe^{2+}]$ / $[Cu^{2+}]$ using the following E^0 (Cu^{2+}/Cu^0) = 0.34 V and E^0 (Fe^{2+}/Fe^0) = -0.41 V in the Nernst equation of the above mentioned system. **(3+5)**

3.3. South Africa is one of the important gold producers in the world. While reef gold minerals as well as refractory gold ores are exploited, activated carbon is used in the extraction of gold from the pregnant liquor. With increasing concentration of cations in solution the capacity of activated carbon for gold increases. A similar trend has been observed for the presence of anions in solution. The following selectivity scale is documented:

$Ca^{2+} > Mg^{2+} > H^+ > Na^+ > K^+$ and $NO_3^- > Cl^- > OH^- > SO_4^{2-} > SCN^- > S_2^- > CN^-$ This means that a salt like $CaCl_2$ enhances gold loading onto activated carbon whereas KCN inhibits it. Explain with details one of the mechanisms by which gold is adsorbed onto the activated carbon surface. **(6)**

QUESTION 4

4.1.You have been appointed as a metallurgist at PEJODEC Holdings (PTY,Ltd) where Cu and Ni are extracted from a sulphide concentrate. As a metallurgist, Management of the plant requires that you suggest an hydrometallurgical extraction route for each of the above mentioned metals. Explain how you would process the Cu and Ni minerals and get them ready for the extraction of Cu and Ni metals through electrolysis. (Hint: reaction mechanisms, hydrometallurgical processes involved, and possible electrode reactions would be useful). **(8)**

4.2. Iron control is one of the very important stages in the purification step of the liquor in the above question 4.1. Explain how you would deal with the removal of iron from the leachate which might have been produced. **(2)**

4.3. Ion-exchange is often used to remove impurities from aqueous solutions. Resins used as ion exchangers have to be regenerated. Explain how one would regenerate an ion-exchanger for the recovery of base metals. **(4)**

4.4. Elaborate on the impact of the poisoning of an ion exchanger resin on the effectiveness of the ion exchanger and suggest means to minimise it. **(6)**

Total: **[100]**
