IMPERIAL COLLEGE LONDON

Metals and Energy Finance (MSc)

Project Evaluation - Extractive Metallurgy

4 May 2017 10.00 – 12.00

Answer <u>THREE</u> out of the FOUR questions.

Each question carried 25 marks. . Do not answer more than three questions.

QUESTION 1 – Comminution Circuit

A crushing circuit consists of a primary gyratory crusher located near the pit. This is in open circuit, with the product being conveyed to the processing plant. In the plant this material is then fed onto a screen, with the underflow acting as the feed for the milling circuit. The overflow from the screen (oversized material) then acts as the feed for a secondary cone crusher, with the product from this crusher being fed back onto the screen.

a) Draw the circuit, labelling items. (3)

The total solids feed rate to the circuit is 1000 t/hr. Consider two particle size fractions, namely particles above and below 1cm. In the feed to the circuit only 10% of the material is below 1cm in size. The gyratory crusher will break 40% of the material above 1cm to below 1cm in size, while the cone crusher will break 50% of this material to below 1cm. The screen has a partition number of 0.8 for the larger particles and a partition number of 0.25 for the finer particles.

b) Carry out a mass balance over the circuit calculating the mass flowrates of each of the components in each of the streams. What is the percentage passing 1cm in the mill circuit feed? (10)

In the crushing circuit a small amount of water will be used in the screens to aid its performance, with most of this water passing through the screen and thus into the mill circuit. This water isn't enough for optimum milling performance and so additional water will be added to the mill feed.

c) If the SG of the solids is 2.8, what is the total water addition rate that will be required to achieve a 35% by volume solids content? (4)

Screens beds are often made of reinforced polyurethane panels with square apertures in them. Over time the apertures in these screens can wear.

d) What will this do to the cut size of the mill feed and the circulating load in the crusher circuit and why? (4)

The 80% passing size for the mill circuit feed is 0.9cm and for the product it is 120 µm.

e) What will the power requirement of the milling circuit be given that the Bond work index of the material is 10kWh/t? (4)

QUESTION 2 – Flotation

A rougher bank has 4 cells in it. The feed to the bank has a solids mass flowrate of 1500 t/hr and a grade of 1% copper. In order to assess the performance the flowrate and grade of the concentrate streams from each of the cells was measured:

	Cell 1	Cell 2	Cell 3	Cell 4
Concentrate Grade	25	20	15	12
Solids flow rate to concentrate (t/hr)	10	8	6	5

a) Calculate the cumulative down the bank grade recovery curve. (8)

Flotation circuits typically consist of banks of cells, with a rougher, cleaner, scavenger arrangement being a commonly used one.

b) Sketch a standard rougher, cleaner, scavenger circuit labelling the banks and streams. (3)

An operator decides to decrease the froth depth in the cells in the rougher bank.

c) What will be the impact on the performance of this bank? (1)
d) If the operating conditions in the other banks are not changed, what will the likely impact be on the performance of the cleaner bank? How is the circulating load in the recycle stream likely to change? What will the overall impact on the circuit performance be? Why? (4)

Industrial flotation circuits are seldom fully instrumented, which means that performance often needs to be calculated based on a range of different measurements.

A flotation cell has continuous measurements for its volumetric feed rate, but there are no flow measurements available for either the tails or concentrate.

e) Assuming that the total volumetric feed rate to cell is 1200 m^3/hr, the SG of the slurry is 1.6 and the SG of the solids is 2.6, what is the mass rate of solids in the feed? (4)

In addition, samples were taken of the solids in the feed, concentrate and the pulp zone of the flotation cell. These were assayed, with the following Nickel grades being measured:

	Nickel Grade (%)
Feed	1.0
Concentrate	10.0
Pulp Zone	0.6

f) Assuming that the pulp zone is well mixed, calculate the overall Nickel recovery for the cell and the flowrate of the concentrate stream? (5)

QUESTION 3 – Classification and Performance

In order to test two new cyclone designs, the same feed material was fed into both of them at the same rate (20 t/hr). The back pressure on the overflow in each cyclone was then varied to give a mass recovery to the underflow of 40%.

To test the performance the flowrate and particle size distribution of the underflow from each cyclone was measured. The particle size distribution for each measured stream was obtained by placing 200g into sequence of sieve screens, with the amount of material retained on each screen being weighed. The following table gives the amount of material retained on the corresponding sized sieve:

	Mass on sieve		
	Feed	Underflow	
Sieve size		Cyclone 1	Cyclone 2
microns	g	g	g
150	0	0	0
105	35	84	62
74	58	70	69
53	61	36	45
Undersize	46	10	24

a) Calculate the cumulative size distribution for the feed and underflow streams. (6)

Performance can be assessed based on the cyclone's partition curves.

b) Calculate the partition number and the appropriate representative size for each size interval for both cyclones. (8)

c) Even though the cut size (d50) for the two cyclones are very similar, which one performs better and why? (3)

While the solids recovery to the underflow in each of these cyclones is the same, the partition curves indicate that the water recoveries are probably different.

d) Which of these cyclones probably has the highest water recovery? What made you choose that cyclone? (3)

Even though they were not directly measured, the properties of the overflow streams can also be calculated:

e) Calculate the cumulative size distribution for the overflow streams. (5)

QUESTION 4 – Hydrometallurgy

For copper there are advantages and disadvantages to using heap leaching versus milling, flotation and smelting.

a) The decision will depend upon both the type and size of the ore body. Under what circumstances might heap leaching be the preferred option and why? (4)

Some mines make use of a combination of heap leaching and more conventional processing routes.

b) How might this be advantageous? (3)

A new copper mine is planning on using an on-off leaching system in which the leach pad is reused, with the leached material being placed onto waste dumps. The cycle will consist of 1 months for heap construction, 12 months of leaching and 1 month for disposal. A number of separate leach pads will be used to ensure continuous production.

The planned rate for the ore to be processed by leaching is 60 000 tpd. The SG of the ore is 2.4 and the stacked heap will have a voidage of 20%. The heaps will have a height of 15m

c) How much land area is required in order for the heaps to achieve this production rate? Include an additional 15% to account for the non-vertical slopes at the edges of the heap and the space for ancillary equipment. (4)

The average copper grade of the ore is 0.7 %. The total pregnant solution flowrate from all the leach pads is 8 000 m^3/hr, with an average concentration of 1.8 kg/m^3, with the concentration of copper in the lixiviant that is irrigated onto the heap being 0.2 kg/m^3 (ignore any solution or copper losses to the environment in these calculations)

d) What is the average copper recovery for the process? (3)

The copper is extracted from the pregnant solution using solvent extraction. In the loading section of this process copper is removed from the pregnant solution into an organic phase, with the barren solution being used as the lixiviant after the addition of appropriate makeup acid (you can ignore the contribution of the acid to the flowrates).

e) If the organic phase entering the loading section has a copper concentration of 1 kg/m^3 and it leaves with a concentration of 6 kg/m^3, what is the flowrate of the organic phase? (2)

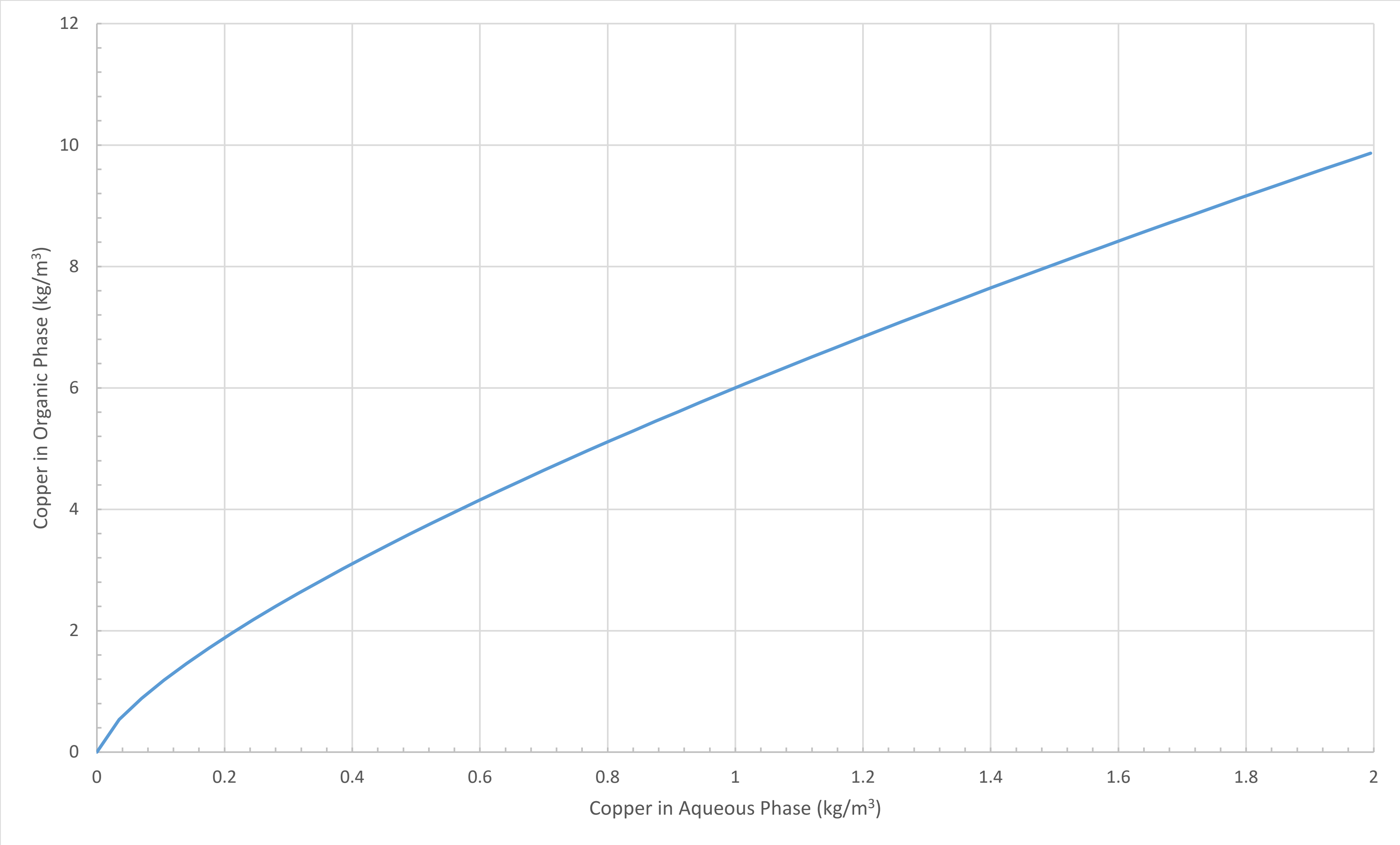
The attached sheet gives the equilibrium curve between the copper in the aqueous solution and that in the organic phase.

f) Use this sheet to calculate the number of loading stages required assuming that each stage achieves equilibrium. Show working and hand in the sheet. (6)

After the loading section the copper is removed from the organic phase into an electrolyte solution in the stripping section. 60% of the copper in solution is then recovered by electro wining, with the remaining copper being recycled in the electrolyte solution to the stripping stage.

g) If the concentration of the copper in the depleted electrolyte is 30 kg/m^3, what is the flowrate of the electrolyte? (3)

CID Number: ____



12
10
8
6
4
2
0
Copper in Organic Phase (kg/m3)
0
0.2
0.4
0.6
0.8
1
1.2
1.4
1.6
1.8
2
Copper in Aqueous Phase (kg/m3)