IMPERIAL COLLEGE LONDON

Metals and Energy Finance (MSc)

Project Evaluation - Extractive Metallurgy

28 April 2016 10.00 – 12.00

Answer THREE out of the FOUR questions.

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

QUESTION 1 – Comminution

A milling circuit consists of a primary SAG mill that is in open circuit. This is then followed by 2 secondary ball mills in parallel. The product from the SAG mill is fed to the ball mills, with the product from the ball mills being combined and classified in cyclones. The underflow from the cyclones is recycled, with the overflow forming the feed to the flotation circuit.

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

The milling circuit has a feed rate of 1 500 t/hr. Consider 2 size classes, above and below 75 microns. The feed has 25% passing 75 microns and each of the mills breaks 50% of the material in the feed above 75 microns to below 75 microns. The partition number for the particles above 75 microns is 0.75, while that below 75 microns is 0.25.

b) Carry out a mass balance to calculate the mass rate of both size fraction in each stream. What is the feed rate to each of the ball mills? What is the percentage passing 75 microns in the circuit product/flotation feed? (9)

This milling circuit's feed has 80% passing 1 cm and the final feed to the flotation circuit has 80% passing 60 microns.

c) If the Bond work index is 15 kWh/t, estimate the energy requirement for this circuit. (2)

The viscosity of the slurry has a strong impact on the milling performance. This viscosity is, in turn, strongly dependent on the volume percent solids in the slurry.

d) Given that the feed rate to the milling circuit is 1500 t/hr of solid, how many tonnes per hour of water do we need to add to achieve a solids content of 30% by volume in the feed given a solid SG of 2.5? (4)

If there is no additional water added to the circuit, the solids content in the feed to the ball mill is likely to be different to that in the feed to the SAG mill.

e) Is the solids content in the feed to the ball mill likely to be higher or lower than that to the SAG mill and why? (3)

It was decided to replace the cyclones in the circuit with ones with a smaller diameter.

f) What would this do to the d50 of the cyclone? (1)

g) What impact would this have on the feed rate into the mill and why? (3)

QUESTION 2 – Flotation

A rougher bank has 4 cells. The feed to the circuit has a mass rate of 1000 t/hr and a grade of 2% copper. The individual cells down the bank have the following grades and recoveries:

	Cell 1	Cell 2	Cell 3	Cell 4
Grade	30	25	18	10
Recovery	35	30	25	20

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

A very standard flotation bank may consist of rougher, scavenger and cleaner banks. In these banks you can change the grade and recovery by varying the froth depth

b) How would the grade and recovery change if you increased the froth depth? (2)

c) As there is virtually always a compromise between grade and recovery when operating a flotation cell, which would you target in the rougher, scavenger and cleaner banks (at least relative to the other banks) and why? (4)

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A plant has a simple circuit layout with a rougher and a cleaner bank (there is no scavenger bank). The feed to the circuit enters the roughers, with the tails of the rougher circuit going to the final tails. The concentrate from the rougher bank feeds the cleaner bank. The cleaner bank's concentrate is the final concentrate and its tails are recycled back to the rougher feed.

d) Sketch the circuit and label the flotation banks and streams. (2)

The feed to the circuit is a 1000 t/hr and the grade of the valuable mineral in the feed is 5%. For the valuable mineral the rougher bank has a recovery of 90% and the cleaner bank a recovery of 60%.

e) What is the overall recovery for the circuit? (6)

The recovery of gangue in each of the banks is 10%.

f) What is the final concentrate grade? (3)

QUESTION 3 – Classification and Performance

A cyclone's performance is being assessed, but the feed is inaccessible and so it is the underflow and overflow streams that are measured. The size distribution of each stream is measured by placing a representative sample into the top of a stack of sieves. The following table gives the mass retained on each of the sieve screens (i.e. the mass is the amount of material larger than the corresponding size and smaller than the size above).

	Mass on sieve	
Sieve size	Underflow	Overflow
microns	g	g
212	0	0
150	37	5
105	25	11
74	14	24
53	12	34
Undersize	16	56

The measure mass flowrate to the underflow is 24 t/hr and the overflow is 35 t/hr.

a) What is the mass recovery to the underflow? (2)
b) Calculate the cumulative size distributions of the underflow and overflow. (4)

The performance can be assessed using partition numbers.

c) Calculate all the partition numbers and their corresponding representative sizes. (5)
d) What is the d50 and bypass ratio? (2)

You have enough information to calculate the size distribution of the feed.

e) Calculate the cumulative size distribution of the feed. (4)

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It is often not possible to measure the flow rates of all streams that you might wish to. Around one cyclone only the flow rate of the underflow can be measured directly, but the density of all the streams can be measured quite easily. The measured total flow rate (water and solid) of the underflow is 35 tph. The feed slurry has an SG of 1.8, the underflow an SG of 2.0 and the overflow an SG of 1.6. The SG of the solids is 2.5.

f) Calculate the mass percent solids in each of the streams. (3)
g) What is the mass flow rate of the feed and overflow? (5)

QUESTION 4 – Gold Processing

A gold mine produces a low grade ore that is leached using cyanide in heap leach. The initial average grade of ore in the heap is 1.5 g/t. A new lift is to be added to the valley fill heap. This lift will contain 1 million tonnes of ore when completed. The specific gravity of the ore is 2.5 and the voidage is 20%.

a) What is the volume of the heap? (3)

The heap has a liquid addition rate to the top surface of 10 litres/m^2/hr (the units are awful, but are those typically used in heap leaching). This mine is in a desert environment and so 5% of the liquid added is lost through evaporation. The total average flowrate of liquid out of the heap is 300 m^3/hr.

b) What is the height of the lift? (3)

This lift is leached for 150 days and the average gold concentration in the pregnant leach solution is 1 mg/litre (the concentration decreases with time, but this is the average).

c) If we ignore the effect of any additional gold that might be leached out of other lifts, what is total gold recovery from this lift? (3)

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Heap leaching for gold is typically used for gold if the head grade is either low or the deposit is too small to justify the capital investment required to build a conventional plant. Another mine has a large deposit with an average head grade of 10.0 g/t. It was therefore decided that milling followed by tank leaching would be used.

It was found that 5% of the gold was refractory and that the rest of the gold followed first order kinetics in its leaching. The gold processing plant uses a set of 5 cyanide leaching tanks in series followed by a CIP circuit. The current tanks achieve an overall leaching extraction of 80%.

d) Assuming that the kinetics for the leachable gold is the same in each tank, what extraction would be achieved if an additional 5 tanks were added to the circuit? (4)

The leaching circuit is fed at the rate of 500 t/hr of solids and the solids content is 50% by weight, with a solids density of 2.6. Each tank in the leaching circuit has a volume of 2000 m^3.

e) What is the total residence time of the 5 tanks in the leaching circuit? (3)

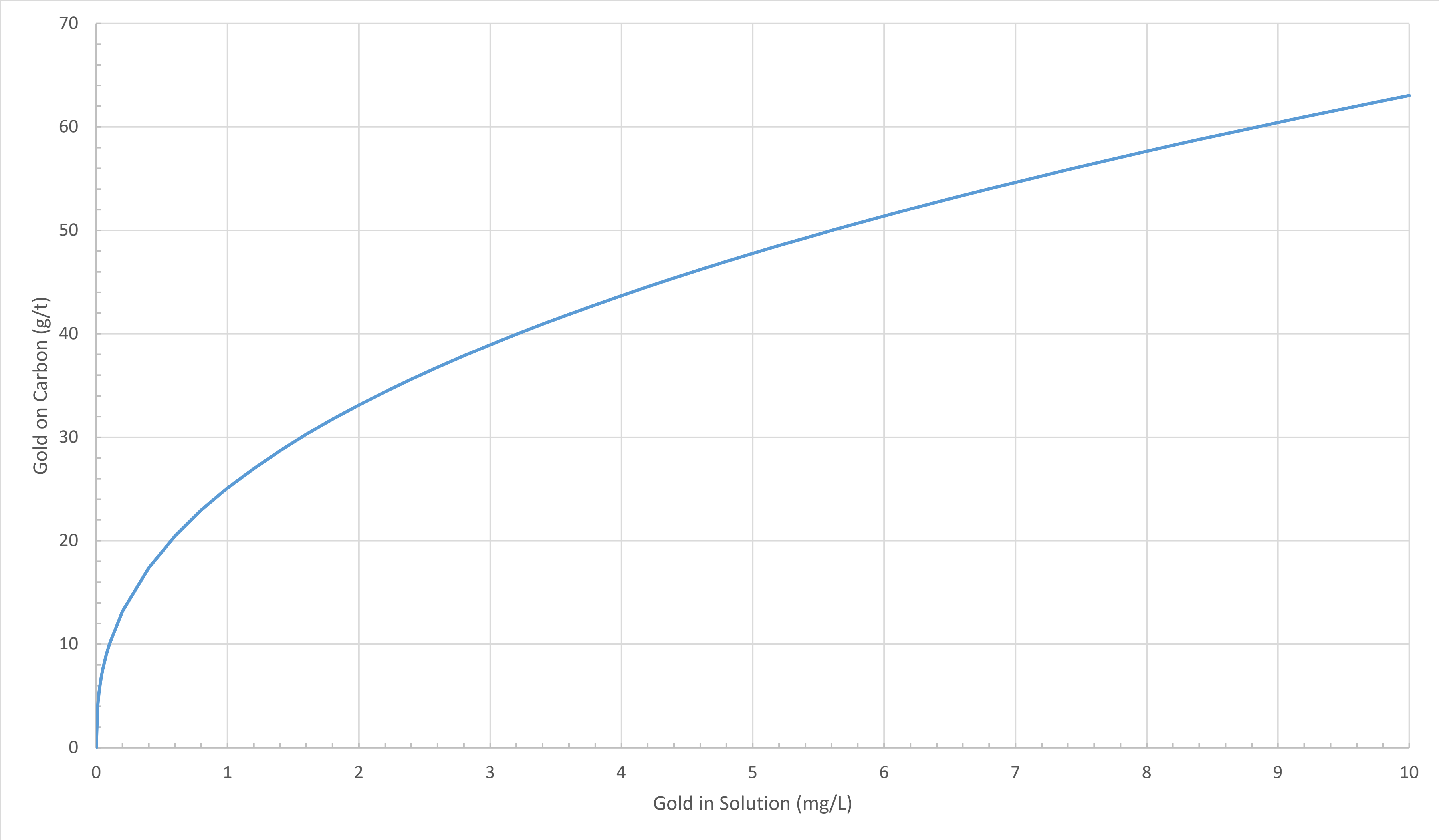
In the CIP circuit which follows the leaching circuit carbon is contacted with the solution in a counter-current fashion. 97.5% of the gold in solution is recovered, resulting in a change in the amount of gold loaded onto the carbon from 10 g/t in the carbon returning from the elution and reactivation to 50 g/t as it leaves the CIP circuit.

f) What is the mass flow rate of carbon through the circuit? (2)

For the purpose of these calculations it can be assumed that each of the CIP stages are in equilibrium and that at equilibrium the relationship between the gold in solution and that loaded on the carbon follows the relationship on the attached graph.

g) How many equilibrium stages are required to achieve this extraction? Show all calculation as well as the constructions on the graph (hand graph in). (7)

CID Number: ____



70
60
50
40
30
20
10
0
Gold on Carbon (g/t)
0
1
2
3
4
5
6
7
8
9
10
Gold in Solution (mg/L)