ORDRE DES INGÉNIEURS DU QUÉBEC

NOVEMBER 2014 SESSION

All documentation allowed
Hand calculators : Authorised models only
Duration of the test : 3 hours

14-MI-A3 Mineral processing

The test consists of 4 pages. Make sure that you have the complete text prior to begin.

Unless it is specified to use another definition:

- *A ton indicates a metric ton (1000 kg);*
- *A $ indicates a canadian $;*
- *Species concentrations are given in % weight (% w/w);*

If required use the data of the following tables:

Molar masses (grams)			
Aluminum : 27.0 Antimony : 121.8 Arsenic : 74.9 Carbon : 12	Copper : 63.5 Iron : 55.8 Magnesium : 24.3 Manganese : 54.9	Gold : 197 Oxygen : 16 Lead : 207	Silicium: 28.1 Silver : 107,9 Sulphur : 32 Zinc : 65.4

Units of length 1 inch = 2.54 cm 1 foot = 12 inches 1 yard = 3 feet 1 m = 100 cm = 1,000,000 microns (µm)	<u>Units of mass</u> 1 kg = 2.204 pounds 1 short ton = 2000 pounds 1 pound = 16 ounces 1 ounce troy = 31.105 g
<u>Units of volume</u> 1 m^3 = 1000 liters 1 US gallon = 0.1336 cubic foot USGPM = US gallon per minute	<u>Units of temperature</u> °C = K - 273 = (°F-32)·5/9

Question 1 : Processing bauxite ores (15 points)

a. Identify the process that is used for alumina production from bauxite. Identify the reagents used and the various steps of the process. Draw a simplified flow sheet of the process (4 pts).
b. What is red mud and what is the main constituent of red mud? (1 pt)
c. A bauxite ore contains 80% $Al_2O_3.3H_2O$, 4% SiO_2, 15% Fe_2O_3, 1%TiO_2. Processing of this bauxite leads to the production alumina assaying 99.7% Al_2O_3, 0.1%SiO_2, 0.1 Fe_2O_3 and 0.1%Na_2O. The aluminum content of the bauxite plant reject is 6.2%. Calculate the mass of alumina that is produced from the processing of 100 tons of this bauxite (5 pts)? What is the plant aluminum recovery from the bauxite plant feed to the alumina concentrate (5 pts)?

Question 2 : Processing of iron ores (15 points)

a. The two major iron carrier minerals are hematite and magnetite. Give the composition of these minerals and the iron content of each mineral (1 pt).
b. Describe the operation of a gravity spiral used for iron ore concetration (2 pts)?
c. Describe the operation of a magnetic separator used for the recovery of magnetite (2 pts)?
d. A concentrator processes an iron ore containing 37%Fe in the form of hematite. The iron oxide concentrate contains 66.5%Fe and the rejects contain 8%Fe and 85% quartz. The concentrator processes 40 000 tons of ore per day. Calculate the mass (tons) of iron oxide concentrate produced each day (5 pts). What is the quartz concentration in the concentrator feed if the concentrate assays 4.2% quartz (5 pts)?

Question 3 : Processing of copper ores (15 points)

a. What is the copper content of chalcopyrite (1 pt);
b. The main copper carrier mineral in a copper ore is chalcopyrite. The gangue minerals are pyrite (FeS_2 and quartz (SiO_2). The copper mineral are concentrated by flotation:
    i. The usual particle size of the ore feeding a Cu-flotation circuit is:
        1. Larger than 1 mm;
        2. Between 0.5 and 0.1 mm;
        3. Less than 0.1 mm?

    Briefly justify your answer (2 pts);

    ii. The pH of the slurry in the rougher bank is usually :
        1. Lower than 2.0;
        2. Neutral or slightly alkaline;
        3. Larger than 11.0?

    Briefly justify your answer in terms of pyrite depression (2 pts);
c. The recovery of copper by the concentrator is 92%. If the ore feeding the concentrator contains 2.4% Cu and that the plant rejects contain 0.21%Cu, calculate the copper content of the concentrate (5 pts). Calculate the pyrite concentration in the concentrate if the iron contents in the concentrate and plant rejects are respectively 34.33% and 15.28% Fe (5 pts).

Question 4 : Semi-batch flotation tests for a Cu-Zn ore (30 points)

Laboratory semi-batch flotation tests are conducted to assess a collector for copper ore minerals. The ore tested consists of chalcopyrite ($CuFeS_2$), pyrite (FeS_2), marmatite ($Zn_{0.94}Fe_{0.06}S$) and SiO_2. Semi-batch flotation tests are conducted using 1kg batches of ground ore. The ore is loaded into a laboratory flotation cell and the volume is completed with water. The pH is adjusted to a target using a base or an acid. The collector is then added and the slurry is conditioned for 2 minutes. Air is injected into the cell and a stop watch is started when the froth reaches the cell lip. The concentrate (floated solids) is collected during 30 seconds and the air injection is shut to recover a first pan of floated material. The process is then repeated for 5 other concentrate samples, i.e. for 30, 60, 60, 120 and 120 seconds. The 6 concentrate samples are dried, weighted and assayed for their copper, zinc and iron contents. The rejects, i.e. the solids that remain in the cell, are also dried, weighted and assayed. The results of a flotation test are shown in Table 1.

Table 1. Semi-batch flotation test results.

Time	Weight	Element concentration (%)		
(min)	(g)	Cu	Zn	Fe
0,5	14,33	24,44	7,34	29,25
0,5	11,69	22,75	8,47	29,09
1,0	17,70	20,08	10,23	28,85
1,0	12,65	16,21	12,70	28,54
2,0	16,99	10,98	15,82	28,22
2,0	11,31	5,49	18,70	28,06
Reject	915,33	0,05	7,85	19,35

You should :

1. Calculate the ore (feed) composition (%Cu, %Fe, %Zn) (5 pts);
2. Calculate the pyrite content of the feed (5 pts);
3. Calculate the cumulative recovery of copper after 5 minutes flotation (5 pts);
4. Calculate the cumulative zinc content (%) of the concentrate after 7 minutes of flotation (5 pts);
5. Roughly approximate the infinite recovery of copper (5 pts);
6. Roughly approximate the rate constant of chalcopyrite if the following model is used to represent the copper flotation:

$$R_{Cu}(t) = R_{Cu}(\infty)(1 - \exp(-k_{Cu}t)$$

Where $R_{Cu}(t)$ is the copper recovery after t minutes of flotation, $R_{Cu}(\infty)$ is the infinite copper recovery et k_{Cu} the chalcopyrite flotation rate constant (5 pts).

Question 5: Grinding circuit (25 points)

The results of a sampling campaign conducted on the grinding circuit shown in Figure 1 are given in Table 2. The slurry solids concentrations are given as weight concentrations. The rod mill is fed by 120 t/h of ore. Calculate:

1. The ore (solids) flow rate (t/h) that circulates through the ball mill (5 pts);
2. The flow rate of the water addition at the pump box (5 pts);
3. The slurry solids concentration of the hydrocyclone feed and the proportion of water in the

hydrocyclone feed that goes to the hydrocyclone underflow. This proportion is called Rf. Comment the value of Rf: Is it good? Too high? Too low? Why? Which operating variable(s) (apex, vortex finder, pressure or other…) influence the Rf value? (5 pts);

4. The partition or efficiency curve of the hydrocyclone (5 pts);
5. The Bond's Operating Work Index' of the ball mill if the motor of the mill is drawing 900 kW (5 pts).

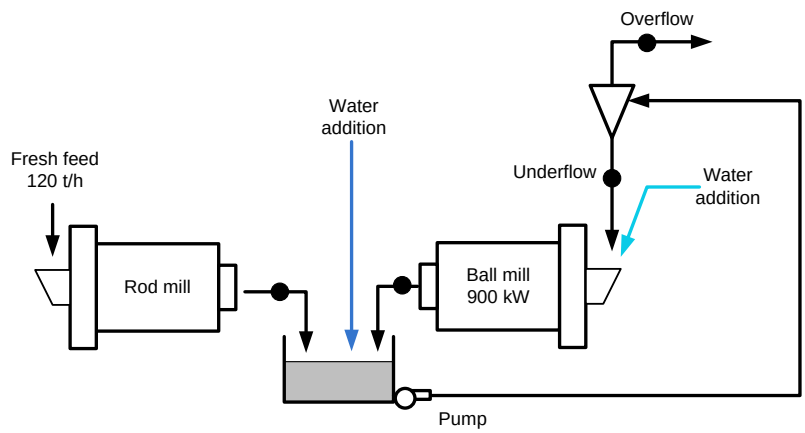

Figure 1. Grinding circuit.

Table 2. Measurements from the sampling of the grinding circuit of Figure 1.

Sieve mesh Top	Sieve mesh Bottom	Size (mm)		% retained et % solids: Rod mill discharge	Ball mill discharge	Hydrocyclone underflow	Hydrocyclone overflow
			% solides	*72,50*	*65,30*	*67,50*	*46,96*
	65		0,212	14,56	5,21	14,20	1,08
65	100	0,212	0,150	32,12	11,20	29,33	4,92
100	150	0,150	0,106	25,42	19,43	29,11	10,90
150	200	0,106	0,075	15,23	29,54	23,55	24,22
200	270	0,075	0,053	5,34	19,23	3,17	29,43
270	Plat	0,053	0,000	7,33	15,39	0,64	29,45