ORDRE DES INGÉNIEURS DU QUÉBEC

NOVEMBER 2019 SESSION

Open-book examination
Calculators : only authorized models
Duration : 3 hours

14-MT-A3 Metal Extraction Processes

The exam is three pages long, including this page. Count and confirm before starting.

Unless otherwise stated:

- ***A tonne refers to a metric tonne;***
- ***$ refers to a Canadian dollar;***
- ***Concentrations are on a weight by weight (w/w) basis.***

Use the following molar weights (g/mol):

• Aluminum : 27 • Nitrogen : 14 • Carbon : 12 • Chlorine : 35 • Copper 63.5	• Iron : 55.8 • Lithium : 6.9 • Nickel : 58.7 • Niobium : 92.9 • Oxygen : 16	• Lead 207.2 • Silicon : 28.1 • Sulphur : 32 • Uranium: 238 • Zinc : 65.4

Units of length	**Units of weight**
1 inch = 2.54 centimeters (cm) 1 foot = 12 inches 1 yard = 3 feet = 36 inches 1 m = 100 cm = 1 000 000 microns (μm)	1 kg = 2.204 lbs 1 short ton = 2000 lbs 1 pound = 16 ounces 1 troy ounce = 31.105 g
Units of volume 1 m^3 = 1000 litres = 1 000 000 cm^3 1 gallon (US) = 0.1336 ft^3 USGPM : US gallons per minute	**Units of temperature** °C = °K - 273 = (°F-32)·5/9 **Units of concentration** ppm = parts per million = grams per tonne (g/t)

Other information :	Faraday's number : 96 500 coulombs/mole
Scrap iron melting point : 1536°C; Cp Solid scrap iron: 0.4 joule/g-°C Cp Liquid iron: 0.8 joule/g-°C Fe Fusion heat : 13 800 joules/kg at 1536°C	R = 0,08206 L•atm•K^{-1}•mol^{-1} 1 mole of perfect gas at 0°C, 1atm = 22.4L

Question #1 (24 points): Keep answers short

a) What is the main factor in choosing between the hydrometallurgical or the pyrometallurgical route for copper extraction for a certain copper ore? (3 pts)
b) What is the difference between alumina and bauxite? (3pts)
c) What is the main gaseous effluent in iron reduction? (3 pts)
d) What type of mineral is required for acid mine drainage to occur? (3 pts)
e) Explain the following: flotation recovery typically follows a first-order rate with respect to time? (3 pts)
f) Explain the concept of a grade-recovery curve. (3pts)
g) Besides cyanide, what is required for gold cyanidation to proceed? How is this achieved? (3 pts)
h) Name **three** mineral properties used to separate gangue from ore. (3 pts)

Question #2 (20 points)

A grinding circuit, shown in Figure 1, is used to liberate minerals prior to separation. The device is sampled and the samples are separated by size and each fraction is weighed. The results of this analysis are shown in Table 1.

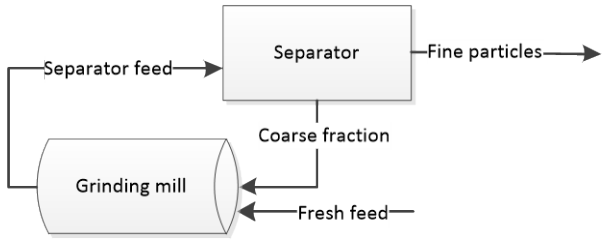

Figure 1: Flowsheet for question #2

Table 1: Mass size distribution for each stream

Size fraction	Separator feed	Coarse	Fine
+212 µm	62.0%	68.7%	11.7%
-212/+106 µm	16.0%	15.0%	23.5%
-106/+53 µm	8.0%	6.6%	21.5%
-53 µm	14.0%	7.6%	43.3%
Total	100%	100%	100%

You are required to:

a) Calculate recovery (%) to the coarse stream for each size fraction. (7 points)
b) Draw a partition curve also called a Tromp curve (name the axes) with the above recoveries and estimate the separator bypass fraction of fines to the coarse stream. (7 points)
c) Name two devices which can be used as a separator and name an advantage (benefit) and a disadvantage (downside) for each. (6 points)

Question #3 (24 points)

A copper concentrate contains 30% Cu and 30% Fe, present as chalcopyrite ($CuFeS_2$) and pyrite (FeS_2). The remainder of the concentrate is quartz (SiO_2). The concentrate is oxidised in a fluidised bed roaster to convert the sulphides to oxides (CuO and Fe_2O_3 only).

a) Calculate the chalcopyrite, pyrite and quartz concentrations of the concentrate. (8 points)
b) Write down the balanced reactions for chalcopyrite and pyrite conversion. (6 points)
c) What are the CuO, Fe_2O_3 and SiO_2 concentrations of the calcine, assuming that 100% of the chalcopyrite and pyrite are converted to ZnO and Fe_2O_3. (10 points)

Question #4 (18 points)

A uranium project intends to leach a concentrate containing 80 % uraninite (UO_2), 10% acid-soluble ankerite ($CaFe(CO_3)_2$) and 10 % unreactive gangue.

a) If ten (10) cubic meters per hour (m^3/h) of acidic solution are added to a feed of 1.5 tonnes per hour (t/h) of concentrate, what would be the U concentration in solution, in g/L, assuming uraninite is completely leached? Assume that the solution volume does not change with concentration. (12 points)
b) Explain a possible method to remove Fe from hydrometallurgical solutions such as the one generated above. (6 points).

Question #5 (14 points)

A copper electrolysis experiment, shown in Figure 2, operates at an intensity of 4 amperes (amps) for a period of 1 hour. The stainless steel electrode is weighed before and after electrolysis. The weight of copper reduced on the stainless steel electrode is 4 grams.

a) Which is the cathode, which is the anode and what is the balanced electrolysis reaction? (7 points)
b) What is the current efficiency according to Faraday's law? (7 points)

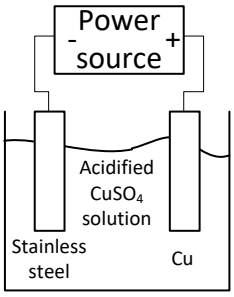

Figure 2: Copper electrolysis experiment of question no.5