



GWANDA STATE UNIVERSITY
FACULTY OF ENGINEERING AND ENVIRONMENT
DEPARTMENT OF METALLURGICAL ENGINEERING
INTRODUCTION TO PROCESS ENGINEERING
EMG 2104
Part II First Semester Examination Paper
September 2024

This examination paper consists of 5 printed pages

Time Allowed: 3 hours

Total Marks: 100

Additional Requirement

Periodic Table

Conversion Tables

INSTRUCTIONS

1. Answer **ALL** questions in Section A and any **TWO** in Section B
2. Each question carries 25 marks
3. Use of calculators is permissible

MARK ALLOCATION

Part Questions	As shown in each part question
Total Attainable	100

Question A1

- a) Define the following terms **[10Marks]**
- Adiabatic process
 - Extensive property
 - System
 - Open system
 - Surroundings
- b) Block flow (BFD), process flow (PFD) and piping and instrumentation (PID) diagrams are widely used in process engineering. With aid of diagrams explain the difference between these diagrams **[15 Marks]**

Question A2

- a) Dry magnetite has an as-received bulk density of 60% of theoretical. Calculate the required storage space for 150 tonnes of magnetite. **[4 Marks]**
Data: The density of magnetite is 5180 kg/m^3
- b) The following equation is proposed to calculate the pressure drop (Δp) across a length of pipe (L) due to flow through the pipe. Determine the dimensional consistency of this equation:

$$\Delta p = \frac{1}{2} v^2 \left(\frac{L}{D} \right) f$$

where v is the average velocity of the fluid flowing through the pipe, D is the diameter of the pipe, and f is a dimensionless coefficient called the friction factor, which is a function of the Reynolds number **[4 Marks]**

- c) A copper concentrate consists of chalcopyrite (CuFeS_2), pyrite (FeS_2) and silica (SiO_2). The laboratory reported the chemical analysis as 29.8 %Cu and 30.2 %Fe. Calculate the mass fraction of each mineral in the concentrate. **[5 Marks]**
- d) An engineering handbook shows that microchip etching roughly follows the relation $d = 16.2 - 16.2e^{-0.021t}$ where $t < 200$.
Where d is the depth of the etch in micrometers (μm) and t is the time of the etch in seconds. What are the units associated with the numbers 16.2 and 0.021? Convert this relation so that d becomes expressed in inches and t can be used in minutes. **[6 Marks]**
- e) An alloy with a mass fraction of 50 % cadmium ($w_{\text{Cd}} = 0.50$) enters a distillation device (a separator) at 1000 kg/h and exits as two streams. At steady state, the gas stream contains 454 kg/h of Cd, and the liquid stream contains 472 kg/h of Zn. Write elemental balances on each constituent and prepare a complete mass balance **[6 Marks]**

SECTION B ANSWER ANY TWO QUESTIONS

Question B1

- i. A potential difference of 2.0V is applied along a circular bar of 0.10 m radius and 2.0 m long. The bar material has a resistivity of $1.7 \times 10^{-6} \Omega\cdot\text{m}$. Calculate the current flow **[5 Marks]**
- ii. Calculate the mass of Al^{+3} ions discharged in 1.0 minute by the current in the above example, if no current is lost to leaks or other processes (i.e., 100% current efficiency). 10.3 grams of aluminum). **[5 Marks]**
- iii. A slurry is a solid-liquid mixture, where the solid phase is usually made up of fine particles. A fluid of high apparent density can be created by suspending an extremely fine dense solid in water. How many kg of magnetite (Fe_3O_4) should be suspended in 1000 kg of water to give slurries of density between 1100 and 1300 kg/m^3 ? The density of magnetite is $5180 \text{ kg}/\text{m}^3$ **[7 Marks]**
- iv. Discuss the advantage and disadvantages of batch and continuous process in metallurgical engineering **[8 Marks]**

Question B2

- a) Oxygen is placed into a closed system fitted with a piston capable of compressing the gas. The initial state is 100 L of O_2 at 1.5 atm pressure and 400 K. The gas is compressed reversibly and isothermally until the pressure reaches 6.5 atm. Calculate the work done on the system **[4Marks]**
- b) Explain the term fluid **[7 Marks]**
- c) Derive the Bernoulli's Equation and explain the various expressions **[7 Marks]**
- d) The reduction of a metal by another is called metallothermic reduction. Metallic titanium is produced by reduction of titanium tetrachloride (TiCl_4) with magnesium. In one plant, a steel reactor vessel is charged with 320 kg of Mg bars and heated in an inert atmosphere to about 850°C to form a pool of molten Mg on the bottom of the furnace. Then 1070 kg of liquid TiCl_4 is run in through a pipe at the top, while a small amount of inert gas is added to maintain a positive pressure in the reactor. Figure B.2 shows a sketch of the Kroll reactor vessel. Determine the excess reactant and its % excess **[7 Marks]**.

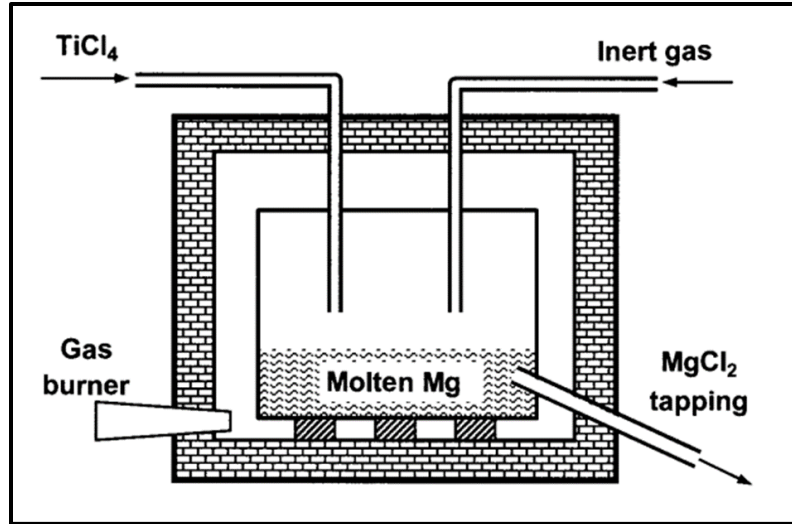


Figure B.2 Schematic of a Kroll reactor to produce titanium sponge

Question B3

A pollution control residue contains heavy metal sulfides, which are being disposed of as hazardous waste. A process is being designed to treat these residues by roasting them in air to convert the sulfides to oxides, from which the metals can be recovered. The roasting process produces a gas having a dust content of 50 g/m^3 at STP. The volume fraction of constituents in the gas phase is: $\phi_{\text{SO}_2} = 0.120$, $\phi_{\text{H}_2\text{O}} = 0.080$, $\phi_{\text{O}_2} = 0.080$, balance N_2 . The roaster gas contains too much dust and SO_2 to be discharged to the environment. This is to be corrected by scrubbing the dusty gas to remove the dust and most of the SO_2 and recover these later. The dusty gas is scrubbed with pure water at 10°C , and the slurry filtered to remove all of the dust. The filter cake is dried and sent to a metal recovery step. The dryer gas contains a weight fraction of H_2O of 0.50. The filtrate contains dissolved SO_2 that must be removed and recovered. The SO_2 will be removed from the filtrate by vacuum extraction at 10°C (possibly with some air to assist removal of SO_2). The objective is to lower the SO_2 in the clean gas, while producing a high- SO_2 gas that can be more easily treated to remove the SO_2 . Make a material balance for a system designed to remove 70 % of the SO_2 from the roaster gas in the scrubber, and explore the effect of device pressure and amount of air from stream H on overall recovery of SO_2 in stream M. Each device pressure is 1.00 atm except for the SO_2 desorption device, which is a variable. Assume dry air contains only N_2 and O_2 . Data. The solubility of SO_2 in water at 10°C is expressed in terms of mass of SO_2 /mass of water as a function of p_{SO_2} in atm, according to the following equation: $p_{\text{SO}_2} = 5.66(\text{mass SO}_2/\text{mass H}_2\text{O})$ [25 Marks].

END OF PAPER