NAMIBIA UNIVERSITY
OF SCIENCE AND TECHNOLOGY

FACULTY OF ENGINEERING AND SPATIAL SCIENCES

DEPARTMENT OF MECHANICAL, MINING AND PROCESS ENGINEERING

QUALIFICATION: BACHELOR OF ENGINEERING IN METALLURGY	
QUALIFICATION CODE: 08BMET	**LEVEL: 8**
COURSE CODE: PNM710S	**COURSE NAME: PYROMETALLURGY OF NON-FERROUS METALS**
SESSION: JUNE 2023	**PAPER: THEORY**
DURATION: 3 HOURS	**MARKS: 100**

FIRST OPPORTUNITY EXAM PAPER	
EXAMINER(S)	**Prof. Godfrey Dzinomwa**
MODERATOR:	**Prof. Sofya Mitropolskaya**

INSTRUCTIONS
1. Answer all questions. 2. Read all the questions carefully before answering. 3. Marks for each questions are indicated at the end of each question. 4. Please ensure that your writing is legible, neat and presentable.

PERMISSIBLE MATERIALS

1. Examination paper.

THIS QUESTION PAPER CONSISTS OF 5 PAGES (Including this front page)

Question 1

(a) Discuss the advantages of using a Top Submerged Lance (TSL) furnace compared to an electric furnace in the smelting of copper sulphide concentrates **(5 marks).**

(b) By applying Stoke's law, derive an expression for the settling velocity V_s of a matte droplet of density ρ_s in a molten slag of density ρ_f in terms of the diameter **d** and density of the matte droplet, and the viscosity μ and density of the slag from first principles. Assume that the rate of settling obeys Stoke's law, and that the frictional force between matte droplets and slag = $6V\mu\pi r$ **(5 marks).**

(c) Given that matte density is 5500kg/m^3, slag density is 3500kg/m^3 and slag viscosity is 0.1 kg/m.s, calculate the settling velocities of and the times taken by matte droplets of radii in mm; 12; 10; 8; 4; 2 settling through 2m of slag? **(10 marks).**

- ρ(matte) = 5500 kg/m^3
- ρ(slag) = 3500 kg/m^3
- μ(slag) = 0.1 kg/m^3
- Settling in 2m of slag.

(d) How do matte droplets get entrained in slag during converting and what practical measures are applied in industry in order to increase the rate at which matte droplets settle out of the slag **(5 marks).**

Question 2

(a) You are given the Cu-S process flowsheet (Figure 1) for the treatment of concentrate (25% Cu) through drying, roasting and smelting to matte (65% Cu). At which stages and in what form are metal losses likely to occur, and how would you minimize the losses? **(5 marks).**

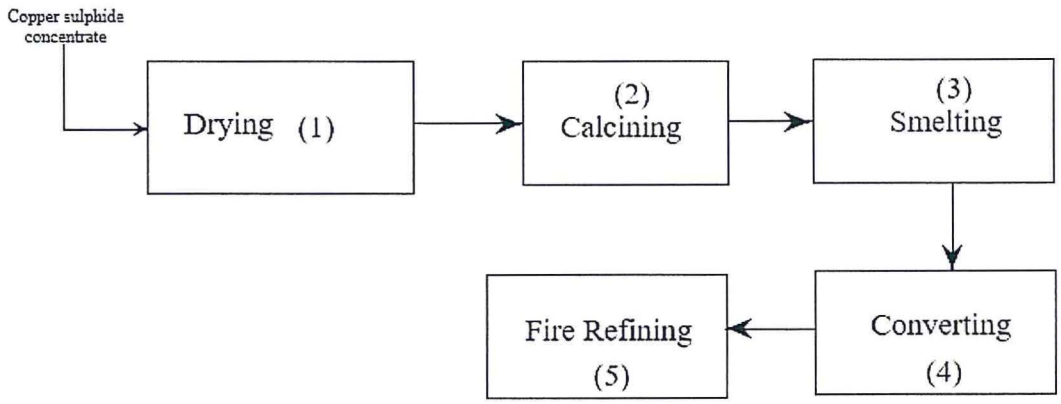

Figure 1. Simplified Flowsheet for pyrometallurgical treatment of copper sulphide concentrates

(b) Explain in terms of slag composition and temperature why the region shown in the ternary phase diagram (Figure 2) is considered to be the common region for slags. What are the disadvantages of operating outside this region **(5 marks).**

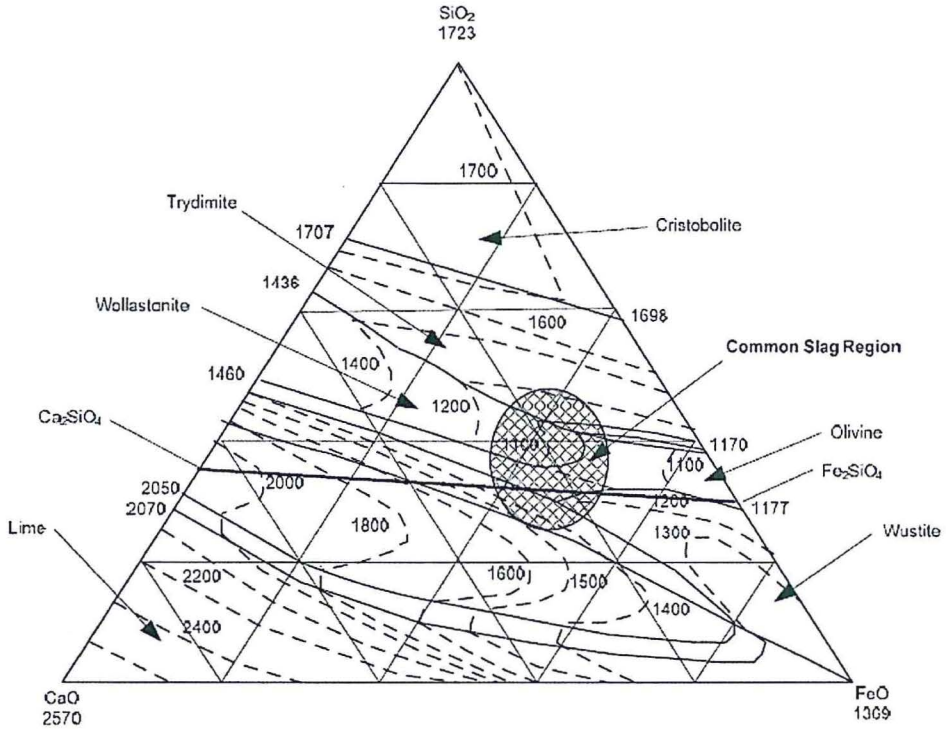

Figure 2. CaO-SiO2-FeO Common slag region

(c) Assume that 3500kg of $MgCO_3$ is decomposed to MgO and CO_2 by heating in a rotary kiln using natural gas as a fuel at an appropriate temperature. The consumption rate of the fuel is 260m^3 per tonne of MgO calcine produced. The analysis of the gas is given as;

Constituent	**Natural Gas,%**	**Flue Gas, %**
CH_4	85	-
C_2H_6	10	-
C_3H_8	5	-
CO_2	-	22
N_2	-	73.55
O_2	-	4.45

Given that the reactions involved are;

$MgCO_3 = MgO + CO_2$

$CH_4 + 2O_2 = CO_2 + 2H_2O$

$C_2H_6 + {}^7/_2\, O_2 = 2CO_2 + 3H_2O$

$C_3H_8 + 5O_2 = 3CO_2 + 4H_2O$

(Atomic weights are given as Mg = 24; C = 12; H = 1; O = 16)

Determine the volume of air consumed in m^3 per tonne of MgO produced **(15 marks).**

Question 3

(a) Explain the reason why the blast furnace has generally been replaced by other types of furnaces such as reverberatory and electric furnaces in the smelting of lead rich ores **(5 marks).**

(b) A furnace is charged with 3 000 kg/min of copper concentrate which is composed of the following constituents;

- Chalcopyrite ($CuFeS_2$): 65%
- Pyrite (FeS_2): 20%
- Silica (Silica): 15%

The Copper Matte produced contains 60% Cu;
15% Fe;
25% S

and the Slag contains 35% Fe

Assume that the reactions involved are;

- $2CuFeS_2 = Cu_2S + 2FeS + {}^1/_2S_2$
- $FeS_2 = FeS + {}^1/_2S_2$
- ${}^1/_2S_2 + O_2 = SO_2$
- $FeS + {}^3/_2O_2 = FeO + SO_2$
- $FeO + SiO_2 = FeO.SiO_2$

- Determine the amount of;
  (i) air blown into the furnace **(5 marks),**
  (ii) matte formed **(5 marks),**
  (iii) slag formed **(5 marks),** and
  (iv) SO_2 in flue gases leaving the furnace **(5 marks)**

*(**Note:** Relevant Atomic weights are Cu = 64; Fe = 56; S = 32; Si = 28; O = 16)*

Question 4

(a) Discuss the factors that you would consider in order to set up a green hydrogen manufacturing plant in a given location, and whether you consider Namibia to be a favourable destination for such an investment. What are the global benefits of utilising green hydrogen energy as compared to fossil fuels **(5 marks).**

(b) What factors would you consider to be critical before you set up an Aluminium smelter in any country? **(5 marks)**

(c) Copper ore concentrate with the following assay

26.5% Cu
20% S
10% H_2O

is processed to produce copper metal assaying 98.5% Cu. The off-gases are treated to recover Sulphur in the form of Sulphuric acid. Assuming 300 tph of ore concentrate;

(i) Determine the amount of H_2SO_4 (dry) produced in tph if 85% of the S in the feed is recovered in the H_2SO_4 acid plant **(10 marks)**

(ii) The process flowsheet shows that Cu is upgraded at three main stages, and 2% of the Cu is lost at each of the stages. How much of the final product is produced in tph? **(5 marks)**

*(**Note:** Atomic weights are Cu = 64, S = 32, O = 16, H = 1)*

END