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 2022	**PAPER: THEORY**
DURATION: 3 HOURS	**MARKS: 100**

SUPPLEMENTARY QUESTION 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 6 PAGES (Including this front page)

Question 1

(a) Discuss the factors that you would consider in order to set up an Aluminium smelter in a given location. What measures could be taken for Namibia to be a favourable destination for such an investment **(5 marks).**

(b) From first principles and applying Stoke's law, derive an expression for the settling velocity **V** of a matte droplet of density ρ_d in a molten slag of density ρ_{sl} in terms of the radius **r** and density of the matte droplet, and the viscosity μ and density of the slag. 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 5200kg/m^3, slag density is 3500kg/m^3 and slag viscosity is 0.1 kg/m.s, calculate the settling velocities of matte droplets of radii in mm; 10; 8; 3 settling through 1.5m of slag? **(5 marks)**

(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)**

(e) What are the environmental and economic impacts of not treating off-gases from a smelter? How would you rehabilitate land that has been contaminated by acid rain caused by such off-gases? **(5 marks).**

Question 2

(a) Explain the properties required for an effective furnace refractory **(5 marks)**

(b) An oil-fired furnace is used to reheat metal 'x' stock from ambient to the working temperature before further treatment. Given the data below,

- Operating temperature: 1300^{o}C
- Exit flue gas temperature after preheater: 750^{o}C
- Ambient temperature: 40^{o}C
- Specific gravity of fuel oil: 0.90
- Average fuel oil consumption: 0.5 m^3 / hr
- Calorific value of oil 14.2 Megajoules/kg
- Weight of stock: 5.5 t/hr
- Specific heat of metal 'x': 0.5 MJ/kg/^{0}C

Calculate

(i) the heat content of metal 'x' as it comes out of the furnace **(5 marks)**

(ii) the heat input into the furnace **(5 marks)**

(iii) the efficiency of the furnace **(5 marks)**

(b) Ideally, all heat added to the furnaces for smelting or other heating purposes should be used to heat the load or stock. In practice, however, a lot of heat is lost in several ways, resulting in typical thermal efficiencies below 50%. Discuss some of the ways by which heat losses occur in the furnace **(5 marks).**

Question 3

(a) With the aid of a flowsheet, explain the unit processes that are involved in the pyrometallurgical treatment of a copper sulphide concentrate from a filter cake through to blister copper with concentration of 99.5% copper **(5 marks).**

(b) In one roasting unit, 1500 kg of an ore concentrate of the composition given below is roasted using excess air.

Ni_3S_2	21%
FeS_2	40%
SiO_2	31%
H_2O	8%

The roasting unit is heated by oil of composition 85% C and 15% H, the amount of oil is 6.2% of the weight of the ore.

The gases from combustion and roasting mix together and are carried through as flue gases. **S** is converted to SO_2. The roasted product consists of NiO, Fe_2O_3 and SiO_2 and the roasting reactions are given as;

$Ni_3S_2 + 7/2O_2 = 3NiO + 2SO_2$

$2FeS_2 + 11/2O_2 = Fe_2O_3 + 4SO_2$

(i) Explain the mechanism by which roasting is achieved. How would you increase the kinetics of roasting and hence the production rate" **(5 marks)**

(ii) Calculate:

a) Weight of roasted product **(5 marks)**

b) Volume of the fuel oil used given that its density is 0.89 g/cm^3 **(5 marks)**

c) Volume of SO_2 in m^3 **(5 marks)**

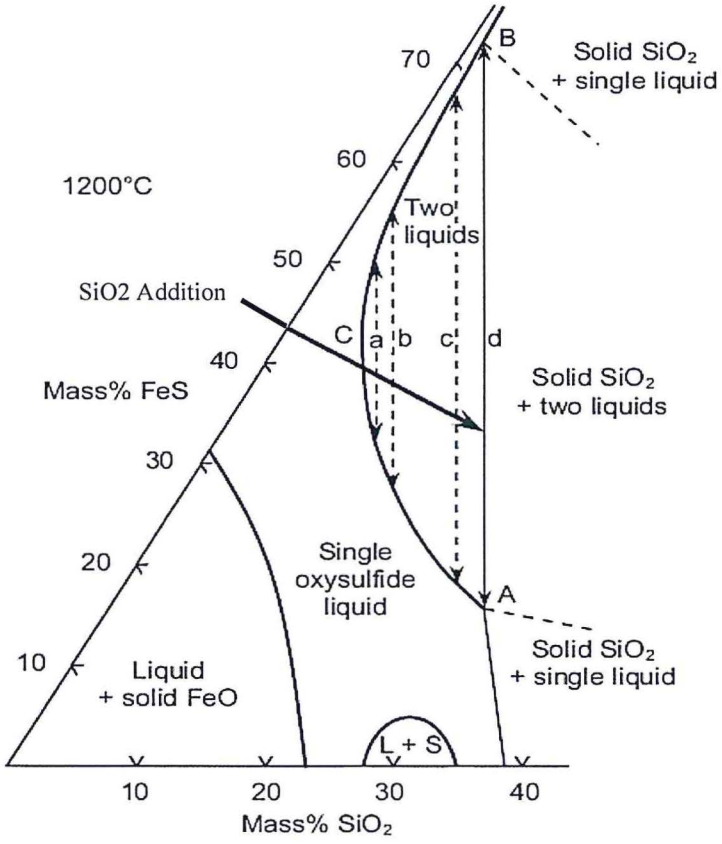
(Note: Atomic weights are Ni = 59, Fe = 56, S = 32, O = 16, H = 1)

Question 4

(a) Explain three of the potential benefits of a Green hydrogen industry in Namibia. What is the significance of green hydrogen globally **(5 marks).**

(b) The partial phase diagram below shows the Fe-O-S-SiO_2 system slag-matte immiscibility which develops due to addition of SiO_2.

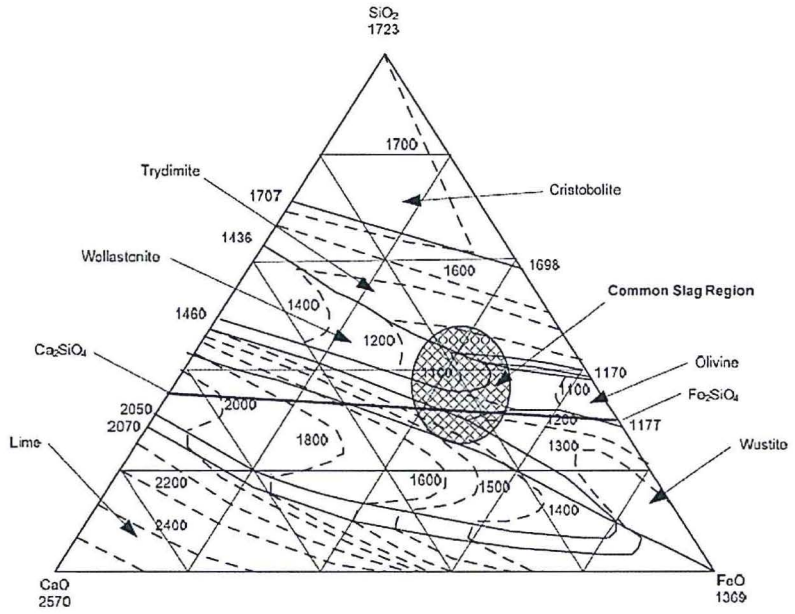
(i) Explain the behaviour of the slag as a result of SiO_2 addition to the bath at a temperature of 1200°C and give the composition of the saturation points A and B in terms of FeS and SiO_2 **(5 marks)**



(c) Discuss the construction of a Flash Smelting Furnace (FSF) and explain how the shell of the FSF is protected from being burnt through by hot metal **(5 marks)**

(d) What operational factors contribute to the accumulation of 'reverts' during smelting and converting? Explain why such accumulation of 'reverts' during operations is considered to be poor metallurgical practice **(5 marks).**

(e) Explain in terms of composition and temperature why the region shown in the ternary phase diagram below is the common region for slags **(5 marks).**



Question 4

(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.

(b) A furnace is charged with 15000 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;

- $2CuFeS_2 = Cu_2S + 2FeS + {}^1/_2S_2$
- $FeS_2 = FeS + {}^1/_2S_2$
- ${}^1/_2S_2 + O_2 = SO_2$

- $FeS + {}^{3}/_{2}O_2 = FeO + SO_2$
- $FeO + SiO_2 = FeO.SiO_2$

- 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)

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