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**

FIRST OPPORTUNITY 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 5 PAGES (Including this front page)

Question 1

(a) A copper sulphide ore concentrate assaying 30% Cu, 25% S and 10% H_2O is to be treated to produce metallic copper assaying 99.5% Cu. The process incorporates recovery of Sulphur in the form of Sulphuric acid. Assuming 150 tph of ore concentrate;

(i) Outline the flowsheet, indicating the main stages in the process of Cu and S recovery **(5 marks)**

(ii) Determine the amount of H_2SO_4 (dry) produced in tph if 65% of the S in the feed is recovered in the H_2SO_4 acid plant **(5 marks)**

(iii) The process flowsheet shows that Cu is upgraded at four main stages, and 1.5% of the Cu is lost at each of the stages. How much of the final product is produced in tph? **(5 marks)**

(iv) In what form is the Copper likely to be lost at each of the stages and what steps would you take to minimize the losses **(5 marks)**

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

(b) For the reaction of 1kg-mol of methane (CH_4) gas at 101.32 kPa and 298K,

$CH_4(g) + H_2O(l) = CO(g) + 3H_2(g)$

Calculate the standard heat of reaction H^o at 298K and comment on whether the reaction can be expected to proceed spontaneously without heat addition, given the following standard heats of formation at the same temperature **(5 marks);**

$CH_4(g)$	ΔH^o	=	-74.848×10^3 kJ/kg mol
$H_2O(l)$	ΔH^o	=	-285.840×10^3 kJ/kg mol
CO (g)	ΔH^o	=	-110.523×10^3 kJ/kg mol
H_2 (g)	ΔH^o	=	0

Question 2

(a) A copper ore mixture amounting to 2500kg is roasted in a furnace to produce a calcine ready for smelting in an electric furnace. The percentage analysis of the ore mixture is provided as

Feed Constituents		**Calcine**	
Cu	8.5	Cu	9.5
SiO_2	24.5	S	12.0
Fe	30.5		
S	25.7		
H_2O	5.0		

- The Copper is present in Calcine in the form of Cu_2S, and Fe is in the form of FeS and Fe_2O_3. Air is supplied and Sulphur burns to produce SO_2. The overall roasting reaction is simplified as: $2Cu + 3Fe + 3S + {}^5/_2O_2 = Cu_2S + FeS + Fe_2O_3 + SO_2$

Calculate the following;
(a) Weight of calcine produced **(5 marks)**
(b) Volume of Air used in m^3 per to roast the ore **(10 marks)**
(c) The weight of Fe_2O_3 formed in the calcine **(5 marks)**
(d) Percentage sulphur removal **(5 marks)**

Question 3

(a) You are the Metallurgical Manager of an integrated Copper Smelter comprising Drying, Smelting and Converting Plants. The Dryer develops a fault and has to undergo repairs for a week. The feedstock for the smelter, and hence the Converter will run out in three days' time at the normal plant throughput (rate). What options will you implement to avoid cooling down the furnace and converter thus damaging refractories? **(5 marks)**

(b) According to Stokes' law, the rate at which matte droplets settle through a layer of slag is given by;

$$V = \frac{1}{18} g \frac{\rho_{drop} - \rho_{slag}}{\mu_{slag}} (\phi_{drop})^2$$

In this expression V is the settling rate of the matte droplets (m/s), g the gravitational constant (9.8 m/s^2), ρ_{drop} matte density (3900–5200 kg/m^3), ρ_{slag} slag density (3300–3700 kg/m^3), μ_{slag} slag viscosity (~0.1 kg/m·s) and ϕ_{drop} the diameter (m) of the settling matte droplet.

(i) Given that matte density is 5100kg/m^3, slag density is 4000kg/m^3 and slag viscosity is 0.1 kg/m.s, calculate the settling velocities and residence times of matte droplets of radii in mm; 8; 5; 2; 1; 0.5 settling through 1.0m of slag **(10 marks)**

(ii) Explain the practical steps the Plant Metallurgist should take to increase the settling rate of the matte drops in slag and therefore increase the rate at which matte and slag separate in the furnace/converter **(5 marks)**

(c) With the aid of a sketch, discuss the key features of the Imperial Smelting Process for Zinc sulphide concentrates. Explain why it has become universally favoured as well as its disadvantages **(5 marks)**

Question 4.

(a) As Chief Metallurgist of a Group of companies, you find that the electrostatic precipitator and the rest of the off-gas treatment plant of Smelter X (Ni-S) has not been operating for some weeks and the Smelter X Manager seems to be accepting the position, mainly motivated by the reduced electricity bill due to the offline units. Outline to the Manager the disadvantages posed to the Company by this situation **(5 marks).**

(b) With the aid of the Cu-S equilibrium phase diagram given below, explain the changes in the composition of the matte bath during the Copper Converting process along the temperature line **abcd (5 marks)**

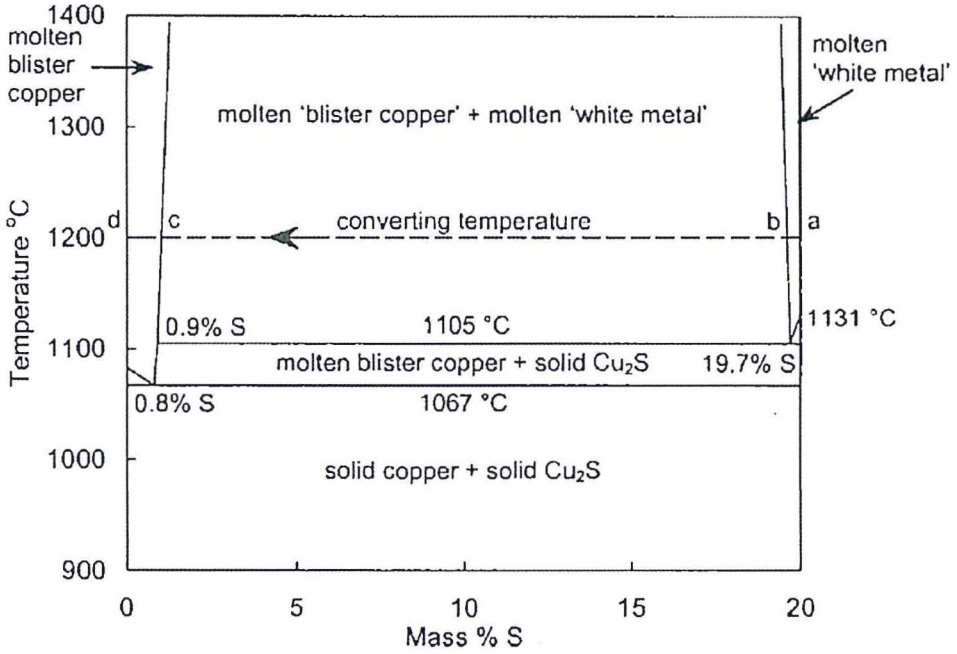
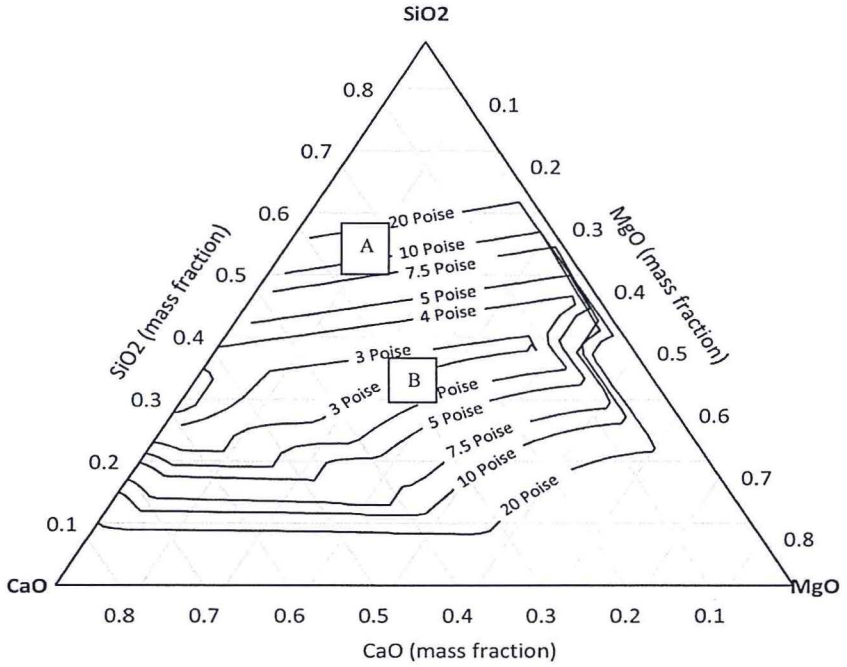


Fig. ..... Cu-S equilibrium phase diagram showing coppermaking reaction path (a, b, c, d, 1200°C) (Sharma and Chang, 1980).

(b) If the operator mistakenly allows the bath temperature to drop from 1200°C to 1100°c when the Sulphur level in the 'white metal' has been reduced to 10%, what products do you expect in the Converter **(5 marks).**

(c) Below is a ternary phase diagram showing the CaO-MgO-SiO2 system. Explain, in terms of composition, acidity and viscosity, the differences experienced with the two slags in the regions marked A and B on the diagram **(5 marks)**



(e) The concentrate charge in an electric furnace separates into matte whose density is 5.0 g/cm^3 and slag with a density of 3.2 g/cm^3. If the residence time in the furnace settler is 7.5 minutes for both matte and slag, what is the volume of matte and slag in the furnace if they are both tapped at the steady rate of 10 tph without build-up. **(5 marks)**

.....End.....