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: 7**
COURSE CODE: PNM 720S	**COURSE NAME: PYROMETALLURGY OF FERROUS METALS**
SESSION: NOVEMBER 2022	**PAPER: THEORY**
DURATION: 3 HOURS	**MARKS: 100**

FIRST OPPORTUNITY QUESTION PAPER	
EXAMINER(S)	**Prof. Sofya Mitropolskaya**
MODERATOR:	**Dr. Silas Ithete Hango (University of Namibia)**

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 (Excluding this front page)

Question 1 **[25 marks]**

(a) A blast furnace makes hot metal containing 2.6 wt.% C, 1.1 wt.% Si, 1.3 wt.%Mn, the remainder being Fe. The ore burden contains 85% Fe_2O_3, the remainder being gangue of SiO_2 and Al_2O_3. Calculate the weight of ore W(ore) used for the production of 1 ton of hot metal.

Note: Atomic weights are – Fe = 56, O = 16. **[10]**

(b) Why do the charge materials descend to the bottom of the blast furnace? Provide five reasons. **[5]**

(c) Below is a simplified Oxygen Potential diagram (Fig. Q1). With the aid of the diagram, specify, in which parts of a blast furnace (throat, stack, cylinder bosh, bosh or hearth) the following oxides can be reduced to pure metals: CaO, MgO, Al_2O_3, SiO_2, and MnO. Provide the relevant reactions. **[10]**

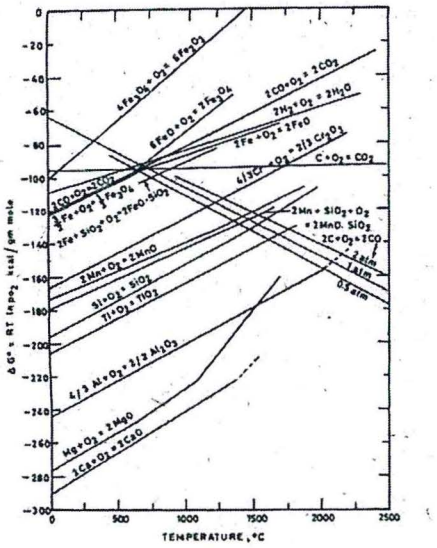


Figure Q1. Oxygen Potential diagram.

Question 2 **[25 marks]**

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

(b) Assume your responsibility is to procure necessary equipment for a sponge ironmaking plant being under construction in Namibia. You have discovered that the following pieces of equipment are marketed at a reasonable price: (a) a coke oven; (b) Ingot-casting machine; (c) a methane reforming unit; (d) a 100 t ladle and (e) a slag-granulating machine. Make up an acquisition list with reference to items (a) to (e). Briefly explain your choice. Since your budget is limited, select only those items that are needed urgently in Namibia. **[5]**

(c) The World Steel Association recently recommended a number of interventions to mitigate CO_2 emission by the global ironmaking industry. The most ambitious initiative involves the replacement of carbon with green hydrogen.

(i) With the aid of Fig. Q2, briefly explain environmental benefits of the coke replacement with hydrogen in ironmaking industry. Provide necessary reactions. **[5]**

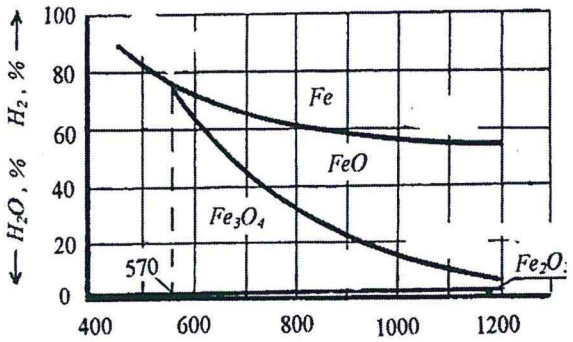


Figure Q2. Equilibrium diagram for H_2 (gas), H_2O (steam) and iron oxides.

(i) What is green hydrogen? What makes Namibia a promising location for green hydrogen production in general? **[5]**

(ii) In your opinion, is it possible to substitute coke totally with green hydrogen in blast furnace ironmaking? Briefly explain. **[5]**

Question 3 [25 marks]

(a) A hypothetical integrated steelmaking plant is processing high-manganese hot metal into steel. Both types of oxygen steelmaking convertors are available: basic type and acidic type. Should they use a basic oxygen converter or an acidic oxygen convertor for this job? Kindly advise and briefly explain your choice by relevant chemical reactions. **[5]**

(b) How much electric energy is consumed by an average basic oxygen converter? Is it possible to run a hypothetical basic oxygen converter using the solar energy only? **[5]**

(c) For obtaining the optimum slag viscosity, the composition of Basic Oxygen Converter slag at "Tata steel" is to meet the following requirements:

$SiO_2/Al_2O_3 = 85/15$; $CaO/SiO_2 = 65/35$.

Estimate the slag composition in the point of interest with the aid of a ternary diagram (Fig. Q3c). **[5]**

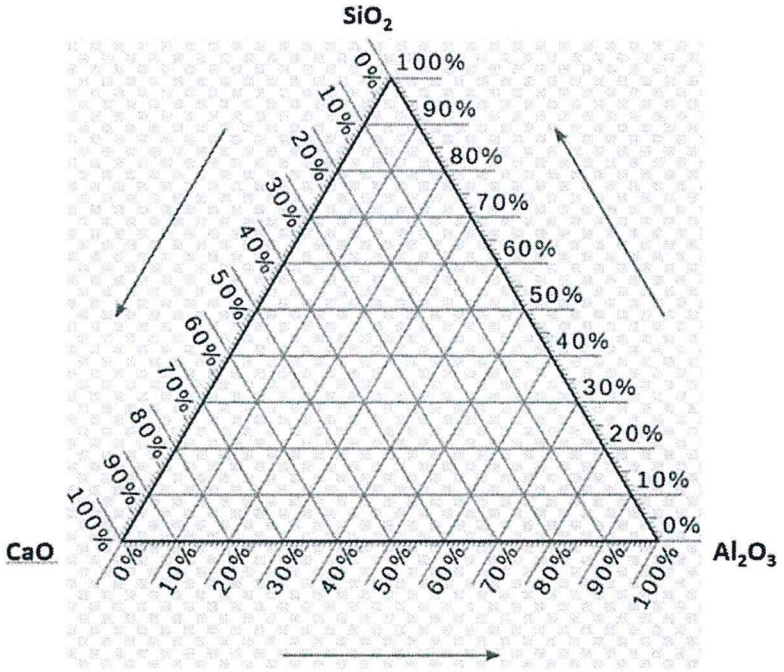


Figure Q3c. Ternary diagram for steelmaking slag.

(d) Overblowing is an excessive oxygen lancing during the final stage of the oxidation period in oxygen convertor steelmaking.

(i) With the aid of Fig. Q3d, briefly indicate the negative consequences of overblowing.**[5]**

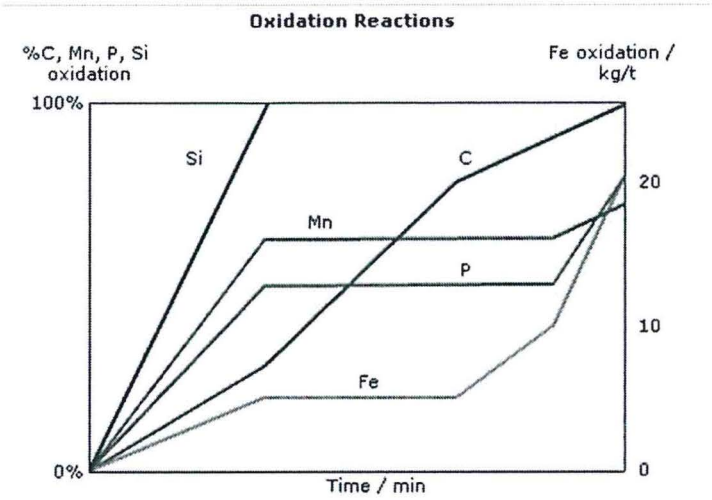
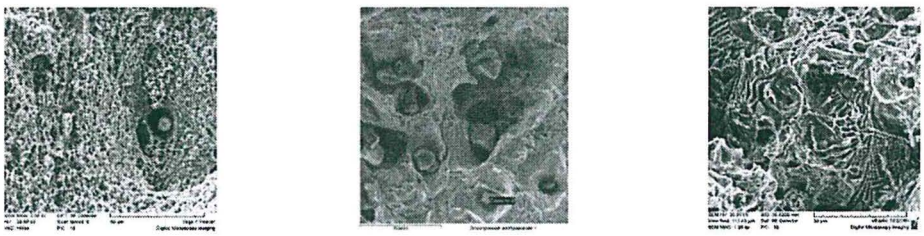


Figure Q3d. Reaction rates for the oxidation reactions in basic oxygen converter (BOC).

(ii) What steps should be practiced to prevent overblowing? **[5]**

Question 4 [25 marks]

(a) Research at a steelmaking plant has revealed three morphological types of non-metallic inclusions formed in the cast steel (see Figure Q4a).



Type A Type B Type C

Figure Q4a. Scanning electron micrographs of the three types of non-metallic inclusions in cast steel. Type A: 2000x. Type B: 3000x. Type C: 2000x.

(i) What type(s) of inclusions are acceptable in final steel products? **[5]**

(ii) Briefly explain a relevant method of the liquid steel treatment to insure the formation of this type of inclusions. Note: morphology means shape and size of particles. **[5]**

(b) Why killed steel is referred to as killed steel? Briefly discuss advantages and limitations of the killed steel. **[5]**

(c) Stokes law estimates the velocity of elimination of solid globular particles through molten steel as follows:

$$V = \frac{g d^2 \ (\rho_s - \rho_f)}{18 \ \mu}$$

In this expression V is the velocity of particles elimination from the molten steel (m/s); g is acceleration due to gravity (9,8 m/s^2); d is diameter of the particle (m); ρ_s is the density of silica; ρ_f is the density of liquid steel; and μ is the viscosity of liquid steel. With the aid of Stokes law calculate the velocity of silica globular particles elimination from the molten steel and the residence time with reference to silica globule of radius 3 mm moving through 2 m of a ladle given that the silica density 2.20×10^3 kg/m^3, the density of liquid steel is 7.16×10^3 kg/m^3 and the viscosity of liquid steel is 6.1×10^{-3} kg/(m·s). **[10]**

End of Examination Question Paper