

## National Exams December 2008

### 98-met-A3, Metal Extraction Processes

3 hours duration

#### NOTES

- 1 Answer only five questions Any five questions(out of seven) constitute a complete paper Only the first five questions as they appear in your answer book will be marked
- 2 All questions are of equal value(20 marks each out of 100)
- 3 If doubt exists as to the interpretation of any question, the candidate is urged to submit with the answer paper a clear statement of any assumptions made
- 4 Candidates may use one of two calculators, the Casio or Sharp approved models This is a closed book exam
- 5 The exam consists of six pages including a Ellingham Diagram(last page)

Question 1	(a) 4, (b) 4, (c) 4, (d) 4, (e) 4
Question 2	(a) 4, (b) 4, (c) 4, (d) 4, (e) 4
Question 3	(a) 4, (b) 4, (c) 4, (d) 4, (e) 4
Question 4	(a) 5, (b) 5, (c) 5, (d) 5
Question 5	(a) 5, (b) 5, (c) 5, (d) 5
Question 6	(a) 20
Question 7	(a) 5, (b) 5, (c) 5, (d) 5

**Problem No 1(20 marks)**

- a) List all the input and output streams for an iron blast furnace in terms of what it is and at approximately which temperature
- b) What key features make the blast furnace a pretty energy efficient furnace
- c) What is the equilibrium oxygen pressure for a gas mixture of equal amounts of CO and CO<sub>2</sub> at 1200 °C (see Ellingham diagram)
- d) Assuming that the pig iron at 1600 °C with an iron activity of 0.95 is in equilibrium with a slag with an FeO activity of 0.1, what is the equilibrium oxygen pressure
- e) What main roles do the BOF(Basic oxygen furnace) play

**Problem No 2(20 marks)** Aluminum is produced by electrolysis of alumina using carbon as a consumable anode. A cell operates under the following conditions

Total current = 250,000 A, total cell voltage = 4.4 V, current efficiency = 96%, current density at the liquid aluminum cathode = 6,000 A/m<sup>2</sup>, density of molten aluminum = 2270 kg/m<sup>3</sup>, molecular mass of aluminum = 0.027 kg/mol

- a) In a day(24 hrs) how much(kg) aluminum is produced per cell
- b) If the metal is not tapped, how much (cm) does the level of molten aluminum raise in 24 hrs
- c) What is the specific energy consumption (kWhr/kg Al)
- d) What are the main gaseous emissions and how can they be controlled
- e) Describe how the molten aluminum is refined in terms of removing sodium and dissolved hydrogen

Faraday's Constant  $F = 96500 \text{ C/mol}$

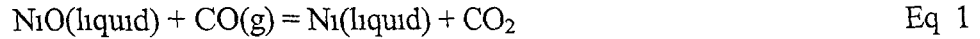
**Problem No 3(20 marks)** For a copper smelter treating chalcopyrite ( $\text{CuFeS}_2$ ) as the feed

- a) what are the main  $\text{SO}_2$  emission issues for most present day smelters
- b) what can be done to reduce these emissions, what technologies are available and what are potential difficulties with these solutions
- c) what are tailings dams, what role do they play and what are the future issues
- d) how does copper converting work(describe slag blow and copper blow)
- e) name some reactors/furnaces used to smelt chalcopyrite concentrate

**Problem No 4(20 marks)** Assuming you have a sulfidic mixed nickel( $(\text{NiFe})_8\text{S}_9$ )-copper ( $\text{CuFeS}_2$ ) ore that contains 1.3% Ni and 1.4% Cu by weight. The ore also contains FeS,  $\text{FeS}_2$  and  $\text{SiO}_2$  as well as some precious metals(0.2 g Au/tonne and 40 g Ag/tonne). The ore is underground and will have to be explored using underground mining. The price of nickel is 12,000 US\$/tonne, copper can be assumed to stay at 2,500 US\$/tonne, gold at 720 US\$/troy ounce(1 troy ounce = 31 g), silver at 10 US\$/troy ounce)

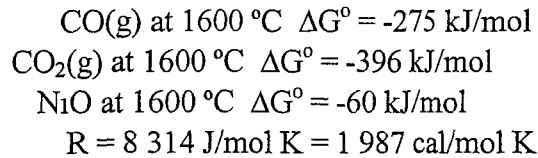
- a) Determine the value of the ore per tonne, and elaborate on its economic feasibility
- b) Draw a schematic flow diagram of mineral processing steps that will have to be taken after the ore is mined until it forms a nickel-copper concentrate that can be fed to a smelter for further processing
- c) Describe briefly the principles of the various unit operations
- d) What are the main environmental issues(advantages and disadvantages) with such mineral processing operations

**Problem No 5(20 marks)** NiO is reduced from a NiO containing slag to metallic ferro-nickel(Fe-Ni alloy) at 1600 °C with CO(gas) according to the following reaction



- Calculate  $\Delta G^\circ$  at 1600 °C for this reaction(Eq 1)
- Determine the minimum CO/CO<sub>2</sub> ratio required to reduce NiO dissolved in a slag to metallic ferro-nickel at 1600 °C The metallic nickel product formed consists of 35 mole% nickel and 65 mole% iron, assume ideality The activity of NiO in the slag is 0.015
- What are the key operating conditions of a reduction kiln used to calcine and reduce nickel lateritic ores that subsequently are treated in electric smelting furnaces
- What key parameters determine if a nickel lateritic ore can be treated hydrometallurgically instead of by the traditional reduction smelting route

Data

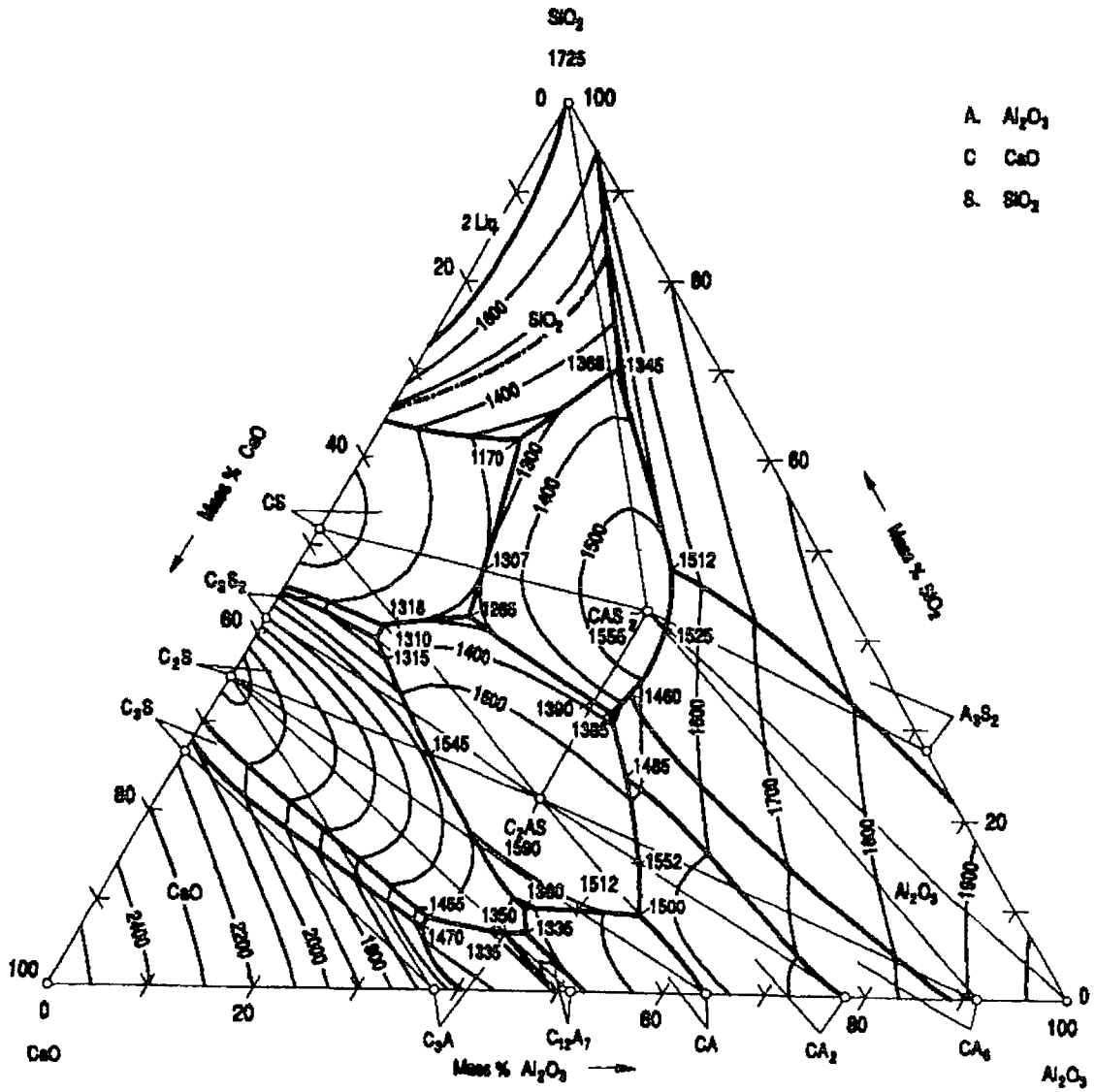


**Problem No 6(20 marks)** Describe a process used to treat a ZnS concentrate(product from the mill) to produce metallic zinc Include flow-diagram, main reactions and main operating parameters for the various stages Also describe the main environmental challenges and possible solutions

**Problem No 7(20 marks)** Below there is a copy of the CaO-Al<sub>2</sub>O<sub>3</sub>-SiO<sub>2</sub> ternary diagram

- Draw the binary diagram for CaO-SiO<sub>2</sub> based on the ternary diagram
- Describe briefly what will happen if a mixture of 20% CaO – 30% SiO<sub>2</sub> and 50% Al<sub>2</sub>O<sub>3</sub> is cooled from 2000 °C to room temperature
- In terms of iron and steelmaking slags, where would you find acid slags and where would you find basic slags
- Describe the main differences between blast furnace and steel making slags What are their roles and how are the compositions different

# Al<sub>2</sub>O<sub>3</sub>-CaO-SiO<sub>2</sub>



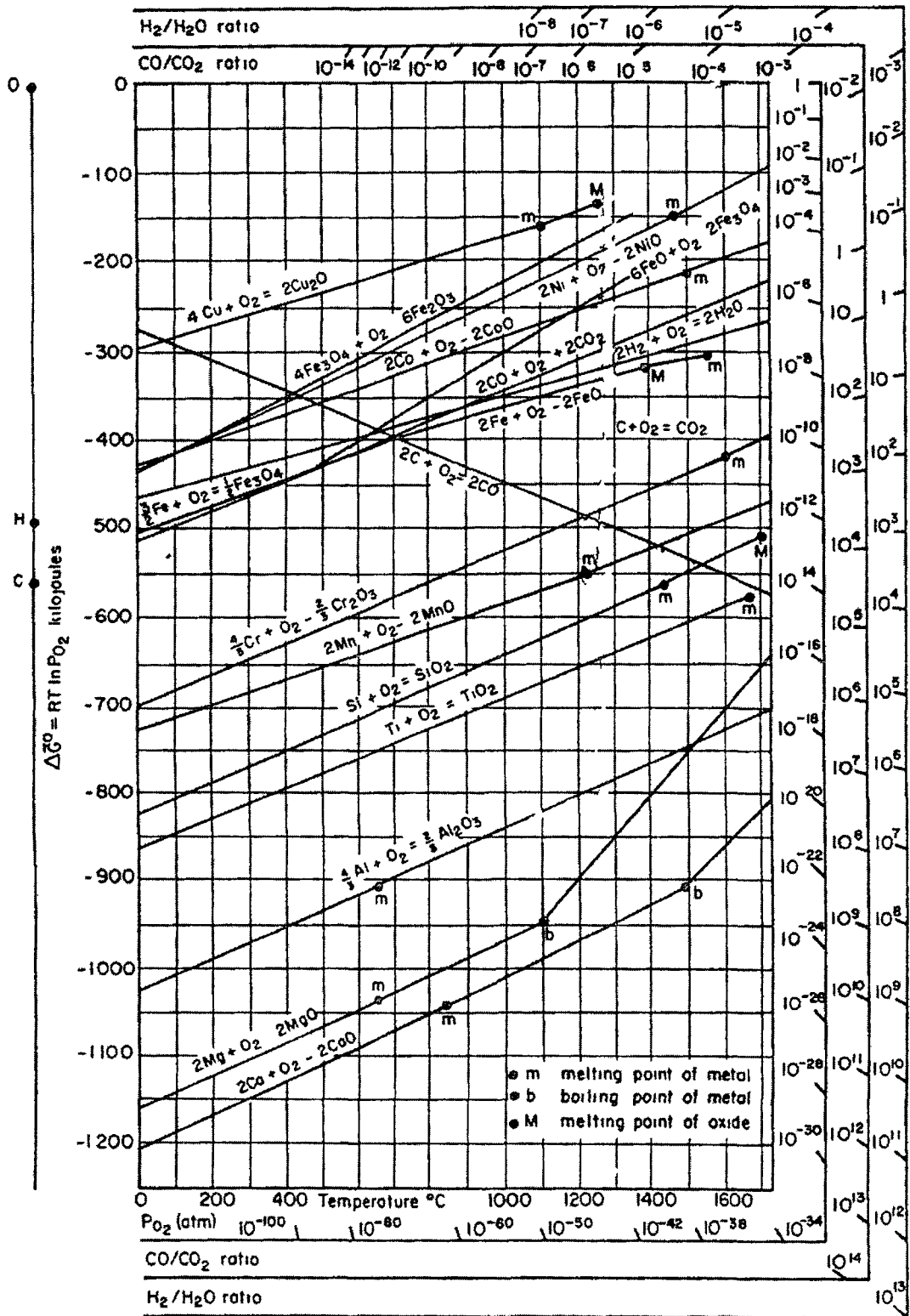


Figure 9-3 Ellingham diagram for some oxides, Richardson nomographic scales are included (Adapted from D R Gaskell, *Introduction to Metallurgical Thermodynamics*, 2nd ed, Hemisphere Publishing, New York, 1981)