

## 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:  $F = 96500 \text{ C/mol}$

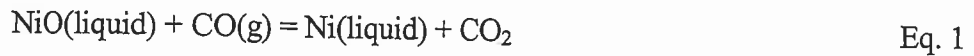
**Problem No. 3(20 marks):** For a copper smelter treating chalcopyrite ( $\text{CuFeS}_2$ ) as the feed

- 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).

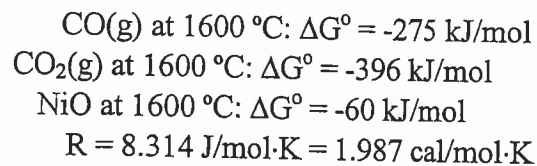
- a) Determine the value of the ore per tonne, and elaborate on its economic feasibility
- b) Draw a schematic flow diagram of mineral processing steps that will have to be taken after the ore is mined until it forms a nickel-copper concentrate that can be fed to a smelter for further processing.
- c) 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:

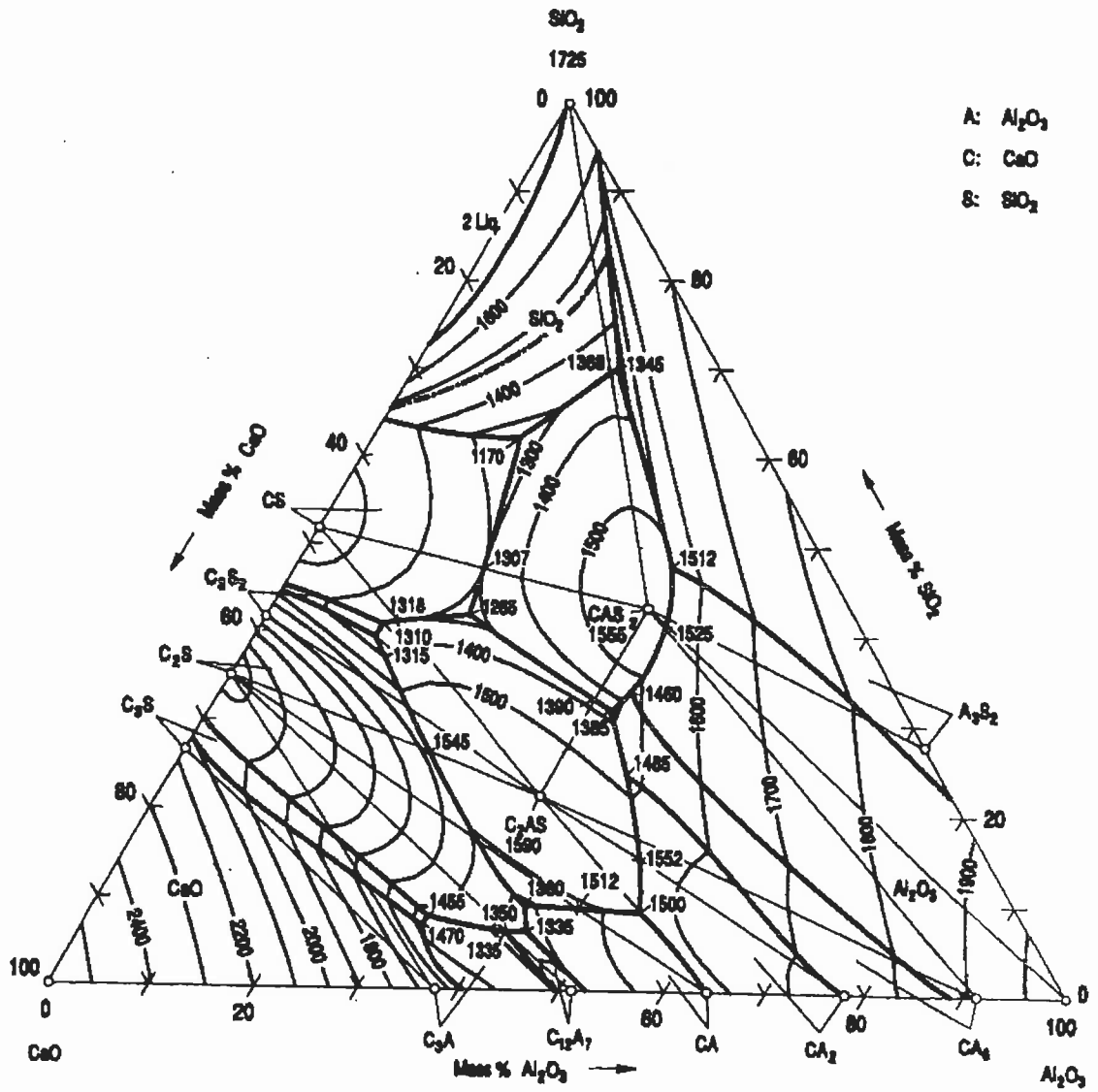


**Problem No. 6(20 marks):** Describe a process used to treat a ZnS concentrate(product from the mill) to produce metallic zinc. Include flow-diagram, main reactions and main operating parameters for the various stages. Also describe the main environmental challenges and possible solutions.

**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>



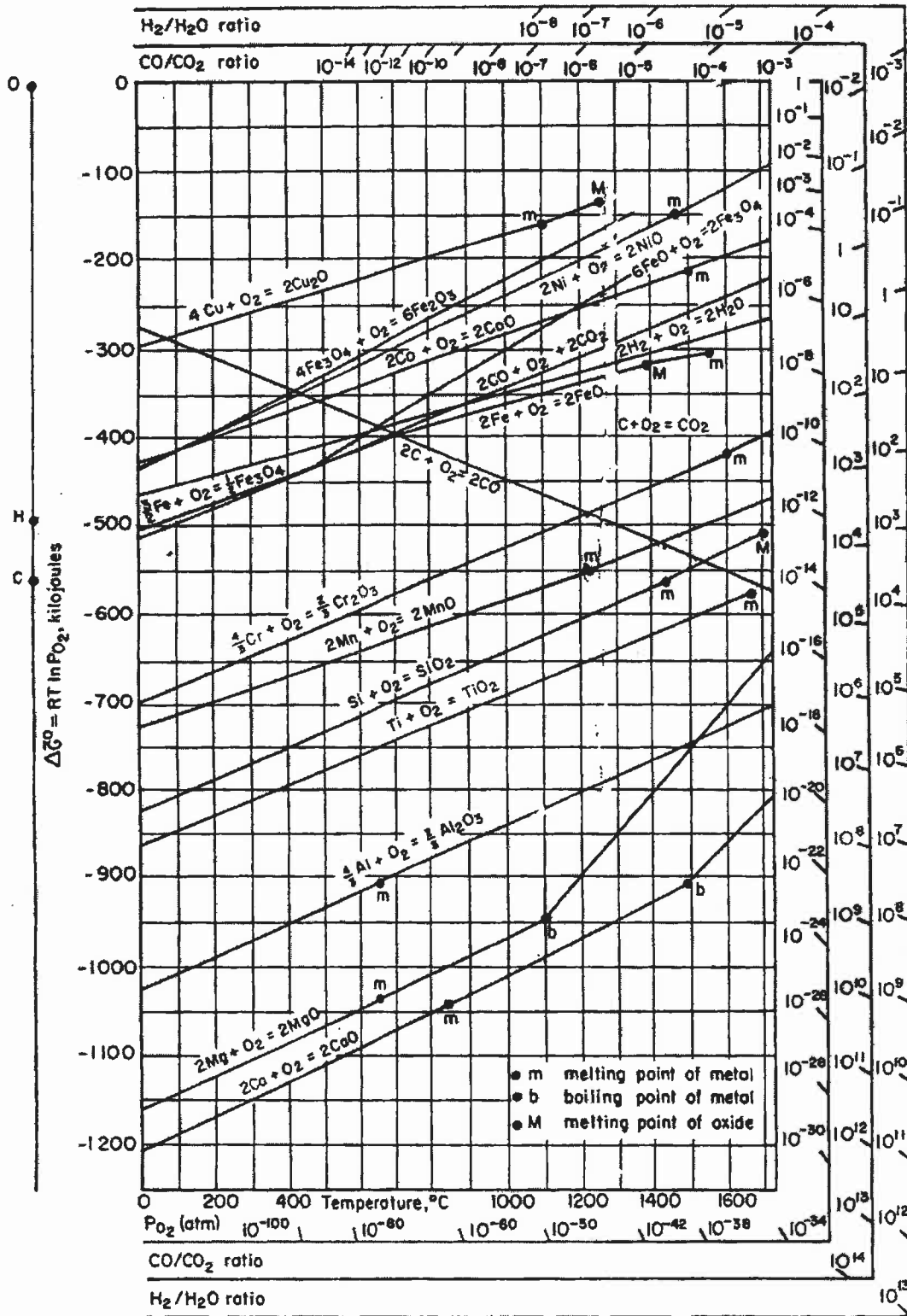


Figure 9-3. Ellingham diagram for some oxides; Richardson nomographic scales are included. (Adapted from D. R. Gaskell, *Introduction to Metallurgical Thermodynamics*, 2nd ed., Hemisphere Publishing, New York, 1981.)