Examination: WB3310TA Extractive metallurgy

9 November 2012

Time: 9:00 AM – 12:00 AM
Location: DTC Zaal 1 and 2, Faculty CiTG

This examination contains 5 questions with total of 70 points. This accounts for 70% of the total evaluation of the course. The rest 30% is accounted for by one report from the case study. Please write down your answers clearly, and avoid scrawled handwriting.

*Note: Please answer **question 5** on separate papers for Dr. Jack Voncken.*

1: General questions *(15 points)*

(1) Please describe what types of processing routes and unit operations are available to extract metals from sulphide ores? Please also state the objectives of these unit operations. *(5 points)*

(2) What is the Ellingham Diagram? Where and how it is used in the evaluation of metallurgical processes, please give one example? *(5 points)*

(3) What are the objectives of roasting of sulphide ores? What types of sulphide roasting processes are available in industrial practice? What are the main roasting reactions zinc sulphide roasting? *(5 points)*

2: Ironmaking and steelmaking *(15 points)*

(1) What are the 3 main functions of metallurgical coke in ironmaking blast furnace process? Please describe all possible reactions involved coke from top to the bottom of the furnace? Are all carbon in the coke and pulverized coal fed into the blast furnace consumed inside the blast furnace? If not, where the rest of carbon go? *(7.5 points)*

(2) What are the two main types of steelmaking processes? What are their general principles of operation: raw materials, heat supply, main reactions, products and by-products or wastes? Please explain how carbon, silicon, sulphur and phosphorus are removed from the steel melt (write down reactions)? *(7.5 points)*

3: Sulphide smelting and refining of copper *(10 points)*

(1) Copper occurs in majority as sulphide ores in the earth. Please describe the main extraction and refining steps and their objectives: from copper concentrates to refined copper as final metal product. *(2 points)*

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(2) Copper matte converting is carried out at about 1200°C in two steps. Please explain: why TWO steps and what TWO steps, please also write down the main chemical reactions? *(2 points)*

(3) The Gibbs energy change for reactions (1) and (2) are given below. *(6 points)*

$$\frac{2}{3}Cu_2S_{(l)} + O_2 = \frac{2}{3}Cu_2O_{(l)} + \frac{2}{3}SO_2 \qquad (1)$$

$$\Delta G^o_{(1)} = -256898 + 81.17T \quad (J/mole\ O_2)$$

$$\frac{2}{3}FeS_{(l)} + O_2 = \frac{2}{3}FeO_{(l)} + \frac{2}{3}SO_2 \qquad (2)$$

$$\Delta G^o_{(2)} = -303340 + 52.68T \quad (J/mole\ O_2)$$

a. Please write down the equilibrium constants for both reactions as the function of activity and/or partial pressure of chemical species in the system.

b. Please calculate the equilibrium constants for both reactions at 1200°C.

c. Please use Gibbs energy change of the reactions to explain the oxidation order of the 2 sulphide compounds (Cu_2S and FeS) in the matte: which is oxidized first, and WHY?

4: Hydrometllurgical processes and electrometallurgy *(15 points)*

(1) ***Leaching*** is one of the most important unit operations in hydrometallurgical processes. Please answer the following two questions.

a. What types of leaching methods can be identified according to the nature of chemical reaction? *(3 points)*

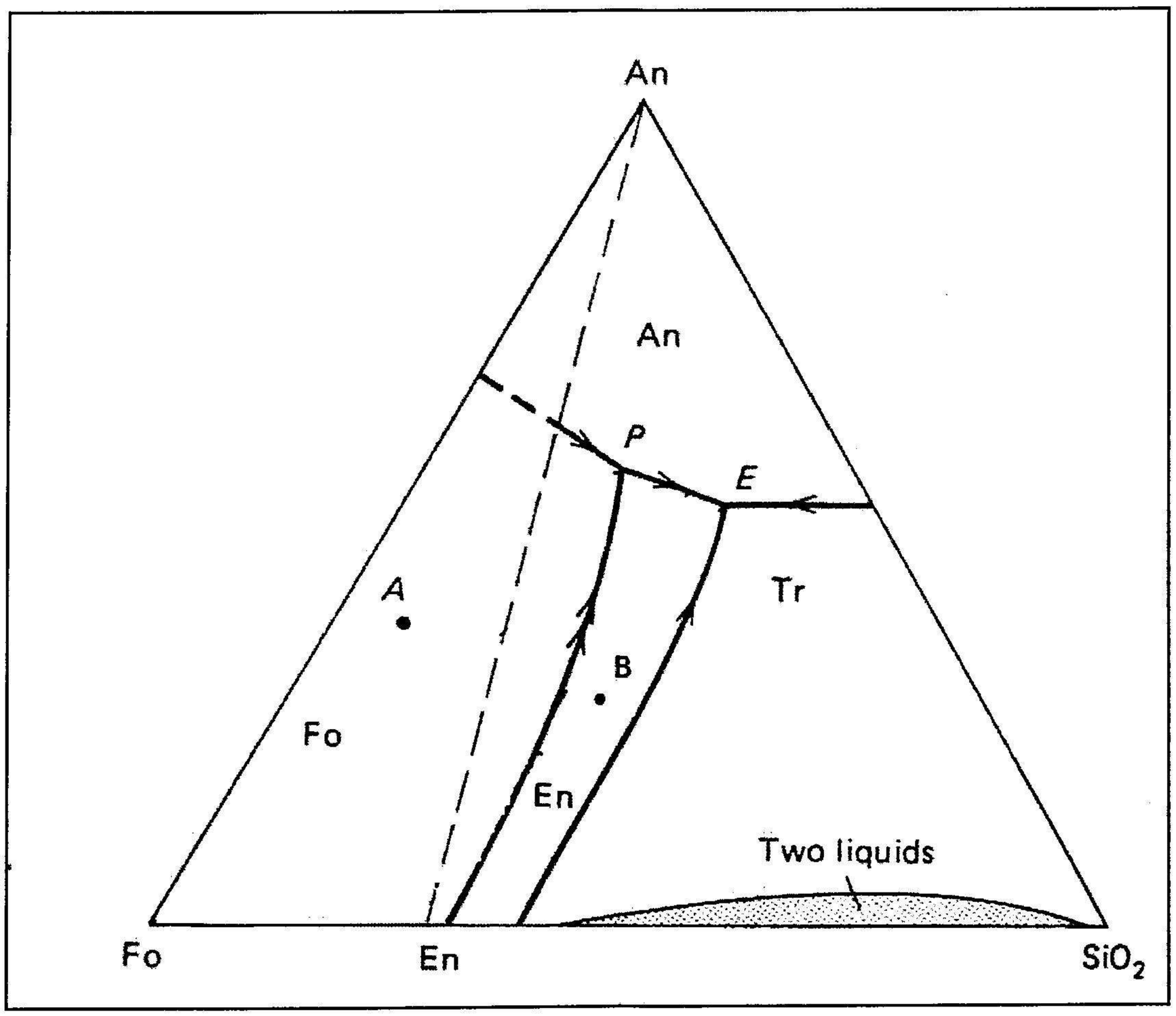
b. What are the main types of leaching processes based on the characteristics of physical form of the ore and reactor type? *(3 points)*

(2) ***Electrometallurgy***

a. What are the principles of electrolysis? What types of electrolytic processes are available for metals extraction and refining? Please give ONE example for each of the electrolytic process in extractive metallurgy. *(6 points)*

b. Electrical power is the most important cost factor for electrolytic process. What *physical law*s and operating parameters are determining the productivity and power consumption of the electrolysis for metals extraction or refining? Please discuss their influences. *(3 points)*

5: Phase diagrams *(15 points)*



The diagram shows the liquidus projection of the system *forsterite-anorthite-silica* ***(Mg_2SiO_4-$CaAl_2Si_2O_8$-SiO_2)*** at a certain temperature. The phases in this system are:

Fo = forsterite, Mg_2SiO_4, a member of the olivine series
An = anorthite, $CaAl_2Si_2O_8$, a member of the feldspar group
En = enstatite, $MgSiO_3$, an orthopyroxene.
Tr = tridymite, SiO_2, a HT-silica polymorph.

The long thin dotted straight line from *En* to *An* is the *Alkemade-line* between *enstatite* and *anorthite.* Also given is the *liquidus composition* A.

Answer the following questions:

a) What does it mean that the boundary curve between Fo and An is shown dotted?

b) Explain the nature of point P and E.

c) Is the point marked by the intersection of the Alkemade line and the dotted boundary curve between Fo and An a <u>maximum</u> in temperature? Explain your answer.

d) Draw on a separate sheet (provided) the crystallization path for the liquidus composition A, and explain what happens during the crystallization of this composition.

e) Draw on a separate sheet (provided) the crystallization path for the liquidus composition B, and explain what happens during the crystallization of this composition.

f) Does the phase En (enstatite) melt congruently or incongruently? Explain you answer.

Rating of the questions a) to f).

The total for this question is 15 points

a) 1 point
b) 1 point
c) 3 points
d) 4 points
e) 4 points
f) 2 points

Bijlage Fasendiagrammen

Naam:.....

Studienummer:.....