# Examination: TA3380 Extractive metallurgy

**11 November 20111**

Time: 9:00 AM – 12:00 AM
Location: TN-Classroom 10 (A272), Faculty TNW

*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.*

*Note: Please answer **question 5** (Phase diagrams) on separate papers for Dr. Voncken.*

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## 1: General questions *(15 points)*

(1) Please describe clearly what types of processing routes and unit operations are available to extract metals from (a) sulphide ores, and (b) oxide ores?

(2) What are the objectives of roasting for processing sulphide ores? What types of sulphide roasting processes are available in industrial practice? What are the main roasting reactions for each types of sulphide roasting?

(3) What types of metal refining operations are available? What are their general metallurgical principles?

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## 2: Ironmaking and steelmaking *(10 points)*

(1) What are the functions of metallurgical coke in iron-making blast furnace process? Please describe all possible reactions involved coke from top to the bottom of the furnace? Are ALL coke into the blast furnace consumed in the blast furnace? If not, where the rest of them in the form of carbon go? (5 points)

(2) What are the main purposes of steelmaking? Please describe the two most important types of steelmaking processes: their general principles of operation (raw materials, heat supply, main reactions, products and by-products or wastes, furnace types etc.)?

(5 points)

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## 3: Sulphide smelting and refining *(15 points)*

(1) Copper occurs in majority as sulphide ores in nature. Please describe the main extraction and refining steps and their functions of copper-making process: from concentrates to refined copper as final metal product. Please also write down the main chemical reactions for each individual step.

(5 points)

(2) Copper matte converting is carried out at about 1200°C. Please use Gibbs free energy functions below to indicate clearly: (a) the oxidation order of the 2 sulphide compounds of $Cu_2S$ and FeS in the matte (which is first); (b) $Cu_2O$ initially formed is unstable if there is substantial amount of FeS in the matte. The Gibbs free energy of the following 2 oxidation reactions as functions of temperature is given below (page 2):

(10 points)

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*Question 3 (2) continued:*

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

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

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

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

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

(1) What are the purposes of leaching? What types of leaching operations are available and what are the main chemical reactions of these leaching operations?

(5 points)

(2) Please describe the unit operation for *hydrometallurgical* extraction of zinc metal from its sulphide concentrates (if it involves a non-hydrometallurgical operation, please describe it also). Please write down the main chemical reactions, major raw materials and products/by-products.

(5 points)

(3) 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.

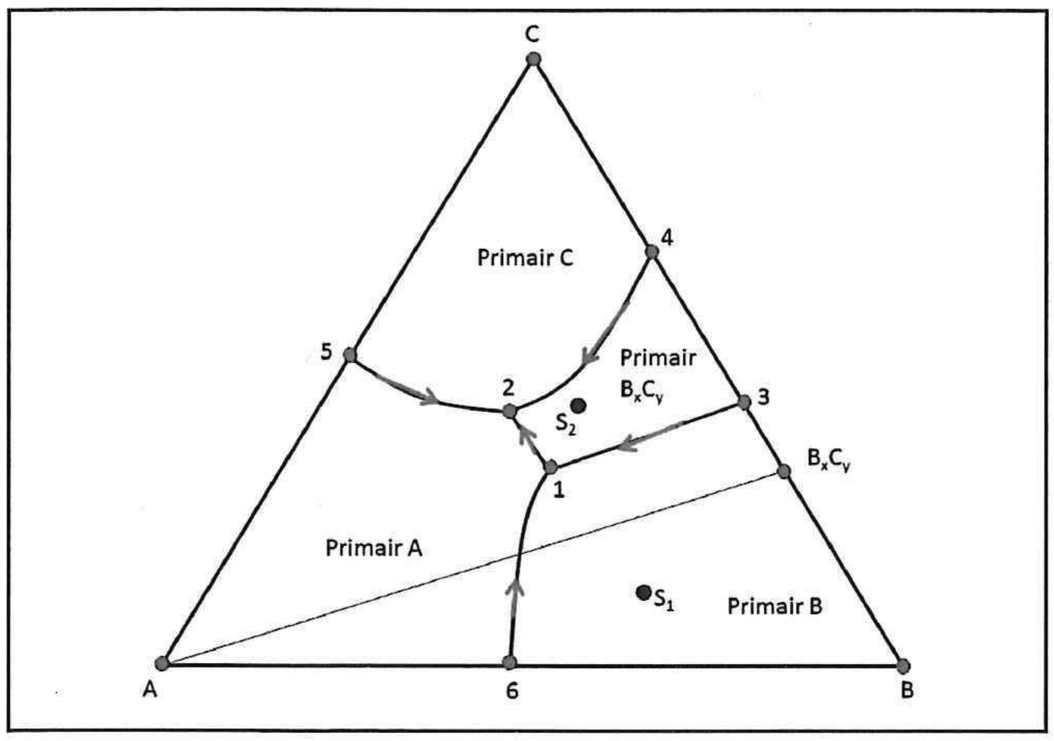
Electrical power is the most important cost factor for electrolysis process. What *physical law* and operating parameters are determining the power consumption of the electrolysis for metals extraction or refining?

(5 points)

**(Turn to page 3 for Question 5)**

## 5: Phase diagrams *(15 points)*

Beschouw het onderstaande ternaire diagram van het system A-B-C. Het betreft een systeem met smeltfasen en vaste fasen.




Please answer Question 5 on two separately supplied sheets.

Beantwoord de volgende vragen:

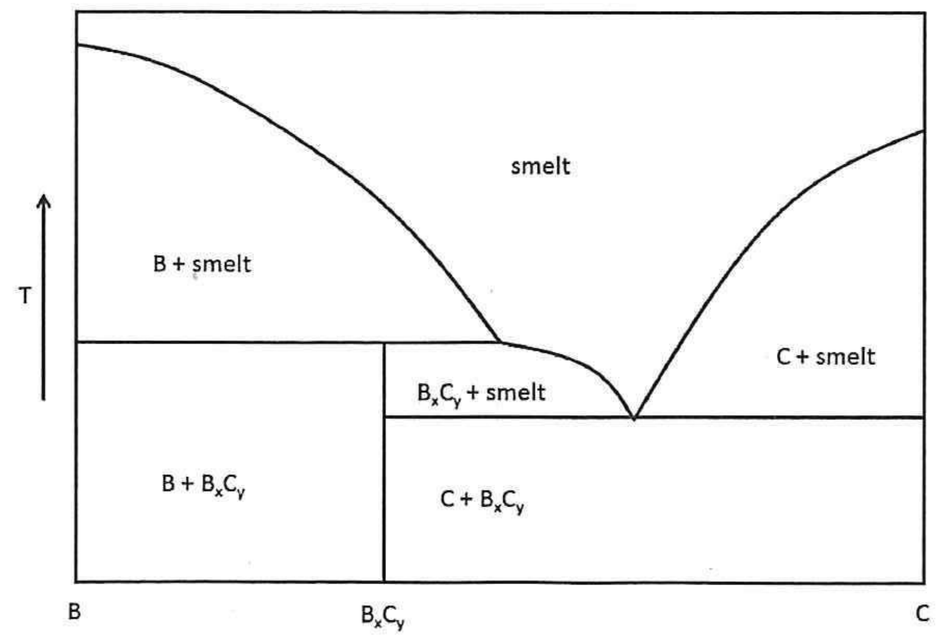
a) Hoe noemt men een lijn van het type A-$B_xC_y$? (5%) Alkemade lijn

b) Als ik langs de lijn A-$B_xC_y$ een binair fasendiagram zou tekenen, zou dat dan een *echt binair system* (true binary system) zijn of een *pseudobinair system* (pseudobinary system)? Verklaar uw antwoord. (20%). True binary bc ligt op een

c) Benoem de punten 1, 2, 3, 4, 5, en 6. (5%)

d) Teken op een apart vel (bijgeleverd) het kristallisatiepad van de smelten met de samenstelling $S_1$ en $S_2$. (30%)

e) In het onderstaande diagram vindt u een schetsmatige voorstelling van de snede BC. Stel, ik verhit een vaste stof met de samenstelling $B_xC_y$ zodat deze gaat smelten. Geef m.b.v. dit diagram (op een apart vel (bijgeleverd)) het gehele smeltproces weer, en verklaar wat er steeds gebeurt (40%).




**(End of exam questions)**