UNIVERSITY OF GHANA

BSC. (Eng.) MATERIALS SCIENCE AND ENGINEERING

FIRST SEMESTER EXAMINATIONS: 2016/2017

DEPARTMENT OF MATERIALS SCIENCE AND ENGINEERING

MTEN 403: REFRACTORIES (2 CREDITS)

INSTRUCTIONS: ANSWER ALL QUESTIONS

TIME ALLOWED: TWO (2) HOURS

1.

a. While silicon carbide (SiC) refractory performs well in a wide range of applications in harsh environmental conditions, one weakness in process industry applications has been in its oxidation resistance, particularly in the temperature range of approximately 900-1100 °C. In refractory applications, the oxidation of silicon carbide leads to volume and linear expansion, which, if severe enough, can result in cracking and failure of the refractory products (See Figure 1 on page 4). With the aid of equations discuss briefly the reaction(s) that may take place when SiC refractory is exposed to

i. Oxidizing atmosphere at elevated temperatures.
ii. Reducing atmosphere at elevated temperatures.
iii. Humid atmosphere.

[9 Marks]

b. A refractory material is to be exposed to a melt with a high content of FeO slag (basic). Which refractory material will you recommend? Justify your answer.

[7 Marks]

c. i. How do oxidation inhibitors work in MgO-C refractory?

ii. Give three inhibitors used to reduce oxidation in MgO-C refractory.
iii. Describe (using equations) how the inhibitors listed in c(ii) prevents the oxidation of MgO-C refractory.

[9 Marks]

d. Silica, SiO_2 provides excellent service particularly in the glass making and steel industry. When firing SiO_2 refractories at temperatures below 600 °C, a carefully controlled heating-up schedule is used. Explain briefly why it is necessary to use such controlled heating-up schedule when firing SiO_2 at temperatures below 600 °C.

[5 Marks]

2.

a. Explain why micro cracks are frequently formed in a refractory material. *Detailed explanation is required.*

[12 Marks]

b. SiC ramming mix is applied in a lining concept as described in the ***Figure*** 2 below. The temperature at the hot face (SiC) side is 1250 °C and the ambience is a stagnant air at 20 °C.

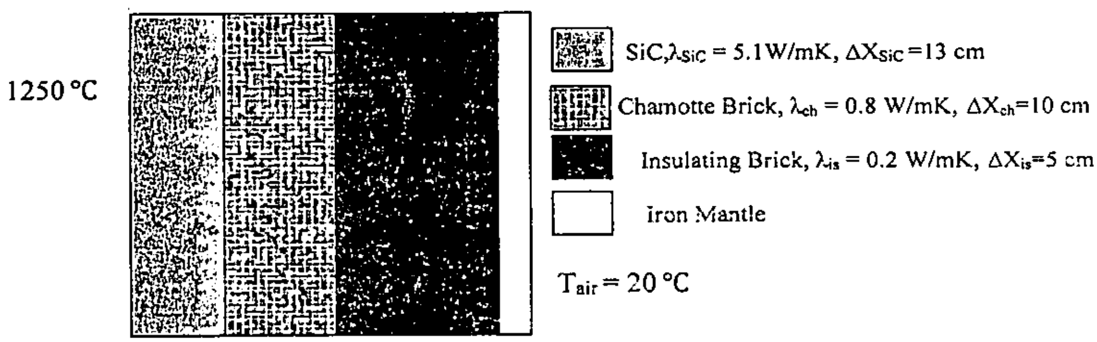

Figure 2: SiC ramming mix lining

The heat transfer number for the mantle/air interface is 48.69 W/m^2K

Calculate:

i. The heat flow through the complex lining
ii. The temperature of the mantle
iii. The necessary thickness of a Chamotte lining replacing the complex lining assuming that, the heat flow through the complex lining is constant.

[18 Marks]

3.

A large number of refractory materials are based on the system SiO_2-Al_2O_3. The different materials are categorized according to the mass ratio between the component oxides.

a. All materials with alumina content higher than 45 mass % are categorized as high alumina materials. Why is 45 mass % chosen as the "magic number"?

[3 Marks]

b. What is the notation for materials with alumina content between 30 and 45 mass % and which minerals are these materials based on? **[6 Marks]**

The remaining part of problem 3 will focus on three different aluminum silicates: Brick A (100 % alumina), Brick B (95 % Alumina) and Brick C (63 % alumina based on andalusite).

c. Assume that brick A is exposed to pure fayalite slag at ***1400*** °C and that equilibrium is established. (USE FIGURE 3a)

  i. Which phases are coexisting at equilibrium and what will be the composition of the liquid phase?

  ii. Assume that you are able to isolate the liquid phase (from c). What will the solidus temperature be and which phases will coexist below the solidus temperature?

[12.5 Marks]

d. Brick B and C are exposed to pure fayalite at ***1300*** °C. However, these bricks are relatively porous and you may assume that the slag infiltrated zone contains 25 mass % of fayalite. (USE Figure 3b)

  i. Report the phase composition qualitatively and quantitatively when equilibrium is established in the slag infiltrated zone in Brick B.

  ii. Report the phase composition qualitatively and quantitatively when equilibrium is established in the slag infiltrated zone in Brick C.

  iii. Comment on the refractoriness of Bricks B and C.

[18.5 Marks]

(a) (b)

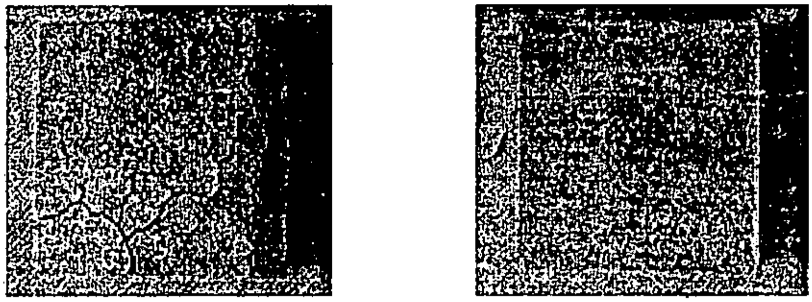

Figure 1: SIC Refractory Before (a) and After (b) Oxidation

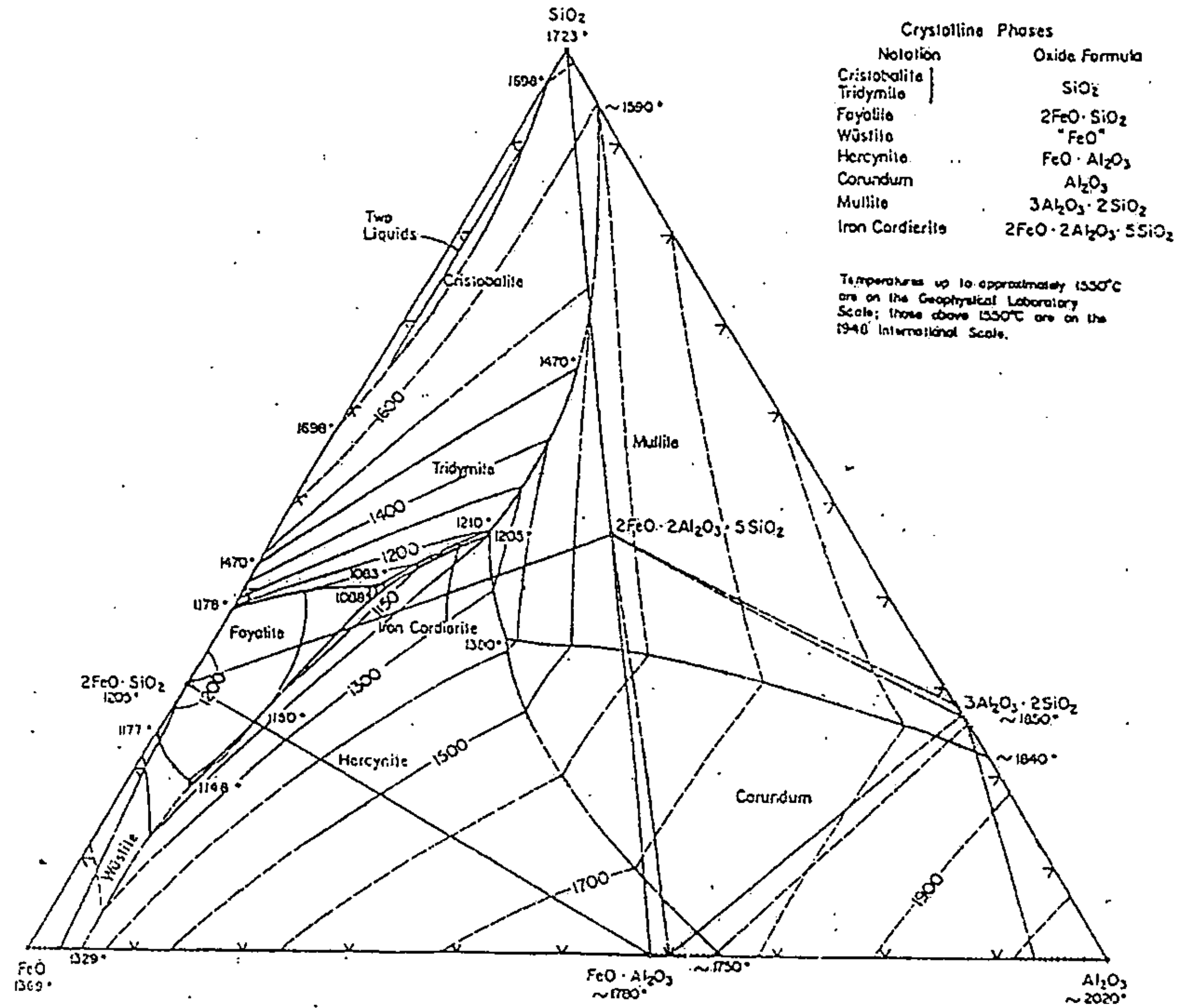

Figure 3b: The System FeO-Al2O3-SiO2