CHEM-E6160 FUNDAMENTALS OF PYROMETALLURGY

ONLINE-EXAM 21.12.2021, 09:00-13:00 (14:00 if you have a permission to one additional hour)

Use of course material in the exam is allowed.

Name:

Student no.

<u>Theory questions</u> (Write your answer directly below the question)

1. Pyrometallurgical furnaces have a crucial task in keeping the high temperature melts (slags, mattes, metals) and hot gases safely inside them. What are the main factors, and their roles, determining furnace integrity?

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2. Metallurgical slags: a) their roles/tasks in metals production, b) their physico-chemical properties and factors determining those, c) differences in different metals' processes?

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3. Examine factors that affect the final impurity concentrations of low-alloy steel.

Calculations (choose two out of the three!)

Calculations can be made directly to an excel file (found in the same place than the exam paper).

4. **Steel production**

The metallic charge of converter process consists of hot metal and scrap in the ratio of 4:1 (i.e., four times more hot metal than scrap). The hot metal contains 4 wt-% C, 1 wt-% Si and rest Fe. The scrap is assumed to be pure iron.

Oxygen of 99.5 % purity is blown for refining and the efficiency of oxygen utilization is 90 %. 2 wt-% of Fe charged is lost in the slag as FeO.

Steel contain 0.2 wt-% C and rest Fe. The rest of the carbon is distributed equally to CO (g) and CO_2 (g)

Calculate the following per ton of steel:

a) Weights of hot metal and scrap to be charged (kg/t steel)

b) Oxygen to be blown (m^3/t steel)
(assume that the oxygen behaves ideally)

Chemical reactions:

$[Si] + O_2(g) \rightarrow (SiO_2)$ $[Fe] + ½O_2(g) \rightarrow (FeO)$ $[C] + ½O_2(g) \rightarrow CO(g)$ $[C] + O_2(g) \rightarrow CO_2(g)$

$M_{Si} = 28.086$ $M_{Fe} = 55.845$ $M_O = 15.999$ $M_C = 12.011$ (g/mol)

$V_m = 22.414$ l/mol (molar volume of ideal gas)

5. **Copper converting**

Liquid matte (82 wt-% Cu_2S, 18 wt-% FeS) from the smelting process is oxidized in a Peirce-Smith converter by blowing oxygen-enriched air (29 vol-% O_2 in blast).

Converting takes place in two stages:

The first stage is the slag-forming stage where FeS is oxidized to FeO and SO_2 (g). Silica flux is added to form a liquid slag with FeO. The slag forming stage is finished when the FeS-content in the matte has been lowered to 1 wt-%.

Calculate

a) The amount of oxygen-enriched air required for slag-forming stage per ton of matte (m^3/t matte).
(assume that the air behaves ideally)

b) How much you need to charge silica flux (kg/t matte) to keep the fluxing ratio, SiO_2/Fe, in the slag at 0.5?

Flux composition: 88 wt-% SiO_2, 6 wt-% Al_2O_3, 3 wt-% K_2O, 3-wt-% Na_2O

$M_{Cu} = 63.546$ $M_{Fe} = 55.845$ $M_S = 32.065$ $M_O = 15.999$ (g/mol)

$V_m = 22.414$ l/mol (molar volume of ideal gas)

6. **Heat transfer**

A furnace wall consists of three layers; a 20-cm inner layer of refractory lining (thermal conductivity 4.2 W/m·K), a 10-cm intermediate layer of insulating brick (thermal conductivity 0.3 W/m·K) and a 1-cm steel shell (thermal conductivity 40 W/m·K). The heat loss from the steel plate to the atmosphere can be represented by a combined heat transfer coefficient for convection and radiation of 13.8 W/m^2·K. The temperature inside the furnace is 1420°C and the atmospheric temperature 23°C. The internal surface temperature of the inner refractory layer stays in a constant freeze lining temperature of 1180°C.

Calculate

a) The heat loss per unit surface area

b) The in & out surface temperatures of the layers.