中南大學
CENTRAL SOUTH UNIVERSITY

Unit 6 Calcination and Roasting

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School of Metallurgy and Environment

New words and expressions

- Calcination [ˌkælsɪ'neɪʃən] n. 焙烧，煅烧
- calcine ['kælsain] 焙砂
- Decomposition [ˌdi:kɒmpə'zɪʃn] n. 分解，裂解
- Metal hydrate ['haɪdreɪt] 金属氢氧化物
- Carbonate ['kɑ:bəneit] n. 碳酸盐
- Basic sulphate ['sʌlfeit] 碱式硫酸盐
- Rotary kiln ['rəʊt(ə)ri] [kiln] 回转窑
- Shaft furnace 竖炉，高炉
- Dead roasting 死烧
- Sulphating roasting 硫酸化焙烧
- Reduction roasting [ri'dʌkʃən] 还原焙烧
- equillibrium constant 平衡常数

New words and expressions

- kellog diagram 凯洛格相图
- predominance [prɪ'dɒmɪnəns] n. 优势，优越
- predominance area 优势区
- partial roasting ['pɑːʃ(ə)l] 部分焙烧
- selective roasting 选择性焙烧
- chloridizing roasting [k'lɔːrɪdaɪzɪŋ]氯化焙烧
- smelt n. v. 熔炼
- noble metal 惰性金属，贵金属
- hypothetical adj. 假定的，有前提的 [ˌhaɪpə'θetɪkl]
- fume n. 烟气
- halide n. 卤化物['helaid]
- Pyrohydrolysis [paɪərəʊhaɪ'drɒlɪsɪs] 热水解
- criterion [kraɪ'tɪriən] 标准

New words and expressions

- volatilizing roasting ['vɒlətəlˌaɪzɪŋ]_挥发焙烧
- magnetizing roasting ['mægnɪtaɪzɪŋ]磁化焙烧
- magnetite ['mægnəˌtaɪt] n. 磁铁矿
- flash roaster 闪速焙烧炉,飘悬焙烧炉
- inject v. 喷射，喷入
- fluidize v. 流态化 ['fluːədaɪz]
- fluidized bed roaster 流态化焙烧炉
- burner n. 喷嘴
- suspend [sə'spend] v. 悬浮，漂浮

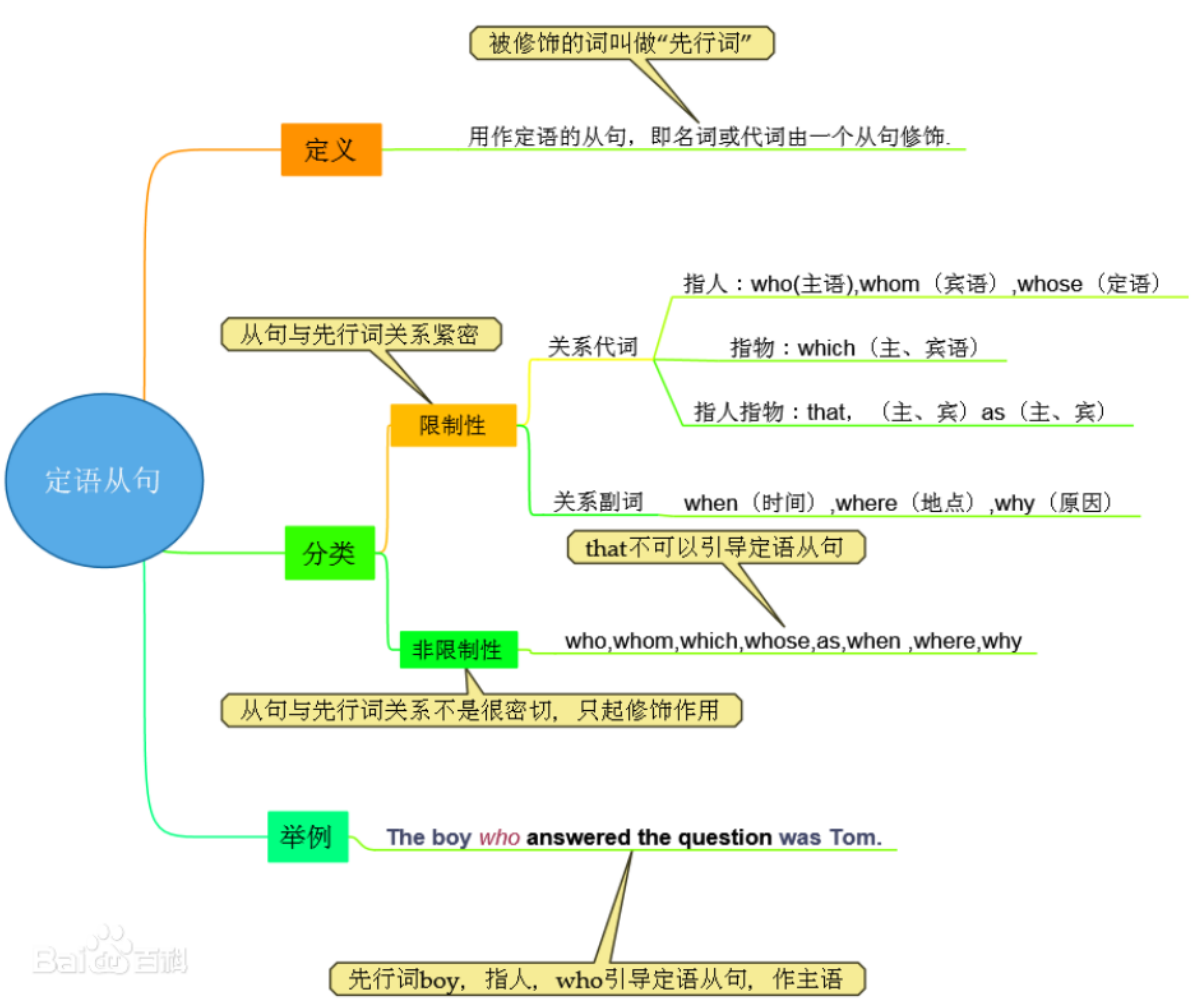
- fluosolids roaster 流态化焙烧炉
- matte n. 冰铜，锍
- reverberatory furnace 反射炉 [rɪ'vɜːbərətərɪ]
- hematite ['hemətait]Fe_2O_3
- chlorination [ˌklɔːrɪ'neɪʃn]氯化
- phase diagram相图

New words and expressions

1	chloridizing roast	氯化焙烧	2	fume	烟气
3	volatilizing roasts	挥发焙烧	4	calcination	煅烧
5	constant temperature	恒温	6	hydrate	水合物
7	fluidized bed furnaces	沸腾炉	8	multihearth unit	多层炉
9	shaft furnaces	竖炉	10	rotary kilns	回转窑
11	sulfating roast	硫酸化焙烧	12	dead roast	死烧
13	reduction roast	还原焙烧	14	bag filters	袋式收尘器
15	flash roasters	闪速焙烧炉	16	Ore fines	粉矿
17	reverberatory furnace	反射击炉	18	criterion	标准
19	equilibrium constant	平衡常数	20	diagonal line	对角线
21	fluo—solids roaster	流化固体焙烧炉	22	phase diagram	相图
23	vertical reaction line	垂直反应线	24	magnetite	磁铁矿
25	magnetizing roast	磁化焙烧	26	hematite	赤铁矿
27	preferentially oxidize	优先氧化	28	partial roasting	部分焙烧
29	differential	微分(的)	30	halide	卤化物

➢Stylistic features of EST（科技英语的文体特点）

□Attributive clause（定语从句）



限制性定语从句与非限制性定语从句的区别：

① 形式不同
② 功能不同
③ 翻译不同
④ 含义不同
⑤ 先行词不同
⑥ 关系词不同

➢What can we learn?

- What are “Calcination” and “Roasting”?
- How are different kinds of “roasting” categorized?
- The relationship between “Kollog diagram” and “roasting” conditions.
- The development of “roasting” furnaces.

- Preposition(介词）
- Chemical equation
- Definition of a process

- Calcination
- Roasting
  - ✓Roasting principle: phase diagram
  - ✓Partial roasting: partial removal of sulfur
  - ✓Dead roasting : completely oxidized
  - ✓sulfating roasting: conversion to sulfate
  - ✓ other roasting :chloridizing roasting, volatilizing roasting,
  - ✓ magnetizing roasting
- Roasting development

➢ Calcination

Chemical decomposition of the mineral, mainly used to remove water, CO_2 and other gases which are chemically bound in metal hydrate and carbonates.

➢ Roasting

Roasting consists of thermal gas-solid reactions, which can include oxidation, reduction, chlorination, sulfation, and pyrohydrolysis [paiərəuhai'drɔlisis]热水解

Categories: Dead roasting, Partial roasting, Preferential roasting, Reduction roasting, Chloridizing roasting, Volatilizing roasting, Magnetizing roasting

Dead Roasting

- The most common example of roasting is the oxidation of metal sulfide ores. The metal sulfide is heated in the presence of air to a temperature that allows the oxygen in the air to react with the sulfide to form sulfur dioxide gas and solid metal oxide. The solid product from roasting is often called "calcine."
- In sulfide roasting, if the temperature and gas conditions are such that the sulfide feed is completely oxidized, the process is known as "dead roasting."

Partial Roasting

- Sometimes, as in the case of pre-treating reverberatory or electric smelting furnace feed, the roasting process is performed with less than the required amount of oxygen to fully oxidize the feed. In this case, the process is called "partial roasting," because the sulfur is only partially removed.

sulfation Roasting

- if the temperature and gas conditions are controlled such that the sulfides in the feed react to form metal sulfates instead of metal oxides, the process is known as "sulfation roasting."

Selective Roasting

- Sometimes, temperature and gas conditions can be maintained such that one metal forms an oxide, while another metal present in the concentrate remains as the sulfide. The process is known as "selective roasting".

sulfation Roasting

- if the temperature and gas conditions are controlled such that the sulfides in the feed react to form metal sulfates instead of metal oxides, the process is known as "sulfation roasting."

1. Calcination

Definition of Calcination

- Calcination involves the chemical decomposition of the mineral and is achieved by heating to above the mineral's decomposition temperature (T_D) or by reducing the partial pressure of the gaseous product (P_{H_2O}, P_{CO_2}) below that of its equilibrium partial pressure for a certain constant temperature. For example,

$CaCO_3 = CaO + CO_2$ $T_D = 900℃$ (under standard thermodynamic conditions)

竖式预热器

石灰回转窑

- Calcination is mainly used to remove water, CO_2 and other gases which are chemically bound in metal hydrate and carbonates as these minerals have relatively low decomposition temperatures.

Main purpose of calcination

- Calcinations are conducted in rotary kilns, shaft furnaces, or fluidized bed furnaces.

Equipment for calcination

rotary kilns / kɪln /:回转窑
shaft furnaces： 冲天炉
fluidized bed furnaces：沸腾炉

2. Roasting of metal concentrates

- The most important roasting reactions are those concerning metal sulfide concentrates and involve chemical combination with the roasting atmosphere.

Possible reactions include:

$MS + 3O_2 = 2MO + 2SO_2$ (dead roasting)

$MS + 2O_2 = MSO_4$ (sulfating roasting)

$MS + O_2 = M + SO_2$ (reduction roasting)

Other equilibria which need to be taken into account include:

$(1/2)S_2 + O_2 = SO_2$ and

$SO_2 + (1/2)O_2 = SO_3$

Attributive clause

- Thus, when P_{SO2} is large and P_{S2} become large. Also when P_{O2} and P_{SO2} become large, P_{SO3} become large which is the required condition for sulfating roasting; the sequence of reactions being

$MS + (3/2)O_2 = MO + SO_2$

$SO_2 + (1/2)O_2 = SO_3$

$MO + SO_3 = MSO_4$

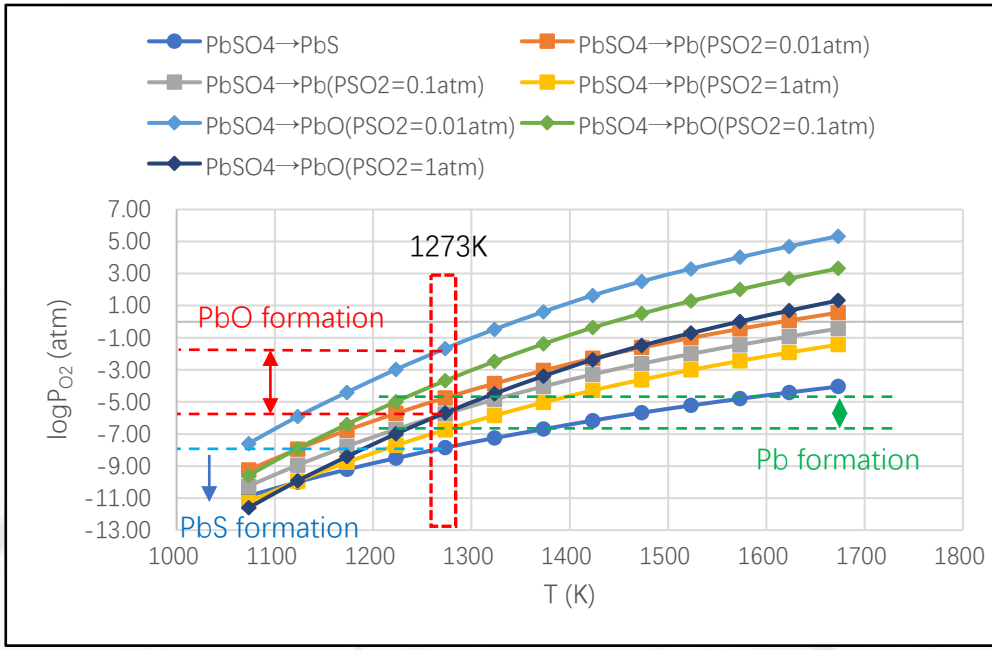
giving the overall sulfating reaction:

$MS + 2O_2 = MSO_4$

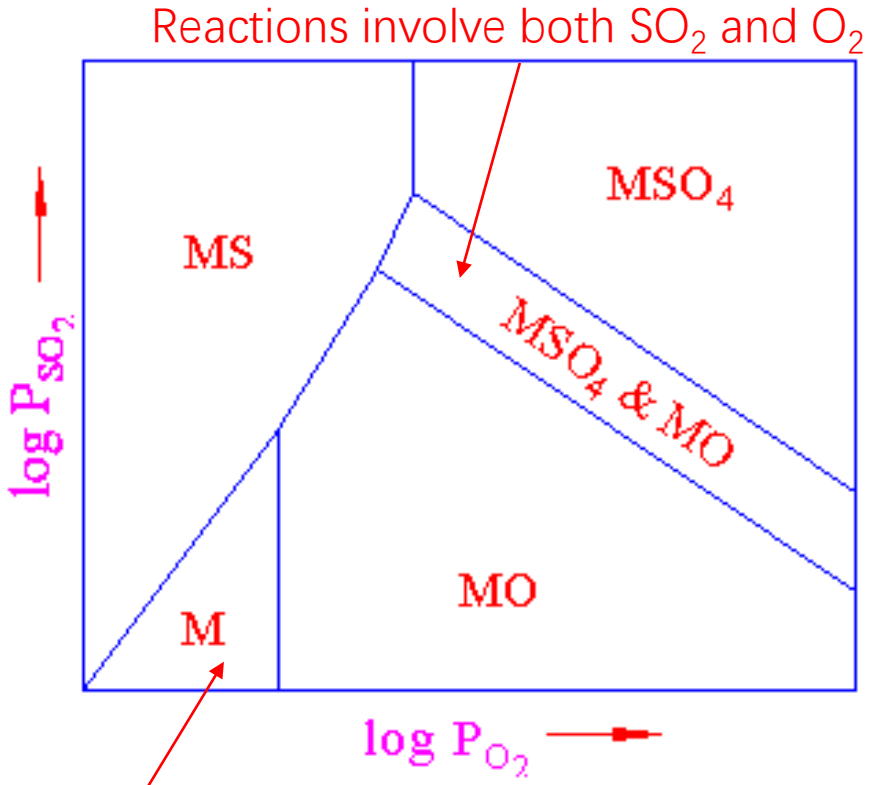
- If the metal forms several sulfides, oxides, sulfates and basic sulfates, e.g. M_2S, M_2O_3, $M_2(SO_4)_3$, MSO_4, XMO_3 further equilibria must be considered. By examination of the equilibrium constant for each of these roasting reactions it is possible to determine the values of P_{O2} and P_{SO2} at which each of the roasting products (calcine) is in equilibrium with the metal sulfide at a constant temperature.

Example: $PbSO_4$ reduction roasting

T	PbSO4+CO→PbS+CO2	PbSO4+CO→Pb+CO+SO2	PbSO4+CO→PbO+CO+SO2
1073.15	-310.49	-147.28	-70.09
1123.15	-309.78	-156.01	-78.28
1173.15	-308.45	-164.09	-86.14
1223.15	-306.78	-171.80	-94.45
1273.15	-305.02	-179.38	-102.66
1323.15	-303.16	-186.83	-110.77
1373.15	-301.23	-194.17	-118.79
1423.15	-300.52	-201.39	-126.72
1473.15	-299.39	-207.66	-133.72

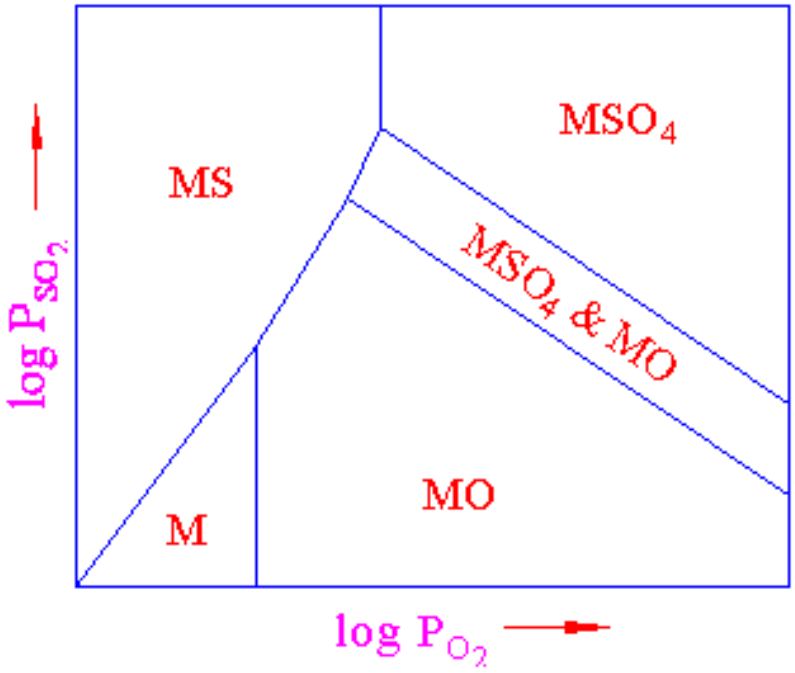


- Increasing or decreasing the P_{O2} or P_{SO2} may produce other roasting reactions. Kellog has used this criterion to construct thermodynamic phase diagrams for the roasting reactions at a constant temperature (Fig. 12-1).
- Reactions which involve both SO_2 and O_2 are seen to have a diagonal line since the equilibrium phases produced will depend on the partial pressure of both gases. The roasting of a metal sulfide to sulfate will produce a vertical reaction line since only O_2 will take part in the reaction.



Kollog diagram

- The 'Kellog diagram' provides the predominance areas for each phase within which P_{O2} and P_{SO2} can be varied without altering the roasting product or calcine. It should be noted that if roasting is carried out in air the sum of the partial pressure of O_2 and SO_2 is about 0.2 atm, i.e. PO_2+ PSO_2 = 0.2 atm.



The relationship between Kellog diagram and roasting conditions

i.e. 与 e.g.区别

- i.e.表示也就是说，换句话说。相当于that is, in other words.
- e.g.举个例子，相当于 for example
- The evaluation noted that the employee had frequently exhibited irresponsible behavior. e.g. coming to work late, failing to complete projects.
- The general rule is that if a number can be expressed in three words or fewer, it should be written out (e.g. two hundred seventy).
- Using a comma to enclose(i.e. both before and after) the year in a month-day-year sequence.

- The ore concentrate will undoubtedly contain other metal sulfide each with their own phase predominance areas dependent upon P_{O2} , P_{SO2} and temperature. By examination of the appropriate diagrams it is possible to obtain information which will enable the roasting operator to select the most appropriate roasting conditions for each particular concentrate. In this way selective roasting of one metal sulfide to its oxide may be achieved while another metal present in the concentrate remains as the sulfide.

The relationship between Kellog diagram and roasting conditions

- One of the most common roasting operations is that of partial roasting in which the metal concentrate containing several metal sulfides is roasted to preferentially oxidize the impurity metal sulfides and to reduce the level of sulfur present. The metal oxide thus formed can be separated and collected in an appropriate slag on subsequent smelting. Thus partial roasting is conducted on the more noble metal sulfides from which impurity sulfides are readily oxidized.

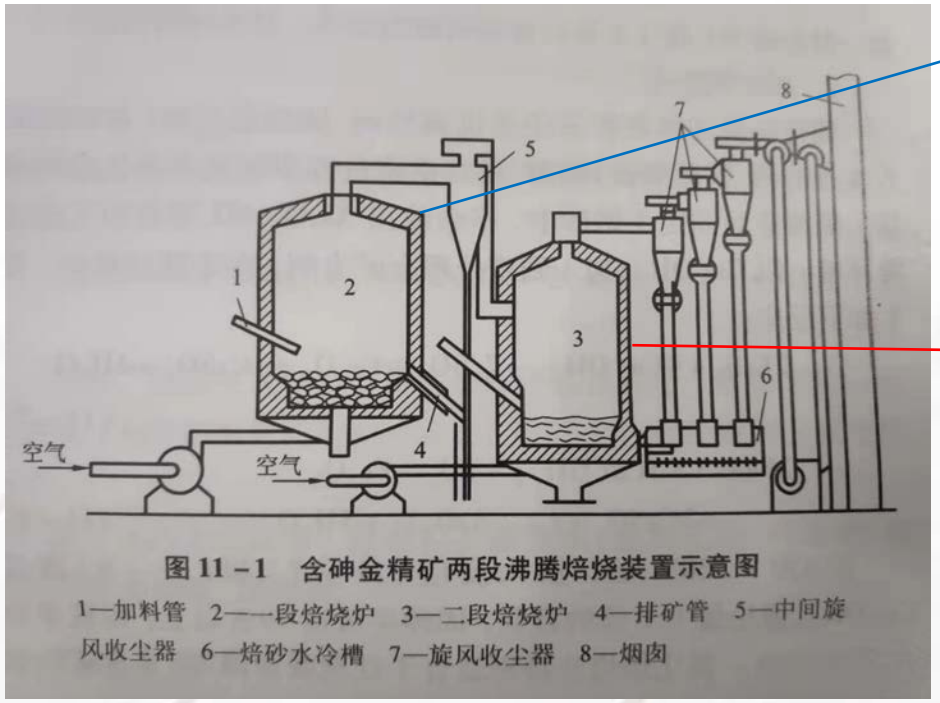


图 11－1 含砷金精矿两段沸腾焙烧装置示意图

1—加料管 2—一段焙烧炉 3—二段焙烧炉 4—排矿管 5—中间旋风收尘器 6—焙砂水冷槽 7—旋风收尘器 8—烟囱

[杨天足, 贵金属冶金及产品深加工，2005]

Partial roasting: low P_{O2}

Main reaction:

$As_2S_3+O_2 \rightarrow As_2O_3+SO_2$

Purpose: Removal of As_2S_3

Roasting: high P_{O2}

Main reaction:

$FeS_2+O_2 \rightarrow Fe_2O_3+SO_2$

Purpose: Removal of Sulfur

Different conditions of various kinds of roasting

A dead roasting is used when the metal oxide is to be reduced by carbon or hydrogen. A sulfating roasting is used when the metal sulfate is subsequently leached with a dilute sulfuric acid solution. Metal sulfates decompose at low temperatures, therefore sulfating is normally conducted at about 600~800°C, i.e. below the corresponding decomposition temperature, with a restricted amount of air, while dead roasting is conducted at 800~900°C with excess air, i.e. a high P_{O_2} / P_{SO_2} ratio.

Different conditions of various kinds of roasting

Differential sulfating roasting is possible by operating at a temperature which will decompose one sulfate but not another. Thus, roasting a Ni_3S_2—FeS concentrate at 850℃ will produce $NiSO_4$ and Fe_2O_3 since $Fe_2(SO_4)_3$ will decompose at this temperature, i.e. $Fe_2(SO_4)_3 \rightarrow Fe_2O_3 + 3SO_3$. Reduction roasting is generally rare since this reaction usually requires very low P_{O_2} values and high temperatures is demanded by the thermodynamic considerations. Other roasting reactions include:

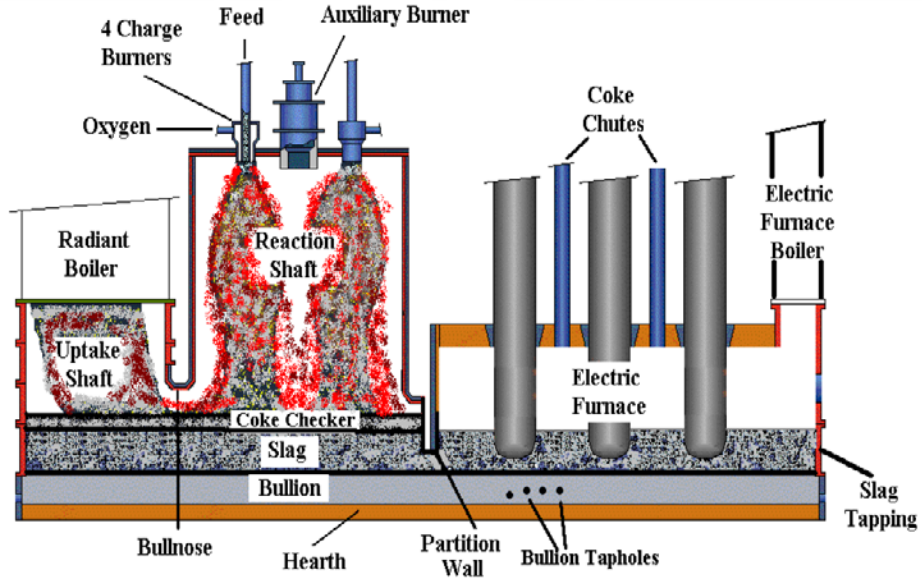
(1) Chloridizing roasting which is generally used for the conversion of a reactive metal such as Ti, Zr, U, which form extremely stable oxides, to a less stable chloride or other halide. The halide is relatively easy to reduce with another element which forms more stable halide.

(2) Volatilizing roasting removes volatile impurity elements and oxides such as Cd, As_2O_3, Sb_2O_3, ZnO. These may be recovered from the process fume using bag filters.

(3) Magnetizing roasting using controlled reduction of hematite (Fe_2O_3) to magnetite (Fe_3O_4) which can be subsequently magnetically separated from the gangue.

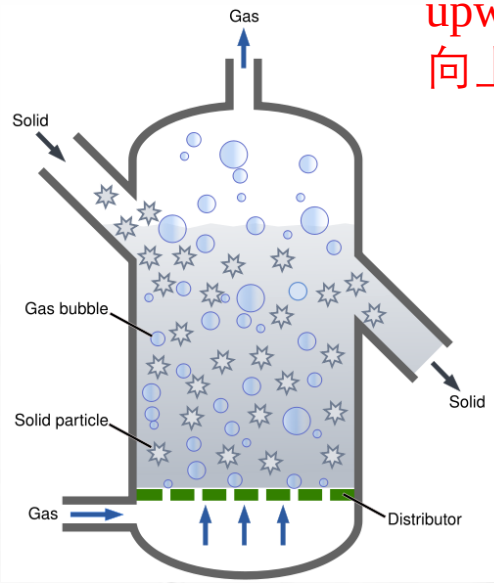
The roasting reactions are gas—solid reactions and therefore rely on the diffusion of oxygen into and sulfur dioxide out of each concentrate particle.

- Reducing the particle size (less than 6 mm) improves the gas--solid contact and increases throughput. This principle is used in the modern flash roasters in which preheated ore particles are injected through a burner with air, and fluidized bed roasters in which the fine ore particles are suspended in the roasting gas. A development which incorporates both these principles is the fluo—solids roaster in which air and ore fines are injected into the side of a reactor and fluidized by an upward draught of preheated (500°C) air.



Flash roaster

upward draught
向上的气流



Fluidized bed roaster

- It has been claimed that the fluo—solids roaster offers certain advantages over the multi-hearth unit for the partial roasting of Cu_2O ores. Such advantages include greater control over sulfur elimination, less space and operating labor required, it is more amenable to automation and a higher quality matte from the reverberatory furnace is produced.

Part I Answer the following questions.

1. What is calcination?
2. What are the differences between calcination and Roasting?
3. What are the most important roasting reactions?
4. Please simply describe Fig. 10-1 (Hypothetical thermodynamic phase diagram for the roasting of a metal sulfide concentrate) at a constant temperature).
5. What are the definitions of dead roast, sulfating roast, differential sulfating roast, reduction roast, chloridizing roast, volatizing roast, and magnetizing roast?

Part II Translate the following into English.

1. 焙烧指矿物的化学分解，可通过加热到矿物的分解温度以上或降低气体产物的分压(P_{H2O}, P_{CO2}) 到某一温度的平衡分压以下来实现。
2. 煅烧主要用来去除金属水合物或碳酸盐中化学键合的水、二氧化碳和其它气体，因为这些矿物的分解温度相对降低。
3. 最通常的一种焙烧作业是部分焙烧，采用这种焙烧方法对含多种金属的硫化物精矿进行焙烧使杂质金属硫化物优先氧化和降低含硫量。
4. 这个原理应用于预热矿物粒子通过燃煤喷嘴与空气一起注入到炉子中的现代闪速焙烧炉和细小矿物粒子悬浮在焙烧气体中的流化床焙烧炉。
5. 这些优点包括除硫更容易控制，所需地面及劳动力更少，易于自动化，另外，比反射炉熔炼产生的冰铜质量更高。

- The definitions of “Calcination” and “Roasting” are studied.
- “Roasting” is categorized into 7 different kinds and their characterization are given.
- The relationship between “Kollog diagram” and “roasting” conditions is explained.

➢**Homework**

Please write a summary about the unit.

THANKS

End

lecturer:

School of Metallurgy and Environment