中南大學
CENTRAL SOUTH UNIVERSITY

Unit 2 Hydrometallurgy

lecturer: Xiyun Yang

School of Metallurgy and Environment

New words and expressions

- sulphur dioxide SO_2
- aqueous solutions ['eɪkwiəs] 水溶液
- kilopascals [kɪlə'pɑ:kl] 千帕
- alchemist ['ælkəmɪst] 炼金术师
- environmental pollution 环境污染
- flowsheets ['floʊʃi:t] 流程
- Pyroprocesses['paɪrəproʊses]火法工艺
- Sodium carbonate 碳酸钠
- leaching ['lɪtʃɪŋ] 浸出
- extracting [ɪks'træktɪŋ] 提取
- ion exchange 离子交换
- crushing ['krʌʃɪŋ] 破碎

- membrane (film) separation['membreɪn] 膜分离
- grinding **['graɪndɪŋ]** 研磨
- pregnant solution ['pregnənt] 母液
- lixiviate [lik'sivieit] **渗滤**
- dilute sulfuric acid [daɪ'l(j)uːt; dɪ-] 稀硫酸
- bauxite ['bɔːksaɪt] 铝土矿
- sulfide mattes硫化冰铜
- pickle liquors酸洗液
- sludge [slʌdʒ]泥渣
- reagent **[ri'eɪdʒənt]** 试剂
- **complementary** [ˌkɑːmplɪ'mentri] 辅助的，补充的

New words and expressions

- vacuum['vækjuəm]真空
- Vacuum pump真空泵
- applicability [ˌæplɪk'bɪləti]适应性
- Roasting焙烧
- smelting熔炼
- converting吹炼
- refining精炼
- imminent threats of depletion 耗尽的威胁
- burgeoning **['bɜːdʒənɪŋ]** 增长迅速的
- Secondary materials二次资源
- slag渣
- Dust尘
- speiss [spaɪs]黄药

➢What can we learn?

1. The definition and history of hydrometallurgy.
2. The features of hydrometallurgy.
3. **Raw material of hydrometallurgy**
4. The difference between hydrometallurgy and pyrometallurgy and furthermore, the role of hydrometallurgy in modern metallurgy
5. **The advantages and disadvantages of hydrometallurgy**.

全文的录音

Text A Hydrometallurgy

1 Introduction

The extraction of metals from ores and/or concentrates is carried out either by pyrometallurgy or by hydrometallurgy. Pyrometallurgy encompasses the traditional high-temperature processes of roasting, smelting, converting, and refining. Hydrometallurgy is a relatively recent development compared with pyrometallurgy, the ancient art of metal production. Thousands of years ago, as history records, people learned to construct furnaces and use fire to melt rocks and extract metals. Much later came the use of water and aqueous solutions in place of dry, high-temperature methods for processing ores. Modern hydrometallurgy, in fact, can be traced back only to the end of the 19th century. Hydrometallurgy is essentially concerned with methods whereby metals, metal salts or other metal compounds are produced by means of chemical reactions involving aqueous and organic solutions. Hydrometallurgy covers a large variety of processes ranging from leaching, concentration/purification, separation to recovery by electrolysis or precipitation. Hydrometallurgical processes normally operate in the temperature range of 25 to 250℃. The processes can operate at pressures of only a few kilopascals (vacuum) to as high as 5000 kPa.

The late 1960s and early 1970s witnessed a grea research and development of hydrometallurgical alternatives to conventional pyrometallurgical processes used to produce the bulk of nonferrous metals in the world. The strong points of hydrometallurgical processing lie in the wide and varied techniques and combinations of techniques that can be used to separate metals once they have been extracted into aqueous solutions. In principle, all the techniques of classic inorganic analytical chemistry are available to the hydrometallurgists and can be adapted to use in industrial processes. It is, indeed, true that it is the hydrometallurgists of recent times who are the main users of the vast amount of chemical knowledge built up by the classic inorganic chemists of the late 19th and early 20th centuries. Hydrometallurgists may aptly call themselves modern alchemists.

全文的录音

2 Raw materials for hydrometallurgy

There is a general awareness of the finite resources of nature around us. High-grade, traditional ore reserves face imminent threats of depletion. The need has arisen to devise ways and means to develop economical methods of processing the lean and complex ores that defy conventional processing. Apart from land-based resources, other unconventional resources such as those on the seabed (for example, manganese nodules) will be increasingly important as a source of a number of nonferrous metals. Secondary materials arising from industrial processes have received a great deal of attention. Secondary resources include complex materials discarded from pyrometallurgical processes, such as slags, dusts, sulfide mattes, and speiss, complex alloy scrap from fabrication processes, pickle liquors, sludges, electronic wastes and other industrial wastes. As far as such different materials are concerned, mention should also be made of the burgeoning new energy automobiles, which produce a great number of spent batteries. Recycling these materials seems to be a growing prospect. Similar is the situation regarding a number of other strategic materials. The extractive metallurgical industry is one of the prime targets for new laws introduced to combat environmental pollution. This is the overall picture against which the role of hydrometallurgy and its relative importance in extractive metallurgy must be assessed.

3 Position of hydrometallurgy in extractive metallurgy

While it is true that technically successful hydrometallurgical processes can be designed, they cannot compete commercially with the pyrometallurgical processes. The hydrometallurgy of copper typically illustrates this situation. In order to alleviate the sulfur dioxide problem associated with copper smelting technology, a number of elegant hydro-based flowsheets displaying the masterly capability of hydrometallurgy appeared on the scene for the treatment of relatively high-grade copper concentrates. Such processes, however, have failed to replace the pyroprocesses. In fact, pyrometallurgical processes themselves have been the subject of considerable development in response to the emission problem arising from the traditional smelting operation of copper. Intense smelting techniques developed by INCO, Noranda, and Mitsubishi have made significant inroads in copper metallurgy. The techniques have relegated copper hydrometallurgy to the treatment of secondary materials and low-grade ores. Hydrometallurgy is not the panacea for extractive metallurgy. It should be allowed to play a complementary role, not a competitive role, in operation of mineral beneficiation and pyrometallurgy.

全文的录音

4 Characteristics of hydrometallurgy

Hydrometallurgy offers a number of significant advantages. There are also some disadvantages associated with hydrometallurgical operation. The limitations and advantages, however, need assessment for each individual application of hydrometallurgy.

(1) **Advantages**

production of a variety of by-product metals. Complex ores and concentrates in which a variety of recoverable metals are present can be effectively processed by hydrometallurgical routes. High overall revenues from by-products may have significant influence on overall process economics which would make the hydrometallurgical approach highly attractive.

② Hydrometallurgical methods have successfully separated closely related metals, such as individual rare earths (zirconium from hafnium, and niobium from tantalum), from their ores.

③ Hydrometallurgy can be less energy-consuming when applied to low-grade ores or to ores at the mine site. Moreover, it operates at relatively low, often ambient, temperatures, compared with temperatures as high as 1500℃ that are typical in pyrometallurgical furnaces. Much of the heat evolved in pyrometallurgy is difficult or impossible to recover.

④ Hydrometallurgy has been suggested, too, as an alternative to traditional pyrometallurgical processes to reduce pollution, especially air pollution caused by smelter emissions of sulfur dioxide.

(2) **Disadvantages**

① From the point of view of consumption of process materials, fuel, and electric power, hydrometallurgical processes are much more demanding than the pyrometallurgical ones because the latter use mostly atmospheric oxygen as a reagent and sulfur present in the ore as a source of heat.

② Hydrometallurgical processes can often generate significant amounts of liquid or solid waste that may pose serious disposal problems.

全文的录音

Hydrometallurgy

- The extraction of metals from ores and /or concentrates is carried out either by pyrometallurgy or by hydrometallurgy.
- Pyrometallurgy encompasses the traditional high-temperature processes of roasting, smelting, converting, and refining.
- Hydrometallurgy is a relatively recent development compared with pyrometallurgy, the ancient art of metal production.

compared with:与什么比较,强调不同，相异点

compared to：比较，比拟，强调相同点

- Thousands of years ago, as history records, people learned to construct furnaces and use fire to melt rocks and extract metals. Much later came the use of water and aqueous solutions in place of dry, high-temperature methods for processing ores.
- Modern hydrometallurgy, in fact, can be traced back only to the end of the 19th century.

- Hydrometallurgy is essentially concerned with methods whereby metals, metal salts, or other metal compounds are produced by means of chemical reactions involving aqueous and organic solutions.

本句译文：湿法冶金是通过在水溶液和有机溶液中发生化学反应来生成金属，金属盐或其它的金属化合物。

- Hydrometallurgical processes normally operate in the temperature range of 25 to 250℃.The processes can operate at pressures of only a few kilopascals(vacuum) to as high as 5000 kPa.

温度，压力表示方法

- The late 1960s and early 1970s witnessed a great spurt in research and development of hydrometallurgical alternatives to conventional pyrometallurgical processes used to produce the bulk of nonferrous metals in the world.

本句译文：60 年代末和 70 年代初，世界范围内研究和发展湿法冶金以取代传统的火法冶金生产有色金属有了重大的突破。

- The strong points of hydrometallurgical processing lie in the wide and varied techniques and combinations of techniques that can be used to separate metals once they have been extracted into aqueous solutions.

- In principle, all the techniques of classic inorganic analytical chemistry are available to the hydrometallurgists and can be adapted to use in industrial processes.
- It is, indeed, true that it is the hydro-metallurgists of recent times who are the main users of the vast amount of chemical knowledge built up by the classic inorganic chemists of the late 19th and early 20th centuries. Hydrometallurgists may aptly call themselves modern alchemists.

that 引导主语从句；

it is …who 为强调句型；

本句译文：现代湿法冶金学家确实是19世纪末和20世纪初古代无机化学家积累的大量化学知识的主要使用者。

- There is a general awareness of the finite nature of resources around us. High-grade, traditional ore reserves face imminent threats of depletion. The need has arisen to devise ways and means to develop economic methods of processing the lean and complex ores that defy conventional processing.
- Apart from land-based resources, other unconventional resources such as those on the seabed (for example, manganese nodules) will be increasingly important as a source of a number of nonferrous metals.

日益重要

Apart from 除。。。之外

lean and complex ores 贫矿和复杂矿

- Secondary materials arising from industrial processes have received a great deal of attention. Secondary resources include complex materials discarded from pyrometallurgical processes, such as slags, dusts, sulfide mattes, and speisses; complex alloy scrap from fabrication processes; pickle liquors, sludges and other industrial wastes.
- As far as such different materials are concerned, mention should also be made of the burgeoning electronics industry which, as we know today, is using increasingly rarer metals and semimetals.

(resulting from)

- Recycling these materials seems to be a growing prospect前景广阔. Similar is the situation regarding a number of other strategic materials. The extractive metallurgical industry is one of the prime targets for new laws introduced to combat environmental pollution.

- This is the overall picture against which the role of hydrometallurgy and its relative importance in extractive metallurgy must be assessed.

本句译文：评估湿法冶金的作用及其相对重要性必须考虑总的环境背景。

This is the overall picture against which the role … must be assessed. Against为前置词，意为“以……为背景”。

Complementary Role

- While it is true that technically successful hydrometallurgical processes can be designed, they cannot compete commercially with the pyrometallurgical processes.
- The hydrometallurgy of copper typically illustrates this situation. In order to alleviate the sulfur dioxide problem associated with copper smelting technology, a number of elegant hydrobased flowsheets displaying masterly exposition of the capability of hydrometallurgy appeared on the scene for the treatment of relatively high-grade copper concentrates.

Complementary Role

- Such processes, however, have failed to replace the pyroprocesses. In fact, pyrometallurgical processes themselves have been the subject of considerable development in response to the emission problem arising from the traditional smelting operation of copper.
- Intense smelting techniques developed by INCO, Noranda, and Mitsubishis have made significant inroads in copper metallurgy. The techniques have relegated copper hydrometallurgy to the treatment of secondary materials and low-grade ores.
- Hydrometallurgy is not the panacea for extractive metallurgy. It should be allowed to play a complementary role, not a competitive role, in operation of mineral beneficiation and pyrometallurgy.

in response to:针对

针对学生逃课skipping clssses的问题，中南大学采取了许多应对的措施

Advantages of Hydrometallurgy

Hydrometallurgy offer a number of significant advantages. There are also some disadvantages associated with hydrometallurgical operation. The limitation and advantages, however, need assessment for each individual application of hydrometallurgy.

Advantages of Hydrometallurgy

I. Hydrometallurgical processes have the flexibility for treatment of complex ores and for production of a variety of by-product metals.

II. Hydrometallurgical methods have successfully separated closely related metals, such as individual rare earths (zirconium from hafnium, and niobium from tantalum), from their ores.

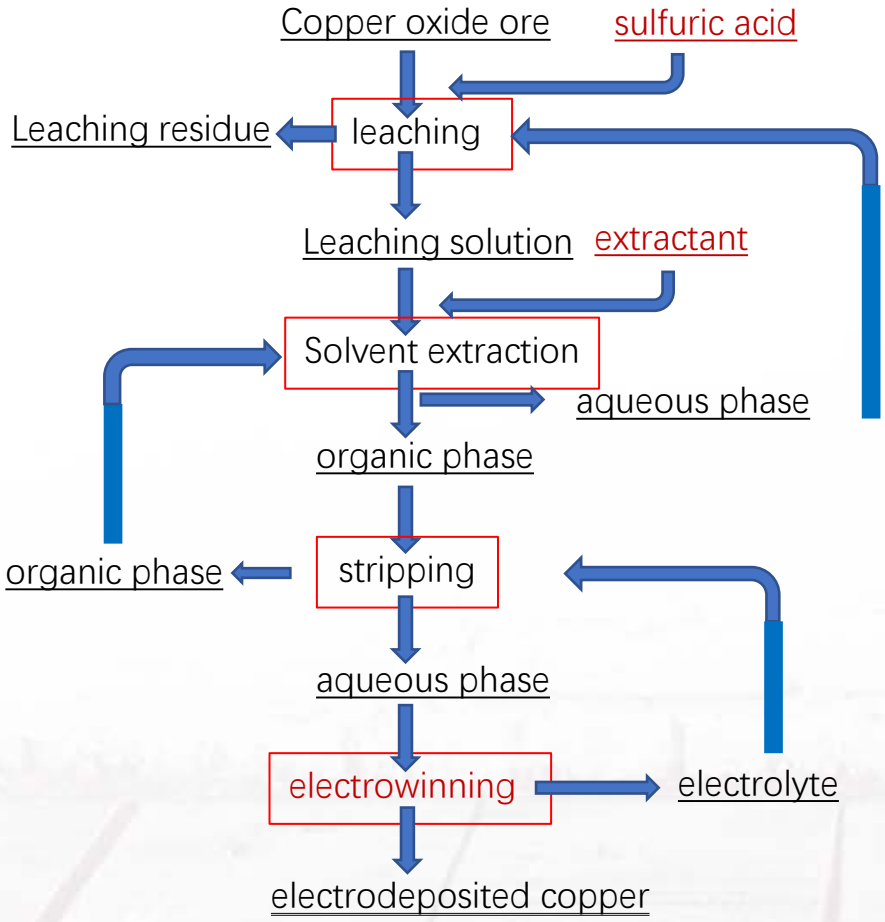
Anode mud: gold、silver、selenium、tellurium

rare earth

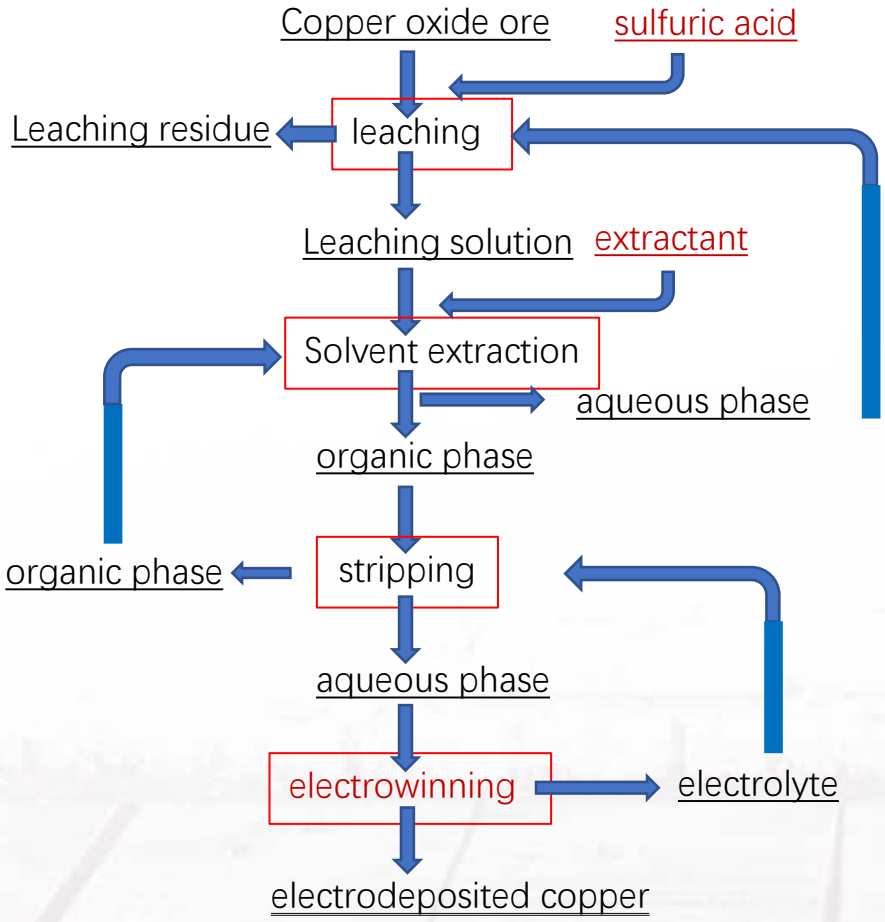
III. Hydrometallurgy can be less energy consuming when applied to low-grade ores or to ores at the mine site.

IV. Hydrometallurgy has been suggested as an alternative to traditional pyrometallurgical processes to reduce pollution, especially air pollution caused by smelter emissions of sulfur dioxide.

I. From the point of view of consumption of process materials, fuel, and electric power, hydrometallurgical processes are much more demanding than the pyrometallurgical ones.



II. Hydrometallurgical processes can often generate significant amounts of liquid or solid wastes that may pose serious disposal problems.



associated with/related to

- 相同点：related to 和 associated with都是和...相关的意思。一般情况下可以通用。
- 区别：
  - associated with的关联更加紧密一些，associated的关联可以紧密到逻辑上的因果关系，或事情发展的前因后果这样的关系，而related to则没有非常紧密的关系。
  - associated with 经常用在说明一个试验的结果和某个原因之间的关系。
- Reaction kinetics describes both the rate and mechanism associated with dynamic chemical systems.

Difference between slurry and residue

- **Sludge** is a semi-solid slurry and can be produced as sewage sludge from wastewater treatment processes or as a settled suspension obtained from conventional drinking water treatment and numerous other industrial processes.

- **Residue** may be the material remaining after a process of preparation, separation, or purification, such as distillation, evaporation, or filtration. It may also denote the undesired by-products of a chemical reaction.

描述一个湿法冶金的实验过程

- 黄铜矿chalcopyrite浸出试验在一个三口的烧瓶中进行，称取100克黄铜矿 chalcopyrite放入三口烧瓶中，加入5 mol/L硫酸，控制液固比liquid/solid ratio为5：1，机械搅拌速度mechanical stirring rate 300rpm，在60 ^{o}C浸出1h。浸出完成后，过滤filter，洗涤wash、烘干dry滤渣，分析渣中铜含量。

- The leaching experiment was carried out in a three-necked flask. 100g chalcopyrite was weighted and put in the flask, then 5 mol/L sulphuric acid was added. The liquid/solid ratio was held at 5:1.The solution was mechanically stirred at 300 rpm. After leaching (for) 1h at 60 ^{o}C, the solution was filtered for the solid/liquid separation. The solid phases/sludges were washed and dried for analysis of the copper content.
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1. 湿法冶金是现代提取冶金中的一个新兴起的，并得到高度重视的分支。
2. 同火法冶金过程比较，湿法冶金过程可在较低的温度下进行。
3. 湿法冶金的理论基础是物理化学。
4. 作为冶金的一个分支，湿法冶金已成功地使用在提取冶金过程的许多领域中。
5. 随着富矿的不断消耗，用来生产金属的矿石的品位正不断降低。
6. 因此，必须研究新的方法来处理传统火法工艺不能处理的低品位矿和复杂矿。
7. 湿法冶金的范围很广，它可以从处理矿石到金属精矿、金属废料和冶金过程的中间产品。
8. 湿法冶金是通过在溶液中发生化学反应从矿石中提取金属。
9. 湿法冶金的优点是适合于处理复杂矿和生产各种冶金副产品。
10. 和火法冶金比较，湿法冶金减少了SO2对大气的污染。

1. 湿法冶金是现代提取冶金中的一个新兴起的，并得到高度重视的分支。

湿法冶金： hydrometallurgy

参考译文：

Hydrometallurgy is one of the established and highly recognized branches of extractive metallurgy today.

2. 同火法冶金过程比较，湿法冶金过程可在较低的温度下进行。

同……比较： compared with …

参考译文：

Compared with pyrometallurgical processes, hydrometallurgical processes operates at relatively low temperatures.

3.湿法冶金的理论基础是物理化学。

理论基础：theoretical basis 物理化学： physical chemistry

参考译文：

The theoretical basis of hydrometallurgy is physical chemistry.

4. 作为冶金的一个分支，湿法冶金已成功地使用在提取冶金过程的许多领域中。

作为……的分支： As a branch of …

参考译文：

As a branch of metallurgy，hydrometallurgy has been successfully used in numerous fields of extractive metallurgy processes.

5. 随着富矿的不断消耗，用来生产金属的矿石的品位正不断降低。

品位：grade　　富矿：high-grade ore

参考译文：

The grade of ores used to produce metals is decreasing with the continuous consumption of high-grade ores.

6. 因此，必须研究新的方法来处理传统火法工艺不能处理的低品位矿和复杂矿。

低品位矿：lean/low-grade ore

参考译文：

Hence，it’s necessary to devise new methods of processing the lean and complex ores that defy conventional pyrometallurgical processing.

7. 湿法冶金的范围很广，它可以从处理矿石到金属精矿、金属废料和冶金过程的中间产品。

……的范围：the scope of…　金属精矿：metal concentrate

金属废料：metal scrap　中间产品：intermediate product

参考译文：

The scope of hydrometallurgy is quite broad and extends beyond the processing ores to the treatment of metal concentrates,metal scrap and intermediate products in metallurgical processes.

8. 湿法冶金是通过在溶液中发生化学反应从矿石中提取金属。

在溶液中： in aqueous solution

参考译文：

Hydrometallurgy is extraction metals from their ores by means of chemical reaction in aqueous solution.

9. 湿法冶金的优点是适合于处理复杂矿和生产各种冶金副产品。

适用于：be suitable for　　副产品：by-product

参考译文：

Hydrometallurgy has the advantage of being suitable for the treatment of complex ores and the production of various metallurgical by-products.

10. 和火法冶金比较，湿法冶金减少了 SO2对大气的污染。

SO2：sulfur dioxide

参考译文：

Hydrometallurgy reduces the air pollution by sulfur dioxide compared with pyrometallurgy.

THANKS

End

lecturer: Xiyun Yang

School of Metallurgy and Environment