Unit 4 Electrometallurgy

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School of Metallurgy and Environment

New words and expressions

- electrowinning [ɪˌlektroʊ'wɪnɪŋ]电解
- solvent ['sɑːlvənt]溶剂
- ambient ['æmbiənt] 室温 at ambient temperature
- anode ['ænoʊd]阳极
- cathode cell ['kæθəud]
- evolution overvoltage [ˌiːvə'luːʃn] [ˌoʊvə'voʊltɪdʒ]析出过电位
- electrolyte [ɪ'lektrəlaɪt] 电解液
- electrode spacing 极间距
- current efficiency 电流效率
- Electrolysis [ɪˌlek'trɑːləsɪs]

New words and expressions

- Electrochemical [ɪˌlektrouˈkemɪkəl] 电化学的
- Electrodeposition [elektrəʊdpɒˈzɪʃn] 电沉积
- at room temperature
- recirculate [ri:ˈsə:kjʊleit]再循环，再流通
- anodic evolution of oxygen阳极析出氧气
- accumulation precipitation **[əˌkju:mjəˈleɪʃn]** [prɪˌsɪpɪˈteɪʃn]累积 沉积
- corrosion resistant [kəˈrəʊʒn] 耐腐蚀性
- halides sodium ['heɪlaɪd] ['səʊdɪəm] 卤化钠
- contamination [kənˌtæməˈneɪʃən] 污染
- feed stock 原料
- scheme [ski:m] 计划

New words and expressions

- dendritic [ˌden'drɪtɪk]树枝状的
- molten salts
- conductivity [ˌkɒndʌk'tɪvəti]导电性
- Ohmic drop欧姆降
- refractory metal难熔金属
- current density电流密度
- organic media有机介质
- aqueous solution electrolysis 水溶液电解
- molten salt electrolysis熔融盐电解
- Mother sheet of pure metal金属始极片
- dehydration [ˌdiːhaɪ'dreɪʃn] 脱水
- graphite [‘græfait] 石墨
- Electrorefining[ɪ'lektroʊ'faɪnɪŋ]电解精炼
- size distribution 尺寸分布
- Solubility [ˌsɒlju'bɪləti]溶解度
- lining ['laɪnɪŋ] 衬里
- deleterious effects [ˌdelə'tɪrɪəs]有毒效应
- chemical reagent化学试剂
- gas sparger ['spɑːdʒə] 气体鼓泡器
- cryolite['kraɪəˌlaɪt] 冰晶石

- Aqueous solution electrolysis
  - Advantage of water as solvent
  - Principle
  - Before electrolysis， removing impurities
- Molten salt electrolysis
  - Disadvantage
  - important factor at the elevated temperature considered
- electrorefining

➢What can we learn?

1. What is electrowinning?

2. The process of aqueous electrowinning.

3. With reference to the overall scheme of electrowinning in aqueous media, the reason why there is no overall acid consumption in acid leaching-electrowinning process.

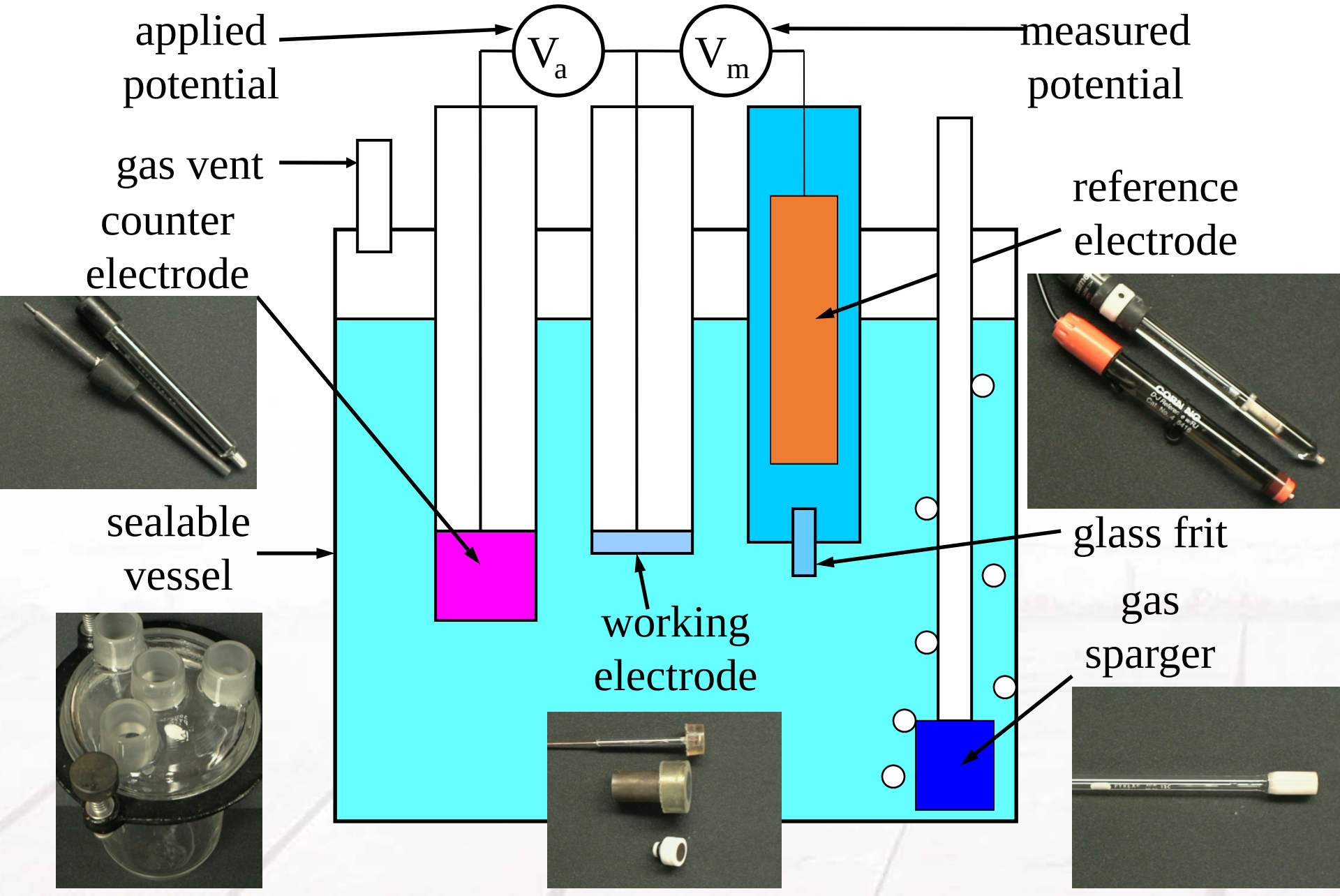
4. What is “Electrowinning in molten salts”?

5. The working conditions of molten salts electrowinning.

6. What is electrorefining?

- Followed by
- Thus
- Increase in
- Rather than
- provided
- In theory ,in practice

Electrochemical Testing Cell (Example)



electrolysis and electrodeposition

Electrolysis is an electrochemical process by which current passes from one electrode to another in an ionized solution that is an electrolyte.

Electrodeposition:the deposition of a substance on an electrode by the action of electricity.

electrolysis	electrolytic manafacturing 电解制造（制造物质）	electrowinning（金属的电解提取）	Al,Mg, Na, Zn
		electrosynthesis（电化学合成）	NaOH,Cl_2,MnO_2, 己二腈
	electrorefining电解精炼(提纯物质)		Cu,Ni,Pb

electrowinning and electrorefining belong to electrodeposition.

- The metallic elements may be extracted from the naturally occurring ores by a reduction which could in every case be electrochemical.
- In practice, chemical reagents such as hydrogen, carbon or active metals may be preferred and the choice is obviously made on economic grounds by considering the required purity of the product, its physical form and the other stages of the overall process.

In practice:在实践中　reagents：试剂　hydrogen：氢　carbon：碳

本句译文：在实践中，氢、碳或活性金属等可能是首选化学试剂，并且显然是基于经济理由，通过考虑产品所需纯度、其物理形式和整个过程的其他阶段来进行选择的。

- These include ore treatment and concentration, separation after reduction, further purification or refining and fabrication.

- Electrometallurgy involves the use of electric energy to recover or to refine a metal from different media.
- The use of water as solvent is restricted to elements less active than zinc and manganese.

cathodic reaction:阴极反应　play a minor role：起次要作用　be restricted to ：限于　　zinc：锌　manganese：锰

本句译文：水仅限于活性低于锌和锰的元素中使用。

- In the laboratory, organic media are employed in investigations on other more active metals but in practice only molten salts have found any application.

- Electrowinning represents an alternative to pyrometallurgy process to produce metals. While electrorefining is preferable to production of high purity metals like copper and aluminum as well as for the recovery of valuable impurities, such as silver and gold from copper.

- Electrowinning is practiced extensively in the metals industry. Copper, zinc, and gold as well as other metals, are produced by this process.
- Electrowinning utilizes an applied potential to drive electrochemical reactions in the desired direction.
- When an electric current passes through a pair of electrodes in the electrolyte, the metal is deposited at the cathode and oxygen is evolved at the inert anode.

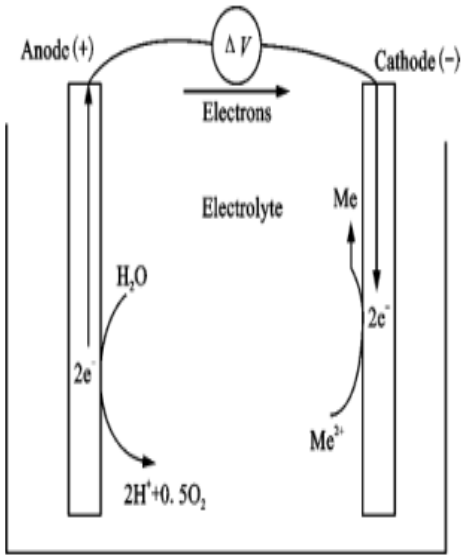


Fig. 4-1 Schematic diagram of a typical hydrometallurgical electrowinning process

- Water containing dissolved metal ions is a common electrolyte.
- The favorable properties of water as a solvent are well known and include the ability to dissolve salts to relatively high concentrations, and to produce solutions of high conductivity at ambient temperatures, especially when acidic.
- These factors are used to advantage when the overall process in considered, since in most cases the following scheme is applicable.

(a) The ore is converted to an acid soluble form, usually an oxide, by roasting. The product is then leached:

$$MO_x + 2xH^+_{aq} \rightarrow M^{2x+}_{aq} + xH_2O$$

(b) The solution is purified and perhaps concentrated.

(c) The anodic and cathodic reactions during electrolysis are

$$M^{2x+}_{aq} + 2xe \rightarrow M$$

$$xH_2O \rightarrow 1/2xO_2 + 2xH^+_{aq} + 2xe$$

(d) The acid liberated at the anode is recirculated to the leach. The net reaction can then be written simply as

$$MO_x \rightarrow M + 1/2xO_2$$

And there should be no overall consumption of water or acid.

- The use of sulphuric acid as the leaching agent favours the anodic evolution of oxygen, whereas in HCl (Hydrochloric acid) solution chlorine would probably be evolved.

  sulphuric acid :硫酸　anodic evolution：阳极析出　chlorine：氯

  本句中evolution和be evolved 含义相同

  译文：使用硫酸作为浸出剂有利于阳极析氧，而在盐酸溶液中可能会析出氯。

- Similarly hydrogen evolution besides giving rise to current inefficiency also leads to acid consumption.

- The high conductivity of the solvated proton reduces the power losses caused by ohmic drop during electrolysis. No other solvent system can combine all these advantages at room temperatures.

(a) Leaching of oxide bearing ores extracts the metal directly without a smelting process.

- This becomes attractive at low concentrations when much unwanted materials would have to be submitted to smelting with resulting in wastage of thermal energy.

be submitted to :提交给　　result in ： 导致

with resulting in wastage of thermal energy 作状语

本句译文：在低浓度下，许多不需要的材料将被送去熔炼，从而导致热能的浪费，此时这一点就变得很有吸引力。

- In many cases, concentration by flotation followed by smelting is also inefficient and leaching is more satisfactory.

(b) Before electrolysis, more noble impurity metals must be removed or these will be preferentially deposited. Hence the more active elements, e.g. Zn and Mn require more extensive purification.

- At the same time, salts of more active metals such as Mg may have to be removed simply to prevent accumulation and precipitation at inconvenient sites. It may also be found that some impurities reduce the hydrogen evolution overvoltage on active metals thus reducing the current efficiency.

(c) Since most operations involve electrolysis of sulphuric acid solutions, it is to be expected that the equipment utilized would be fairly uniform. Thus lead is often used as a corrosion resistant material for lining the tanks and for the anodes. Descriptions of many plants are available in the literature and are indicated under the appropriate metal without going into much detail here.

One of the major advantages of electrowinning should be the production of a high purity metal thus eliminating the need for further refining.

- Normally, under cathodic conditions the electrodeposit is not attacked by the solvent in aqueous systems and the only impurity is likely to be hydrogen provided that the electrolyte is suitably processed.

be attacked by：受…侵蚀　　provided：倘若，只要；引导条件状语从句

本句译文：通常，在阴极条件下，电沉积层不会受到水体系中溶剂的侵蚀，只要电解液经过适当处理，唯一的杂质可能是氢。

- This is not always the case in molten salt regimes as will be seen later.

- 句型：因此,……..
  - Thus,……　　Therefore,……
  - As a result,…..　　It follows that …..
  - …so that….,　　….such that…
  - The bus was held up by the snowstorm, *thus* causing the delay.
- Followed by 接着
  - We had fish for the first course, *followed by* pork and fresh vegetables
  - 我们吃的第一道菜是鱼，接著上的菜是猪肉和新鲜蔬菜。

- Although attempts have been made to electrowin the refractory metals from aqueous and organic media, it is probably true to say that in most cases the cathodic product is grossly contaminated and it is necessary to resort to fused salt systems.
- In theory, any metal could be claimed by direct electrolysis of one of its salts; halides are usually considered, but in practice, it is often preferable to dissolve the compound in salts of the more active metals, sodium and potassium. （翻译？？）

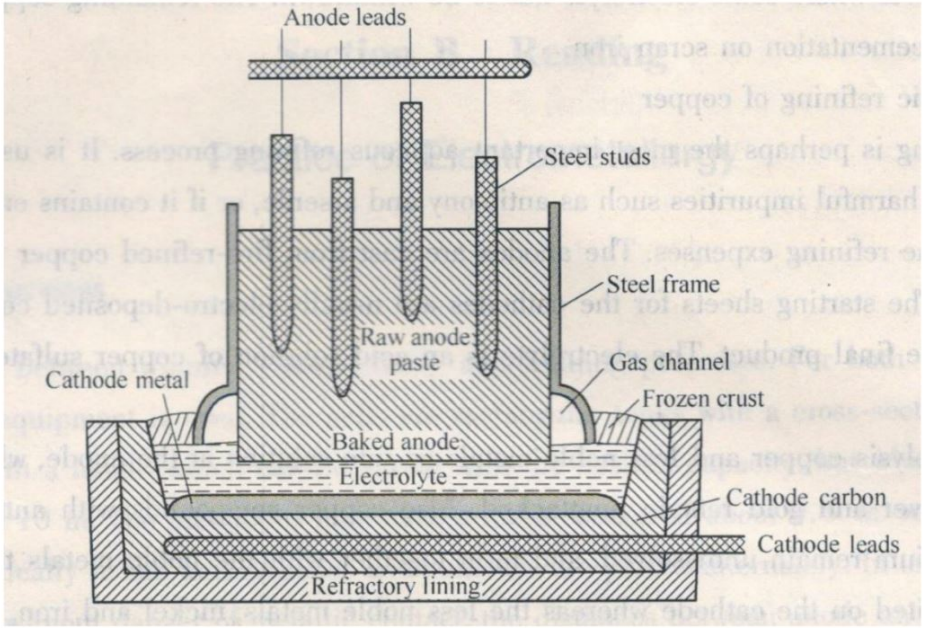
in theory：理论上 be claimed by：由…获得 halide：卤化物

sodium：钠 potassium：钾

本句译文：理论上，任何一种金属都可以通过直接电解其中一种盐来获得；通常考虑卤化物，但在实践中，通常优先将化合物溶解在活性更高的金属、钠和钾的盐中。

fused salt electrolysis of cryolite-alumina

/	fused salt electrolysis of aluminum
anode	carbon block
cathode	cell pot lined with carbon



- This procedure improves the conductivity and lowers the melting point of resultant mixture and may also permit continuous operation by replenishing the metal feedstock.
- Since alternative media are not possible for several metals, it is perhaps appropriate to stress the disadvantages rather than the advantages of molten salt winning. The high temperatures of operation result in increased contamination through corrosion and reaction with the anodic products.

- For example, carbon monoxide may diffuse through the melt and react with the product to increase the carbon and oxygen content of the metal with deleterious effects in metallurgical properties. For similar reasons, inert atmospheres and expensive cell linings may be required and the feedstock may need careful dehydration and other purification.
- Unless the metal is formed as a liquid, it is often quite difficult to separate from the melt since deposition in powder or dendritic form is frequently encountered, so that the number of operations may have to be increased.

be formed as :形成为，以…形式存在； separate from：从…分离

power：粉末 dendritic：树枝晶的

本句译文：除非金属以液体形式存在，否则(杂质)通常很难从熔体中分离出来，因为经常会遇到粉末状或树枝状的沉积，因此可能不得不增加(脱水和纯化)操作次数。

- At the same time, solubility in the melt becomes an important factor at the elevated temperatures considered and is often a source of current inefficiency. Continuous processes have not always been developed but where available these are based on oxide or chloride feedstocks with oxygen and chlorine evolved at the anode respectively.
- In the former instance the oxygen combines with the carbon to liberate CO or CO_2. Carbon and graphite are the only suitable anode materials.

- The cell electrolyte is never cycled for leaching purposes, as in aqueous electrowinning, for obvious reasons and indeed the molten salt electrolysis may represent only a relatively small fraction of the total production cost since complicated concentration and separation techniques are necessary for many of the elements treated.

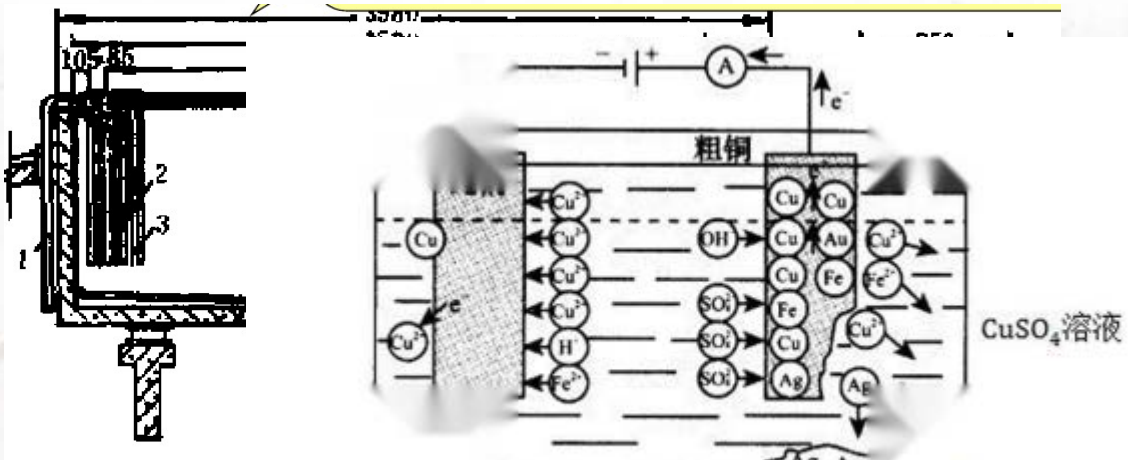
A small fraction of:一小部分　　as：像……一样　　since引导原因状语从句

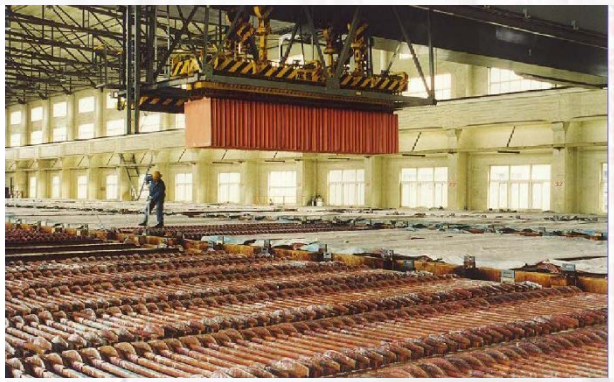
本句译文：由于显而易见的原因，电池电解液从未像在水溶液电解提取中那样为浸出而循环，并且实际上熔盐电解可能仅占总生产成本的相对小的一部分，因为复杂的浓缩和分离技术对于许多元素的处理是必要的。

- The reduction may therefore be replaced by alternative methods without a major effect on the overall scheme. Temperature is usually maintained by resistive heating. This may imply an increase in the electrode spacing; schemes incorporating external fossil fuel heating are normally unsuccessful.

Electrolytic winning of copper Vs Electrolytic refining of copper

electrometallurgy	Electrowinning of copper	Electrolytic refining of copper
anode	Pt-Ag/Pb-Sb alloy plate	fire-refined /blister copper
cathode	pure copper	electrodeposited copper
electrolyte	an acid solution of copper sulfate	
overall reaction	$CuSO_4+H_2O \rightarrow Cu+H_2SO4+1/2O_2$	Cu（impure）→Cu（pure）
cathodic reaction	$Cu^{2+}+2e^- \rightarrow Cu$	$Cu^{2+}+2e^- \rightarrow Cu$
anodic reaction	$2H_2O-4e^- \rightarrow O_2+4H^+$	$Cu-2e- \rightarrow Cu^{2+}$
major impurities	Fe^{2+}、Fe^{3+}、As、Sb、Bi	As、Bi





- Electrorefining is one of the most important purification processes of metals, usually obtained by electrowinning. The electrolyte is an acid solution of metallic salts, usually chlorides and sulfates.
- Here, the anode, which is made of impure metal, dissolves in the electrolytic bath and the resulting cations of the basic metal are selectively deposited on the cathode, which is made of a mother sheet of pure metal. The operating conditions ensure this selective deposition. All the other components of the anode remain in solution or form slimes in the electrolytic bath.

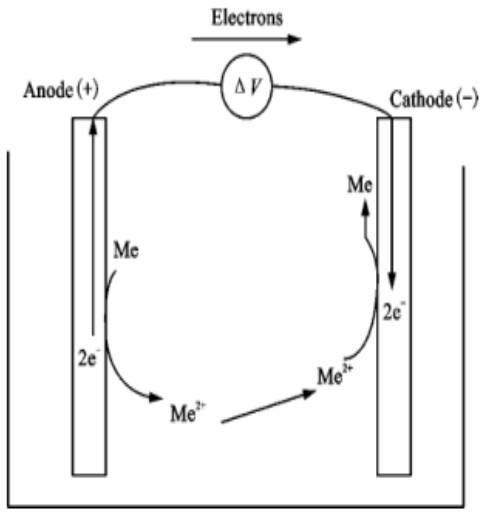


Fig. 4−2 Schematic diagram of the electrorefining process

The basic characteristic of this electrolysis is that the voltage to be applied is low, as the energy consumed by electro-reduction at the cathode is balanced by the energy obtained by oxidation at the anode. The applied voltage only has to overcome the ohmic drop, IR and the anodic and cathodic overvoltages. Thus, the current efficiency is high (about 95%) and energy consumption is low. The main industrial application includes electrorefining of copper, nickel, lead, tin and nickel mattes.

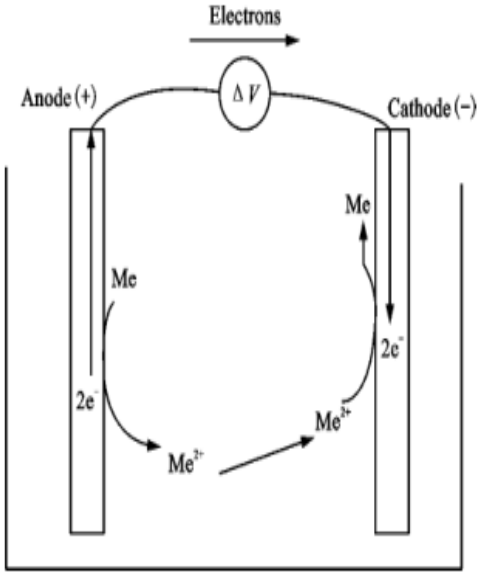


Fig. 4-2 Schematic diagram of the electrorefining process

1. 电解提取及电解精炼是金属生产的重要方法，三十多种金属曾经或正在以电解法生产。

2. 电解法有水溶液电解和熔盐电解两种：水溶液电解用于生产较不活泼金属；较活泼金属需用熔盐电解方法生产。

3. 水作为水溶液电解的溶剂有价钱低廉、金属化合物溶解度高、溶液常温时导电率高等优点。

4. 熔盐电解温度高、物料较贵，但在某些金属的生产中不得不使用它。

5. 电解法的共同优点是产品纯度高、生产环境好、过程易于控制。

1. 电解提取及电解精炼是金属生产的重要方法，三十多种金属曾经或正在以电解法生产。

电解提取：electrowinning 电解精炼：electrorefining

参考译文：

Electrowinning and electrorefining are important methods of metal production. More than 30 metals used to be produced or are produced by electrolysis.

2. 电解法有水溶液电解和熔盐电解两种： 水溶液电解用于生产较不活泼金属；较活泼金属需用熔盐电解方法生产。

水溶液电解： aqueous solution electrolysis 熔盐电解： molten salt electrolysis

参考译文：

There are two kinds of electrolysis methods: aqueous solution electrolysis and molten salt electrolysis；the former is used for production of less active metals and the latter is suited to production of active metals.

3. 水作为水溶液电解的溶剂有价钱低廉、金属化合物溶解度高、溶液常温时导电率高等优点。

电解提取：electrowinning 电解精炼：electrorefining

参考译文：

The advantages of water as solvent for aqueous solution electrolysis are cheapness, high solubility of metal compounds and high conductivity at ambient temperatur.

4. 熔盐电解温度高、物料较贵，但在某些金属的生产中不得不使用它。

参考译文：

Molten salt electrolysis requires high temperature and rather expensive raw maters, but it is necessary for production of some metals.

5. 电解法的共同优点是产品纯度高、生产环境好、过程易于控制。

参考译文：

The common advantages of electrolysis are high purity of product, good environment condition and easy control of operation.

- 铜电解精炼过程中，阳极炉浇铸得到的铜板为阳极,铜板重750磅，3-inch 厚, 矩形厚板rectangular slabs，铜薄片sheet为阴极。45片阳极和46片阴极插入电解槽中，电解液为硫酸铜和硫酸溶液。在阳极发生氧化反应，铜失去loss电子成为铜离子，铜离子从阳极迁移migrate到阴极，在阴极发生还原反应，得到gain两个电子变为铜金属.杂质金属溶解沉入电解槽底部成为阳极泥。

- In copper electrorefining, the copper from the anode furnace is cast into 750-pound, 3-inch thick, rectangular slabs called anodes. The thin sheets of pure copper are used as cathodes. Forty-five anodes and 46 cathodes are immersed alternatively in an electrolysis tank filled with an electrolyte of sulfuric acid and copper(II) sulfate.
- Oxidation occurs at the anode, where copper metal is converted to copper(II) ions with the loss of two electrons. Then the copper ions migrate from anode to cathode and **gain two electrons (at that site) to be reduced to copper metal** (are reduced to copper metal with the gain of two electrons). The impurity metals drop to the bottom of the electrolysis cell and form anode slime.

Homework:

Based on literature review and copper metallurgy, describing the differences and relations between hydrometallurgy and pyrometallurgy, and pounding the advantages and disadvantages of hydrometallurgy and pyrometallurgy from the aspects of energy consumption, environmental pollution and so on.

（300-400 words）

THANKS

End

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School of Metallurgy and Environment