Alternative methods of extracting metals (HT only)

5.10.1.4 · Chemistry · revision notes

Higher tier only. Why new ways of extracting copper from low-grade ores are needed, how phytomining and bioleaching work, and how copper is obtained from the compounds they produce. Expect 'describe' questions, 'evaluate' questions based on given information and sometimes equations or calculations on Paper 2.

Key facts

- Copper ores are becoming scarce, so copper is extracted from low-grade ores
- Bioleaching: bacteria produce leachate solutions containing metal compounds
- Copper from solution: displacement using scrap iron, or electrolysis
- Grade 7+ only $Fe + Cu^{2+} \rightarrow Fe^{2+} + Cu$
- Phytomining: plants absorb metal compounds → harvest → burn → ash contains metal compounds → dissolve in acid
- Both avoid digging, moving and disposing of large amounts of rock
- iron + copper sulfate → iron sulfate + copper
- Grade 7+ only Cathode: $Cu^{2+} + 2e^{-} \rightarrow Cu$

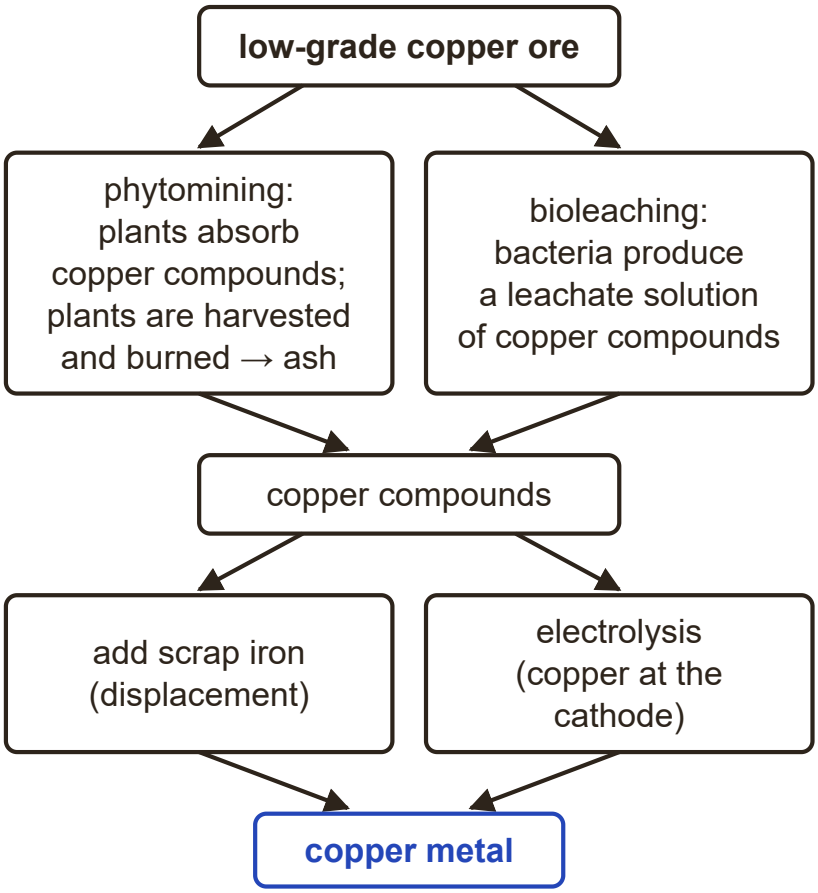
Notes

Why new methods are needed

- The Earth's resources of metal ores are limited. Copper ores are becoming scarce.
- **Low-grade ores** contain only a small percentage of copper. Mining them in the traditional way would mean digging up, moving and disposing of huge amounts of rock for very little copper.
- **Phytomining** and **bioleaching** extract copper from low-grade ores and avoid most of this digging, moving and disposing of rock.

Phytomining and bioleaching

- **Phytomining**: plants are grown on land containing low-grade ore. The plants **absorb metal compounds** from the soil.
- The plants are **harvested and burned**. The **ash** contains the metal compounds. The ash is dissolved in acid to give a solution of the copper compound.
- **Bioleaching**: **bacteria** are used to produce **leachate** solutions that contain metal compounds.
- Both methods are slow, and the metal compounds they produce still have to be processed to obtain the metal.



The biological methods give copper compounds; displacement or electrolysis gives the metal.

Getting copper metal from its compounds

- **Displacement**: **scrap iron** is added to a solution of a copper compound. Iron is more reactive than copper, so it displaces the copper: iron + copper sulfate → iron sulfate + copper.
- Ionic equation: $Fe + Cu^{2+} \rightarrow Fe^{2+} + Cu$. Iron atoms lose electrons (oxidised); copper ions gain electrons (reduced). Grade 7+ only
- **Electrolysis** of a solution of the copper compound: copper metal forms at the negative electrode (cathode).
- Half equation at the cathode: $Cu^{2+} + 2e^{-} \rightarrow Cu$ (reduction). Grade 7+ only

Evaluating the biological methods

- For: they can use low-grade ores and old mine waste; they avoid digging, moving and disposing of large amounts of rock; there is less damage to the landscape; they help conserve a limited resource.
- Against: they are slow (crops take time to grow; bioleaching can take months or years); they produce only small amounts of copper; phytomining needs large areas of land; leachate solutions could pollute soil and water if they escape; further processing is needed.

How to answer each type of question

Describe how phytomining or bioleaching works 2 to 3 marks **Grade 5**

1. Phytomining: plants absorb metal compounds, are harvested, then burned; the ash contains the metal compounds.
2. Bioleaching: bacteria produce leachate solutions that contain metal compounds.
3. If there is a further mark, say the compounds are then processed to obtain the metal.

Example. Describe how phytomining is used to obtain copper compounds from land containing low-grade copper ore. (3 marks)

Model answer. Plants are grown on the land and absorb copper compounds (1). The plants are harvested and burned (1). The ash produced contains the copper compounds (1).

Explain how copper is obtained from a solution 2 to 4 marks **Grade 7**

1. Name the method: displacement using scrap iron, or electrolysis.
2. For displacement, give the reason: iron is more reactive than copper.
3. Write an equation if asked; in half equations, balance the charges with electrons.
4. Say which species is oxidised or reduced, in terms of electrons.

Example. A solution produced by bioleaching contains copper(II) sulfate. Scrap iron is added to the solution.
(a) Explain why copper is produced. (1 mark)
(b) Write an ionic equation for the reaction. Iron(II) ions are formed. (1 mark)
(c) Which substance is reduced? Explain your answer. (2 marks)

Model answer.

(a) Iron is more reactive than copper, so it displaces copper from the solution (1).

(b) $Fe + Cu^{2+} \rightarrow Fe^{2+} + Cu$ (1)

(c) The copper(II) ions (1), because they gain electrons (1).

Evaluate a biological method using given information 4 to 6 marks **Grade 8**

1. Use the information given: quote figures such as the percentage of metal or the time taken.
2. Give advantages: uses low-grade ore, avoids digging, moving and disposing of rock.
3. Give disadvantages: slow, small amounts, possible pollution, further processing needed.
4. Finish with a justified conclusion.

Example. A company owns a heap of waste rock left from an old copper mine. The rock contains 0.2% copper by mass.
(a) Calculate the mass of copper in 50 000 tonnes of the waste rock. (1 mark)
(b) The company plans to use bioleaching to extract copper from the heap. Evaluate this plan. (4 marks)

Model answer.

(a) 50 000 × 0.2 ÷ 100 = 100 tonnes (1)

(b) Any four, with at least one advantage and one disadvantage: the rock has already been dug up, so no further digging, moving or disposing of rock is needed (1); bioleaching can use low-grade material like this, which is too poor for traditional methods (1); it recovers copper, a limited resource, from waste (1); but bioleaching is slow, taking months or years (1); the leachate could escape and pollute soil or water (1); the copper compounds still need to be processed by displacement or electrolysis (1).

Don’t lose marks

- Saying the plants 'make' copper. They absorb copper compounds that are already in the soil.
- Forgetting that the plants are burned and that the ash contains the metal compounds.
- Saying phytomining or bioleaching produces copper metal directly. They produce copper compounds, which still need displacement or electrolysis.
- Writing that bacteria 'eat' the copper. The bacteria produce leachate solutions that contain copper compounds.
- Writing Fe^{3+} in the displacement equation when told iron(II) ions form, or leaving the charges unbalanced.

More tips

Memory tricks

- PHYTO means plants (as in photosynthesis); BIO-leaching uses bacteria to leach the metal out.
- Phytomining in three verbs: grow, harvest, burn.
- Scrap iron works because iron is above copper in the reactivity series, and it is cheap.
- OIL RIG: iron atoms lose electrons (oxidised); copper ions gain electrons (reduced).

Exam technique

- In 'evaluate' questions, give advantages and disadvantages, use figures from the information, and end with a conclusion.
- The key phrase for the main advantage: these methods avoid digging, moving and disposing of large amounts of rock.
- If asked why scrap iron is used, give both ideas: iron is more reactive than copper, and scrap iron is cheap.

What each grade needs

What you need to be able to do, from the first marks up to the top grade.

Grade 5 — **Explain why new extraction methods are needed**
Metal ores are limited and copper ores are becoming scarce, so low-grade ores must be used.

Grade 5 — **Describe how phytomining works**
Plants absorb metal compounds; they are harvested and burned, and the ash contains the metal compounds.

Grade 6 — **Describe how bioleaching works**
Bacteria are used to produce leachate solutions that contain metal compounds.

Grade 6 — **Name ways to get copper from solutions**
Displacement using scrap iron, or electrolysis.

Grade 7 — **Explain displacement and electrolysis of copper compounds**
Iron is more reactive than copper; at the negative electrode $Cu^{2+} + 2e^{-} \rightarrow Cu$.

Grade 8 — **Evaluate biological extraction methods using given data**
Weigh up using low-grade ores without digging up rock against slow rates, small yields and possible pollution.

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