



Give the marks for the points in the marking scheme; an answer in other words that says the same is right.

1 Key words

1. minerals
2. ore
3. native
4. gangue
5. concentration
6. roasting
7. calcination
8. metallurgy

K • 4

Each carries 0.5 mark.

2 Label the diagram

1. froth with the ore
2. air in
3. stirrer
4. water + a little pine oil + powdered ore
5. ore particle on a bubble
6. sand (gangue) sinks

K • 3

Each carries 0.5 mark.

3 Multiple choice

- i. c. hematite

K • 1

Hematite (Fe_2O_3) is the chief ore of iron. Bauxite is an ore of aluminium and argentite of silver; pyrite (FeS_2) contains iron but too much sulphur to be used as its ore.

- ii. d. gold

K • 1

Gold is so unreactive that it is found native. (Copper is sometimes found native too, but most copper comes from its ores; gold is the clear answer.)

- iii. d. grinding

K • 1

The ore must first be crushed and ground into a powder; only then can the gangue be separated from it (concentration), the first step that actually removes impurities.

- iv. d. reduction

U • 1

Smelting is reduction carried out above the melting point of the metal, so that the molten metal separates from the slag.

- v. a. roasting, because it is a sulphide ore

A • 1

Sulphide ores are roasted in air: $2\text{Cu}_2\text{S} + 3\text{O}_2 \rightarrow 2\text{Cu}_2\text{O} + 2\text{SO}_2$. Calcination is for carbonate (and hydrated) ores. Ores that are already oxides, like hematite and cuprite, skip this step.

4 Very short answers

- a. MARKING SCHEME

K • 1

✓ Bauxite.

- b. MARKING SCHEME

K • 1

✓ CuFeS_2 .

- c. MARKING SCHEME

U • 1

✓ The positive terminal (it is the anode).



5 Short answers

a. MARKING SCHEME

U • 2

- ✓ Every ore is a natural element or compound of the Earth's crust, so it is a mineral.
- ✓ Only a mineral from which a metal can be extracted easily and profitably is an ore; e.g. clay has aluminium but is not its ore, bauxite is.

b. MARKING SCHEME

U • 2

- ✓ A metal is most easily got from its oxide (by reducing it with C, CO or H_2), so sulphide and carbonate ores are first changed into oxides.
- ✓ Done after concentration, only the ore and not the gangue has to be heated, which saves fuel.

c. MARKING SCHEME

U • 2

- ✓ Any one difference, e.g. in roasting the ore is heated in a supply of air; in calcination without air.
- ✓ Any second difference, e.g. roasting is for sulphide ores and gives off SO_2 ; calcination is for carbonate ores and gives off CO_2 .

6 Long answers

a. ANSWER

U • 4

A metal can't be taken out of its ore in one go; each step prepares the ore for the next:

1. **Grinding:** the ore is crushed into powder, so its surface area is large.
2. **Concentration:** the gangue (sand, mud, rock) is removed by gravity separation, magnetic separation or froth flotation, so the percentage of metal rises.
3. **Oxidation:** the concentrated ore is changed into an oxide, by roasting (sulphide ores, in air) or calcination (carbonate ores, without air).
4. **Reduction:** oxygen is removed from the oxide by heating it with a reducing agent such as carbon, carbon monoxide or hydrogen (often as smelting), or, for reactive metals, by electrolysis.
5. **Refining:** the impure metal is purified by distillation or electro-refining.

Example: zinc blende (ZnS) → froth flotation → roasting to ZnO → reduction with carbon to zinc → distillation to pure zinc.

MARKING SCHEME

- ✓ Grinding and concentration: the ore is powdered and the gangue removed (gravity, magnetic or froth flotation).
- ✓ Oxidation: sulphide ores roasted in air, carbonate ores calcined without air, to give the oxide.
- ✓ Reduction: the oxide heated with C, CO or H_2 (smelting), or electrolysis for reactive metals, to give the metal.
- ✓ Refining: the impure metal purified by distillation or electro-refining.



b. ANSWER

U • 4

In electro-refining, a block of impure metal is made the anode and a thin sheet of pure metal the cathode, in a solution of a salt of the same metal, and an electric current is passed.

Activity (copper): fill a voltmeter with copper sulphate solution. Connect impure copper to the positive terminal of a battery (anode) and a thin pure copper plate to the negative terminal (cathode), and pass a current.

At the anode, copper atoms lose electrons and dissolve as ions: $\text{Cu} \rightarrow \text{Cu}^{2+} + 2\text{e}^-$. At the cathode, copper ions gain electrons and are deposited as pure copper: $\text{Cu}^{2+} + 2\text{e}^- \rightarrow \text{Cu}$. The anode wears away and the cathode grows thicker with pure copper, while the impurities fall below the anode as anode mud or stay in the solution. The copper obtained is about 99.99% pure.

MARKING SCHEME

- ✓ Impure copper made the anode (positive terminal) and a thin pure copper sheet the cathode (negative terminal).
- ✓ Both dipped in copper sulphate solution (a salt of the same metal) and a current passed.
- ✓ At the anode $\text{Cu} \rightarrow \text{Cu}^{2+} + 2\text{e}^-$; at the cathode $\text{Cu}^{2+} + 2\text{e}^- \rightarrow \text{Cu}$, so pure copper is deposited on the cathode.
- ✓ The anode wears away and the impurities fall below it as anode mud (or stay in the solution).

7 Numerical problems

a. ANSWER

A • 2

Molecular mass of $\text{Fe}_2\text{O}_3 = 2 \times 56 + 3 \times 16 = 112 + 48 = 160$. Percentage of iron = $112 \div 160 \times 100 = 70\%$.

MARKING SCHEME

- ✓ Molecular mass = $2 \times 56 + 3 \times 16 = 160$.
- ✓ Iron = $112 \div 160 \times 100 = 70\%$.

b. ANSWER

A • 2

Iron = $70\% \text{ of } 500 \text{ kg} = 70 \div 100 \times 500 = 350 \text{ kg}$.

MARKING SCHEME

- ✓ Iron = $70 \div 100 \times 500$.
- ✓ 350 kg.

8 Chemical equations

a. MARKING SCHEME

A • 1

- ✓ $2\text{ZnS} + 3\text{O}_2 \rightarrow 2\text{ZnO} + 2\text{SO}_2$ (balanced).

b. MARKING SCHEME

A • 1

- ✓ $\text{ZnCO}_3 \rightarrow \text{ZnO} + \text{CO}_2$.

c. MARKING SCHEME

A • 1

- ✓ $\text{Fe}_2\text{O}_3 + 3\text{CO} \rightarrow 2\text{Fe} + 3\text{CO}_2$ (balanced).



9 Think

ANSWER

HA · 2

Aluminium is much higher than zinc in the reactivity series: it holds on to oxygen so tightly that carbon can't take the oxygen away from aluminium oxide. Only electrolysis (passing electricity through the molten compound, alumina dissolved in cryolite) can separate the aluminium. Zinc, in the middle of the series, gives up its oxygen to carbon: $\text{ZnO} + \text{C} \rightarrow \text{Zn} + \text{CO}$.

MARKING SCHEME

- ✓ Aluminium is very reactive (high in the reactivity series), so its oxide is very stable and carbon can't remove its oxygen.
- ✓ So electrolysis of the molten compound is used; zinc, less reactive, gives its oxygen to carbon ($\text{ZnO} + \text{C} \rightarrow \text{Zn} + \text{CO}$).

10 Activity: Separating with a magnet

(not marked)

WHAT STUDENTS SHOULD FIND

Only the iron filings jump to the magnet; the sand and the aluminium powder (or salt) stay on the paper. Iron is magnetic and the others are not, so the magnet separates them: this is magnetic separation, used in mines to concentrate magnetite, Fe_3O_4 .

See it at Science Playground

Exhibits and plants at the center, Bhaktapur, that go with this unit. Book a class visit at science-playground.com/booking.

- **Stone & Mineral Collection** (exhibit): Look for crystals, shine and weight among the specimens: clues to the minerals inside.

Marks by level	Knowledge	Understanding	Application	Higher ability	Total
Marks	12	16	8	2	38

