Unit 7 · Study of Heavy Metals

ANSWER KEY · FOR TEACHERS

Full marks 33

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. froth flotation
2. matte
3. slag
4. blister copper
5. spelter
6. amalgam
7. calomel
8. lunar caustic

K · 4

Each carries 0.5 mark.

2 Label the diagram

1. slag
2. air
3. tuyeres
4. molten matte

K · 2

Each carries 0.5 mark.

3 Multiple choice

i. **b.** zinc blende — K · 1

Zinc blende, ZnS. Cinnabar (HgS) is the ore of mercury, argentite (Ag_2S) of silver and chalcopyrite ($CuFeS_2$) of copper.

ii. **c.** self-reduction — U · 1

The sulphide itself reduces the oxide: **self-reduction** (auto-reduction). Roasting and smelting come before it; poling is a refining step after it.

iii. **d.** wrought iron — U · 1

Wrought iron has under 0.1% carbon, steel 0.1–2%, cast iron 2–4.5% and pig iron, straight from the blast furnace, about 4%.

iv. **b.** zinc dust — K · 1

Zinc, more reactive than silver, displaces it: $2\,Na[Ag(CN)_2] + Zn \rightarrow Na_2[Zn(CN)_4] + 2\,Ag$.

v. **b.** iron forms no amalgam with mercury — U · 1

Iron hardly dissolves in mercury and forms **no amalgam**, so the flask is not attacked. Most other metals, such as copper, zinc and silver, would form amalgams.

4 Short answers

a. MARKING SCHEME — U · 2

- ✓ $Zn + 2HCl \rightarrow ZnCl_2 + H_2$.
- ✓ $Zn + 2NaOH \rightarrow Na_2ZnO_2 + H_2$.

b. MARKING SCHEME — U · 2

- ✓ Coating iron with zinc.
- ✓ Zinc is more reactive, so it is oxidized in place of the iron (sacrificial anode).

c. MARKING SCHEME — A · 3

- ✓ $C + O_2 \rightarrow CO_2$.
- ✓ $CO_2 + C \rightarrow 2CO$.
- ✓ $Fe_2O_3 + 3CO \rightarrow 2Fe + 3CO_2$, with CO the reducing agent.

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5 Long answer

ANSWER U · 4

The ore is crushed, ground and concentrated by **froth flotation**.
Leaching: the concentrate is stirred with dilute sodium cyanide solution while air is blown through: $Ag_2S + 4\,NaCN \rightleftharpoons 2\,Na[Ag(CN)_2] + Na_2S$. The air oxidizes the sodium sulphide, $Na_2S + 2\,O_2 \rightarrow Na_2SO_4$, so the reaction goes to completion.
Displacement: the solution is filtered and zinc dust added:
$2\,Na[Ag(CN)_2] + Zn \rightarrow Na_2[Zn(CN)_4] + 2\,Ag$. The spongy silver is filtered off and melted.
Electrolytic refining: impure silver is the anode, a sheet of pure silver the cathode, and acidified silver nitrate the electrolyte. At the anode $Ag \rightarrow Ag^+ + e^-$; at the cathode $Ag^+ + e^- \rightarrow Ag$. Gold and platinum fall as anode mud.

MARKING SCHEME

- ✓ Concentration by froth flotation, then leaching with NaCN in air (equation).
- ✓ Air oxidizes Na_2S to Na_2SO_4, so the silver dissolves completely.
- ✓ Displacement with zinc dust (equation).
- ✓ Electrolytic refining: the electrodes, the electrolyte and the electrode reactions.

6 Numerical problems

a. **ANSWER** A · 4

i. $M(CuFeS_2) = 63.5 + 56 + 2 \times 32 = 183.5$: % Cu $= 63.5/183.5 \times 100 =$ **34.6%**.
ii. Chalcopyrite = 25% of 500 = 125 kg; copper $= 125 \times 63.5/183.5 =$ **43.3 kg**.
iii. $43.3/0.98 =$ **44.1 kg** of blister copper.
iv. Sulphur $= 125 \times 64/183.5 = 43.6$ kg; $S \rightarrow SO_2$ doubles the mass (32 → 64): **87.2 kg** of SO_2.

MARKING SCHEME

- ✓ 34.6% copper.
- ✓ 43.3 kg of copper.
- ✓ 44.1 kg of blister copper.
- ✓ 87.2 kg of SO_2.

b. **ANSWER** A · 4

i. $Fe_2O_3 = 800$ kg; $M = 2 \times 56 + 3 \times 16 = 160$ g/mol: 800,000/160 = **5000 mol**.
ii. 2 mol Fe per mol Fe_2O_3: 10,000 mol × 56 g = **560 kg**.
iii. CO: $3 \times 5000 = 15{,}000$ mol × 28 g = **420 kg**. CO_2: 15,000 mol × 22.4 L = 336,000 L = **336 m^3**.
iv. $560/0.95 =$ **589 kg** of pig iron.

MARKING SCHEME

- ✓ 5000 mol of Fe_2O_3.
- ✓ 560 kg of iron.
- ✓ 420 kg of CO and 336 m^3 of CO_2.
- ✓ 589 kg of pig iron.

7 Think

ANSWER HA · 3

$HgS + O_2 \rightarrow Hg + SO_2$ and $2\,ZnS + 3\,O_2 \rightarrow 2\,ZnO + 2\,SO_2$.
Mercury(II) oxide is unstable when hot: it breaks up into mercury and oxygen, $2\,HgO \rightarrow 2\,Hg + O_2$, so any oxide formed at the roasting temperature gives the metal at once, and the mercury distils off. Zinc oxide is very stable and doesn't decompose on heating, so it needs a reducing agent, carbon, at a high temperature: $ZnO + C \rightarrow Zn + CO$.

MARKING SCHEME

- ✓ The two balanced roasting equations.
- ✓ HgO decomposes on heating into mercury and oxygen, so the metal comes off directly.
- ✓ ZnO is stable to heat, so it must be reduced with carbon (equation).

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8 Activity: Copper and zinc in salt solutions

(not marked)

WHAT STUDENTS SHOULD FIND

The zinc strip is coated with red-brown copper and the blue of the solution fades: $Zn + CuSO_4 \rightarrow ZnSO_4 + Cu$. Nothing happens to the copper in zinc sulphate. Zinc is more reactive than copper, so it displaces copper from its salt, but copper can't displace zinc.

Marks by level	Knowledge	Understanding	Application	Higher ability	Total
Marks	8	11	11	3	**33**

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