Unit 10 · Chemistry of Metals

ANSWER KEY · FOR TEACHERS

Full marks 40

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. mineral
2. ore
3. gangue
4. flux
5. slag
6. calcination
7. roasting
8. poling

K · 4

Each carries 0.5 mark.

2 Label the diagram

1. anode (impure Cu)
2. $CuSO_4 + H_2SO_4$
3. anode mud (Ag, Au)
4. cathode (pure Cu)

K · 2

Each carries 0.5 mark.

3 Multiple choice

i. **c.** froth flotation — K · 1

Zinc blende is a sulphide ore, and sulphide ores are concentrated by froth flotation: the collector makes their grains water-repelling, so they rise with the froth.

ii. **b.** limestone — U · 1

Silica is an acidic gangue, so it needs a basic flux: limestone gives CaO, which forms the slag $CaSiO_3$.

iii. **c.** lilac (pale violet) — K · 1

Lithium is crimson red, sodium golden yellow, potassium lilac; apple green is barium's.

iv. **b.** $Li < K < Na < Rb < Cs$ — U · 1

Density generally rises down the group, but potassium (0.89 g/cm^3) is less dense than sodium (0.97 g/cm^3), because its atom is so much larger.

v. **c.** Mg^{2+} — A · 1

Zinc and aluminium hydroxides are amphoteric and dissolve in excess NaOH; copper(II) hydroxide is pale blue. Magnesium hydroxide is white and stays.

4 Very short answers

a. MARKING SCHEME — K · 1

✓ $CaSO_4 \cdot ½H_2O$ (or $(CaSO_4)_2 \cdot H_2O$).

b. MARKING SCHEME — K · 1

✓ Leaching (hydrometallurgy).

c. MARKING SCHEME — U · 1

✓ The metal ions are positive and gain electrons (are reduced) at the cathode.

5 Short answers

a. MARKING SCHEME — U · 2

✓ The difference in air supply and in the ores each is used for.

✓ One correct balanced equation for each.

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b. MARKING SCHEME U · 2

- ✓ In water, hydrogen is set free at the cathode instead of sodium (and any sodium formed would react with the water).
- ✓ Calcium chloride lowers the melting point from 801 °C to about 600 °C, so the sodium formed doesn't boil away (it boils at 883 °C).

c. MARKING SCHEME A · 2

- ✓ $2\,Na + O_2 \xrightarrow{\Delta} Na_2O_2$
- ✓ $3\,Mg + N_2 \xrightarrow{\Delta} Mg_3N_2$

d. MARKING SCHEME U · 2

- ✓ The sulphate ion is large, so the lattice energy stays nearly the same as the cation grows.
- ✓ The hydration energy falls steadily as the cation grows, so less energy is released on dissolving and solubility falls.

e. MARKING SCHEME U · 3

- ✓ The set-up: impure anode, pure cathode, acidified $CuSO_4$.
- ✓ The two electrode equations.
- ✓ Silver into the anode mud, zinc stays in solution.

6 Long answer

ANSWER U · 4

All the Group 2 carbonates decompose on heating to the oxide and carbon dioxide:

$CaCO_3 \xrightarrow{\Delta} CaO + CO_2$.

A small cation with a 2+ charge has a high charge density and polarizes the large carbonate ion: it pulls the carbonate's electron cloud towards itself and weakens the C–O bonds on that side, so the carbonate breaks up more easily.

Down the group the cation grows, its polarizing power falls, and a higher temperature is needed.

Order: $BeCO_3 < MgCO_3 < CaCO_3 < SrCO_3 < BaCO_3$ (increasing thermal stability).

MARKING SCHEME

- ✓ The balanced equation for $CaCO_3$.
- ✓ Polarizing power: a small, highly charged cation distorts the carbonate ion and weakens its C–O bonds.
- ✓ Down the group the cation grows and polarizes less, so stability increases.
- ✓ The correct order.

7 Numerical problems

a. ANSWER A · 4

i. Molar mass of $CuFeS_2 = 63.5 + 56 + 2 \times 32 = 183.5$ g/mol; % Cu $= 63.5 \div 183.5 \times 100 =$ **34.6%**.

ii. Chalcopyrite in the ore = 4.0% of 1000 kg = 40 kg; copper $= 40 \times 0.346 =$ **13.8 kg**.

iii. Concentrate $= 40 \div 0.80 =$ **50 kg**.

MARKING SCHEME

- ✓ Molar mass 183.5 g/mol.
- ✓ 34.6% copper.
- ✓ 13.8 kg of copper.
- ✓ 50 kg of concentrate.

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b. **ANSWER** A · 4

$CaCO_3 \xrightarrow{900\ ^\circ C} CaO + CO_2$

$CaCO_3 = 0.90 \times 500 = 450$ kg $= 450\,000$ g $\div 100$ g/mol $= 4500$ mol.

i. $CaO = 4500$ mol $\times 56$ g/mol $= 252\,000$ g $=$ **252 kg**.

ii. $CO_2 = 4500$ mol $\times 22.4$ L/mol $= 100\,800$ L $\approx$ **1.01×10^5 L** (about 101 m^3).

MARKING SCHEME

✓ The balanced equation.

✓ 4500 mol of $CaCO_3$.

✓ 252 kg of CaO.

✓ 1.01×10^5 L of CO_2 at STP.

8 Think

ANSWER HA · 3

The electrode potential measures the whole change $M(s) \rightarrow M^+(aq) + e^-$, in water, not only the removal of an electron from a gaseous atom. Li^+ is the smallest alkali metal ion, so it attracts water molecules most strongly: its hydration energy (about −519 kJ/mol, against −276 kJ/mol for Cs^+) is so large that it more than makes up for lithium's higher ionization energy. So in water lithium loses its electron most readily and is the strongest reducing agent.

MARKING SCHEME

✓ The electrode potential is for the change in water, which includes hydration of the ion.

✓ Li^+, the smallest ion, has by far the largest hydration energy.

✓ This outweighs its higher ionization energy, so lithium is the strongest reducing agent in water.

9 Activity: Metals and alloys at home

(not marked)

WHAT STUDENTS SHOULD FIND

Typical answers: a karahi or rod of steel (Fe with a little C); a sink or spoon of stainless steel (Fe, Cr, Ni: doesn't rust); a tap or statue of brass (Cu, Zn); a bell or plate of bell metal (Cu, Sn); a heater coil of nichrome (Ni, Cr); a wire of pure copper (a good conductor). The steels are ferrous alloys; brass, bell metal and nichrome are non-ferrous.

Marks by level	Knowledge	Understanding	Application	Higher ability	Total
Marks	10	16	11	3	**40**

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