Materials, metals and corrosion

AQA GCSE Chemistry (8462) · Foundation and Higher

Show your working where needed. Check the worked answers when you finish.

Name _____ Date _____

1. Conditions for rusting

After a week, nail A in dry air and nail C in oxygen-free water have not rusted. Nail B in air and water has rusted. Explain what comparing B with A and B with C tells you.

2. Protecting a scratched coating

A steel panel has a thin zinc coating. Explain how the coating protects it when intact and why the zinc can still protect the iron after a small scratch.

3. Comparing copper and brass

Brass is harder to deform than pure copper. Brass contains copper and zinc atoms of different sizes. Explain the difference in hardness at the level of atoms.

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4. Choose a material for a part

A part must have density below 2.0 g/cm^3 and bend less than 3 mm in a standard load test.

Polymer: 1.2 g/cm^3, 6 mm. Steel: 7.8 g/cm^3, 1 mm. Fibre composite: 1.6 g/cm^3, 2 mm. Choose a material and use the data to justify it.

5. Choose an extraction method

A metal producer has ores containing aluminium oxide and iron oxide. For each oxide, choose between carbon reduction and electrolysis. Use the relative positions of aluminium, iron and carbon in the reactivity series to justify your choices.

6. Cost and environmental effect

On the same basis, making 1 tonne of a metal from ore uses 14 GJ and makes 1.8 tonnes CO_2 equivalent. Making it from scrap uses 5 GJ and makes 0.7 tonnes. Compare the two routes and give a cost the figures miss.

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7. Higher · recovering copper

A plant-based process produces ash containing copper compounds. A bacterial process produces a solution containing copper ions. A learner says both products are samples of copper metal. Explain the error, give a method for obtaining metal from the solution and state a reason for using low-grade ore.

8. Compare two nanoparticles

A manufacturer can make a coating from 2 nm or 6 nm cubes of the same material. Calculate the surface-area-to-volume ratio for each. Which offers more exposed surface for the same total volume of the material, if the particles stay separated?

9. Extra challenge · Explain two coating results

An intact paint coating and an intact zinc coating both protect the same steel. After identical scratches reach the steel, the painted sample rusts but the zinc-coated sample shows mostly zinc corrosion.

Explain both results at the scratch. Predict how the result would change if a thin copper coating replaced the zinc, using the relative reactivities of zinc, iron and copper.

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Worked answers

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1. Conditions for rusting

B rusts while A does not, showing that water is needed when air is present. B rusts while C does not, showing that oxygen is needed when water is present.

2. Protecting a scratched coating

An intact coating keeps water and oxygen from the steel. Zinc is more reactive than iron, so it is oxidised in preference to the exposed iron. This is sacrificial protection.

3. Comparing copper and brass

The zinc atoms disrupt the regular layers of copper atoms. The layers are harder to slide past one another, so brass resists deformation more than pure copper.

4. Choose a material for a part

Choose the fibre composite. At 1.6 g/cm^3 and 2 mm it meets both limits. The polymer meets the density limit but bends too far. The steel meets the bending limit but exceeds the density limit.

5. Choose an extraction method

Aluminium is more reactive than carbon, so carbon cannot reduce its oxide. Use electrolysis with aluminium oxide in a molten electrolyte. Iron is less reactive than carbon, so its oxide can be reduced using carbon or carbon monoxide.

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Worked answers

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6. Cost and environmental effect

For each tonne of metal, the scrap route saves 14 − 5 = 9 GJ and avoids 1.8 − 0.7 = 1.1 tonnes CO_2 equivalent. The energy and emissions figures do not tell us the cost of collecting or sorting scrap.

7. Higher · recovering copper

The ash still contains copper compounds and the solution contains copper ions. To get copper metal from the solution, use electrolysis or displace the copper with iron.

These methods can use material with a copper content too low for conventional extraction to be economical.

8. Compare two nanoparticles

For a cube of side a, surface area ÷ volume = $6a^2 \div a^3 = 6 \div a$. The ratios are 3 nm^{-1} and 1 nm^{-1}, respectively. The 2 nm particles give the larger surface area for the same volume of material.

9. Extra challenge · Explain two coating results

An intact coating keeps water and oxygen away. The scratch exposes bare iron on the painted sample, so it can rust. Zinc is more reactive than iron, so it oxidises in preference to the iron and can protect it at the scratch.

Copper is less reactive than iron. An intact copper coating can still form a barrier, but it does not provide the sacrificial protection that zinc gives. Exposed iron at the scratch can rust.

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