

Metals

Mark scheme and worked solutions for 30 questions: 15 multiple choice, 15 structured.

1 Core Properties of metals

[1]

Answer: C

Worked solution

Compare the typical physical properties. Metals: good conductors of heat and electricity, malleable and ductile, usually high melting and boiling points. Non-metals: poor conductors of heat and electricity, brittle when solid, usually low melting and boiling points. Only "good conductor of heat" belongs in the metal column, so the answer is C.

2 Core Properties of metals

[1]

Answer: D

Worked solution

Check each equation against the general patterns:

- metal + oxygen → metal oxide (D fits this pattern and is correct)
- reactive metal + cold water → metal hydroxide + hydrogen (so A should give calcium hydroxide)
- metal + steam → metal oxide + hydrogen (so C should give magnesium oxide)
- metal + dilute acid → salt + hydrogen, but only for metals above hydrogen in the reactivity series. Copper is below hydrogen, so B does not happen.

A common mistake is to mix up the water and steam products: cold water gives the hydroxide, steam gives the oxide.

3 Core Alloys and their properties

[1]

Answer: B

Worked solution

An alloy is a mixture of a metal with other elements. Brass is made by mixing copper with zinc, so the answer is B. Keep brass (copper + zinc) separate in your memory from steel (iron + carbon), and stainless steel (iron with chromium, nickel and carbon).

4**Core**

Reactivity series

[1]

Answer: D

Worked solution

Recall the reactivity series: potassium, sodium, calcium, magnesium, aluminium, carbon, zinc, iron, hydrogen, copper, silver, gold (most reactive first). Pick out the four metals: magnesium, iron, copper, gold. "Increasing reactivity" means start with the least reactive, so reverse this list: gold, copper, iron, magnesium. That is option D. Read the direction in the question carefully: B is the same list in the opposite direction.

5**Core**

Corrosion of metals

[1]

Answer: C

Worked solution

Rusting is the reaction of iron with oxygen and water to form hydrated iron(III) oxide. Remove either oxygen or water and rusting stops, so both are needed. Option C is the only pair containing both. Salt (sodium chloride) can make rusting faster, but it is not one of the conditions that must be present.

6**Core**

Extraction of metals

[1]

Answer: A

Worked solution

Two facts are needed. First, the main ore of aluminium is bauxite (hematite is iron ore). Second, aluminium is above carbon in the reactivity series, so carbon cannot remove the oxygen from aluminium oxide. Aluminium has to be extracted by electrolysis. The row with bauxite and electrolysis is A.

Mark scheme

(a) [2]

- W and Z (1)
- good electrical conductivity when solid / flatten when hammered (malleable) (1)

ALLOW either reason for the second mark**REJECT** high melting point as the reason (Y has a high melting point but is not a metal; Z has a low one)

(b) [1]

- good thermal conductivity / good conductor of heat / ductile (can be drawn into wires) (1)

ALLOW shiny / lustrous / sonorous / high density**IGNORE** high melting point / malleable / conducts electricity (already in table)

(c) [1]

- hydrogen (1)

ALLOW H₂**REJECT** oxygen

(d) [1]

- copper + oxygen → copper(II) oxide (1)

ALLOW copper oxide**Worked solution**

(a) The two properties in the table that separate metals from non-metals are electrical conductivity and behaviour when hammered. Metals conduct electricity when solid and are malleable (they flatten rather than shatter). W and Z both conduct and both flatten, so they are the metals. Do not use melting point here: most metals have high melting points, but Z (like sodium) melts at a low temperature, and non-metal Y (like diamond) has a very high melting point.

(b) The table shows melting point, electrical conductivity and malleability. Other typical metal properties are good thermal conductivity and ductility (being drawn out into wires).

(c) A reactive metal and cold water form a metal hydroxide and hydrogen gas, so the gas is hydrogen.

(d) A metal and oxygen form a metal oxide: copper + oxygen → copper(II) oxide.

Mark scheme

(a)(i)

[1]

- hydrogen (1)

ALLOW H₂

(a)(ii)

[1]

- potassium (1)

(a)(iii)

[1]

- calcium + water → calcium hydroxide + hydrogen (1)

REJECT calcium oxide as a product

(b)

[1]

- magnesium oxide (1)

ALLOW MgO**REJECT** magnesium hydroxide

(c)

[3]

- zinc: bubbles / fizzing / effervescence (and zinc gets smaller) (1)
- copper and silver: no (visible) reaction / no bubbles (1)
- zinc is above hydrogen in the reactivity series; copper and silver are below hydrogen (1)

ALLOW "zinc is more reactive than hydrogen; copper and silver are less reactive than hydrogen"**REJECT** "copper reacts slowly"**Worked solution**

(a) The most reactive metals react with cold water to make a metal hydroxide and hydrogen gas. Potassium is highest in the reactivity series of the three (potassium > sodium > calcium), so it reacts most vigorously. For calcium: calcium + water → calcium hydroxide + hydrogen.

(b) With steam, metals form the metal oxide (not the hydroxide) and hydrogen: magnesium + steam → magnesium oxide + hydrogen.

(c) A metal can only displace hydrogen from dilute acid if it is above hydrogen in the reactivity series. Zinc is above hydrogen, so it reacts and you see bubbles of hydrogen. Copper and silver are below hydrogen, so nothing happens in their tubes.

Mark scheme

(a)(i)

[1]

- tube 1 (1)

(a)(ii)

[1]

- hydrated iron(III) oxide (1)

ALLOW $\text{Fe}_2\text{O}_3 \cdot x\text{H}_2\text{O}$ / hydrated iron oxide**REJECT** iron(III) oxide without "hydrated"; iron hydroxide

(b)

[2]

- boiling removes dissolved oxygen / air from the water (1)
- the oil layer stops oxygen / air dissolving back into the water / reaching the nail (1)

ALLOW "no oxygen present" for 1 mark only if neither point above is made

(c)

[2]

- tube 3: the calcium chloride absorbs water (vapour) so there is no water / the air is dry (1)
- tube 4: the paint is a barrier that keeps oxygen and water away from the iron (1)

Worked solution

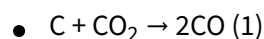
Rusting needs both oxygen and water.

- Tube 1 has water and air, so this nail rusts. Rust is hydrated iron(III) oxide.
- Tube 2 has water but no oxygen: boiling drives the dissolved air out, and the oil layer stops air dissolving back in. No oxygen means no rust.
- Tube 3 has oxygen but no water: the drying agent absorbs any water vapour, and the stopper stops more moist air getting in.
- Tube 4 has both water and oxygen in the tube, but the paint forms a barrier over the iron so neither can reach its surface.

Each "control" tube removes one condition, which is how the experiment shows that both are needed.

Mark scheme

(a) [1]



(b) [2]

- correct formulae $\text{Fe}_2\text{O}_3 + \text{CO} \rightarrow \text{Fe} + \text{CO}_2$ (1)
- correctly balanced: $\text{Fe}_2\text{O}_3 + 3\text{CO} \rightarrow 2\text{Fe} + 3\text{CO}_2$ (1)

IGNORE state symbols

(c) [3]

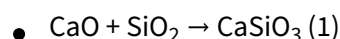
- Mr of $\text{Fe}_2\text{O}_3 = (2 \times 56) + (3 \times 16) = 160$ (1)
- moles of $\text{Fe}_2\text{O}_3 = 480\,000 \div 160 = 3000$ mol; moles of Fe = $2 \times 3000 = 6000$ mol (1)
- mass of Fe = $6000 \times 56 = 336\,000$ g = 336 kg (1)

ALLOW the mass-fraction method: $112/160 \times 480 = 336$ kg (3)

ALLOW working in kg throughout

ECF from an incorrect Mr for the second and third marks

(d) [1]

**Worked solution**

(a) Carbon dioxide made lower in the furnace is reduced by hot coke: $\text{C} + \text{CO}_2 \rightarrow 2\text{CO}$. Check: 2 C and 2 O on each side.

(b) Carbon monoxide takes the oxygen from iron(III) oxide: $\text{Fe}_2\text{O}_3 + 3\text{CO} \rightarrow 2\text{Fe} + 3\text{CO}_2$. Check: Fe 2 = 2; C 3 = 3; O 3 + 3 = 6 on the left and $3 \times 2 = 6$ on the right.

(c) Mr of $\text{Fe}_2\text{O}_3 = 2 \times 56 + 3 \times 16 = 112 + 48 = 160$. Convert 480 kg to grams: 480 000 g. Moles of $\text{Fe}_2\text{O}_3 = 480\,000 \div 160 = 3000$ mol. The equation shows 1 Fe_2O_3 gives 2 Fe, so moles of Fe = 6000 mol. Mass of Fe = $6000 \times 56 = 336\,000$ g = 336 kg.

Check another way: iron is $112/160 = 0.70$ of the mass of Fe_2O_3 , and 0.70×480 kg = 336 kg.

(d) Calcium oxide (from the limestone) is a basic oxide and reacts with the acidic impurity silicon dioxide to form calcium silicate, which is slag: $\text{CaO} + \text{SiO}_2 \rightarrow \text{CaSiO}_3$.

11 Core Alloys and their properties

[1]

Answer: D

Worked solution

Look for two features. (1) Close packing in layers, which shows a solid metal lattice. This rules out B and C, where the particles are far apart and random, as in a gas. (2) Atoms of more than one size mixed through the lattice, which shows a metal mixed with another element. A has close-packed layers but only one kind of atom, so it is a pure metal. Only D has both features, so D is the alloy.

12 Core Reactivity series

[1]

Answer: C

Worked solution

Work from the most vigorous reaction down.

1. Only R reacts with cold water, so R is the most reactive. (It was not put in acid because the reaction would be too violent.)
2. P, T and V do not react with cold water, so compare them with acid. The faster the bubbling, the more reactive the metal: V (rapid) > P (slow) > T (none).
3. Combined order: R, V, P, T. That is option C.

T is probably below hydrogen in the reactivity series, because it does not react with dilute acid.

13 Supplement Reactivity series

[1]

Answer: A

Worked solution

Use the order $\text{Mg} > \text{Zn} > \text{Fe} > \text{Cu} > \text{Ag}$. For each experiment, ask whether the solid metal is higher in the series than the metal whose ions are in solution.

- 1: Zn vs Ag. Zn is higher, so it reacts (silver is displaced).
- 2: Cu vs Fe. Cu is lower, so no reaction.
- 3: Fe vs Mg. Fe is lower, so no reaction.
- 4: Mg vs Zn. Mg is higher, so it reacts (zinc is displaced).

Reactions happen in 1 and 4 only, which is option A. The more reactive metal has the greater tendency to lose electrons and form positive ions, so it gives electrons to the ions of the less reactive metal.

14**Core**

Corrosion of metals

[1]

Answer: B

Worked solution

All barrier methods protect iron by keeping oxygen and water away from its surface. The best method depends on how the object is used. A bicycle chain bends and rubs against the gears all the time, so a rigid layer such as paint or plastic would soon crack and flake off. Grease stays in place as a flexible layer and also lubricates the chain, so B is the answer. Washing with water would make rusting more likely.

15**Core**

Extraction of metals

[1]

Answer: B

Worked solution

The higher a metal is in the reactivity series, the harder it is to extract from its ore. Metals below carbon (such as zinc, iron and copper) can be extracted by heating their oxides with carbon, because carbon removes the oxygen. Metals above carbon (such as magnesium and aluminium) cannot be extracted this way, so electrolysis is used. Metal M's oxide is not reduced by carbon, so M must be above carbon. Magnesium is, so the answer is B, which pairs magnesium with electrolysis.

Mark scheme

(a) [1]

- low density (1)

ALLOW light (for its size) / light-weight

IGNORE strong

(b) [2]

- aluminium has a (much) lower density, so the cables are lighter / pylons can be further apart / pylons need to support less weight (1)
- aluminium is still a good electrical conductor (1)

REJECT aluminium is a better conductor than copper

(c) [2]

- good electrical conductivity / good conductor of electricity (1)
- ductile / can be drawn into wires (1)

ALLOW malleable / bends easily for the second mark

IGNORE cheap

(d) [1]

- (very good) resistance to corrosion (1)

ALLOW does not corrode / not attacked by food or drink

Worked solution

Match each use to the property it needs.

(a) Aircraft must be as light as possible, and aluminium's density (2.7 g/cm^3) is much lower than copper's (8.9 g/cm^3).

(b) Copper conducts better, but overhead cables hang between pylons and must carry their own weight. Aluminium is about a third as dense as copper, so an aluminium cable is much lighter, and it still conducts electricity well (61% as well as copper). Low density plus good conductivity makes it the better choice.

(c) House wiring must conduct electricity well, and the metal must be ductile so it can be drawn out into thin wires. Copper is both.

(d) Food containers must not corrode when they touch food and drink, and aluminium resists corrosion very well.

Mark scheme

(a) [1]

- a mixture of a metal with other elements (1)

REJECT a compound of two metals; a mixture of two metals only (as the only definition)

(b) [2]

- any two from: chromium / nickel / carbon (1 each)

(c) [2]

- hard / strong (1)
- resistant to rusting / corrosion (1)

ALLOW does not rust / stays shiny

IGNORE cheap / looks nice (on their own)

(d) [2]

- mass of iron = $250 - 45 - 20 = 185$ g (1)
- percentage = $185 \div 250 \times 100 = 74$ (%) (1)

ALLOW 74% with no working (2)

ECF for the second mark from an incorrect mass of iron

Worked solution

(a) An alloy is a mixture of a metal with other elements. The other elements are mixed in, not chemically combined, so an alloy is not a compound.

(b) Stainless steel is iron mixed with elements such as chromium, nickel and carbon.

(c) Cutlery must be hard so it does not bend or scratch easily, and it must not rust when it is washed and in contact with food. Stainless steel has both properties. Alloys are often harder and stronger than the pure metals, which makes them more useful.

(d) The iron is the mass left over: $250 - (45 + 20) = 185$ g. Percentage of iron = $185/250 \times 100 = 74\%$. Check: 74% of 250 g = 185 g, and $185 + 45 + 20 = 250$ g.

Mark scheme

(a) [2]

- iron is more reactive than copper, so it displaces copper (from the solution) (1)
- the pink-brown solid is copper; the solution goes green because iron(II) ions form / copper(II) ions (which are blue) are used up (1)

(b) [2]

- $\text{Fe} + \text{Cu}^{2+} \rightarrow \text{Fe}^{2+} + \text{Cu}$ (2)

ALLOW state symbols: $\text{Fe(s)} + \text{Cu}^{2+}(\text{aq}) \rightarrow \text{Fe}^{2+}(\text{aq}) + \text{Cu(s)}$

- correct species with incorrect charges, or with spectator sulfate ions included, (1)

REJECT Fe^{3+} as a product

(c) [2]

- silver has a lower tendency to form positive ions than iron / iron forms positive ions more readily than silver (1)
- so silver cannot give electrons to the Fe^{2+} ions / cannot displace iron / the Fe^{2+} ions stay in solution (1)

ALLOW silver is less reactive than iron (so no displacement) for 1 mark only

Worked solution

(a) Iron is above copper in the reactivity series. The more reactive iron displaces copper from its compound. Copper metal appears as a pink-brown coating on the nail. Blue copper(II) ions are removed from the solution and pale-green iron(II) ions are formed, so the colour changes from blue to pale green.

(b) The sulfate ions do not change, so leave them out: $\text{Fe} + \text{Cu}^{2+} \rightarrow \text{Fe}^{2+} + \text{Cu}$. Check: 1 Fe and 1 Cu on each side; charge 2+ on each side. Iron atoms lose two electrons each ($\text{Fe} \rightarrow \text{Fe}^{2+} + 2\text{e}^-$), and copper(II) ions gain them ($\text{Cu}^{2+} + 2\text{e}^- \rightarrow \text{Cu}$).

(c) Reactivity measures how readily a metal forms positive ions by losing electrons. Iron forms positive ions more readily than silver. For silver to displace iron, silver atoms would have to lose electrons to Fe^{2+} ions, which would mean silver forming ions more readily than iron. It does not, so there is no reaction.

Mark scheme

(a) [1]

- coating iron / steel with (a layer of) zinc (1)

(b) [1]

- the zinc layer stops / excludes oxygen (air) and water from reaching the steel (1)

(c) [3]

- zinc is more reactive than iron / zinc is above iron in the reactivity series (1)
- zinc loses electrons (to form Zn^{2+} ions) more readily than iron / zinc is oxidised instead of iron (1)
- so iron does not lose electrons / does not form ions, and the zinc corrodes instead (sacrificial protection) (1)

ALLOW $\text{Zn} \rightarrow \text{Zn}^{2+} + 2\text{e}^-$ as evidence for the second mark

(d) [2]

- copper is less reactive than iron / below iron in the reactivity series (1)
- so iron would lose electrons / corrode in preference to copper (once the coating is scratched) (1)

ALLOW the copper would not be sacrificed / would not protect the exposed iron

IGNORE copper is expensive

Worked solution

(a) Galvanising means coating iron or steel with zinc.

(b) While the zinc coating is unbroken, it is a barrier: oxygen and water cannot reach the steel, so the steel cannot rust.

(c) Once the coating is scratched, the barrier no longer works where the steel is exposed, but galvanising still protects it. Zinc is more reactive than iron, so it loses electrons more readily: $\text{Zn} \rightarrow \text{Zn}^{2+} + 2\text{e}^-$. The zinc corrodes in place of the iron, and the iron does not lose electrons, so it does not rust. This is sacrificial protection, because the zinc is "sacrificed" to save the iron.

(d) Sacrificial protection only works if the coating metal is more reactive than iron. Copper is less reactive than iron, so at a scratch the iron would be the metal that loses electrons and corrodes. Copper would act only as a barrier, and would give no protection once it is scratched.

Mark scheme

(a) [2]

- to provide heat / to raise the temperature (the reaction is exothermic) (1)
 - to produce carbon dioxide (which is then reduced to carbon monoxide) (1)
- ALLOW** to produce carbon monoxide (the reducing agent) for the second mark

(b) [1]

- carbon monoxide (1)
- ALLOW** CO
- REJECT** carbon dioxide / carbon

(c) [2]

- calcium oxide (1)
- carbon dioxide (1)

(d) [2]

- calcium oxide reacts with the impurities / sand (silicon dioxide) (1)
 - the slag removes the impurities / it floats on the molten iron and is run off separately (1)
- ALLOW** slag named as calcium silicate

Worked solution

(a) Coke (carbon) burns in the hot air: carbon + oxygen → carbon dioxide. This reaction releases a lot of heat, which keeps the furnace hot, and the carbon dioxide it makes is needed for the next step.

(b) Carbon dioxide reacts with more hot coke to form carbon monoxide. Carbon monoxide then removes oxygen from iron(III) oxide (reduces it) to form iron: iron(III) oxide + carbon monoxide → iron + carbon dioxide.

(c) Heat decomposes limestone: calcium carbonate → calcium oxide + carbon dioxide.

(d) Calcium oxide reacts with the sand (silicon dioxide) impurity to form slag (calcium silicate). Slag is less dense than molten iron, so it floats on top and can be drained off separately. This removes the impurities from the iron.

21 Supplement Alloys and their properties

[1]

Answer: C

Worked solution

Metals are malleable because their atoms sit in regular layers that can slide over one another when a force is applied. When atoms of a different size are mixed in to make an alloy, they break up the regular layers. The layers then "catch" on the odd-sized atoms and can no longer slide over each other easily, so the alloy is harder and stronger. That is option C. The bonding is still metallic, with delocalised electrons, so A and B are wrong.

22 Supplement Reactivity series

[1]

Answer: A

Worked solution

Aluminium's position in the reactivity series (above zinc and iron) suggests it should react with water and acids quite readily. In practice it reacts with oxygen in the air straight away to form a very thin layer of aluminium oxide on its surface. This oxide layer is unreactive and sticks firmly to the metal, so it protects the aluminium underneath. The aluminium only appears unreactive, and this is also why aluminium is good for saucepans and food containers. The answer is A.

23 Supplement Corrosion of metals

[1]

Answer: B

Worked solution

Sacrificial protection uses a metal higher in the reactivity series than iron. The more reactive metal has the greater tendency to lose electrons and form positive ions, so it is oxidised (corrodes) instead of the iron, and the iron stays protected. Magnesium and zinc are both above iron. Row B pairs magnesium with the correct reason. Row D has a suitable metal, but its reason is false, so it is not correct. The question asks for both the metal and the reason to be right.

24**Supplement**

Extraction of metals

[1]

Answer: D

Worked solution

Electrolysis needs the ions to be free to move, so the aluminium oxide must be liquid. Pure aluminium oxide melts at over 2000 °C, which would use a huge amount of energy. A solution of aluminium oxide in molten cryolite is liquid at a much lower temperature (about 950 °C). The role of cryolite is to lower the operating temperature and so reduce energy costs. That is option D.

25**Supplement**

Alloys and their properties

[6]

Mark scheme

(a)

[2]

- (atoms all the same size, arranged) in regular layers / rows (1)
- the layers can slide over each other (easily) when a force is applied (1)

(b)

[2]

- the magnesium atoms are a different size and disrupt / distort the regular layers (1)
- so the layers can no longer slide over each other (easily) (1)

REJECT magnesium atoms bond (covalently) to the aluminium atoms

(c)

[2]

- an alloy is a mixture (1)
 - the elements are not chemically combined / not bonded together in a fixed ratio / the proportions can vary (1)
-

Worked solution

(a) In pure aluminium, all the atoms are the same size and are packed in regular layers. When a force is applied, whole layers can slide over one another, so the metal changes shape easily. This is why it is soft.

(b) In the alloy, some magnesium atoms (a different size) are mixed in among the aluminium atoms. They disrupt the regular layers, so the layers cannot slide over each other easily. More force is needed to change the shape, so the alloy is harder and stronger, which makes it suitable for a ladder that must not bend.

(c) An alloy is a mixture of a metal with other elements. In a compound, elements are chemically joined in a fixed ratio. In an alloy the elements are only mixed together, and the amount of magnesium can be varied to change the alloy's properties. So the alloy is a mixture, not a compound.

Mark scheme

(a) [1]

- hardness increases as the percentage of carbon increases (1)

(b) [1]

- they are mixtures of a metal (iron) with another element (carbon) (1)

REJECT compound of iron and carbon

(c) [1]

- any value from 170 to 200 (1)

ALLOW about 185

(d) [1]

- steel is harder than pure iron (e.g. 120 to 210 units compared with 70), so it does not dent / bend / wear as easily (1)

ALLOW steel is stronger

Worked solution

(a) Reading down the table, hardness goes up every time more carbon is added (70 → 120 → 160 → 210). So the more carbon, the harder the sample.

(b) An alloy is a mixture of a metal with other elements. Each steel sample is iron (a metal) mixed with carbon (another element), so each one is an alloy.

(c) 0.6% lies halfway between 0.4% (160) and 0.8% (210). Halfway between 160 and 210 is 185, so a value close to 185 is expected.

(d) All the steels are harder than pure iron. Alloys can be harder and stronger than the pure metal, which makes them more useful for things like tools, building frames and machine parts.

Mark scheme

(a) [2]

- E, L, G, J (2)

ALLOW 1 mark for an order with one adjacent pair swapped, or for the correct order written least to most reactive

(b) [2]

- J (1)
- J does not react with dilute hydrochloric acid, because copper is below hydrogen in the reactivity series / J is the least reactive metal (1)

(c) [2]

- calcium (1)
- E reacts (steadily) with cold water, whereas magnesium reacts only very slowly with cold water (and reacts quickly only with steam) (1)

ALLOW calcium reacts readily with cold water, forming (alkaline) calcium hydroxide

(d) [1]

- any one from: concentration of acid / volume of acid / temperature / size or mass or surface area of the metal pieces (1)

Worked solution

(a) Use each experiment in turn.

- Experiment 1: only E reacts with cold water, so E is the most reactive.
- Experiment 2: with acid, L bubbles rapidly, G slowly and J not at all, so $L > G > J$.
- Experiment 3: L takes the oxygen from G's oxide, so L is more reactive than G. This agrees with Experiment 2.

Overall order: E, L, G, J.

(b) Copper is below hydrogen in the reactivity series, so it does not react with dilute hydrochloric acid. The only metal that gave no bubbles with acid is J. J is also the least reactive of the four, which fits copper.

(c) Calcium reacts steadily with cold water, giving bubbles of hydrogen and an alkaline solution of calcium hydroxide. Magnesium reacts only very slowly with cold water (it needs steam to react quickly), so you would not see steady fizzing. E is therefore calcium.

(d) To compare reactivity fairly, only the metal should change. Keep the concentration and volume of acid, the temperature and the size of the metal pieces the same.

Mark scheme

(a)(i)

[1]

- painting (1)

ALLOW coating with plastic / galvanising

REJECT greasing (it would rub off onto hands and clothes and collect dirt)

(a)(ii)

[1]

- coating with plastic (1)

ALLOW painting / galvanising

REJECT greasing (it would contaminate the dishes)

(b)

[2]

- they cover the surface with a layer / coating (1)
- which stops oxygen (air) and / or water reaching the iron (1)

ALLOW "excludes oxygen or water"

(c)

[2]

- at the scratch, the steel / iron is exposed to both oxygen and water (1)
- elsewhere the paint is still a barrier, keeping oxygen and water away (1)

Worked solution

(a) Choose a method that suits the object. A garden gate is large, stays outdoors and is not a moving machine part, so paint works well and lasts for years. A dish rack is wet all the time and touches plates, so a waterproof plastic coating is ideal, and it does not chip easily or contaminate food. Grease suits moving parts such as chains and hinges, not objects that people touch or that hold food.

(b) Iron rusts only when both oxygen and water reach it. A barrier method covers the surface with a layer (paint, plastic or grease) that keeps oxygen and water away from the metal, so rusting cannot start.

(c) The scratch breaks the barrier. The iron under the scratch now meets air (oxygen) and rain (water), so it rusts there. Everywhere else, the unbroken paint still keeps oxygen and water out, so no rust forms.

Mark scheme

(a)

[2]

- $\text{Al}^{3+} + 3\text{e}^- \rightarrow \text{Al}$ (2)
- correct species but wrong number of electrons (1)

ALLOW e for e^-

(b)

[2]

- $2\text{O}^{2-} \rightarrow \text{O}_2 + 4\text{e}^-$ (2)

ALLOW $2\text{O}^{2-} - 4\text{e}^- \rightarrow \text{O}_2$ (2)

- correct species but not balanced (1)

(c)

[2]

- (the oxygen formed at the anode) reacts with the carbon (at the high temperature) (1)
- to form carbon dioxide, so the anodes burn away / get smaller (1)

ALLOW carbon monoxide as the product**Worked solution**

(a) Aluminium ions are positive (Al^{3+}) and are attracted to the negative cathode. Each ion gains three electrons to become an aluminium atom: $\text{Al}^{3+} + 3\text{e}^- \rightarrow \text{Al}$. Check the charge: 3+ plus 3- gives 0 on each side.

(b) Oxide ions (O^{2-}) are attracted to the positive anode. They lose electrons, and pairs of oxygen atoms join to form O_2 molecules: $2\text{O}^{2-} \rightarrow \text{O}_2 + 4\text{e}^-$. Check: 2 O on each side; charge 4- on the left and $0 + 4(-) = 4-$ on the right.

(c) The cell runs at a high temperature, and the oxygen made at the anode reacts with the hot carbon to form carbon dioxide: carbon + oxygen $\rightarrow$ carbon dioxide. The carbon anodes are slowly used up (they burn away), so they must be replaced regularly.

Mark scheme

(a) [1]

- gold is very unreactive, so it does not react with (oxygen or water or) other substances to form compounds (1)

ALLOW gold is at the bottom of the reactivity series

(b) [1]

- carbon is more reactive than zinc and iron (so it can remove the oxygen from their oxides) (1)

ALLOW zinc and iron are below carbon in the reactivity series

(c) [1]

- sodium is more reactive than carbon / sodium is above carbon in the reactivity series (1)

(d) [1]

- the higher the metal is in the reactivity series (the more reactive it is), the harder it is to obtain from its ore (1)

ALLOW the reverse: the lower / less reactive the metal, the easier it is to obtain

Worked solution

(a) Gold is at the bottom of the reactivity series. It is so unreactive that it has not combined with oxygen or other elements over time, so it is found as the pure metal.

(b) Carbon is above zinc and iron in the reactivity series. When their oxides are heated with carbon, the more reactive carbon removes the oxygen (reduces the oxide) and leaves the metal.

(c) Sodium is above carbon, so carbon cannot take the oxygen (or other element) away from sodium. Instead, a strong method, electrolysis, is needed.

(d) The general rule is that the more reactive a metal is, the more tightly it holds on to other elements in its compounds, and the harder (and more expensive) it is to extract. Unreactive metals such as gold are the easiest to obtain. Very reactive metals such as sodium and aluminium need electrolysis.