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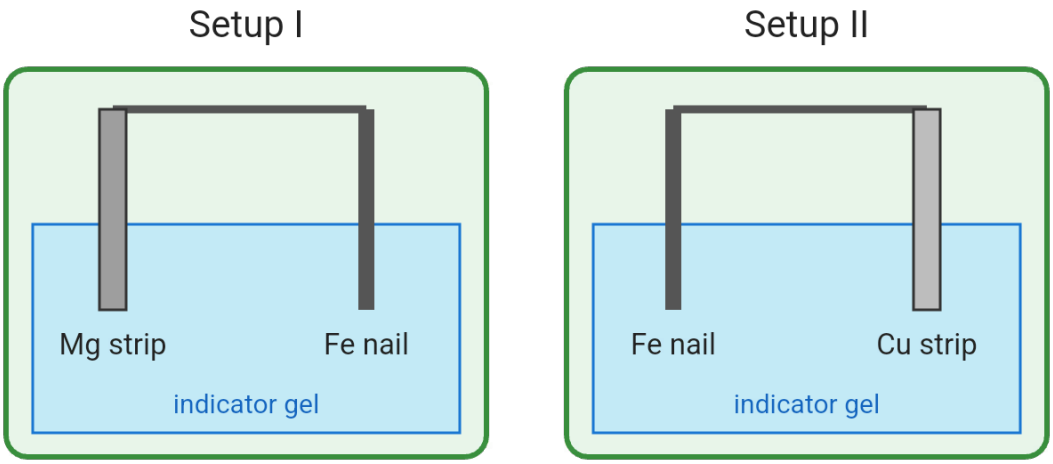
Secondary 5 - Chemistry

Metals: Corrosion, Reactivity and Extraction

Name: _____

Class: _____

1. Two identical iron nails are partly immersed in separate portions of an aerated gel containing potassium hexacyanoferrate(III) and phenolphthalein. Each nail is connected to the metal strip shown below. Assume the gel is initially neutral and both wires remain in good contact.



Which prediction is correct after the electrochemical processes have proceeded for some time?

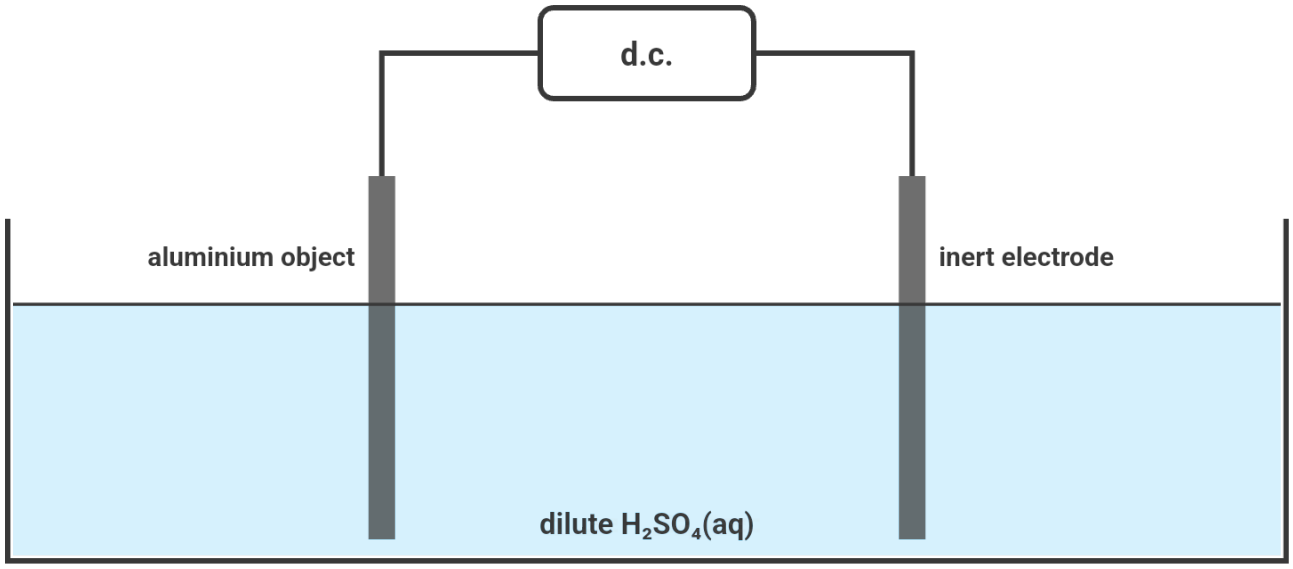
A. Setup I: pink develops near the iron nail, but no blue colour develops near it; Setup II: blue develops near the iron nail and pink near the copper strip.

B. Setup I: blue develops near the iron nail and pink near the magnesium strip; Setup II: pink develops near the iron nail and blue near the copper strip.

C. Setup I: pink develops near the magnesium strip and blue near the iron nail; Setup II: blue develops near the iron nail and no colour develops near the copper strip.

D. Both setups produce blue near the iron nail and pink near the same iron nail.

2. The electrolytic set-up below is intended to anodise an aluminium object.



Which statement correctly describes the electrical connection and the surface change required?

A. Connect the aluminium object to the positive terminal; oxidation forms a thicker, adherent Al_2O_3 layer.

B. Connect the aluminium object to the negative terminal; reduction removes the natural oxide layer and produces the protective coating.

C. Connect the aluminium object to the positive terminal; aluminium ions are reduced and a copper coating forms.

D. Connect the aluminium object to the negative terminal; sulfate ions are reduced to sulfur on its surface.

3. A steel railing at a coastal housing estate is tested under three conditions. In each trial, water and dissolved oxygen can reach a deliberate scratch. Trial I has a zinc coating, Trial II has a tin coating, and Trial III has bare iron electrically connected to a zinc block. Which statement is most accurate?

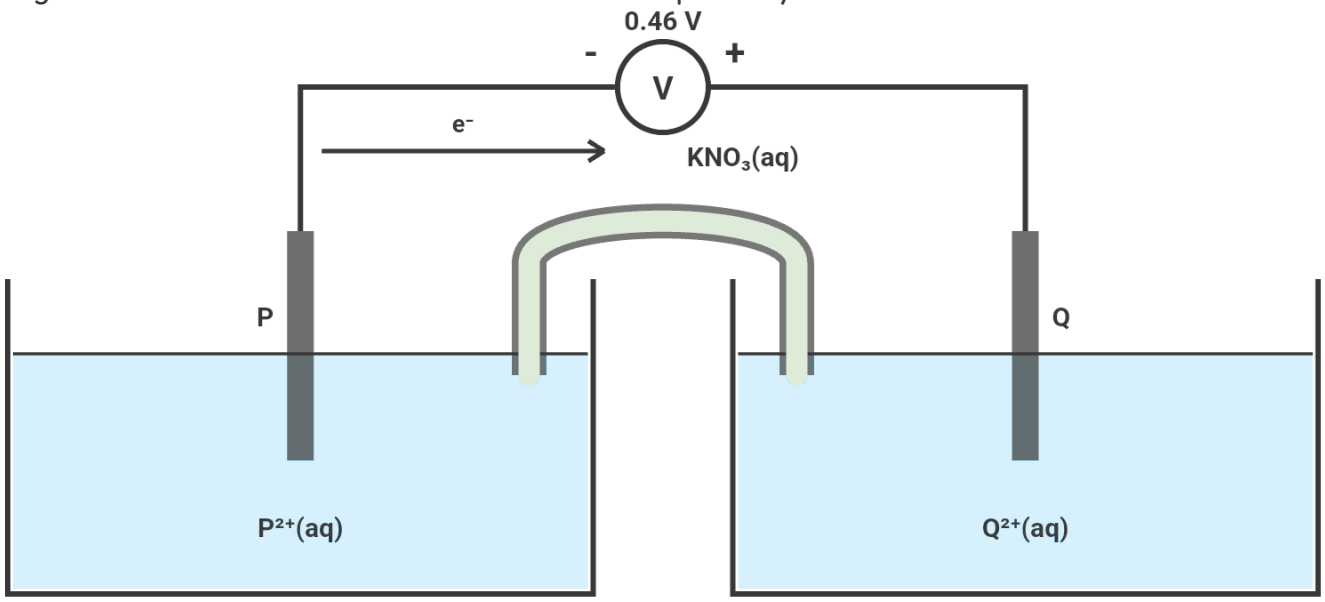
A. All three trials protect the scratched iron because each coating metal blocks air and water.

B. Trials I and III protect the iron by sacrificial oxidation of zinc, whereas a scratch in Trial II can make local rusting faster.

C. Trials II and III protect the iron because the iron becomes the anode and accepts electrons from the coating.

D. Trial I accelerates rusting because zinc is more reactive, whereas Trial II remains protective after any scratch.

4. The diagram shows a working cell at room conditions. Metals P and Q each form ions with charge $2+$. The electron direction and terminal polarity are shown.



Which statement correctly describes the process at the P electrode and the relative reactivity of the metals?

A. At P: $\mathrm{P(s) \rightarrow P^{2+}(aq) + 2e^-}$; P is more reactive than Q.

B. At P: $\mathrm{P^{2+}(aq) + 2e^- \rightarrow P(s)}$; P is more reactive than Q.

C. At P: $\mathrm{P(s) \rightarrow P^{2+}(aq) + 2e^-}$; Q is more reactive than P.

D. At P: $\mathrm{Q^{2+}(aq) + 2e^- \rightarrow Q(s)}$; P is less reactive than Q.

5. Metal X is one of Mg, Zn, Fe or Cu. It reacts with dilute hydrochloric acid to give hydrogen, displaces iron from iron(II) sulfate solution, but does not displace zinc from zinc sulfate solution. Its oxide can be reduced by carbon on heating. Which conclusion is correct?

A. $\mathrm{X = Mg}$; it is extracted by electrolysis of molten $\mathrm{MgCl_2}$.

B. $\mathrm{X = Zn}$; $\mathrm{Zn(s) + Fe^{2+}(aq) \rightarrow Zn^{2+}(aq) + Fe(s)}$, and zinc can be obtained from its oxide by carbon reduction.

C. $\mathrm{X = Fe}$; $\mathrm{Fe(s) + Zn^{2+}(aq) \rightarrow Fe^{2+}(aq) + Zn(s)}$, and iron oxide requires electrolysis.

D. $\mathrm{X = Cu}$; $\mathrm{Cu(s) + 2HCl(aq) \rightarrow CuCl_2(aq) + H_2(g)}$, and copper oxide requires electrolysis.

6. When a copper strip is heated with hot, concentrated sulphuric acid, which option gives the overall equation and the redox changes correctly?

A. $\mathrm{Cu(s) + 2H_2SO_4(l) \rightarrow CuSO_4(aq) + SO_2(g) + 2H_2O(l)}$; copper is oxidised and sulfur is reduced.

B. $\mathrm{Cu(s) + 2HCl(aq) \rightarrow CuCl_2(aq) + H_2(g)}$; copper is oxidised and hydrogen ions are reduced.

C. $\mathrm{Cu(s) + H_2SO_4(l) \rightarrow CuSO_4(aq) + H_2(g)}$; sulfate ions remain unchanged.

D. $\mathrm{Cu(s) + 2H_2SO_4(l) \rightarrow CuSO_4(aq) + 2SO_2(g) + 2H_2O(l)}$; copper and sulfur are both oxidised.

7. The following information is obtained for three metals.
Metal A: It occurs in some deposits as the native metal, and its oxide decomposes when strongly heated.
Metal B: Its oxide is reduced to the metal by carbon on heating.
Metal C: Its chloride is electrolysed in the molten state to obtain the metal.
Which inference is best supported by the evidence?

A. A was likely available and discovered earlier than B and C because it occurs free and needs little reduction.

B. B is more reactive than C because carbon is a stronger reducing method than electricity.

C. C can be extracted more easily by electrolysis of an aqueous chloride solution than by electrolysis of a molten chloride.

D. A must be extracted by carbon reduction because metals in ores always occur in combined form.

8. A manufacturer can either produce fresh aluminium from aluminium oxide ore or remelt collected aluminium cans. Which evaluation is scientifically and economically sound?

A. Remelting regenerates aluminium ore and makes primary extraction unnecessary forever.

B. Remelting reuses existing aluminium, conserves finite ores and usually lowers energy use, but still requires collection, processing and melting.

C. Recycling consumes more ore because aluminium atoms are destroyed during melting.

D. Recycling is impossible because aluminium can only be produced by electrolysis of molten $\mathrm{Al_2O_3}$.

9. $40.0\,\mathrm{cm^3}$ of $0.150\,\mathrm{mol\,dm^{-3}}$ $\mathrm{Al_2(SO_4)_3(aq)}$ is mixed with $60.0\,\mathrm{cm^3}$ of $0.200\,\mathrm{mol\,dm^{-3}}$ $\mathrm{Ba(NO_3)_2(aq)}$. Barium sulfate precipitates according to the equation:
$\mathrm{Al_2(SO_4)_3(aq) + 3Ba(NO_3)_2(aq) \rightarrow 3BaSO_4(s) + 2Al(NO_3)_3(aq)}$
Which ion has the highest concentration in the final mixture?

A. $[\mathrm{Al^{3+}}] = 0.120\,\mathrm{mol\,dm^{-3}}$

B. $[\mathrm{NO_3^-}] = 0.240\,\mathrm{mol\,dm^{-3}}$

C. $[\mathrm{SO_4^{2-}}] = 0.120\,\mathrm{mol\,dm^{-3}}$

D. $[\mathrm{Ba^{2+}}] = 0.120\,\mathrm{mol\,dm^{-3}}$

10. A mixture contains only magnesium carbonate and calcium carbonate. On strong heating, both carbonates decompose to the metal oxide and carbon dioxide. A $2.2444\,\mathrm{g}$ sample produces $0.0240\,\mathrm{mol}$ of $\mathrm{CO_2(g)}$. What mass of calcium carbonate was present?
Relative atomic masses: $\mathrm{Mg} = 24.3$, $\mathrm{Ca} = 40.1$, $\mathrm{C} = 12.0$, $\mathrm{O} = 16.0$.

A. $0.843\,\mathrm{g}$

B. $1.40\,\mathrm{g}$

C. $1.56\,\mathrm{g}$

D. $2.2444\,\mathrm{g}$

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Answers

1 **A**

The more reactive metal acts as the anode and is oxidised. At a cathode, dissolved oxygen is reduced:

$$O_2(g) + 2H_2O(l) + 4e^- \rightarrow 4OH^-(aq)$$

Phenolphthalein turns pink in the alkaline region containing OH^-. Potassium hexacyanoferrate(III) gives a blue colour when Fe^{2+} is produced.

In Setup I, magnesium is more reactive than iron:

$$Mg(s) \rightarrow Mg^{2+}(aq) + 2e^-$$

Iron is the cathode, so the region near the iron nail becomes pink. Iron is not oxidised there, so no Fe^{2+} is formed near it.

In Setup II, iron is more reactive than copper and is oxidised. Blue develops near the iron nail, while oxygen reduction makes the region near the copper strip pink.

2 **A**

Anodisation is an electrolytic oxidation process. The aluminium object must be the anode, so it is connected to the positive terminal. Oxidation at the surface supports the formation of a thicker, adherent aluminium oxide layer:

$$2Al(s) + 3H_2O(l) \rightarrow Al_2O_3(s) + 6H^+(aq) + 6e^-$$

The thicker Al_2O_3 layer is more protective and improves aluminium's resistance to corrosion.

3 **B**

In galvanising, zinc is more reactive than iron. If a scratch exposes the iron, zinc is oxidised preferentially and supplies electrons to the iron, giving sacrificial protection.

The zinc block in Trial III works by the same principle: it acts as a sacrificial anode, while the iron is made the cathode.

Tin is less reactive than iron. A complete tin coating can isolate iron from air and water, but at a scratch the exposed iron becomes the anode and tin becomes the cathode. This can make local corrosion of the iron rapid.

4 **A**

The diagram shows electrons moving from P to Q. Electrons leave the anode, so P undergoes oxidation:
$\mathrm{P(s)} \rightarrow \mathrm{P^{2+}(aq)} + 2\mathrm{e^-}$
A more reactive metal forms positive ions more readily because it loses electrons more easily. Therefore, P is more reactive than Q, while $\mathrm{Q^{2+}}$ is reduced at the cathode.

5 **B**

Displacing iron shows that X is more reactive than iron. The absence of displacement from zinc sulfate places X at or below zinc. Among the metals listed, the only metal fitting both observations is zinc.

The displacement is represented by the net ionic equation:
$\mathrm{Zn(s)} + \mathrm{Fe^{2+}(aq)} \rightarrow \mathrm{Zn^{2+}(aq)} + \mathrm{Fe(s)}$
Zinc is less reactive than magnesium, so zinc oxide can be reduced by carbon on heating, whereas magnesium compounds require electrolysis.

6 **A**

Hot concentrated sulphuric acid acts as an oxidising acid. Copper loses electrons and is oxidised from oxidation number 0 to $+2$. Sulfur in sulfate is reduced from $+6$ to $+4$ in sulfur dioxide.

The balanced equation is:
$\mathrm{Cu(s)} + 2\mathrm{H_2SO_4(l)} \rightarrow \mathrm{CuSO_4(aq)} + \mathrm{SO_2(g)} + 2\mathrm{H_2O(l)}$
The products include aqueous copper(II) sulfate and sulfur dioxide gas.

7 **A**

The extraction method indicates how strongly a metal tends to form positive ions. A metal found in the free state and obtained from its oxide by heating alone has a relatively weak tendency to form ions, so A is the least reactive of the three.

Carbon reduction is suitable for the intermediate metal B. Molten electrolysis is needed for the more reactive metal C, because its ions are too difficult to reduce chemically. Metals that are easier to obtain were generally available for discovery earlier.

8 **B**

Recycling remelts aluminium that has already been extracted, so it avoids reducing a new batch of aluminium ions from aluminium oxide. It conserves finite ores and usually uses less energy than primary extraction, although collection, sorting, transport and remelting still have costs and environmental impacts.

Therefore, recycling is valuable but cannot remove the need for all primary extraction.

9 **B**

First calculate the initial amounts:

$n\left(\mathrm{Al_2(SO_4)_3}\right) = 0.150 \times 0.0400 = 0.00600\,\mathrm{mol}$

$n\left(\mathrm{Ba(NO_3)_2}\right) = 0.200 \times 0.0600 = 0.0120\,\mathrm{mol}$

The equation requires 3 moles of barium nitrate for every 1 mole of aluminium sulfate. The $0.00600\,\mathrm{mol}$ of aluminium sulfate would require $0.0180\,\mathrm{mol}$ of barium nitrate, so barium nitrate is limiting.

Amounts remaining or formed are:

$n(\mathrm{Al^{3+}}) = 2(0.00600) = 0.0120\,\mathrm{mol}$

$n(\mathrm{NO_3^-}) = 2(0.0120) = 0.0240\,\mathrm{mol}$

$n(\mathrm{SO_4^{2-}}) = 3(0.00600) - 0.0120 = 0.00600\,\mathrm{mol}$

$n(\mathrm{Ba^{2+}}) = 0$

The final volume is $0.1000\,\mathrm{dm^3}$, so:

$[\mathrm{Al^{3+}}] = 0.120\,\mathrm{mol\,dm^{-3}}$

$[\mathrm{NO_3^-}] = 0.240\,\mathrm{mol\,dm^{-3}}$

$[\mathrm{SO_4^{2-}}] = 0.0600\,\mathrm{mol\,dm^{-3}}$

Thus nitrate ions have the highest concentration.

10 **B**

Each mole of either carbonate produces one mole of carbon dioxide. Let x and y be the amounts, in moles, of magnesium carbonate and calcium carbonate.
$x + y = 0.0240$

The molar masses are:
$M(\mathrm{MgCO_3}) = 24.3 + 12.0 + 3(16.0) = 84.3\,\mathrm{g\,mol^{-1}}$
$M(\mathrm{CaCO_3}) = 40.1 + 12.0 + 3(16.0) = 100.1\,\mathrm{g\,mol^{-1}}$

The mass equation is:
$84.3x + 100.1y = 2.2444$
Substitute $x = 0.0240 - y$:
$84.3(0.0240 - y) + 100.1y = 2.2444$
$2.0232 + 15.8y = 2.2444$
$15.8y = 0.2212$
$y = 0.0140\,\mathrm{mol}$

Therefore, the mass of calcium carbonate is:
$m = 0.0140 \times 100.1 = 1.4014\,\mathrm{g} \approx 1.40\,\mathrm{g}$