Neap

Diagnostic Topic Test 2024

VCE Chemistry Units 3&4

Suggested Solutions

Test 4: How can the rate and yield of chemical reactions be optimised?

- Production of chemicals using electrolysis

SECTION A – MULTIPLE-CHOICE QUESTIONS

Question 1 D

D is an incorrect comparison and so is the required response. In a galvanic cell, electrons are released spontaneously (oxidation) at the anode, creating a negative charge. In an electrolytic cell, a forced release of electrons (oxidation) occurs at the positively charged electrode.

A, **B** and **C** are correct comparisons and so are not the required response.

Question 2 A

A is correct, and **B** and **D** are incorrect. Oxidation occurs at the anode. The strongest reducing agent present will undergo oxidation, which in this case is the copper electrode itself.

C is incorrect. This option shows a reduction.

Question 3 C

C is correct and **A** is incorrect. Water is a stronger oxidising agent than the aluminium ion, so water is reduced rather than the aluminium ion. Electrolysis of an aqueous solution of aluminium ion would therefore produce hydrogen and hydroxide ions, not aluminium.

B is incorrect. Aluminium oxide does dissolve in acid to form aluminium ions and water.

D is incorrect. The required product, aluminium, is a solid at room temperature. A molten product is not required.

Question 4 D

The deposition reaction is $Cd^{2+}(aq) + 2e^- \rightarrow Cd(s)$. This is a reduction process and so occurs at the cathode. The reduction is forced by electron flow from the power supply, making the electrode negatively charged.

Question 5 B

oxidising agents present: Ni^{2+}, H_2O; the strongest oxidising agent is Ni^{2+}

reducing agents present: H_2O

reduction half-equation: $Ni^{2+}(aq) + 2e^- \rightarrow Ni(s)$

oxidation half-equation: $2H_2O(l) \rightarrow O_2(g) + 4H^+(aq) + 4e^-$

Water is therefore the reducing agent and the solvent.

Question 6 D

The negatively charged nitrate ions will be attracted to the positively charged anode. They will migrate to the anode but will not undergo oxidation as they are not reducing agents and so cannot be oxidised at the electrode. The nitrogen atom in nitrate ions is in its highest oxidation state of +5 and so cannot be oxidised.

Question 7 C

C is correct. The mole ratio involved is $O_2 : 4e^- = 1 : 4$ or $0.25 : 1$.

A is incorrect. One Faraday of charge is 96 500 C.

B is incorrect. One Faraday of charge represents one mole of electrons reacting at the electrodes.

D is incorrect. The mole ratio involved is $Ni^{2+} : 2e^- = 1 : 2$ or $0.5 : 1$.

Question 8 C

$$n\left(e^-\right) = \frac{It}{F} = \frac{0.50 \times 45 \times 60}{96\,500} = 0.0140 \text{ mol}$$

$$n\left(Sc\right) = \frac{m}{M} = \frac{0.21}{45.0} = 0.00467 \text{ mol}$$

$$n(e^-) = a \times n\left(Sc\right)$$

$$\begin{aligned} \therefore a &= \frac{0.0140}{0.00467} \\ &= 3 \end{aligned}$$

Question 9 B

B is correct, and **A** and **C** are incorrect. Oxidation occurs at the positive electrode of the electrolytic cell operating during the recharging of the NiCad cell. The best reducing agent, $Ni(OH)_2$ (with Ni in a +2 oxidation state), is oxidised to NiO(OH) (with Ni in a +3 oxidation state). The products are NiO(OH) and H_2O.

D is incorrect. The cell has an alkaline electrolyte, so H^+ will not be produced.

Question 10 A

A is correct. This option outlines the chemical principle allowing all galvanic cells (both primary and secondary) to produce electrical energy.

B is incorrect. This option describes a fuel cell.

C is incorrect. This option describes a primary cell.

D is incorrect. This option describes a secondary cell.

SECTION B

Question 1 (5 marks)

a. $Pb(s) + 2H_2SO_4(aq) + PbO_2(s) \rightarrow 2PbSO_4(s) + 2H_2O(l)$ 1 mark

b. The products of the electrode reactions adhere to the electrodes. This enables the reactions to be reversed by the application of a current in the recharging process. 1 mark

c. positive 1 mark

The reverse of the second equation to regenerate the $PbO_2(s)$ is an oxidation. The electrode must therefore be positive to force the oxidation (loss of electrons). 1 mark

d. $2H_2O(l) \rightarrow O_2(g) + 4H^+(aq) + 4e^-$ 1 mark

(Oxidation occurs at the anode.)

Question 2 (4 marks)

a. **i.** silver and gold 1 mark

ii. Zinc and nickel are stronger reducing agents than copper and, as the cell voltage is set to cause copper metal to be oxidised, zinc and nickel will be oxidised as well. 1 mark

b. pure copper sheet: –

(Reduction of Cu^{2+} occurs here.)

blister copper: + 1 mark

(Oxidation of Cu occurs here.)

Note: Both polarities need to be correct to be awarded the mark.

c. $Cu^{2+}(aq) + 2e^- \rightarrow Cu(s)$ 1 mark

Question 3 (6 marks)

a. Using molten electrolytes is costly because of the energy required to melt the solid and keep it molten. 1 mark

The melting point of magnesium chloride is likely to be much lower than the melting point of magnesium oxide. Less energy is required to produce a molten electrolyte, and so costs are reduced. 1 mark

b. **i.**

	Positive	Negative
Anode	✓	
Cathode		

1 mark

ii. The ceramic hood ensures that the electrolytic products, magnesium metal and chlorine gas, do not come into contact; otherwise, a spontaneous reaction will occur. 1 mark

c. **i.** Iron is a stronger reducing agent than the chloride ion and so the iron would undergo oxidation in preference to the chloride ion. No chlorine would be produced and the anode would slowly dissolve into the electrolyte. 1 mark

ii. Predictions are made at standard conditions. The cell is not at 25°C and 1 M solution concentration, and so predictions may not be accurate. 1 mark

Question 4 (10 marks)

a. **i.** $2H_2O(l) + 2e^- \rightarrow H_2(g) + 2OH^-(aq)$ 1 mark

ii. The electrolyte increases the conductivity of the solution, allowing for better flow of current. 1 mark

iii. $n(e^-) = \frac{It}{F} = \frac{3.5 \times 5.0 \times 60}{96\,500}$ 1 mark

$n(H_2) = \frac{1}{2} \times n(e^-)$ 1 mark

$V(H_2) = n \times 24.8 = \frac{1}{2} \times \frac{3.5 \times 5.0 \times 60}{96\,500} \times 24.8 = 0.135 \text{ L} = 135 \text{ mL}$ 1 mark

b. **i.** from anode *(where H^+ is generated)* to cathode 1 mark

ii. *For example, any one of:*

- if the PEM electrolysis process is conducted using solar-powered electricity generation
- if the PEM electrolysis process is conducted using wind-powered electricity generation

1 mark

c. *For example:*

One process is photobiological hydrogen production using microorganisms and sunlight to split water or organic matter into hydrogen. 1 mark

This would be a sustainable hydrogen source as the sunlight, microorganisms, organic matter and water can all be replenished at a suitable rate, 1 mark
and the process has minimal environmental impact as the products are only hydrogen and oxygen. 1 mark