Neap

Diagnostic Topic Test 2024

VCE Chemistry Units 3&4

Question and Answer Booklet

Test time: 45 minutes
Total marks: 35 marks

Test 2: What are the current and future options for supplying energy?

- Primary galvanic cells and fuel cells as sources of energy

Student's Name: _____

Teacher's Name: _____

Instructions

Write your **name** and your **teacher's name** in the space provided above on this page.

A data booklet is provided.

Unless otherwise indicated, the diagrams in this booklet are **not** drawn to scale.

Answer **all** questions in the spaces provided.

SECTION A – MULTIPLE-CHOICE QUESTIONS

Instructions for Section A

Circle the response that is **correct** or that **best answers** the question.
A correct answer scores 1; an incorrect answer scores 0.
Marks will **not** be deducted for incorrect answers.
No marks will be given if more than one answer is completed for any question.
Unless otherwise indicated, the diagrams in this booklet are **not** drawn to scale.

Question 1
Which of the following equations represents a redox reaction?

A. $3NO_2(g) + H_2O(l) \rightarrow 2HNO_3(aq) + NO(g)$
B. $Na_2CO_3(aq) + CaCl_2(aq) \rightarrow CaCO_3(s) + 2NaCl(aq)$
C. $C_2H_5Cl(g) + NaOH(aq) \rightarrow C_2H_5OH(aq) + NaCl(aq)$
D. $HNO_3(aq) + KOH(aq) \rightarrow KNO_3(aq) + H_2O(l)$

Question 2
Using the electrochemical series, a student predicted a cell voltage of 1.56 V for a cell constructed of a zinc and a silver half-cell. However, when the cell was constructed, the recorded cell voltage was only 1.05 V.

Which of the following is the most likely explanation for the difference between the predicted and observed cell voltages?

A. The student had connected the electrodes to the wrong terminals of the voltmeter.
B. The concentration of the solutions used was not 1.0 M.
C. The experiment was conducted on a warm day with a room temperature of 25°C.
D. The student used $NaNO_3(aq)$ instead of $KNO_3(aq)$ in the salt bridge.

Question 3
The lead-based pigments used in traditional artists' paint can react with pollutants from the air to produce the black compound lead(II) sulfide, PbS. To restore the paintings to their original colour, the PbS is converted to colourless lead(II) sulfate, $PbSO_4$, by treating it with a solution of hydrogen peroxide.
The reaction can be represented by the following equation.

$$PbS(s) + 4H_2O_2(aq) \rightarrow PbSO_4(s) + 4H_2O(l)$$

In this reaction, the oxidation number of

A. lead changes from +1 to +2, and hydrogen peroxide acts as an oxidising agent.
B. lead changes from +2 to +4, and hydrogen peroxide acts as a reducing agent.
C. sulfur changes from –2 to +6, and hydrogen peroxide acts as an oxidising agent.
D. sulfur changes from –2 to +2, and hydrogen peroxide acts as a reducing agent.

Question 4

Which of the following is likely to oxidise $Sn^{2+}(aq)$ but not $Fe^{2+}(aq)$?

A. $Br_2(l)$

B. $I_2(s)$

C. $H_2O_2(aq)$

D. $Pb^{2+}(aq)$

Use the following information to answer Questions 5 and 6.

A galvanic cell was constructed using the Ag^+/Ag and Ni^{2+}/Ni half-cells at standard laboratory conditions (SLC), with solutions at 1.0 M concentrations. After the cell had operated for some time the change in mass at the silver electrode was 0.016 g.

Question 5

Which species in the galvanic cell was operating as the oxidising agent?

A. Ag^+

B. Ag

C. Ni^{2+}

D. Ni

Question 6

What was the change in mass expected at the Ni electrode when the change in mass at the silver electrode was 0.016 g?

A. 0.0044 g

B. 0.0087 g

C. 0.016 g

D. 0.017 g

Question 7

Which of the following statements correctly identifies the function of a salt bridge in a galvanic cell?

A. The salt bridge enables electrons to flow from the cathode to the anode in a galvanic cell.

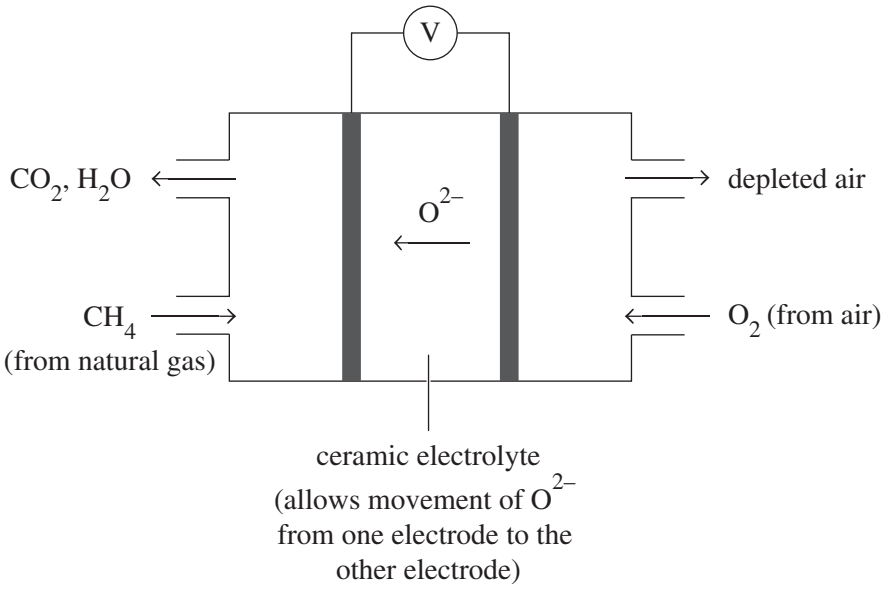
B. The salt bridge enables anions to flow from the anode to the cathode in a galvanic cell.

C. Ions migrate through the salt bridge to maintain electrical neutrality in each galvanic half-cell.

D. The salt bridge converts electrical energy to chemical energy in a galvanic cell.

Use the following information to answer Questions 8 and 9.

An innovative way of using natural gas with a fuel cell is being developed by an Australian company. These cells use a ceramic electrolyte with natural gas and oxygen being channelled onto the appropriate electrodes. Stacks of the individual fuel cells provide the high voltages required for domestic applications such as water heating and electricity generation. The design of the cell is shown below.



Question 8

The reactions occurring in the natural gas fuel cell are shown below (states have been omitted).

$$O_2 + 4e^- \rightarrow 2O^{2-}$$

$$CH_4 + 4O^{2-} \rightarrow CO_2 + 2H_2O + 8e^-$$

In the overall balanced equation for the reaction occurring in this fuel cell the mole ratio of CH_4 to O_2 is

A. 1 : 1

B. 1 : 2

C. 1 : 4

D. 2 : 1

Question 9

Which of the following statements concerning this fuel cell is **incorrect**?

A. The mass of carbon dioxide produced per gram of methane used in this fuel cell would equal the mass of carbon dioxide produced per gram of methane used in an electricity generator powered by methane gas.

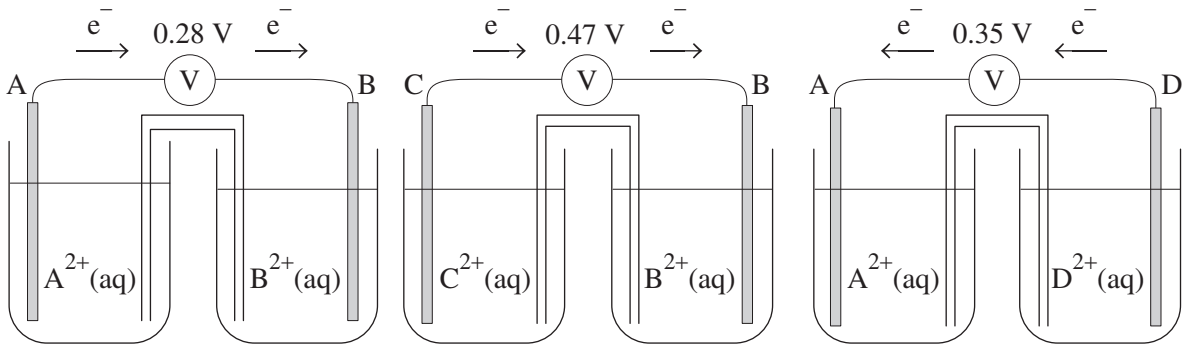
B. Using methane obtained from biogas in this fuel cell would align with the green chemistry principle of use of renewable feedstocks.

C. This fuel cell is likely to be 100% efficient and produce energy that can be used for high-voltage applications such as domestic water heating.

D. Using methane obtained from biogas would reduce the overall contribution of the electricity generation process to the carbon dioxide level in the atmosphere.

Question 10

During a practical class, a student constructed a number of half-cells. Each half-cell contained a metal electrode and a solution containing the metal ion. The half-cells were connected as shown below. The direction of electron flow and cell voltage for each cell was recorded. All solutions used were 1 M.



cell 1 cell 2 cell 3

Based on these observations, the student could conclude that the strongest oxidising agent was

A. A^{2+}

B. B^{2+}

C. C^{2+}

D. D^{2+}

END OF SECTION A

SECTION B

Instructions for Section B

Answer **all** questions in the spaces provided.

Give simplified answers to all numerical questions, with an appropriate number of significant figures; unsimplified answers will not be given full marks.

Show all working in your answers to numerical questions; no marks will be given for an incorrect answer unless it is accompanied by details of the working.

Ensure chemical equations are balanced and that the formulas for individual substances include an indication of state, for example, $H_2(g)$, NaCl(s).

Unless otherwise indicated, the diagrams in this booklet are **not** drawn to scale.

Question 1 (5 marks)

a. Sodium oxalate, $Na_2C_2O_4$, reacts with potassium permanganate, $KMnO_4$, in a redox reaction. The products of the reaction include Mn^{2+} and CO_2.

i. Write the oxidation half-equation for the reaction of the oxalate ion with the permanganate ion in acidic solution. 1 mark

ii. Write the reduction half-equation for the reaction of the oxalate ion with the permanganate ion in acidic solution. 1 mark

b. Consider the standard reduction potentials for the three half-cells listed below.

$$Mn^{2+}(aq) + 2e^- \rightarrow Mn(s) \qquad E° = -1.18 \text{ V}$$

$$Au^{3+}(aq) + 3e^- \rightarrow Au(s) \qquad E° = 1.50 \text{ V}$$

$$Cd^{2+}(aq) + 2e^- \rightarrow Cd(s) \qquad E° = -0.14 \text{ V}$$

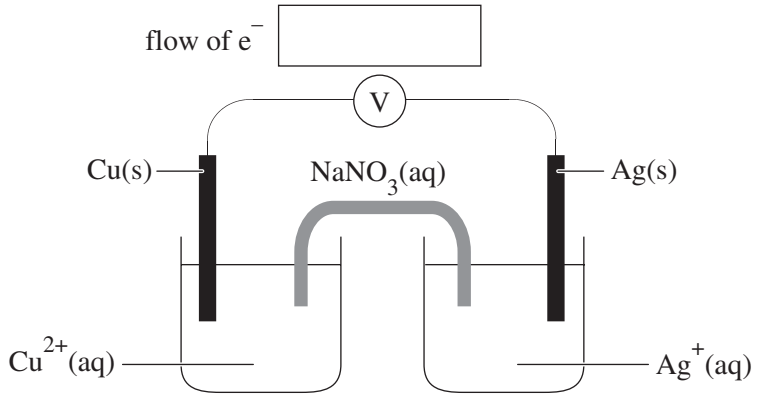
i. Which species shown in the above half-equations is the strongest reducing agent? 1 mark

ii. Write an equation for the reaction occurring in the combination of half-cells that would produce the largest voltage when arranged as a galvanic cell. 1 mark

iii. What is the expected voltage of the cell in **part b.ii.** at standard laboratory conditions (SLC)? 1 mark

Question 2 (9 marks)

a. An electrochemical cell was constructed using Cu^{2+}/Cu and Ag^{+}/Ag half-cells at standard laboratory conditions (SLC). The two half-cells were joined by an inverted U-tube containing a solution of sodium nitrate, as shown below.



i. Indicate the direction of the flow of the electrons through the wire when the cell is operating by placing an arrow in the box in the above diagram. 1 mark

ii. Which electrode (Cu or Ag) is the anode? 1 mark

_____

iii. Which ions in the salt bridge would migrate into the Cu half-cell when the cell is operating? 1 mark

_____

iv. State **two** observations that could be made in the beakers to indicate that the cell is operating. 2 marks

_____

_____

_____

_____

v. With the aid of an ionic equation, explain why it would be unsuitable to use a solution of potassium chloride in the salt bridge in this cell. 2 marks

_____

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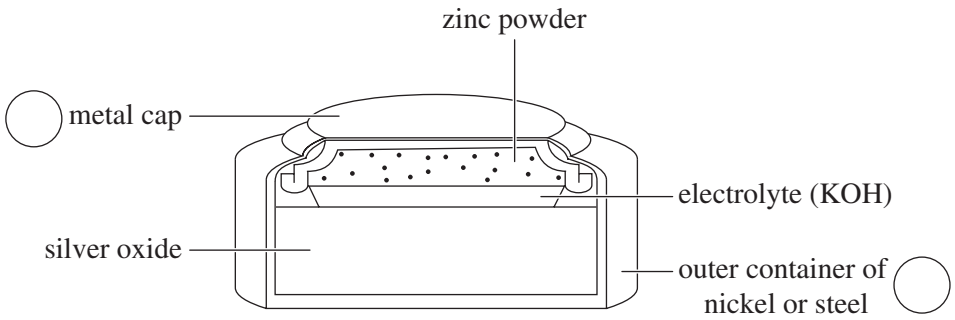
b. Silver is also used as the basis for some button cells. Button cells are primary cells developed to meet the need for very small cells in devices such as watches and calculators. The basic design features and overall reaction occurring in the silver–zinc button cell are shown below.



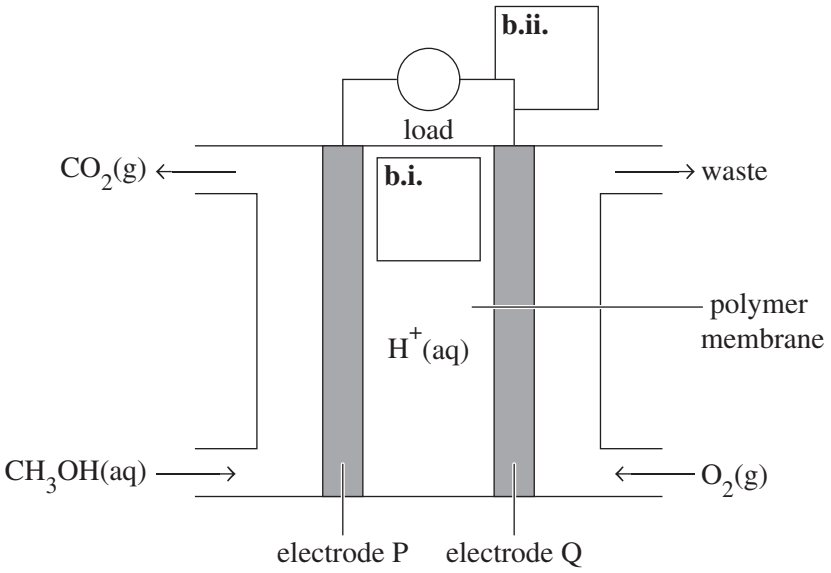
$$Ag_2O(s) + Zn(s) + H_2O(l) \rightarrow Zn(OH)_2(s) + 2Ag(s)$$

i. Label the positive and negative electrodes of the cell by placing the appropriate symbols (+ and –) in the circles on the diagram above. 1 mark

ii. Write the half-equation for the reaction occurring at the anode when the cell is operating. 1 mark

Question 3 (11 marks)

The direct methanol fuel cell (DMFC) uses proton exchange membrane technology. The solid polymer membrane acts as the electrolyte and separates the anode and cathode compartments. It is an excellent conductor of hydrogen ions but is also an electrical insulator. Methanol, CH_3OH, is used as the fuel. The cell uses an aqueous methanol solution.



a. The overall fuel cell reaction is the same as the combustion reaction of methanol.

i. Write the half-equation for the oxidation process occurring in the fuel cell. 1 mark

_____

ii. Write the half-equation for the reduction process occurring in the fuel cell. 1 mark

_____

b. **i.** In the space on the diagram above, use an arrow to mark the direction of movement of the H^+ ion through the polymer membrane. 1 mark

ii. In the space on the diagram above, use an arrow to mark the direction of electron flow in the external circuit. 1 mark

iii. Which electrode (P or Q) is the cathode? 1 mark

_____

c. The DMFC is more efficient when run at high temperatures and pressures, and yet the conditions most commonly used are 50°C to 120°C and atmospheric pressure.

Suggest a reason to explain the use of these lower temperatures and pressures. 1 mark

_____

_____

_____

d. State **two** roles performed by the electrodes in fuel cells. 2 marks

e. State **two** disadvantages of fuel cells that explain why they are not a major source of electricity at the present time. 2 marks

f. State **one** way in which a fuel cell, such as the DMFC, is different from a primary cell. 1 mark

END OF TEST