Student Name: _____

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CHEMISTRY 2021

Unit 3
Key Topic Test 4 – Commercial and Rechargeable Cells

Recommended writing time*: 45 minutes
Total number of marks available: 50 marks

QUESTION BOOK

* The recommended writing time is a guide to the time students should take to complete this test. Teachers may wish to alter this time and can do so at their own discretion.

Conditions and restrictions

- Students are permitted to bring into the room for this test: pens, pencils, highlighters, erasers, sharpeners and rulers.
- Students are NOT permitted to bring into the room for this test: blank sheets of paper and/or white out liquid/tape.
- A calculator is permitted in this test.

Materials supplied

- Question and answer book of 11 pages.

Instructions

- Print your name in the space provided on the top of the front page.
- All written responses must be in English.

Students are NOT permitted to bring mobile phones and/or any other unauthorised electronic communication devices into the room for this test.

SECTION A – Multiple-choice questions

Instructions for Section A

Answer **all** questions.
Choose the response that is **correct** for the question.
A correct answer scores 1, an incorrect answer scores 0.
Marks are **not** deducted for incorrect answers.
If more than one answer is completed for any question, no mark will be given.

Question 1

Button cells are used for small scale applications such as watch batteries. An alkaline electrolyte is used and the reaction is;

$$HgO_{(s)} + Zn_{(s)} \rightarrow Hg_{(l)} + ZnO_{(s)}$$

The half equation occurring at the cathode would be;

A. $Zn_{(s)} + H_2O_{(l)} \rightarrow ZnO_{(s)} + 2H^+_{(aq)} + 2e^-$

B. $Zn_{(s)} + 2OH^-_{(s)} \rightarrow ZnO_{(s)} + H_2O_{(l)} + 2e^-$

C. $HgO_{(s)} + H_2O_{(l)} + 2e^- \rightarrow Hg_{(l)} + 2OH^-_{(s)}$

D. $HgO_{(s)} + 2H^+_{(aq)} + 2e^- \rightarrow Hg_{(l)} + H_2O_{(l)}$

The following information refers to the next two questions;

A common car battery is the lead-acid battery consisting of 6 cells connected in series. Each cell contains a lead dioxide electrode and a lead electrode and has a potential difference of about 2.2 V. A 4M sulfuric acid solution acts as the electrolyte. The density of pure sulfuric acid is about 1.8 times the density of water.

The reactions occurring when the cell is discharging are;

$$Pb_{(s)} + H_2SO_{4(aq)} \rightarrow PbSO_{4(s)} + 2H^+_{(aq)} + 2e^-$$

$$\text{and } PbO_{2(s)} + H_2SO_{4(aq)} + 2H^+_{(aq)} + 2e^- \rightarrow PbSO_{4(s)} + 2H_2O_{(l)}$$

Question 2

As the battery discharges;

A. Electrons flow from the PbO_2 to the Pb electrode

B. The anode has a positive polarity

C. The density of the electrolyte decreases

D. The mass of lead oxide increases

Question 3

During recharging;

A. A potential difference of at least 13.2V needs to be applied so electrons travel from the lead electrode to the lead oxide solution

B. Lead sulfate needs to remain in contact with both the lead and lead oxide electrodes

C. The concentration of sulphuric acid will decrease

D. The lead electrode has a positive polarity

Question 4

Compared to the use of octane as a fuel in an internal combustion engine, a hydrogen fuel cell,

A. is more dangerous due to its very high flammability

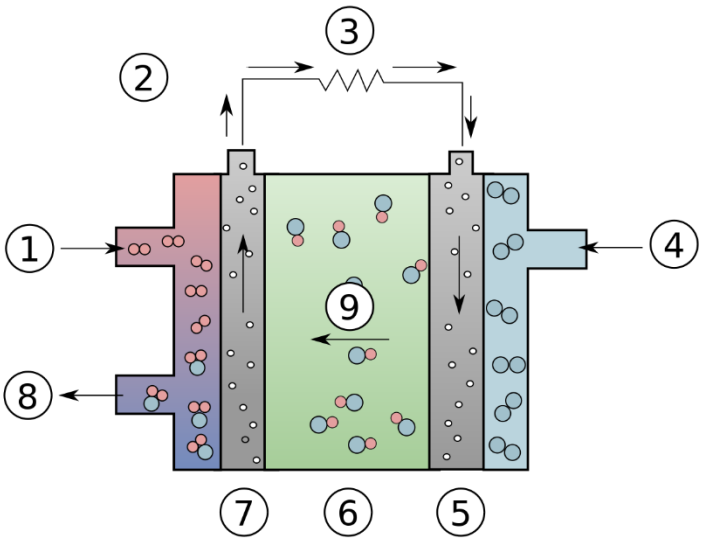
B. is about twice as energy efficient

C. can easily store the fuel as it is light

D. usually obtain hydrogen from renewable sources

The information below relates to the next three questions.

The diagram below represents an alkaline hydrogen fuel cell. The electrolyte used is KOH



Question 5

The species labelled with an 8 would be;

A. hydrogen

B. oxygen

C. water

D. Carbon dioxide

Question 6

The potential difference of this cell is

A. 2.2V

B. 1.5V

C. 1.23V

D. 0.83V

Question 7

The arrow labelled with a 9 represents

A. The movement of electrons from the anode to the cathode

B. The movement of electrons from the cathode to the anode

C. The movement of hydrogen ions from the cathode to the anode

D. The movement of hydroxide ions from the cathode to the anode

Question 8

Molten carbonate fuel cells have an overall cell reaction of

$$H_2 + ½O_2 \rightarrow H_2O$$

The half equation at the anode is;

$$CO_3^{2-} + H_2 \rightarrow H_2O + CO_2 + 2e^-$$

The half equation at the cathode could be;

A. $CO_2 + O_2 + 2e^- \rightarrow CO_3^{2-}$

B. $2CO_2 + O_2 + 2e^- \rightarrow 2CO_3^{2-}$

C. $2CO_2 + O_2 + 4e^- \rightarrow 2CO_3^{2-}$

D. $CO_2 + ½ O_2 + 4e^- \rightarrow CO_3^{2-}$

Question 9

Compared to Primary Cells, Secondary Cells

A. Use oxygen as the oxidant

B. Use chemicals that are renewable

C. Have a faster rate of reaction as the electrodes are porous

D. Can be recharged by applying an external current

Question 10

Self-discharge of a battery occurs when;

A. It is stored at low temperatures slowing the rate of reaction

B. Side reactions occur reducing the amount of active material

C. Electrons move through the cell over time

D. Crystals of the active material slowly decrease in size

SECTION B- Short-answer questions

Instructions for Section B

Questions must be answered in the spaces provided in this book.
To obtain full marks for your responses you should:

- Give simplified answers with an appropriate number of significant figures to all numerical questions; unsimplified answers will not be given full marks.
- Show all workings in your answers to numerical questions. No credit will be given for an incorrect answer unless it is accompanied by details of the working.

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

Question 1

The reaction occurring in the alkaline cell is:

$2MnO_{2(s)} + H_2O_{(l)} + Zn_{(s)} \rightarrow Zn(OH)_{2(s)} + Mn_2O_{3(s)}$

a. i. Describe how the oxidation number of manganese (Mn) changes.

_____

ii. Is MnO_2 undergoing oxidation or reduction?

_____

2 + 1 = 3 marks

b. Write half equations for reactions occurring at the

i. Anode _____

ii. Cathode _____

1 + 1 = 2 marks

c. The products of the reaction slowly migrate away from the electrodes. This explains why batteries that are left to rest for a few hours often then perform a little better. Is this cell a primary or secondary cell?

_____

1 mark

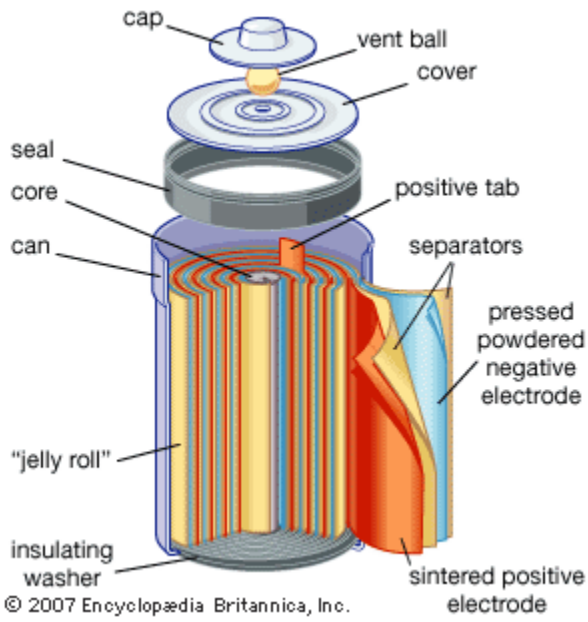
Total 6 marks

Question 2

The reactions occurring in a Ni-Cad cell are;

$$Cd_{(s)} + 2OH^-_{(aq)} \rightarrow Cd(OH)_{2(s)} + 2e^-$$

$$2NiO(OH)_{(s)} + 2H_2O_{(l)} + 2e^- \rightarrow 2Ni(OH)_{2(s)} + 2OH^-_{(aq)}$$



a. What chemical would the

i. negative electrode be composed of?

_____

ii. positive electrode be made of

_____

1 + 1 = 2 marks

b. What properties might the separators have?

_____

_____

2 marks

c. Ni-Cad cells are rechargeable. What characteristics must the products have, in order for this cell to be rechargeable?

_____

_____

2 marks

d. Write half equations and a full equation for the cell during recharging?

_____

_____

_____

3 marks

e. What is the polarity of the cadmium (Cd) electrode during recharging?

_____

1 mark

f. Ni-Cad cells operate at a potential difference of about 1.3 volts. Describe how the cell would be recharged.

_____

_____

2 marks

g. Suggest a suitable electrolyte for this cell.

_____

1 mark

Total 13 marks

Question 3

A hydrogen fuel cell has been used as a source of power in vehicles. Usually the hydrogen fuel is obtained from the steam reforming of natural gas. An electrolyte of phosphoric acid (H_3PO_4) can be used.

a. It is very expensive to store hydrogen as a liquid or a compressed gas. What other alternative are there to these storage options?

_____

_____

1 mark

b. Determine the half reactions taking place at the

i. Negative electrode _____

ii. Positive electrode _____

1 + 1 = 2 marks

c. It has been claimed that the use of hydrogen in fuel cells will reduce the production of greenhouse gases. Discuss this claim.

_____

_____

_____

2 marks

d. One issue with fuel cells can be that the rate of reaction can be too slow. How can the rate of reaction and hence power output of the cell be increased?

_____

_____

_____

2 marks

e. What is a major advantage of using fuel cells rather than an internal combustion engine in cars.

_____

_____

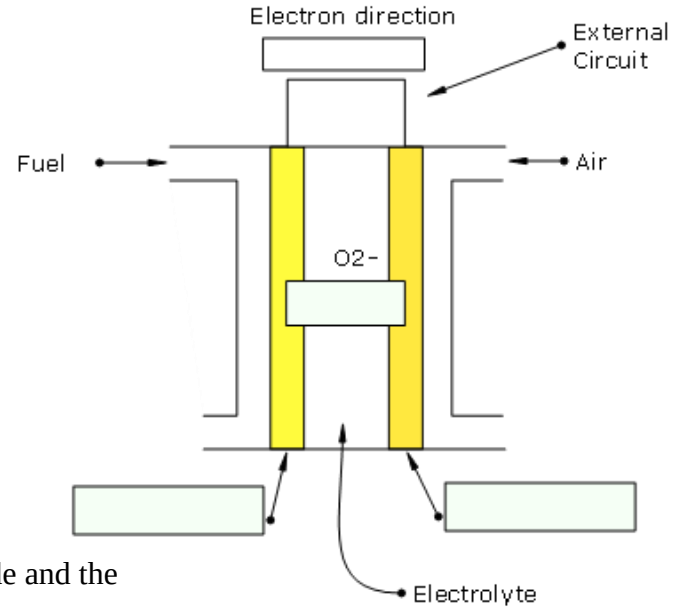
1 mark

Total 8 marks

Question 4

Solid oxide fuel cells (SOFCs) use a solid material as the electrolyte. Because SOFCs are made entirely of solid materials, they are not limited to the flat plane configuration of other types of fuel cells and are often designed as rolled tubes. They require high operating temperatures (800–1000 °C) and can be run on a variety of fuels including natural gas. The half equations are;

Anode reaction: $2H_2 + 2O^{2-} \rightarrow 2H_2O + 4e^-$
Cathode reaction: $O_2 + 4e^- \rightarrow 2O^{2-}$



a. On the diagram above right, label the anode and the cathode.

2 marks

b. On the diagram above, mark in;

i. The direction of electron flow.

ii. The direction of the movement of oxide ions.

1 + 1 = 2 marks

c. Write an overall equation for the reaction occurring.

_____

1 mark

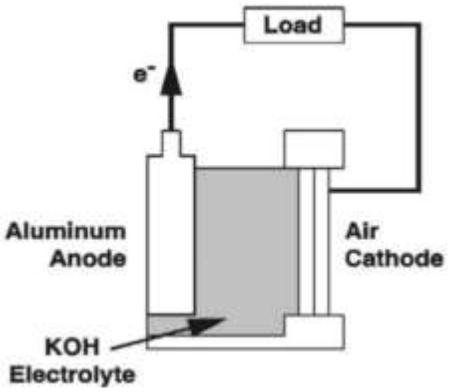
d. If methane is used instead of hydrogen write the half equation that would represent the reaction at the anode.

_____

2 marks
Total 7 marks

Question 5

A cell that utilizes the reaction between aluminium and oxygen has been proposed as a future power source in cars. A car could be refuelled by replacing the aluminium rods. The cell has a voltage of 2.72 Volts.
The half-equation for the reaction at the anode is
$Al_{(s)} + 3OH^-_{(aq)} \rightarrow Al(OH)_{3(aq)} + 3e^-$



a. i. What is the polarity of the cathode?

_____

ii. Write a half equation for the reaction occurring at the cathode.

_____

1 + 1 = 2 marks

b. Give 2 advantages of using this cell rather than lead acid batteries

_____

_____

_____

2 marks

c. Why is this cell regarded as a fuel cell?

_____

_____

_____

2 marks
Total 6 marks

END OF KEY TOPIC TEST