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VCE Chemistry ¾
AOS 2 Revision I [0.16]
Workshop Solutions

Error Logbook:

New Ideas/Concepts	Didn't Read Question
Pg / Q #: _____ Notes:	Pg / Q #: _____ Notes:
Algebraic/Arithmetic/ Calculator Input Mistake	**Working Out Not Detailed Enough**
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Section A: Warm Up (11 Marks)

INSTRUCTION: 11 Marks. 7 Minutes Writing.

Question 1 (1 mark)

An aluminium can is to be silver-plated in an electrolytic cell. The can forms one electrode and a silver rod the other electrode. The electrolyte provides a source of $Ag^+(aq)$.

The can to be plated, is connected to the:

A. Positive terminal of a battery so that oxidation occurs at the can.

B. Positive terminal of a battery so that reduction occurs at the can.

C. Negative terminal of a battery so that oxidation occurs at the can.

D. Negative terminal of a battery so that reduction occurs at the can.

Question 2 (1 mark)

Two types of electrochemical cells are the primary cell and the secondary cell. Which one of these features is exhibited by only one of these cells?

A. An energy transformation is from chemical energy to electrical energy.

B. The efficiency of the cell is close to 100%.

C. Products of the cell reaction remain in contact with the electrodes.

D. A spontaneous redox reaction is the overall reaction of the cell.

Space for Personal Notes

Question 3 (1 mark)

Which one of the following is the **most** accurate?

A. All fuel cells are galvanic cells.

B. All galvanic cells are primary cells.

C. All secondary cells have porous electrodes.

D. All fuel cells are more efficient than all secondary cells.

Question 4 (3 marks)

A solution containing 1.0 *M* of KBr(aq) is electrolysed with a silver attached to the positive terminal of the battery, and lead attached to the negative terminal of the battery.

a. Write the balanced half-equation which occurs at the:

i. Positive electrode. (1 mark)

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

ii. Negative electrode. (1 mark)

$2H_2O(l) + 2e^{-} \rightarrow H_2(g) + 2OH^{-}(aq)$

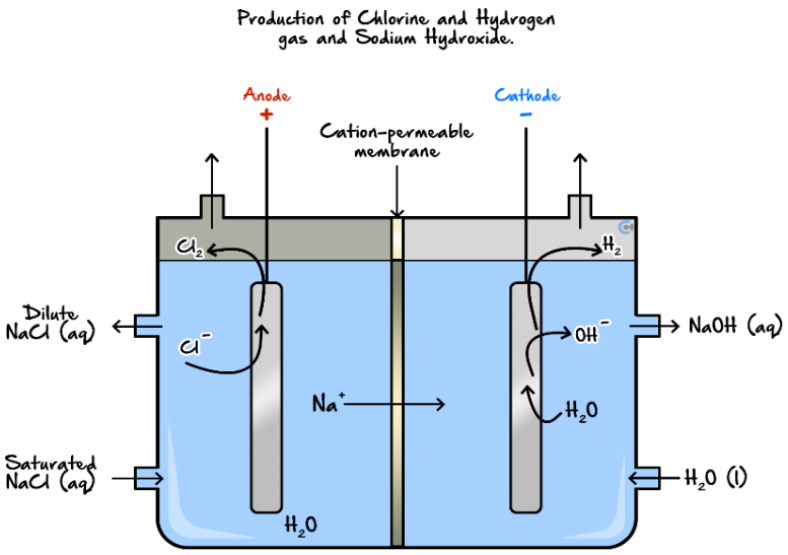
b. State the EMF required to be inputted for the reaction to take place. (1 mark)

$> 1.63\ V$

Space for Personal Notes

Question 5 (5 marks)

The set-up below is used to produce a number of important chemicals. Sodium chloride is used as the raw material.



a. Determine the reaction occurring at the:

i. Anode. (1 mark)

$2Cl^-_{(g)} \rightarrow Cl_{2(g)} + 2e^-$

ii. Cathode. (1 mark)

$2H_2O_{(l)} + 2e^- \rightarrow 2OH^-_{(aq)} + H_{2(g)}$

b. Why is it important to remove diluted NaCl from the cell and replace it with saturated NaCl? (1 mark)

If the concentration of Cl^- falls too low, H_2O will be reduced in preference to Cl^- * as it is a stronger reductant than H_2O when the Cl^- concentration is 1M.*

c. State **two** roles of the "cation permeable membrane". (2 marks)

Separate products apart.
Allow only cations to move through, but not the anions such as Cl^- or OH^-.

Section B: Ramping Up (9 Marks)

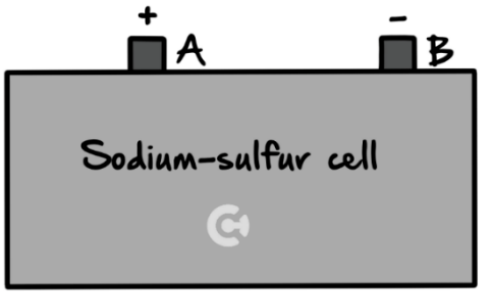
INSTRUCTION: 9 Marks. 7 Minutes Writing.

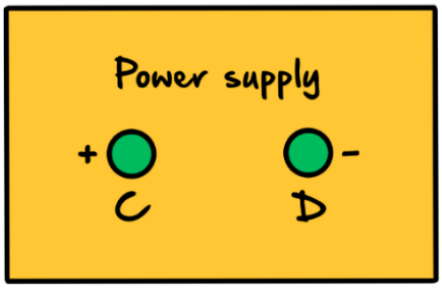
Question 6 (1 mark)

The sodium-sulphur cell shown below is a secondary galvanic cell with the overall cell reaction:

$$2Na(l) + S(l) \rightleftharpoons Na_2S(l)$$

The cell produces 2.1 volts.





The cell is to be recharged by connecting it to the power supply.

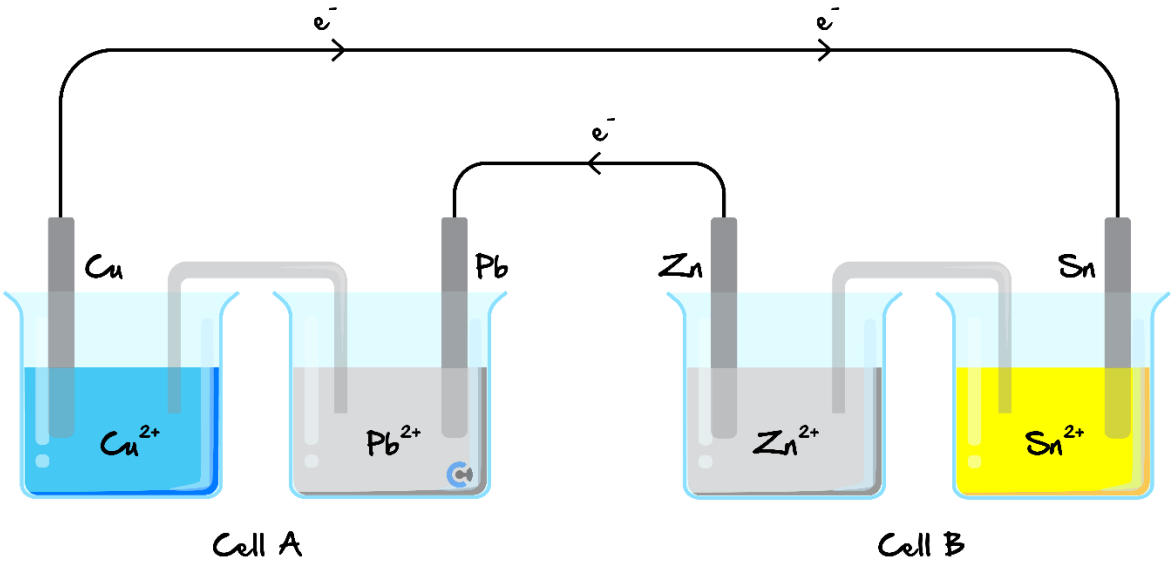
Which one of the following best describes the arrangement for recharging the cell?

	Power Supply Voltage	Connect Terminals
A.	2.1 volts.	*A* to *C* and *B* to *D*.
B.	2.1 volts.	*A* to *D* and *B* to *C*.
C.	More than 2.1 volts.	*A* to *C* and *B* to *D*.
D.	More than 2.1 volts.	*A* to *D* and *B* to *C*.

Space for Personal Notes

Question 7 (2 marks)

The following cell is set up.



a. Identify if each of cell *A* and cell *B* act as galvanic or electrolytic cells. (1 mark)

Cell *A*	**Cell *B***
Electrolytic	Galvanic

b. Select the correct option. (1 mark)

A. The copper electrolyte will become less intensely blue.

B. The negative electrode in cell *A* will decrease in size.

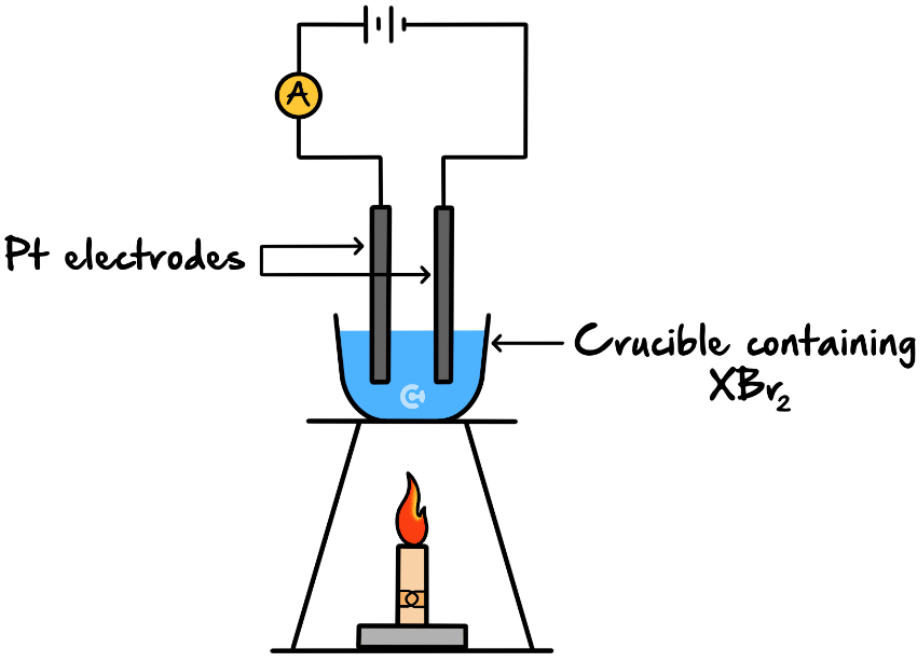
C. The mass deposited at the cathode of cell *A* will be greater than the mass deposited at the cathode of cell *B*.

D. The concentration of tin (II) ions will increase with time.

Space for Personal Notes

Question 8 (6 marks)

A teacher demonstrated the process of electrolysis of a molten salt using an unknown metal salt, $X\text{Br}_2$. The apparatus was set up as shown below.



At the conclusion of the demonstration, the students were provided with the following information.

- A current of 1.50 amperes was applied for 30.0 minutes.
- 2.90 g of metal X was produced.

a. Write a balanced half-equation for the anode reaction in this electrolytic cell. (1 mark)

Marks	0	1	Average
%	91	9	**0.1**

$2Br^-(l) \rightarrow Br_2(l + g) + 2e^-$

The majority of students incorrectly included (aq) as the state for Br^- in their equations. The 'electrolysis of a molten salt' should have indicated that an aqueous solution was not present. Students should be aware that molten ionic compounds are liquids, and that oxidation occurs at the anode.

Equilibrium arrows in the half-equations on the electrochemical series reflect the fact that, in an electrochemical cell, whether a particular half-reaction proceeds to the left or the right depends on the other oxidant/reductant pair present in the cell. Once a decision has been made about the direction in which the half-reaction proceeds, equilibrium arrows are not included in the half-equation.

b.

i. Determine the amount, in mol, of metal X that was deposited on the cathode. (3 marks)

Marks	0	1	2	3	Average
%	19	5	22	54	2.1

$Q = It$
$= 1.50 \times 30.0 \times 60$
$= 2.70 \times 10^3$ C
$n(e^-) = Q \div F$
$= 2.7 \times 10^3 \div 96500$
$= 2.80 \times 10^{-2}$ mol
Reduction of metal $X^{2+} + 2e^- \rightarrow X$
$n(X) = n(e^-) \div 2$
$= 2.8 \times 10^{-2} \div 2$
$= 1.4 \times 10^{-2}$ mol

The most common error on this part of the question was the omission or incorrect use of the relationship between the $n(X)$ and the $n(e^-)$.

ii. Identify metal X. (2 marks)

Marks	0	1	2	Average
%	31	5	64	1.3

$M(X) = m \div n = 2.90 \div 1.4 \times 10^{-2} = 207.2\ g\ mol^{-1}$
Lead (Pb)
Since the answer to this question was dependent on the answer to **part b. i.**, it may seem strange that significantly more students obtained full marks for **part b. ii.** This shows how 'consequential' marks are applied. If the element identified in **part b. ii.** was consistent with the $n(X)$ calculated in **part b. i.**, and forms ions with a $+2$ charge, full marks were awarded for **part b. ii.** Therefore, if

- $n(X) = 0.0280\ mol$ in **part b. i.** due to not dividing $n(e)$, then $M(X) = 103.6\ g\ mol^{-1} \rightarrow$ Rhodium (Rh).
- $n(X) = 0.0560\ mol$ in **part b. ii.** due to multiplying $n(e-)$ by 2, then $M(X) = 51.8\ g\ mol^{-1} \rightarrow$ Chromium (Cr).

This consequential mark was not awarded if a clearly monovalent metal such as K was given, since this was not consistent with the data provided as the metal ion had a charge of $+2$.

Space f

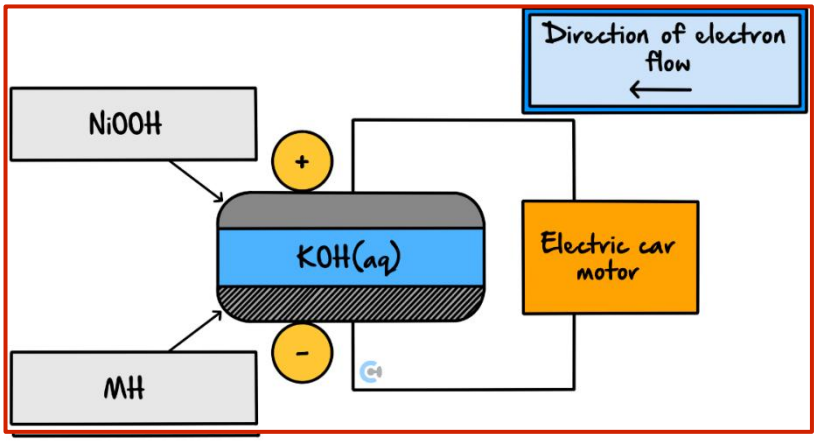
Section C: Getting Trickier I (13 Marks)

INSTRUCTION: 13 Marks. 10 Minutes Writing.

Question 9 (6 marks)

Inspired from VCAA Chemistry Exam 2015
https://www.vcaa.vic.edu.au/Documents/exams/chemistry/2015/2015chem-w.pdf#page=37

The storage battery to be used in the hybrid cars is comprised of a series of nickel metal hydride, NiMH, cells. MH represents a metal hydride alloy that is used as one electrode. The other electrode contains nickel oxide hydroxide, NiOOH. The electrolyte is aqueous KOH.



The simplified equation for the reaction at the anode while **recharging** is:

$$Ni(OH)_2(s) + OH^-(aq) \rightarrow NiOOH(s) + H_2O(l) + e^-$$

The simplified equation for the reaction at the cathode while **recharging** is:

$$M(s) + H_2O(l) + e^- \rightarrow MH(s) + OH^-(aq)$$

a. What is the overall equation for the **discharging** reaction? (1 mark)

Marks	0	1	Average
%	39	61	0.6

$$MH(s) + NiOOH(s) \rightarrow M(s) + Ni(OH)_2(s)$$

The equation for the discharging reaction was the reverse of the sum of the half-equations provided for the recharging reaction.

b. In the boxes on the diagram above, indicate which is the MH electrode and which is the NiOOH electrode. (1 mark)

Marks	0	1	Average
%	42	58	0.6

c. In the bold box provided above the cell diagram, use an arrow, → or ←, to indicate the direction of the electron flow as the cell is discharging. (1 mark)

During discharging, electrons flow from (–) to (+), from the oxidation of MH to the reduction NiOOH.

Marks	0	1	Average
%	42	58	0.6

d. The battery discharged for 60 minutes, producing a current of 1.15 A. What mass, in grams, of NiOOH would be used during this period? (3 marks)

Marks	0	1	2	3	Average
%	22	6	13	59	2.1

$$Q = It = 1.15 \times 60 \times 60$$
$$= 4.14 \times 10^3\ C$$
$$n(\text{e}^-) = Q/F = 4.14 \times \frac{10^3}{96500} = 0.0429\ mol$$
$$n(\text{NiOOH}) = 0.0429\ mol$$
$$m(\text{NiOOH}) = n(\text{NiOOH}) \times M(\text{NiOOH}) = 0.0429 \times 91.7 = 3.9\ g$$

One mark each was awarded for:

- accurate calculation of charge
- accurate calculation of n(NiOOH)
- accurate calculation of m(NiOOH). The most common error was using the molar mass of Ni rather than the required molar mass of NiOOH.

Question 10 (7 marks)

The lithium-ion battery is a secondary cell that is now widely used in portable electronic devices.

In these batteries, lithium ions, Li^+, move through a special non-aqueous electrolyte between the two electrodes. The batteries are housed in sealed containers to ensure that no moisture can enter them.

Both electrodes are made up of materials that allow the lithium ions to move into and out of their structures. The anode consists of LiC_6, where lithium is embedded in the graphite structure. Lithium cobalt oxide, $LiCoO_2$, is commonly used as the material in the cathode. The reaction at the cathode is quite complex.

When the cell discharges, Li^+ ions move out of the anode and enter the cathode. During discharge, the half-cell reaction at the anode is:

$$LiC_6 \rightarrow Li^+ + e^- + C_6$$

a. During discharge, what is the polarity of the graphite electrode? (1 mark)

Negative (–)

b. Write the half-equation for the reaction that occurs at the cathode of a lithium-ion battery when it is recharged. (1 mark)

$Li^+ + e^- + C_6 \rightarrow LiC_6$

c. In a lithium-ion battery, lithium metal must not be in contact with water. Explain why and justify your answer with the use of appropriate equations. (3 marks)

Li is a strong reductant that reacts readily with water.

- $Li(s) \rightarrow Li^+(aq) + e^-$ / $2H_2O(l) + 2e^- \rightarrow H_2(g) + 2OH^-(aq)$
- $2Li(s) + 2H_2O(l) \rightarrow H_2(g) + 2LiOH(aq)$

Hydrogen gas is explosive/Heat is generated/LiOH is a strong base/current does not flow.

One mark each was awarded for:

- appropriate reference to lithium's ready reaction with water
- both half-equations correctly balanced or a correctly balanced overall equation
- a significant consequence of lithium in contact with water

d. Identify **one** design feature of the lithium-ion battery that enables it to be recharged. (1 mark)

The movement of lithium ions into and out of the electrodes enables the reactions at the electrodes to be reversed.

e. What is **one** advantage of using a secondary cell compared to using a fuel cell? (1 mark)

Possible responses included:

- A secondary cell is more convenient for on–off usage since it does not need a continuous external supply of reactants.
- A secondary cell can be recharged (electrically), whereas a fuel cell continuously needs fresh reactants.
- Secondary cells are usually cheaper than fuel cells.
- Secondary cells are more suitable for most of today's electronic devices.
- Secondary cells are storage devices.

Space for Personal Notes

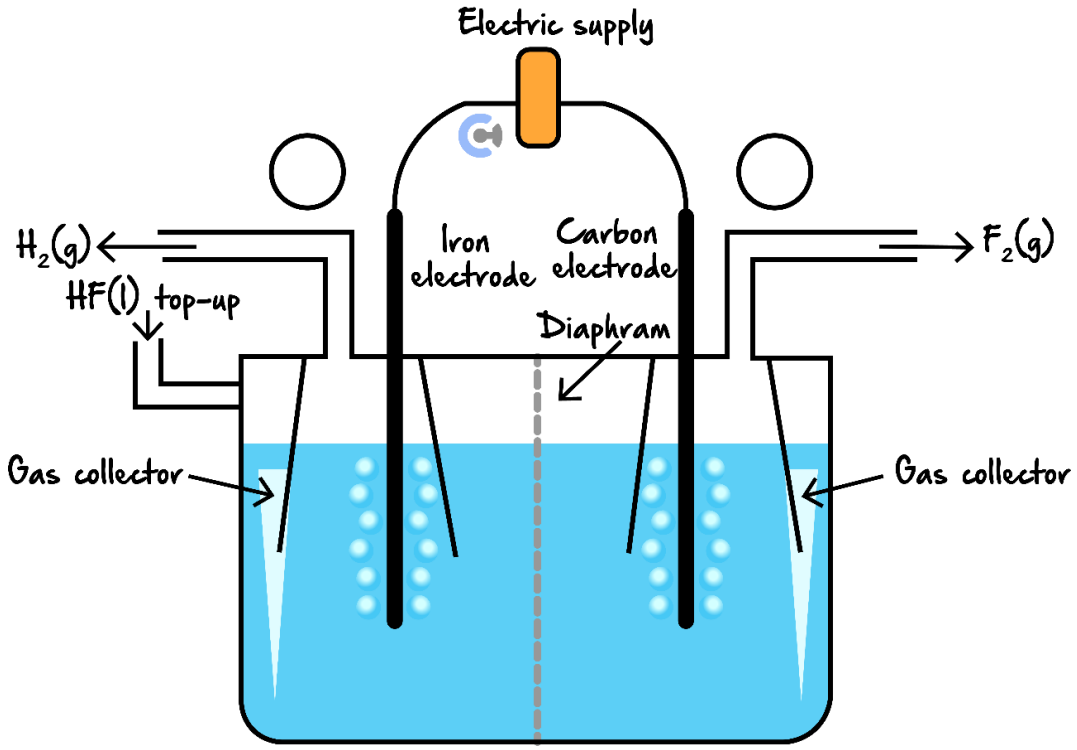
Section D: Getting Trickier II (14 Marks)

INSTRUCTION: 14 Marks. 13 Minutes Writing.

Question 11 (14 marks)

Inspired from VCAA Chemistry Exam 2017
https://www.vcaa.vic.edu.au/Documents/exams/chemistry/2017/2017chem-w.pdf#page=30

Given that fluorine gas, F_2, is the most reactive of all metals, it is extremely beneficial to have access to it. In order to form fluorine gas, we electrolyse liquid hydrogen fluoride, HF, to form fluorine and hydrogen gases.



a. Write the equation for:

i. The half-reaction occurring at the cathode. (1 mark)

$2H^+(l) + 2e^- \rightarrow H_2(g)$

ii. The overall reaction. (1 mark)

$2HF(l) \rightarrow F_2(g) + H_2(g)$

b. Label the polarities for each electrode in the circles provided above. (1 mark)

c. Suggest why the diaphragm, as shown in the diagram above, is important for the safe operation of the cell. (2 marks)

Acceptable responses included:
- If the products H_2 and F_2 can mix they will react explosively.
- The diaphragm keeps the products of the electrolysis, $H_2(g)$ and $F_2(g)$, from coming in contact.

Many responses to this question suggested that the safe operation of the cell was not the key focus. The significance of the structure of the diaphragm – solid in the gas collection region, but porous in the electrolyte – was missed by many students.

d. Explain why the carbon electrode cannot be replaced with an iron electrode. (2 marks)

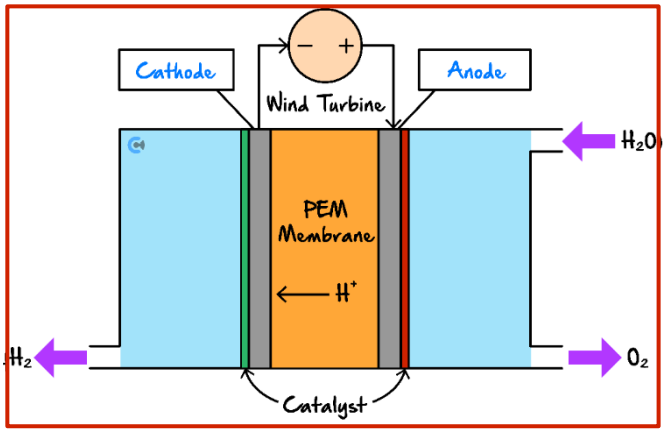
Distinct points that could have been made were:
- iron is a stronger reducing agent than $F^-_{(HF)}$ and would be preferentially oxidised at the anode.
- no F_2 would be produced.
- $Fe\ (s) \longrightarrow F^{2+}_{(HF)} + 2e^-$

This proved to be one of the more challenging questions on the examination. Students should have considered the likelihood of the change of electrode having an impact on the reaction occurring at the anode. The implication of the change given the purpose of the cell was the production of fluorine. While predictions based on the electrochemical series are most accurate at standard conditions, it was still a valid point of reference. There was evidence that many students struggled to interpret the supplied information effectively.

e. Explain why the left electrode as shown in the diagram above can be made of iron. (2 marks)

It is the cathode → reduction occurs at the cathode → oxidation cannot occur → even though in theory iron is a stronger reductant than F^-, the iron cannot oxidise.

f. This method of producing hydrogen gas is then compared to obtaining hydrogen gas from a Polymer Electrolyte Membrane (PEM) Electrolyser. An example of a PEM electrolyser powered by wind energy is shown below.



i. Label the cathode and anode in the boxes provided above. (1 mark)

ii. Write the balanced half-equation which takes place at the electrode attached to the positive electrode. (1 mark)

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

iii. Production of hydrogen gas using this cell is considered to be 'green'. State **one** requirement for a fuel to be considered to be 'green', and explain how the PEM electrolyser fulfils this requirement. (2 marks)

Requirement: Renewable or no greenhouse gas emissions.

Explanation:
It uses renewable energy such as wind energy in this example.
OR
It does not produce greenhouse gases.

iv. One method to source the water used for this electrolysis is from freshwater sources in rivers and lakes. State **one** sustainability challenge which arises from this, with reference to United Nations Sustainable Development Goal 14. (1 mark)

Sourcing water from freshwater rivers affects the livelihood of fishes/ducks/wildlife which may lead to habitat destruction.

Let's take a BREAK!

Section E: VCAA-Level Questions I (10 Marks)

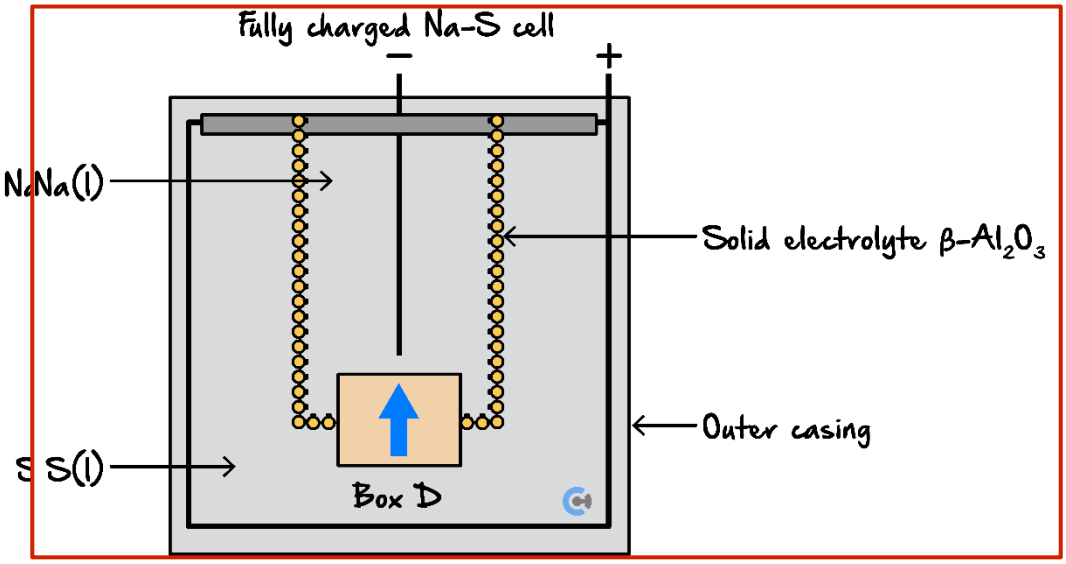
INSTRUCTION: 10 Marks. 30 Seconds Reading. 10 Minutes Writing.

Question 12 (10 marks)

Inspired from VCAA Chemistry Exam 2022
https://www.vcaa.vic.edu.au/Documents/exams/chemistry/2022/NHT/2022ChemistryNHT-w.pdf#page=28

Researchers are developing rechargeable cells containing sodium, Na, and sulphur, S. A simplified diagram of a fully charged Na-S cell is shown below.

The solid electrolyte consists of ceramic beta-alumina, β-Al_2O_3. β-Al_2O_3 separates the two half-cells and selectively conducts sodium ions, Na^+.



a.

i. Draw an arrow in Box *D* to show the direction of flow of Na^+ across the membrane when the cell is charging. (1 mark)

ii. Identify and explain **one** of the features of the Na-S cell that would make it suitable to power electric vehicles. (2 marks)

Possible responses included that the cell is:

- reversible * – allows the cell to be recharged *
- portable – enables it to be used in a vehicle that is moving
- two separated half cells – avoids a spontaneous reaction
- anode/cathode – enables an external circuit to be connected
- contains an electrolyte that conducts ions – completes the circuit.

b. Environmental conditions can influence reactions during the discharge of the battery. When a particular Na-S test cell is discharging, the half-equation for the reaction at one of the electrodes is:

$$3S + 2e^- \rightarrow S_3^{2-}$$

i. Write the half-equation that occurs for the reaction at the other electrode. (1 mark)

$Na(l) \rightarrow Na^+(l) + e^-$

ii. When the Na-S test cell is discharging, solid sodium trisulphide, Na_2S_3, is formed. Write the overall equation for the charging process in this cell. (1 mark)

$Na_2S_3(s) \rightarrow 2Na(l) + 3S(l)$

iii. Identify and explain one factor that may affect the useful life of the Na-S test cell. (2 marks)

Possible features (one mark) and explanations (one mark) included:

- If discharge product is not in contact with the electrode battery life/efficiency is reduced because the battery cannot be recharged, and reactions cannot be reversed.
- Side reactions reduce the efficiency of the cell by reducing the amount of useful product that can be recharged.
- High temperatures increase the possibility of increasing side reactions.
- Low temperatures increase the possibility of crystallisation.

c. The Na-S cell contains pure Na metal. Safety information for a Na-S cell includes the requirement that the system must be protected from water. Explain why this would be one of the safety requirements. Include any relevant equations in your answer. (3 marks)

According to the electrochemical series, Na is a strong reductant and reacts violently with water. *

Equation: $2Na(s) + 2H_2O(l) \rightarrow 2NaOH(aq) + H_2(g)$ * *or* $2H_2O(l) + 2e^- \rightarrow H_2(g) + 2OH^-(aq)$

Safety issues: $H_2(g)$ is explosive * / $H_2(g)$ is stored under pressure / the reaction generates a lot of heat.

Section F: Multiple Choice Questions (5 Marks)

INSTRUCTION: 5 Marks. 5 Minutes Writing.

Question 13 (1 mark)

A highly concentrated salt solution, called brine, is used as the electrolyte.

The main reason that a highly concentrated, rather than a dilute solution is used is in order to:

A. Allow an electric current to pass through the cell.

B. Produce chlorine gas, in preference to oxygen gas.

C. Allow sodium hydroxide to be separated from the salt by crystallisation.

D. Create non-standard conditions that ensure hydrogen gas production.

Question 14 (1 mark)

A student prepares aqueous solutions of 1.0 M $AgNO_3$, $Co(NO_3)_2$, and KNO_3 all in the same beaker. Platinum electrodes were placed in the solution and the cell undergoes electrolysis with the current applied under SLC. Each cathode is then dried and weighed to determine mass change. The cell runs for a very long time until no reaction occurs. The last product that was produced at the cathode is:

A. Potassium.

B. Cobalt.

C. Silver.

D. Hydrogen gas.

Space for Personal Notes

Question 15 (1 mark)

When comparing the electrolysis of molten CuI_2 with that of a 1.0 M aqueous solution of CuI_2, which one of the following statements is correct?

A. The products at the anode and the cathode are the same in both cases.

B. The product at the cathode is the same in both cells but the products at the anode are different.

C. The product at the anode is the same in both cells but the products at the cathode are different.

D. The products at the cathodes of both cells are different as are the products at the anodes.

Question 16 (1 mark)

The silver oxide-zinc battery is rechargeable and utilises sodium hydroxide, NaOH, solution as the electrolyte. The battery is used as a backup in spacecraft, if the primary energy supply fails. The overall reaction during discharge is:

$$Zn + Ag_2O \rightarrow ZnO + 2Ag$$

When the silver oxide-zinc battery is being recharged, the reaction at the anode is:

A. $2Ag + 2OH^- \rightarrow Ag_2O + H_2O + 2e^-$

B. $Ag_2O + H_2O + 2e^- \rightarrow 2Ag + 2OH^-$

C. $ZnO + H_2O + 2e^{-1} \rightarrow Zn + 2OH^-$

D. $Zn + 2OH^- \rightarrow ZnO + H_2O + 2e^-$

Question 17 (1 mark)

Which of the following processes will **not** produce a gas at the anode?

A. Electrolysis of silver nitrate solution using carbon electrodes.

B. Electrolysis of dilute lead (II) nitrate using platinum electrodes.

C. Electrolysis of very concentrated sodium chloride solution using carbon electrodes.

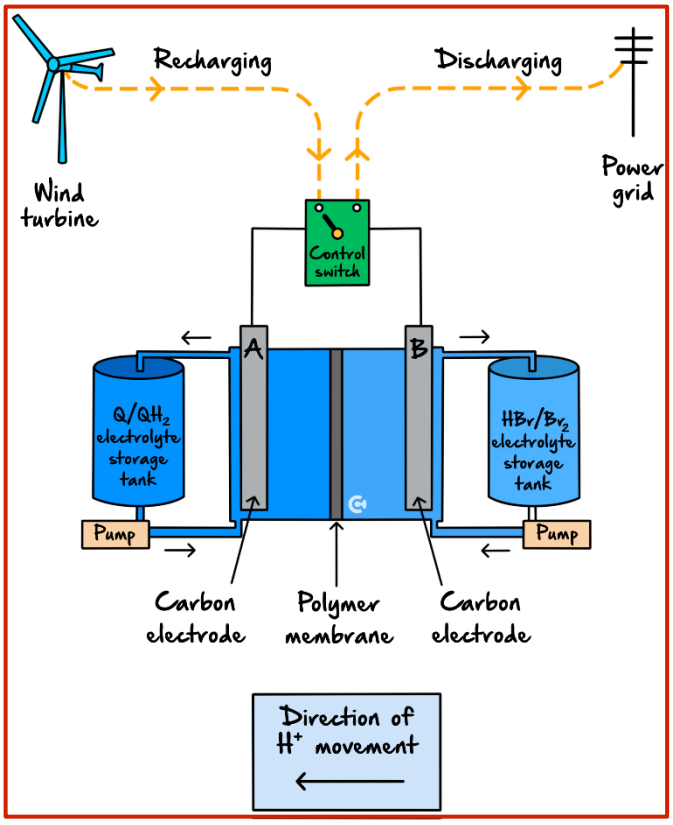
D. Electrolysis of dilute copper (II) chloride solution using a carbon cathode and a copper anode.

Section G: VCAA-Level Questions II (7 Marks)

INSTRUCTION: 7 Marks. 30 Seconds Reading. 7 Minutes Writing.

Question 18 (7 marks)

Redox flow batteries are used to store the excess electrical energy generated by commercial wind and solar farms. The batteries are recharged using electricity generated by the wind turbines or solar cells. A scientific report, published in January 2014, described a redox flow battery that used a family of chemicals commonly occurring in plants such as rhubarb. These are organic and are known as quinones and hydroquinones. A diagram showing how such a redox flow battery might operate is provided below. In the diagram, Q represents the quinone and QH_2 represents the corresponding hydroquinone. The researchers made a model of the redox flow battery using aqueous solutions of the redox pairs, Q/ QH_2 and Br_2/Br^-. Refer to the diagram below.



During discharge, QH_2 is converted to Q and Br_2 is converted to HBr.

a. Write balanced half-equations for the reactions occurring at the positive and negative electrodes as the cell is **discharged**. Assume the electrolytes are acidic. (2 marks)

Positive electrode: $Br_2 + 2H^+ + 2e^- \rightarrow 2HBr/Br_2 + 2e^- \rightarrow 2Br^-$

Negative electrode: $QH_2 \rightarrow Q + 2H^+ + 2e^-$

Marks	0	1	2	Average
%	50	25	25	0.8

Students need to recognise that oxidation occurred at the (–) electrode and reduction occurred at the (+) electrode. The question stated that QH_2 was converted to Q and Br_2 was converted to HBr, from which it could be deduced that Br_2 was reduced (the oxidation number of Br decreases from 0 to – 1) and so QH_2 was oxidised. Given that the diagram suggested the movement of H+ ions, the half-equations should have included H^+ . As the question referred to the Br_2/Br^- redox pair, $Br_2 + 2e^- \rightarrow 2Br^-$ was also accepted for the half-equation at the (+) electrode.

b. Write an overall equation for the reaction that occurs when the cell is **recharged**. (1 mark)

Marks	0	1	Average
%	57	43	0.5

$2HBr + Q \rightarrow Br_2 + QH_2$ / $2Br^- + 2H^+(aq) + Q \rightarrow Br_2 + QH_2$

One mark is to be awarded for a 'recharging' equation consistent with the 'discharging' half-equations in **part (a)** – that is, if the equation was balanced and consistent with the reverse of the overall equation implied in part a. While students realised that they needed to add together the reverse of their half-equations from **part a.**, a significant proportion provided an unbalanced overall half-equation.

c. The researchers reported that their tests indicated that only hydrogen ions were able to move through the polymer membrane separating the cells.

i. In the box provided on the diagram, use an arrow, → or ←, to indicate the direction of movement of hydrogen ions as the cell is **recharged**. (1 mark)

ii. Why is it important that the other reactants in the half-cells are not able to pass through the polymer? (1 mark)

Marks	0	1	2	Average
%	40	40	20	0.8

Acceptable responses included: **(1.)** if the oxidant and reductant are allowed to come into contact they can react together in the solution rather than individually at the electrodes **(2.)** chemical energy would be converted to thermal energy rather than electrical energy **(3.)** to prevent the oxidant and reductant coming into contact with each other **(4.)** to prevent spontaneous direct reaction between the oxidant and reductant **(5.)** to ensure that the cell can be recharged. Students needed to identify a significant disadvantage of the oxidant and reductant being in the same half of the flow battery – that is, coming into contact. Most students struggled to frame an appropriate response. A key factor in the effective operation of a battery is that oxidant and reductant react at different electrodes to ensure conversion of chemical energy to electrical energy and a flow of electrons through the external circuit. Should the oxidant and reductant come into contact spontaneous reaction may occur with chemical energy being converted to thermal energy and the cell not operating as intended.

d. The researchers also reported that the voltage applied to the cell during recharging was kept below 1.5 V to avoid the electrolysis of water.

Write an equation for the overall reaction that occurs when water is electrolysed. (1 mark)

Marks	0	1	Average
%	86	14	0.2

$2H_2O(l) \rightarrow 2H_2(g) + O_2(g)$

Few students recalled that
It is possible to deduce the overall equation from the half-equations for the oxidation and reduction of water – that is $2H_2O(l) \rightarrow O_2(g) + 4H^+(aq) + 4e^-$ and $2H_2O(l) + 2e^- \rightarrow H_2(g) + 2OH^-(aq)$ from which the overall equation

e. Quinones have a number of industrial applications and are cheaply synthesised on a large scale from anthracene, which is found in crude oil. The report's researchers suggest that because these compounds also exist in plants such as rhubarb, the electrolyte material is itself a renewable resource.

What is meant by the term 'renewable' in this context? (1 mark)

Marks	0	1	Average
%	43	57	0.6

Rhubarb (the raw material for the quinones) can readily be replenished. Rhubarb is a plant-based source of quinones and can be easily grown. Many students answered this question well. Statements such as 'can be produced as fast as it is needed' were also acceptable. Some students made incorrect statements such as 'recycled', 'used again', 'environmentally friendly' and 'carbon neutral', suggesting that further improvement is needed in achieving real understanding of the concept of renewability.

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