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VCE Chemistry ¾
Features of Electrolytic Cells [0.13]
Workshop

Error Logbook:

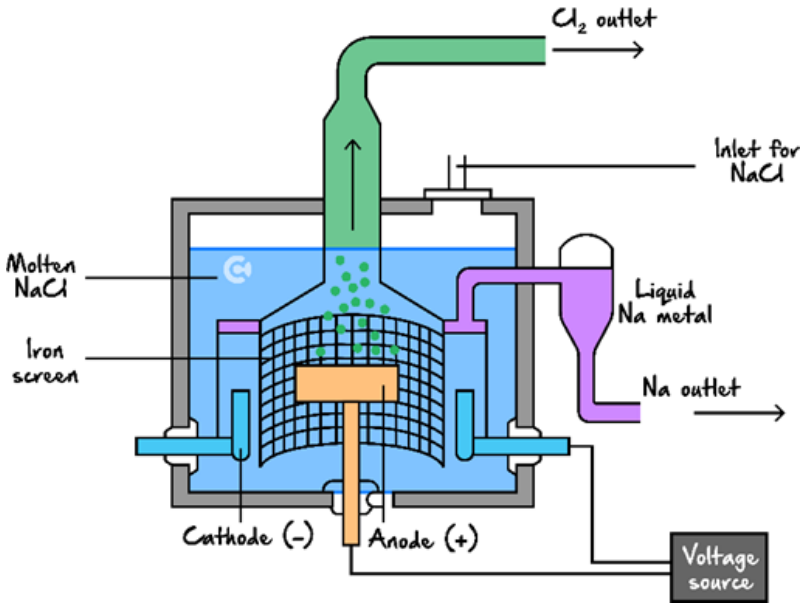
New Ideas/Concepts	Didn't Read Question
Pg / Q #: _____ Notes:	Pg / Q #: _____ Notes:
Algebraic/Arithmetic/ Calculator Input Mistake	**Working Out Not Detailed Enough**
Pg / Q #: _____ Notes:	Pg / Q #: _____ Notes:

Section A: Recap

Learning Objective: [2.2.1] – Find Electrolytic Reactions in Non-Standard Conditions (Molten & High Concentration)

- **High Concentration**:
  - Chloride ions at concentrations greater than _____ concentration become a [stronger] / [weaker] reductant and [react] / [do not] react in preference to water.
  - Sodium ions are concentrations greater than $4.0\ M$ concentration [react] / [do not] react in preference to water.
- **Molten Concentration**: _____ is not present, and the state of ions is _____.

Learning Objective: [2.2.2] – Identify Features of Electrolytic Cells & Their Purpose

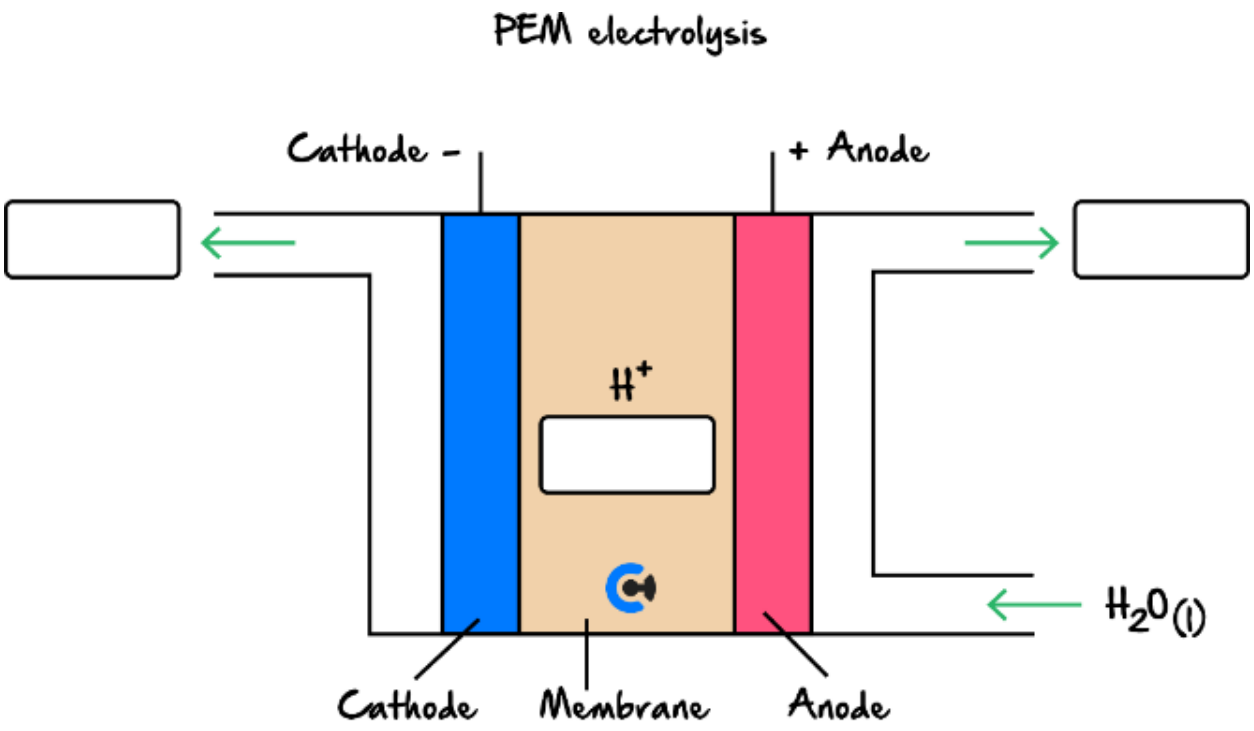


- Molten electrolyte purpose: _____.
- Iron at the cathode: _____.
- Other electrolytes (e.g., $CaCl_2$) added: _____.
- Barrier within the cell:
  - _____.
  - _____.

- Products constantly removed:
  - _____.
  - _____.
- Enclosed container: _____.

Learning Objective: [2.2.3] – Identify Key Features, Write Reactions & Relate to Sustainability & Green Chemistry Principles Regarding Production of Green Hydrogen (PEM & Artificial Photosynthesis)

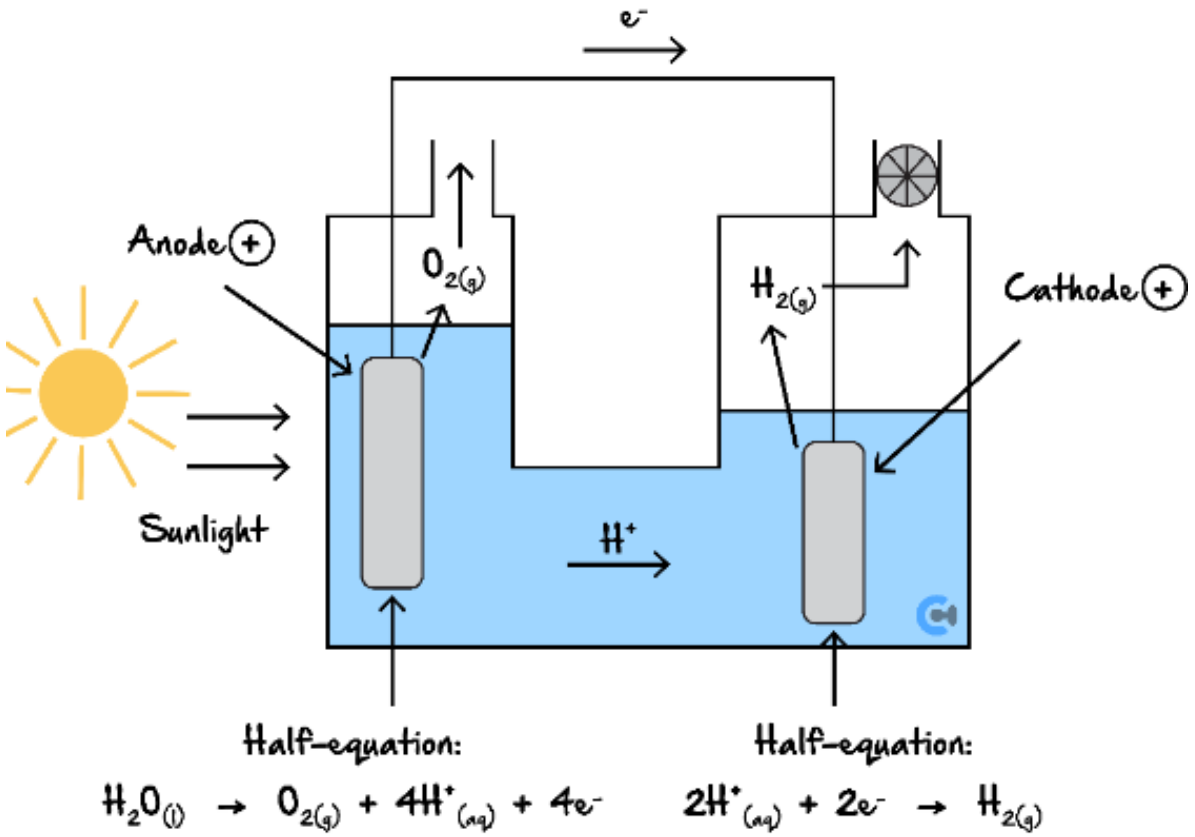
- Both PEM electrolyser & artificial photosynthesis involve electrolysis of _____.
- PEM Electrolyser:



Cathode	Anode

- **Energy Used:** _____.
- **Green Chemistry Principle:** _____.

- Artificial Photosynthesis:



- Energy Conversion: _____.
- Green Chemistry Principle: _____.

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Question 1 Walkthrough.

A solution of aluminium chloride is electrolysed at high concentrations and is compared to when molten aluminium chloride is electrolysed.

a. Write the half-equations that occur when it is electrolysed at higher concentrations at the:

i. Cathode.

_____

ii. Anode.

_____

b. Write the half-equations that occur when it is electrolysed at molten at the:

i. Negative electrode.

_____

ii. Positive electrode.

_____

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Section B: Warm Up (17 Marks)

INSTRUCTION: 17 Marks. 11 Minutes Writing.

Question 2 (1 mark)

Which statement is true for both a galvanic cell and an electrolytic cell?

A. Oxidation occurs at the negative electrode.

B. The anode is negatively charged.

C. The strongest oxidant will react with the weakest reductant.

D. Electrons flow from the anode to the cathode.

Question 3 (7 marks)

a.

i. Write the half-equation occurring at the positive electrode during the electrolysis of a 1.0 *M* solution of NaCl. (1 mark)

_____

ii. Write the half-equation occurring at the positive electrode during the electrolysis of a 10 *M* solution of NaCl. (1 mark)

_____

iii. Write the half-equation occurring at the positive electrode during the electrolysis of a molten mixture of NaCl. (1 mark)

_____

b. Suggest why a molten NaCl electrolyte is used in certain commercial cells if a concentrated solution of NaCl could be used as a cheaper alternative. Justify your reasoning. (2 marks)

_____

_____

_____

_____

c.

i. Explain what material commercial cells typically use as the anode. (1 mark)

_____

_____

ii. Explain why a reactive metal such as iron is often used as the material for the cathode in commercial cells rather than inert ones like platinum or graphite. (1 mark)

_____

_____

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Question 4 (3 marks)

a. Outline why hydrogen gas leaks are challenging to detect without a gas detector. (1 mark)

_____

_____

b. Explain the safety concerns associated with the leakage of hydrogen, and subsequently, outline what precautions can be taken to mitigate these risks. (2 marks)

_____

_____

_____

_____

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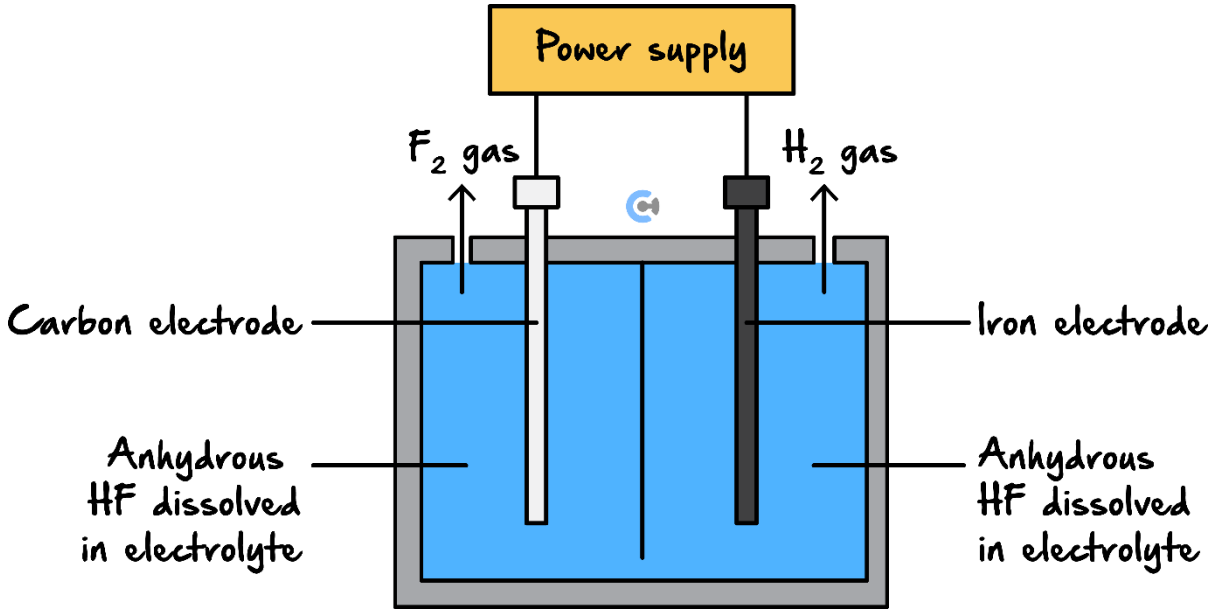
Question 5 (6 marks)

Many industrial processes result in the accumulation of deposits in reaction chambers. To clean these chambers a powerful oxidant, such as fluorine gas, F_2, is required. A safe and cheap method of generating F_2 on-site uses anhydrous hydrogen fluoride, HF.

Anhydrous is when there is no water present, whereby a solvent other than water is used instead.

An electrolytic cell used for the on-site production of F_2 is shown below.



a. Indicate which of the electrodes is the cathode. (1 mark)

_____

b. Write the half equations for the reactions expected at the:

i. Iron electrode. (1 mark)

_____

ii. Carbon electrode. (1 mark)

_____

c. Anhydrous hydrogen fluoride is used rather than an aqueous solution of HF. Suggest a reason for this and include a relevant chemical equation to assist in your response. (2 marks)

_____

_____

_____

_____

d. The cell is fully enclosed, with only passageways for the products to come out of the cell. State one reason for this. (1 mark)

_____

_____

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Section C: Ramping it Up (13 Marks)

INSTRUCTION: 13 Marks. 10 Minutes Writing.

Question 6 (8 marks)

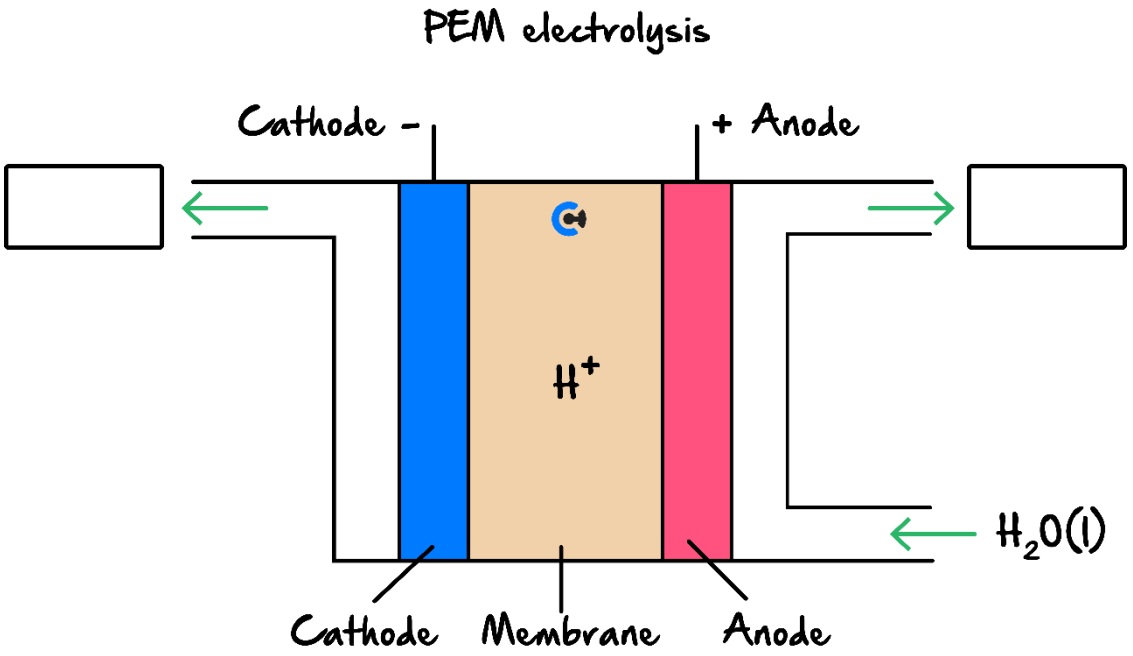
Society has recently been pushing for 'green' chemistry. One such example of this principle is the 'green' production of hydrogen gas.

a. Outline why the 'regular' electrolysis of water use is not considered to be green. (1 mark)

_____

_____

b. The polymer electrolyte membrane (PEM) electrolyser is a commercial cell that will be used in society very soon. A diagram of it is shown below:



i. Explain **one** feature of this electrolyser that makes it more environment-friendly than the electrolysis of an acidic solution and refer to **one** United Nations Sustainability Development Goals. Use Item 26. i of the Data Book. (2 marks)

_____

_____

_____

_____

ii. State **one** disadvantage of this electrolyser, and refer to **one** United Nations Sustainability Development Goals. Use Item 26. i of the Data Book. Justify your answer. (2 marks)

_____

_____

_____

_____

iii. Write the products formed at the cathode and anode by filling in the boxes provided on the diagram above. (1 mark)

c.

i. Indium, a porous material, is often used in this cell as the material for the electrodes. Explain how this feature aids the functioning of the cell. (1 mark)

_____

_____

ii. Indium also poses a second benefit in that it increases the rate of the reactions occurring. State **one** green chemistry principle this quality relates to. (1 mark)

_____

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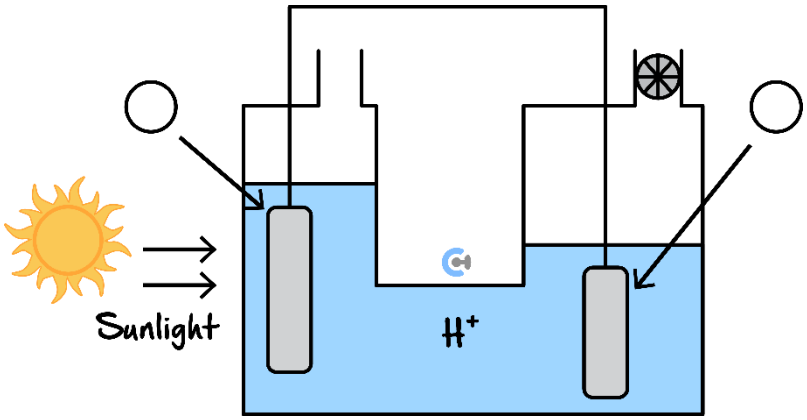
Question 7 (5 marks)

Another green method for the production of hydrogen gas is via the principle of artificial photosynthesis. The cell which allows for this process to occur is depicted below.



a. Given that the sunlight causes the oxidation of water, label the polarities of the electrodes by placing a + or – sign in the circles above. (1 mark)

b.

i. Compare the energy conversions in this cell compared to that in the polymer electrolyte membrane (PEM) electrolyser. (1 mark)

_____

_____

ii. Explain whether this artificial photosynthesis cell or the PEM electrolyser is more energy efficient. Refer to **one** green chemistry principle. (Use **Item (26) (ii)** of the Data Book) (2 marks)

_____

_____

_____

_____

c. State the alternative name for the artificial photosynthesis cell. (1 mark)

_____

_____

Section D: Getting Trickier I (8 Marks)

INSTRUCTION: 8 Marks. 6 Minutes Writing.

Question 8 (8 marks)

The electrolysis of 1 *M* LiBr (aq), and molten LiBr, i.e. LiBr (l) were investigated using carbon electrodes and a potential difference of 5 volts.

a. Write balanced half-equations for the reactions expected during:

i. The electrolysis of 1 *M* LiBr (aq). (2 mark)

Cathode: _____

Anode: _____

ii. The electrolysis of molten LiBr (l). (2 marks)

Cathode: _____

Anode: _____

iii. Explain how pH changes at one of the electrodes during the electrolysis of 1 *M* LiBr. (1 mark)

_____

_____

b. When 0.1 *M* LiBr (aq) was electrolysed instead of 1 *M* LiBr (aq), it was observed that the products produced were different.

Write half equations for the reactions at each half cell and thus describe which products are observed to be produced, giving justification for your reasoning. (2 marks)

_____

_____

_____

_____

_____

c. The production of the products for the electrolysis of 0.1 *M* LiBr (aq) comes with a safety risk. List one safety precaution which should be undertaken to minimise this risk. (1 mark)

_____

_____

Space for Personal Notes

Section E: Getting Trickier II (9 Marks)

INSTRUCTION: 9 Marks. 8 Minutes Writing.

Question 9 (1 mark)

Pure NaCl is not used in a Down's cell. The liquid that is in a Down's cell is a mixture of $CaCl_2$ and NaCl.
The $CaCl_2$/NaCl mixture is used instead of pure NaCl because it:

A. Has a higher melting temperature.

B. Improves the yield of chlorine produced.

C. Improves the purity of the sodium produced.

D. Enables the process to be carried out at a lower temperature.

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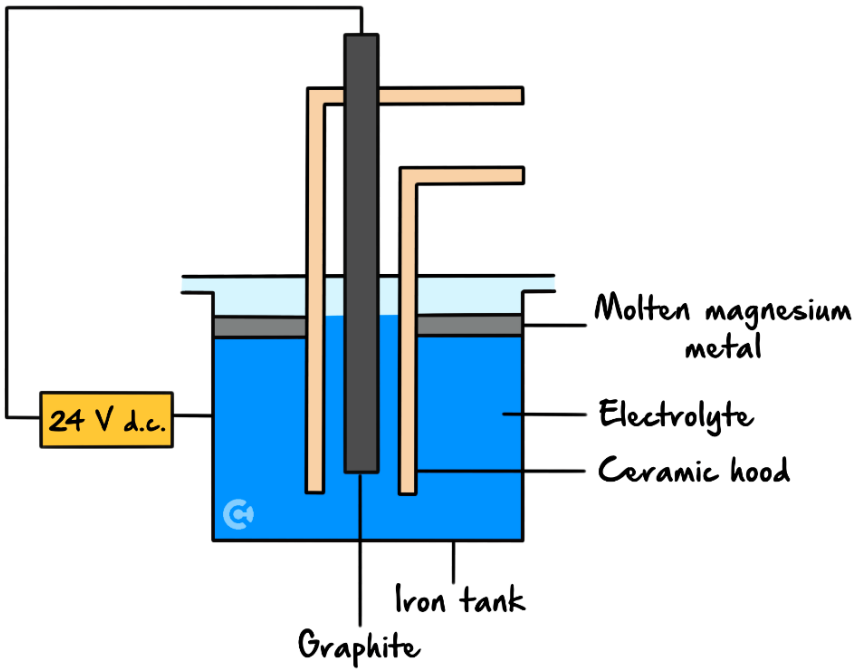
Question 10 (8 marks)

Magnesium is produced by the electrolysis of molten magnesium chloride. The diagram below shows the main features of the electrolytic cell, which is used.



a.

i. Write the half-equation for the process which occurs at the graphite electrode. (1 mark)

_____

ii. Tick one box in the table below to show the identity and polarity of the graphite electrode in the electrolytic cell shown above. (1 mark)

	Positive	**Negative**
Anode		
Cathode		

iii. Explain the likely role of the ceramic hood. (1 mark)

_____

_____

b. It can be predicted from the electrochemical series that the magnesium ions in the electrolyte will not react with the iron tank.

i. What is the basis of this prediction? (1 mark)

_____

_____

ii. This prediction could be unreliable. Explain why. (2 marks)

_____

_____

_____

_____

c. To obtain the magnesium chloride electrolyte, the following reaction is used:

$$MgO(s) + C(s) + Cl_2(g) \rightarrow MgCl_2(s) + CO(g)$$

Suggest one reason why molten magnesium oxide is not used directly in the electrolytic cell to produce magnesium. (2 marks)

_____

_____

_____

_____

Let's take a BREAK!

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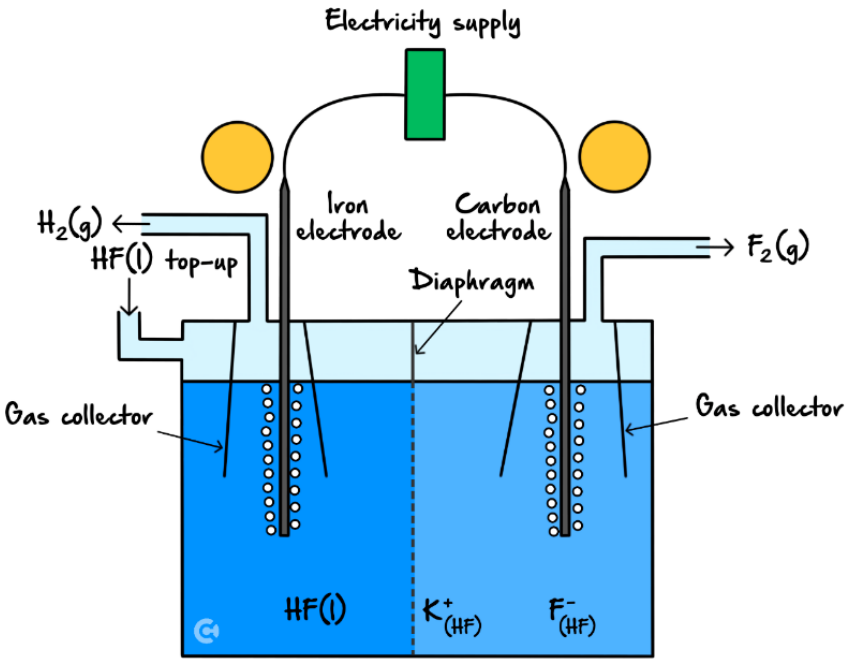
Section F: VCAA-Level Questions I (9 Marks)

INSTRUCTION: 9 Marks. 30 Seconds Reading. 8 Minutes Writing.

Question 11 (9 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)

_____

_____

ii. The overall reaction. (1 mark)

_____

_____

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)

_____

_____

_____

_____

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

_____

_____

_____

_____

_____

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

_____

_____

_____

_____

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Section G: Multiple Choice Questions (6 Marks)

INSTRUCTION: 6 Marks. 6 Minutes Writing.

Question 12 (1 mark)

If we compare a galvanic cell with an electrolytic cell, it is true to state that:

A. In a galvanic cell reduction occurs at the negative electrode.

B. In both cells the anode is positive and the cathode is negative.

C. In an electrolytic cell oxidation occurs at the cathode.

D. In both cells reduction occurs at the cathode.

Question 13 (1 mark)

To produce magnesium metal and chlorine gas from magnesium chloride, a molten electrolyte needs to be used. This is because:

A. Water is a stronger reductant than chloride ions.

B. Water is a stronger oxidant than magnesium ions.

C. Less energy is used when electrolysing a molten electrolyte as water does not react.

D. The products produced from an aqueous solution can react together spontaneously.

Question 14 (1 mark)

Calcium metal can be obtained from the electrolysis of molten calcium chloride. During this process, calcium ions flow to the:

A. Anode and are reduced to calcium metal.

B. Anode and are oxidised to calcium metal.

C. Cathode and are reduced to calcium metal.

D. Cathode and are oxidised to calcium metal.

Question 15 (1 mark)

Inspired from VCAA Chemistry NHT Exam 2022
https://www.vcaa.vic.edu.au/Documents/exams/chemistry/2022/NHT/2022ChemistryNHT-w.pdf#page=14

Fluorine can be produced commercially by the electrolysis of a mixture of potassium hydrogen difluoride, KHF_2, and hydrogen fluoride, HF. HF is a molecular gas at standard laboratory conditions (SLC).

Which of the following about the electrolysis of HF to produce fluorine is correct?

	Molten HF is not used in electrolysis to produce fluorine because	**Aqueous HF is not used in electrolysis to produce fluorine because**
A.	HF is a molecule.	Oxygen would be produced.
B.	HF is a molecule.	Hydrogen would be produced.
C.	The melting temperature of HF is too high.	Oxygen would be produced.
D.	The melting temperature of HF is too high.	Hydrogen would be produced.

Question 16 (1 mark)

Brine is a concentrated solution of sodium chloride. The electrolysis of brine is a common industry due to the useful products it yields. The products are:

A. Hydrogen gas, chlorine gas and sodium hydroxide.

B. Hydrogen gas and oxygen gas.

C. Sodium metal and oxygen gas.

D. Sodium metal and chlorine gas.

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Question 17 (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 from the products at the anodes.

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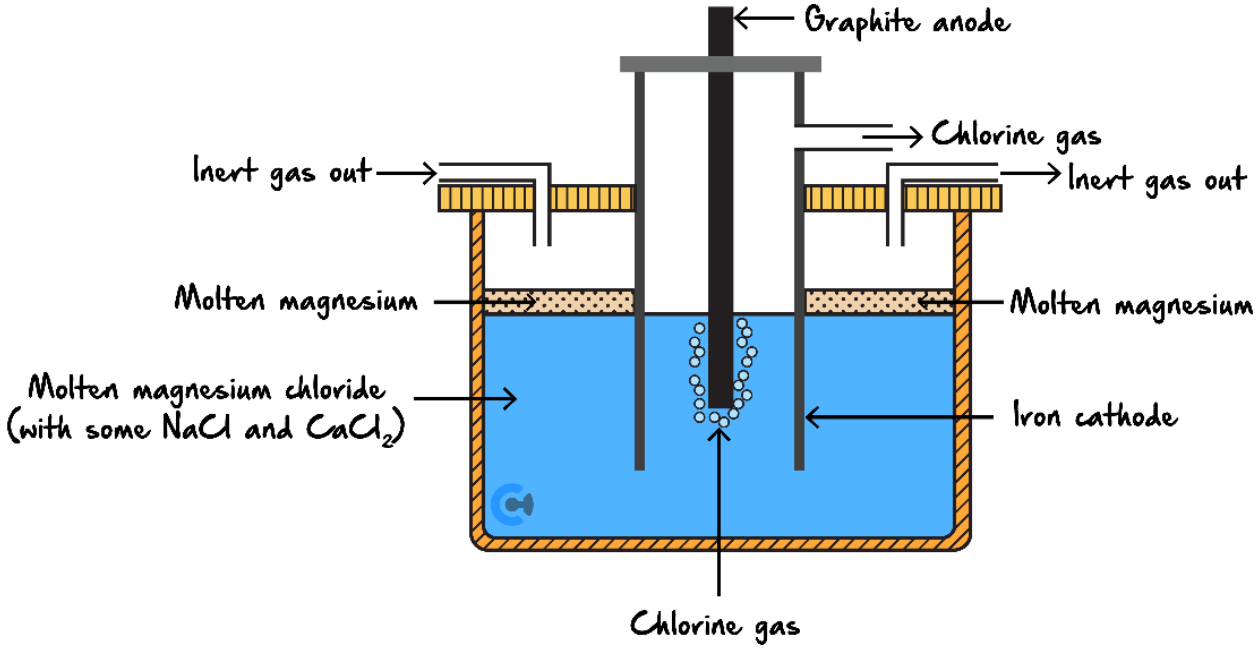
Section H: VCAA-Level Questions II (8 Marks)

INSTRUCTION: 8 Marks. 30 Seconds Reading. 7 Minutes Writing.

Question 18 (8 marks)

Magnesium is one of the most abundant elements on Earth. It is used extensively in the production of magnesium-aluminium alloys. It is produced by the electrolysis of molten magnesium chloride. A schematic diagram of the electrolytic cell is shown below.



The design of this cell takes into account the following properties of both magnesium metal and magnesium chloride:

- Molten magnesium reacts vigorously with oxygen.
- At the temperature of molten magnesium chloride, magnesium is a liquid.
- Molten magnesium has a lower density than molten magnesium chloride and forms a separate layer on the surface.

a. Write a balanced half-equation for the reaction occurring at each of: (2 marks)

Anode: _____

Cathode: _____

b. Explain why an inert gas is constantly blown through the cathode compartment. (1 mark)

_____

c. The melting point of a compound can often be lowered by the addition of small amounts of other compounds. In an industrial process, this will save energy. In this cell, NaCl and $CaCl_2$ are used to lower the melting point of $MgCl_2$. Why can NaCl and $CaCl_2$ be used to lower the melting point of $MgCl_2$ but $ZnCl_2$ cannot be used? (2 marks)

_____

_____

_____

_____

d. What difference would it make to the half-cell reactions if the graphite anode were replaced with an iron anode? Write the half-equation for any different half-cell reaction. Justify your answer. (3 marks)

_____

_____

_____

_____

_____

_____

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Section I: Extension Questions (19 Marks)

Question 19 (11 marks)

It has been suggested that aluminium could be used as a fuel source by reacting it with water to produce hydrogen gas. The aluminium rods could be replaced when the vehicle is "refuelled". The hydrogen gas produced could then be used in a fuel cell.

a. What is the advantage of producing hydrogen gas in this way? (1 mark)

_____

b. The aluminium could be prepared using electrolysis.

i. Should the electrolyte be a molten liquid or an aqueous solution? Why? (2 marks)

_____

_____

_____

ii. Write the half equation for the reaction occurring at the cathode. (1 mark)

_____

iii. Assuming aluminium chloride is being electrolysed to create aluminium, calculate the voltage required to prevent the products from re-reacting and hence, justify why this is the minimum potential to be provided in the electrolysis cell. (2 marks)

_____

_____

_____

_____

c. When the aluminium is reacted to form hydrogen from water, write half equations for the oxidation and reduction process.

i. Oxidation. (1 mark)

_____

ii. Reduction. (1 mark)

_____

d. The fuel cell uses a potassium hydroxide electrolyte.

i. Write the half equation for the reaction occurring at the positive electrode. (1 mark)

_____

ii. Ions move through the electrolyte. In what direction would the hydroxide ions move and why do they move in this direction? (2 marks)

_____

_____

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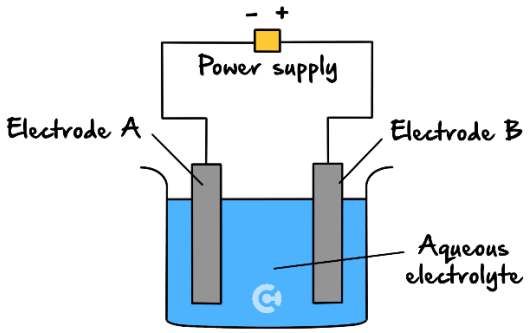
Question 20 (8 marks)

Three experiments were conducted to investigate electrolytic cell reactions.

a. In the experiment 1, the apparatus shown below was used.



After the current had passed through the cell for some time, a reddish brown liquid was formed at the electrode *B*, while a metal was found deposited on the electrode *A*.

i. Suggest the probable formula of the reddish-brown liquid. (1 mark)

_____

ii. Explain why the deposited metal could not be magnesium. (2 marks)

_____

_____

_____

iii. Suggest a possible electrolyte for this cell which is consistent with the observations made. (1 mark)

_____

iv. Explain why, regardless of the choice of electrolyte (assuming no spontaneous reaction occurs), identify which of the electrodes can be iron and explain why this is so. (2 marks)

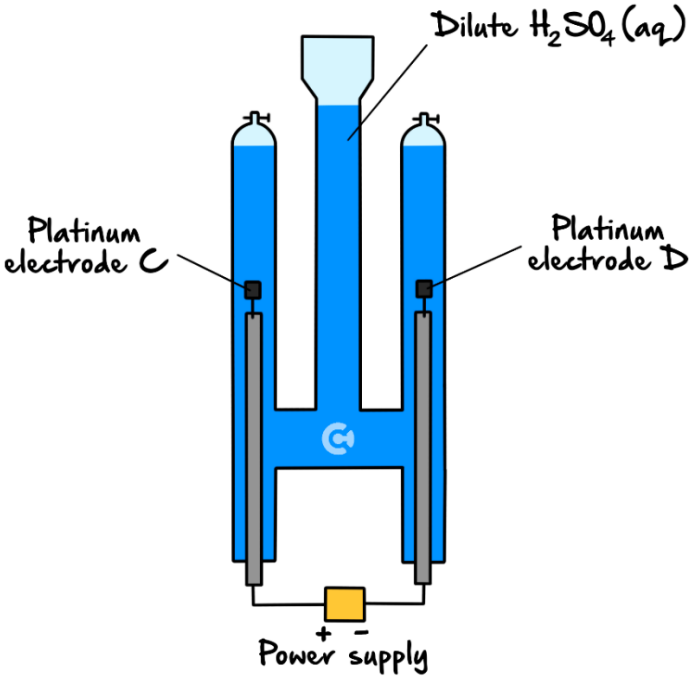
_____

_____

_____

_____

b. In experiment 2, the apparatus shown below was used with a dilute sulphuric acid solution as the electrolyte. A steady current of 0.060 amperes was maintained during the experiment.



i. Write a half-equation for the gas-producing reaction expected at the electrode C. (1 mark)

_____

ii. The cell is planned to be used to create reactants for an acidic fuel cell. Identify the component of the cell that allows this to occur. (1 mark)

_____

_____

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