Victorian Certificate of Education
2024

Name: _____

Teacher's name: _____

UNIT 3 CHEMISTRY

SAC 1: *An analysis and evaluation of a chemical innovation, research study, case study, socio-scientific issue, or media communication.*

2024

QUESTION AND ANSWER BOOK

Structure of book

Number of questions	*Number of questions to be answered*	*Number of marks*
2	2	40
		Total 40

- Students are permitted to bring into the assessment room: pens, pencils, highlighters, erasers, sharpeners, rulers and one scientific calculator.
- Students are NOT permitted to bring into the assessment room: blank sheets of paper and/or correction fluid/tape.

Materials supplied
- Question and answer book.
- Additional space is available at the end of the book if you need extra space to complete an answer.

Instructions
- Write your name in the space provided above on this page.
- All written responses must be in English.

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

Use the following information to answer Question 1.

Case Study

Both methanol and hydrogen can be used as fuel sources to produce electricity through fuel cells. These fuel cells can then provide electricity to run cars or buses.

Methanol and hydrogen production processes are presented in Figure 1. Hydrogen can be produced through the electrolysis of water, where the electricity is sourced from renewable energy; the hydrogen gas is then liquefied at high pressure and transported for the end use. The methanol production involves capturing CO_2 from the air (or from heavy industry) and synthesising it with added hydrogen to obtain methanol through green chemistry processes.

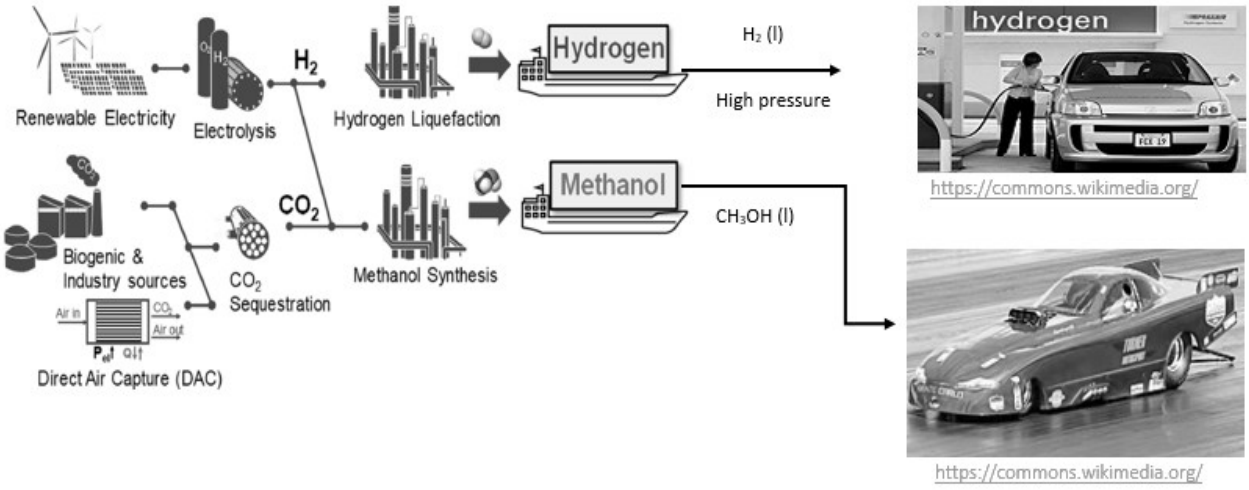
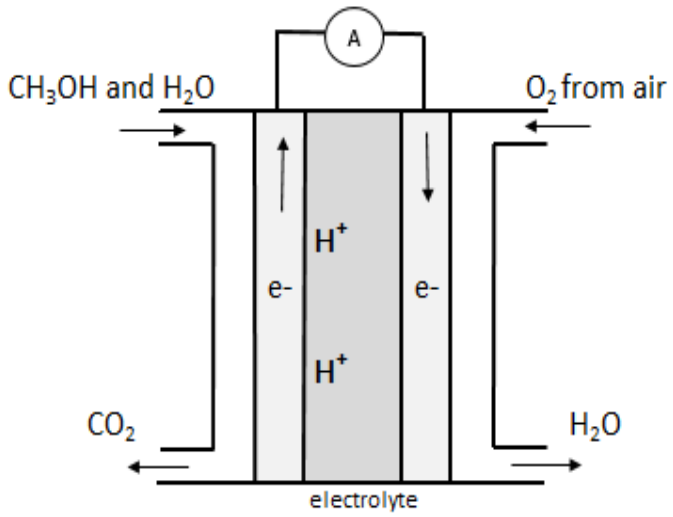


Figure 1. A diagram of hydrogen and methanol production using green chemistry approaches.

After production, each of these fuels can be used to power cars or buses by using either a Methanol Fuel Cell (MFC) or a Hydrogen Fuel Cell (HFC) respectively (see Figure 2).

Source: Adapted from Schorn et al 2021. Methanol as a renewable energy carrier: An assessment of production and transportation costs for selected global locations, *Advances in Applied Energy 3 2021*, Published by Elsevier, accessed on the 15th July 2023 from https://www.sciencedirect.com/science/article/pii/S2666792421000421?via%3Dihub

Methanol Fuel Cell (MFC)



Hydrogen Fuel Cell (HFC)

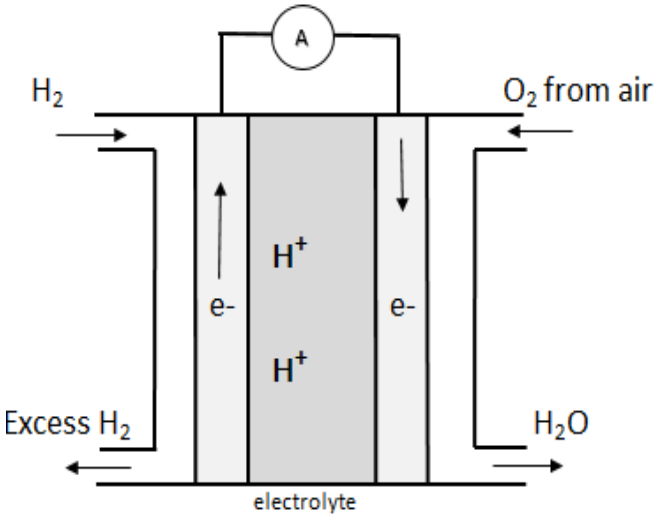


Figure 2. Diagrams of a methanol fuel cell (MFC) and a hydrogen fuel cell (HFC).

A selection of fuel properties is shown in Table 1.

Table 1. Selected Fuel Properties

Property	**CH_3OH**	**H_2**
Density (kg/m^3)	792 as liq.	0.08375 (as gas) 70.8 (as liq.)
Flashpoint (˚C)	11	-253
Heat of Combustion (kJ/g)	22.7	141
Heat of Combustion (kJ/mol)	726	282
Volume expansion ratio from Liquid to Gas	-	1 to 848

Sources: Adapted from:
Barbir F., n.d.. Safety issues of hydrogen in vehicles, accessed on the 15th July 2023 from https://courses.engr.illinois.edu/npre470/sp2019/web/readings/Hydrogen%20safety%20issues.pdf
Lanz, A., et al., 2001. Hydrogen Fuel Cell Engines and Related Technologies College of the Desert, Palm Desert, CA, USA, accessed on the 15th July from https://www.energy.gov/hydrogen-fuel-cells
Advanced motor fuels, 2023. Methanol, accessed on the 15th July from https://www.iea-amf.org/content/fuel_information/methanol#:~:text=Low%20lean%20flammability%20limit,to%20the%20lower%20heating%20value

Media Communication

[1] - "Hydrogen and methanol both qualify as substitutes for current energy carriers." The method proposes an option for, "…a methanol production plant with power stations and other manufacturing plants, such as cement and pulp-and-paper mills, to reduce carbon dioxide emissions and store excess energy generated from power plants."

[2] - "Methanol, a liquid fuel with controlled flammability, easy transportation, storage, versatility, retrofitting capabilities and the ability to serve as a fuel additive, offers advantages over hydrogen, despite hydrogen having the highest energy density."

[3] - "Acute exposure of humans to methanol by inhalation or ingestion may result in visual disturbances, such as blurred or dimness of vision, leading to blindness…".

[4] - "…Hydrogen has a very low ignition energy, about one order of magnitude lower than other fuels. […] [It also] has a flame velocity seven times faster than that of natural gas or gasoline".

Sources: Adapted from:

[1] – Schorn et al 2021. Methanol as a renewable energy carrier: An assessment of production and transportation costs for selected global locations, *Advances in Applied Energy 3 2021*, Published by Elsevier, accessed on the 15th July 2023 from https://www.sciencedirect.com/science/article/pii/S2666792421000421?via%3Dihub

[2] – Samuel Emebu [a e], Clara Mendoza Martinez [b], Osaze Omoregbe [c e], Aleksi Mankonen [b], Ebuka A. Ogbuoji [f], Ibrahim Shaikh [a], Even Pettersen [d], Marek Kubalčík [a], Charity Okieimen [e] Chemical Engineering Science, Volume 278, 15 August 2023, 118888

[3] – USEPA, 2000. Methanol, accessed on the 15th July 2023 from https://www.epa.gov/sites/default/files/2016-09/documents/methanol.pdf

[4] – Barbir F., n.d.. Safety issues of hydrogen in vehicles, accessed on the 15th July 2023 from https://courses.engr.illinois.edu/npre470/sp2019/web/readings/Hydrogen%20safety%20issues.pdf

Instructions

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, H2(g), NaCl(s).

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

Final answers must include correct units.

Question 1 (17 marks)

a. After production (see Figure 1), methanol and hydrogen are transported to fuel stations. 1 mark

Outline a safety issue with either the transport, storage or usage of hydrogen compared to methanol.

b. Identify a similarity between MFCs and HFCs that explains why they are considered fuel cells. 1 mark

c. Write half equations for the reactions occurring at the anode and cathode of the MFC. Write the overall equation (including states) for the MFC as it operates. 3 marks

Anode:

Cathode:

Overall equation:

d. Write half equations for the reactions occurring at the anode and cathode of the HFC. Write the overall equation (including states) for the HFC as it operates. 3 marks

Anode:

Cathode:

Overall equation:

e. The theoretical voltage produced by a MFC is +1.6 V and the actual efficiency is 40%. The actual efficiency of the HFC is 60%. 3 marks

Which cell provides the highest actual voltage? Show your working.

f. Compare and discuss the environmental impact of using MFCs and HFCs when their reactants are sourced via renewable processes. 2 marks

g. Assuming SLC, what is the amount of greenhouse gas, in kg, that is produced from the reaction of 1.0 kg of fuel in a methanol fuel cell? Show your working. 3 marks

h. Write the thermochemical equation for the complete combustion of methanol at SLC. 1 mark

Question 2 (23 marks)

A student researched whether a small battery can be replaced with a galvanic cell that can be assembled in the school laboratory.

The Primary Cell – Battery

Zinc-silver oxide cells are frequently used to power small electronics and photographic equipment. The cell configuration below (Figure 3) includes: an amalgamated zinc anode; silver oxide as the cathode material; and a potassium hydroxide electrolyte. During discharge, zinc will form zinc oxide whilst silver (I) oxide will form silver.

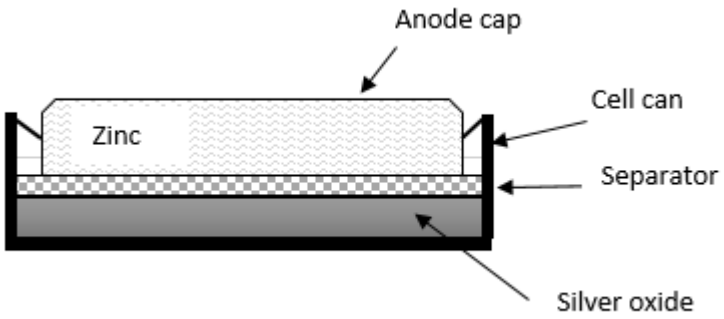


Figure 3. A schematic representation of a zinc-silver oxide cell.

Through the research, the student identified the battery discharge curve as well as other properties:

- a long service life;
- a lack of mercury, lead and cadmium, making the silver oxide batteries environmentally friendly; and
- a silver oxide system that is best suited for operation between -20°C and 54°C (with the starting cell potential being 1.55 V).

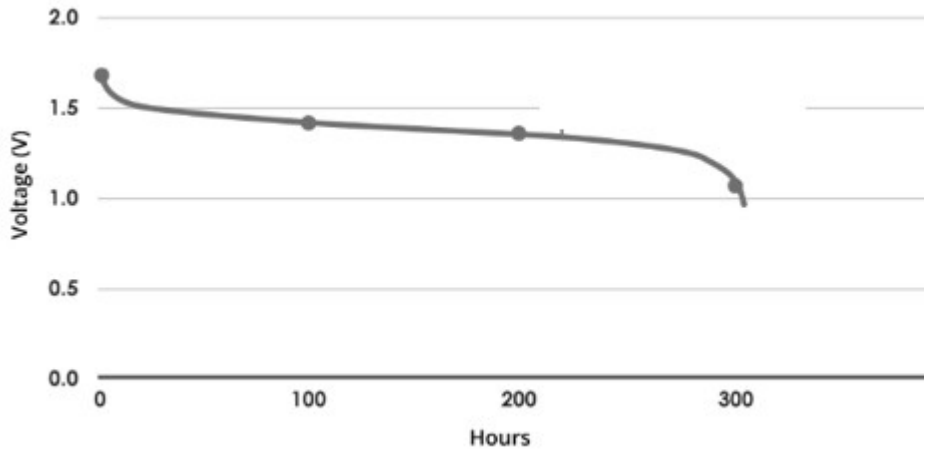


Figure 4. A silver oxide battery discharge curve.

Source: GP Industrial, 2023. Silver oxide button batteries, accessed on the 15th July 2023 from https://ind.gpbatteries.com/products/primary-batteries/silver-oxide-batteries/silver-oxide-button-batteries.html

a. State the polarity of the zinc electrode. 1 mark

b. Write the equations for the reactions that are occurring at the anode and the cathode as well as the overall equation. 3 marks

Anode:

Cathode:

Overall equation:

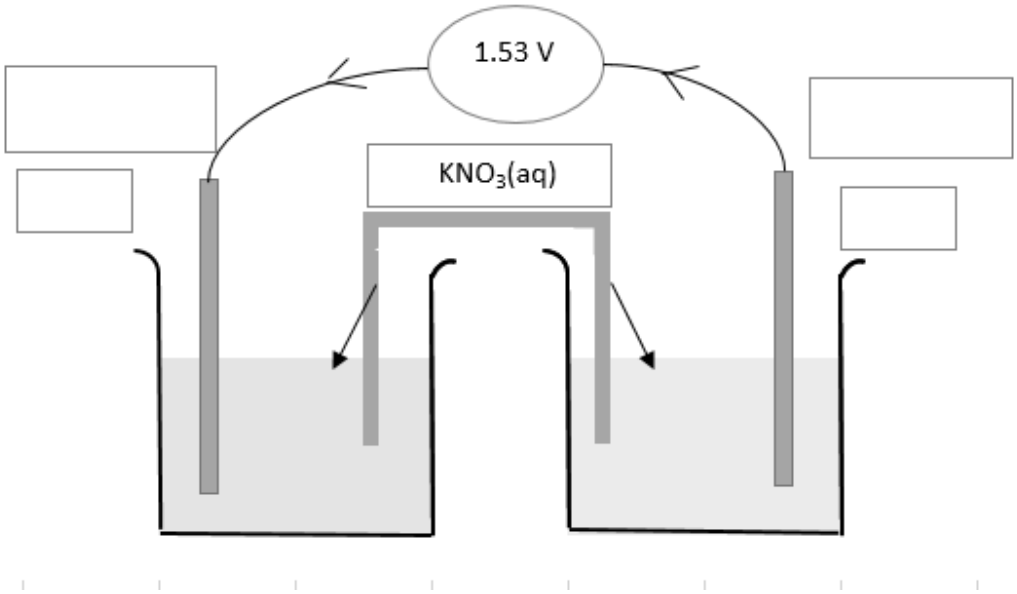
c. Identify the oxidising agent (oxidant) in the battery. Justify your answer using oxidation numbers. 2 marks

The Galvanic Cell

Using the electrochemical series, the student constructs a galvanic cell with a similar potential difference to the zinc-silver oxide cell. The electrodes are made of reactive metals and the electrolytes consist of ions of the same metal as the electrode. The metals available in the lab are Al, Zn, Fe, Pb and Cu. The student chooses a combination of oxidising and reducing agents that give a potential difference of +1.53 V. The galvanic cell is tested at SLC.

d. Annotate the diagram below identifying: 4 marks

- The anode and its polarity
- The cathode and its polarity
- The electrode material (metal species) in each half cell
- The movement of ions from the internal circuit.



e. Write the equations for the reactions that are occurring at the anode and the cathode as well as the overall equation. 3 marks

Anode:

Cathode:

Overall equation:

f. Assume that the mass of each of the electrodes is 3.00g and that they are 70.0% immersed in the electrolyte. 4 marks

If the operating current is 0.500 A, how many hours can this galvanic cell generate electricity for? Show your working.

g. Using the data from the student's research, compare the small battery and the galvanic cell. Analyse their durability, operational reliability and the materials that are used, including their structures and how they operate. 6 marks

Durability:

Operational reliability:

Materials used:

END OF QUESTION AND ANSWER BOOK

Extra space for responses

Clearly number all responses in this space.