Topic C.6 Electrochemistry, Rechargeable Batteries & Fuel Cells

Past Exam Questions (Paper 3)

1a. *[2 marks]*

A fuel cell is an energy conversion device that generates electricity from a spontaneous redox reaction.

The *Geobacter* species of bacteria can be used in microbial fuel cells to oxidise aqueous ethanoate ions, $CH_3COO^-(aq)$, to carbon dioxide gas.

State the half-equations for the reactions at both electrodes.

Negative electrode (anode):

. . . . . .

Positive electrode (cathode):

. . . . . .

1b. *[3 marks]*

A concentration cell is an example of an electrochemical cell.

(i) State the difference between a concentration cell and a standard voltaic cell.

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(ii) The overall redox equation and the standard cell potential for a voltaic cell are:

$Zn\ (s) + Cu^{2+}\ (aq) \rightarrow Zn^{2+}\ (aq) + Cu\ (s) \quad E^{\theta}_{cell} = +1.10\ V$

Determine the cell potential *E* at 298 K to three significant figures given the following concentrations in mol dm^{-3}:

$[Zn^{2+}] = 1.00 \times 10^{-4} \quad [Cu^{2+}] = 1.00 \times 10^{-1}$

Use sections 1 and 2 of the data booklet.

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(iii) Deduce, giving your reason, whether the reaction in (b) (ii) is more or less spontaneous than in the standard cell.

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2a. *[3 marks]*

A fuel cell converts chemical energy directly to electrical energy.

Deduce the half-equations and the overall equation for the reactions taking place in a direct methanol fuel cell (DMFC) under acidic conditions.

Negative electrode (anode):

. . . . . .

. . . . . .

Positive electrode (cathode):

. . . . . .

. . . . . .

Overall equation:

. . . . . .

. . . . . .

2b. *[2 marks]*

Outline **one** advantage and **one** disadvantage of the methanol cell (DMFC) compared with a hydrogen-oxygen fuel cell.

Advantage:

. . . . . .

. . . . . .

Disadvantage:

. . . . . .

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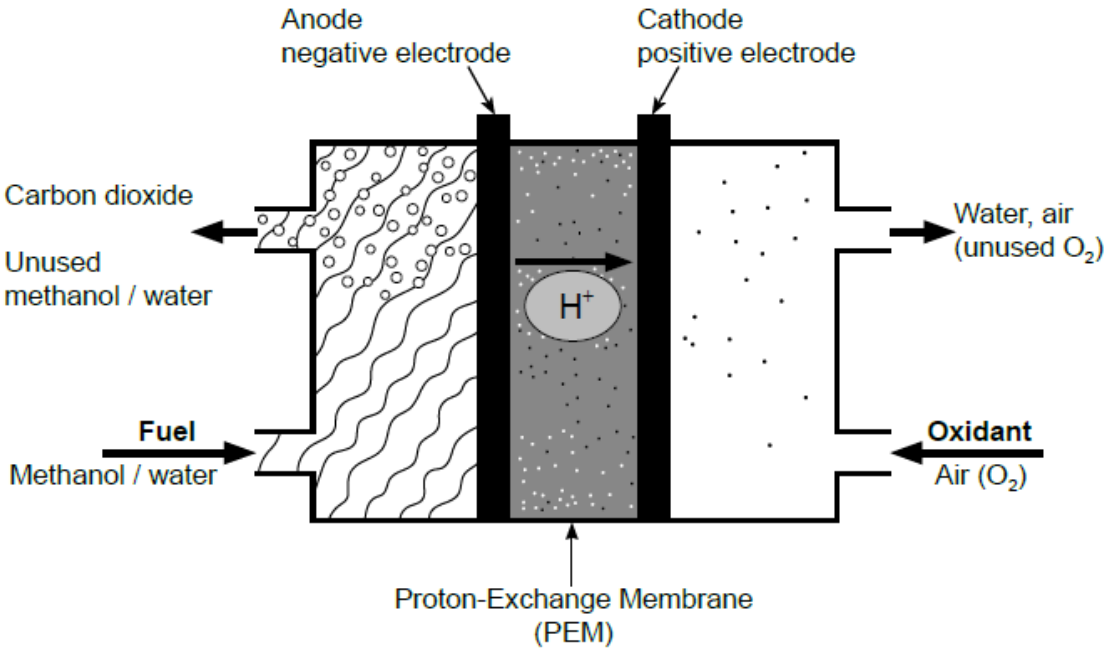
3a. *[3 marks]*

As well as being burnt, methanol can also be used to provide electricity through a fuel cell. A schematic diagram of such a fuel cell, that depends on the transfer of hydrogen ions between the electrodes, is shown below.



[Source: adapted from http://greenbigtruck.com]

Deduce half-equations for the reactions at the two electrodes and hence the equation for the overall reaction.

Negative electrode (anode):

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.....

Positive electrode (cathode):

.....

.....

Overall equation:

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.....

3b. *[1 mark]*

Even though fuel cells, primary cells and rechargeable cells have similar fundamental characteristics, there are important differences between them.

Suggest a way in which they are similar.

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3c. *[1 mark]*

Outline the difference between primary and rechargeable cells.

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3d. *[2 marks]*

Identify **one** factor that affects the voltage of a cell and **a different factor** that affects the current it can deliver.

Voltage:

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. . . . . .

Current:

. . . . . .

. . . . . .

4a. *[2 marks]*

There are many sources of energy available.

Methanol fuel cells provide a portable energy source. The process can be represented by the overall equation $CH_3OH(aq) + \frac{3}{2}O_2(g) \rightarrow CO_2(g) + 2H_2O(g)$.

Deduce the half-cell equations occurring at each electrode during discharge.

Negative electrode (anode):

. . . . . .

. . . . . .

Positive electrode (cathode):

. . . . . .

. . . . . .

4b. *[1 mark]*

Outline the function of the proton-exchange membrane (PEM) in the fuel cell.

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4c. *[2 marks]*

Explain how the flow of ions allows for the operation of the fuel cell.

5a. *[1 mark]*

Chemical energy from redox reactions can be used as a source of electrical energy.

Outline how a rechargeable battery differs from a primary cell.

5b. *[2 marks]*

Formulate half-equations for the reactions at the anode (negative electrode) and cathode (positive electrode) during discharge of a lithium-ion battery.

Negative electrode (anode):

Positive electrode (cathode):

5c. *[2 marks]*

A voltaic cell consists of a nickel electrode in 1.0 mol dm^{-3} Ni^{2+} (aq) solution and a cadmium electrode in a Cd^{2+} (aq) solution of unknown concentration.

$Cd\ (s) + Ni^{2+}\ (aq) \rightarrow Cd^{2+}\ (aq) + Ni\ (s)$ $\quad\quad$ $E^{\Theta}_{cell} = 0.14$ V

Determine the concentration of the Cd^{2+} (aq) solution if the cell voltage, *E*, is 0.19 V at 298 K. Use section 1 of the data booklet.

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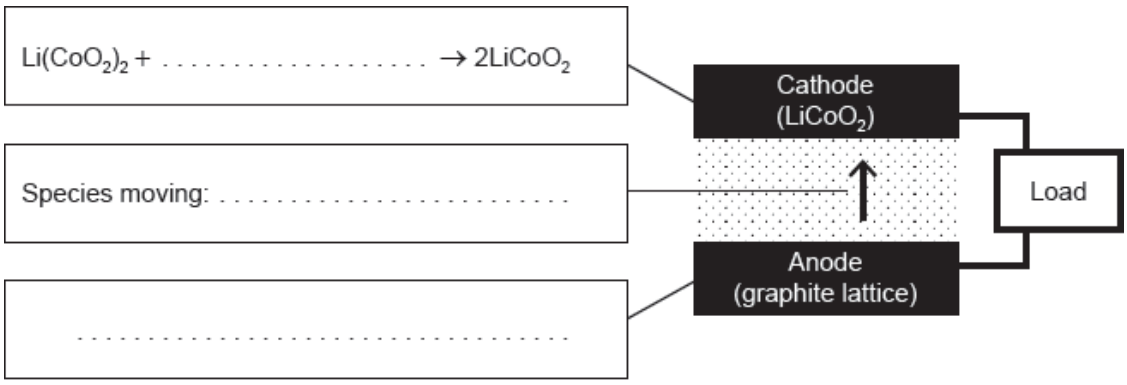
6a. *[3 marks]*

Modern electric cars store their energy in lithium ion batteries.

The diagram represents a cell in such a battery delivering a current.

Complete the half-equations on the diagram and identify the species moving between the electrodes.



6b. *[2 marks]*

State the factor that limits the maximum current that can be drawn from this cell and how electrodes are designed to maximize the current.

Limiting factor:

. . . . . .

. . . . . .

Electrodes design:

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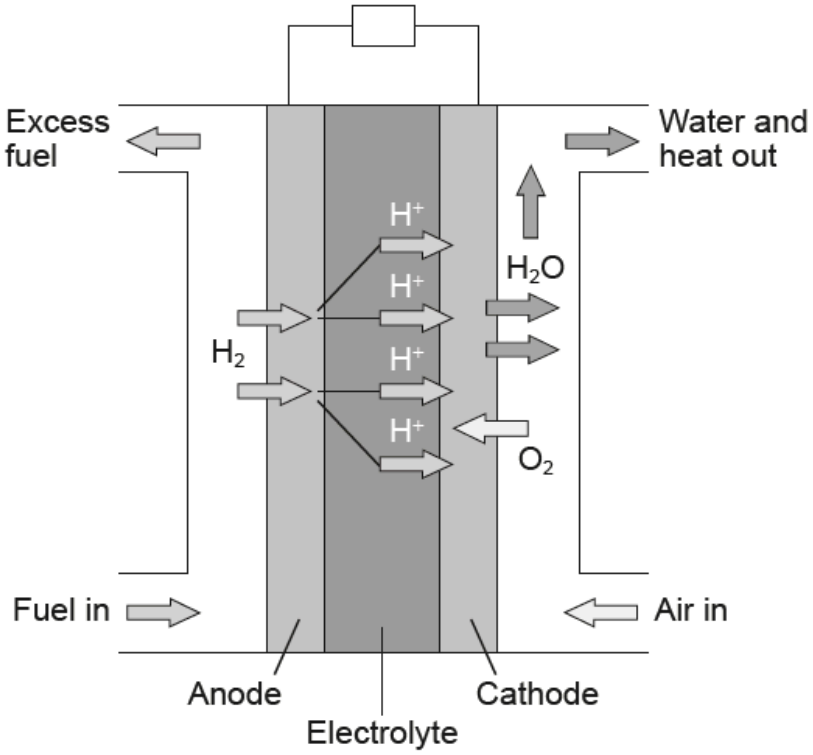
. . . . . .

7a. *[2 marks]*

A proton-exchange membrane (PEM) fuel cell uses pure hydrogen gas as the fuel and a proton exchange membrane as the electrolyte.



Deduce the half-equations for the reactions occurring at the electrodes.

Negative electrode (anode):

. . . . . .

. . . . . .

Positive electrode (cathode):

. . . . . .

. . . . . .

7b. *[1 mark]*

Calculate the cell potential, E^{θ}, in V, using section 24 of the data booklet.

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7c. *[1 mark]*

Suggest how PEM fuel cells can be used to produce a larger voltage than that calculated in (b)(i).

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7d. *[1 mark]*

Suggest an advantage of the PEM fuel cell over the lead-acid battery for use in cars.

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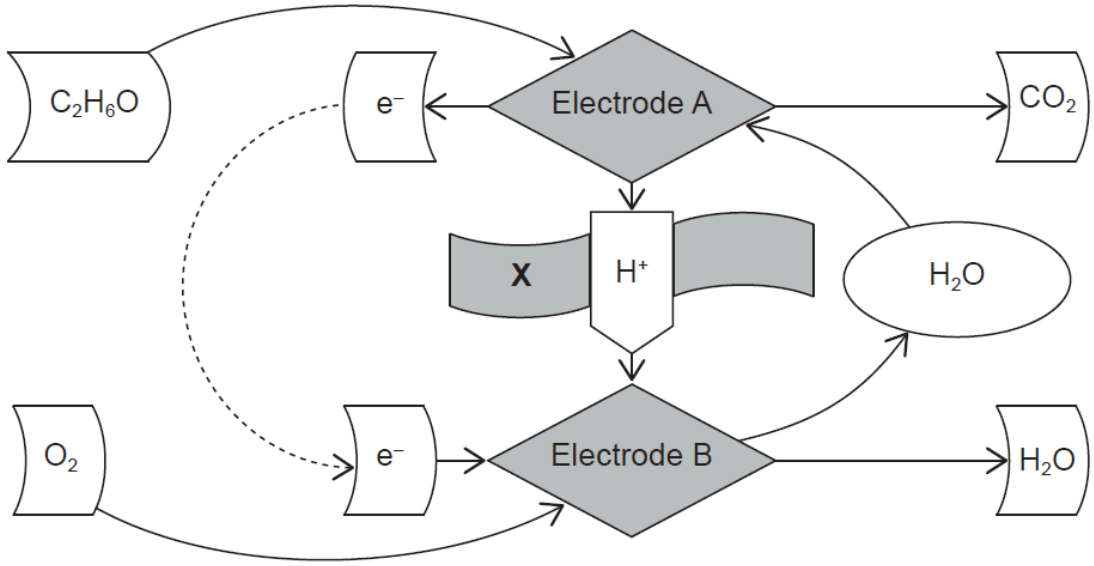
8a. *[2 marks]*

E10 is composed of 10% ethanol and 90% normal unleaded fuel.

Ethanol can be used in a direct-ethanol fuel cell (DEFC) as illustrated by the flow chart.



Deduce the half-equations occurring at electrodes A and B.

Electrode A:

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. . . . . .

Electrode B:

. . . . . .

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8b. *[2 marks]*

State the name and function of **X** in the diagram in (b)(i).

Name:

. . . . . .

. . . . . .

Function:

. . . . . .

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8c. *[1 mark]*

Outline why aqueous ethanol, rather than pure ethanol, is used in a DEFC.

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9a. *[3 marks]*

Electricity can be generated in a variety of ways.

Outline how a microbial fuel cell produces an electric current from glucose.

$C_6H_{12}O_6$ (aq) + $6O_2$ (g) → $6CO_2$ (g) + $6H_2O$ (l)

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9b. *[2 marks]*

The cell potential for the spontaneous reaction when standard magnesium and silver half-cells are connected is +3.17 V.

Determine the cell potential at 298 K when:

$[Mg^{2+}] = 0.0500$ mol dm^{-3}
$[Ag^{+}] = 0.100$ mol dm^{-3}

Use sections 1 and 2 of the data booklet.

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9c. *[1 mark]*

Outline **one** difference between a primary and a secondary cell.

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