VCE CHEMISTRY 2018

Year 12 Unit 3 – Unit Test 1

What are the options for energy production?

Time allowed: 50 minutes
Total marks: 45

12 Multiple Choice Questions
4 Short Answer Questions

An Answer Sheet is provided for Section A.
Answer all questions in Section B in the space provided.

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STUDENT NUMBER Letter

Figures									
Words									

Student Name..

VCE Chemistry 2018 Year 12 Unit 3 – Unit Test 1

How can chemical processes be designed to optimise efficiency?

Area of Study 1: What are the options for energy production?

Student Answer Sheet

There are **12 Multiple Choice** questions to be answered by circling the correct letter in the table below. Use only a 2B pencil. If you make a mistake, erase and enter the correct answer. Marks will not be deducted for incorrect answers

Question 1	A	B	C	D
Question 2	A	B	C	D
Question 3	A	B	C	D
Question 4	A	B	C	D
Question 5	A	B	C	D
Question 6	A	B	C	D
Question 7	A	B	C	D
Question 8	A	B	C	D
Question 9	A	B	C	D
Question 10	A	B	C	D
Question 11	A	B	C	D
Question 12	A	B	C	D

VCE Chemistry 2018 Year 12 Unit 3 – Unit Test 1

How can chemical processes be designed to optimise efficiency?

Area of Study 1 – What are the options for energy production?

SECTION A – Multiple Choice Questions

(12 marks)

This section contains 12 multiple choice questions.
For each question, choose the response that is correct or best answers the question.
Indicate your answer on the answer sheet provided.
(Choose only ***one*** *answer for each question.)*

Question 1
A hydrogen fuel cell produced 65 MJ of electrical energy for each 1.0 kg of hydrogen gas consumed. The efficiency of this fuel cell as an energy convertor would be

A. 23 %
B. 46 %
C. 54 %
D. 77 %

Question 2
The VO^{2+}(aq) and VO_2^{+}(aq) ions form one conjugate redox pair in a galvanic cell. When this cell is discharging, the electrode in the half-cell containing these ions has a positive charge. The half-equation that would best describe what is occurring would be

A. $VO_2^+(aq) + 2H^+(aq) + e^- \rightarrow VO^{2+}(aq) + H_2O(l)$
B. $VO^{2+}(aq) + H_2O(l) \rightarrow VO_2^+(aq) + 2H^+(aq) + e^-$
C. $VO_2^+(aq) + e^- \rightarrow VO^{2+}(aq) + O^{2-}(aq)$
D. $VO^{2+}(aq) + O^{2-}(aq) \rightarrow VO_2^+(aq) + e^-$

Question 3
A 2.200 g sample of carbon dioxide in a 2.00 L cylinder at 83.5 °C would have a pressure of

A. 0.750 atm.
B. 0.976 atm.
C. 98.9 kPa.
D. 555 mmHg.

Question 4

Figure 1 shows a galvanic cell constructed from standard $Cr^{3+}(aq)/Cr^{2+}(aq)$ and $Sn^{2+}(aq)/Sn(s)$ half-cells.

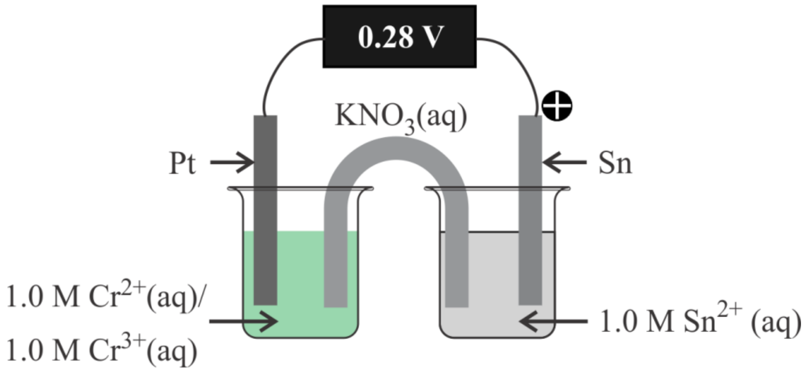


Figure 1

The E° value for the standard $Cr^{3+}(aq)/Cr^{2+}(aq)$ half-reaction would be closest to

A. -0.42 V.
B. -0.14 V.
C. 0.14 V.
D. 0.42 V.

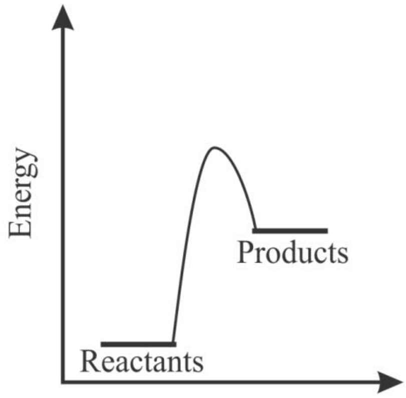
Question 5

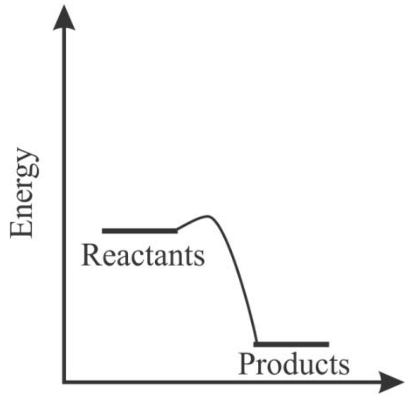
The heat of combustion for standard grade petrol is 33800 kJ L^{-1}. The typical efficiency for a car engine is 26 %.

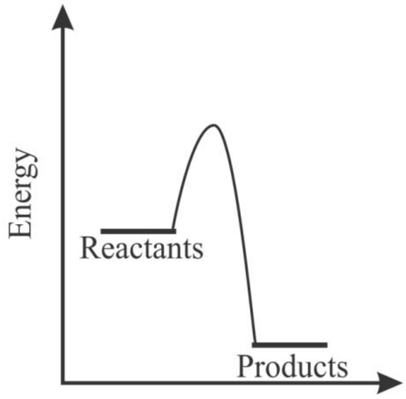
The amount of useful energy that could be obtained from the fuel in a 50 L tank would be closest to

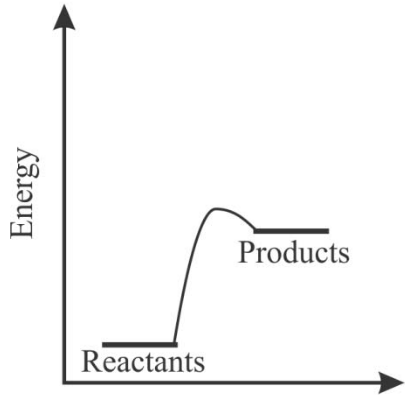
A. 180 MJ.
B. 440 MJ.
C. 1690 MJ.
D. 6500 MJ.

Question 6
The energy profile diagram that would best describe the combustion of hydrogen gas at SLC would be

A.


B.


C.


D.


Question 7
Figure 2 shows a typical proton exchange membrane fuel cell.

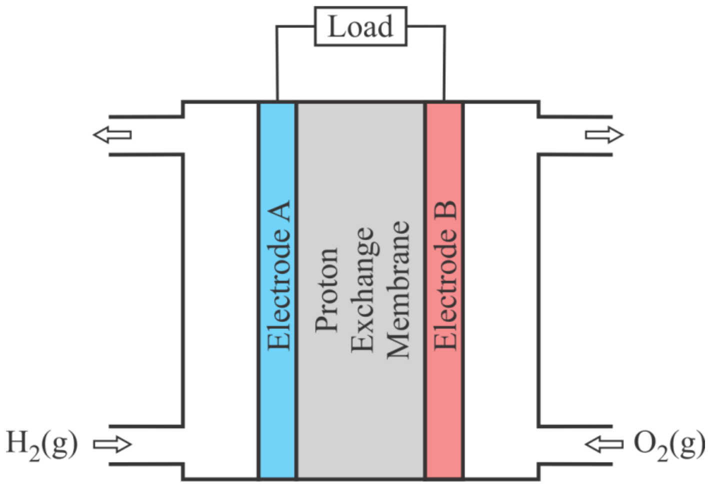


Figure 2

Which of the following would be correct when this fuel cell is releasing energy?

	Electrode A	Electrode B	Ion movement in the membrane
A.	Anode	Cathode	OH^- moving from electrode B to electrode A
B.	Cathode	Anode	H^+ moving from electrode B to electrode A
C.	Cathode	Anode	OH^- moving from electrode A to electrode B
D.	Anode	Cathode	H^+ moving from electrode A to electrode B

Question 8
Which one of the following gaseous hydrocarbons will release the most carbon dioxide when burnt completely to provide 5 MJ of energy at SLC?
A. Butane, C_4H_{10}.
B. Ethane, C_2H_6.
C. Methane, CH_4.
D. Propane, C_3H_8.

Question 9
What would be the minimum mass of methanol required to be completely burnt to raise the temperature of 250.0 mL of water from 22.3 °C to 48.6 °C?
A. 1.02 g
B. 1.21 g
C. 2.23 g
D. 3.25 g

Question 10
The silver oxide button cell used in some calculators provides a very steady voltage of 1.5 V over its lifespan. The overall discharge can be represented by the chemical equation

$$Zn(s) + Ag_2O(s) + H_2O(l) \rightarrow Zn(OH)_2(s) + Ag(s)$$

The composition of the anode, cathode and electrolyte in this cell will be

	Anode	Cathode	Electrolyte
A.	Silver oxide/graphite	Zinc powder	Potassium hydroxide paste
B.	Zinc powder	Silver oxide/graphite	Ammonium chloride paste
C.	Zinc powder	Silver oxide/graphite	Potassium hydroxide paste
D.	Silver oxide/graphite	Zinc powder	Ammonium chloride paste

Question 11
The complete combustion of ethane, at SLC, can be represented by the chemical equation

$$2C_2H_6(g) + 7O_2(g) \rightarrow 4CO_2(g) + 6H_2O(l)$$

Dry air contains 20.9 % oxygen by volume. What is the minimum volume of dry air at SLC that would be needed to completely burn 2.956 g of ethane?
A. 1.79 L
B. 8.55 L
C. 40.9 L
D. 81.8 L

Question 12
A renewable fuel source is one that
A. can be replaced by an industrial process within a relatively short time period.
B. removes greenhouse gases from the atmosphere when the feedstock is grown.
C. does not emit greenhouse gases when it is consumed.
D. can be replaced by a natural process within a relatively short time period.

End of Section A

VCE Chemistry 2018 Year 12 Unit 3 – Unit Test 1

How can chemical processes be designed to optimise efficiency?

Area of Study 1 – What are the options for energy production?

SECTION B – Short Answer Questions

(33 marks)

This section contains four questions, numbered 1 to 4.
All questions should be answered in the spaces provided.
The mark allocations for each question are given.

Question 1 (9 marks)
Figure 3 shows how a group of students set up their equipment to investigate the heat of combustion for a hydrocarbon gas. The gas that they used was a product available from the local hardware store that was used in camping stoves.

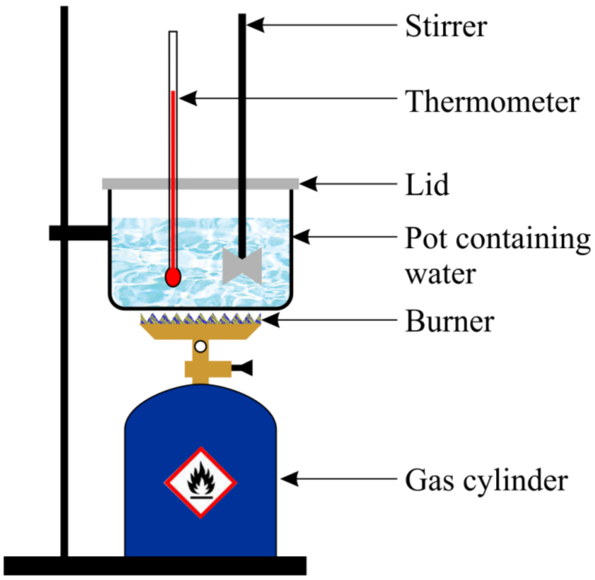


Figure 3

The data that the students recorded from their experiment are shown below.

Mass of pot	184.56 g
Mass of pot plus water	1363.03 g
Initial mass of gas cylinder plus burner	635.94 g
Initial temperature of water	25.78 °C
Final mass of gas cylinder plus burner	631.79 g
Maximum temperature reached	51.84 °C

a. Determine the amount of energy absorbed, in kJ, by the water. **2 marks**

b. Determine the heat of combustion for the fuel. **2 marks**

c. Explain why the heat of combustion for this fuel must be expressed in terms of kJ g^{-1} rather than kJ mol^{-1}. **1 mark**

d. The hydrocarbon gases that are commonly used in this type of product are butane and propane. Give **two** reasons why the value for the heat of combustion that the students calculated was significantly different from the heats of combustion for either butane or propane. **2 marks**

e. If the fuel had been pure butane, what would be the efficiency of the burner in heating the water? **1 mark**

f. Give one way that the students could improve the reliability of their result. **1 mark**

Question 2 (8 marks)
A student, as part of an experimental investigation of galvanic cells, constructed a cell using $Fe^{3+}(aq)/Fe^{2+}(aq)$ and $Br_2(l)/Br^-(aq)$ half-cells as shown in **Figure 4**.

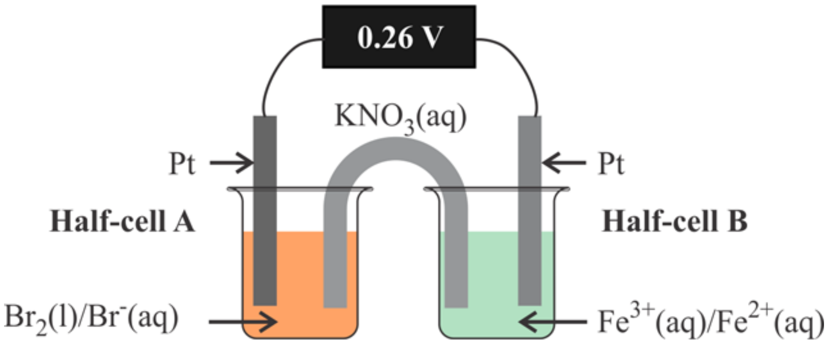


Figure 4

a. Explain what charges would be on the electrodes and the half-reactions that would occur in each of the half-cells. **2 marks**

b. Write an appropriate chemical equation to describe the reaction that would occur when this cell is delivering a current. **1 mark**

c. Explain which way the cations and anions would flow through the salt bridge. **1 mark**

d. Determine the maximum voltage that this cell would deliver. **1 mark**

e. The student observed that the cell they constructed delivered 0.26 V.
Provide an explanation as to why this was different to the voltage determined in **Question 2d.** **1 mark**

f. Explain the effect that replacing the platinum electrode in half-cell B with an iron electrode would have on:

i. The maximum voltage that the cell could deliver. **1 mark**

ii. The reaction that would occur in the cell. **1 mark**

Question 3 (11 marks)

a. One of the hydrocarbon compounds present in petrodiesel is duodecane, $C_{12}H_{26}$. The molar heat of combustion for liquid duodecane is 8090 kJ mol^{-1} at SLC.

i. Write an appropriate thermochemical equation to describe the complete combustion of duodecane. **2 marks**

ii. The combustion of carbon and carbon monoxide can be described by the thermochemical equations

$CO(g) + \frac{1}{2}O_2(g) \rightarrow CO_2(g) \qquad \Delta H_c = -283 \text{ kJ mol}^{-1}$

$C(s) + O_2(g) \rightarrow CO_2(g) \qquad \Delta H_c = -394 \text{ kJ mol}^{-1}$

In an incomplete combustion reaction of duodecane, water, carbon dioxide, carbon monoxide and carbon were present in the emissions. The amounts of carbon dioxide, carbon monoxide and carbon were in the mole ratio 8:3:1 respectively. What amount of energy would be available at SLC when one mole of duodecane is burnt under these conditions? **3 marks**

b. Biodiesel is a renewable fuel that can be made from various fats and oils. The main fatty acid present in canola oil is oleic acid.

i. Explain the basic chemical process used to convert fats and oils into biodiesel. **1 mark**

ii. What would be the chemical formula for the compound formed from oleic acid that would be present in the biodiesel? **1 mark**

iii. The National Institute of Standards and Technology lists the enthalpy of combustion for this compound as $\Delta H_c = -11800 \text{ kJ mol}^{-1}$.
Explain how the energy available from this material compares with the energy released by petrodiesel. **2 marks**

iv. Explain why it would be a disadvantage to use biodiesel to replace petrodiesel in vehicles used during winter on the Victorian ski fields? **2 marks**

Question 4 (5 marks)

Figure 5 shows a cross-sectional schematic for the zinc-air cell. This cell contains zinc powder and a potassium hydroxide electrolyte. There is a small hole in the bottom of the cell to allow air to be drawn in. The cell produces 1.4 V and is often used in hearing aids. When the cell is discharging, zinc oxide is formed.

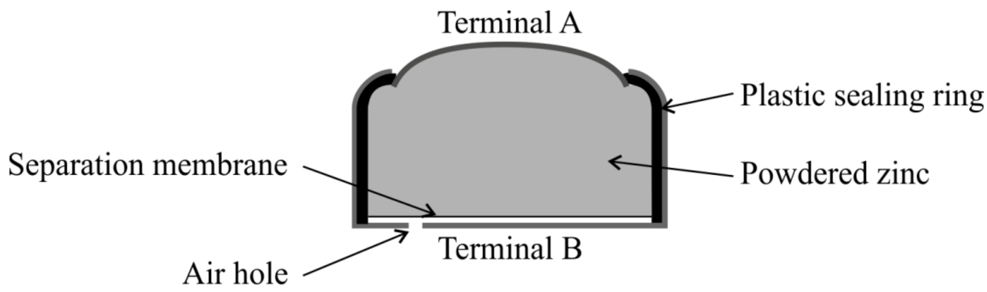


Figure 5

a. What would be the charge on Terminal B when the cell is discharging? **1 mark**

b. Write an appropriate half-equation for the formation of zinc oxide when the cell is discharging. **1 mark**

c. Write an appropriate chemical equation for the discharge reaction. **1 mark**

d. Explain why this cell could be considered as a fuel cell. **1 mark**

e. A material that will absorb carbon dioxide from the air is between the separation membrane and Terminal B. Explain why this material would need to be present in the cell. **1 mark**

End of Section B

End of Unit Test

Suggested Answers

VCE Chemistry 2018 Year 12 Unit 3 – Unit Test 1

How can chemical processes be designed to optimise efficiency?

Area of Study 1 – What are the options for energy production?

SECTION A – Multiple Choice Answers

(1 mark per question)

Q1 B Referring to Heats of combustion of common fuels, ***Table 11: VCE Chemistry Data Book***, the heat of combustion for hydrogen gas equals 141 kJ g^{-1}.
1.00 kg = 1000 g therefore
Energy available = 141 × 1000 = 141000 kJ = 141 MJ

$$\text{Efficiency} = \frac{\text{Energy obtained}}{\text{Energy available}} \times \frac{100}{1} = \frac{65}{141} \times \frac{100}{1} = 46\ \%$$

Q2 A The positive electrode in a galvanic cell will be the cathode and reduction will occur at this electrode.
The oxidation state for vanadium in the $VO^{2+}(aq)$ and $VO_2^+(aq)$ ions are +4 and +5 respectively. Therefore $VO_2^+(aq)$ is being reduced to $VO^{2+}(aq)$ when the cell is discharging.

$$VO_2^+(aq) \rightarrow VO^{2+}(aq)$$

$$VO_2^+(aq) \rightarrow VO^{2+}(aq) + H_2O(l)$$

$$VO_2^+(aq) + 2H^+(aq) \rightarrow VO^{2+}(aq) + H_2O(l)$$

$$VO_2^+(aq) + 2H^+(aq) + e^- \rightarrow VO^{2+}(aq) + H_2O(l)$$

Note: While Response C also shows the reduction of the VO_2^+ ion to the VO^+ ion, the formation of oxide ions, O^{2-}, in aqueous solutions is not likely, especially if an acidic environment is assumed. Therefore Response A is the better answer.

Q3 D $m(CO_2)$ = 2.200 g; $M(CO_2)$ = 12.0 + 2×16.0 = 44.0 g mol^{-1}
V = 2.00 L; T = 273 + 83.5 = 356.5 K
$n(CO_2)$ = m/M = 2.200 / 44.0 = 0.0500 mol
Using the General Gas Equation: PV = nRT

$$P = \frac{nRT}{V} = \frac{0.0500 \times 8.31 \times 356.5}{2.00} = 74.1\ \text{kPa}$$

P = 74.1 × (0.987/100) = 0.731 atm
P = 74.1 × (750/100) = 555 mmHg

Q4 **A** Reduction is occurring at the tin electrode, therefore oxidation will be occurring in the $Cr^{3+}(aq)/Cr^{2+}(aq)$ half-cell.
Therefore $Cr^{3+}(aq)$ is a weaker oxidant than $Sn^{2+}(aq)$.
The voltage produced by the cell is the difference between the two standard electrode potentials for the half-cells.
Referring to The Electrochemical Series, ***Table 2: VCE Chemistry Data Book***, the E° for the standard $Sn^{2+}(aq)/Sn(s)$ half-cell = -0.14 V.
$E°(Cr^{3+}(aq)/Cr^{2+}(aq)) = -0.14 – 0.28 = -0.42$ V

Q5 **B** Total energy available = 33800 × 50 = 1.7×10^6 kJ = 1.7×10^3 MJ
Useful energy = energy available × efficiency
Useful energy = $1.7\times10^3 \times (26/100) = 4.4\times10^2$ MJ

Q6 **C** Since it is a combustion reaction it will be exothermic.
Referring to Heats of combustion of common fuels, ***Table 11: VCE Chemistry Data Book***, $\Delta H_c = -282$ kJ mol^{-1}.
Therefore the energy of the reactants is greater than the energy of the products.
Some energy has to be applied to a mixture of hydrogen gas and air (or oxygen gas) for the reaction to proceed. This is the activation energy. For the forward reaction this is the energy required to break the hydrogen-hydrogen single bonds and the oxygen-oxygen double bonds.
The energy profile in Response C best fulfils these criteria, since the magnitude of the ΔH is the same in all four responses.

Q7 **D** Fuel cells are electrochemical cells, with oxidation occurring at the anode and reduction occurring at the cathode. Additionally the fuel cell involves a galvanic, spontaneous, process, therefore the anode will have the negative charge and the cathode will have the positive charge.
Referring to The Electrochemical Series, ***Table 2: VCE Chemistry Data Book***, hydrogen is the stronger reductant and oxygen the stronger oxidant.
Hydrogen will be oxidised at the anode, which will be Electrode A.
Oxygen will be reduced at the cathode, which will be Electrode B.
Since it is a proton exchange membrane fuel cell, then the H^+ ions formed at Electrode A will migrate through the membrane to Electrode B.

Q8 **A** Referring to Heats of combustion of common fuels, ***Table 11: VCE Chemistry Data Book***, to obtain the heats of combustion for the four fuels.
The complete combustion of one mole of methane, ethane, propane and butane will release one, two, three and four mole of carbon dioxide respectively.
Therefore the energy released per mole of carbon dioxide for the four fuels will be:
Methane: E(per mole CO_2) = 890 kJ
Ethane: E(per mole CO_2) = 1560/2 = 780 kJ
Propane: E(per mole CO_2) = 2200/3 = 740 kJ
Butane: E(per mole CO_2) = 2880/4 = 720 kJ
Therefore butane will release the largest amount of carbon dioxide when it is completely burnt to provide 5 MJ of energy.
$n(CO_2) = (5 \times 1000) / 720 = 6.9$ mol

Q9 B Referring to Heats of combustion of common fuels, ***Table 11: VCE Chemistry Data Book***, to obtain the heats of combustion for methanol.

Heat of combustion(methanol) = 22.7 kJ g^{-1}

$\Delta T = 48.6 - 22.3 = 26.3$ °C

$m(H_2O) = 250.0 \times 0.997 = 249$ g

Energy required to increase the temperature of the water by 1 °C

CF = $249 \times 4.18 = 1040$ J $°C^{-1}$

E = $1040 \times 26.3 = 27400$ J = 27.4 kJ

$m(CH_3OH) = 27.4 / 22.7 = 1.21$ g

Q10 C The chemical equation for the discharge reaction is

$$Zn(s) + Ag_2O(s) + H_2O(l) \rightarrow Zn(OH)_2(s) + Ag(s)$$

The zinc is being oxidised to zinc(II) ions, therefore the anode will need to contain the zinc.

The silver oxide is being reduced to silver, therefore this needs to be at the cathode. Since the oxide will not be a conductor, a conducting material such as graphite will need to be present.

Since one of the products of the reaction is zinc hydroxide, the electrolyte will need to be basic. A potassium hydroxide paste will be basic, whereas an ammonium chloride paste will be acidic.

Q11 C $m(C_2H_6) = 2.956$ g; $M(C_2H_6) = 2\times12.0 + 6\times1.0 = 30.0$ g mol^{-1}

$$2C_2H_6(g) + 7O_2(g) \rightarrow 4CO_2(g) + 6H_2O(l)$$

$n(C_2H_6) = m/M = 2.956 / 30.0 = 9.85\times10^{-2}$ mol

$n(O_2) = {}^{7}/{}_{2}n(C_2H_6) = ({}^{7}/{}_{2}) \times 9.85\times10^{-2} = 3.45\times10^{-1}$ mol

$V(O_2, SLC) = n\times V_m = 3.45\times10^{-1} \times 24.8 = 8.55$ L

$V(air,SLC) = V(O_2, SLC) / (\%O_2 \text{ by vol.}) = 8.55 / (20.9/100) = 40.9$ L

Q12 D A renewable fuel source is one that can be replaced by a natural process within a relatively short time period.

For example; growing corn to produce bioethanol.

SECTION B – Short Answer (Answers)

Question 1 (9 marks)

a. $m(H_2O) = 1363.03 – 184.56 = 1178.47$ g

$CF = m(H_2O) \times c(H_2O) = 1178.47 \times 4.18 = 4.93 \times 10^3$ J °C^{-1} = 4.93 kJ °C^{-1} **(1 mark)**

$\Delta T = 51.84 – 25.78 = 26.06$ °C

$E = CF \times \Delta T = 4.93 \times 26.06 = 1.28 \times 10^2$ kJ **(1 mark)**

b. m(Fuel) = 635.94 - 631.79 = 4.15 g **(1 mark)**

Heat of combustion = E/m = $1.28 \times 10^2 / 4.15 = 30.9$ kJ g^{-1} **(1 mark)**

c. As the composition of the gas is unknown then the molecular formula and the molar mass cannot be determined, therefore the heat of combustion must be quoted as the amount of energy released for a given unit of mass of the fuel, kJ g^{-1} **(1 mark)**.

d. Possible answers include:

[Mark allocation: 1 mark for suitable answer. Total: 2 marks]

Incomplete combustion is occurring in the burner flame; therefore less energy will be available from the combustion reaction.

Some of the energy released by the combustion reaction is being used to increase the temperature of the environment.

Energy released by the burner is being used to increase the temperature of the container which has not been included in the calculations.

The energy released by the reaction will be less than that in the data table (SLC) as the water formed is most likely to remain a gas and not a liquid.

e. Referring to Heats of combustion of common fuels, ***Table 11: VCE Chemistry Data Book***, the heat of combustion for butane = 49.7 kJ g^{-1}

Efficiency = Actual / Expected = $30.9/49.7 \times 100/1 = 62.2$ % **(1 mark)**

f. To improve the reliability of the results the students would need to repeat the experiment two or three times to obtain consistent data **(1 mark)**.

The masses of water and fuel used can be varied as these could be considered as the independent variables.

The temperature increase of the water would be the dependent variable.

The fuel used, water container, type of burner and distance between burner head and container should be treated as the controlled variables and kept constant.

Question 2 (8 marks)

a. Referring to The Electrochemical Series, ***Table 2: VCE Chemistry Data Book***, the two appropriate half-reactions and their E° values are:

$$Br_2(l) + 2e^- \rightleftarrows 2Br^-(aq) \qquad E^\circ = +1.09\ V$$

$$Fe^{3+}(aq) + e^- \rightleftarrows Fe^{2+}(aq) \qquad E^\circ = +0.77\ V$$

From these data, the $Br_2(l)$ would be the oxidant and the $Fe^{2+}(aq)$ would be the reductant.

In Half-cell A, the bromine, $Br_2(l)$ would be reduced to bromide ions, $Br^-(aq)$, and since reduction is occurring, the charge on the electrode would be **positive**.

$Br_2(l) + 2e^- \rightarrow 2Br^-(aq)$ **(1 mark)**

Since this is a galvanic cell the electrode will be the cathode.

In Half-cell B, the iron(II) ions, $Fe^{2+}(aq)$, will be oxidised to iron(III) ions, $Fe^{3+}(aq)$, and since oxidation is occurring, the charge on the electrode would be **negative**.

$Fe^{2+}(aq) \rightarrow Fe^{3+}(aq) + e^-$ **(1 mark)**

The electrode would be the anode.

b. The overall equation for the reaction that would occur when the cell is delivering a current is the sum of the two half-cell reactions adjusted to ensure that the number of electrons consumed and produced are equal.

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

$$(Fe^{2+}(aq) \rightarrow Fe^{3+}(aq) + e^-) \times 2$$

$Br_2(l) + 2Fe^{2+}(aq) \rightarrow 2Br^-(aq) + 2Fe^{3+}(aq)$ **(1 mark)**

c. Since Half-cell A contains the cathode then the cations, $K^+(aq)$, will flow through the salt bridge into this half-cell, and the anions, $NO_3^-(aq)$, will flow into Half-cell B **(1 mark)**.

Bromide ions, $Br^-(aq)$, are being formed in Half-cell A, therefore to maintain charge neutrality in this solution, cations must flow into this half-cell. In Half-cell B, iron(II) ions, $Fe^{2+}(aq)$, are being oxidised to iron(III)ions, $Fe^{3+}(aq)$, so anions must flow into this half-cell to maintain charge neutrality.

d. The maximum voltage that the cell can produce is the difference between the two standard electrode potentials.

E = 1.09 – 0.77 = 0.32 V **(1 mark)**.

e. The maximum voltage is calculated from the standard electrode potentials at SLC. In this cell it would require that the concentrations of the four species involved have concentrations of 1.0 M. Deviations from the standard conditions can alter the voltage that the cell will produce, as it most likely has in this experimental investigation **(1 mark)**.

f. Referring to The Electrochemical Series, ***Table 2: VCE Chemistry Data Book***, it can be determined that changing the platinum electrode in Half-cell B to an iron electrode will now have iron as the stronger reductant.

$$Fe^{2+}(aq) + 2e^- \rightleftarrows Fe(s) \qquad E^\circ = -0.44\ V$$

i. The maximum voltage that could be produced would be
E = 1.09 – (-0.44) = 1.53 V **(1 mark)**

ii. The reaction in Half-cell A will remain unchanged, while in Half-cell B the iron will be oxidised to iron(II) ions **(1 mark)**.

Half-cell B: $Fe(s) \rightarrow Fe^{2+}(aq) + 2e^-$

Overall: $Br_2(l) + Fe(s) \rightarrow 2Br^-(aq) + Fe^{2+}(aq)$

Some oxidation of the iron(II) ions to iron(III) ions will still occur, however the oxidation of the iron will be the dominant reaction as this is the stronger reductant.

Question 3 (11 marks)

a. **i.** The products of the complete combustion of a hydrocarbon are carbon dioxide and water.

Systematically develop the equation:

$C_{12}H_{26}(l) + O_2(g) \rightarrow CO_2(g) + H_2O(l)$

Balance carbons:

$C_{12}H_{26}(l) + O_2(g) \rightarrow 12CO_2(g) + H_2O(l)$

Balance hydrogens:

$C_{12}H_{26}(l) + O_2(g) \rightarrow 12CO_2(g) + 13H_2O(l)$

Balance oxygens:

$C_{12}H_{26}(l) + \frac{37}{2}O_2(g) \rightarrow 12CO_2(g) + 13H_2O(l)$

Since the molar coefficient for oxygen is a fraction, then the equation can be multiplied by 2.

$2C_{12}H_{26}(l) + 37O_2(g) \rightarrow 24CO_2(g) + 26H_2O(l)$

The molar heat of combustion is 8090 kJ mol^{-1}, therefore the enthalpy change will be, ΔH_c = -8090 kJ mol^{-1}, for each mole of duodecane.

$C_{12}H_{26}(l) + \frac{37}{2}O_2(g) \rightarrow 12CO_2(g) + 13H_2O(l) \qquad \Delta H_c = -8090 \text{ kJ mol}^{-1}$

$2C_{12}H_{26}(l) + 37O_2(g) \rightarrow 24CO_2(g) + 26H_2O(l) \qquad \Delta H_c = -16180 \text{ kJ mol}^{-1}$

[Mark Allocation: Balanced equation (1 mark), correct ΔH_c (1 mark)]

ii. Complete combustion of one mole of duodecane releases 8090 kJ of energy and 12 mol of carbon dioxide.

$CO_2(g) \rightarrow CO(g) + \frac{1}{2}O_2(g) \qquad \Delta H = +283 \text{ kJ mol}^{-1}$

For each mole of carbon monoxide formed instead of carbon dioxide, 283 kJ less of energy will be released.

Therefore since 3 mol carbon monoxide is formed,

283 × 3 = 849 kJ less of energy will be released **(1 mark)**.

$CO_2(g) \rightarrow C(s) + O_2(g) \qquad \Delta H = +394 \text{ kJ mol}^{-1}$

For each mole of carbon formed instead of carbon dioxide, 394 kJ less of energy is released.

Therefore since 1 mol of carbon is formed, 394 kJ less of energy will be released **(1 mark)**.

Energy released = 8090 – 849 – 394 = 6847 kJ **(1 mark)**.

Alternative solution:

$C_{12}H_{26}(l) + \frac{37}{2}O_2(g) \rightarrow 12CO_2(g) + 13H_2O(l) \qquad \Delta H_c = -8090 \text{ kJ mol}^{-1}$

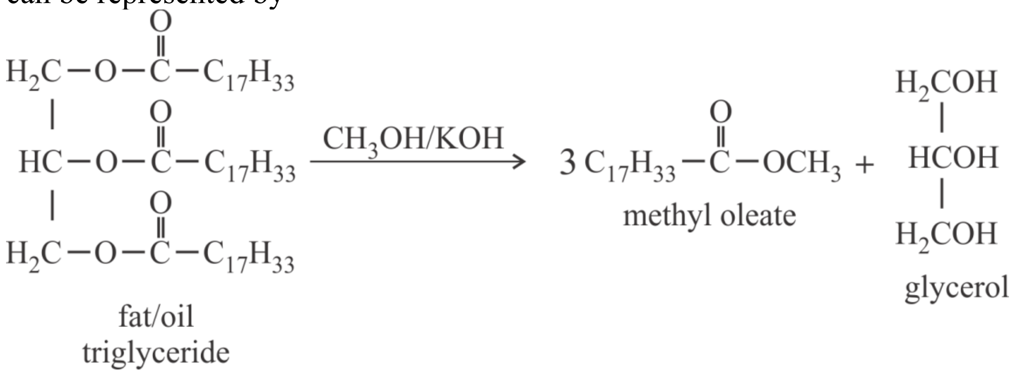
$(CO_2(g) \rightarrow CO(g) + \frac{1}{2}O_2(g) \qquad \Delta H = (+283 \text{ kJ mol}^{-1}) \times 3$

$CO_2(g) \rightarrow C(s) + O_2(g) \qquad \Delta H = +394 \text{ kJ mol}^{-1}$

$C_{12}H_{26}(l) + 16O_2(g) \rightarrow 8CO_2(g) + 3CO(g) + 1C(s) + 13H_2O(l)$

ΔH = -8090 + 849 + 394 = -6847 kJ mol^{-1}

b. **i.** The basic chemical process involved in the conversion of fats and oils into biodiesel is a transesterification reaction where the triglycerides present are converted to methyl esters **(1 mark)**. The by-product of this reaction is glycerol. This reaction is usually carried out by reacting the triglyceride with methanol in the presence of a base such as potassium hydroxide. The reaction can be represented by



ii. The compound would be the methyl ester of oleic acid.
Referring to Formulas of some fatty acids, ***Table 9: VCE Chemistry Data Book***, oleic acid; $C_{17}H_{33}COOH$.
The methyl ester would be: $C_{17}H_{33}COOCH_3 = C_{19}H_{36}O_2$ **(1 mark)**.

iii. Referring to Heats of combustion of common blended fuels, ***Table 12: VCE Chemistry Data Book***, The heat of combustion for diesel = 45.0 kJ g^{-1}.
$M(C_{19}H_{36}O_2) = 19\times12.0 + 36\times1.0 + 2\times16.0 = 296.0$ g mol^{-1}
Energy available per g = 11800 / 296.0 = 39.9 kJ g^{-1} **(1 mark)**.
Therefore the energy available for a given mass of biodiesel would be less than that available from the same mass of petrodiesel **(1 mark)**.

iv. The viscosity of a fuel increases as the temperature is lowered and because there are stronger intermolecular forces between the larger molecules present in biodiesel, it tends to be more viscous when compared to petrodiesel. Fuel transfer issues will therefore have a greater effect for biodiesel at low temperatures, as the liquid will not be able to flow as freely **(1 mark)**.
Also the freezing point of the compounds present in biodiesel are higher, therefore blockages can occur in the fuel lines at low temperatures **(1 mark)**.

Question 4 (5 marks)

a. Referring to The Electrochemical Series, ***Table 2: VCE Chemistry Data Book***, it can be determined that zinc is a strong reductant and oxygen from the air is a strong oxidant.
Since the oxygen (air) is present near Terminal B, then it is the oxygen that will be reduced at this electrode. Reduction occurs at the cathode in electrochemical cells and in a galvanic cell this will be the positive electrode **(1 mark)**.
$O_2(g) + 2H_2O(l) + 4e^- \rightarrow 4OH^-(aq)$ (*From Table 2*)

b. The zinc is being oxidised to zinc oxide, in the presence of a basic (hydroxide ion) electrolyte.

$Zn(s) \rightarrow ZnO(s)$

$Zn(s) + 2OH^-(aq) \rightarrow ZnO(s) + H_2O(l)$

$Zn(s) + 2OH^-(aq) \rightarrow ZnO(s) + H_2O(l) + 2e^-$ **(1 mark)**

Alternative method:

Using the standard acidic environment method, then eliminating $H^+(aq)$ ions using the self ionisation of water equation.

1. $Zn(s) \rightarrow ZnO(s)$
2. $Zn(s) + H_2O(l) \rightarrow ZnO(s)$
3. $Zn(s) + H_2O(l) \rightarrow ZnO(s) + 2H^+(aq)$
4. $Zn(s) + H_2O(l) \rightarrow ZnO(s) + 2H^+(aq) + 2e^-$

4'.
$Zn(s) + H_2O(l) \rightarrow ZnO(s) + 2H^+(aq) + 2e^-$

$2H^+(aq) + 2OH^-(aq) \rightarrow 2H_2O(l)$

$Zn(s) + 2OH^-(aq) \rightarrow ZnO(s) + H_2O(l) + 2e^-$

c. The two half-equations are:

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

Oxidation: $(Zn(s) + 2OH^-(aq) \rightarrow ZnO(s) + H_2O(l) + 2e^-) \times 2$

Overall: $O_2(g) + 2Zn(s) \rightarrow 2ZnO(s)$ **(1 mark)**

d. Because the oxidant is being continually replenished from the surrounding air, this cell can be considered to be a fuel cell **(1 mark)**.

e. Carbon dioxide is an acidic oxide and will react with the hydroxide ions present in the electrolyte, thereby reducing the efficiency of the cell over time **(1 mark)**.

$CO_2(g) + OH^-(aq) \rightarrow HCO_3^-(aq)$

$CO_2(g) + 2OH^-(aq) \rightarrow CO_3^{2-}(aq) + H_2O(l)$

End of Suggested Answers