



VCE CHEMISTRY 2009

YEAR 12 UNIT 4

Supplying & Using Energy

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Time allowed: 50 minutes

Total marks: 46

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.

To download the Chemistry Data Book please visit the VCAA website:

http://www.vcaa.vic.edu.au/vce/studies/chemistry/chem1_sample_2008.pdf Page 20

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Student Name.....

VCE Chemistry 2009 Year 12 Unit 4 - Supplying & Using Energy

Student Answer Sheet

Instructions for completing test. Use only a 2B pencil. If you make a mistake erase and enter the correct answer. Marks will not be deducted for incorrect answers.

Write your answers to the Short Answer Section in the space provided directly below the question. There are 12 Multiple Choice questions to be answered by circling the correct letter in the table below.

Question 1 A B C D

Question 3 A B C D

Question 5 A B C D

Question 7 A B C D

Question 9 A B C D

Question 11 A B C D

Question 2 A B C D

Question 4 A B C D

Question 6 A B C D

Question 8 A B C D

Question 10 A B C D

Question 12 A B C D

VCE Chemistry 2009 Year 12 Unit 4 - Supplying & Using Energy

Multiple Choice Questions

Section A – (12 marks, 13 minutes)

*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

When a piece of nickel foil is placed in an aqueous solution of lead(II) nitrate

- A. no reaction will occur.
- B. the nickel atoms will lose electrons and the lead(II) ions will be reduced.
- C. the nickel atoms will gain electrons and the lead(II) ions will be reduced.
- D. the nickel atoms will lose electrons and the lead(II) ions will be oxidised.

Question 2

In a nuclear fission reaction the energy released is the result of

- A. breaking apart the nuclei present in the fuel so that they are not joined to each other.
- B. joining the smaller nuclei present in the fuel to form larger nuclei.
- C. rearranging the bonds present in the fuel to form new compounds.
- D. splitting the nuclei present in the fuel to form smaller nuclei.

Question 3

A solution calorimeter containing 250.0 mL of deionised water was electrically calibrated by passing a 2.36 A current at 5.67 V through a heating coil for 10.00 minutes. This resulted in a 6.39 °C temperature change for the calorimeter and its contents.

The calibration factor for this calorimeter and its contents is

- A. 2094 kJ mol⁻¹
- B. 532 kJ mol⁻¹
- C. 1260 kJ mol⁻¹
- D. 8030 kJ mol⁻¹

Question 4

The reaction between zinc metal and copper(II) ions can be represented by the thermochemical equation



When 1.365 g of zinc metal was added to 100.0 mL of 0.25 M copper(II) sulfate in a calorimeter with a calibration factor of 495 J °C⁻¹, the temperature would

- A. decrease by 11.0 °C.
- B. increase by 9.19 °C.
- C. increase by 11.0 °C.
- D. decrease by 9.19 °C.

Question 5

A bomb calorimeter would not be a suitable instrument to determine

- A. the enthalpy change for the combustion of a gaseous hydrocarbon.
- B. the total energy available from a commercial food product.
- C. the enthalpy change for an acid-base reaction.
- D. the energy available from a sample of brown coal.

Question 6

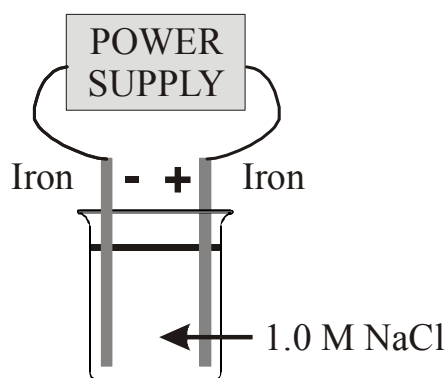
Methane can be used in some fuel cells to produce electricity. Alternatively, a generator can be driven using an internal combustion engine, fuelled by methane. The advantage of using the fuel cell to produce electricity over the alternative method is that

- A. methane fuelled internal combustion engines are expensive to operate and maintain.
- B. the fuel cell converts the chemical energy directly to electrical energy.
- C. the power from a generator can vary while that from a fuel cell is regular.
- D. the fuel cell would produce no greenhouse gas emissions.

Question 7

An electrolytic cell was set as shown in the diagram. When this cell is initially connected to the external power supply,

- A. iron will be oxidised at the positive electrode.
- B. hydrogen gas will be formed at the positive electrode.
- C. oxygen gas will be formed at the negative electrode.
- D. chlorine gas will be formed at the positive electrode.



Question 8

For a discharging galvanic cell, use of the electrochemical series will **not** be helpful in determining the

- A. potential difference for the cell.
- B. identity of the oxidant and reductant in the cell.
- C. direction of ion flow in the salt bridge.
- D. current flowing through the external circuit.

Question 9

Which one of the following fuels would provide the most energy for a given mass of fuel?

- A. Butane, C_4H_{10} .
- B. Carbon, C .
- C. Octane, C_8H_{18} .
- D. Ethanol, C_2H_5OH .

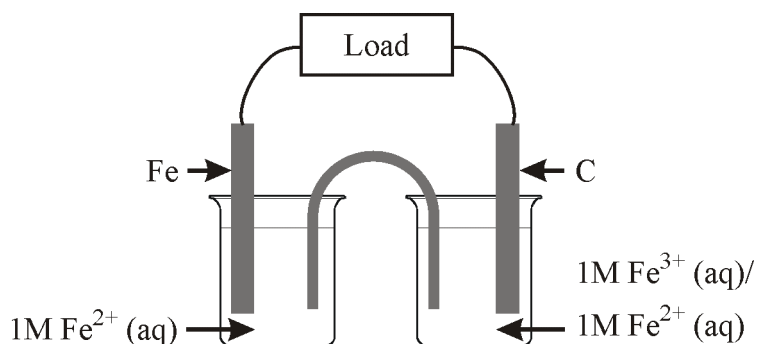
Question 10

The electrolysis of an aqueous solution containing metal(II) ions over a 10.0 minute period, using a current of 1.27 A, resulted in the cathode mass increasing by 0.469 g. The metal formed at the cathode would be

- A. copper.
- B. nickel.
- C. lead.
- D. tin.

Questions 11 and 12 refer to the following information.

The diagram below shows a galvanic cell that was constructed from the Fe^{2+}/Fe and $\text{Fe}^{3+}/\text{Fe}^{2+}$ half-cells.

**Question 11**

Which one of the following is correct when this cell is discharging?

	Reaction occurring in the Fe^{2+}/Fe half-cell	Reaction occurring in the $\text{Fe}^{3+}/\text{Fe}^{2+}$ half-cell	Ions flowing into the Fe^{2+}/Fe half-cell from salt bridge
A.	Reduction	Oxidation	Cations
B.	Oxidation	Reduction	Cations
C.	Reduction	Oxidation	Anions
D.	Oxidation	Reduction	Anions

Question 12

The potential difference for this cell during discharge would be

- A. 1.21 V.
- B. 0.33 V.
- C. 1.65 V.
- D. 1.98 V.

End of Section A

VCE Chemistry 2009 Year 12 Unit 4 - Supplying & Using Energy

Short Answer Questions

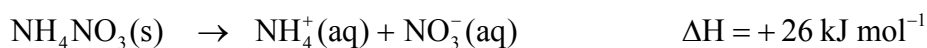
Section B – (34 marks, 37 minutes)

*This section contains four questions, numbered 1 to 4.
All questions should be answered in the spaces provided.
The mark allocation and approximate time that should be spent on each question are given.*

Question 1 (8 marks, 9 minutes)

A group of students constructed a simple solution calorimeter using a polystyrene cup, stirrer and thermometer.

When they dissolved 15.28 g of ammonium nitrate in 100.0 mL of deionised water, the temperature decreased by 10.2 °C. The dissolution of ammonium nitrate in water can be represented by the thermochemical equation

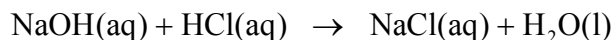


- a. What is the calibration factor for this calorimeter?

(3 marks)

- b. The students then used the calorimeter calibrated in a. above to determine the enthalpy change when 50.00 mL of 1.00 M sodium hydroxide solution is neutralised by 50.00 mL of 1.00 M hydrochloric acid solution. Both solutions were initially at 19.3 °C and when mixed in the calorimeter the temperature increased to 25.1 °C.
- i. Calculate the energy change that occurred in this reaction.

- ii. Calculate the enthalpy change for the reaction represented by the chemical equation



- iii. Another group of students in the class used 50.00 mL of 1.00 M potassium hydroxide solution in place of the sodium hydroxide solution. Explain how their enthalpy change results should compare with those of the first group.

(1 + 2 + 1 = 4 marks)

- c. A third group of students followed a similar procedure to the first group to determine the calibration factor for their calorimeter. But in determining the enthalpy change for the neutralisation reaction, they used 25.00 mL of 1.00 M sulfuric acid solution as this would completely neutralise the 50.00 mL of 1.00 M sodium hydroxide solution. Explain the error in this procedure.

(1 mark)

Question 2 (9 marks, 10 minutes)

- a. What half-cell are all other half-cell standard electrode potentials measured relative to?

(1 mark)

- b. A galvanic cell was constructed by combining the vanadyl/vanadium(III), $\text{VO}^{2+}(\text{aq})/\text{V}^{3+}(\text{aq})$, half-cell with the $\text{Zn}^{2+}(\text{aq})/\text{Zn(s)}$ half-cell. When this cell was discharging, the charge on the electrode in the $\text{Zn}^{2+}(\text{aq})/\text{Zn(s)}$ half-cell had a negative charge and the potential difference produced under standard conditions was 1.10 V.
- i. What would the electrode in the vanadyl/vanadium(III) half-cell be made from?

- ii. What is the oxidant in this reaction?

- iii. Write appropriate chemical half-equations for the reactions occurring in both half-cells when this cell is discharging.

- iv. Write an appropriate chemical equation for the overall reaction that occurs when this cell is discharging.

- v. What is the standard electrode potential for the vanadyl/vanadium(III) half-cell?

(1 + 1 + 2 + 1 + 1 = 6 marks)

- c. During the discharge of a galvanic cell containing the $\text{Ni}^{2+}(\text{aq})/\text{Ni}(\text{s})$ half-cell, the mass of the nickel electrode decreased by 0.470 g over a 3.00 hour period. What current did the cell deliver during this period?

(2 marks)

Question 3 (10 marks, 11 minutes)

Petrol-bioethanol fuel blends are now readily available at many service stations around Australia, and can be used in most cars to replace unleaded petrol.

Assume that unleaded petrol consists of octane only.

- a. Calculate the following:
- The amount of energy available from 1.00 kg of octane.
 - The amount of carbon dioxide released by 1.00 kg of octane.
 - The amount of energy available from 1.00 kg of a blended fuel that contained 10.0 % ethanol by mass.
 - The amount of carbon dioxide released by 1.00 kg of the blended fuel that contained 10.0 % ethanol by mass.
 - The amount of carbon dioxide released by a mass of the 10.0 % ethanol blended fuel, so that it released the same amount of energy as that released by 1.00 kg of octane.

(2 + 1 + 2 + 2 + 1 = 8 marks)

- b. i. What is one advantage of using a petrol-ethanol blended fuel in place of unleaded petrol?
- ii. What is one disadvantage of using a petrol-ethanol blended fuel in place of unleaded petrol?

1 + 1 = (2 marks)

Question 4 (7 marks, 7 minutes)

Solar energy is considered by some people as being the best alternative energy source. However, often the energy is required at night or at distances remote from the photovoltaic cells or as a portable energy source. One proposal to overcome these is to produce hydrogen by the electrolysis of dilute aqueous acid solutions.

- a. What energy transformations would occur in this process of converting the energy from the Sun into hydrogen?

(1 mark)

- b. Write the chemical half-equations for the reactions that occur during the electrolysis of an aqueous sulfuric acid solution using unreactive electrodes.

(1 mark)

- c. Explain why the pH of the solution would not alter significantly during the electrolysis, if the electrolyte volume was kept the same by the addition of water.

(1 mark)

- d. A laboratory investigation was set up using a small photovoltaic cell that produced an average current of 0.70 A over a 6.0 hour period. This current was passed through four electrolytic cells containing unreactive electrodes as shown in the diagram.



What would be the combined volume of hydrogen produced at SLC after the 6.0 hour period?

(3 marks)

- e. What would be one advantage of producing hydrogen gas by this process?

(1 mark)

End of Section B

End of Unit Test

Suggested Answers

VCE Chemistry 2009 Year 12 Unit 4 - Supplying & Using Energy

Multiple Choice Questions - Section A

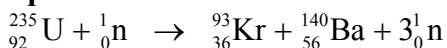
(1 mark per question)

- Q1 B **The relevant chemical equations from the Electrochemical Series, Table 2:**



Nickel metal is the stronger reductant, therefore when placed in a solution containing lead(II) ions it **will be oxidised and lose electrons to form nickel(II) ion, Ni^{2+}** . The **lead(II) ions will be reduced** as they accept electrons to form lead.

- Q2 D **A nuclear fission reaction involves splitting the nuclei present in the fuel to form smaller nuclei. For example, a nuclear reaction that occurs when uranium-235 undergoes a fission reaction can be represented by the nuclear equation**



- Q3 C **The energy supplied to the heating coil is given by: $E = VIt$**

$$E = 5.67 \times 2.36 \times (10.00 \times 60) = 8030 \text{ J}$$

The **calibration factor, cf**, is the **amount of energy required to change the temperature of the calorimeter and its contents by 1.0°C** .

$$\text{cf} = 8030 / 6.39 = \mathbf{1260 \text{ J }^{\circ}\text{C}^{-1}}$$

- Q4 B $\text{Zn}(\text{s}) + \text{Cu}^{2+}(\text{aq}) \rightarrow \text{Zn}^{2+}(\text{aq}) + \text{Cu}(\text{s}) \quad \Delta H = -218 \text{ kJ mol}^{-1}$

$$n(\text{Zn}) = m / M = 1.365 / 65.4 = 2.09 \times 10^{-2} \text{ mol}$$

$$n(\text{Cu}^{2+}) = c \times V = 0.25 \times (100.0/1000) = 2.50 \times 10^{-2} \text{ mol}$$

Since the reaction stoichiometry is 1:1 then the limiting reagent will be the zinc metal.

The reaction is exothermic because the ΔH is less than zero. From the thermochemical equation, 218 kJ of energy will be released when 1 mol of zinc reacts

$$E = n \times 218 = 2.09 \times 10^{-2} \times 218 = 4.55 \text{ kJ} = 4550 \text{ J}$$

$$\Delta T = E / \text{cf} = 1550 / 495 = 9.19^{\circ}\text{C}$$

Since the reaction is exothermic the temperature will **increase by 9.19°C** .

- Q5 C **Bomb calorimeters are designed for the combustion reactions where the products are generally in the gaseous phase. Therefore a bomb calorimeter would not be suitable for determining the enthalpy change for an acid-base reaction which usually takes place in the aqueous solution phase.**

- Q6 B **A fuel cell directly converts the chemical energy from the reaction into electrical energy and is therefore more efficient than other methods of electrical generation that involve multiple energy conversions.**

- Q7 A **The relevant chemical equations from the electrochemical series are:**
- $$\text{Cl}_2(\text{g}) + 2\text{e}^- \rightleftharpoons 2\text{Cl}^-(\text{aq}) \quad E^\circ = +1.36 \text{ V}$$
- $$\text{O}_2(\text{g}) + 2\text{H}^+(\text{aq}) + 2\text{e}^- \rightleftharpoons 2\text{H}_2\text{O}(\text{l}) \quad E^\circ = +1.23 \text{ V}$$
- $$\text{Fe}^{2+}(\text{aq}) + 2\text{e}^- \rightleftharpoons \text{Fe}(\text{s}) \quad E^\circ = -0.44 \text{ V}$$
- $$2\text{H}_2\text{O}(\text{l}) + 2\text{e}^- \rightleftharpoons 2\text{OH}^-(\text{aq}) + \text{H}_2(\text{g}) \quad E^\circ = -0.83 \text{ V}$$
- $$\text{Na}^+(\text{aq}) + \text{e}^- \rightleftharpoons \text{Na}(\text{s}) \quad E^\circ = -2.71 \text{ V}$$
- In an electrolytic cell, oxidation occurs at the positive electrode and reduction at the negative electrode.**
- The strongest reductant in this cell is the **iron electrode which will be oxidised at the positive electrode.**
- The strongest oxidant present initially is water which will be reduced at the negative electrode to form hydrogen gas and hydroxide ions.**
- The initial reaction for this cell will be given by the chemical equation**
- $$\text{Fe}(\text{s}) + 2\text{H}_2\text{O}(\text{l}) \rightarrow \text{Fe}^{2+}(\text{aq}) + 2\text{OH}^-(\text{aq}) + \text{H}_2(\text{g})$$
- After the cell has been operating for some time, the iron(II) ions would migrate towards the negative electrode, however it is unlikely that these will be reduced to any extent as they would react with the hydroxide ions to form insoluble iron(II) hydroxide.**
- $$\text{Fe}^{2+}(\text{aq}) + 2\text{OH}^-(\text{aq}) \rightarrow \text{Fe}(\text{OH})_2(\text{s})$$
- Q8 D **The main limitation that the electrochemical series has in predicting redox reactions is that it does not provide any information about the rate at which the reaction occurs.** The current flowing through the external circuit is the flow of electrons per second, **therefore is directly related to the rate of reaction.**
- Q9 A **The molar enthalpies of combustion are found in Table 13. These can be used to determine the amount of energy released per gram of fuel.**
- A. Butane, C_4H_{10} : $M = 4 \times 12.0 + 8 \times 1.0 = 58.0 \text{ g mol}^{-1}$
 1 mol releases 2874 kJ of energy
 1 g releases $2874 / 58.0 = 49.6 \text{ kJ g}^{-1}$.
- B. Carbon, C: $M = 12.0 \text{ g mol}^{-1}$
 1 mol releases 394 kJ of energy
 1 g releases $394 / 12.0 = 32.8 \text{ kJ g}^{-1}$.
- C. Octane, C_8H_{18} : $M = 8 \times 12.0 + 18 \times 1.0 = 114.0 \text{ g mol}^{-1}$
 1 mol releases 5464 kJ of energy
 1 g releases $5464 / 114.0 = 47.9 \text{ kJ g}^{-1}$.
- D. Ethanol, $\text{C}_2\text{H}_5\text{OH}$: $M = 2 \times 12.0 + 6 \times 1.0 + 16.0 = 46.0 \text{ g mol}^{-1}$
 1 mol releases 1364 kJ of energy
 1 g releases $1364 / 46.0 = 29.6 \text{ kJ g}^{-1}$.
- Q10 D **The reduction of metal(II) ions can be represented by the general electrochemical half-equation**
- $$\text{M}^{2+}(\text{aq}) + 2\text{e}^- \rightleftharpoons \text{M}(\text{s})$$
- The total charge flowing into the cell is given by $Q = I \times t$
 $Q = 1.27 \times (10.0 \times 60) = 762 \text{ C}$
 $n(\text{e}^-) = Q / F = 762 / 96500 = 7.90 \times 10^{-3} \text{ mol}$
 $n(\text{M}) = \frac{1}{2} n(\text{e}^-) = \frac{1}{2} \times 7.90 \times 10^{-3} = 3.95 \times 10^{-3} \text{ mol}$
 The molar mass of the metal
 $M(\text{M}) = m(\text{M}) / n(\text{M}) = 0.469 / 3.95 \times 10^{-3} = 118.7 \text{ g mol}^{-1}$
 This is the molar mass for **tin**.

- Q11 D **The relevant chemical equations from the electrochemical series are:**
 $\text{Fe}^{3+}(\text{aq}) + \text{e}^{-} \rightleftharpoons \text{Fe}^{2+}(\text{aq}) \quad E^{\circ} = +0.77 \text{ V}$
 $\text{Fe}^{2+}(\text{aq}) + 2\text{e}^{-} \rightleftharpoons \text{Fe}(\text{s}) \quad E^{\circ} = -0.44 \text{ V}$
The stronger oxidant is $\text{Fe}^{3+}(\text{aq})$ which will be reduced and the stronger reductant is Fe which will be oxidised.
The reaction in the Fe^{2+}/Fe half-cell is oxidation, therefore the Fe electrode is the anode, and anions will flow into this half-cell from the salt bridge.
- Q12 A **The potential difference for a cell operating under standard conditions is given by the differences in the E° values.**
 Potential Difference = $0.77 - (-0.44) = 1.21 \text{ V}$

Short Answer (Answers) - Section B

Question 1 (8 marks, 9 minutes)

- a. $M(\text{NH}_4\text{NO}_3) = 2 \times 14.0 + 4 \times 1.0 + 3 \times 16.0 = 80.0 \text{ g mol}^{-1}$.
 $n(\text{NH}_4\text{NO}_3) = m / M = 15.28 / 80.0 = 0.191 \text{ mol}$. **(1 mark)**
 1 mol of NH_4NO_3 will absorb 26 kJ from the surrounding environment when it is dissolved in water.
 $26 \text{ kJ} = 26000 \text{ J}$
 $E = n \times 26000 = 0.191 \times 26000 = 4970 \text{ J}$ **(1 mark)**
 $cf = E / \Delta T = 4970 / 10.2 = 487 \text{ J }^{\circ}\text{C}^{-1}$ **(1 mark)**
- b. i. $\Delta T = 25.1 - 19.3 = 5.8 \text{ }^{\circ}\text{C}$
 $E = cf \times \Delta T = 487 \times 5.8 = 2800 \text{ J}$ **(1 mark)**
- ii. $n(\text{NaOH}) = n(\text{HCl}) = c \times V = 1.000 \times (50.00/1000) = 5.00 \times 10^{-2} \text{ mol}$
 $5.00 \times 10^{-2} \text{ mol}$ of reactants released 2800 J of energy
 Therefore 1 mol of reactants would release
 $E = 2800 / 5.00 \times 10^{-2} = 56000 \text{ J} = 56 \text{ kJ}$ **(1 mark)**
 Since energy is released the reaction is **exothermic and the $\Delta H < 0$** .
 Therefore $\Delta H = -56 \text{ kJ mol}^{-1}$. **(1 mark)**
- iii. Since a neutralisation reaction occurs between the **$\text{H}^{+}(\text{aq})$ ions from the acid and the $\text{OH}^{-}(\text{aq})$ ions from the base**, then changing the spectator ions should have **no effect on the value for the enthalpy change**. **(1 mark)**
 The neutralisation reaction can be represented by the ionic chemical equation:
 $\text{H}^{+}(\text{aq}) + \text{OH}^{-}(\text{aq}) \rightarrow \text{H}_2\text{O}(\text{l})$
- c. The calibration factor for the calorimeter is the amount of energy required to change the calorimeter and its contents by $1 \text{ }^{\circ}\text{C}$. **The error in this procedure is that the calibration factor was determined with 100.0 mL of solution, whereas the reaction only used a total of 75.0 mL of solution.** **(1 mark)** Therefore less energy would be required to increase the temperature of the smaller volume of solution. The heat capacity for water is $4.18 \text{ J }^{\circ}\text{C}^{-1} \text{ mL}^{-1}$ and this is the main contributing component to the calibration factor. The lower volume of solution will result in a larger temperature change, since all three groups have the same number of mole of reactants, for the reaction. Therefore this group of students would calculate a higher value of the enthalpy change, ΔH .

Question 2 (9 marks, 10 minutes)

- a. The half-cell that standard electrode potentials are measured relative to is the **hydrogen, $\text{H}^+(\text{aq})/\text{H}_2(\text{g})$, half-cell**. In the electrochemical series the standard electrode potential for this half-cell is 0.00 V. **(1 mark)**
- b. i. Since the vanadyl/vanadium(III) half-cell involves two ions, the electrode for this half-cell would have to be constructed from a material that would not react, therefore **platinum metal or carbon (graphite)** would be used. **(1 mark)** The role of the electrode in this half-cell is to transfer electrons to or from the reactants and not be part of the half-cell's reaction.
- ii. Since the charge on the electrode in the $\text{Zn}^{2+}(\text{aq})/\text{Zn}(\text{s})$ half-cell is negative, then oxidation is occurring in this half-cell. Therefore reduction is occurring in the other half-cell and the **vanadyl ion, VO^{2+} , must be the oxidant**. **(1 mark)**
- iii. The half-equation for the $\text{Zn}^{2+}(\text{aq})/\text{Zn}(\text{s})$ half-cell can be determined using the electrochemical series.
- $$\text{Zn}(\text{s}) \rightarrow \text{Zn}^{2+}(\text{aq}) + 2\text{e}^- \quad \textbf{(1 mark)}$$
- The half-equation for the $\text{VO}^{2+}(\text{aq})/\text{V}^{3+}(\text{aq})$ half-cell can be worked out.
Write down the reactant and product ions and balance atoms other than hydrogen and oxygen.
- $$\text{VO}^{2+}(\text{aq}) \rightarrow \text{V}^{3+}(\text{aq})$$
- Balance oxygen atoms by adding water molecules
- $$\text{VO}^{2+}(\text{aq}) \rightarrow \text{V}^{3+}(\text{aq}) + \text{H}_2\text{O}(\text{l})$$
- Balance hydrogen atoms by adding H^+ ions
- $$\text{VO}^{2+}(\text{aq}) + 2\text{H}^+(\text{aq}) \rightarrow \text{V}^{3+}(\text{aq}) + \text{H}_2\text{O}(\text{l})$$
- Balance charges using electrons.
- $$\text{VO}^{2+}(\text{aq}) + 2\text{H}^+(\text{aq}) + \text{e}^- \rightarrow \text{V}^{3+}(\text{aq}) + \text{H}_2\text{O}(\text{l}) \quad \textbf{(1 mark)}$$
- iv. The overall reaction is the sum of the two half-reactions so that the number of electrons produced in the oxidation reaction is the same as the number of electrons consumed in the reduction reaction.
- $$\text{Zn}(\text{s}) \rightarrow \text{Zn}^{2+}(\text{aq}) + 2\text{e}^-$$
- $$(\text{VO}^{2+}(\text{aq}) + 2\text{H}^+(\text{aq}) + \text{e}^- \rightarrow \text{V}^{3+}(\text{aq}) + \text{H}_2\text{O}(\text{l})) \times 2$$
- $$\text{Zn}(\text{s}) + 2\text{VO}^{2+}(\text{aq}) + 4\text{H}^+(\text{aq}) \rightarrow \text{Zn}^{2+}(\text{aq}) + 2\text{V}^{3+}(\text{aq}) + 2\text{H}_2\text{O}(\text{l}) \quad \textbf{(1 mark)}$$
- v. The potential difference is the difference between the standard electrode potentials for the two half-cells.
- $$E^\circ(\text{reduction}) - E^\circ(\text{oxidation}) = 1.10 \text{ V}$$
- From Table 2: $E^\circ(\text{oxidation, Zn}^{2+}/\text{Zn}) = -0.76 \text{ V}$
- $$E^\circ(\text{reduction, VO}^{2+}/\text{V}^{3+}) = 1.10 + (-0.76) = \textbf{+0.34 V} \quad \textbf{(1 mark)}$$
- c. Since the nickel electrode has lost mass then it must be undergoing oxidation.
The appropriate chemical half-equation is: $\text{Ni}(\text{s}) \rightleftharpoons \text{Ni}^{2+}(\text{aq}) + 2\text{e}^-$
- $$n(\text{Ni}) = m / M = 0.470 / 58.7 = 8.0 \times 10^{-3} \text{ mol}$$
- From the half-equation
- $$n(\text{e}^-) = 2 n(\text{Ni}) = 2 \times 8.00 \times 10^{-3} = 1.60 \times 10^{-2} \text{ mol} \quad \textbf{(1 mark)}$$
- $$Q = n(\text{e}^-) \times F = 1.60 \times 10^{-2} \times 96500 = 1.54 \times 10^3 \text{ C}$$
- $$t = 3.00 \text{ hr} = 3.00 \times 60 \times 60 = 10800 \text{ s}$$
- $$I = Q / t = 1.54 \times 10^3 / 10800 = \textbf{0.143 A} \quad \textbf{(1 mark)}$$

Question 3 (10 marks, 11 minutes)

- a. i. $M(C_8H_{18}) = 8 \times 12.0 + 18 \times 1.0 = 114.0 \text{ g mol}^{-1}$
 $1.00 \text{ kg} = 1000 \text{ g}$
 $n(C_8H_{18}) = m / M = 1000 / 114.0 = 8.77 \text{ mol}$ **(1 mark)**
From Table 13 the molar enthalpy of combustion for octane is $-5464 \text{ kJ mol}^{-1}$
Therefore 1 mol of octane will release 5464 kJ of energy when burnt.
 $E = n \times 5464 = 8.77 \times 5464 = 4.79 \times 10^4 \text{ kJ}$ **(1 mark)**
- ii. Each mol of octane burnt will result in the formation of 8 mol of CO_2
 $n(CO_2) = 8 \times n(C_8H_{18}) = 8 \times 8.77 = 70.2 \text{ mol}$ **(1 mark)**
- iii. $M(C_2H_5OH) = 2 \times 12.0 + 6 \times 1.0 + 16.0 = 46.0 \text{ g mol}^{-1}$
From Table 13 the molar enthalpy of combustion for ethanol is $-1364 \text{ kJ mol}^{-1}$
Therefore 1 mol of ethanol will release 1364 kJ of energy when burnt.
The blend contains 10.0 % ethanol by mass, therefore 1.00 kg of fuel contains:
 $m(C_2H_5OH) = 100 \text{ g}$
 $m(C_8H_{18}) = 900 \text{ g}$
 $n(C_2H_5OH) = m / M = 100 / 46.0 = 2.17 \text{ mol}$
 $E(\text{from ethanol}) = 2.17 \times 1364 = 2.96 \times 10^3 \text{ kJ}$ **(1 mark)**
 $n(C_8H_{18}) = 900 / 114.0 = 7.89 \text{ mol}$
 $E(\text{from octane}) = 7.89 \times 5464 = 4.31 \times 10^4 \text{ kJ}$
 $E(\text{Total}) = 2.96 \times 10^3 + 4.31 \times 10^4 = 4.61 \times 10^4 \text{ kJ}$ **(1 mark)**
- iv. Each mol of ethanol burnt will result in the formation of 2 mol of CO_2
 $n(CO_2, \text{total}) = 8 \times n(C_8H_{18}) + 2 \times n(C_2H_5OH)$ **(1 mark)**
 $n(CO_2, \text{total}) = 8 \times 7.89 + 2 \times 2.17 = 67.4 \text{ mol}$ **(1 mark)**
- v. Since the blended fuel releases less energy then the amount of carbon dioxide released, to obtain the same amount of energy will be given by
$$n(CO_2) = \frac{n(CO_2, \text{blended fuel}) \times E(C_8H_{18})}{E(\text{blended fuel})}$$

$$n(CO_2) = \frac{67.4 \times 4.79 \times 10^4}{4.61 \times 10^4} = 70.0 \text{ mol}$$
 (1 mark)
- b. i. Possible answers could include: **(1 mark)**
The blended fuel contains bioethanol which is a renewable resource.
The use of bioethanol will reduce the demand on the limited fossil fuel reserves of crude oil.
The bioethanol can be produced locally and therefore reduces imports of crude oil.
Growing the feedstock for bioethanol production will mean that the carbon dioxide emitted by the ethanol will be removed from the atmosphere.
- ii. Possible answers could include: **(1 mark)**
The use of food crops to produce bioethanol has increased the price of many staple foods.
Biofuel production is currently receiving large government subsidies.
Land for growing biofuels is resulting in deforestation.
Land being used to grow biofuels is lowering the amount of land available for growing food crops.
Water resources are being taken away from growing food crops to produce biofuel crops.

Question 4 (7 marks, 7 minutes)

- a. The light energy from the sun is converted as follows:
Light Energy → Electrical Energy → Chemical Energy
(1 mark)
- b. The appropriate half-equations can be obtained from the electrochemical series **Table 2**.
A dilute aqueous solution of sulfuric acid contains $\text{H}^+(\text{aq})$, $\text{HSO}_4^-(\text{aq})$ and $\text{SO}_4^{2-}(\text{aq})$ ions in addition to the $\text{H}_2\text{O}(\text{l})$.
For the negative electrode, cathode, the $\text{H}^+(\text{aq})$ ion is a stronger oxidant than water therefore this will be reduced.
$$2\text{H}^+(\text{aq}) + 2\text{e}^- \rightarrow \text{H}_2(\text{g})$$

At the positive electrode, anode, water is the reductant, therefore it will be oxidised.
$$2\text{H}_2\text{O}(\text{l}) \rightarrow \text{O}_2(\text{g}) + 4\text{H}^+(\text{aq}) + 4\text{e}^-$$

(Both half-equations required: 1 mark)
- c. The pH would remain unchanged because the $\text{H}^+(\text{aq})$ ions reduced at the cathode are replaced by the $\text{H}^+(\text{aq})$ ions formed at the anode, as the current flows through the cell **(1 mark)**
- d. $Q = I \times t = 0.70 \times (6.0 \times 60 \times 60) = 1.5 \times 10^4 \text{ C}$ **(1 mark)**
 $n(\text{e}^-) = Q / F = 1.5 \times 10^5 / 96500 = 0.16 \text{ mol}$
For each cell from the half-equation: $2\text{H}^+(\text{aq}) + 2\text{e}^- \rightarrow \text{H}_2(\text{g})$
 $n(\text{H}_2) = \frac{1}{2}n(\text{e}^-) = \frac{1}{2} \times 0.16 = 0.080 \text{ mol}$ **(1 mark)**
Since the apparatus has four cells and the same current passes through each then the combined volume of hydrogen at SLC is
 $V(\text{H}_2) = 4 \times 0.080 \times 24.5 = 7.8 \text{ L}$ **(1 mark)**
- e. The advantage of generating hydrogen by this type of process is that it uses a renewable energy source. **(1 mark)**

End of Suggested Answers