CSE CENTRE FOR STRATEGIC EDUCATION
*Leading educational thinking and practice*

IARTV

| STUDENT: | TEACHER: |
|---|---|

# CSE TEST – OCTOBER 2009

# YEAR 12 – CHEMISTRY

## Written examination 2

**Reading time: 15 minutes**
**Writing time: 1 hour 30 minutes**

## QUESTION AND ANSWER BOOK

**Structure of book**

| *Section* | *Number of questions* | *Number of questions to be answered* | *Number of marks* |
|---|---|---|---|
| A | 20 | 20 | 20 |
| B | 8 | 8 | 54 |
| | | | Total 74 |

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

**Materials supplied**

- Question and answer book of 16 pages.
- Data book
- Detachable answer sheet for multiple choice questions. You may detach this during reading time.

**Instructions**

- Write your **name** and that of your teacher in the space provided above on this page AND on the answer sheet for multiple-choice questions.
- All written responses must be in English

**At the end of the examination**

- Place the answer sheet for multiple-choice questions inside the front cover of this book.

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

## SECTION A – Multiple choice questions

**Instructions for Section A**

Answer all questions in pencil on the answer sheet provided for multiple-choice questions.

Choose the response that is correct or that best answers the question.

A correct answer scores 1, an incorrect answer scores 0.

Marks will not be deducted for incorrect answers.

No marks will be given if more than one answer is completed for any question.

**Questions 1, 2 and 3** all refer to the equilibrium system shown below.

$$NO_2(g) + CO(g) \rightleftharpoons NO(g) + CO_2(g) \quad \Delta H = -216 \text{ kJ mol}^{-1}$$

**Question 1**

The yield from the above equilibrium will be increased by

**A.** increasing the pressure.

**B.** introducing a catalyst.

**C.** decreasing the temperature.

**D.** increasing the surface area.

**Question 2**

If the activation energy, $E_{A,}$, for the above reaction has a value of 125 kJ, the $\Delta H$ value and activation energy for the reverse reaction are

**A.** $\Delta H = +216 \text{ kJ mol}^{-1}$ and $E_A = 125$ kJ.

**B.** $\Delta H = +216 \text{ kJ mol}^{-1}$ and $E_A = 341$ kJ.

**C.** $\Delta H = -216 \text{ kJ mol}^{-1}$ and $E_A = -125$ kJ.

**D.** $\Delta H = -216 \text{ kJ mol}^{-1}$ and $E_A = 91$ kJ.

**Question 3**

Initially all four gases were placed in a 1.00 L vessel and had concentrations of 0.800 mol $L^{-1}$. If the concentration at equilibrium for $CO_2$ was 1.20 mol $L^{-1}$ then the equilibrium constant is

**A.** 9.00

**B.** 2.25

**C.** 0.444

**D.** 0.111

**Question 4**

An equilibrium reaction has an equilibrium constant of $4.93 \times 10^{-6}$.

It can be said that

**A.** there are significant amounts of product formed.

**B.** the reaction can be considered to have gone to completion.

**C.** both reactants and products are present in significant amounts.

**D.** the yield of the reaction is negligible.

**Question 5**

Consider the equilibrium system below.

$$Co(H_2O)_6^{2+}(aq) + 4Cl^-(aq) \rightleftharpoons CoCl_4^{2-}(aq) + 6H_2O(l)$$

pink blue

At 25°C the solution appears purple while at 40°C the solution appears blue. From this we can deduce that the system is

**A.** endothermic and there are fewer $Cl^-$ ions present at 40°C.

**B.** endothermic and there are more $Cl^-$ ions present at 40°C.

**C.** exothermic and there are fewer $Cl^-$ ions present at 40°C.

**D.** exothermic and there are more $Cl^-$ ions present at 40°C.

**Question 6**

Hydrocyanic acid, HCN, is a very toxic weak acid. The pH of a particular solution is measured at 4.9. From this it can be calculated that the concentration of the HCN solution is

**A.** $5.0 \times 10^{-5}$ mol $L^{-1}$

**B.** 0.10 mol $L^{-1}$

**C.** 0.25 mol $L^{-1}$

**D.** 4.0 mol $L^{-1}$

**Question 7**

At 25°C, the pH of pure water is 7.0. If the temperature of water is lowered to 11°C then the concentration of hydroxide ions will

**A.** increase and the pH will increase.

**B.** decrease and the pH will increase.

**C.** increase and the pH will decrease.

**D.** decrease and the pH will decrease.

**Question 8**

The pH of blood is maintained by means of the following equilibrium system.

$$H_2CO_3(aq) + H_2O(l) \rightleftharpoons HCO_3^-(aq) + H_3O^+(aq)$$

Some bacterial infections lower the pH of blood. If this occurs, the effect on the equilibrium system above is

**A.** a decrease in the equilibrium constant.

**B.** a net shift to the left.

**C.** an overall decrease of the hydronium ion concentration.

**D.** an overall decrease of the hydroxide ion concentration.

**Question 9**

Which of the following methods of electricity production is the most sustainable?

**A.** Hydroelectric power station

**B.** Brown coal fired power station

**C.** Hydrogen fuel cell

**D.** Nuclear power station

**Question 10**

A solution calorimeter is used in two experiments to examine the endothermic reaction of ammonium nitrate with water. In the first experiment 10.0 g of $NH_4NO_3$ was added to 100.0 mL of water at 25°C in the calorimeter. In the second experiment 100.0 g of $NH_4NO_3$ was added to 100.0 mL of water at 25°C. The temperature of the second experiment compared with the first will

**A.** fall at the same rate to the same temperature.

**B.** fall at the same rate to a lower temperature.

**C.** fall at the faster rate to the same temperature.

**D.** fall at the faster rate to a lower temperature.

**Question 11**

When 16.0 g of methane reacts with 16.0 g of oxygen according to the following equation

$$CH_4(g) + 2O_2(g) \rightarrow CO_2(g) + 2H_2O(g) \quad \Delta H = -889 \text{ kJ mol}^{-1}$$

**A.** 222 kJ of energy is absorbed.

**B.** 222 kJ of energy is released.

**C.** 445 kJ of energy is absorbed.

**D.** 889 kJ of energy is released.

**Question 12**

The specific heat of brass is 0.37 J $g^{-1}$ $°C^{-1}$. 1.2 kJ of heat is absorbed by a 50.0 g bar of brass initially at 20°C. The final temperature of the brass bar is therefore

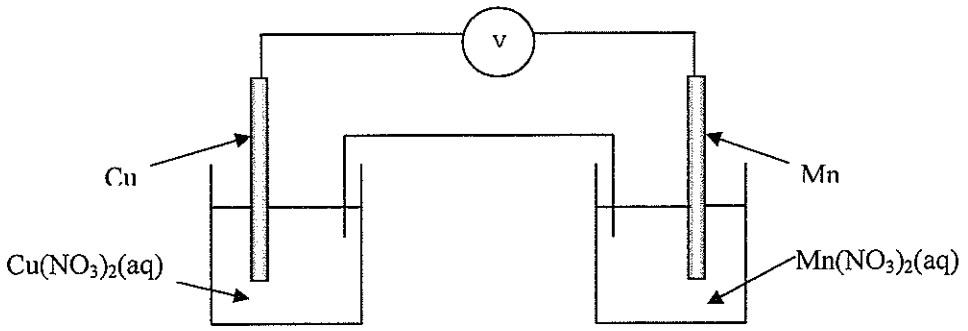
**A.** 21°C

**B.** 26°C

**C.** 65°C

**D.** 85°C

**Question 13**




For the galvanic cell above, the reaction at the cathode is

**A.** $Mn^{2+}(aq) + 2e^- \rightarrow Mn(s)$

**B.** $NO_3^-(aq) + 4H^+(aq) + 3e^- \rightarrow NO(g) + 2H_2O(l)$

**C.** $Cu^{2+}(aq) + 2e^- \rightarrow Cu(s)$

**D.** $Cu(s) \rightarrow Cu^{2+}(aq) + 2e^-$

**Question 14**

The sodium-sulfur cell is being trialled in electric vehicles. It operates at around 350°C. Sulfur is a liquid at this temperature. The half equations for this cell are

$$S(l) + 2e^- \rightarrow S^{2-}(l) \quad E^\circ = -0.7\ V$$
$$Na^+(l) + e^- \rightarrow Na(l) \quad E^\circ = -2.7\ V$$

Which is the reactant at the negative electrode?

**A.** Sodium

**B.** Sodium cations

**C.** Sulfur

**D.** Sulfur anions

**Question 15**

Which electrolysis cell could be used to coat a copper spoon with silver?

**A.** The copper spoon as the anode, a silver cathode and silver nitrate as the electrolyte

**B.** The copper spoon as the cathode, a silver anode and silver nitrate as the electrolyte

**C.** The copper spoon as the anode, a silver cathode and copper sulfate as the electrolyte

**D.** The copper spoon as the cathode, a silver anode and copper sulfate as the electrolyte

**Question 16**

During electroplating, the mass of metal deposited on the cathode depends on

**A.** only the current used.

**B.** only the current used and the time taken.

**C.** only the current used and the charge on the metal ion.

**D.** the current used, the charge on the metal ion and the time taken.

**Question 17**

An electric current is passed through a dilute solution using platinum electrodes, producing a gas at each electrode. Which solution is it most likely to be?

**A.** copper(II) nitrate

**B.** silver nitrate

**C.** sodium nitrate

**D.** tin(II) nitrate

**Question 18**

In a copper/zinc galvanic cell, the mass of copper deposited at the cathode

A. equals the mass of zinc lost at the anode.

B. is greater than the mass of zinc lost at the anode.

C. is less than the mass of zinc lost at the anode.

D. is less than the mass of zinc deposited at the anode.

**Question 19**

When an electric current is passed through a dilute copper(II) sulfate solution using copper electrodes

A. the anode dissolves and the blue colour fades.

B. the anode dissolves and there is no colour change.

C. a colourless gas is produced at both electrodes.

D. a colourless gas is produced at the anode and the colour fades.

**Question 20**

The number of Faradays of electricity needed to produce 2.24 L of chlorine gas at STP from molten NaCl is

A. 0.0500

B. 0.100

C. 0.200

D. 9650

## SECTION B – Short answer questions

**Instructions for Section B**

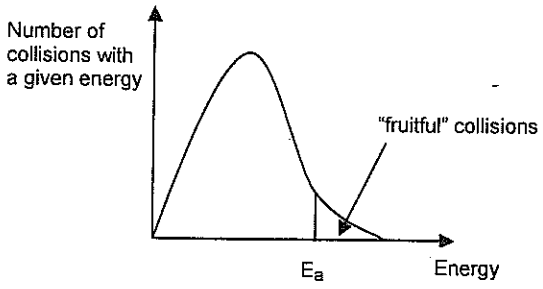
Answer **all** questions in the spaces provided.

To obtain full marks for your responses you should

- give simplified answers with an appropriate number of significant figures to all numerical questions; unsimplified answers will not be given full marks.
- show all working in your answers to numerical questions. No credit will be given for an incorrect answer unless it is accompanied by details of the working.
- make sure chemical equations are balanced and that the formulas for individual substances include an indication of state; for example, $H_2(g)$; NaCl(aq)

**Question 1**

**a.** The diagram below represents a reaction without the use of a catalyst. On the same diagram sketch the profile of the same reaction if a catalyst were used.




1 mark

**b.** Ethene can be hydrogenated according to the equation

$$CH_2{=}CH_2(g) + H_2(g) \rightleftharpoons CH_3CH_3(g)$$

The reaction is quite slow at room temperature unless a catalyst (usually nickel) is used. Describe the steps that would be expected to occur in the presence of a nickel catalyst.

2 marks

**c.** Explain why the rate of a reaction is affected by the

**i.** orientation of the molecular collisions.

**ii.** frequency of molecular collisions.

**iii.** kine energy of the molecules during collisions.

3 marks

**d.** Hypobromous acid, HOBr, hypochlorous acid, HOCl, and hypoiodous acid, HOI are all weak acids. Using the table in your data booklet state how the value of the acidity constant for HOI will compare to the other two acids. Explain your answer.

2 marks

**e.** Circle the correct answer in the following.

As the concentration of lactic acid increases, the

| | | | |
|---|---|---|---|
| **pH** | increases | decreases | stays the same. |
| **[$OH^-$]** | increases | decreases | stays the same. |
| **K** | increases | decreases | stays the same. |

3 marks

**Total: 11 marks**

**Question 2**

The Claus process is an important industrial process used to remove sulfur compounds from fossil fuels. It provides a source of pure sulfur for the fertiliser industry. Use your knowledge of the industrial process you studied to examine the Claus process.
One critical step known as the catalytic step uses an equilibrium system that is exothermic. A catalyst of activated alumina or titanium dioxide is employed. The following equation represents the reaction.

$$2H_2S(g) + SO_2(g) \rightleftharpoons 3S(g) + 2H_2O(g)$$

**a.** Comment on the compromise that must be made for the temperature.

1 mark

**b.** Comment on the compromise that must be made for the pressure.

1 mark

**c.** Typically in the pass over the first of three passes over catalyst beds a temperature of between 315°C and 330°C is used. It is vitally important that sulfur not condense at this point. Why might this be so?

1 mark

**d.** If two passes are made over the catalyst beds a yield of 97% can be achieved. This means over 2.6 tonnes of steam will be generated for each tonne of sulfur produced. What could the steam be used for?

1 mark

**e.** What are two health and safety measures that would be needed in the Claus Process?

1 mark

**Total: 5 marks**

**buestion 3**

**a.** Consider the equilibrium

$$CO(g) + 2H_2(g) \rightleftharpoons CH_3OH(g) \qquad \Delta H = -92 \text{ kJ mol}^{-1}$$

Complete the table below after the following changes are made and equilibrium is re-established.

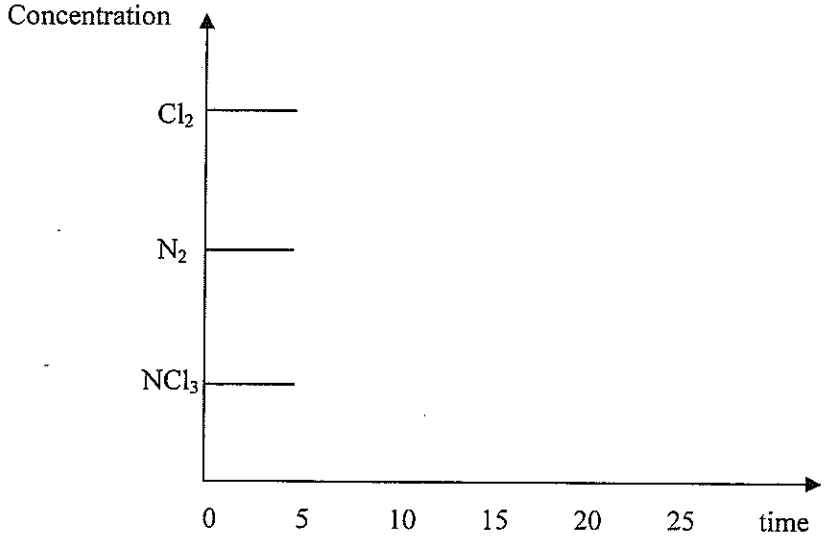
| Change to the system | Net shift | Effect on the number of moles of $H_2$ | Effect on the concentration of $H_2$ |
|---|---|---|---|
| Addition of nitrogen | | | |
| Decrease of pressure | | | |
| Increase of temperature | | | |
| Volume halved | | | |
| Methanol removed | | | |

5 marks

**b.** The equation for the equilibrium involved in the production of nitrogen trichloride can be written as

$$N_2(g) + 3Cl_2(g) \rightleftharpoons 2NCl_3(g) \quad \Delta H = +223 \text{ kJ mol}^{-1}$$

Sketch a concentration – time graph if at 5 minutes the temperature is increased. After this the system comes to equilibrium but at 15 minutes the concentration of chlorine is increased. The system then establishes equilibrium again at 20 minutes.




2 marks

**Total: 7 marks**

**Question 4**

Kerosene is a volatile hydrocarbon fuel that may be used in lamps and camp stoves. It has a heat of combustion of 44 100 kJ $kg^{-1}$.

**a.** Explain why the heat evolved from the combustion of kerosene is measured in kJ $kg^{-1}$ rather than kJ $mol^{-1}$.

1 mark

**b.** Kerosene has a density of 0.817 g $mL^{-1}$.

**i.** What is the mass of 12.5 mL of kerosene ?

1 mark

**ii.** What is the heat released when 12.5 mL of kerosene undergoes combustion?

1 mark

**c.** Two experiments involving samples of butane and ethanol are carried out.
The first experiment is performed in a bomb calorimeter.
1.01 g of butane is used to calibrate the bomb calorimeter. The butane is placed in the bomb calorimeter with excess oxygen and the mixture ignited. After the reaction is completed the temperature of the water surrounding the bomb in the calorimeter rose by 32.5°C.

**i.** Calculate to the appropriate number of significant figures the calibration factor of the calorimeter in kJ $°C^{-1}$.

2 marks

**ii.** The second experiment involved a 2.10 g sample of ethanol. The ethanol was placed with excess oxygen in the calorimeter and the mixture ignited. To what temperature is the water surrounding the bomb in the calorimeter increased if the initial temperature was 31.0°C?

3 marks

**Total: 8 marks**

**Question 5**

Give concise explanations for the following:

**a.** The amount of carbon dioxide in the Earth's atmosphere has increased since the start of the industrial age.

1 mark

**b.** Nuclear energy is used in many countries despite the problem of dealing with the wastes produced during the process.

1 mark

**c.** The commercial production of sodium is done by electrolysis of a molten liquid, not by electrolysis of an aqueous solution.

1 mark

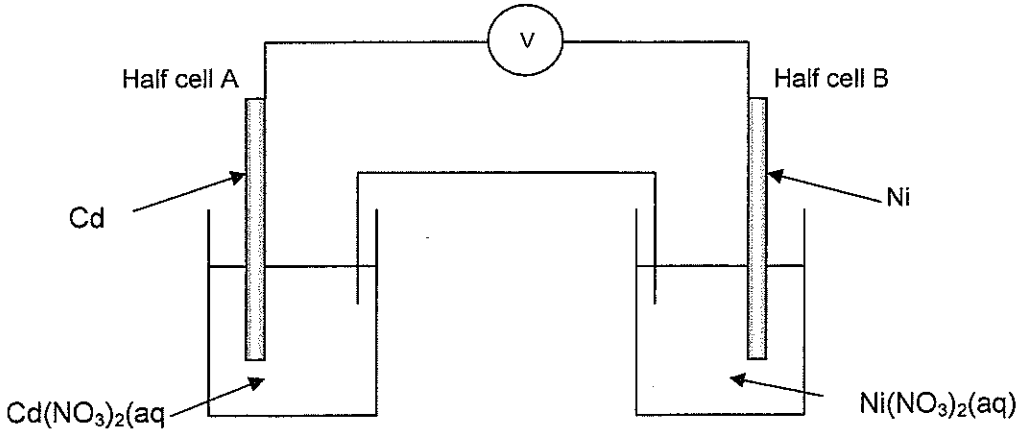
**Total: 3 marks**

**Question 6**

A galvanic cell is constructed from two half cells under standard conditions as shown below.

Half cell A: a cadmium electrode in a solution of 1.0 M cadmium nitrate

Half cell B: a nickel electrode in a solution of 1.0 M nickel nitrate




The standard reduction potential of $Cd^{2+}(aq)/Cd(s)$ is –0.40 V.

**a.** Mark on the diagram above the direction in which the electrons will flow in the external circuit of the galvanic cell and the electrode polarities.

1 mark

**b.** Calculate the expected overall cell voltage that is produced when the cell operates.

1 mark

**c.** Write the half cell reaction that takes place at the anode of this cell.

1 mark

**d.** What is one factor that needs to be taken into consideration when selecting an appropriate solution for use in the salt bridge?

1 mark

**e.** Write the formula of a reductant that will produce a higher cell voltage than the cell above if it were to replace the cadmium electrode.

1 mark

**Total: 5 marks**

**Question 7**

An advertisement from the aluminium industry claims:

> The energy saved from one recycled aluminium can will operate a television set for 3.0 hours.

Assume that the average television set uses a current of 0.75 A and an aluminium can has a mass of 14.7 g

**a.** Calculate the amount, in mole, of electrons passing through the average television set in 3.0 hours.

1 mark

**b.** Write a balanced half-equation for the reaction at the electrode where the aluminium is produced in an electrolysis cell.

1 mark

**c.** Calculate the mass of aluminium that could be produced by the energy saved.

2 marks

**d.** Calculate the mass of aluminium that could be produced by the energy saved as a percentage of the mass of an aluminium can.

1 mark

**e.** Give two environmental advantages of recycling aluminium.

1 mark

**f.** In the Hall-Heroult cell used to produce aluminium, the aluminium oxide (alumina) is dissolved in cryolite ($Na_3AlF_6$). Why is cryolite used?

1 mark

**Total: 7 marks**

**Question 8**

The molten carbonate fuel cell is being developed for electricity generation on a large scale, using hydrogen as a fuel and molten carbonates of lithium, sodium or potassium as the electrolyte. The only product is water.

The reaction at the anode is

$$H_2(g) + CO_3^{2-}(l) \rightarrow H_2O(g) + CO_2(g) + 2e^-$$

**a.** Give the formula of a suitable electrolyte.

1 mark

**b.** Write a balanced ionic half-equation for the reaction at the cathode.

1 mark

**c.** Write a balanced equation for the overall reaction.

1 mark

**d.** What properties of the electrodes are needed for the cell to function effectively?

1 mark

**e.** Give two advantages of electricity generation using the molten carbonate fuel cell over traditional coal-fired power stations.

2 marks

**f.** Give two disadvantages of using this process

2 marks

**Total: 8 marks**

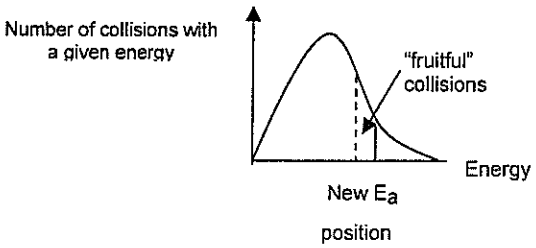
**END OF QUESTION BOOK**

## SECTION A – Multiple choice questions (20 marks)

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 1 | C | 5 | A | 9 | A | 13 | C | 17 | C |
| 2 | B | 6 | C | 10 | D | 14 | A | 18 | C |
| 3 | A | 7 | B | 11 | B | 15 | B | 19 | B |
| 4 | D | 8 | B | 12 | D | 16 | D | 20 | C |

### Question 1 (11 marks)

**a.**




1 mark

**b.** Reactant molecules adsorb onto the catalyst surface with a specific orientation. Reactant bonds break and reform to produce product molecules.

2 marks

**c.** **i.** Reactant molecules only break when molecules collide in certain alignments or orientations.

**ii.** Reactions cannot occur without collision of reactant molecules. Increasing the frequency of collisions directly increases the number of 'fruitful' collisions or reaction rate.

**iii.** Increased kinetic energy increases the frequency of collisions and the number of molecules with sufficient $E_a$ to react.

3 marks

**d.** The $K_a$ will be less using the data book trend. The O to H bond strength increases as iodine is less electronegative than the halogens above it in the group.

2 marks

**e.**

| | | | |
|---|---|---|---|
| **pH** | increases | (decreases) | stays the same. |
| **$[OH^-]$** | increases | (decreases) | stays the same. |
| **K** | increases | decreases | (stays the same). |

3 marks

### Question 2 (5 marks)

**a.** Higher temperature favours faster reaction rate but also favours a lower yield in terms of the equilibrium constant magnitude (for exothermic reactions).

**b.** Low pressure favours higher yield but this is not economic.

**c.** Condensed sulfur will 'poison' the catalyst.

**d.** Pre-heat reactant gases, generate electricity, etc.

**e.** Monitor plant for emissions, correct safety equipment, monitor plant equipment, recycle gases, etc.

5 x 1 = 5 marks

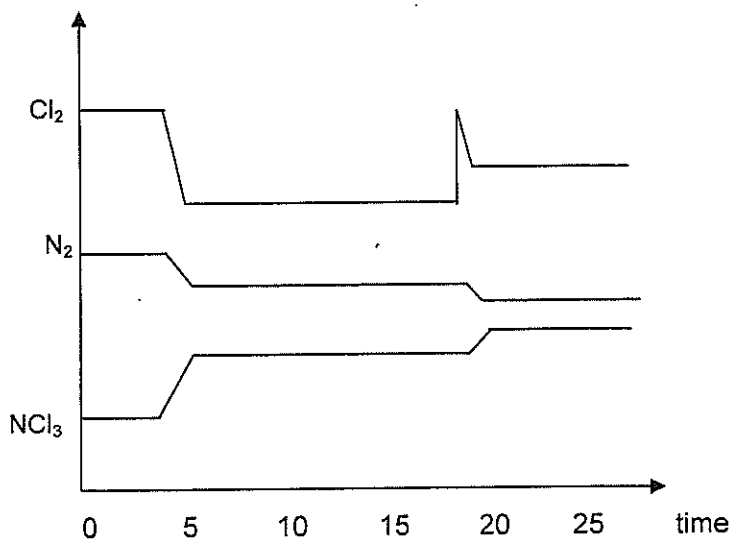
**Question 3 (7 marks)**

**a.**

| Change to the system | Net shift | Effect on the number of moles of $H_2$ | Effect on the concentration of $H_2$ |
|---|---|---|---|
| Addition of nitrogen | none | none | none |
| Decrease of pressure | left | increase | decrease |
| Increase of temperature | left | increase | increase |
| Volume halved | right | decrease | increase |
| Methanol removed | right | decrease | decrease |

5 marks

**b.**




2 marks

**Question 4 (8 marks)**

**a.** Kerosene is a mixture of hydrocarbons so it has no defined Mr (or it is a more useful unit for commercial use).

1 mark

**b. i.** $m$(kerosene) = $d$ x $V$ = 0.817 x 12.5 = 10.2 g

1 mark

**ii.** Energy = 44 100 x 0.0102 = 450 kJ

1 mark

**c. i.** $n$(butane) = 1.01 / 58.0 = 0.0174 mol

$E = \Delta H \times n$ = 2874 x 0.0174 = 50.0 kJ

C.F. = $E$ / $\Delta T$ = 50.0 kJ / 32.5 = 1.54 kJ $°C^{-1}$

2 marks

**ii.** $n$(ethanol) = 2.10/46.0 = 0.0457 mol

$E = \Delta H \times n$ = 1364 x 0.0457 = 62.3 kJ

$\Delta T$ = C.F / $E$ = 62.3/1.54 = 40.4°C

$T$(final) = 40.4 + 31.0 = 71.4°C

3 marks

**Question 5 (3 marks)**

**a.** Increased combustion of fossil fuels for production of energy, transport and production of materials such as steel, aluminium, etc.

1 mark

**b.** Electricity generation using nuclear energy as an alternative to fossil fuel energy. Country may lack fossil fuels. Less greenhouse gas emissions during electricity production.

1 mark

**c.** Water is a stronger oxidant than sodium ions and would react preferentially at the cathode.

1 mark

**Question 6 (5 marks)**

**a.** Electrons move from Cd to Ni electrode. The Cd electrode has a negative polarity and the nickel electrode has a positive polarity.

1 mark

**b.** Cell potential difference = $E^\circ$ half cell higher – $E^\circ$ half cell lower = -0.23 - (-0.40) = +0.17 V

1 mark

**c.** $Cd(s) \rightarrow Cd^{2+}(aq) + 2e^-$ 1 mark

**d.** Provides ions which do not chemically react with either half cell components. 1 mark

**e.** Any metal in the electrochemical series from Fe to Mg 1 mark

**Question 7 (7 marks)**

**a.** $Q = It = 0.75 \times 3.0 \times 60 \times 60 = 8100$ C

$n(e^-) = Q / 96500 = 8100 / 96500 = 0.084$ mol 1 mark

**b.** $Al^{3+}(l) + 3e^- \rightarrow Al(l)$ 1 mark

**c.** $n(Al) = 0.084 / 3 = 0.028$ mol

$m = n \times Mr = 0.028 \times 27.0 = 0.76$ g

2 marks

**d.** $0.76 / 14.7 \times 100 = 5.1\%$

**e.** Reduced mining, $CO_2$ emissions, landfill, energy usage, etc. 1 mark

**f.** Lowers melting temperature of $Al_2O_3$ and so less energy is required than using molten aluminium oxide. 1 mark

**Question 8 (8 marks)**

**a.** $Li_2CO_3$ or $Na_2CO_3$ or $K_2CO_3$ 1 mark

**b.** $2CO_2(g) + O_2(g) + 4e^- \rightarrow 2CO_3^{2-}(l)$ 1 mark

**c.** $2H_2(g) + O_2(g) \rightarrow 2H_2O(g)$ 1 mark

**d.** Electrode must conduct electricity, catalyse reaction and be porous to gases. 1 mark

**e.** More efficient, no greenhouse gas emissions, no other non-metallic oxide emissions, electrolyte not used up. 2 marks

**f.** High operating temperatures, cost of hydrogen, energy required to melt electrolyte, needs to continually supply electricity as it is difficult to stop and start. 2 marks