THE SCHOOL FOR EXCELLENCE (TSFX)

UNIT 4 CHEMISTRY 2010

WRITTEN EXAMINATION 2

Reading Time: 15 minutes
Writing Time: 1 hour 30 minutes

QUESTION AND ANSWER BOOK

Structure of Booklet

Section		*Number of Questions*	*Number of Questions to be Answered*	*Number of Marks*	*Suggested Times (min)*
A	Multiple choice questions	20	20	20	20
B	Short answer questions	7	7	71	70
				Total 91	Total 90

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SECTION A - MULTIPLE CHOICE QUESTIONS

Instructions For Section A

Section A consists of 20 multiple-choice questions. Answer all 20 questions.
Choose the response that is **correct** or **best answers the question.**
A correct answer scores 1, an incorrect answer scores 0.
No marks will be given if more than one answer is shown for any question.

QUESTION 1
Which of the following would increase the **initial** reaction rate between 5.0 g aluminium and 20.0 mL of 1.00 M hydrochloric acid?

A Conducting the experiment in a 50 mL beaker rather than a 100mL beaker.
B Using a larger volume of acid.
C Cleaning the surface of the metal with sandpaper.
D Increasing the pressure under which the experiment was conducted.

QUESTION 2
Not all collisions between reactant particles result in the formation of products.
This could be due to

i. the molecules not colliding with sufficient energy.
ii. the concentration of reactants being low.
iii. the reaction reaching equilibrium.
iv. the reactants not colliding in the correct orientation.

A all of the above
B i only
C iii only
D i and iv

QUESTION 3
Which statement regarding the following reaction is correct?

$$2SO_{2(g)} + O_{2(g)} \rightarrow 2SO_{3(g)} \; \Delta H = -198.4 \; kJ/mol$$

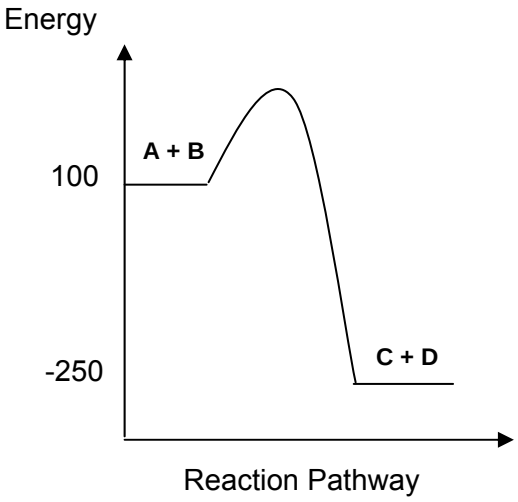
A The total energy needed to break the reactant bonds is greater than the energy released when the product bonds are created.

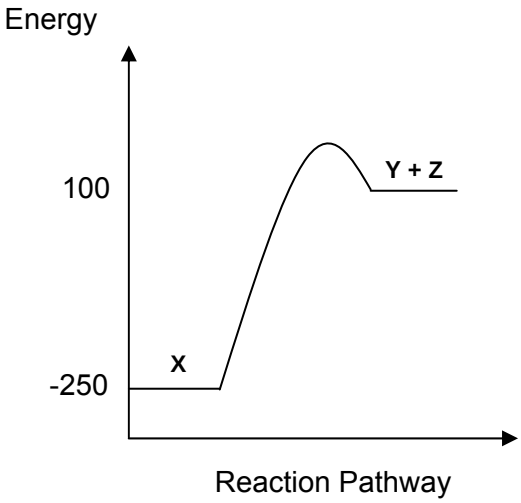
B The products are more stable than the reactants and less able to do work.

C The enthalpy of the reactants is less than the enthalpy of the products.

D The products have weaker bonds, on average, than the reactants and more stored chemical energy.

QUESTION 4
The energy profiles of two reactions are shown below.





The reaction with the lowest activation energy is

A A + B → C + D
B X → Y + Z
C C + D → A + B
D Z + Y → X

QUESTION 5
Which of the following statements regarding catalysts is incorrect?
When a catalyst is used

A the percent reduction in activation energy is the same for the forward and reverse reaction.

B the number of reactant particles with enough energy to overcome the activation energy increases.

C the amount of energy needed to break the reactant bonds and amount of energy released when new bonds are created is reduced by the same amount.

D an alternate reaction pathway is provided for the reaction.

QUESTION 6
Consider the following thermochemical equations:

$$Pb_{(s)} + CO_{(g)} \rightarrow PbO_{(s)} + C_{(s)} \quad \Delta H = -106.8\ kJ/mol$$
$$2C_{(s)} + O_{2(g)} \rightarrow 2CO_{(g)} \quad \Delta H = -221.0\ kJ/mol$$

The amount of heat released when 250 g of lead reacts with oxygen to form lead oxide is closest to

A -262 kJ
B +262 kJ
C -435 kJ
D +435 kJ

QUESTION 7
Which of the following options correctly describes the changes that occur to $N_{2(g)}$ when the volume of the following equilibrium system is reduced at constant temperature?

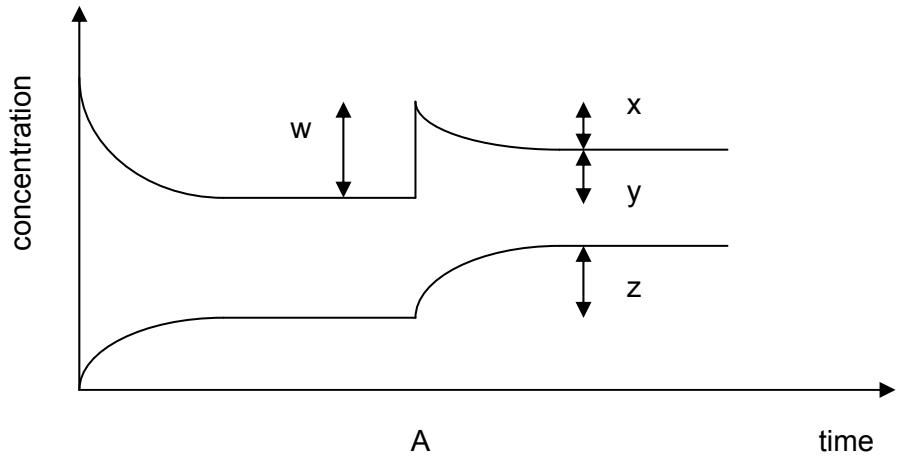
$$2NH_{3(g)} \rightarrow N_{2(g)} + 3H_{2(g)}$$

	Equilibrium Concentration (M)	Equilibrium Amount (M)
A	↑	↑
B	↑	↓
C	↓	↑
D	↓	↓

Questions 8 & 9 refer to the following information:

Consider the following equilibrium: $N_2O_{4(g)} \rightleftharpoons 2NO_{2(g)}$

Some $N_2O_{4(g)}$ was placed in an evacuated gas syringe and allowed to come to equilibrium. At time *A*, a change (at constant temperature and pressure) was made to the equilibrium system as shown in the graph below.



QUESTION 8
Which of the following relationships correctly describes the change in concentrations of $N_2O_{4(g)}$ and $NO_{2(g)}$ as equilibrium is being re-established?

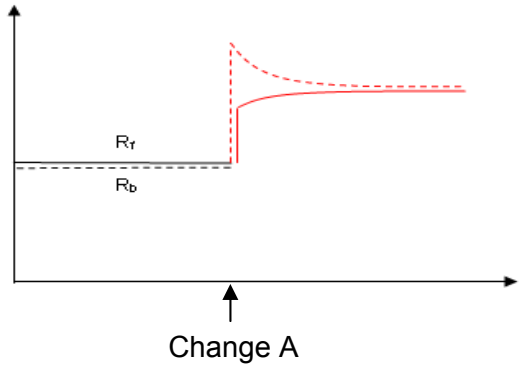
A z = 2y
B z = 2x
C w = z
D 2z =x

QUESTION 9

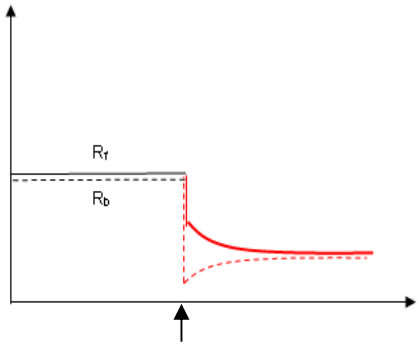
Which of the following graphs correctly identifies the changes in the forward and backward reaction rate when the change at A was made?

(R_f = Forward reaction rate, R_b = Backward reaction rate)

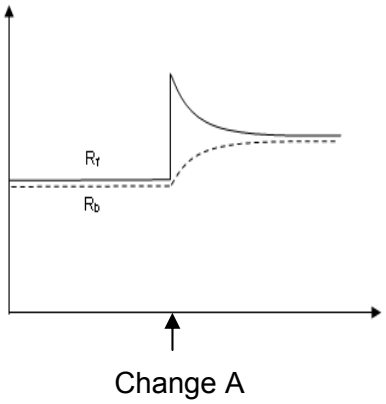
A



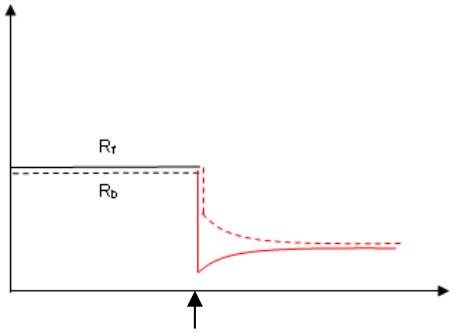
B



C



D



QUESTION 10

The following equilibrium $2SO_{3(g)} \rightleftharpoons 2SO_{2(g)} + O_{2(g)}$ has an equilibrium constant of K_c.

The concentration of SO_2 at equilibrium is given by

A $\sqrt{\frac{K_c[SO_3]^2}{[O_2]}}$

B $\sqrt{\frac{[O_2]}{K_c[SO_3]^2}}$

C $K_c\frac{[SO_3]^2}{[O_2]}$

D $\sqrt{\frac{K_c \times 2[SO_3]}{[O_2]}}$

QUESTION 11
A 1.0 M solution of ethanoic acid is at equilibrium at 25˚C. If a small amount of concentrated $H_2SO_{4(aq)}$ is added to the solution at constant temperature which of the following statements is incorrect?

A The pH of the solution will decrease when equilibrium is re-established.
B The value of K_w will decrease.
C The amount of ethanoic acid will have increased when equilibrium is re-established.
D The $[H^+]$ will be higher when equilibrium is re-established.

QUESTION 12
An experiment was carried out where 0.500 g of a gas was ignited in a bomb calorimeter with a calibration factor of 2780 J˚C^{-1}. The temperature increased by 9.06˚C. Which gas was burnt in the calorimeter?

A Methane
B Ethane
C Propane
D Butane

QUESTION 13
The E^0 values for reduction reactions involving chromium are shown below.

$$Cr_2O_{7(aq)}^{2-} + 14H_{(aq)}^{+} + 6e^- \rightarrow 2Cr_{(aq)}^{3+} + 7H_2O_{(l)} \quad 1.33V$$

$$Cr_{(aq)}^{3+} + e^- \rightarrow Cr_{(aq)}^{2+} \quad -0.41V$$

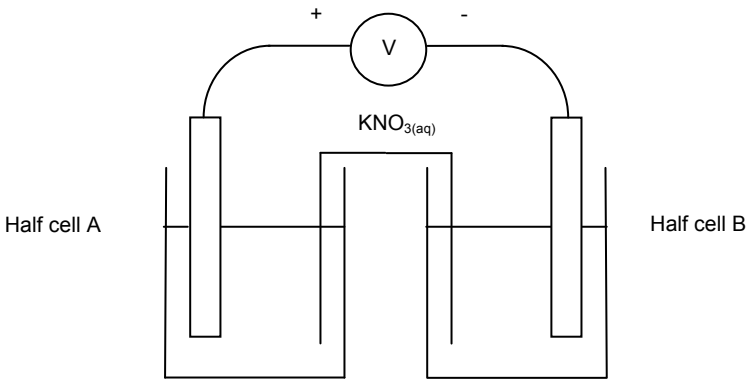
$$Cr_{(aq)}^{3+} + 3e^- \rightarrow Cr_{(s)} \quad -0.76V$$

$$Cr_{(aq)}^{2+} + 2e^- \rightarrow Cr_{(s)} \quad -0.91V$$

Which of the following could be used to reduce chromium from an oxidation state of +6 to +3?

A Cu
B Al
C Mn
D Fe

QUESTION 14
A galvanic cell was constructed using standard conditions as shown below.



Each half cell is made up of an inert electrode and an aqueous solution. The reading on the voltmeter is 1.00 V. The half cells could consist of

	Half Cell A	**Half Cell B**
A	$H_2O_{2(aq)}$	$Au^+_{(aq)}/Au_{(s)}$
B	$Au^+_{(aq)}/Au_{(s)}$	$Fe^{3+}_{(aq)}$, $Fe^{2+}_{(aq)}$
C	$H_2O_{2(aq)}$, $H^+_{(aq)}$	$Fe^{3+}_{(aq)}$, $Fe^{2+}_{(aq)}$
D	$H_2O_{2(aq)}$	$Fe^{3+}_{(aq)}$, $Fe^{2+}_{(aq)}$

QUESTION 15
A galvanic cell was constructed using an inert electrode in an acidified solution of $H_2O_{2(aq)}$ and a piece of lead in a lead solution. When the cell is connected

A lead would erode away at the cathode.
B the pH at the positive electrode would decrease.
C electrons would move from the cathode to the anode.
D anions from the salt bridge would move towards the $Pb_{(s)}/Pb^{2+}_{(aq)}$ half cell.

QUESTION 16
A 1.00 M solution of zinc chloride was electrolysed using graphite electrodes. In this electrolytic cell, water is acting as

A a solvent only.
B an oxidant and a solvent.
C a reductant and a solvent.
D an oxidant, reductant and a solvent.

QUESTION 17
A university student set up three different electrolytic cells. The substances that were electrolysed were $NaCl_{(l)}$, 0.05 M $NaCl_{(aq)}$ and 5.0 M $NaCl_{(aq)}$. Which of the following statements correctly describes the results of the experiment?

A The reactions occurring for the aqueous solutions will produce the same products at the anode and cathode.

B Chlorine gas is the major product when molten $NaCl_{(aq)}$ and 0.05 M $NaCl_{(aq)}$ are electrolysed.

C The pH at the cathode increases when solutions of NaCl are electrolysed.

D The only means by which different products can be produced for varying concentrations of NaCl is to alter the voltage.

QUESTION 18
A typical 12 V lead-acid car battery has six cells connected in series, each of which delivers about 2 V. When the battery is being recharged by the alternator, reactions occurring in the battery are:

$$PbSO_{4(s)} + 2e^- \rightarrow Pb_{(s)} + SO^{2-}_{4(aq)}$$
$$PbSO_{4(s)} + 2H_2O_{(l)} \rightarrow PbO_{2(s)} + SO^{2-}_{4(aq)} + 4H^+_{(aq)} + 2e^-$$

Which of the following is true when the battery is supplying energy to the headlights?

A The oxidation number of Pb decreases at the negative electrode.
B The pH at the cathode increases.
C The amount of $PbSO_{4(s)}$ in the battery decreases.
D The alternator is supplying electrons to the cathode.

QUESTION 19
In many ways, nuclear fusion is considered a superior power source to many of the other available energy sources. However, there are currently no nuclear fusion power plants in operation. This is because

A more energy can be harnessed from nuclear fission reactions.
B nuclear fusion power plants produce radioactive products which are difficult to manage.
C fusion reactions currently cannot be contained in a sustained manner.
D the raw materials are not renewable.

QUESTION 20
Chlorine dioxide is a good bleaching agent. It is used to bleach wood-pulp for paper making, in the de-tanning of leather and to bleach flour. It is also used in water sterilisation and acts as an antimicrobial pesticide which can kill microorganisms including bacteria, viruses or fungi.

Exposure to chlorine dioxide can cause acute irritation to the nose and throat, causing coughing and chest pain; eye irritation with watery eyes and seeing halos around lights.

Some typical reaction involving chlorine dioxide are:

$$4S_{(s)} + 6ClO_{2(aq)} + 4H_2O_{(l)} \rightarrow 4H_2SO_{4(aq)} + 3Cl_{2(g)}$$
$$Zn_{(s)} + 2ClO_{2(g)} \rightarrow Zn(ClO_2)_{2(aq)}$$

Chlorine dioxide could be classified as

i. an oxidant
ii. toxic
iii. corrosive
iv. dangerous to the environment

A i only
B i and iii only
C ii and iv only
D i, ii, iii and iv

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 for 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 that all chemical equations are balanced and that the formulas for individual substances include an indication of state (for example, $H_{2(g)}$; $NaCl_{(s)}$).

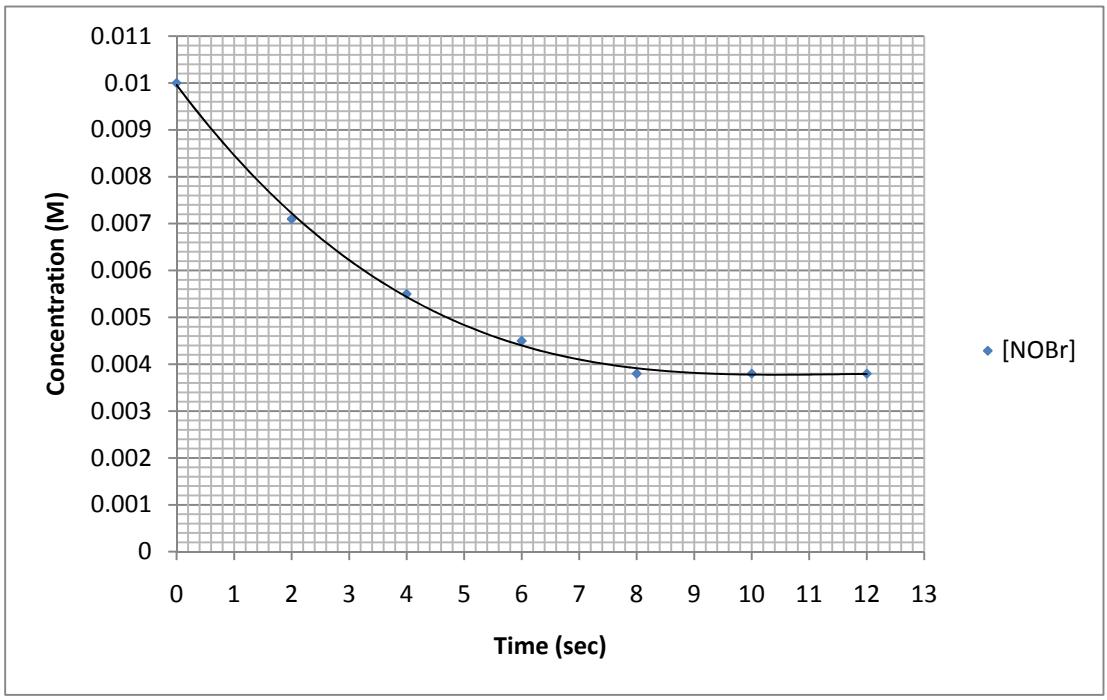
QUESTION 1
Nitrosyl bromide decomposes according to the following equation

$$2NOBr_{(g)} \rightarrow 2NO_{(g)} + Br_{2(g)}$$

A student placed some nitrosyl bromide in a container and used a manometer (an instrument for comparing pressures) to collect the following data.

Time (sec)	Concentration NOBr (M)
0	0.0100
2	0.0071
4	0.0055
6	0.0045
8	0.0038
10	0.0038
12	0.0038

The data collected was used to plot the following graph.



a. Determine:

(i) The initial rate of reaction in terms of [NOBr].

(ii) The average rate of reaction in terms of [NOBr] for the first 8 seconds.

1 + 1 = 2 marks

b. Why is the initial rate of reaction greater than the average rate over the first 8 seconds?

1 mark

c. On the given graph, show how the concentration of Br_2 would change over the 10 second period.

2 marks

d. The student repeats the experiment, this time using a higher pressure, which was accomplished by decreasing the volume of the container at constant temperature.

(i) State what will happen to the reaction rate giving a reason for the observed change. Show these changes on the graph provided on the previous page.

3 marks

(ii) An increase in pressure (by decreasing the volume) does not increase the reaction rate for the following reaction type:

$AB_{(g)} \rightarrow A_{(g)} + B_{(g)}$.

Explain why this is the case and suggest one way the reaction rate could be increased.

2 marks

Total 10 Marks

QUESTION 2

Ammonium carbamate ($NH_2COONH_{4(s)}$) is an ionic salt derived from carbamic acid, which is found in the blood of mammals. At 250˚C, the value of K_c = 1.58 x 10^{-8}.

$$NH_2COONH_{4(s)} \leftrightarrow 2NH_{3(g)} + CO_{2(g)} \qquad K_c = 1.58 \times 10^{-8} \text{ at } 250^{\circ}C$$

a. Write the equilibrium expression for the above equation, stating the appropriate units.

2 marks

b. If 30.0 g of ammonium carbamate was placed into an empty 2.00 L gas cylinder, what would be the pressure in the container when equilibrium was established?

3 marks

c. What percentage of $NH_2COONH_{4(s)}$ would have decomposed?

1 mark

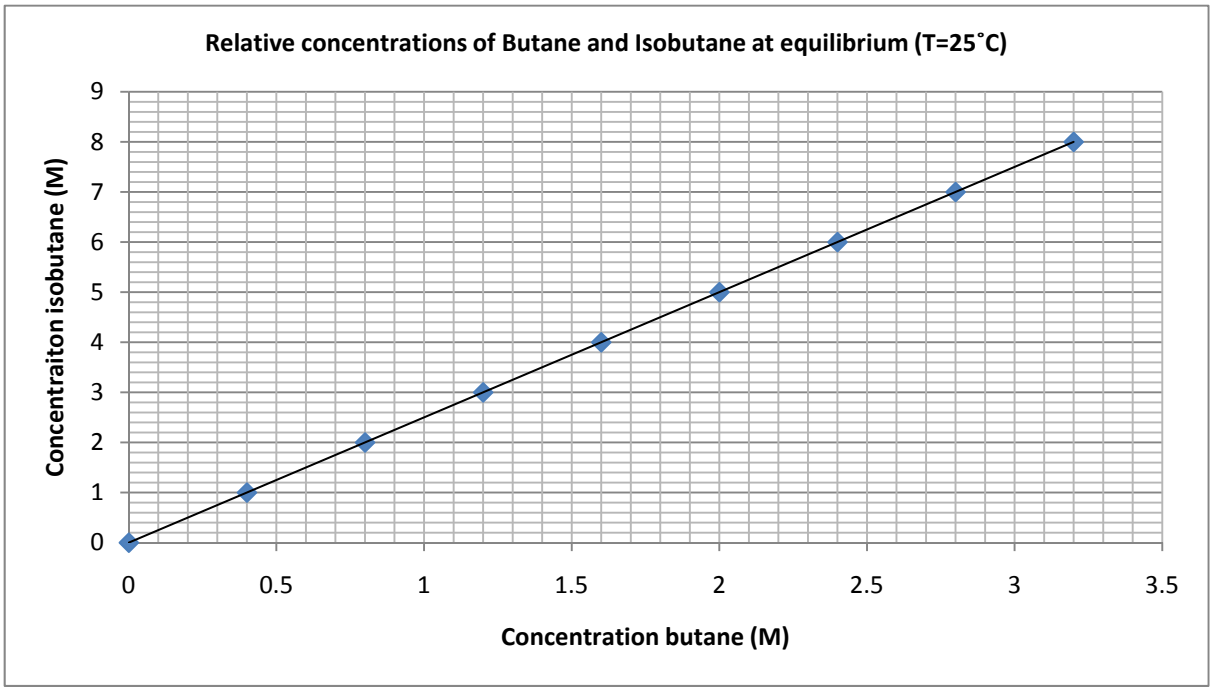
Total 6 Marks

QUESTION 3

The line on the graph below indicates the concentrations at which butane and isobutane are at equilibrium at 25˚C.

$$butane \leftrightarrow isobutane$$

1 : 1



a. Use the graph to determine the equilibrium constant for this reaction.

_____

_____

1 mark

b. Suppose the equilibrium concentration of butane is 0.50 M.

(i) Mark a point on the graph that represents the equilibrium at this time. Label this point **A**.

(ii) Mark a point on the graph that indicates the relative concentrations of butane and isobutane at the instant 1.5 mol/L of butane is added. Label this point **B**.

(iii) Consider the reaction quotient, Q. At the time butane is added, would the value of the equilibrium constant, K, be greater or less than Q. Give a reason for your answer.

_____

_____

_____

_____

1 + 1 + 2 = 4 marks

c. Consider the system at Point **B**. Equilibrium is restored when

[butane] = 0.93 M
[isobutane] = 2.32 M

If points B and C were connected, the slope would have a gradient of -1.
Give a reason for this observation.

_____

_____

1 mark

d. Draw a concentration-time graph clearly showing the following:

(i) The butane/isobutane system at equilibrium when [butane] = 2.5 M.

(ii) The change in concentration of butane and isobutane if *x* mole of butane is added to the system at constant temperature and volume.

(iii) The final concentration of butane and isobutane if $[butane]_{final}$ = 3.2 M.

3 marks

Total 9 Marks

QUESTION 4

Phenylacetic acid ($C_6H_5CH_2COOH$) is a weak acid and is known to build up in the blood stream of people suffering from phenylketonuria, a genetic disorder that can cause mental retardation and death if not treated.

A 0.120 M solution of the acid has a pH of 2.60 at 25˚C.

a. Write an expression for the acidity constant.

1 mark

b. Determine the value of the acidity constant for phenylacetic acid.

2 marks

c. When calculating K_a in part (a) above, it is assumed that the $[H^+]$ in the solution is not significantly affected by the self ionisation of water. Show that this assumption is justified by determining what percentage of H^+ are due to the self ionisation of water in this solution.

1 mark

d. Determine the pH of the solution if it is diluted by a factor of 10.

2 marks

e. At 35˚C, the K_a value for the dissociation of phenylacetic acid is 0.48×10^{-5}.

(i) Is the dissociation of phenylacetic acid endothermic or exothermic? Give a reason for your answer.

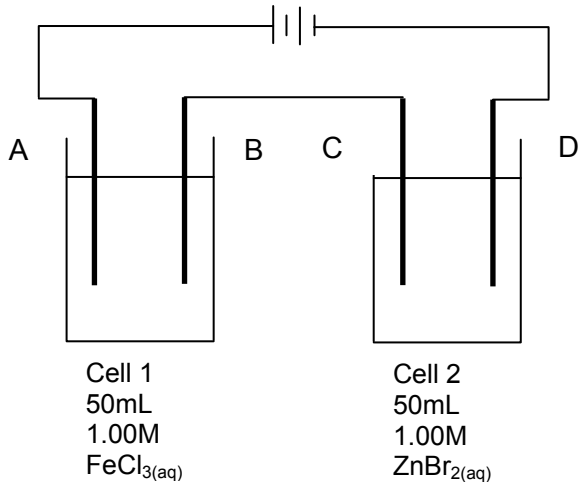
2 marks

(ii) What happens to the pH of the acid as the temperature of a solution of the acid increases?

1 mark

Total 9 Marks

QUESTION 5
Two electrolytic cells were connected in series using platinum electrodes as shown below.



a. (i) Predict the reactions occurring at:

Electrode A: _____

Electrode B: _____

Electrode C: _____

Electrode D: _____

(ii) Write an overall equation for Cell 1.

_____

_____

(iii) Determine the voltage that would be required for the electrolysis of the two solutions. Using equations if appropriate, describe the effect, if any, that this voltage will have on the predicted reactions occurring at electrodes A to D.

_____

_____

_____

_____

_____

_____

2 + 1 + 3 marks = 6 marks

b. When a current of 2.50 A was applied to the cell, 1.02 g of Zn was produced in Cell 2.

(i) Determine the amount, in mole, of electrons that passed through the cell.

1 mark

(ii) What would be the concentration of $Fe^{3+}_{(aq)}$ in Cell 1 at this time?

3 marks

(iii) How long would it have taken for these changes to take place?

2 marks

c. If 50.0 mL of 1.00 M $PbI_{2(aq)}$ was used instead of $ZnBr_{2(aq)}$ under the same conditions, what would be the effect on the concentration of $Fe^{3+}_{(aq)}$?

1 mark

d. How would the operation of the two cells be affected if the size of the electrodes was increased and the distance between the electrodes in each cell was decreased? Explain why this is the case.

2 marks

Total 15 Marks

QUESTION 6

Ethanol is a clear, colourless liquid that is generally derived from grain or sugar. Recent research has led to ethanol being blended with petrol in various proportions in order to produce a fuel with a lower carbon footprint. Some countries like Brazil have made it mandatory to use ethanol/petrol blends in motor vehicles with the maximum legal blend being 25% ethanol : 75% petrol.

A laboratory experiment is set up to determine the percentage ethanol in 'Ethogas', a fuel consisting of ethanol and octane. 5.000 g of the fuel was combusted in a bomb calorimeter and the temperature of the calorimeter changed from 15.50˚C to 90.17˚C. A current of 2.750 A was then passed through the calorimeter for 90.0 sec with a voltage of 6.000 V. The final temperature of the calorimeter was 90.651˚C.

a. Determine the calibration constant of the calorimeter.

1 mark

b. Determine the energy content of ethanol and octane in $kJ.g^{-1}$.

2 marks

c. Use your answers from parts (a) and (b) to determine the percentage ethanol in 'Ethogas'.

3 marks

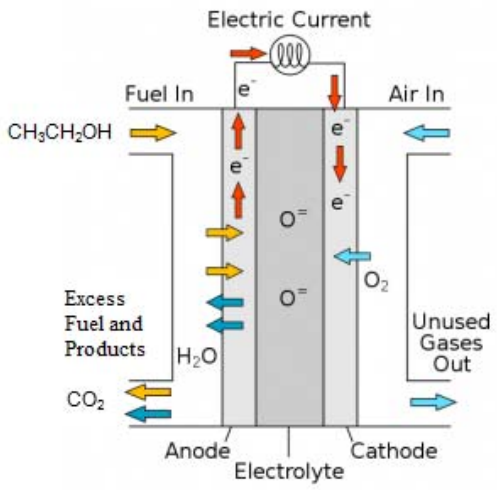
d. If the power supply in the calorimeter was faulty and delivered a voltage less than the expected 6.00V, what would be the effect on the calculated % ethanol in Ethogas? Give a reason for your answer.

2 marks

e. Why is ethanol considered to be an eco-friendly fuel?

1 mark

f. Ethanol energy from ethanol can also be converted into electricity using Solid Oxide Fuel Cells as shown below.



(i) The overall cell equation and the reaction occurring at the anode are shown below.

Anode: $6O^{2-}_{(in\ ceramic)} + C_2H_5OH_{(l)} \rightarrow 2CO_{2(g)} + 3H_2O_{(l)} + 12e^-$

Overall: $3O_{2(g)} + C_2H_5OH_{(l)} \rightarrow 2CO_{2(g)} + 3H_2O_{(l)}$

Write an equation for the reaction occurring at the cathode.

1 mark

(ii) Explain one advantage and one disadvantage of using an ethanol solid oxide fuel cell to generate electricity rather than a conventional coal fired power station.

2 marks

(iii) List three functions of the electrodes in a fuel cell.

1 mark

Total 13 Marks

QUESTION 7
'Atom Economy' is a principle which applies to large scale chemical production. It involves designing plant processes and conditions so that maximum amounts of raw materials are converted into products.

The equations in the table below illustrate one step in the production of the chemical indicated. Choose one of the chemicals as the basis of your answers to the following questions.

Circle your choice of chemical.

Sulphuric acid	$2SO_{2(g)} + O_{2(g)} \leftrightarrow 2SO_{3(g)}\ \Delta H = -197\ kJ/mol$
Nitric acid	$4NH_{3(g)} + 5O_{2(g)} \leftrightarrow 4NO_{(g)} + 6H_2O_{(g)}\ \ \Delta H = -907\ kJ/mol$
Ammonia	$N_{2(g)} + 3H_{2(g)} \leftrightarrow 2NH_{3(g)}\ \ \Delta H = -91kJ/mol$
Ethene	$C_2H_{6(g)} \leftrightarrow C_2H_{4(g)} + H_{2(g)}\ \ \Delta H = +138\ kJ/mol$

a. State two ways in which maximum atom economy could be achieved for your chosen reaction.

2 marks

b. The conditions needed for achieving high atom economy often conflicts with achieving high yields in a cost effective manner. Indentify these conflicts and discuss the conditions that are actually used in the production of your selected chemical.

2 marks

c. Detail two (2) ways in which waste is minimised and managed for your chosen chemical.

2 marks

d. Discuss one health and one safety issue involving the production of your chosen chemical.

2 marks

e. If you have chosen sulphuric acid or nitric acid as your chemical, write an equation demonstrating its corrosive nature.

If you have chosen ethene or ammonia as your chemical, write an equation to show how this chemical is oxidised.

1 mark

Total 9 Marks

END OF PAPER

BONUS QUESTION

The Snowy Mountains Hydro-electric scheme is one of the most complex hydro-electric power plants in the world. It took 25 years to build and employed over 100,000 people from over 30 countries. Hydro Tasmania also generates a large amount of hydro power in Australia, utilising the high rainfall and mountainous terrain of Tasmania and other Australian states, and has recently been expanding further into the Pacific area.

In the period 2003 – 2004, the total amount of electricity produced by hydro-electric schemes in Australia was 15,400 GWh. This equated to 7.2% of all of the electricity generated in that year.

Note: A kilowatt hour is a unit of energy equal to 3.6 mega joules, which is the amount of energy converted if work is done at an average rate of one thousand watts for one hour).

1 kWh = 10^3 Wh
1 MWh = 10^6 Wh
1 GWh = 10^9 Wh

a. If the average domestic household uses 15.0 kWh of energy per day, determine how many households can be supplied by hydro-electric power for one year.

3 marks

b. The Snowy Mountains Hydro-electric Scheme alone prevents approximately 4.57 x 10^6 tonnes of carbon dioxide from being released into the atmosphere per year. Assuming that petrol is 100% octane and the average car uses 2500 L of petrol in a year, determine the number of cars needed to generate this amount of carbon dioxide. (Density Octane = 0.703 g/mL)

3 marks

c. The current dollar cost of building the Snowy Mountains Hydro-electric scheme is equivalent to over $6 billion. Why are hydro-electric schemes considered worth investing in considering the huge expense in building them?

2 marks

Total 8 Marks