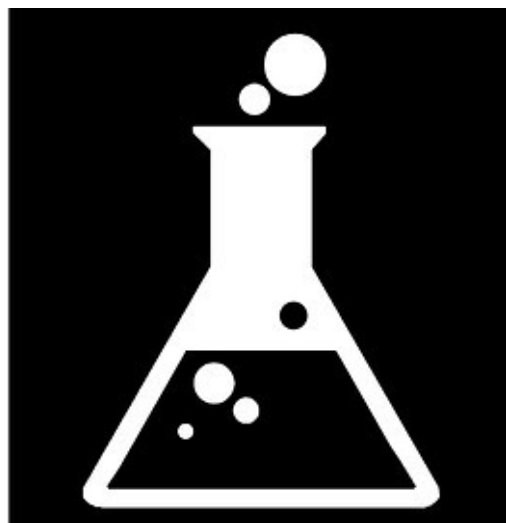# ROSSMOYNE SENIOR HIGH SCHOOL

CHEMISTRY

SEMESTER 1
EXAM

2016

Name: _____

Teacher: _____

TIME ALLOWED FOR THIS PAPER
Reading time before commencing work: ten minutes
Working time for the paper: three hours

MATERIALS REQUIRED/RECOMMENDED FOR THIS PAPER

To be provided by the supervisor:
This Question/Answer Booklet
Multiple-choice Answer Sheet
Chemistry Data Book

To be provided by the candidate:
Standard items: pens (blue/black preferred), pencils (including coloured), sharpener, eraser, correction tape/fluid, ruler, highlighters

Special items: up to three non-programmable calculators approved for use in the WACE examinations

IMPORTANT NOTE TO CANDIDATES
No other items may be taken into the examination room. It is **your** responsibility to ensure that you do not have any unauthorised notes or other items of a non-personal nature in the examination room. If you have any unauthorised material with you, hand it to the supervisor **before** reading any further.

Structure of this paper

Section	Number of questions available	Number of questions to be answered	Suggested working time (minutes)	Marks available	Percentage of exam
Section One: Multiple-choice	25	25	50	/50	/26
Section Two: Short answer	9	9	60	/66	/34
Section Three: Extended answer	5	5	70	/76	/40
/192		Total Marks Available :			/100

Instructions to candidates

1.   Answer the questions according to the following instructions.

        Section One: Answer all questions on the separate Multiple-choice Answer Sheet provided. For each questions shade the box to indicate your answer. Use only a blue or black pen to shade the boxes. If you make a mistake, place a cross through that square then shade your new answer. Do not erase or use correction fluid/tape. Marks will not be deducted for incorrect answers. No marks will be given if more than one answer is completed for any question.

        Sections Two and Three: Write your answers in this Question/Answer Booklet.
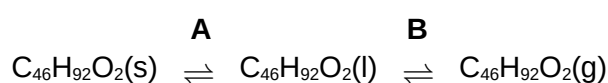
2.   When calculating numerical answers, show your working or reasoning clearly. Express numerical answers to the appropriate number of significant figures and include appropriate units where applicable.

3.   You must be careful to confine your responses to the specific questions asked and to follow any instructions that are specific to a particular question.

4.   Spare pages are included at the end of this booklet. They can be used for planning your responses and/or as additional space if required to continue an answer.
   •   Planning: If you use the spare pages for planning, indicate this clearly at the top of the page.
   •   Continuing an answer: If you need to use the space to continue an answer, indicate in the original answer space where the answer is continued, i.e. give the page number. Fill in the number of the question(s) that you are continuing to answer at the top of the page.

5.   The Chemistry Data Book is **not** handed in with your Question/Answer Booklet.

Section One: Multiple-choice   **25%   (50 marks)**

This section has **25** questions. Answer **all** questions on the separate Multiple-choice Answer Sheet provided. For each question, shade the box to indicate your answer. Use only a blue or black pen to shade the boxes. If you make a mistake, place a cross through that square then shade your new answer. Do not erase or use correction fluid/tape. Marks will not be deducted for incorrect answers. No marks will be given if more than one answer is completed for any question.

Suggested working time: 50 minutes.

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1.   When a candle burns, there are many different chemical processes occurring. Firstly the solid candle wax ($C_{46}H_{92}O_2$) is melted by the heat of the flame. This liquid wax is then drawn up the wick, where the heat of the flame vaporises it. The wax vapour then burns in air to produce the heat and light seen. The equation below represents the physical changes taking place in the candle wax **before** combustion occurs.

$$\begin{array}{ccccc} & \textbf{A} & & \textbf{B} & \\ C_{46}H_{92}O_2(s) & \rightleftharpoons & C_{46}H_{92}O_2(l) & \rightleftharpoons & C_{46}H_{92}O_2(g) \end{array}$$

Classify the processes labelled A and B as endothermic or exothermic.

	A	**B**
(a)	endothermic	endothermic
(b)	endothermic	exothermic
(c)	exothermic	exothermic
(d)	exothermic	endothermic

2.   Consider the information in the table below regarding three different monoprotic acids.

Acid	**K_a**
Formic acid	1.82×10^{-4}
Hydrofluoric acid	6.76×10^{-4}
Propionic acid	1.35×10^{-5}

If separate 0.5 mol L^{-1} solutions of these three acids were tested with a pH meter, at the same temperature, which would have the highest pH?

(a)   Formic acid.
(b)   Hydrofluoric acid.
(c)   Propionic acid.
(d)   More information is required.

3.   Which of the following statements regarding a 'salt bridge' is **not** correct?

(a)   A salt bridge allows ions to move between half-cells.
(b)   A salt bridge prevents build up of charge in half-cells.
(c)   A salt bridge is an optional component of a galvanic cell.
(d)   A salt bridge takes no part in the chemical reaction occurring in either half-cell.

**Questions 4 and 5 refer to the information below.**

The Haber process is the final step in the production of ammonia. It involves the reaction of nitrogen and hydrogen gases in the presence of an iron/iron oxide catalyst. This process is carried out at 350-550 °C and 15-35 MPa. The reaction can be represented by the equation below.

$$N_2(g) + 3 H_2(g) \rightleftharpoons 2 NH_3(g)$$
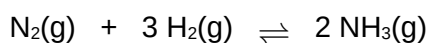
4.   Which statement is **not** correct regarding the action of a catalyst?

        (a)   A catalyst increases the rate of reaction.
        (b)   A catalyst increases the average kinetic energy of the reactant particles.
        (c)   A catalyst allows a greater proportion of particles to react.
        (d)   A catalyst provides an alternate reaction pathway.

5.   The iron/iron oxide catalyst is added to this system **before** it establishes equilibrium. What is the resulting effect?

        (a)   The activation energy for the forward reaction is lowered more than that of the reverse reaction
        (b)   The reverse reaction rate would be increased more than the forward reaction rate.
        (c)   The system would establish equilibrium faster.
        (d)   The yield of NH_3 would be increased.

6.   A student had five different 0.2 mol L^{-1} solutions on her lab bench. They were;

                - nitric acid, $HNO_3(aq)$
                - zinc chloride, $ZnCl_2(aq)$
                - lithium hydrogencarbonate, $LiHCO_3(aq)$
                - potassium hydroxide, $KOH(aq)$
                - ammonium chloride, $NH_4Cl(aq)$

        Rank these solutions in order of **increasing** pH (i.e. lowest to highest).

        (a) HNO_3 < NH_4Cl < $ZnCl_2$ < $LiHCO_3$ <   KOH
        (b)   KOH   < NH_4Cl < $ZnCl_2$ < $LiHCO_3$ < HNO_3
        (c) HNO_3 < $LiHCO_3$ < NH_4Cl < $ZnCl_2$ <   KOH
        (d)   KOH   < $ZnCl_2$ < $LiHCO_3$ < NH_4Cl < HNO_3

7.   Consider the following reaction between cobalt metal and hydrochloric acid.

$$Co(s) + 2 H^+(aq) \rightarrow Co^{2+}(aq) + H_2(g)$$
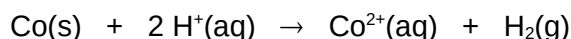
        Which of the following statements is **correct**?

        (a)   Electrons are transferred from Co(s) to $H^+(aq)$.
        (b)   Electrons are transferred from $H^+(aq)$ to Co(s).
        (c)   Both Co(s) and $H^+(aq)$ will each gain and lose some electrons.
        (d)   Electrons are not transferred, as this is not a redox reaction.

Questions 8, 9 and 10 refer to the following information.

Consider the following equilibrium system, which is formed when solid white phosphorus reacts with fluorine gas to form phosphorus trifluoride vapour.

$$P_4(s) \; + \; 6\,F_2(g) \; \rightleftharpoons \; 4\,PF_3(g)$$
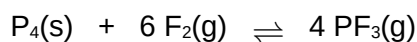
8.   What is the correct equilibrium constant (K) expression for the following reaction?

(a) $K \; = \; \dfrac{[P_4][F_2]^6}{[PF_3]^4}$

(b) $K \; = \; \dfrac{4[PF_3]}{6[F_2]}$

(c) $K \; = \; \dfrac{[PF_3]^4}{[F_2]^6}$

(d) $K \; = \; \dfrac{[PF_3]^4}{[P_4][F_2]^6}$

9.   If the total volume of the system was increased, which of the following effects would **not** occur while equilibrium is being re-established?

(a)   The forward reaction rate would decrease.
(b)   The reverse reaction rate would be higher than the forward reaction rate.
(c)   The reverse reaction rate would increase.
(d)   The forward reaction rate would have the greater change in rate.

10.   Once the system has re-established equilibrium (after the increase in total volume), which of the following statements would **not** be correct?

(a)   The mass of $P_4(s)$ would not have changed.
(b)   The concentration of $F_2(g)$ would have decreased.
(c)   The number of moles of $PF_3(g)$ present would have decreased.
(d)   The number of moles of $F_2(g)$ present would have increased.

11.   "A non-rechargeable cell is constructed from a nickel oxyhydroxide cathode and an anode composed of an hydrogen-absorbing alloy. This cell has the ability to produce a voltage in the range of 1.4-1.6V."

This description is consistent with a;

(i)   primary cell
(ii)   secondary cell
(iii)   electrolytic cell
(iv)   galvanic cell
(v)   fuel cell

(a)   (i) and (iii) only
(b)   (i) and (iv) only
(c)   (ii) and (iv) only
(d)   (i) and (v) only

12.   Calculate the pH of a solution formed by mixing 10.0 mL of 0.125 mol L^{-1} nitric acid, $HNO_3(aq)$, with 90.0 mL of water.

       (a)   2.90
       (b)   1.86
       (c)   0.90
       (d)   1.90

13.   Examine the following energy profile diagrams which represent four different chemical processes. You may assume the scale on the y-axis is the same for each diagram.
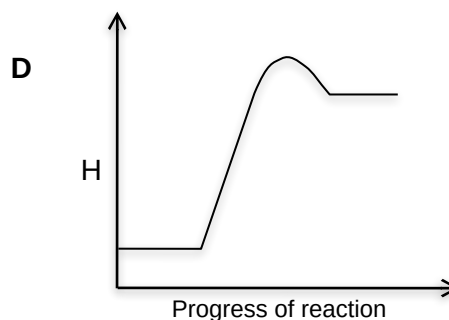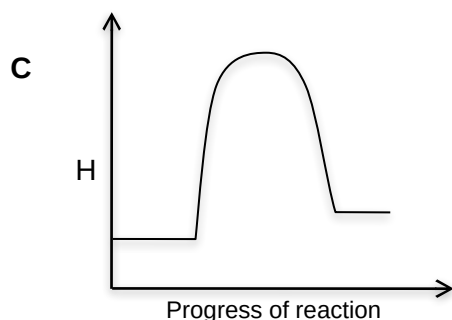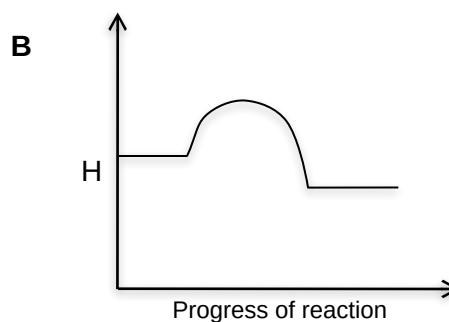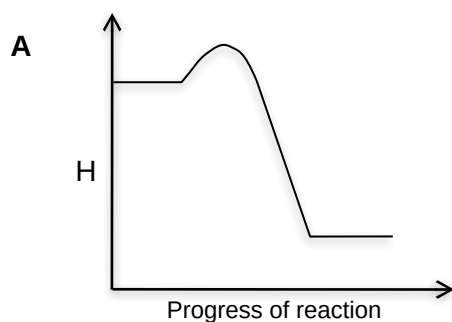
       Considering the forward and reverse activation energies of these reactions, which is **most likely** to be a reversible reaction (i.e. the reaction that is most likely to proceed in both the forward and reverse directions)?

       (a)   A
       (b)   B
       (c)   C
       (d)   D

14.   A craftsman wanted to coat/plate some metal light fixtures with a thin layer of silver metal to prevent corrosion. He decided to use an electrolytic cell to do this. Which of the following would **not** be a correct feature of his cell design?

       (a)   The light fixtures would be the cathode.
       (b)   The silver electrode would be connected to the positive terminal of the power source.
       (c)   The silver electrode would become oxidised.
       (d)   Silver would plate at the positive electrode.

Questions 15 and 16 refer to the information below.

An acid-base titration was conducted by a chemistry professor, with the pH being monitored throughout the experiment. From the data collected, the following titration curve was produced.

Addition of burette reagent
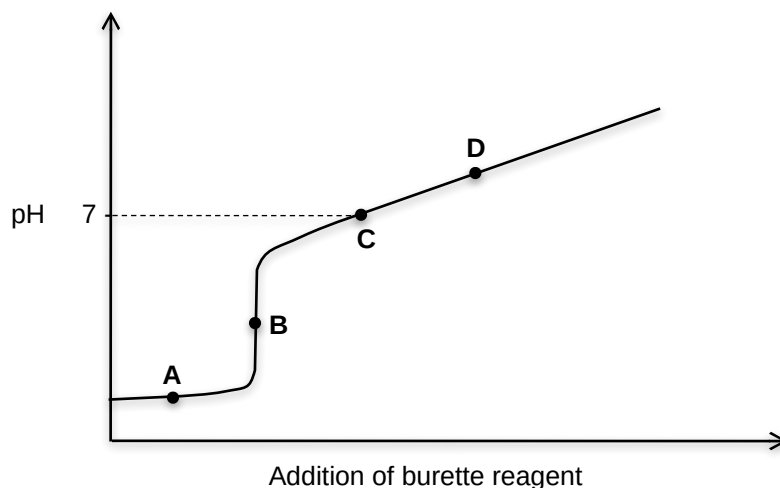
15.   Which of the following arrangements could have produced this titration curve?

	Burette reagent	**Conical flask reagent**
(a)	$HNO_3(aq)$	$KOH(aq)$
(b)	$NH_3(aq)$	$HCl(aq)$
(c)	$NaOH(aq)$	$CH_3COOH(aq)$
(d)	$HCl(aq)$	$Na_2CO_3(aq)$

16.   Which letter represents the equivalence point of the titration?

(a)   A
(b)   B
(c)   C
(d)   D

17.   The endothermic auto-ionisation of water can be represented by the equation below.

$$H_2O(l) \; + \; H_2O(l) \; + \; heat \; \rightleftharpoons \; H_3O^+(aq) \; + \; OH^-(aq) \qquad K_w = 1.0 \times 10^{-14} \text{ at } 25 \,^{\circ}C$$
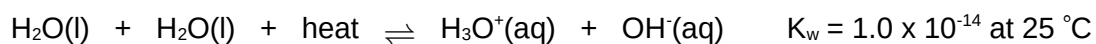
If the temperature of pure water was raised to 50 $^{\circ}$C, which of the following statements are **correct**?

(i)   The concentration of $H_3O^+(aq)$ would be greater than 1.0×10^{-7} mol L^{-1}.
(ii)   The concentration of $OH^-(aq)$ would be lower than 1.0×10^{-7} mol L^{-1}.
(iii)   The value of K_w would increase.
(iv)   The pH of the water would increase.
(v)   The acidity of the water would increase.

(a)   (i) and (ii) only
(b)   (iii) and (iv) only
(c)   (i), (iii) and (v) only

(d)   (i) and (iii) only

Questions 18 and 19 refer to the following information.

Consider the following equilibrium which is formed between iron(III) ions and citrate ions, when 50 mL of iron(III) nitrate, $Fe(NO_3)_3(aq)$, is mixed with 50 mL of sodium citrate, $Na_3C_6H_5O_7(aq)$.

$$Fe^{3+}(aq) + C_6H_5O_7^{3-}(aq) \rightleftharpoons FeC_6H_5O_7(aq) \qquad K = 6.3 \times 10^{11} \text{ at } 25\ ^{\circ}C$$

very pale brown   colourless   yellow

18.   If this system was allowed to establish equilibrium at 25 $^{\circ}$C, which of the following would be the **best prediction** of the appearance of the system?

(a)   The solution would appear yellow.
(b)   The solution would appear brown-yellow.
(c)   The solution would appear very pale brown.
(d)   The colour of the solution cannot be predicted.

19.   If a few drops of citric acid ($C_6H_8O_7$) were added to this equilibrium system, which of the following gives the expected result?

	Favoured direction	**New concentration of $Fe^{3+}(aq)$**
(a)	forward	increased
(b)	forward	decreased
(c)	reverse	increased
(d)	reverse	decreased

Questions 20 and 21 refer to the following information.

The equation for the complete combustion of butanol is shown below.

$$C_4H_{10}O(l) + 6\ O_2(g) \rightarrow 4\ CO_2(g) + 5\ H_2O(l)$$
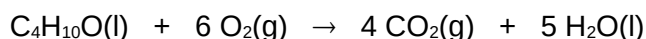
20.   How does the oxidation number of the element carbon (C) change during this reaction?

(a)   +2 to +4
(b)   -2 to +2
(c)   -2 to +4
(d)   +2 to 0

21.   Which of the following statements regarding combustion is **not** correct?

(a)   Combustion requires oxygen.
(b)   Combustion is exothermic.
(c)   Oxygen (O_2) is the oxidant/oxidising agent.
(d)   Combustion is spontaneous.

22.   Consider the buffer solution shown below.

$$HF(aq) \ + \ H_2O(l) \ \rightleftharpoons \ F^-(aq) \ + \ H_3O^+(aq)$$

Which of the following would be **true** after the addition of a small amount of $H_3O^+(aq)$ to the buffer solution?

(a)   The forward reaction rate would decrease.
(b)   The amount of HF present in the system would increase.
(c)   The pH of the system would increase.
(d)   The forward reaction would be favoured.

Questions 23 and 24 refer to the information below.

Corrosion occurs when metals are oxidised by coming into contact with oxygen. This process is increased in the presence of water or acidic and basic conditions. When iron is corroded it often forms rust.

23.   Which of the following is **correct** in relation to the rusting of iron metal?

(a)   Oxygen gas is the reducing agent / reductant
(b)   Liquid water is the reducing agent / reductant
(c)   The oxidation number of iron would decrease
(d)   The presence of salt water would increase the rate of rusting

24.   Using your table of standard reduction potentials, choose the metal that is **not** likely to corrode under standard conditions.

(a)   Zn
(b)   Ni
(c)   Cu
(d)   Au

25.   Consider the diagram below, which shows the various colours of the indicator 'cresol red' under different pH conditions.

	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14
pH															
cresol red	red			yellow								red			

Which of the following pairs of solutions would **most easily** be distinguished by adding a few drops of cresol red indicator to each?

(a)   0.5 mol L^{-1} NaH$_2$PO$_4$ and   0.5 mol L^{-1} NaCl
(b)   2.0 mol L^{-1} H$_2$SO$_4$ and   2.0 mol L^{-1} NaOH
(c)   0.25 mol L^{-1} NH$_3$ and   water
(d)   0.7 mol L^{-1} H$_2$CO$_3$ and   0.7 mol L^{-1} NH$_4$NO$_3$

End of Section One

Section Two: Short answer   **35%   (70 marks)**

This section has **9** questions. Answer **all** questions. Write your answers in the spaces provided.

When calculating numerical answers, show your working or reasoning clearly. Express numerical answers to the appropriate number of significant figures and include appropriate units where applicable.

Spare pages are included at the end of this booklet. They can be used for planning your responses and/or as additional space if required to continue an answer.
* Planning: If you use the spare pages for planning, indicate this clearly at the top of the page.
* Continuing an answer: If you need to use the space to continue an answer, indicate in the original answer space where the answer is continued, i.e. give the page number. Fill in the number of the question(s) that you are continuing to answer at the top of the page.

Suggested working time: 60 minutes.

Question 26   **(6 marks)**

Arsenic acid (H_3AsO_4) can be produced by reacting solid arsenic trioxide (As_2O_3) with nitric acid. This produces arsenic acid, as well as the gaseous by-product dinitrogen trioxide.

Write the oxidation and reduction half-equations and the overall redox equation for this reaction, assuming acidic conditions.

Oxidation half-equation	
Reduction half-equation	
Overall redox equation	

Question 27 **(4 marks)**

Litmus is a very common acid-base indicator which is extracted from lichens. It turns red in solutions that have a pH below 7 and blue when the pH is above 7. The substance responsible for the colour of litmus indicator is called 7-hydroxyphenoxazone. The structure of this molecule is shown below in its 'red form'.
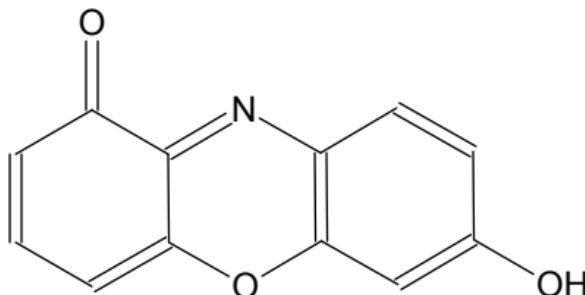
A simplified way to express this molecule is H*Lit*. This simplified notation is used in the equation below to demonstrate the reaction that litmus undergoes to change colour.

$$H\textit{Lit}(aq) \ + \ H_2O(l) \ \rightleftharpoons \ \textit{Lit}^-(aq) \ + \ H_3O^+(aq)$$
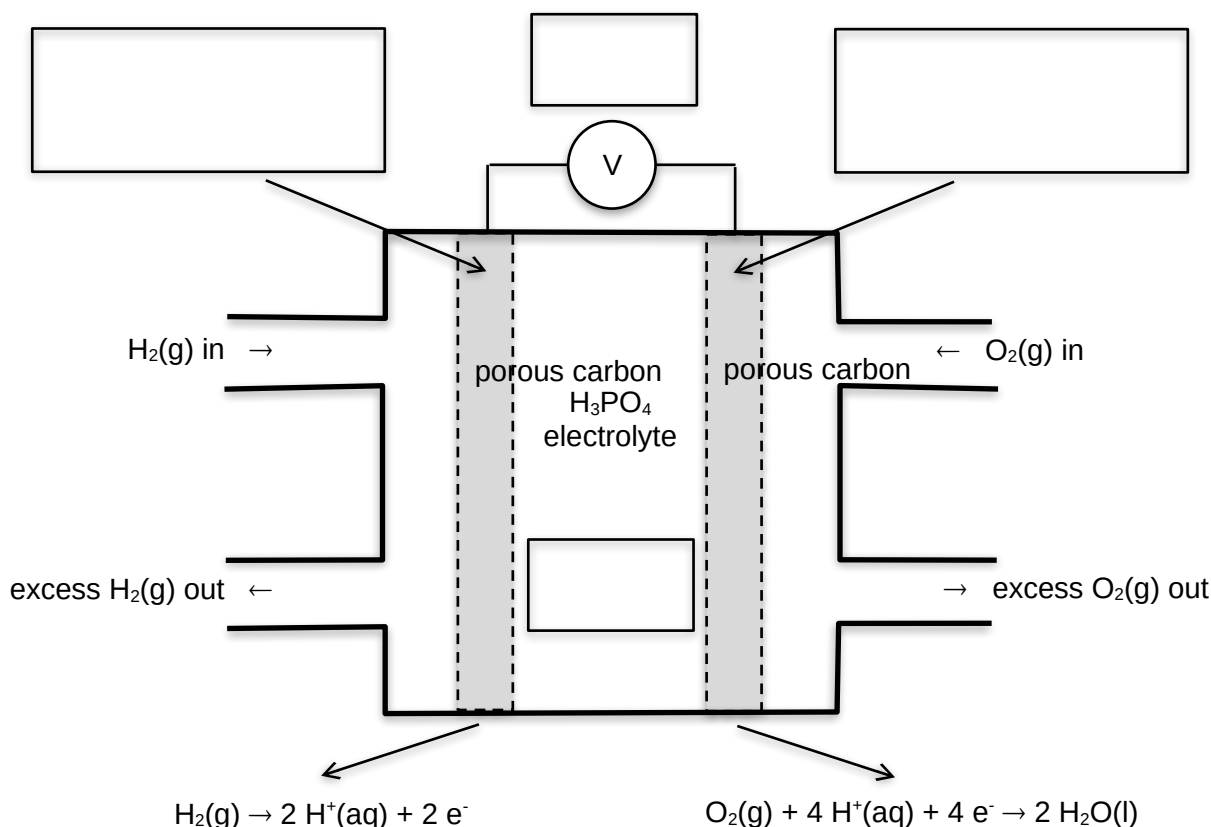$$\textit{red} \qquad\qquad\qquad \textit{blue}$$
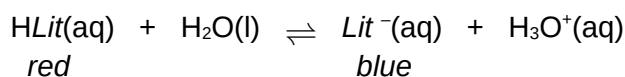
(a) Explain how litmus indicator works. Include details of the colour change observed in acidic and basic solution. (3 marks)

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(b) Draw the 'blue form' of 7-hydroxyphenoxazone. (1 mark)

Question 28 **(12 marks)**

The phosphoric acid fuel cell (PAFC) uses gaseous oxygen and hydrogen to produce electricity. The cell is named so, because the electrolyte is an extremely concentrated solution of phosphoric acid. Both electrodes are made from porous carbon, which is coated with a platinum catalyst. The cell operates at temperatures of 150-210 °C and a single cell can produce a maximum of 1 volt, though most are in the range of 0.6-0.8 volts. PAFC's can be used to power buses and in stationary power generators. A simplified diagram of a PAFC is shown below.

$H_2(g)$ in →

porous carbon

H_3PO_4 electrolyte

porous carbon

← $O_2(g)$ in

excess $H_2(g)$ out ←

→ excess $O_2(g)$ out

$H_2(g) \rightarrow 2\ H^+(aq) + 2\ e^-$

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

(a) What is the key difference between fuel cells and other galvanic cells? (2 marks)

_____

_____

_____

_____

(b) In the boxes on the diagram above, label the;
- anode and cathode
- charge of each electrode
- direction of electron flow, and
- direction of cation (H^+) flow. (4 marks)

(c) Explain why many consider this fuel cell to be a 'clean' source of energy. Use a chemical equation to support your answer. (2 marks)

_____

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_____

Question 29 **(9 marks)**

Consider the following closed equilibrium system, which has been allowed to establish equilibrium at a temperature of 600 $^{\circ}$C. The value of K for this reaction at 600 $^{\circ}$C is 7.94 x 10^{-7}.

$$2 \, Cu_2O(s) \rightleftharpoons 4 \, Cu(s) + O_2(g)$$
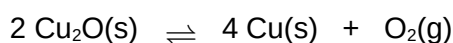
(a) Write an equilibrium constant (K) expression for this reaction. (1 mark)

Some additional $O_2(g)$ is injected into this equilibrium system at 600 $^{\circ}$C. The system was then allowed to re-establish equilibrium.

(b) How has the mass of Cu(s) present changed in this new equilibrium? (circle) (1 mark)

increased decreased no change

(c) At this new equilibrium, state the concentration of $O_2(g)$, in mol L^{-1}. Explain your answer. (2 marks)

_____

_____

_____

(d) A small amount of $Cu_2O(s)$ was then added to this equilibrium system. Explain how this would effect the equilibrium position. (2 marks)

_____

_____

(e)   At 800 $^\circ$C, the value of K for this reaction is 3.16 x 10^{-5}. What does this tell you about the enthalpy change (ΔH) for this reaction? Explain your answer.   (3 marks)

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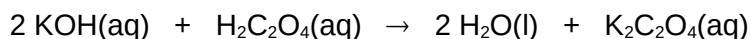**Question 30**   **(9 marks)**

Oxalic acid ($H_2C_2O_4$) is an organic acid, found in high levels in foods such as almonds, banana, rhubarb and spinach. It is a weak, diprotic acid which has many uses in the laboratory, such as in volumetric analysis where it can be used as a primary standard.

(a)   Explain what is meant when oxalic acid is referred to as a 'weak, diprotic acid'. Use relevant chemical equations to support your answer.   (4 marks)

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Some oxalic acid dihydrate crystals were used to produce a primary standard for use in a titration. 4.434 g of $H_2C_2O_4.2H_2O$(s) was dissolved in water and made up to 250.0 mL in a volumetric flask.

(b)   Calculate the concentration of the oxalic acid primary standard.   (2 marks)

_____

_____

_____

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_____

The oxalic acid solution was then used to standardise some aqueous potassium hydroxide. A 20.00 mL sample of KOH(aq) required 17.85 mL of oxalic acid to reach equivalence. The relevant chemical equation for the titration is shown below.

$$2\ KOH(aq)\ +\ H_2C_2O_4(aq)\ \rightarrow\ 2\ H_2O(l)\ +\ K_2C_2O_4(aq)$$

(c)   Calculate the concentration of KOH(aq).   (3 marks)

_____

_____

_____

_____

_____

Question 31   **(6 marks)**

Two beakers contained separate samples of zinc bromide solution, $ZnBr_2$(aq). To one beaker a piece of tin metal, Sn(s), was added. To the second beaker a piece of magnesium metal, Mg(s), was added. In one beaker, a reaction took place, while in the other beaker no reaction was observed.

(a)   Which of these metals (i.e. magnesium or tin) is the strongest reducing agent? Explain your answer.   (2 marks)

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(b)   Write a balanced chemical equation for the reaction that does occur, and explain why no reaction is observed in the other beaker.   (2 marks)
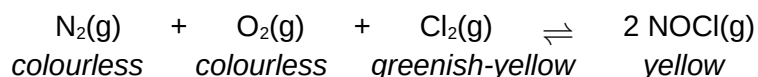
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Some chlorine water, $Cl_2(aq)$, was added to a separate third sample of zinc bromide solution.

(c)   Explain what would occur when these solutions were mixed. Include in your answer the
        expected observations.   (2 marks)

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Question 32   **(8 marks)**

In the following equilibrium system, nitrogen, oxygen and chlorine gases combine to produce
nitrosyl chloride vapour. This equilibrium system can form at temperatures of around 400 °C.

$$N_2(g) \quad + \quad O_2(g) \quad + \quad Cl_2(g) \quad \rightleftharpoons \quad 2\ NOCl(g)$$
$$\textit{colourless} \qquad \textit{colourless} \qquad \textit{greenish-yellow} \qquad \textit{yellow}$$

If an equal number of moles of $N_2(g)$, $O_2(g)$ and $Cl_2(g)$ were injected into a sealed flask at 400 °C;

(a)   Explain what would happen to the forward and reverse reaction rates as the system moved
        to establish equilibrium.   (3 marks)

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(b)   Explain what would happen to the concentration of all gases as the system moved to
        establish equilibrium.   (3 marks)

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(c)   Explain what you would observe as the system;

     i.   moved to establish equilibrium.   (1 mark)

_____

_____

and

     ii.   at equilibrium   (1 mark)

_____

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Question 33   **(8 marks)**

Phosphate buffered saline (PBS) is a solution which is commonly used in biological research. It was specifically designed so that the ion concentrations of the buffer solution match those found in the human body. The table below gives a standard 'recipe' for making PBS. The four salts are dissolved in water to produce the concentrations indicated.

Salt	Final concentration when dissolved in distilled water	
	Conc. (g L^{-1})	**Conc. (mmol L^{-1})**
NaCl	8.0	137
KCl	0.2	2.7
Na_2HPO_4	1.42	10
KH_2PO_4	0.24	1.8

(a)   Which components would produce the buffering effect observed in PBS? Explain your answer.   (2 marks)

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(b)   Write an equation showing the buffering system that would form.   (1 mark)

_____

(c)   Explain how this buffer is able to resist a change in pH when a small amount of NaOH(aq) is added.   (2 marks)

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PBS is specially designed for use in molecular biology and microbiology labs, so it is made to particular specifications.

(d)   Define 'buffering capacity' and describe how you could increase the buffering capacity of PBS if you did not have to take into account its biological uses.   (3 marks)

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Question 34   **(8 marks)**

The diagram below is a simplified, incomplete, representation of the final stage of copper purification, where the electrorefining of copper metal is carried out.
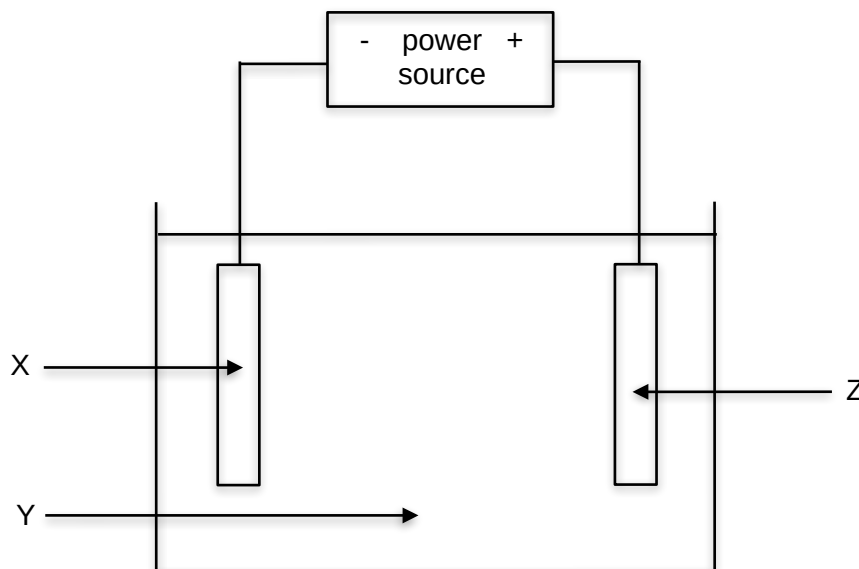
(a)   Why is a power source required for this process?   (2 marks)

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(b)   Give the name or formula of the substance that would be used for;   (3 marks)

                X   _____

                Y   _____

                Z   _____

(c)   Which letter denotes the cathode?   (1 mark)

_____

(d)   Write the half equation for the reaction occurring at X.   (1 mark)

_____

(e)   Why would $AgNO_3$(aq) be an inappropriate substance to use for Y?   (1 mark)

_____

_____

End of Section Two

Section Three: Extended answer   **40%   (80 marks)**

This section contains **five (5)** questions. You must answer **all** questions. Write your answers in the spaces provided below.

Where questions require an explanation and/or description, marks are awarded for the relevant chemical content and also for coherence and clarity of expression. Lists or dot points are unlikely to gain full marks.

Final answers to calculations should be expressed to the appropriate number of significant figures.
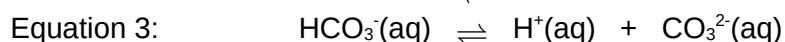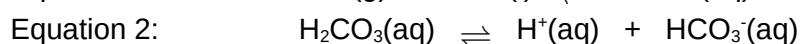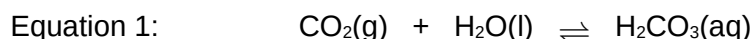
Spare pages are included at the end of this booklet. They can be used for planning your responses and/or as additional space if required to continue an answer.
•   Planning: If you use the spare pages for planning, indicate this clearly at the top of the page.
•   Continuing an answer: If you need to use the space to continue an answer, indicate in the original answer space where the answer is continued, i.e. give the page number. Fill in the number of the question(s) that you are continuing to answer at the top of the page.

Suggested working time: 70 minutes.

Question 35   **(8 marks)**

For the last few decades, the climate change debate has been taking place between the scientists, governments, companies and citizens of our planet. Rising carbon dioxide levels are thought to have contributed significantly to this climate change, including the phenomenon known as 'ocean acidification'. Some of the chemistry behind carbon dioxide and its link to ocean acidification is represented in the equations below.

$$\text{Equation 1:} \quad CO_2(g) \ + \ H_2O(l) \ \rightleftharpoons \ H_2CO_3(aq)$$

$$\text{Equation 2:} \quad H_2CO_3(aq) \ \rightleftharpoons \ H^+(aq) \ + \ HCO_3^-(aq)$$

$$\text{Equation 3:} \quad HCO_3^-(aq) \ \rightleftharpoons \ H^+(aq) \ + \ CO_3^{2-}(aq)$$

One of the many negative consequences of ocean acidification is thought to be the disruption of the chemistry of ocean water, leading to things such as a decreased rate of calcification amongst many marine organisms. For example, one of the main compounds from which coral build their structure is calcium carbonate. Ocean acidification decreases the amount of calcium carbonate available to these organisms and thereby severely impacts their survival. This has already been observed in the Great Barrier Reef and many countries are already committed to reducing their nation's carbon dioxide emissions in an effort to combat the climate change we are witnessing.

(a)   Explain how an increase in atmospheric carbon dioxide, $CO_2(g)$, levels can cause a change in the pH of our oceans.   (3 marks)

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A chemistry teacher was attempting to demonstrate the process of ocean acidification to her class using the apparatus shown in the diagram below. A sample of ocean water was placed in a glass fish tank and a canister of carbon dioxide was attached by a tube. When the canister was opened, additional carbon dioxide gas was introduced into the air in the fish tank. A small vent ensured the overall air pressure in the fish tank remained constant.
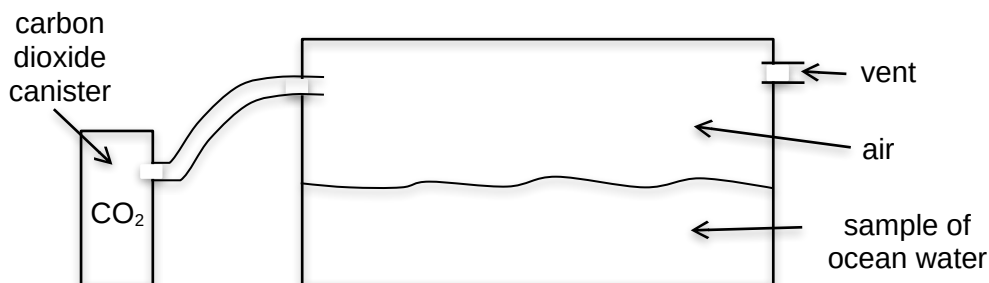
(b)   Explain, in terms of the collision theory and with reference to Equation 1, the effect on both the forward and reverse reaction rates, when the partial pressure of $CO_2(g)$ present in the tank was increased.   (3 marks)

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(c)   Does the teacher's demonstration represent an open or closed equilibrium system? Explain.   (2 marks)

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**Question 36**   **(17 marks)**

In the process of cheese making a bacterial culture is added to milk, which causes the milk to separate into the curds (solid cheese) and whey (remaining liquid). During this process the bacteria convert the lactose present in milk, into lactic acid, $CH_3CHOHCOOH$. Lactic acid is a weak, monoprotic, organic acid. Cheese makers use the concentration of lactic acid in the whey to determine when the reaction has proceeded to the extent that the cheese (curds) are ready for consumption or storage.

The concentration of lactic acid present in the whey can be determined at any time during the cheese making process via a simple titration. This usually involves taking a 10 mL sample of whey and titrating it against some standard sodium hydroxide solution, NaOH(aq), using phenolphthalein as an indicator.

(a)   Explain why phenolphthalein indicator is used. Use a chemical equation to support your
         answer.   (3 marks)

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A cheese maker added 4.00 L of milk to a small sample of bacterial culture. He knew that once the concentration of lactic acid reached 1.25×10^{-2} mol L^{-1} the cheese would be ready. He took a 10.00 mL sample of the whey, added several drops of phenolphthalein, and titrated the sample against a 0.111 mol L^{-1} NaOH solution. 1.15 mL of NaOH was required for equivalence. The reaction that took place in the titration is shown below.

$$CH_3CHOHCOOH(aq) \ + \ NaOH(aq) \ \rightarrow \ H_2O(l) \ + \ CH_3CHOHCOONa(aq)$$
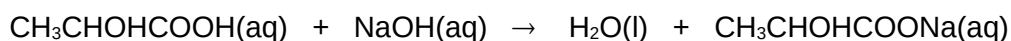
(b)   Determine the concentration of lactic acid in the whey, and comment on whether or not the
         cheese maker should allow the reaction to proceed for longer before isolating the curds.
                                                                                          (4 marks)

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(c)   Determine the percent by mass of lactic acid present in the whey at this point in time, if the 10.00 mL sample was taken from a total volume of 3.10 L of whey. The density of the whey is 1.040 kg L^{-1}.   (5 marks)

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(d)   The cheese maker only took one 10.00 mL sample of whey to examine, but he could have performed multiple trials of the titration if he had wished. Explain how this would improve the accuracy of his calculated lactic acid concentration.   (2 marks)

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Another cheese maker mistakenly used methyl orange indicator in an identical titration.

(e)   Would he have obtained a smaller or larger NaOH titre reading? Comment on whether this is a random or systematic error. Explain your answer.   (3 marks)

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Question 37   **(13 marks)**

A group of chemistry students were asked to carry out an investigation. They were given three different standard half-cells as follows;

- A nickel electrode in a solution of 1.0 mol L^{-1} nickel nitrate, i.e. Ni / Ni^{2+}(aq)
- A silver electrode in a solution of 1.0 mol L^{-1} silver nitrate, i.e. Ag / Ag$^+$(aq)
- A lead electrode in a solution of 1.0 mol L^{-1} lead(II) nitrate, i.e. Pb / Pb^{2+}(aq)

(a)   Describe how you could experimentally determine which of these three half-cells could be used to produce an electrochemical cell with the maximum possible voltage/EMF. You may assume you have access to standard laboratory equipment. Include a sketch of your apparatus.   (5 marks)

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(b)   Assuming standard conditions, what results would you expect? Give your answer in the
        form of a table displaying the predicted EMF values.   (4 marks)

(c)   Briefly describe the chemical principles behind an electrochemical cell and explain why
        different cells are able to produce different voltages.   (4 marks)

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**Question 38**   **(19 marks)**

Silicon dioxide (SiO_2) is one of the most abundant substances in the Earth's crust. It is most commonly found in quartz and many types of sand and because of this, is often found in metal ores that are mined from the Earth's crust. One of the methods that can be used to remove silicon dioxide from an ore is illustrated in the equation below.

$$SiO_2(s) \ + \ H_2(g) \ \rightleftharpoons \ SiO(g) \ + \ H_2O(g) \qquad \Delta H = +534 \text{ kJ mol}^{-1}$$
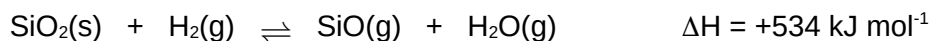
This chemical equation represents the equilibrium that forms between silicon dioxide and silicon monoxide. The activation energy for this reaction is 565 kJ mol^{-1}.

(a)   Identify the oxidising agent (oxidant) and reducing agent (reductant) in this reaction. Use oxidation numbers to support your answer.   (2 marks)

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(b)   Draw an energy profile diagram for this reaction. Label the activation energy and the enthalpy change.   (4 marks)

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Progress of reaction
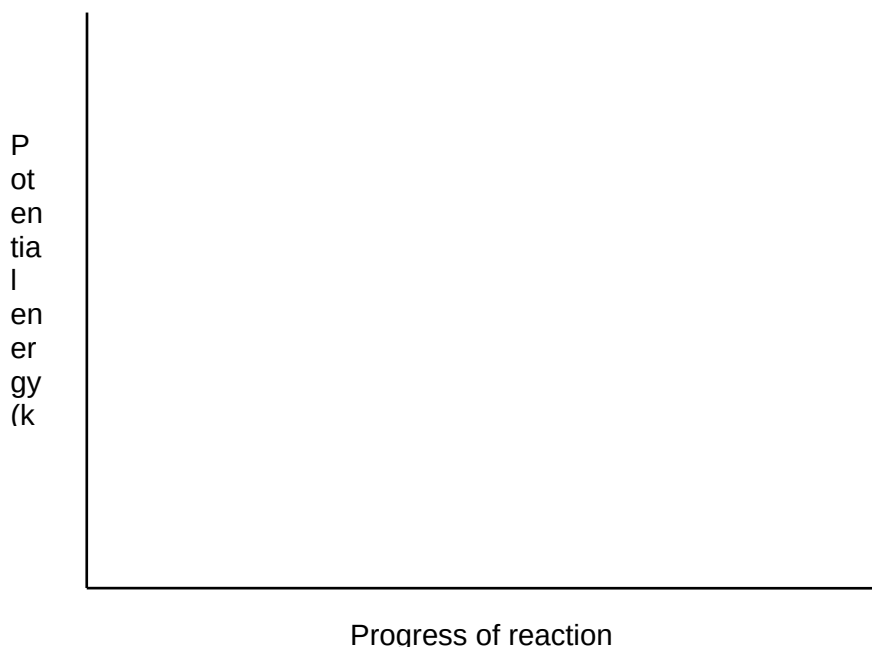
(c)   Determine the value of;   (2 marks)

        Ea(rev)   _____

        ΔH(rev)   _____

Quite a low pressure, around atmospheric, is used for this process. However a high temperature of 1550 °C is maintained in the reaction chamber.

(d)   Explain, in terms of the collision theory, the effect of each of the following on reaction rate.
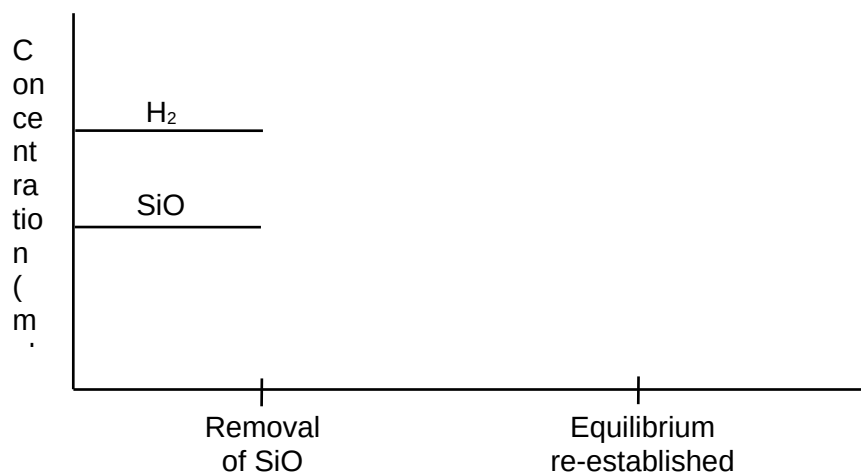
(5 marks)

Use of high temperature	
Use of low pressure	

(e)   State the effect (increased, decreased or no change) of each of the following on yield.

(2 marks)

Use of high temperature	
Use of low pressure	

Since the silicon monoxide is produced in gaseous form, SiO(g), it is easily removed from the system. This in turn helps to favour the forward reaction.

(f)   Continue the concentration graph below, by sketching the effect of removing a batch of SiO(g) from the reaction chamber.   (4 marks)

Question 39 **(19 marks)**

Barium hydroxide, $Ba(OH)_2(s)$, also known as 'baryta' is often found in hydrated form and appears as white crystals. It is corrosive, toxic and moderately soluble in water. It can be used in titrations, for the manufacture of organic substances, as well as in the synthesis of other barium-containing compounds.

A barium hydroxide solution was made by dissolving 1.31 g of solid anhydrous $Ba(OH)_2$ crystals into 795 mL of water. Assume the volume remains constant.

(a)   Calculate the pH of this solution.   (5 marks)

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This solution of barium hydroxide was then neutralised by the addition of hydrochloric acid, $HCl(aq)$, as shown in the equation below.

$$Ba(OH)_2(aq) \ + \ 2\,HCl(aq) \ \rightarrow \ BaCl_2(aq) \ + \ 2\,H_2O(l)$$
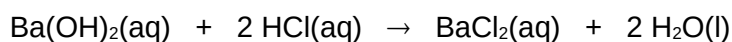
(b)   Davy was one of the first chemists to study the composition of hydrochloric acid. Briefly
        state the main developments he made in the field of acid-base theory.   (2 marks)

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(c)   Using the equation above, explain how it relates to the definition of an acid and a base as proposed by Arrhenius, and why it is that these two substances are able to neutralise each other.   (3 marks)

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Hydrocyanic acid, HCN(aq), is an extremely poisonous acid with a Ka value of 6.17×10^{-10}. It is made by dissolving liquid or gaseous hydrogen cyanide in water. Small amounts of hydrogen cyanide can be extracted from the stones of some fruits such as cherries, apricots and apples, however it is generally manufactured on an industrial scale.

(d)   Write two (2) equations for the ionisation of HCN in water, one illustrating the Arrhenius theory and one the Bronsted-Lowry theory.   (2 marks)

Arrhenius	
Bronsted-Lowry	

(e)   On the Bronsted-Lowry equation above, label the conjugate acid-base pairs.   (2 marks)

(f)   What information does the value of Ka give us about hydrocyanic acid, HCN(aq)? Explain your answer.   (2 marks)

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The Bronsted-Lowry theory accounts for the acidic and basic properties of a much wider array of substances whose properties cannot be explained by earlier theories.

(g)   Complete the following table by stating the pH and giving a supporting equation for each of the substances.   (3 marks)

Substance	pH (acidic, basic or neutral)	Equation
MgS(aq)		
NH_3(aq)		
$KHSO_4$(aq)		

End of questions

Spare answer page

Question number: _____

Spare answer page

Question number: _____