St Hilda's Anglican School For Girls
Mock Examination, 2010

Question/Answer Booklet

CHEMISTRY
Stage 3

Please place your student identification label in this box

Student Number: In figures | | | | | | | | |

In words Answer Key

Time allowed for this paper
Reading time before commencing work: ten minutes
Working time for 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 Sheet

To be provided by the candidate
Standard items: pens, pencils, eraser, correction fluid, ruler, highlighters
Special items: non-programmable calculators satisfying the conditions set out by the Curriculum Council for this course

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.

See next page

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	25	25
Section Two: Short answer	12	12	60	70	35
Section Three: Extended answer	6	6	70	80	40
					100

Instructions to candidates

1. The rules for the conduct of Western Australian external examinations are detailed in the *Year 12 Information Handbook 2010.* Sitting this examination implies that you agree to abide by these rules.

2. Answer the questions according to the following instructions.

   Section One: 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, do not erase or use correction fluid, and shade your new answer. 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 answers in this Question/Answer Booklet.

3. When calculating numerical answers, show your working or reasoning clearly unless instructed otherwise.

4. 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.

5. 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.

See next page

Section One: Multiple-choice 25% (25 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, do not erase or use correction fluid, and shade your new answer. 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 for this section is 50 minutes.

---

1. Which one of the following solids has the highest conductivity?

   (a) ice

   (b) graphite

   (c) sodium sulfate

   (d) silicon dioxide

2. Eight consecutive elements on the Periodic Table have the following first ionisation energies (kJ mol^{-1}):

   707 833 870 1010 1170 376 502 540

   One of these elements is a noble gas. Which one of the following values represents the first ionisation energy of a noble gas?

   (a) 1170

   (b) 1010

   (c) 707

   (d) 376

3. The species $^{71}_{33}Ga^{3+}$ contains

   (a) 71 protons, 33 neutrons and 68 electrons

   (b) 33 protons, 38 neutrons and 30 electrons

   (c) 33 protons, 38 neutrons and 33 electrons

   (d) 38 protons, 33 neutrons and 35 electrons

4. An element, X, is in one of the first three rows of the Periodic Table, is a solid at room temperature and forms a basic oxide. Which one of the following is the element most likely to be?

   (a) a metal

   (b) a member of group 17

   (c) carbon

   (d) sulfur

See next page

5. Which one of the following best explains why sodium chloride is almost insoluble in ethanol?

(a) Sodium and chloride ions do not form strong enough interactions with ethanol to disrupt the sodium chloride crystal lattice and break the van der Waals forces in ethanol.

(b) Ethanol cannot interact with sodium ions and chloride ions and so sodium chloride will not dissolve.

(c) Although sodium chloride and ethanol are polar they are not similar enough for the 'like dissolves like' rule to apply.

(d) Ethanol has strong hydrogen bonds between its molecules and tends to retain its molecular network.

6. In which one of the following pairs of substances will hydrogen bonding between the substances NOT occur?

(a) HF and $CH_3CH_2COCH_3$

(b) CH_3NH_2 and $CH_3CHOHCH_3$

(c) CH_3COOH and CH_3COCH_3

(d) CH_3CH_3 and CH_3CH_2OH

7. Which one of the following statements best describes the effect of an addition of a catalyst on a chemical reaction?

(a) The activation energy is increased and the equilibrium changes rapidly to favour the formation of products.

(b) The rate of reaction and equilibrium position both change.

(c) The rates of the forward and reverse reaction both increase.

(d) The forward reaction rate is increased but these is no change to the reverse rate of reaction.

8. A student attempting to standardise an oxalic acid solution by titration of 20.00 mL aliquots against standard potassium permanganate solution experienced difficulty in obtaining consistent values for the volume of titrant added. Which one of the following sequential steps could be responsible for this lack of precision?

(a) The burette was cleaned and rinsed thoroughly with standard potassium permanganate solution before being filled.

(b) Several 250 mL conical flasks were washed and rinsed thoroughly with oxalic acid solution.

(c) A clean pipette was rinsed with the oxalic acid solution and a 20.00 mL aliquot was carefully pipetted into each conical flask.

(d) Approximately 20 mL of sulfuric acid was added from a measuring cylinder to each flask before they were heated to approximately 60^oC.

See next page

9. Which one of the following statements is true?

(a) The pH of a 0.100 mol L^{-1} solution of a strong acid is the same as a 0.100 mol L^{-1} solution of a weak acid.

(b) Weak acids and weak bases do not react with each other.

(c) It is not possible for water to act as an acid and a base.

(d) When an acid and a base react, the products consist of a new acid and a new base.

10. A dilute solution of ammonia was titrated with dilute hydrochloric acid. If the indicator used was phenolphthalein, which one of the following statements is true?

(a) The end-point occurs before the equivalence point.

(b) The end-point occurs at the equivalence point.

(c) The end-point occurs after the equivalence point.

(d) There is no equivalence point because it is the wrong indicator.

11. In the standardization of a hydrochloric acid solution, a student accidently used some partially hydrated sodium carbonate, instead of the anhydrous salt. As a result, the calculated concentration of HCℓ would

(a) equal the actual concentration, as the extra water would have no effect on the reaction.

(b) Appear greater than the actual concentration.

(c) Appear less than the actual concentration.

(d) Appear greater, or less, than the actual concentration depending on the degree of hydration.

12. Which one of the following equations represents a disproportionation reaction?

(a) $Pb^{2+}(aq) + 2I^{-}(aq) \rightarrow PbI_2(s)$

(b) $4Fe(s) + 3O_2(g) \rightarrow 2Fe_2O_3(s)$

(c) $2H_2O_2(l) \rightarrow 2H_2O(l) + O_2(g)$

(d) $Cu^{2+}(aq) + 4NH_3(aq) \rightarrow [Cu(NH_3)_4]^{2+}(aq)$

13. In which one of the following equations is sulfuric acid acting as an oxidising agent?

(a) $NaC\ell + H_2SO_4 \rightarrow HC\ell + NaHSO_4$

(b) $HCOOH + H_2SO_4 \rightarrow CO + H_3O+ + HSO_4^{-}$

(c) $2Br^{-} + 5H_2SO_4 \rightarrow Br_2 + SO_2 + 2H_3O^{+} + 4HSO_4^{-}$

(d) $Ba(NO_3)_2 + H_2SO_4 \rightarrow BaSO_4 + 2H^{+} + 2NO_3^{-}$

See next page

14. Car batteries are of the lead-acid type. The overall reaction which occurs as the battery discharges is:

$$Pb(s) + PbO_2(s) + 4H^+(aq) + 2SO_4^{2-}(aq) \rightarrow 2PbSO_4(s) + 2H_2O(l)$$

Which one of the following statements about the recharging process is true?

(a) The pH of the solution in the battery increases.

(b) All Pb^{2+} ions in the battery are oxidised to Pb^{4+}

(c) The lead plates in the battery dissolve as Pb^{2+} ions are produced.

(d) Pb^{2+} ions are either oxidised or reduced depending on the electrode they are near.

15. Which of the following statements best describes the function of a hydrogen/oxygen fuel cell?

(a) It converts heat energy from a chemical reaction to electrical energy.

(b) It stores electrical energy produced from the reaction between oxygen and hydrogen.

(c) It converts energy from the oxidation of hydrogen directly to electrical energy.

(d) It promotes the reaction between hydrogen and oxygen using an external energy source.

The next two questions refer to the following information:

Metal X reacts with water to produce hydrogen.

16. Which one of the following is X behaving as?

(a) Acid

(b) Base

(c) A reducing agent.

(d) An oxidising agent.

17. Given the further information that

I the reaction of X with water is extremely vigorous.
II X is in period 4
III X forms a solid hydrogencarbonate

Which one of the following is the most probable identify of X?

(a) Calcium

(b) Potassium

(c) Magnesium

(d) Sodium

18. Which one of the following best describes the role of $H_2PO_4^-$ in the equation below:

$$2H_2PO_4^-(aq) \rightarrow H_3PO_4(aq) + HPO_4^{2-}(aq)$$

(a) $H_2PO_4^-$ is acting only as an acid.

(b) $H_2PO_4^-$ is acting as both an acid and a base.

(c) $H_2PO_4^-$ is acting only as a reducing agent.

(d) $H_2PO_4^-$ is acting as both an oxidising and reducing agent.

19. LP gas, which is used as a fuel in camping stoves, consists mainly of propane. Propane burns in oxygen according to the equation:

$$C_3H_8(g) + 5O_2(g) \rightarrow 3CO_2(g) + 4H_2O(l) \qquad \Delta H = -2217 \text{ kJ mol}^{-1}$$

Which one of the following statements about this reaction is true?

(a) Propane is acting as an oxidising agent.

(b) The reaction is endothermic.

(c) The chemical potential energy of the products is more than the chemical potential energy of the reactants.

(d) One mole of propane produces 2217 kJ of heat energy on complete combustion.

20. The following question refer to the structures given below:

I $CH_3(CH_2)_2CH_3$
II $CH_3CH_2CH_2CH_3$
III $CH_3CH(CH_3)_2$
IV $(CH_3)_4C$
V $CH_3C(CH_3)_3$

Which one of the following lists different isomers of C_4H_{10}?

(a) I and II

(b) II and IV

(c) III and V

(d) II and III

21. Which one of the following lists the solubilities of pentane, propan-1-ol and propanone in order of decreasing solubility in water?

(a) pentane > propanone > propan-1-ol

(b) propanone > pentane > propan-1-ol

(c) propan-1-ol > pentane > propanone

(d) propan-1-ol > propanone > pentane

See next page

22. Iron(II) thiocyanate [$Fe(SCN)_3$] dissolves readily in water to give a red solution. The red colour is due to the presence of hydrated $FeSCN^{2+}$ ions. The equilibrium between the undissociated $FeSCN^{2+}$ ions and the Fe^{3+} and SCN^- ions can be represented by the equation:

$$FeSCN^{2+}(aq) \rightarrow Fe^{3+}(aq) + SCN^-(aq)$$

Red yellow colourless

If 2.00 g of iron(II) thiocyanate is dissolved in 100 mL of distilled water, which one of the following will increase the concentration of iron(III) ions in the mixture?

(a) Adding 2 mL of water to the mixture.
(b) Adding sodium hydroxide to the mixture.
(c) Adding a solution of iron(III) chloride to the mixture
(d) Adding sodium thiocyanate solution to the mixture.

23. Which one of the following will have the lowest hydrogen ion concentration?

(a) 1.0 mol L^{-1} H_3PO_4
(b) 1.0 mol L^{-1} $HC\ell$
(c) H_2O
(d) 1.0 mol L^{-1} CH_3COONa

24. The cell reaction occurring in some 'button' batteries as current is drawn is

$$Ag_2O(s) + Zn(s) + H_2O(l) \rightarrow 2Ag(s) + Zn(OH)_2(s)$$

Which one of the following statements about the electrochemical cell is correct?

(a) Zinc forms the anode and is oxidized.
(b) Silver forms the anode and is oxidized.
(c) Zinc forms the cathode and is reduced.
(d) Silver oxide forms the anode and is oxidized.

25. Consider the following reaction:

$$C_3H_8 + Br_2 \rightarrow C_3H_7Br + HBr$$

Which of the following can this reaction be classified as?

I addition
II substitution
III redox

(a) I only
(b) II only
(c) I and III only
(d) II and III only

See next page

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

This section has **12** questions. Answer **all** questions. Write your answers in the space provided.

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 for this section is 60 minutes.

Question 26 **(2 marks)**

Write the equilibrium constant expression for each of the following.

Equation	$HCN(aq) + H_2O(l) \rightleftharpoons H_3O^+(aq) + CN^-(aq)$
Equilibrium constant expression	$K = \frac{[H_3O^+][CN^-]}{[HCN]}$

(1 mark)

Equation	$As_4O_6(g) + 6\ C(s) \rightleftharpoons As_4(g) + 6\ CO(g)$
Equilibrium constant expression	$K = \frac{[As_4][CO]^6}{[As_4O_6]}$

(1 mark)

Question 27 **(10 marks)**

The amide ion, NH_2^-, is a strong base in an aqueous solution.

(a) Write an equation for the hydrolysis of the amide ion. (2 marks)

$NH_2^- + H_2O \rightarrow NH_3 + OH^-$

(b) A solution of sodium amide is water was found to have a pH of 10.3. Calculate the concentration of the hydrogen ions in mol L^{-1}. (1 mark)

$[H^+] = 10^{-10.3}$

$= 5.01 \times 10^{-11}$ mol L^{-1}

(c) A buffer solution can be produced from ammonia and ammonium chloride in solution.

(i) Write an equation for the buffer produced from this combination. (2 marks)

$NH_3 + H_2O \rightleftharpoons NH_4^+ + OH^-$ or

$NH_4^+ + H_2O \rightleftharpoons NH_3 + H_3O^+$

-1 for each error

(ii) Explain, using Le Chatelier's Principle, why the addition of a small amount of sodium hydroxide solution would have minimal impact on the pH of the buffer solution. (3 marks)

Addition of OH^- causes reverse reaction to be favoured (1 mark), consuming most of added OH^- (1 mark) reducing the decrease in H^+ and therefore pH change very small.(1 mark)

Or similar statement if students wrote second equation in part (i)

(iii) Explain why a sodium amide/ammonia mixture could not be used as a buffer solution. (2 marks)

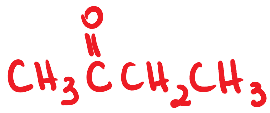
When amide is added to water it reacts completely so that only ammonia is present in solution (1 mark). A buffer requires both an acid and a base present in solution to react with any added OH^- or H^+ (1 mark)

See next page

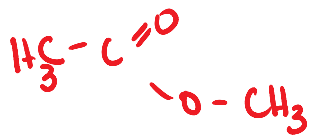
Question 28 **(6 marks)**

Draw structural formulae and give the IUPAC name for the organic products formed in each of the following reactions. Show all atoms in the structural formulae.

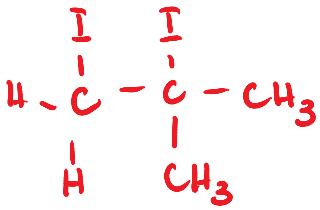
(a) When butan-2-ol is oxidised by acidified $KMnO_4$ (2 marks)

Structure	Name
	butanone

(b) When acetic acid reacts with acidified methanol (2 marks)

Structure	Name
	Methyl ethanoate Or Methyl acetate

(c) When iodine reacts with methyl propene (2 marks)

Structure	Name
	1, 2-di-iodomethylpropane (accept 1,2 –diiodo-2-methylpropane)

Full or semi-structural acceptable
-1 for missing Hs overall
-1 for each error
1 mark if structure incorrect but name matches structure

See next page

Question 29 **(8 marks)**

A sample of white powder was known to be either ibuprofen or aspirin.

(a) Calculate the molar mass of the compound. (2 marks)

PV = nRT

$$n = \frac{0.172x171}{(250+273)x8.315}$$ (1 mark)

$$= 6.76 \times 10^{-3} \text{ mol}$$

M= 1.22/6.76 x 10^{-3} (1 mark)

= 180.4 g mol^{-1}

-1 for no unit.

(b) Determine the molecular formula each of the compounds from their structural formulas. (4 marks)

Aspirin – $C_9H_8O_4$

Ibuprofen – $C_{13}H_{17}O_2$

-1 for each error.

(c) Which of the above two compounds is the painkiller analysed? (2 marks)

Aspirin'

Question 30 **(4 marks)**

Write the equation for the reaction that occurs in each of the following procedures.

(a) Acetic acid solution is added to solid cobalt(II) carbonate. (2 marks)

Equation: $2\ CH_3COOH + CoCO_3 \rightarrow Co^{2+} + 2\ CH_3COO^- + CO_2 + H_2O$

(b) Methanol is warmed with excess acidified potassium dichromate. (2 marks)

Equation: $3\ CH_3OH + 2\ Cr_2O_7^{2-} + 16\ H^+ \rightarrow 3\ CHOOH + 4\ Cr^{3+} + 11\ H_2O$

-1 for each error

See next page

Question 31 **(4 marks)**

Write observations for any reactions that occur in the following procedures. In each case describe in full what you would observe, including any

(a) Excess sodium hydroxide is added to copper(II) sulfate solution. (2 marks)

Observation: Colourless solution is added to blue solution (1 mark) to form blue precipitate and solution fades to colourless (1 mark).

(b) Zinc metal is added to excess nickel(II) nitrate solution. (2 marks)

Observation: Silver solid dissolves in green solution (1 mark). Black ppt forms and solution colour fades (1 mark)

Question 32 **(6 marks)**

Sodium tripolyphosphate, $Na_5P_3O_{10}$ has been used as a filler in detergents. The main source of this compound is phosphate rock, an ore consisting mainly of calcium phosphate ($Ca_3(PO_4)_2$) and silicon dioxide (SiO_2).

(a) Calculate the mass of calcium phosphate in the ore. (2 marks)

$M(ore) = 5.43 \times 10^7$ g (1 mark)

$M(Ca_3(PO_4)_2) = 5.43 \times 10^7 \times 0.45$

$= 2.443 \times 10^7$ g (1 mark)

(b) Calculate the number of moles of phosphorus in the calcium phosphate. (2 marks)

$N(Ca_3(PO_4)_2) = 2.443 \times 10^7/310.18$

$= 7.88 \times 10^4$ mol (1 mark)

$N(P) = 2 \times n(Ca_3(PO_4)_2)$

$= 1.58 \times 10^5$ mol (1 mark)

(c) Calculate the mass of $Na_5P_3O_{10}$ that could be produced from the mass of calcium phosphate in (a). (2 marks)

$N(Na_5P_3O_{10}) = 1/3\ n(P)$

$= 5.25 \times 10^4$ mol (1 mark)

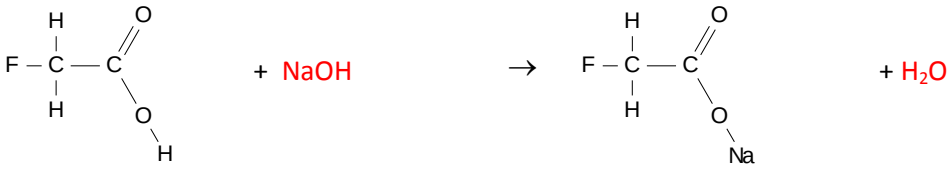
$M(Na_5P_3O_{10}) = (5.25 \times 10^4) \times 367.86$

$= 1.93 \times 10^7$ g (19.3 tonne) (1 mark)

See next page

Question 33 **(2 marks)**

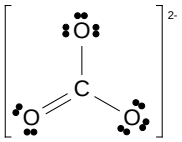
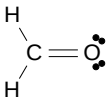
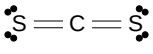
Complete the following equation by adding the missing reactant and product.



1 mark each

If Na/H_2 given – 1 mark overall unless equation balanced then 2 marks)

Question 34 **(6 marks)**

Molecule	**Structural formula (showing all valence shell electrons)**	**Shape (sketch or name)**
Carbonate ion CO_3^{2-}		Triangular planar/ trigonal planar
Methanal CH_2O		Triangular planar/ trigonal planar
Carbon disulphide CS_2		linear

See next page

Question 35 **(8 marks)**

Complete the following table and briefly explain your reasoning.

Molecule	Boiling point ranking (1 = highest, 4 = lowest)
$CH_3CH_2CHOHCH_3$	2
$CH_3CH_2CH_2CHO$	3
$CH_3CH_2CH_2CH_3$	4
CH_3CH_2COOH	1

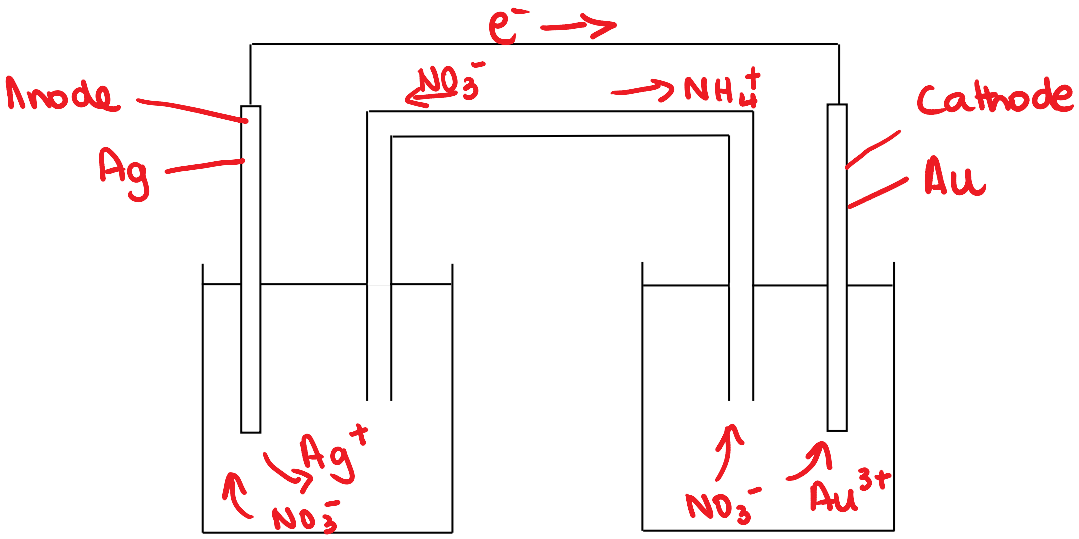
Boiling point is dependent on the strength of intermolecular forces.
Hydrogen bonding is the strongest form of intermolecular forces for molecules of similar size.
Propanoic acid has hydrogen bonding between the molecules, as does butan-2-ol, but it can form more hydrogen bonds and they are stronger (the OH group is shielded in the alcohol).
Butanone is a polar molecule while butane is non-polar. The dipole-dipole + dispersion forces between butanone are stronger than the dispersion forces only between butane molecules.

(2 marks for order. -1 if order completely reversed, -1 for 2 wrong)
(6 marks for explanation)

See next page

Question 36 **(9 marks)**

Below is a diagram of an electrochemical cell constructed from Ag/Ag^+ and Au/Au^{3+} half cells with an ammonium chloride salt bridge.



(a) Label the cell showing (4 marks)

(i) The anode and the cathode (1 mark)

(ii) The direction of electron flow (1 mark)

(iii) The direction of ion flow within the half-cells and the salt bridge (2 marks)

(b) Write half-equations for the oxidation and reduction reactions. (2 marks)

Oxidation $Ag \rightarrow Ag^+ + e^-$

Reduction $Au^{3+} + 3e^- \rightarrow Au$

(c) Why would sodium carbonate solution be an inappropriate choice for the salt bridge? (1 mark)

It would form a precipitate with the cell components.

(d) After the cell has been operating for some time describe the appearance of each electrode. (2 marks)

Anode: electrode partially dissolves (decreases in mass)

Cathode: ppt formed on electrode [yellow solution colour fades]

See next page

Question 37 **(5 marks)**

A fuel cell was supplied with 0.663 g of hydrogen and 1.87 L of oxygen at 345 kPa at a temperature of 150°C. The reaction between oxygen and hydrogen can be represented as:

$$2H_2(g) + O_2(g) \rightarrow 2\ H_2O(g)$$

(b) What volume of water would be produced from this reaction at 150°C, assuming the reaction is 65 % efficient?

$n(H_2) = 0.329$ mol $n(O_2) = 0.1834$ mol (1 mark)

1 mol of O_2 requires 2 mol of H_2

0.1834 mol of O2 requires 0.3668 mol of H_2

$n(H_2$ required) is > $n(H_2$ available), therefore H_2 is LR (2 marks)

$n(H_2O) = n(H_2) \times 0.65$

$= 0.214$ mol (1 mark)

$V(H_2O) = (0.214 \times 8.315 \times (150 + 273))/345$

$= 2.18$ L (1 mark)

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

This section contains **six (6)** questions. You must answer **all** questions. Write your answers in the space provided.

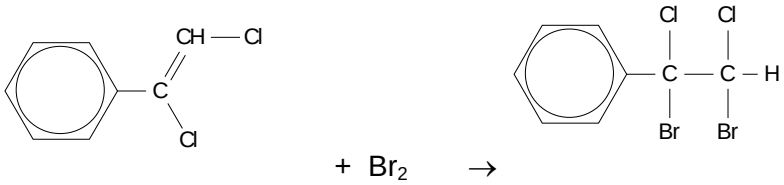
Spare pages are included at the end of this booklet. They can be used for planning your responses and/or as additional space if required to continue an answer.

- 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 for this section is 70 minutes.

Question 38 **(9 marks)**

(a) Write an equation for the reaction between this compound and liquid bromine. (2 marks)



(b) Describe fully what you would expect to observe when a few drops of bromine liquid are added to this compound. (2 marks)

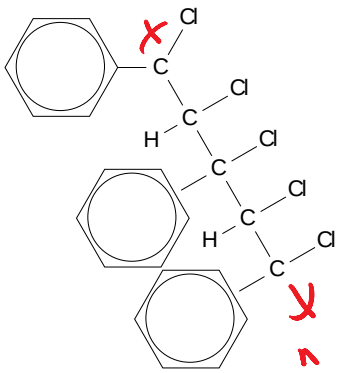
Red liquid is added to colourless liquid (1 mark)

Fades to colourless (1 mark)

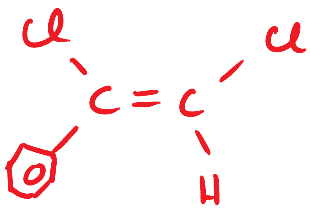
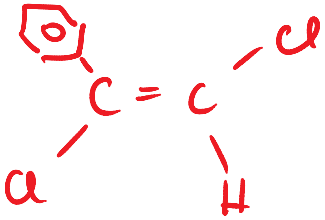
(c) What type of polymer would be produced from this compound? (1 mark)

Addition

(d) Draw part of this polymer showing at least three repeating units. (2 marks)



(e) There are two isomers of this compound that are cis and trans isomers. Draw these structures. (2 marks)

Structure



Question 39 **(14 marks)**

Methanal, better known as formaldehyde which is used as a preservative, is made from the controlled oxidation of methanol. When the reaction reaches equilibrium it can be represented by the following equation:

$$2\ CH_3OH(g) + O_2(g) \rightleftharpoons 2\ CH_2O(g) + 2H_2O(g) \qquad \Delta H = -570\ kJ$$

(a) Complete the following table by predicting the effect on the rate of the forward reaction and the equilibrium yield of methanal for each of the changes after equilibrium has been re-established. Use increase, decrease or no change. (6 marks)

Imposed Change	Effect on forward rate of reaction	Effect on equilibrium yield
Increase in temperature	increase	decrease
Decrease in system volume	increase	decrease
Addition of a catalyst	increase	No change

(1 mark each)

(b) Suggest the conditions that would be most suitable for the commercial production of formaldehyde. Give reasons for your answers. (8 marks)

Moderate temperature
Rate is favoured by high temperature as more particles have sufficient energy to react.
Yield is favoured by low temperature as forward reaction is exothermic.
Compromise required. (3 marks)
Moderate pressure
Rate is favoured by high pressure as there are more particles available for collision.
Yield is favoured by low pressure as there are more gas particles on the product side.
Compromise required. (3 marks)
Addition of catalyst
Rate increased due to pathway with lower activation energy available so more particles have sufficient energy to react.
Does not affect yield (2 marks)

Question 40 **(13 marks)**

The chromium content in a sample can be determined by oxidising the chromium to sodium dichromate with excess persulfate solution, boiling to destroy the excess oxidant and then titrating the acidified dichromate solution with standard ammonium iron(II) sulfate solution. Using this method a 7.598 g sample of a chromium containing mineral was converted into an acidified solution of sodium dichromate and dilute to 250.0 mL. A 20.00 mL sample of this solution was then titrated against 0.399 mol L^{-1} ammonium iron(II) sulfate solution and the following data obtained:

	1	2	3	4
Final volume	25.65	25.46	27.00	25.33
Initial volume	0.25	1.24	2.76	1.12
Titre				

(a) Write a balanced equation for the reaction. (3 marks)

$6Fe^{2+} + Cr_2O_7^{2-} + 14H^+ \rightarrow 6Fe^{3+} + 2Cr^{3+} + 7H_2O$

1 mark for dichromate half-equation

1 mark for Fe half equation

1 mark for balanced equation

(b) Calculate the percentage by mass of the chromium in the mineral. (8 marks)

Average titre = 24.22 mL (1 mark)

n(Fe2+) = 0.399 x 0.02422

= 9.665×10^{-3} mol (1 mark)

n(Cr) = 1/3 n(Fe^{2+}) (1 mark)

= 1/3 (9.665×10^{-3})

= 3.22×10^{-3} mol in 20.00 mL (1 mark)

n(Cr in 250 mL) = 3.22×10^{-3} x 250/20

= (2 marks)

m(Cr) = x 52.00

= 2.09 g (1 mark)

%Cr = 2.09/7.598 x 100

= 27.56 % (1 mark)

(c) Why doesn't this titration need an indicator? (2 marks)

See next page

As the dichromate changes colour from orange to green at the equivalence point, it acts as its own indicator.

Question 41 **(17 marks)**

Tooth enamel consists mainly of a substance called hydroxyapatite. This is the hardest substance in the body. Tooth cavities are caused when acids dissolve tooth enamel. The formula for hydroxyapatite can be represented by $Ca_x(PO_4)_y(OH)_z$.

(a) A 5.00 g sample of hydroxyapatite was dissolved in excess dilute hydrochloride acid. Excess barium chloride was added to precipitate the phosphate ions to produce barium phosphate ($Ba_3(PO_4)_2$). The mass of precipitate obtained was 9.00 g.
A second 5.00 g sample of hydroxyapatite was also dissolves in acid and excess sodium fluoride solution was added to precipitate the calcium ions to form calcium fluoride. 2.94 g of calcium fluoride was obtained.

Calculate the empirical formula of hydroxyapatite and show all working. (7 marks)

$n(Ba_3(PO_4)_2) = 9/601.92$
$= 0.01495$ mol
$n(PO_4^{3-}) = 2\ n(Ba_3(PO_4)_2)$
$= 0.0299$ mol
$m(PO_4^{3-}) = 0.0299 \times 94.97$
$= 2.84$ g
$n(CaF_2) = 2.94/78.07$
$= 0.03766$ mol
$n(Ca^{2+}) = n(CaF_2)$
$= 0.03766$ mol
$m(Ca^{2+}) = 0.03766 \times 40.08$
$= 1.51$ g
$m(OH^-) = 5 - (1.51 + 2.84)$
$= 0.6506$ g
$N(OH-) = 0.6506/17.008$
$= 0.0382$ mol

	Ca	PO4	OH
N	0.03766	0.0299	0.0382
Ratio /0.0299	1.25	1	1.27
X 4	5	4	5

EF = $Ca_5(PO_4)_4(OH)_5$

The acids that react with the hydroxyapatite are formed by the interaction of some bacteria with sugars and carbohydrates that can be found in the plaque that sticks to teeth.

Fluoride ions will react with hydroxyapatite and replace the OH^-. This mineral is more resistant to reaction with acids because the fluoride ion is a weaker base than OH^-.

Since fluoride ions are so effective at preventing tooth decay, they are often added to water supplies. Various compounds can be used, with the most common being NaF or Na_2SiF_6.

When sodium silicon hexafluoride is added to water, the following reaction occurs

$$SiF_6^-(aq) + 2H_2O(l) \rightarrow 6F^-(aq) + 4H^+(aq) + SiO_2(s)$$

(b) What mass of sodium silicon hexafluoride would need to be added to 100 000 L of water to obtain a fluoride ion concentration of 1 ppm? (Assume that 1.00 L = 1.00 kg for water.) (6 marks)

M(F-) = 100 g (2 marks)

N(F) = 100/19.00

= 5.263 mol (1 mark)

$N(Na_2SiF_6)$ = 1/6 x n(F)

= 0.877 mol (2 marks)

$M(Na_2SiF_6)$ = 0.877 x 188.14

= 1.65 x 10^2 g (1 mark)

About 80% of all toothpastes sold contain fluoride compounds. Usually the concentration of the fluoride ions is around 0.1 % by mass. The most common compounds are sodium fluoride and sodium monofluorophosphate (Na_2PO_4F) and tin(II) fluoride.

The pH of most toothpastes is around 9.

(d) Explain, with the aid of an equation, why a solution of sodium fluoride is basic.(4 marks)

Na+ ions do not react with water. (1 mark)

F- ions are a weak base and so react with water to produce OH- which makes the solution basic. (2 marks)

$F^- + H_2O \rightleftharpoons HF + OH^-$ (1 mark)

Question 42 **(16 marks)**

(a) Write an equation for the self-ionisation of water. (1 mark)

$2H_2O \rightleftharpoons H_3O^+ + OH^-$

At a constant temperature, the self-ionisation of water is at equilibrium. The equilibrium constant expression for this reaction is

$K_w = [H^+][OH^-]$

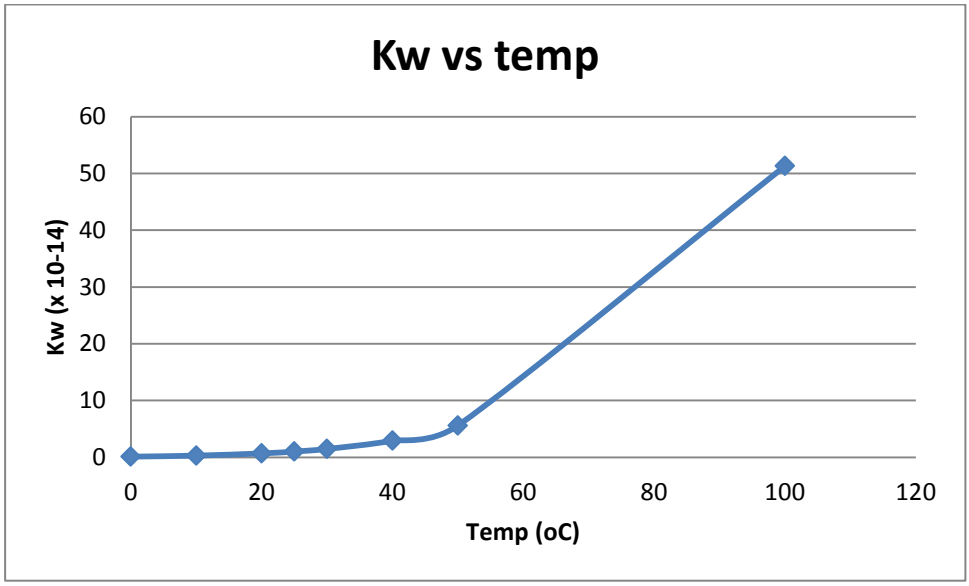
See next page

The values for the equilibrium constant at a range of temperatures are given in the table below.

Temperature (^oC)	0	10	20	25	30	40	50	100
Kw (x 10^{-14})	0.11	0.29	0.68	1.01	1.47	2.92	5.60	51.3
$[H^+]$ mol L^{-1}	3.3×10^{-8}	5.3×10^{-8}	8.2×10^{-8}	1.0×10^{-7}	1.2×10^{-7}	1.7×10^{-7}	2.4×10^{-7}	7.2×10^{-7}

(b) Plot a graph of the temperature vs the K_w value. (5 marks)

1 mark points plotted
1 mark line of best fit
1 mark axes labelled
1 mark correct scale
1 mark title



(c) Calculate the missing values for $[H^+]$ and complete the table. (2 marks)

(d) Calculate the pH of water at 10^oC and 40^oC. (2 marks)

10^o – 7.28

40^o – 6.92

(e) Describe the relationship between K_w and temperature. (1 mark)

As temperature increases, so does the value of Kw

(f) From your graph, estimate the value of K_w at 45^oC. (1 mark)

4×10^{-14}

(g) What is the relationship between $[H^+]$ and temperature? (1 mark)

As temperature increases, so does $[H^+]$

See next page

(h) From this data, is the ionisation of water an endothermic or exothermic reaction? Justify your answer. (3 marks)

Endothermic (1 mark)

As temperature increases, the amount of products increases. (1 mark)

Increase in temperature favours endothermic direction, therefore, forward reaction is endothermic. (1 mark)

Question 43 **(12 marks)**

There are a number of trends that occur across and down the Periodic Table that are related to the structure of the atoms and the types of bonding between atoms.

For each of the following,

(i) describe the trends across and down the Periodic Table for Period 3 and Group 1.
(ii) explain the trend with the aid of examples in terms of structure and bonding. Where appropriate include equations and diagrams.

(a) Atomic radius

(b) First ionisation energy

(c) Acidity/basicity of oxides

Your answer should be approximately two pages in length.

Atomic Radius (the distance between the nucleus and the outer electrons)

Atomic radius decreases across Period 3 and increases down Group 1

Across the period, electrons are being added to the same valence shell. The number of protons is increasing and so, therefore is the attractive force on the outer electrons. As the number of inner electrons remains constant, there is a greater attractive force on the outer electrons and they are pulled closer.

Down the group, electrons are being added to successive electrons shells. Although the number of protons is increasing, shielding by inner electrons results in minimal change in attracting power of the nucleus.

1st ionisation energy (the amount of energy required to remove one mole of electrons from one mole of atoms of an element in the gaseous state)

1st ionisation energy increases across period 3 and decreases down Group 1

Across the period, electrons are slightly closer to the nucleus (due to being added to the same valence shell) and the number of protons in the nucleus is increasing. Therefore the force of attraction between the outer electron and the nucleus is increasing. A greater force of attraction will require more energy to remove the outermost electron.

Down the group, as electrons are further away from the nucleus (in successive electron shells) and shielding by inner electrons means the attracting power of the nucleus remains relatively constant,

See next page

the force of attraction between the nucleus and the outermost eletron decreases. Lower force of attraction, less energy required to remove it.

Acidity of oxides.

Across the period, the oxides are becoming increasingly acidic. Group 1 oxides are all strong bases.

Across the period, as the bonding changes from ionic to covalent, the reaction with water changes. Ionic oxides (where soluble) dissociate and the oxide ion reacts with water to produce OH- (example equation e.g. $Na_2O + H_2O \rightarrow 2Na^+ + 2OH^-$. Covalent network oxides do not dissolve in water but will react with bases. Covalent molecular oxides (where soluble) will react with water to produce species that will act as proton donors. E.g. $SO_3 + H_2O \rightarrow HSO_4^- + H^+$.

Down the group – as all group 1 oxides are strong, their acidity/basicity does not change.

Each section 4 marks

(No examples -2)

See next page